EISSN 2148-9505

Indexed in PubMed, Web of Science and Scopus

Turkish Orthodontic Society

TURKISH JOURNAL of ORTHODONTICS

ORIGINAL ARTICLES

SYSTEMATIC REVIEWS

galenos Publishing House

turkjorthod.org

Volume 36
Issue 03
September 2023

TURKISH JOURNAL of ORTHODONTICS

Galenos Publishing House
Owner and Publisher
Derya Mor
Erkan Mor

Publication Coordinator
Burak Sever

Graphics Department
Ayda Alaca
Ceyda Beyazlar
Çiğdem Birinci
Gülşah Özgül

Project Coordinators
Aybuke Ayvaz
Aysel Balta
Gamze Aksoy
Gülay Akın
Hatice Sever
Melike Eren
Özlem Çelik Çekil
Pınar Akpınar
Rabia Palazoğlu
Sümeyye Karadağ

Web Coordinators
Ethem Candan
Fuat Hocalar
Turgay Akpınar

Research&Development
Asya Işık
Fırat Kahraman Aykara

Digital Marketing Specialist
Ümit Topluoğlu

Finance Coordinators
Sevinç Çakmak

Publisher Contact
Address: Molla Gürani Mah. Kaçamak Sk. No: 21/1 34093 İstanbul, Turkey
Phone: +90 (530) 177 30 97
E-mail: info@galenos.com.tr/yayin@galenos.com.tr
Web: www.galenos.com.tr **Publisher Certificate Number:** 14521

Printing Date: September 2023
E-ISSN: 2148-9505
International scientific journal published quarterly.

TURKISH JOURNAL of ORTHODONTICS

Aims and Scope

Turkish Journal of Orthodontics (Turk J Orthod) is a scientific, open access periodical published by independent, unbiased, and double-blinded peer-review principles. The journal is the official publication of the Turkish Orthodontic Society, and it is published quarterly in March, June, September, and December.

Turkish Journal of Orthodontics publishes clinical and experimental studies on on all aspects of orthodontics including craniofacial development and growth, reviews on current topics, case reports, editorial comments and letters to the editor that are prepared in accordance with the ethical guidelines. The journal's publication language is English and the Editorial Board encourages submissions from international authors.

Journal's target audience includes academicians, specialists, residents, and general practitioners working in the fields of orthodontics, dentistry, medicine and other related fields.

Turkish Journal of Orthodontics is currently indexed in **PubMed Central, Web of Science-Emerging Sources Citation Index, Scopus, CNKI, Gale, DOAJ** and **TUBITAK ULAKBİM TR Index.**

The editorial and publication processes of the journal are shaped in accordance with the guidelines of the International Committee of Medical Journal Editors (ICMJE), World Association of Medical Editors (WAME), Council of Science Editors (CSE), Committee on Publication Ethics (COPE), European Association of Science Editors (EASE), and National Information Standards Organization (NISO). The journal is in conformity with the Principles of Transparency and Best Practice in Scholarly Publishing (doaj.org/bestpractice).

Processing and publication are free of charge with the journal. No fees are requested from the authors at any point throughout the evaluation and publication process. All manuscripts must be submitted via the online submission system, which is available at www.turkjorthod.org. The journal guidelines, technical information, and the required forms are available on the journal's web page.

All expenses of the journal are covered by the Turkish Orthodontic Society.

Statements or opinions expressed in the manuscripts published in the journal reflect the views of the author(s) and not the opinions of the Turkish Orthodontic Society, editors, editorial board, and/or publisher; the editors, editorial board, and publisher disclaim any responsibility or liability for such materials.

All published content is available online, free of charge at www.turkjorthod.org.

OPEN ACCESS

Editor in Chief: Çağla Şar
Address: Sütlüce Mah. İmrahor Cad. No: 82 Beyoğlu, İstanbul/Turkey
Phone: +90 (212) 416 61 13
E-mail: info@turkjorthod.org

Publisher
Galenos Publishing House
Address: Molla Gürani Mah. Kaçamak Sok. 21/1 Fındıkzade, Fatih, Istanbul/Turkey
Phone: +90 (530) 177 30 97 / +90 (539) 307 32 03
Web page: http://www.galenos.com.tr
E-mail: info@galenos.com.tr

TURKISH JOURNAL of ORTHODONTICS

Instructions to Authors

PUBLICATION APPROVAL FORM FOR IDENTIFYING CLINICAL IMAGES

Turkish Journal of Orthodontics (Turk J Orthod) is a scientific, open access periodical published by independent, unbiased, and double-blinded peer-review principles. The journal is the official publication of the Turkish Orthodontic Society, and it is published quarterly in March, June, September, and December.

Turkish Journal of Orthodontics publishes clinical and experimental studies on all aspects of orthodontics including craniofacial development and growth, reviews on current topics, case reports, editorial comments and letters to the editor that are prepared in accordance with the ethical guidelines. The journal's publication language is English and the Editorial Board encourages submissions from international authors.

The editorial and publication processes of the journal are shaped in accordance with the guidelines of the International Council of Medical Journal Editors (ICMJE), the World Association of Medical Editors (WAME), the Council of Science Editors (CSE), the Committee on Publication Ethics (COPE), the European Association of Science Editors (EASE), and National Information Standards Organization (NISO). The journal conforms to the Principles of Transparency and Best Practice in Scholarly Publishing (doaj.org/bestpractice).

Originality, high scientific quality, and citation potential are the most important criteria for a manuscript to be accepted for publication. Manuscripts submitted for evaluation should not have been previously presented or already published in an electronic or printed medium. The journal should be informed of manuscripts that have been submitted to another journal for evaluation and rejected for publication. The submission of previous reviewer reports will expedite the evaluation process. Manuscripts that have been presented in a meeting should be submitted with detailed information on the organization, including the name, date, and location of the organization.

Manuscripts submitted to Turkish Journal of Orthodontics will go through a double-blind peer-review process. Each submission will be reviewed by at least two external, independent peer reviewers who are experts in their fields in order to ensure an unbiased evaluation process. The editorial board will invite an external and independent editor to manage the evaluation processes of manuscripts submitted by editors or by the editorial board members of the journal. The Editor in Chief is the final authority in the decision-making process for all submissions.

An approval of research protocols by the Ethics Committee in accordance with international agreements (World Medical Association Declaration of Helsinki "Ethical Principles for Medical Research Involving Human Subjects," amended in October 2013, www.wma.net) is required for experimental, clinical, and drug studies and for some case reports. If required, ethics committee reports or an equivalent official document will be requested from the authors. For manuscripts concerning experimental research on humans, a statement should be included that shows that written informed consent of patients and volunteers was obtained following a detailed explanation of the procedures that they may undergo. For studies carried out on animals, the measures taken to prevent pain and suffering of the animals should be stated clearly. Information on patient consent, the name of the ethics committee, and the ethics committee approval number should also be stated in the Materials and Methods section of the manuscript. It is the authors' responsibility to carefully protect the patients' anonymity. For photographs that may reveal the identity of the patients, authors are required to obtain publication consents from their patients or the parents/legal guardians of the patients. The publication approval form is available for download at turkjorthod.org. The form must be submitted during the initial submission.

All submissions are screened by a similarity detection software (iThenticate by CrossCheck).

In the event of alleged or suspected research misconduct, e.g., plagiarism, citation manipulation, and data falsification/fabrication, the Editorial Board will follow and act in accordance with COPE guidelines.

Each individual listed as an author should fulfill the authorship criteria recommended by the International Committee of Medical Journal Editors

(ICMJE - www.icmje.org). The ICMJE recommends that authorship be based on the following 4 criteria:

I. Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; AND

2. Drafting the work or revising it critically for important intellectual content; AND

3. Final approval of the version to be published; AND

4. Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

In addition to being accountable for the parts of the work he/she has done, an author should be able to identify which co-authors are responsible for specific other parts of the work. In addition, authors should have confidence in the integrity of the contributions of their co-authors.

All those designated as authors should meet all four criteria for authorship, and all who meet the four criteria should be identified as authors. Those who do not meet all four criteria should be acknowledged in the title page of the manuscript.

Turkish Journal of Orthodontics requires corresponding authors to submit a signed and scanned version of the authorship contribution form (available for download through www.turkjorthod.org) during the initial submission process in order to act appropriately on authorship rights and to prevent ghost or honorary authorship. If the editorial board suspects a case of "gift authorship," the submission will be rejected without further review. As part of the submission of the manuscript, the corresponding author should also send a short statement declaring that he/she accepts to undertake all the responsibility for authorship during the submission and review stages of the manuscript.

Turkish Journal of Orthodontics requires and encourages the authors and the individuals involved in the evaluation process of submitted manuscripts to disclose any existing or potential conflicts of interests, including financial, consultant, and institutional, that might lead to potential bias or a conflict of interest. Any financial grants or other support received for a submitted study from individuals or institutions should be disclosed to the Editorial Board. To disclose a potential conflict of interest, the ICMJE Potential Conflict of Interest Disclosure Form should be filled in and submitted by all contributing authors. Cases of a potential conflict of interest of the editors, authors, or reviewers are resolved by the journal's Editorial Board within the scope of COPE and ICMJE guidelines.;

The Editorial Board of the journal handles all appeal and complaint cases within the scope of COPE guidelines. In such cases, authors should get in direct contact with the editorial office regarding their appeals and complaints. When needed, an ombudsperson may be assigned to resolve cases that cannot be resolved internally. The Editor in Chief is the final authority in the decision-making process for all appeals and complaints.

When submitting a manuscript to Turkish Journal of Orthodontics, authors accept to assign the copyright of their manuscript to Turkish Orthodontic Society. If rejected for publication, the copyright of the manuscript will be assigned back to the authors. Turkish Journal of Orthodontics requires each submission to be accompanied by a Copyright Transfer Form (available for download at www.turkjorthod.org). When using previously published content, including figures, tables, or any other material in both print and electronic formats, authors must obtain permission from the copyright holder. Legal, financial and criminal liabilities in this regard belong to the author(s).

Statements or opinions expressed in the manuscripts published in Turkish Journal of Orthodontics reflect the views of the author(s) and not the opinions of the editors, the editorial board, or the publisher; the editors, the editorial board, and the publisher disclaim any responsibility or liability for such materials. The final responsibility in regard to the published content rests with the authors.

MANUSCRIPT PREPARATION

The manuscripts should be prepared in accordance with ICMJE-Recommendations for the Conduct, Reporting, Editing, and Publication of Scholarly Work in Medical Journals (updated in May 2022 - https://www.icmje.org/recommendations/). Authors are required to prepare manuscripts in accordance with the CONSORT guidelines for randomized research studies, STROBE guidelines for observational original research studies, STARD guidelines for studies on diagnostic accuracy, PRISMA guidelines for systematic reviews and meta-analysis, ARRIVE guidelines for experimental animal studies, and TREND guidelines for non-randomized public behavior.

Manuscripts can only be submitted through the journal's online manuscript submission and evaluation system, available at www.turkjorthod.org. Manuscripts submitted via any other medium will not be evaluated.

Manuscripts submitted to the journal will first go through a technical evaluation process where the editorial office staff will ensure that the manuscript has been prepared and submitted in accordance with the journal's guidelines. Submissions that do not conform to the journal's guidelines will be returned to the submitting author with technical correction requests.

Language

Submissions that do not meet the journal's language criteria may be returned to the authors for professional language editing. Authors whose manuscripts are returned due to the language inadequacy must resubmit their edited papers along with the language editing certificate to verify the quality. Editing services are paid for and arranged by authors, and the use of an editing service does not guarantee acceptance for publication.

Authors are required to submit the following:

Copyright Agreement and Acknowledgement of Authorship Form, and ICMJE Potential Conflict of Interest Disclosure Form (should be filled in by all contributing authors) during the initial submission. These forms are available for download at www.turkjorthod.org.

Preparation of the Manuscript

Title page: A separate title page should be submitted with all submissions and this page should include: The full title of the manuscript as well as a short title (running head) of no more than 50 characters, Name(s), affiliations, and highest academic degree(s) of the author(s), Grant information and detailed information on the other sources of support, Name, address, telephone (including the mobile phone number) and fax numbers, and email address of the corresponding author, Acknowledgment of the individuals who contributed to the preparation of the manuscript but who do not fulfill the authorship criteria.

Abstract: An abstract should be submitted with all submissions except for Letters to the Editor. The abstract of Original Articles should be structured with subheadings (Objective, Methods, Results, and Conclusion). Please check Table I below for word count specifications.

Keywords: Each submission must be accompanied by a minimum of three to a maximum of six keywords for subject indexing at the end of the abstract. The keywords should be listed in full without abbreviations. The keywords should be selected from the National Library of Medicine, Medical Subject Headings database (https://www.nlm.nih.gov/mesh/MBrowser.html).

Main Points: All submissions except letters to the editor should be accompanied by 3 to 5 "main points" which should emphasize the most noteworthy results of the study and underline the principle message that is addressed to the reader. This section should be structured as itemized to give a general overview of the article. Since "Main Points" targeting the experts and specialists of the field, each item should be written as plain and straightforward as possible.

Manuscript Types

Original Articles: This is the most important type of article since it provides new information based on original research. The main text of original articles should be structured with Introduction, Methods, Results, Discussion, and Conclusion subheadings. Please check Table I for the limitations for Original Articles.

Statistical analysis to support conclusions is usually necessary. Statistical analyses must be conducted in accordance with international statistical reporting standards (Altman DG, Gore SM, Gardner MJ, Pocock SJ. Statistical guidelines for contributors to medical journals. Br Med J 1983: 7; 1489-93). Information on statistical analyses should be provided with a separate subheading under the Materials and Methods section and the statistical software that was used during the process must be specified.

Units should be prepared in accordance with the International System of Units (SI).

Editorial Comments: Editorial comments aim to provide a brief critical commentary by reviewers with expertise or with high reputation in the topic of the research article published in the journal. Authors are selected and invited by the journal to provide such comments. Abstract, Keywords, and Tables, Figures, Images, and other media are not included.

Review Articles: Reviews prepared by authors who have extensive knowledge on a particular field and whose scientific background has been translated into a high volume of publications with a high citation potential are welcomed. These authors may even be invited by the journal. Reviews should describe, discuss, and evaluate the current level of knowledge of a topic in clinical practice and should guide future studies. The main text should contain Introduction, Clinical and Research Consequences, and Conclusion sections. Please check Table I for the limitations for Review Articles.

Case Reports: There is limited space for case reports in the journal and reports on rare cases or conditions that constitute challenges in diagnosis and treatment, those offering new therapies or revealing knowledge not included in the literature, and interesting and educative case reports are accepted for publication. The text should include Introduction, Case Presentation, Discussion, and Conclusion subheadings. Please check Table I for the limitations for Case Reports.

Letters to the Editor: This type of manuscript discusses important parts, overlooked aspects, or lacking parts of a previously published article. Articles on subjects within the scope of the journal that might attract the readers' attention, particularly educative cases, may also be submitted in the form of a "Letter to the Editor." Readers can also present their comments on the published manuscripts in the form of a "Letter to the Editor." Abstract, Keywords, and Tables, Figures, Images, and other media should not be included. The text should be unstructured. The manuscript that is being commented on must be properly cited within this manuscript.

Tables

Tables should be included in the main document, presented after the reference list, and they should be numbered consecutively in the order they are referred to within the main text. A descriptive title must be placed above the tables. Abbreviations used in the tables should be defined below the tables by footnotes (even if they are defined within the main text). Tables should be created using the "insert table" command of the word processing software and they should be arranged clearly to provide easy reading. Data presented in the tables should not be a repetition of the data presented within the main text but should be supporting the main text.

Figures and Figure Legends

Figures, graphics, and photographs should be submitted as separate files (in TIFF or JPEG format) through the submission system. The files should not be embedded in a Word document or the main document. When there are figure subunits, the subunits should not be merged to form a single image. Each subunit should be submitted separately through the submission system. Images should not be labeled

(a, b, c, etc.) to indicate figure subunits. Thick and thin arrows, arrowheads, stars, asterisks, and similar marks can be used on the images to support figure legends. Like the rest of the submission, the figures too should be blind. Any information within the images that may indicate an individual or institution should be blinded. The minimum resolution of each submitted figure should be 300 DPI. To prevent delays in the evaluation process, all submitted figures should be clear in resolution and large in size (minimum dimensions: 100 × 100 mm). Figure legends should be listed at the end of the main document.

Where necessary, authors should Identify teeth using the full name of the tooth or the FDI annotation.

All acronyms and abbreviations used in the manuscript should be defined at first use, both in the abstract and in the main text. The abbreviation should be provided in parentheses following the definition.

When a drug, product, hardware, or software program is mentioned within the main text, product information, including the name of the product, the producer of the product, and city and the country of the company (including the state if in USA), should be provided in parentheses in the following format: "Discovery St PET/CT scanner (General Electric, Milwaukee, WI, USA)"

All references, tables, and figures should be referred to within the main text, and they should be numbered consecutively in the order they are referred to within the main text.

Limitations, drawbacks, and the shortcomings of original articles should be mentioned in the Discussion section before the conclusion paragraph.

References

Both in-text citations and the references must be prepared according to the AMA Manual of style.

While citing publications, preference should be given to the latest, most up-to-date publications. Authors are responsible for the accuracy of references If an ahead-of-print publication is cited, the DOI number should be provided. Journal titles should be abbreviated in accordance with the journal abbreviations in Index Medicus/MEDLINE/PubMed. When there are six or fewer authors, all authors should be listed. If there are seven or more authors, the first three authors should be listed followed by "et al." In the main text of the manuscript, references should be cited in superscript after punctuation. The reference styles for different types of publications are presented in the following examples.

Journal Article: Economopoulos KJ, Brockmeier SF. Rotator cuff tears in overhead athletes. Clin Sports Med. 2012;31(4):675-692.

Book Section: Fikremariam D, Serafini M. Multidisciplinary approach to pain management. In: Vadivelu N, Urman RD, Hines RL, eds. Essentials of Pain Management. New York, NY: Springer New York; 2011:117-28.

Books with a Single Author: Patterson JW. Weedon's Skin Pahology. 4th ed. Churchill Livingstone; 2016.

Editor(s) as Author: Etzel RA, Balk SJ, eds. Pediatric Environmental Health. American Academy of Pediatrics; 2011.

Conference Proceedings: Morales M, Zhou X. Health practices of immigrant women: indigenous knowledge in an urban environment. Paper presented at: 78th Association for Information Science and Technology Annual Meeting; November 6-10; 2015; St Louis, MO. Accessed March 15, 2016. https://www.asist.org/files/meetings/am15/proceedings/openpage15.html

Thesis: Maiti N. Association Between Behaviours, Health Charactetistics and Injuries Among Adolescents in the United States. Dissertation. Palo Alto University; 2010.

Online Journal Articles: Tamburini S, Shen N, Chih Wu H, Clemente KC. The microbiome in early life: implications for health outcometes. Nat Med. Published online July 7, 2016. doi:10.1038/nm4142

Epub Ahead of Print Articles: Websites: International Society for Infectious Diseases. ProMed-mail. Accessed February 10, 2016. http://www.promedmail.org

REVISIONS

When submitting a revised version of a paper, the author must submit a detailed "Response to the reviewers" that states point by point how each issue raised by the reviewers has been covered and where it can be found (each reviewer's comment, followed by the author's reply and line numbers where the changes have been made) as well as an annotated copy of the main document. Revised manuscripts must be submitted within 30 days from the date of the decision letter. If the revised version of the manuscript is not submitted within the allocated time, the revision option may be canceled. If the submitting author(s) believe that additional time is required, they should request this extension before the initial 30-day period is over.

Accepted manuscripts are copy-edited for grammar, punctuation, and format by professional language editors. Once the publication process of a manuscript is completed, it is published online on the journal's webpage as an ahead-of-print publication before it is included in its scheduled issue. A PDF proof of the accepted manuscript is sent to the corresponding author and their publication approval is requested within 2 days of their receipt of the proof.

Editor in Chief: Çağla Şar

Address: Sütlüce Mah. İmrahor Cad. No: 82 Beyoğlu, İstanbul/Turkey

Phone: +90 (212) 416 61 13

E-mail: info@turkjorthod.org

Publisher

Galenos Publishing House

Address: Molla Gürani Mah. Kaçamak Sok. 21/1 Fındıkzade, Fatih, Istanbul/Turkey

Phone: +90 (530) 177 30 97 / +90 (539) 307 32 03

Web page: http://www.galenos.com.tr

E-mail: info@galenos.com.tr

TURKISH JOURNAL of ORTHODONTICS

Contents

Original Articles

Systematic Reviews

DOI: 10.4274/TurkJOrthod.2022.2022.84

TURKISH JOURNAL of ORTHODONTICS

Original Article

Conventional Twin-Block Versus Cervical Headgear and Twin-Block Combination: Therapeutic Effects on the Craniofacial Structures in Growing Subjects

Beytullah Gülsoy[1], Mehmet Ali Yavan[2]

[1]Private Orthodontist, İstanbul, Turkey
[2]Adıyaman University Faculty of Dentistry, Department of Orthodontics, Adıyaman, Turkey

Cite this article as: Gülsoy B, Yavan MA. Conventional Twin-Block Versus Cervical Headgear and Twin-Block Combination: Therapeutic Effects on the Craniofacial Structures in Growing Subjects. *Turk J Orthod.* 2023; 36(3): 149-157.

Main Points

- The cervical headgear twin-block combination was more effective in limiting maxillary development in the sagittal direction, but the side effects of upper incisor retroclination were found to be greater in this appliance.
- The conventional twin-block appliance was more effective in mandibular movement in the sagittal direction, but the lower incisor proclination side effects were found to be greater in this appliance.
- No significant difference was found between the two appliances in terms of their effects on maxillary and mandibular soft tissues.

Objective: To compare the short-term effects of the conventional twin-block (TB) appliance and the cervical headgear TB (CHG-TB) appliance on craniofacial structures.

Methods: The retrospective controlled study examined lateral cephalograms taken from 46 growing subjects. Individuals were divided into two groups according to the treatment. Group I consisted of 15 individuals (9 girls, 6 boys, mean age: 12.34±1.23 years) treated with the TB appliance and Group II consisted of 16 individuals (9 girls, 7 boys) treated with the CHG-TB appliance (mean age: 12.50±1.30 years). To distinguish the treatment effects of these appliances on growth, a control group of 15 untreated individuals (9 girls, 6 boys, mean age: 11.82±1.16 years) was included from the archives.

Results: Significant improvements were found in the interdental and maxillo-mandibular measurements in the treatment groups ($p<0.001$). Significant differences were observed in the SNA, SN/PP, and SN/GoGn values in the CHG-TB group compared to other groups ($p<0.05$). The mandible showed a significant downward movement in both treatment groups compared with the control group ($p<0.001$), while the change in SNB angle was statistically significant only in the TB group compared to the control group ($p<0.05$). Lower incisors showed significant proclination only in the TB group ($p<0.05$).

Conclusion: The CHG-TB appliance was found to be more effective in limiting maxillary growth and preventing lower incisor proclination compared with the TB appliance, whereas the TB appliance was more effective in anterior mandibular movement.

Keywords: Cephalometry, Cervical headgear, Class II malocclusion, Twin-Block

INTRODUCTION

Class II malocclusion are the anomalies most frequently encountered and treated by orthodontists.[1] Although functional appliances are viable treatment options for many malocclusion, they are mostly used for treating Class II Division 1 malocclusion caused by mandibular retrognathia.[2] Among functional appliances, the twin-block (TB) appliance is frequently used due to patient comfort, good patient cooperation, partial effect on speech, lower risk of aesthetic problems, and clinically significant skeletal and dental effects.[3] Nevertheless, functional appliances such as TB cause undesirable outcomes such as mandibular incisor protrusion and maxillary incisor

Corresponding author: Mehmet Ali Yavan, e-mail: yavanmehmetali@gmail.com

Received: May 27, 2022
Accepted: September 29, 2022
Epub: March 06, 2023
Publication Date: September 29, 2023

retrusion.[4] To eliminate such adversities, various modifications have been tried on functional appliances in numerous studies.[5-7]

The literature indicates that the primary reason for attaching extraoral traction to functional appliances is to prevent antero-inferior maxillary growth.[8-10] In 1975, functional appliances were first combined with extraoral traction by Pfeiffer and Grobéty.[11] Based on the results obtained with this method, the authors indicated that the dentoalveolar development was affected, the anterior growth of the maxilla in the sagittal direction was prevented, the palatal and mandibular planes were rotated downward and backward, eruption and mesialization of the mandibular molar teeth were observed, and the mandibular anterior teeth showed uprighting rather than achieving protrusion. The authors concluded that the combined use of the two appliances completed and positively improved their effects.[11,12] The activator headgear combination used for treating growing individuals with mandibular retrognathia is an effective treatment method in correcting the sagittal imbalance by preventing antero-inferior maxillary growth while stimulating anterior mandibular development.[13-16]

To our knowledge, there has been only one study that combined TB and cervical headgear. However, that study is highly limited concerning the parameters evaluated and it also lacks a control group for distinguishing the effects of growth and development.[15] This study compared the effects of traditional TB and cervical headgear TB (CHG-TB) on skeletal, dentoalveolar, and soft tissues in individuals with mandibular retrognathia. Our null hypothesis was that there was no significant difference between these two appliances.

METHODS

Subjects

The retrospective controlled study examined lateral cephalometric radiographs taken before and after treatment/observation from 46 individuals during the growth and developmental period who were treated at Adıyaman University Faculty of Dentistry Department of Orthodontics due to increased overjet and skeletal Class II Division 1 malocclusion. Approval was obtained from the Adıyaman University Non-Interventional Clinical Research Ethics Committee (approval date: February 16, 2021, approval no: 2021/02-32).

Sample size was calculated using GPOWER (Ver. 3.1 Franz Foul, Universitat Kiel, Germany) and the effect size was calculated with an alpha value of 0.05 and a power of 80% according to the study by Mills and McCulloch.[17] In the same study, the change in the distance between point B and vertical reference plane was 3.8±2.0 mm in the TB group and 1.7±1.7 mm in the control group. Accordingly, the effect size was found to be 1.13 and thus a minimum of 11 subjects were needed for each group. To increase the power of the study, 46 individuals from three groups were included: 15 subjects in the TB group, 16 subjects in the CHG-TB group, and 15 subjects in the control group.

The inclusion criteria were as follows: having a minimum of 4 mm overjet, mandibular retrognathia (SNB <78°), skeletal Class II malocclusion (ANB >4°), dental Class II Division 1 malocclusion (bilateral half or full-step Class II molar relationship), an SN/GoGn angle of less than 36°, normal or increased overbite, being in the onset or peak of pubertal growth spurt and having radiographic images obtained by the same operator using the same device with the patient's head and soft tissue-positioned parallel to the Frankfort horizontal plane, the teeth in centric occlusion, and the lips in a tension-free position. The exclusion criteria were as follows: syndromes, cleft lip and palate or craniofacial anomalies, prior orthodontic treatment, and missing or extra teeth. The growth and development of individuals were evaluated using wrist X-rays following the Björk method,[18] and only individuals between the S and DP3 union periods were included in the study.

Trial Design

Twin-block Appliance

The TB appliance (Figure 1A) used in the study was prepared in accordance to Clark's[3] guidelines. The maximum anterior mandibular activation was 6-7 mm and the maximum vertical mandibular activation was 4-5 mm. The appliance consisted of vestibular arches, eyelet clasps between the premolars, and Adams clasps in the molars in both the maxillary and mandibular parts. A screw was placed at the level of premolar teeth and in the midline of the upper plate to achieve a transversal expansion. The slope between the two parts of the appliance was 70°. All subjects were instructed to wear the TB appliance all day except during meal times. During monthly follow-up appointments, sagittal and transversal relationships were evaluated for each subject. The expansion screw was activated with one turn every 4 days until the transversal stenosis was resolved. The appliances were used full time for an average period of 7 months and the active phase was terminated when the canine and molars had a Class III relationship and the mandible could not be pushed back. In the supportive phase, the appliance was used only at night, and this phase lasted for an average of 4 months.

Cervical Headgear Twin-Block Appliance

During the construction stages of the TB appliance, tubes were placed on both sides of the appliance at the level of the second premolar of the maxillary plate (Figure 1B). The tubes were designed to remain embedded in the acrylic, allowing the inner arms of the cervical headgear could pass through them. Patients were provided with information on how to use both the TB appliance and the cervical headgear appliance (Figure 1C). The extraoral arms of the cervical headgear were raised at the level of the second premolars (15-30°), and care was taken to pass the maxillary dentition through or near the center of resistance. The strength of the cervical headgear was adjusted to 400-450 g, and the patients were asked to wear it with TB all day except during meal times. The force was measured at monthly controls and if it decreased, it was readjusted to 400-450 g. As with patients using TB in the active phase, the molar relationship was terminated when the molar relationship became Class III and

the mandible could no longer be pushed back. The active phase lasted an average of 7 months. As with patients using TB in the supportive phase, the CHG-TB appliance was used only at night. The supportive phase lasted for an average period of 4 months.

To compare the treatment and growth effects, a control group was formed using radiographs selected from the archives. These radiographs were obtained from individuals who had registered for treatment but did not start the treatment for various reasons. Second radiographs of these individuals were obtained after a minimum of six months when they returned for a second treatment.

Analysis of Lateral Cephalometric Radiographs

Measurements of digital lateral cephalometric radiographs taken before and after treatment/observation were performed using Vistadent OC software. A total of 23 cephalometric measurements (Supplementary Table 1), including 7 angular and 16 linear measurements (Figure 2) were performed by an expert orthodontist (BG), who was blinded to the treatment group. Pre- and post-treatment radiographs were superimposed using the cephalometric superimposition method described by Björk and Skieller.[19] To detect errors in individual markings and measurements, all measurements were repeated for 15 randomly selected lateral cephalometric radiographs 21 days after the first measurements.

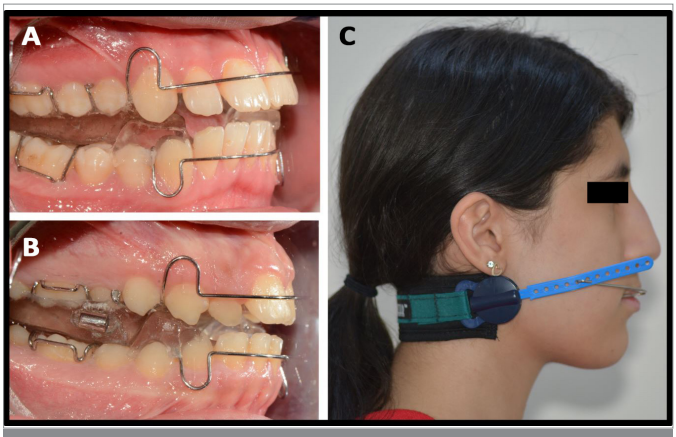

Figure 1. A. A conventional twin-block appliance, B. The twin-block part of the cervical headgear twin-block appliance, C. The cervical headgear part of the cervical headgear twin-block appliance

Statistical Analysis

Data were analyzed using SPSS software for Windows (version 22.0, IBM Corp, Armonk, NY, USA). The normal distribution of continuous variables was assessed using the Shapiro-Wilk test. One-Way ANOVA followed by post-hoc Bonferroni test was used to compare three or more groups. For in-group comparisons, dependent groups were compared using the Paired Samples t-test. The chi-square test was used for comparisons between groups with non-parametric data. Interrater reliability was assessed with an intraclass correlation coefficient (ICC). A p value of <0.05 was considered significant.

RESULTS

The results indicated that the correlation between repeated measurements was remarkably high and the coefficient was close to 1 (0.961-1). Table 1 presents a comparison of the demographic characteristics and treatment durations of the groups. No significant difference was found among the groups concerning baseline demographic characteristics (p>0.05). Similarly, there was no significant difference between the treatment groups concerning treatment/observation time (p>0.05), whereas a significant difference was found between the treatment groups and the control group (p<0.001).

Table 2 presents a comparison of the baseline cephalometric measurements of the groups. No significant difference was found among the groups concerning baseline cephalometric measurements (p>0.05).

Results of Lateral Cephalometric Radiographs

Table 3 presents a comparison of pre- and post-treatment/observation parameters. Regarding the maxillary skeletal measurements of the CHG-TB group, there was a significant decrease in the SNA angle by a mean of 1.21°±1.37° and a significant increase in the SN/PP value by a mean of 1.31°±1.78° (p<0.01). In the other groups, no significant change was found in these measurements. There was a significant increase in the A-HR value in all three groups (p<0.05), while a significant change was observed in the A-VR value only in the control group (p<0.05).

Table 1. Baseline demographic characteristics of the samples

		1. TB	2. CHG-TB	3. C	p	1 vs. 2	2 vs. 3	1 vs. 3
Age (years)		**12.34±1.23**	**12.5±1.30**	**11.82±1.16**	**0.300[a]**	**NS**	**NS**	**NS**
Gender	**Female (n)**	9	9	9	0.970[b]	NS	NS	NS
	Male (n)	6	7	6				
Maturation stage	**S**	7	8	8	0.752[b]	NS	NS	NS
	MP3cap	5	6	7				
	PP3u	1	1	0				
	DP3u	2	1	0				
Duration/Observation (months)		11.07±1.10	10.88±1.31	7.43±2.01	0.000*[a]	NS	0.000*	0.000*

TB, Conventional twin-block group; CHG-TB, cervical headgear twin-block group; C, Control group; [a], ANOVA test; [b], Chi-square test; NS, Not significant, *: p<0.05

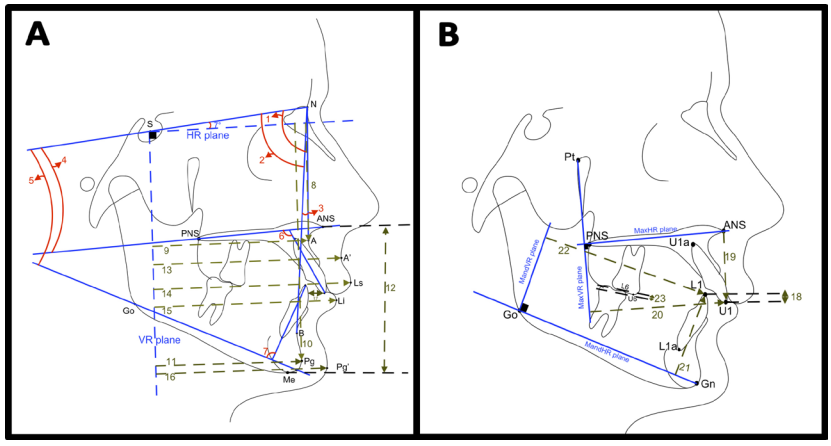

Figure 2. A. Lateral cephalometric measurements used in the study: 1. SNA (°): Angle between the S, N, and A points, 2. SNB(°): Angle between the S, N and B planes, 3. ANB(°): Angle between the N, A, and B points, 4. SN/PP(°): Angle between the plane formed by the S and N points and the plane formed by the ANS and PNS points, 5: SN/GoGn(°): Angle between the plane formed by the S and N points and the plane formed by the Go and Gn points, 6. U1/PP(°): Angle between the plane formed by the U1 and U1a points and the planes formed by the ANS and PNS points, 7. IMPA (°): Angle between the plane formed by the L1 and L1a points and the plane formed by the ANS and PNS points, 8. A-HR (mm): Distance between the A point and the HR plane, 9. A-VR (mm): Distance between the A point and the VR plane, 10. Pg-HR (mm): Distance between the Pg point and the HR plane, 11. Distance between the Pg point and VR plane, 12. ANS-Me (mm): Distance between the ANS and Me points, 13. Distance between point the A' point and the VR plane, 14. Distance between the Ls point and the VR plane, 15. Distance between the Li point and the VR plane, 16. Distance between the Pg' point and the VR plane, 17. Overjet (mm): Perpendicular distance between the U1 point and the lower incisors. B. Lateral cephalometric measurements used in the study (continued): 18. Perpendicular distance between the U1 and L1 points, 19. Perpendicular distance between the U1 point and the MaxHR plane, 20. Perpendicular distance between the U1 point and the MaxVR plane, 21. Perpendicular distance between the L1 point to the MandHR plane, 22. Perpendicular distance between the L1 point and the MandVR plane, 23. Perpendicular distance between the U6 and L6 points

Table 2. Pretreatment values of parameters for each group

Parameters		TB	CHG-TB	C			
		Mean±SD	Mean±SD	Mean±SD	F	Overall P[a] value	Significance
Maxillary skeletal measurements	SNA°	79.33±3.75	82.23±3.78	80.86±3.62	2.35	0.107	NS
	A-HR (mm)	51.57±4.72	52.31±4.55	49.90±3.20	1.32	0.278	NS
	A-VR (mm)	65.60±5.25	68.78±5.51	65.74±5.06	1.82	0.175	NS
Mandibular skeletal measurements	SN/PP°	9.33±4.32	6.56±3.35	8.20±2.70	2.44	0.099	NS
	SNB°	72.90±3.05	75.75±3.30	74.51±2.68	3.45	0.051	NS
	Pg-HR (mm)	97.70±7.03	100.94±8.54	98.57±4.49	0.911	0.410	NS
	Pg-VR (mm)	54.40±6.71	58.53±6.82	56.70±7.91	1.29	0.285	NS
	SN/GoGn°	31.73±4.14	30.80±3.64	30.75±3.82	0.31	0.735	NS
Maxillo-mandibular measurements	ANB°	6.43±2.08	6.49±1.89	6.35±1.90	0.02	0.982	NS
	ANS-Me (mm)	57.47±5.26	59.25±6.06	58.27±4.22	0.45	0.642	NS
Maxillary dental measurements	U1/PP°	116.46±11.59	118.23±5.86	119.48±5.03	0.54	0.586	NS
	U1-MaxHR (mm)	28.14±5.52	29.54±5.23	28.54±1.92	0.41	0.664	NS
	U1-MaxVR (mm)	51.73±3.52	52.57±3.82	51.23±3.62	0.50	0.608	NS
Mandibular dental measurements	IMPA°	96.80±7.88	96.75±6.54	98.73±6.85	0.38	0.683	NS
	L1-MandVR (mm)	64.13±5.88	65.81±4.78	64.73±4.79	0.422	0.658	NS
	L1-MandHR (mm)	38.13±1.82	38.91±3.53	38.13±2.29	0.436	0.649	NS
Interdental measurements	Overjet (mm)	9.69±2.50	10.06±2.28	9.33±1.85	0.41	0.663	NS
	Overbite (mm)	3.84±2.58	4.48±1.68	3.40±1.65	1.14	0.331	NS
	Posterior overbite (mm)	1.46±0.52	1.44±0.51	1.40±0.51	0.064	0.938	NS
Soft-tissue measurements	A'-VR (mm)	80.53±5.42	80.50±4.60	80.80±6.82	0.013	0.987	NS
	Ls-VR (mm)	82.10±5.90	82.28±4.98	82.06±7.28	0.006	0.984	NS
	Li-VR (mm)	75.23±6.03	75.03±6.10	75.67±6.94	0.040	0.961	NS
	Pg'-VR (mm)	64.37±8.45	64.13±7.70	64.60±7.61	0.014	0.986	NS

TB, Conventional twin-block group; CHG-TB, Cervical headgear twin-block group; C, Control group; [a], ANOVA test; mm, Millimeter; SD, Standard deviation; NS, Not significant, Significance: p<0.05

Table 3. Comparison of pre- and post-treatment/observation parameters

	TB			CHG-TB			C		
	Pretreatment	Post-treatment	P[q]	Pretreatment	Post-treatment	P[q]	Pre-observation	Post-observation	P[q]
	Mean±SD			Mean±SD			Mean±SD		
SNA°	79.33±3.75	79.41±3.85	0.838	82.23±3.78	81.02±4.07	0.003*	80.86±3.62	81.27±3.40	0.193
A-HR (mm)	51.57±4.72	52.90±5.22	0.024*	52.31±4.55	54.47±4.88	0.002*	49.90±3.20	51.02±3.87	0.000*
A-VR (mm)	65.60±5.25	65.97±5.25	0.524	68.78±5.51	68.72±5.87	0.940	65.74±5.06	66.98±5.22	0.001*
SN/PP°	9.33±4.32	8.87±4.60	0.187	6.56±3.35	7.88±4.22	0.010*	8.20±2.70	7.67±2.92	0.120
SNB°	72.90±3.05	74.97±3.82	0.000*	75.75±3.30	76.74±3.55	0.023*	74.51±2.68	74.97±2.48	0.127
Pg-HR (mm)	97.70±7.03	102.77±7.97	0.000*	100.94±8.54	107.28±7.68	0.000*	98.57±4.49	99.97±3.95	0.002*
Pg-VR (mm)	54.40±6.71	58.10±7.59	0.000*	58.53±6.82	61.50±7.78	0.003*	56.70±7.91	58.13±7.56	0.014*
SN/GoGn°	31.73±4.14	32.00±4.51	0.395	30.80±3.64	32.59±3.73	0.001*	30.75±3.82	30.95±3.66	0.259
ANB°	6.43±2.08	4.45±2.36	0.000*	6.49±1.89	4.27±1.67	0.000*	6.35±1.90	6.30±1.87	0.650
ANS-Me (mm)	57.47±5.26	60.47±5.50	0.000*	59.25±6.06	63.69±6.10	0.000*	58.27±4.22	59.41±3.23	0.009*
U1/PP°	116.46±11.59	111.31±8.01	0.004*	118.23±5.86	108.71±7.34	0.000*	119.48±5.03	119.23±6.48	0.834
U1-MaxHR (mm)	28.14±5.52	29.87±6.85	0.040*	29.54±5.23	29.57±4.48	0.969	28.54±1.92	28.34±2.92	0.651
U1-MaxVR (mm)	51.73±3.52	50.33±3.64	0.006*	52.57±3.82	49.66±4.93	0.000*	51.23±3.62	51.49±4.58	0.665
IMPA°	96.80±7.88	100.60±5.89	0.008*	96.75±6.54	98.13±5.58	0.156	98.73±6.85	99.07±7.06	0.519
L1-MandVR (mm)	64.13±5.88	66.87±6.35	0.000*	65.81±4.78	67.16±4.58	0.000*	64.73±4.79	64.73±5.21	1.000
L1-MandHR (mm)	38.13±1.82	38.03±2.47	0.819	38.91±3.53	39.38±3.70	0.038*	38.13±2.29	38.53±2.25	0.022*
Overjet (mm)	9.69±2.50	3.65±1.38	0.000*	10.06±2.28	3.51±1.58	0.000*	9.33±1.85	9.15±2.54	0.656
Overbite (mm)	3.84±2.58	2.06±1.48	0.005*	4.48±1.68	2.78±1.68	0.001*	3.40±1.65	3.57±1.42	0.586
Posterior overbite (mm)	1.46±0.52	-1.73±1.31	0.000*	1.44±0.51	-1.69±1.94	0.000*	1.40±0.51	1.47±0.40	0.433
A'-VR (mm)	80.53±5.42	81.06±5.24	0.305	80.50±4.60	79.09±5.38	0.066	80.80±6.82	83.13±6.75	0.000*
Ls-VR (mm)	82.10±5.90	82.87±6.28	0.180	82.28±4.98	80.78±5.68	0.111	82.06±7.28	84.00±7.32	0.001*
Li-VR (mm)	75.23±6.03	78.97±7.28	0.000*	75.03±6.10	78.38±6.58	0.000*	75.67±6.94	77.93±6.94	0.001*
Pg'-VR (mm)	64.37±8.45	69.20±9.82	0.000*	64.13±7.70	67.72±8.62	0.000*	64.60±7.61	68.20±7.63	0.000*

TB, Conventional twin-block group; CHG-TB, Cervical headgear twin-block group; C, Control group; SD, Standard deviation; [q], Paired Samples t-test; mm, Millimeter, *: p<0.05

Table 4 presents a comparison of the parameters among the three groups. No significant difference was found among the groups concerning A-HR and A-VR values (p>0.05), while the changes in SNA and SN/PP values were statistically significant in the CHG-TB group compared to other groups (p>0.05). However, there was no significant difference between the TB and control groups (p>0.05).

In mandibular skeletal measurements, the SNB angle increased significantly by a mean of 2.07°±1.50° in the TB group (p<0.001) and by a mean of 0.99°±1.57° in the CHG-TB group (p<0.05), whereas no significant change was observed in the control group. The Pg-HR and Pg-VR values increased significantly in all three groups (p<0.05), while the SN/GoGn value changed significantly only in the CHG-TB group. Although there was no significant difference among the three groups concerning the change in the Pg-VR value (p>0.05), the Pg-HR value showed a significant difference between the treatment groups and the control group (p<0.001). However, no significant difference was established between the treatment groups (p>0.05). No significant difference was observed between the TB and control groups concerning the changes in the SNB and SN/GoGn values (p>0.05), while significant differences were found between the CHG-TB and TB groups and between the CHG-TB and control groups (p<0.01).

The ANB angle decreased significantly by a mean of 1.98° in the TB group and a mean of 2.22° in the CHG-TB group (p<0.001), while no significant change was found in the control group (p>0.05). The ANS-Me value showed a significant increase in all three groups (p<0.01). Although no significant difference was found between the treatment groups concerning the change in the ANB angle (p>0.05), a significant difference was observed

Table 4. Comparison of the parameters among the three groups

		1. TB Mean±SD	2. CHG-TB Mean±SD	3. C Mean±SD	P[a]	1-2	1-3	2-3
Maxillary skeletal measurements	SNA°	0.07±1.36	-1.21±1.37	0.41±1.17	0.003*	0.027*	NS	0.004 *
	A-HR (mm)	1.33±2.03	2.16±2.32	1.12±0.88	0.273	NS	NS	NS
	A-VR (mm)	0.37±2.18	-0.06±3.26	1.24±1.15	0.309	NS	NS	NS
Mandibular skeletal measurements	SN/PP°	-0.47±1.30	1.31±1.78	-0.53±1.25	0.001*	0.005 *	NS	0.003*
	SNB°	2.07±1.50	0.99±1.57	0.46±1.10	0.010*	NS	0.009*	NS
	Pg-HR (mm)	5.07±1.57	6.34±3.36	1.40±1.42	0.000*	NS	0.000*	0.000*
	Pg-VR (mm)	3.70±2.66	2.97±3.40	1.43±1.99	0.083	NS	NS	NS
	SN/GoGn°	0.27±1.18	1.79±1.67	0.20±0.66	0.001*	0.006*	NS	0.001*
Maxillo-mandibular measurements	ANB°	-1.98±0.90	-2.22±1.09	-0.05±0.45	0.000*	NS	0.000*	0.000*
	ANS-Me (mm)	3.00±1.65	4.44±1.41	1.14±1.47	0.000*	0.034*	0.005*	0.000*
Maxillary dental measurements	U1/PP°	-5.15±5.89	-9.53±5.35	-0.25±4.47	0.000*	NS	0.044*	0.000*
	U1-MaxHR (mm)	1.73±3.04	0.03±3.21	-0.20±2.01	0.111	NS	NS	NS
	U1-MaxVR (mm)	-1.40±1.64	-2.91±2.55	0.26±1.83	0.001*	NS	NS	0.000*
Mandibular dental measurements	IMPA°	3.80±4.78	1.38±3.69	0.33±1.95	0.038*	NS	0.039*	NS
	L1-MandVR (mm)	2.73±1.43	1.34±0.93	0.00±0.94	0.000*	0.004*	0.000*	0.005*
	L1-MandHR (mm)	-0.10±1.66	0.47±0.83	0.40±0.60	0.320	NS	NS	NS
Interdental measurements	Overjet (mm)	-6.04±1.98	-6.55±2.41	-0.18±1.53	0.000*	NS	0.000*	0.000*
	Overbite (mm)	-1.78±2.08	-1.71±1.75	0.17±1.16	0.004*	NS	0.010*	0.012*
	Posterior overbite (mm)	-3.20±1.35	-3.13±2.05	0.07±0.32	0.000*	NS	0.000*	0.000*
Soft-tissue measurements	A'-VR (mm)	0.53±1.94	-1.41±2.84	2.33±1.54	0.000*	NS	NS	0.000*
	Ls-VR (mm)	0.76±2.10	-1.50±3.54	1.93±1.79	0.002*	NS	NS	0.002*
	Li-VR (mm)	3.73±2.74	3.34±2.45	2.27±2.08	0.244	NS	NS	NS
	Pg'-VR (mm)	4.83±3.46	3.59±2.53	3.60±2.90	0.426	NS	NS	NS

TB, Conventional twin-block group; CHG-TB, Cervical headgear twin-block group; C, Control group; SD, Standard deviation; [a], ANOVA test; mm, Millimeter, *: p<0.05

between the treatment groups and the control group (p<0.001). The change in the ANS-Me value showed a significant difference among all three groups (p<0.05).

In terms of maxillary dental measurements, the U1/PP and U1-MaxVR values showed a significant decrease in both treatment groups (p<0.01). The U1-MaxHR value showed a significant change only in the TB group. In the control group, no significant change was observed in the U1/PP and U1-MaxVR values. There was no significant difference found between the treatment groups concerning the changes in maxillary measurements (p>0.05). While a significant difference was observed between the treatment groups and the control group regarding the change in the U1/PP value (p<0.05), the U1-MaxVR value showed a significant difference only between the CHG-TB and control groups (p<0.001).

The IMPA value increased significantly only in the TB group (p<0.01), whereas the L1-MandVR value increased significantly in both treatment groups (p<0.001). The L1-MandHR value showed a significant change in the CHG-TB and control groups (p<0.05). Although no significant difference was found among the three groups concerning the change in the L1-MandHR value (p>0.05), a significant difference was observed between the TB and control groups concerning the change in the IMPA value. The change in the L1-Mand VR value showed a significant difference among all three groups (p<0.01).

In interdental measurements, both treatment groups showed a significant decrease in overjet, overbite, and posterior overbite (p<0.01), while no significant change was observed in the control group (p>0.05). No significant difference was found between the treatment groups concerning the changes in those values (p>0.05), but a significant difference was found between the treatment groups and the control group (p<0.05).

In soft tissue measurements, both treatment groups showed a significant increase in Li-VR and Pg'-VR values (p<0.001), while no significant change was observed in the Ls-VR and A'-VR values (p>0.05). In the control group, a significant increase was observed in all of these measurements ().

DISCUSSION

This study compared the effects of full-time use of an appliance combining CHG-TB with a conventional TB appliance and an

untreated control group and found significant differences among the groups. Accordingly, the null hypothesis was rejected. Our findings indicated no significant difference between the TB and control groups during the treatment/observation period concerning the change in maxillary skeletal measurements. Some researchers[20-22] have shown that TB significantly limited the maxillary growth, while other researchers, in line with our findings, have reported that it had no significant effect on maxillary growth.[23,24] Clark[25] suggested that TB should be used along with headgear when it is necessary to limit the sagittal growth of the maxilla and stimulate mandibular development. In our study, the SNA angle decreased significantly in the CHG-TB group compared to the other two groups ($p<0.01$). In line with our findings, studies in the literature[12,15] on the functional appliance-cervical headgear have also reported a significant limiting effect on the maxilla. Our results showed that the CHG-TB appliance could be applied when a limiting effect on the maxilla is desired. Moreover, the CHG-TB appliance was found to significantly rotate the maxilla clockwise. Similarly, Pfeiffer and Grobéty.[12] reported that the SHG-activator combination increased the palatal plane by 2°. This finding could be explained by the fact that the force vector passes well below the center of resistance of the maxilla through the combined use of cervical headgear and the functional appliance.

In our study, a significant increase was observed in the TB group concerning the sagittal movement of the mandible, and a significant increase was observed in the same group and compared to the control group regarding the SNB angle. The effect of functional appliances on mandibular growth remains controversial, with some studies reporting significant mandibular movement in the sagittal direction compared to the control group,[23,24] while others[17] have reported no significant effect. This controversy could be due to the differences in the designs of the appliances, daily usage time, and the amount of mandibular activation. In our study, although the anterior movement of the mandible was statistically significant in the CHG-TB group, no significant difference was found compared with the control group. This finding suggests that the posterior force exerted by the CHG-TB appliance on the maxilla may be transmitted to the mandible through TB and partially limit the anterior movement of the mandible. Additionally, a significant posterior rotation of the mandible was observed in the CHG-TB group compared to the TB and control groups, likely due to the force exerted distally and inferiorly by the cervical headgear attached to the TB appliance, causing clockwise rotation of the maxilla and posterior rotation of the mandible. Because of these effects, the increase in lower facial height (ANS-Me) was significantly higher in the CHG-TB group than in the other groups. Therefore, the CHG-TB appliance may not be suitable for individuals with a tendency towards vertical growth.

In our study, significant improvements were observed in the sagittal relationship between the jaws (ANB) in both treatment groups compared with the control group. The decrease in the ANB angle was due to the increase in the SNB angle in the TB group and due to the increase in the SNB angle and the significant decrease in the SNA angle in the CHG-TB group. These findings are consistent with those of the TB[22,26,27] and functional appliance-headgear[12,13] studies in the literature.

Our findings also revealed a significant retroclination of the maxillary incisors in both treatment groups compared with the control group. This finding is consistent with the TB studies in the literature[20,26,28,29] and can be explained by the fact that the anterior positioning of the mandible by conventional TB exerts a distal force on maxillary teeth, based on the action and reaction principle. Moreover, it was also observed that this decrease was higher and the distal movement of the upper incisors was statistically significant in the CHG-TB group compared with the control group. In addition to the force exerted by the TB appliance on the maxillary teeth, the distalizing effect of the cervical headgear may have contributed to this result. This finding is consistent with the those of activator-headgear studies in the literature.[13,16,30] Based on these findings, we suggest that the CHG-TB appliance can be recommended in cases with proclined maxillary incisors, whereas this appliance may be avoided or only applied with torque springs if the maxillary incisor angles are within normal limits.

In our study, although the mandibular incisors protruded and proclined significantly in the TB group compared with the control group, no significant change was observed in the CHG-TB group compared with the control group. Lower incisor proclination, which is a frequently reported side effect of TB, was statistically insignificant in the CHG-TB group.[20,31,32] In the CHG-TB appliance, the protrusion force on the mandibular anterior teeth decreases due to the distalizing force on the upper part of the TB appliance. This notion could explain the lower proclination observed in the mandibular anterior teeth. Additionally, retroclinations of the maxillary incisors in the CHG-TB group may have prevented the protrusion of the lower incisors.

In this study, a significant decrease was found in overjet and overbite measurements in both groups compared with the control group, and there was no significant difference between the two treatment groups. This finding is consistent with previous studies on TB[7,17,21,23,24,26,28,29] and activator-headgear appliances.[13,14] Additionally, lateral open bite was observed in both treatment groups. DeVincenzo[33] reported a posterior open bite after the administration of the TB appliance, which could be attributed to the posterior acrylic blocks that prevent tooth eruption after anterior relocation of the mandible by the TB appliance. Although there was no significant difference between the two treatment groups in our study regarding soft tissue measurements, maxillary soft tissues showed significant retrusion in the CHG-TB group compared with the control group. Therefore, it is predictable that the maxillary soft tissues would move posteriorly after the retrusion of the maxillary base and incisors in the CHG-TB group.

The first limitation of this retrospective study was that it only evaluated the immediate effects of two different appliances.

Therefore, further studies evaluating long-term changes are needed to investigate treatment stability in patients. The second limitation was that the follow-up period of the control group, which was used to compare treatment effects with growth effects, was shorter than that of the treatment groups. This may be clinically significant, and further prospective studies with treatment and follow-up periods across all groups are necessary. Additionally, different appliance models should be studied with different age groups and larger sample sizes.

CONCLUSION

The conclusions drawn from our findings can be summarized as follows:

- The CHG-TB combination was more effective in limiting maxillary development in the sagittal direction, but had greater side effects of upper incisor retroclination.
- The conventional TB appliance was more effective in mandibular movement in the sagittal direction, but had greater side effects of lower incisor proclination.
- There was no significant difference between the two appliances in terms of their effects on maxillary and mandibular soft tissues.

Ethics

Ethics Committee Approval: An approval was obtained from Adıyaman University Non-Interventional Clinical Research Ethics Committee (approval date: February 16, 2021, approval no: 2021/02-32).

Informed Consent: Written informed consent was obtained from the patients who agreed to take part in the study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - M.A.Y.; Design - M.A.Y.; Supervision - M.A.Y.; Materials - B.G.; Data Collection and/or Processing - B.G.; Literature Review - M.A.Y.; Writing - M.A.Y.; Critical Review - M.A.Y.

Declaration of Interests: The authors have no conflicts of interest to declare.

Funding: The authors declared that this study has received no financial support.

References

1. Proffit WR, Fields HW Jr, Moray LJ. Prevalence of malocclusion and orthodontic treatment need in the United States: estimates from the NHANES III survey. *Int J Adult Orthodon Orthognath Surg.* 1998;13(2):97-106. [CrossRef]
2. Bishara SE, Ziaja RR. Functional appliances: a review. *Am J Orthod Dentofacial Orthop.* 1989;95(3):250-258. [CrossRef]
3. Clark W. Twin-Block Functional Therapy. 1995.
4. McNamara JA, Brudon WL, Kokich VG. Orthodontics and dentofacial orthopedics. Needham Press; 2001. [CrossRef]
5. Vogt W. The Forsus fatigue resistant device. *J Clin Orthod.* 2006;40(6):368-358. [CrossRef]
6. Geserick M, Olsburgh SR, Petermann D. The bite-jumping screw for modified twin-block treatment. *J Clin Orthod.* 2006;40(7):432-420. [CrossRef]
7. Parkin NA, McKeown HF, Sandler PJ. Comparison of 2 modifications of the Twin-block appliance in matched Class II samples. *Am J Orthod Dentofacial Orthop.* 2001;119(6):572-577. [CrossRef]
8. Teuscher U. A growth-related concept for skeletal Class II treatment. *Am J Orthod.* 1978;74(3):258-275. [CrossRef]
9. Joffe L, Jacobson A. The maxillary orthopedic splint. *Am J Orthod.* 1979;75(1):54-69. [CrossRef]
10. Thurow RC. Craniomaxillary orthopedic correction with en masse dental control. *Am J Orthod.* 1975;68(6):601-624. [CrossRef]
11. Pfeiffer J, Grobéty D. The Class II malocclusion: differential diagnosis and clinical application of activators, extraoral traction, and fixed appliances. *Am J Orthod.* 1975;68(5):499-544. [CrossRef]
12. Pfeiffer JP, Grobéty D. Simultaneous use of cervical appliance and activator: an orthopedic approach to fixed appliance therapy. *Am J Orthod.* 1972;61(4):353-373. [CrossRef]
13. Lehman R, Romuli A, Bakker V. Five-year treatment results with a headgear-activator combination. *Eur J Orthod.* 1988;10(1):309-318. [CrossRef]
14. Levin RI. Activator headgear therapy. *Am J Orthod.* 1985;87(2):91-109. [CrossRef]
15. Singh GD, Hodge MR. Bimaxillary morphometry of patients with class II division 1 malocclusion treated with twin block appliances. *Angle Orthod.* 2002;72(5):402-409. [CrossRef]
16. Van Beek H. Overjet correction by a combined headgear and activator. *Eur J Orthod.* 1982;4(4):279-290. [CrossRef]
17. Mills CM, McCulloch KJ. Posttreatment changes after successful correction of Class II malocclusions with the twin block appliance. *Am J Orthod Dentofacial Orthop.* 2000;118(1):24-33. [CrossRef]
18. Björk A. Timing of interceptive orthodontic measures based on stages of maturation. *Trans Eur Orthod Soc.* 1972:61-74. [CrossRef]
19. Björk A, Skieller V. Normal and abnormal growth of the mandible. A synthesis of longitudinal cephalometric implant studies over a period of 25 years. *Eur J Orthod.* 1983;5(1):1-46. [CrossRef]
20. Mills CM, McCulloch KJ. Treatment effects of the twin block appliance: a cephalometric study. *Am J Orthod Dentofacial Orthop.* 1998;114(1):15-24. [CrossRef]
21. Illing HM, Morris DO, Lee RT. A prospective evaluation of Bass, Bionator and Twin Block appliances. Part I--The hard tissues. *Eur J Orthod.* 1998;20(5):501-516. [CrossRef]
22. Lee RT, Kyi CS, Mack GJ. A controlled clinical trial of the effects of the Twin Block and Dynamax appliances on the hard and soft tissues. *Eur J Orthod.* 2007;29(3):272-282. [CrossRef]
23. Lund DI, Sandler PJ. The effects of Twin Blocks: a prospective controlled study. *Am J Orthod Dentofacial Orthop.* 1998;113(1):104-110. [CrossRef]
24. Toth LR, McNamara Jr JA. Treatment effects produced by the Twin-block appliance and the FR-2 appliance of Fränkel compared with an untreated Class II sample. *Am J Orthod Dentofacial Orthop.* 1999;116(6):597-609. [CrossRef]
25. Clark WJ. The twin block traction technique. *Eur J Orthod.* 1982;4(2):129-138. [CrossRef]
26. Parekh J, Counihan K, Fleming PS, Pandis N, Sharma PK. Effectiveness of part-time vs full-time wear protocols of Twin-block appliance on dental and skeletal changes: A randomized controlled trial. *Am J Orthod Dentofacial Orthop.* 2019;155(2):165-172. [CrossRef]
27. Yavan MA, Aycan M, Aysoyler D, Essiz A. Comparison of twin block appliance and Forsus Fatigue Resistant Device therapies on uvulo-glossopharyngeal dimensions: A retrospective study. *APOS Trends*

Orthod. 2021;11(1):23-31. [CrossRef]

28. Qadir M. Cephalometric assessment of Twin Block appliance in treatment of Class II div 1 malocclusion. *IJADS.* 2017. [CrossRef]
29. Ahmadian-Babaki F, Araghbidi-Kashani SM, Mokhtari S. A cephalometric comparison of Twin Block and bionator appliances in treatment of class II malocclusion. *J Clin Exp Dent.* 2017;9(1):107-111. [CrossRef]
30. Öztürk Y, Tankuter N. Class II: a comparison of activator and activator headgear combination appliances. *Eur J Orthod.* 1994;16(2):149-157. [CrossRef]
31. Faltin KJ, Faltin RM, Baccetti T, Franchi L, Ghiozzi B, McNamara JA Jr. Long-term effectiveness and treatment timing for Bionator therapy. *Angle Orthod.* 2003;73(3):221-230. [CrossRef]
32. Flores-Mir C, Major PW. A systematic review of cephalometric facial soft tissue changes with the Activator and Bionator appliances in Class II division 1 subjects. *Eur J Orthod.* 2006;28(6):586-593. [CrossRef]
33. DeVincenzo JP. Changes in mandibular length before, during, and after successful orthopedic correction of Class II malocclusions, using a functional appliance. *Am J Orthod Dentofacial Orthop.* 1991;99(3):241-257. [CrossRef]

Supplementary Table 1. Cephalometric landmarks and planes

Variables	Definition
Landmarks	
S	Geometrical midpoint of sella turcica
N	The deepest and most anterior point where the frontonasal suture intersects the middle oxal plane
A	The deepest point of the bony concavity between the anterior nasal spine and the upper incisors
B	The deepest point of the bone concavity that lies between the lower incisors and the tip of the jaw
ANS	The most extreme point of the maxillary prominence at the base of the anterior nasal opening
PNS	Most posterior and end point of the maxillary hard palate in the sagittal plane on lateral cephalometric radiographs
U1	Apex of the incisal edge of the maxillary central incisor
U1a	Apex of the maxillary central incisor
L1	Apex of the incisal edge of the mandibular central incisor
L1a	Apex of the mandibular central incisor
U6	Apex of the mesiobuccal tubercle of the maxillary first molar
L6	Apex of the mesiobuccal tubercle of the mandibular first molar
Gn	Midpoint of the structure between the most anterior and lowest points in the outer contour of the mandibular symphysis
Me	Lowest point in the vertical plane on the outer borders of the mandibular symphysis
Go	The point where the bisector of the angle formed by drawing tangents to the posterior edge of the mandibular ramus and the lower edge of its corpus intersects with the mandibular angle
Ls	The most anterior point of the upper lip in the sagittal plane
Li	The most anterior point of the lower lip in the sagittal plane
A'	The deepest point between the subnasale point and the most forward point of the upper lip in the sagittal plane
Pg'	The most anterior point of the chin soft tissue in the sagittal plane
Planes	
HR	Horizontal reference plane: the plane created by drawing 7° below SN through the S point
VR	Vertical reference plane: the plane created by drawing 90° perpendicular to the HR plane through the S point
MaxHR	Maxillary horizontal reference plane: the plane connecting the ANS and PNS points
MaxVR	Maxillary vertical reference plane: the plane perpendicular to the MaxHR plane from the Pt point
MandHR	Mandibular horizontal reference plane: the plane connecting the Go and Gn points
MandVR	Mandibular vertical reference plane: the plane perpendicular to the MandHR plane from the Go point

TURKISH JOURNAL of ORTHODONTICS

DOI: 10.4274/TurkJOrthod.2022.2022.54

Original Article

Starting Mandibular Advancement Device Therapy in Patients with Good Protrusive Capacity: A Randomized Pilot Study

Marie Marklund

Umea University Faculty of Medicine, Department of Odontology, Umea, Sweden

Cite this article as: Marklund M. Starting Mandibular Advancement Device Therapy in Patients with Good Protrusive Capacity: A Randomized Pilot Study. *Turk J Orthod.* 2023; 36(3): 158-164.

Main Points
- Obstructive sleep apnea patients with a good protrusive capacity may experience unnecessary side effects with the mandible advanced by 70% at start.
- The advancement measured in millimeters correlated with the occurrence of severe side-effects, r=0.64, in this group of patients.
- The patients had difficulty estimating whether they had started with a smaller or larger advancement.
- A description in both millimeters and per cent will facilitate comparisons between patients with varying protrusive capacities.

ABSTRACT

Objective: Discomfort has been related to the poor acceptance of a mandibular advancement device (MAD) in patients with obstructive sleep apnea. The present study compared severe initial side effects between a smaller and a larger degree of mandibular advancement in patients with a good protrusive capacity.

Methods: Consecutive patients with obstructive sleep apnea and a good protrusive capacity (≥8 mm) were randomized to start treatment with the mandible advanced by either 70% of maximum protrusion ($Adv_{70\%}$) or by 4 mm (Adv_{4mm}) in a pilot study with a parallel design. The main outcome was tenderness or pain in the teeth or jaws using a 0-10 visual analogue scale (VAS) (from "not at all" to "very extensive") or excluded use because of side effects during the first week of treatment. Secondary outcomes included salivation problems and bite changes.

Results: Eighteen patients were randomly selected and 17 patients fulfilled the study protocol. Four patients in the $Adv_{70\%}$ group and none in the Adv_{4mm} group reported severe tenderness or pain (VAS ≥7) on five or more of the seven days (p=0.03). The degree of mandibular advancement measured in millimeters correlated with the number of days with severe side effects, r=0.64 (p=0.006). The secondary side effects were minor.

Conclusion: Starting MAD treatment with 70% mandibular advancement was related to more severe side effects during the first week of treatment compared with a smaller fixed millimeter value in patients with a good protrusive capacity in this pilot study.

Keywords: Oral appliances, mandibular advancement devices, mandibular repositioning appliances, side-effects, obstructive sleep apnoea

INTRODUCTION

The repositioning of the lower jaw anteriorly to facilitate breathing during sleep is the key mechanism of a mandibular advancement device (MAD) for treating patients with obstructive sleep apnea (OSA). Treatment with MAD may, however, also cause side effects leading to poor adherence,[1,2] in accordance with what has been found for treatment with positive airway pressure (PAP).[3] Good adherence already during the first week of treatment has been related to the long-term acceptance of both MAD and PAP.[4,5] Several routines have been suggested to identify the most effective jaw position for the MAD, as it will differ from patient to patient.[2,6] The American

Corresponding author: Marie Marklund, e-mail: marie.marklund@umu.se

Received: May 6, 2022
Accepted: December 22, 2022
Epub: September 20, 2023
Publication Date: September 29, 2023

Academy of Dental Sleep Medicine has published the results of a task force that evaluated all the steps in the procedure of finding the therapeutic position of the mandible, from the beginning of treatment through the titration process to verifying the outcome with a follow-up sleep apnea recording.[2] These differences pertain to the posterior reference point used for measuring the advancement, whether the advancement should be measured in percent or in millimeters, and the appropriate magnitude of the initial advancement.

The degree of mandibular advancement can be measured either from the most retruded position of the lower jaw that the patient can achieve in a gauge or from centric occlusion, which is defined as the position with the maximum intercuspation of the teeth. Alternatively, it is also possible, although maybe more complex, to measure the advancement from a centric relation. The distance between centric occlusion and centric relation is usually also negligible.[7] The most retruded position in a gauge will be more posteriorly located than centric occlusion, as the mandible tends to rotate backward when the jaw opens up in the gauge.[7,8] Moreover, the location of the most retruded position in the gauge can vary from patient to patient,[8] making comparisons of mandibular advancement uncertain, whether measured in percent or in millimetres.

A titration procedure starting at a smaller degree of mandibular advancement is often recommended.[9] However, larger advancements, intended to provide a higher likelihood of direct treatment success, may also be used. Aarab et al.[10] conducted a study to compare the efficacy of a mandibular advancement device (MAD) at four different degrees of mandibular advancement (0%, 25%, 50% and 75%) in a random order measured from centric occlusion.[11] After approximately three weeks of using each mandibular position, they conducted interviews and found that initial side effects were more common with advancements of 50% or 75% than with smaller ones. In another study by de Ruiter et al.[12] MAD therapy was initiated with a 60% mandibular advancement, which was measured using a gauge.[12] Four of 36 patients reported severe side effects or discomfort while wearing the device. Two patients opted to switch to a smaller mandibular advancement, which reduced their problems. A mandibular advancement of 50% to 60% corresponds to an advancement of three to nine millimeters in sleep apnea patients. These patients have been reported to have a protrusive capacity between five and 15 millimetres.[7]

This randomized pilot study aimed to compare severe side effects during the first week of treatment between two different starting jaw positions. The idea for this randomized pilot study originated from our positive experiences with significantly reduced immediate pain at the start of treatment when we switched from monoblock devices to duoblock devices some years ago. When using monoblock devices, patients usually start with the mandible advanced to the anticipated therapeutic position. In contrast, adjustable duoblock devices allow for smaller initial advancements followed by a titration procedure. This approach appeared to be beneficial in allowing patients to adapt to an advanced mandibular position. We measured the advancement in millimetres, but percentage values of advancement are advancement are suitable for suitable for identifying the therapeutic mandibular position. Patients with a good protrusive capacity may, however, face a higher risk of experiencing large initial advancements if they start at an anticipated therapeutic position identified by a percentage value. This is because larger protrusive ranges lead to proportionally larger millimeter values with percentage advancement. Therefore, for this pilot study, only patients with a good protrusive capacity were selected. One advancement was intended to provide a relatively higher chance of direct treatment success. Therefore, a relative measure was chosen to provide a sufficiently advanced jaw position for all patients with different protrusive capacities. The other advancement was intended to represent a small initial advancement. An absolute value was chosen, which would result in a stable initial small advancement without interfering with the degree of advancements in the other randomization group. The null hypothesis for this study was that there would be no difference in severe side effects between the two starting positions.

METHODS

Consecutive patients referred from the Pulmonary Department at the University Hospital, Umeå University, Umeå, Sweden to the Dental School, Department of Orthodontics were asked to participate in the study. These patients had previously been undergone examination by a pulmonary physician and including a respiratory polygraphy (Level III) before MAD treatment. The patients underwent an odontological examination including measurements of the protrusion capacity defined from centric occlusion with maximum intercuspation of the teeth. Centric occlusion was reproduced on a wax index (Alminax, Kemdent, Swindon, England) and subsequently identified on plaster casts by marking two occluding teeth in the premolar area. The maximum protrusion capacity was measured on the central incisors.

The inclusion criterion for participation in the study was being treatment-naïve patients with a mandibular protrusive range of ≥8 mm. Exclusion criteria comprised recent or ongoing temporomandibular disorders, having too few teeth to anchor the appliance, unwillingness to participate, and fear of side effects or other problems that interfered with the opportunity for the subjects to fulfill the study protocol. All subjects provided informed consent before taking part in the study.

The patients were randomized using a block design, with four patients in each block to ensure even distribution between the two arms: $Adv_{70\%}$ with 70% maximum mandibular protrusion and Adv_{4mm} with 4 mm mandibular advancement. A computer-generated table was utilized for this randomization and it was kept by a person outside the study staff to maintain blinding. The participants were informed about the aim of the study, which involved comparing two different starting positions in terms of

side effects. During the visit for device delivery, the patients only tested the appliances to ensure their suitablitiy for wear. They received repeated information about the study protocol at this stage. The patients, but not the dentist, were blinded regarding the randomization group. This blinding was intended to prevent any bias in reporting side effects. This way, the dentist could make an immediate decision on how to proceed if the patient experienced initial problems with the device. The main outcome was tenderness or pain in the teeth or jaws using a 0-10 visual analogue scale (VAS) or exclusion from using the device due to these side effects during the first week of treatment. Secondary aims were assessed using the same scale and included salivation problems during appliance wear and occlusal changes after the appliance had been removed.

The patients were given the option to choose between the two types of appliances available at the clinic: a fin coupling type of device (SomnoDent Fusion™) or a traction type device (NarvalCC™) (Figure 1). All patients were advised to use elastic bands to secure the degree of mandibular advancement during the night.[13,14] For this study, two different degrees of advancement were chosen. The first degree involved 70% of maximum protrusion (resulting in ≥5.6 mm advancement in the patients with ≥8 mm protrusive capacity) and this advancement was intended to provide the patients with a mandibular position that could give immediate treatment success. The second advancement was a fixed millimeter value of 4 mm (resulting in ≤50% advancement) and intended to represent a milder treatment start in terms of side effects. Both measurements of advancement were assessed from centric occlusion, providing a standardized reference point for the evaluation.

A construction bite in wax was taken with the mandible advanced by approximately four millimeters, considering the comfort level for each patient. The teeth and jaw position with the construction bite in place were then scanned and sent to dental laboratories for fabrication of the appliances. Upon receiving the delivered appliances, adjustments were made on plaster casts based on the jaw position taken directly from each patient. These adjustments were made to achieve the randomized degree of advancement specific to each individual patient. Subsequently, the devices were tried out on the patients. The degree of initial mandibular advancement was measured with bite registration between the upper and lower parts of plaster casts. The randomized mandibular position was then achieved using the adjustment mechanism on the device.

Questionnaires

Shortly before the treatment's commencement, the patients completed a first questionnaire each day of the week, which assessed tenderness or pain in the teeth or jaws and salivation problems using a VAS graded from 0 to 10 (ranging from "not at all" to "very extensive"). Upon treatment initiation, they answered a second questionnaire daily during the first week of appliance use. These questions included inquiries about the excluded use of the appliance, the occurrence of tenderness or pain in the teeth or jaws during the day or night, and problems with chewing due to tenderness or pain, all reported on the VAS. Using the same scale, they reported the problems related to hypersalivation or dry mouth that disturbed sleep and bite changes. Before the finalization of the study, the patients responded to a third questionnaire, indicating their willingness to continue treatment. The response options ranged from "absolutely", "likely", "not likely", "absolutely not" or "don't know". In addition, the participants were asked to indicate whether they believed they had used larger or smaller advancement or did not know.

The ethical approval was obtained from the Ethics Committee of Umea University (EPN2018/44-31).

Statistical Analysis

The data were presented as median and interquartile range (IQR). Severe tenderness or pain was identified by the 75th percentile of the results reported in the study. The Mann-Whitney U test for independent samples was used to test differences in baseline characteristics and the occurrence of severe side effects during the first week between the two randomization groups. Fisher's exact test was used to compare the occurrence of severe tenderness or pain, appliance design, patients' estimation of the degree of advancement, and differences in sex distribution between the randomization groups. Spearman's rank correlation was used to study the relationship between mandibular advancement and the number of nights on which the patients had reported severe tenderness or pain or had excluded use because of these side effects. A p value of less than 0.05 was considered significant.

RESULTS

Thirty-five consecutive eligible patients were asked to participate in the study from March 2018 until June 2019. Out of these, seventeen patients were excluded for various reasons, including unwillingness to participate or lack of time (7), the need for dental treatment (1), desire for small initial advancement due to fear of jaw pain or bite changes, or recent temporomandibular disorder (6), and problems with device delivery (3). Eighteen patients were randomized, but due to the misunderstanding of the second questionnaire by one patient, the data from day two to day seven were partially or entirely unanswered. Therefore, 17 patients (12 men) were included in the analysis (Table 1). Among 17 patients, 9 had mild OSA, 7 had moderate OSA, and 1 had severe OSA (AHI 31). The final degree of advancement, presented in both percentage and millimeters, for the randomization groups is summarized in Table 2. In the $Adv_{70\%}$ group, the advancements differed by around 2 millimeters between the patients.

Fifteen out of the 17 patients responded to the first daily questionnaire before starting MAD therapy (Table 3). During the first week of treatment, four patients (13 nights) in the $Adv_{70\%}$ group and one patient (3 nights) in the Adv_{4mm} group did not

Table 1. Patient characteristics (n=17)

	Total sample (n=17)		$Adv_{70\%}$ group (n=8)		Adv_{4mm} group(n=9)		
	Median	IQR	Median	IQR	Median	IQR	p value
Age (yrs)	56.4	46.8-61.3	51.8	31.9-59.6	60.4	53.6-62.2	0.123
Apnoea-hypopnoea index (AHI)	13	10-20	11	6-19	16	12-23	0.134
BMI (kg/m^2) (n=7 in $Adv_{70\%}$)	25.8	24.8-29.1	27.3	25-29.8	25	23.6-27.2	0.313
ESS (n=5 in $Adv_{70\%}$ and n=8 in Adv_{4mm})	8	2-12	8	1-12	9	2-14	0.460
Maximum protrusion (mm)	10	8.5-11.5	10.3	8.5-11	10.0	8.5-12.5	0.560
Overjet (mm)	3.0	2.3-4.0	3.0	2.1-3.8	3.0	2.3-5.0	0.461
Overbite (mm)	4.0	2.5-6.0	2.8	1.8-5.8	4.0	3.3-6.0	0.310
Height between incisors (mm)	5.5	5.0-6.5	5.5	5.1-6.4	6.0	5.0-6.8	0.557
Elastics use (nights) (n=6 in each group)	7	4-7	6	4-7	7	3-7	0.818
	n		n		n		
Male (%)	12 (71)		5 (63)		7 (78)		0.620
Fin/traction type of device	13/4		5/3		8/1		0.294

*Statistical significance p<0.05. The Mann-Whitney U test for independent samples and Fisher´s exact test were used to test differences between randomization groups

Table 2. Degrees of advancement in millimeters and percent of maximum protrusion in the randomization groups

	$Adv_{70\%}$ (n=8) group		Adv_{4mm} (n=9) group		
	Median	Minimum-maximum	Median	Minimum-maximum	p value
Advancement (mm)	7.2	5.6-7.7	4.0		<0.001*
Advancement (%)	70		40	31-50	<0.001*

*Statistical significance p<0.05. The Mann-Whitney U test for independent samples was used to test differences between randomization groups

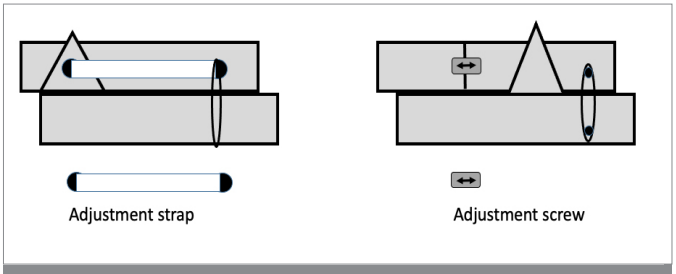

Figure 1 . The illustration of the traction type of MAD (left) and the fin coupling type of MAD (right). The traction type of the appliance is adjusted by different lengths of the straps. The fin coupling type of device is adjusted using a screw in the upper jaw, which pushes the lower jaw forward with the help of a wing.

use their appliances due to tenderness or pain in the teeth or jaws. These occasions were graded as worst pain. The median VAS score for tenderness or pain in the teeth or jaws during the week was two nights/days (IQR 0 to 7) (n=17).

The number of nights and days with severe tenderness or pain in the teeth or jaws before appliance use and during the first week of treatment, using a VAS cut-off of 7 (75^{th} percentile), are summarized in Table 3. Four patients in the $Adv_{70\%}$ group and none in the Adv_{4mm} group reported a score of ≥7 on VAS on five or more of the first seven nights (75^{th} percentile) of treatment (p=0.03) (Figure 2). There was a correlation (r=0.64, p=0.006) between the advancement of the mandible in millimeters

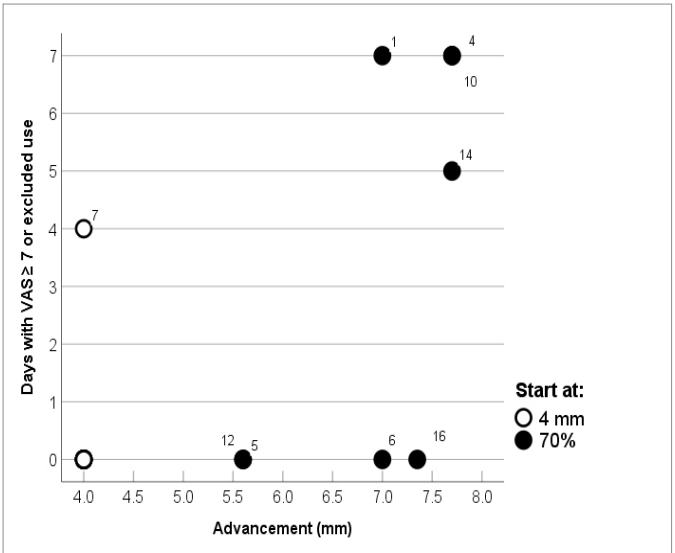

Figure 2. Scatter plot illustrating the relationship between the degree of mandibular advancement (mm) and the number of nights that the patients had reported tenderness or pain ≥ 7 on VAS or excluded use because of such side effects. Labels refer to patient identification.

and the occasions on which the patients reported severe side effects during the first week. Salivation problems or experienced bite changes were small and did not differ between the randomization groups (Table 3).

Table 3. Symptoms during the week before treatment and during the first week of treatment

The number of nights and days with severe symptoms (VAS ≥7)	Total sample (n=17)		$Adv_{70\%}$ (n=8) group		Adv_{4mm} (n=9) group		Between randomization groups
	Median	IQR	Median	IQR	Median	IQR	p value*
Without treatment							
Tenderness or pain in teeth or jaw¤	0	0-0	0	0-0	0	0-0	1.00
Salivation problems¤	0	0-0	0	0-0	0	0-0	1.00
During the first week of treatment							
Tenderness or pain in teeth or jaw or not used	0	0-5	3	0-7	0	0-0	0.055
Start on day:			1,1,1,3	n=4	4	n = 1	
Occlusal changes¤¤	0	0-1	0	0-4	0	0-0	0.110
Salivation problems¤¤	0	0-2	0	0-3	0	0-1	0.677

¤n=7 in $Adv_{70\%}$
n=8 in Adv_{4mm}
¤¤n=7 in $Adv_{70\%}$
*Statistical significance p<0.05. The Mann-Whitney U test for independent samples was used to test differences between randomization groups. IQR, Interquartile range

All 15 patients who responded to the third questionnaire expressed a desire to continue treatment, with 13 patients responding as "absolutely" and 2 patients responding as "likely." There was no difference in the responses between the randomization groups (p=0.2). The two patients who did not respond to the questionnaire belonged to separate randomization groups.

In the Adv_{4mm} group, four out of the eight responding patients (50%) correctly believed that they had used the smaller advancement, three patients thought they had used the larger one, and one patient was unsure. In the $Adv_{70\%}$ group, two of the seven responding patients (29%) correctly believed they had used the larger advancement, four patients thought that it was the smaller one, and one patient was unsure. There was no significant difference between the randomization groups in terms of patient perception (p=1.00).

DISCUSSION

In this study, the first week of MAD therapy was evaluated regarding side effects and the null hypothesis was rejected. Patients with a good protrusive capacity of ≥8 mm who initiated MAD treatment with 70% mandibular advancement experienced more severe tenderness or pain compared to those who began with 4 mm of advancement. The degree of mandibular advancement correlated with the patients' reports of severe side effects. However, there were only a few reports of severe early salivation problems or disturbances due to a change in bite during the first week of treatment in this sample.

Severe tenderness or pain lasting for 5 days or more was observed exclusively in patients belonging to $Adv_{70\%}$ group (Figure 2). These patients had undergone the largest advancements in the study, with advancements of seven millimeters or more (Table 2). Among these patients, severe side effects commenced on day one for three patients and on day three for one patient (Table 3). Only one patient from the Adv_{4mm} group reported any severe side effects and they were experienced for only four days. These side effects occurred during the last days of the week (Table 3). This patient had used 50% advancement, which was the largest advancement in the Adv_{4mm} group. This study is the first to evaluate the first week of MAD treatment regarding side effects that might disrupt treatment initiation. The findings shed light on this aspect of the treatment and provide support for the notion of commencing treatment with a smaller degree of mandibular advancement before proceeding to titration.

There was a positive correlation (r=0.64, p=0.006) between the assessment of mandibular advancement in millimeters and the occurrence of severe side effects during the first week among patients with a good protrusive capacity in this study. Using a percentage value to define the degree of mandibular advancement results in multiple millimeter values being used. Therefore, providing a measure of both the advancement and the protrusive capacity in millimeters with a percentage description would facilitate comparisons between patients with varying protrusive capacities. In our $Adv_{70\%}$ group, the patients' maximum protrusive capacity varied between eight and 11 millimeters, leading to mandibular advancements between 5.6 and 7.7 mm (Table 2). Sleep apnea patients may, however, protrude their mandibles up to 15 mm,[7] measured from centric occlusion, which corresponds to 11.5 mm with 70% advancement. It is also unknown if patients with a good protrusive capacity would require a larger mandibular advancement resulting from a percentage degree of advancement to achieve an optimal degree of pharyngeal widening.

Millimeter and percentage values of mandibular advancement were utilized in this study. Kazemeini et al.[15] conducted a comparison of personalized titration procedures and found no differences regarding final mandibular positioning or final AHI between them. One method started treatment in the maximally comfortable mandibular position followed by subjectively

accomplished titration. The other two methods utilized titration during polysomnography or drug-induced endoscopy. Although side effects were not evaluated in that study, it demonstrated that a subjectively guided titration procedure might yield similar final results on AHI as methods that commence at the most effective mandibular positioning.

The efficacy of MAD after titration is finalized is not proportional to the degree of advancement, according to a meta-analysis conducted by Bartolucci et al.[16] This conclusion is supported by three recent studies. Ma et al.[17] found no dose-dependent effect of mandibular advancement on the apnea and hypopnea index in the entire sample of 42 patients, although the relationship strengthened in patients with increased severity of OSA. In that study, patients with milder OSA could be effectively treated with an average advancement of 4 mm or 40% of maximum protrusion, while patients with more severe OSA needed an average advancement of 6 mm or 70% of maximum protrusion.[17] A pilot study[18] utilized pharyngometry to determine the optimal degree of advancement and found that the effective mandibular position was located 5 mm less advanced compared to 70% advancement, as measured in the gauge.[18] Furthermore, Anitua et al.[19] reported that treatment success was achievable with an advancement of zero or only a few millimetres. The generalized suggestion made by Aarab et al.[10] of starting at 50% advancement to balance the treatment effect with side effects can be modified. The above studies and the results of the present study indicate that even smaller percentage or millimeter values could be considered at the start of treatment to avoid unnecessary side effects. This is particularly relevant for patients with a good protrusive capacity, who may be at risk of side effects with routine percentage advancement at the beginning of treatment.

In the present study, thirteen patients had used the fin coupling type of MAD, and four patients had chosen the traction type of device.[20] Both types of appliances are equipped with lateral adjustment mechanisms, which provide more similar types of forces on the teeth compared to a centrally located type of adjustment mechanism.[20] However, the same study also revealed differences in the distribution of forces among various types of lateral adjustment mechanisms. This finding highlights the importance of using the same type of device in future studies, that aim to evaluate the side effects of MAD.

Only six out of the 15 patients (40%) who responded to the third questionnaire were able to identify whether they belonged to the smaller or the larger advancement group. This finding is consistent with previous research that indicates patients often have difficulty identifying changes in their dental occlusion. Additionally, many patients find it challenging to notice bite changes that occur over prolonged use of an MAD.[21] Consequently, it may be difficult for many patients to accurately assess how far forward their mandibles are repositioned at the beginning of treatment. Therefore, it might be beneficial to start with a gentle advancement to minimize potential side effects and discomfort.

Study Limitations

The sample size of this study was small. Nevertheless, the primary aim was to preliminarily evaluate the strength of a clinical observation. The inclusion criteria ensured that only patients with a good protrusive capacity of 8 mm or above were included. Therefore, it would be of interest to conduct further studies to investigate whether patients with smaller protrusive capacities can tolerate larger percentage degrees of advancement, which correspond to smaller millimeter values. Additionally, including more objective measures in such studies would be valuable.

The sample mainly comprised mild and moderate patients with OSA, a group of patients who generally require smaller therapeutic advancements.[17,22] These milder OSA patients constitute the majority of patients referred to our clinic; thus, finding more severe OSA patients who might require larger advancements was challenging. The particular aim of this pilot study was to investigate patients with a good protrusive capacity due to the lack of knowledge in this subgroup of patients regarding initial side effects. A recent study reported that no mild to moderate OSA patients experienced pain after 2-3 months of treatment with either 50% or 75% mandibular advancement, but information about the patients' protrusive capacity was not provided.[22] Future studies should be designed to provide more insight into the relationships between mandibular advancement, the efficacy of the device concerning disease severity and the patients´ protrusive capacity.

No cephalograms were taken for this pilot study. In future studies, new analysis methods could be employed to account for potential differences in skeletal mandibular shapes may influence the actual degree of mandibular movement.[23] It is important to recognize that the same degree of mandibular protrusion, as measured in relation to the teeth, may result in variable actual mandibular advancements in relation to the skull and pharynx.

Finally, it would have been ideal for a person outside the study, unaware of the randomization groups, to delivere the appliances to avoid possible bias. Initially, this was the intention; however it later became impossible due to the lack of personnel at the time of the study.

CONCLUSION

According to this pilot study, starting treatment with mandibular advancement device (MAD) for sleep apnea at 70% of the maximum mandibular advancement was associated with more severe tenderness or pain in patients with a good protrusive capacity during the first week of treatment compared to starting with a lower degree of advancement.

Ethics

Ethics Committee Approval: The ethical approval was obtained from the Ethics Committee of Umea University (EPN2018/44-31).

Informed Consent: All subjects signed informed consent.

Peer-review: Externally peer-reviewed.

Funding: The author declared that this study has received no financial support.

References

1. Mullane S, Loke W. Influence of short-term side effects on oral sleep appliance compliance among CPAP-intolerant patients: An objective monitoring of compliance. *J Oral Rehabil*. 2019;46(8):715-722. [CrossRef]
2. Sheats R, Essick G, Grosdidier J, et al. Identifying the Appropriate Therapeutic Position of an Oral Appliance. *JDSM*. 2020;7(4):7158. [CrossRef]
3. Ulander M, Johansson MS, Ewaldh AE, Svanborg E, Broström A. Side effects to continuous positive airway pressure treatment for obstructive sleep apnoea: changes over time and association to adherence. *Sleep Breath*. 2014;18(4):799-807. [CrossRef]
4. Van Ryswyk E, Anderson CS, Antic NA, et al. Predictors of long-term adherence to continuous positive airway pressure in patients with obstructive sleep apnea and cardiovascular disease. *Sleep*. 2019;42(10):zsz152. [CrossRef]
5. Xu L, Xie D, Griffin KS, et al. Objective adherence to dental device versus positive airway pressure treatment in adults with obstructive sleep apnea. *J Sleep Res*. 2021;30(4):e13240. [CrossRef]
6. Dieltjens M, Vanderveken OM, Heyning PH, Braem MJ. Current opinions and clinical practice in the titration of oral appliances in the treatment of sleep-disordered breathing. *Sleep Med Rev*. 2012;16(2):177-185. [CrossRef]
7. Fransson AM, Tegelberg A, Svenson BA, Wenneberg B, Isacsson G. Validation of measurements of mandibular protrusion in the treatment of obstructive sleep apnoea and snoring with a mandibular protruding device. *Eur J Orthod*. 2003;25(4):377-383. [CrossRef]
8. Ippolito DR, Stipa C, Cameli M, Sorrenti G, Pelligra I, Alessandri-Bonetti G. Maximum voluntary retrusion or habitual bite position for mandibular advancement assessment in the treatment of obstructive sleep apnoea patients. *J Oral Rehabil*. 2020;47(3):301-306. [CrossRef]
9. Bernhardt O, Giannakopoulos NN, Heise M, et al. Mandibular advancement device: prescription in adult dental sleep medicine - guideline of the German Society of Dental Sleep Medicine. *Sleep Breath*. 2023;27(1):389-397. [CrossRef]
10. Aarab G, Lobbezoo F, Hamburger HL, Naeije M. Effects of an oral appliance with different mandibular protrusion positions at a constant vertical dimension on obstructive sleep apnea. *Clin Oral Investig*. 2010;14(3):339-345. [CrossRef]
11. Aarab G, Lobbezoo F, Wicks DJ, Hamburger HL, Naeije M. Short-term effects of a mandibular advancement device on obstructive sleep apnoea: an open-label pilot trial. *J Oral Rehabil.* 2005;32(8):564-570. [CrossRef]
12. de Ruiter MHT, Aarab G, de Vries N, Lobbezoo F, de Lange J. A stepwise titration protocol for oral appliance therapy in positional obstructive sleep apnea patients: proof of concept. *Sleep Breath.* 2020;24(3):1229-1236. [CrossRef]
13. Milano F, Mutinelli S, Sutherland K, et al. Influence of Vertical Mouth Opening on Oral Appliance Therapy Outcome in Positional Obstructive Sleep Apnea. Retrospective Study. *JDSM*. 2018;5(1):17-23. [CrossRef]
14. Norrhem N, Marklund M. An oral appliance with or without elastic bands to control mouth opening during sleep-a randomized pilot study. *Sleep Breath*. 2016;20(3):929-938. [CrossRef]
15. Kazemeini E, Op de Beeck S, Vroegop A, et al. A pilot study on comparison of subjective titration versus remotely controlled mandibular positioning during polysomnography and drug-induced sleep endoscopy, to determine the effective protrusive position for mandibular advancement device therapy. *Sleep Breath*. 2022;26(4):1837-1845. [CrossRef]
16. Bartolucci ML, Bortolotti F, Raffaelli E, D'Antò V, Michelotti A, Alessandri Bonetti G. The effectiveness of different mandibular advancement amounts in OSA patients: a systematic review and meta-regression analysis. *Sleep Breath*. 2016;20(3):911-919. [CrossRef]
17. Ma Y, Yu M, Gao X. The effect of gradually increased mandibular advancement on the efficacy of an oral appliance in the treatment of obstructive sleep apnea. *J Clin Sleep Med*. 2020;16(8):1369-1376. [CrossRef]
18. Hu JC, Comisi JC. Vertical dimension in dental sleep medicine oral appliance therapy. *Gen Dent*. 2020;68(4):69-76. [CrossRef]
19. Anitua E, Durán-Cantolla J, Almeida GZ, Alkhraisat MH. Minimizing the mandibular advancement in an oral appliance for the treatment of obstructive sleep apnea. *Sleep Med*. 2017;34:226-231. [CrossRef]
20. Caragiuli M, Mandolini M, Landi D, et al. A finite element analysis for evaluating mandibular advancement devices. *J Biomech*. 2021;119:110298. [CrossRef]
21. Marklund M. Subjective versus objective dental side effects from oral sleep apnea appliances. *Sleep Breath*. 2020;24(1):111-117. [CrossRef]
22. Makihara E, Watanabe T, Ogusu H, Masumi SI. The comparison of two different mandibular positions for oral appliance therapy in patients with obstructive sleep apnea. *Clin Exp Dent Res*. 2022;8(6):1567-1574. [CrossRef]
23. García M, Cabrera JA, Bataller A, Vila J, Mayoral P. Mandibular movement analisys by means of a kinematic model applied to the design of oral appliances for the treatment of obstructive sleep apnea. *Sleep Med*. 2020;73:29-37. [CrossRef]

DOI: 10.4274/TurkJOrthod.2022.2022.59

TURKISH JOURNAL of ORTHODONTICS

Original Article

Evaluation of First Molar Buccolingual Angulations and Dental Arch Parameters in Adolescents with Bilateral Posterior Crossbite

Taner Öztürk[1], Ahmet Yağcı[1], Sabri İlhan Ramoğlu[2]

[1]Erciyes University Faculty of Dentistry, Department of Orthodontics, Kayseri, Turkey
[2]Altınbaş University Faculty of Dentistry, Department of Orthodontics, İstanbul, Turkey

Cite this article as: Öztürk T, Yağcı A, Ramoğlu Sİ. Evaluation of First Molar Buccolingual Angulations and Dental Arch Parameters in Adolescents with Bilateral Posterior Crossbite. *Turk J Orthod.* 2023; 36(3): 165-172.

Main Points
- The dental arch parameters differ between the sexes regardless of the presence of a posterior crossbite.
- The difference in the molar angulation between individuals with and without the posterior crossbite increases with age during adolescence.
- The dental parameters and molar angulation of individuals with bilateral posterior crossbite do not significantly differ between the different age groups.

ABSTRACT

Objective: This study aimed to compare the maxillary and mandibular transverse dental arch widths and buccolingual inclinations of the molar teeth in patients with and without bilateral posterior crossbite (BPC) divided into different age groups.

Methods: The study included dental models from 120 patients (age: 12-18 years), including 60 with BPC (32 boys and 28 girls) and 60 without BPC (controls; 30 boys and 30 girls), who were divided into three age groups (12-14, 14-16, and 16-18 years). The centroid and lingual transverse arch widths, dental arch perimeters, dental arch depths, and buccolingual angulation of the molar teeth in the maxillary and mandibular regions were evaluated using scanned three-dimensional dental models.

Results: Dental arch parameters and buccolingual molar angulation did not significantly differ between the different age groups in either the patients with BPC or the controls ($p>0.05$). However, several dental arch width parameters differed significantly between sexes in both groups, with higher values in boys than in girls ($p<0.05$). The difference in the upper and lower molar buccolingual angulation between patients with BPC and controls was greater at the age of 16-18 years than the age of 12-14 years ($p<0.05$).

Conclusion: Patients with BPC have smaller maxillary dental arch widths and larger mandibular intermolar widths than those without BPC. The difference in the molar buccolingual angulation between them increases with advancing age.

Keywords: Posterior crossbite, dental model analysis, buccolingual angulation

INTRODUCTION

Posterior crossbite is defined as unilateral or bilateral positioning of the lower molars more lingually in relation to the buccolingual position and angle of the upper molars. While the unilateral crossbite may be of a dental or skeletal origin, bilateral crossbite typically the result of a narrow maxilla.[1] However, while the skeletal structure is in the normal position, the buccolingual angulation of the upper molars may be inclined lingually.[1] The prevalence of posterior crossbite ranges from 8% to 23%[2] and and it tends to increase with age.[2,3] Additionally, the prevalence of bilateral crossbite is higher than that of unilateral crossbite, and it is more commonly seen in the permanent dentition than in the primary dentition.[4,5] Various treatment options are available for correcting

Corresponding author: Taner Öztürk, e-mail: tanertr35@gmail.com

Received: April 11, 2022
Accepted: September 27, 2022
Epub: April 26, 2023
Publication Date: September 29, 2023

posterior crossbite, including expansion and grinding. However, spontaneous correction can also occur in some cases, although it occurs at a relatively low rate.[6]

Most studies have focused indiscriminately on crossbite or unilateral crossbite; resulting in a lack of research on bilateral crossbite.[7-13] These mostly include radiographic analysis methods that result in radiation exposure.[7,9,14,15] Although radiographic analysis can provide more detailed information, dental model analysis maintains its importance for basic orthodontic diagnoses.[1] Dental arch parameters, such as arch width, arch length, and tooth angulation, are frequently evaluated in dental model analyses to assess transverse problems and relationships.[8,10-12,16] Andrews[17] identified key features of an ideal occlusal relationship, including an ideal buccolingual angulation relationship. Similarly, a compensation curve viewed from the frontal plane defined by Wilson has been used to define the buccolingual relationship of the molar teeth.[16] Studies have reported that posterior crossbite is caused by the difference in the buccolingual angulations.[7-13,15,18] Additionally, these studies have examined the changes in the buccolingual angulation during correction of the anomaly.[8,10,12]

Notably, Sayania et al.[19] reported that the maxillary molars erupted with buccal crown torque and lingual inclination over time; while mandibular molars erupted with lingual crown torque, and buccal inclination. However, to our knowledge, no study has investigated the dental characteristics of different age groups and the differences in posterior crossbite among these groups. Thus, this study aims to evaluate and compare the angulation of the permanent first molar teeth and the maxillary and mandibular dental arch parameters to interpret the transverse anomaly in individuals with bilateral posterior crossbite (BPC) at different age groups during adolescence. Our null hypothesis is that there are no differences in permanent first molar angulation and maxillary and mandibular dental arch parameters between individuals with and without bilateral crossbite in different age groups during adolescence.

METHODS

This study was approved by the Erciyes University Clinical Research Ethics Committee (approval number: 2020/44, date: 15.01.2020) and was registered at the US National Institutes of Health Ongoing Trials Register (ClinicalTrials.gov) [registration number-(ID): NCT04955860]. A power analysis was conducted to determine the sample size of the study, indicating that a minimum of 18 samples in each group was needed for an alpha value of 0.05, a d value of 1.12, and a power of 90%.[10] Accordingly, this study included radiographic and dental model records from 120 patients, including 60 with BPC (32 boys and 28 girls) and 60 without BPC (controls; 30 boys and 30 girls). Patients were randomly selected from those who sought orthodontic treatment at the Erciyes University Department of Orthodontics.

The inclusion criteria for the study were: (1) no history of orthodontic treatment, (2) presence of bilateral posterior crossbite (for the study group), (3) no restoration or permanent tooth loss, (4) permanent dentition, and (5) absence of a syndrome or systemic disease affecting the craniofacial region.

The dental cast models were obtained using a three-dimensional model scanning device (3Shape R700 3D Scanner, 3Shape A/S, Copenhagen, Denmark) and analyzed using the 3Shape Orthoanalyzer software (3Shape A/S). For each tooth, points were placed on the distal, facial, mesial, and lingual surfaces, from the right first permanent molar to the left first permanent molar within the same arch, thus eliminating the effect of dental rotations (Figure 1A).[10,20] Transverse dental arch measurements were obtained between the following teeth: permanent canines, first premolars, second premolars, and permanent first molars. The dental arch width, defined as the distance between these teeth, was evaluated on the basis of two sets of measurements: the distance from the lingual point of the selected tooth to the same point on its antimere and between the centroid and the antimere of the tooth (Figure 1A and B). The arch depth was determined by measuring the distance between the midpoint between the facial surfaces of the central incisors and the tangent drawn between the mesial surfaces of the right and left permanent first molars (Figure 1C). The arch perimeter was calculated by drawing a line between the mesial and distal contact points of the teeth between the mesial surface of the permanent first molar and the contact point between the permanent first molar on the other side of the arch (Figure 1D).[10] To evaluate the molar tooth angulation the buccal and lingual cusp tips of the maxillary (Figure 1E) and mandibular (Figure 1F) permanent first molars were selected. An angulation below 180° indicated that the molar teeth were inclined buccally, while that above 180° indicated that these teeth were inclined lingually.[10]

Statistical Analysis

The obtained data were statistically analyzed using the SPSS software (version 24.0, IBM Corp., Armonk, NY, USA). The Shapiro-Wilk test was used to assess data normality and the Levene test to analyze homogeneity. It was determined that all the data are normally and homogeneously distributed. One-way ANOVA (post-hoc Tukey's test) was used for comparisons between the age groups and the independent samples t-test between the study groups and sexes. For method errors, 10% of the sample was randomly selected for re-evaluation by the same investigator 1 month after the first measurements. The intra-class correlation coefficient was found to be between 0.897 and 0.915, indicating a high reproducibility of the measurements.

RESULTS

The dental arch parameters did not show significant differences between the age groups in individuals with BPC ($p>0.05$; Table 1). However, the mandibular arch perimeter (MdAP) and maxillary molar angulation (MxMAg) and mandibular MAg (MdMAg) showed significant differences between the sexes ($p<0.05$). While the MdAP and MxMAg were significantly larger in the boys than in the girls, the MdMAg was found to be smaller

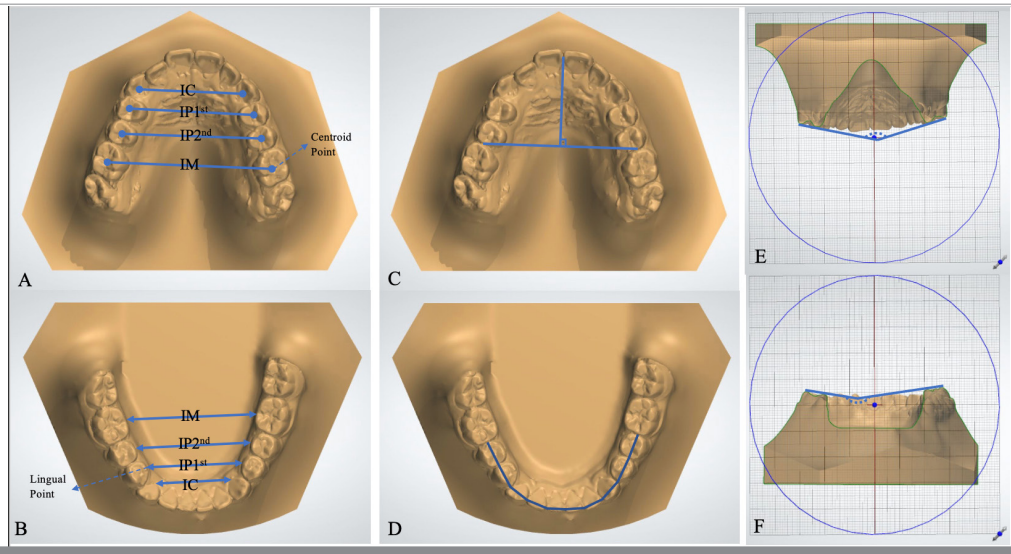

Figure 1. A- Intermolar (IM), interpremolar (IP1st and IP2nd) and intercanine (IC) distances from the centroid points of posterior teeth were measured in the transversal dimension. B- Intermolar (IM), interpremolar (IP1st and IP2nd) and intercanine (IC) from the lingual points where lingual grooves of posterior teeth meet with palatal and lingual mucosa were measured in transversal dimension. C- Arch depth parameter was measured as the length of the perpendicular line connecting the mesial contact point of right and left first molars from the mesial contact point of central incisors. D- Arch perimeter parameter was calculated as the length of lines from the mesial contact point of the first molar on one side to the mesial contact point of the first molar on the other side and passing through the mesial and distal contact points of teeth in between. E and F- Angulation of maxillary and mandibular first molars was calculated as the intersection angle of lines passing through the buccal and lingual cups of these teeth[10]

Table 1. Comparison of dental arch characteristics according to age groups and genders of individuals with bilateral posterior crossbite

Bilateral posterior crossbite		12-14 Age group (N=20)	14-16 Age group (N=20)	16-18 Age group (N=20)	p values[OWA]	Males (N=32)	Females (N=28)	p values[Is]
		Mean±SD	Mean±SD	Mean±SD		Mean±SD	Mean±SD	
Age		13.14[a]±0.62	15.29[b]±1.11	17.30[c]±0.66	<0.001***	15.53±2.10	14.99±1.69	0.145
Maxillary arch width (Centroid)	IM	43.80±3.04	43.41±3.20	43.12±4.12	0.826	43.20±4.09	43.66±2.79	0.612
	IP (2nd)	37.71±2.32	37.02±3.40	36.94±3.79	0.711	36.90±3.99	37.51±2.31	0.465
	IP (1st)	32.91±2.39	31.98±3.49	32.21±3.04	0.594	31.97±3.49	32.71±2.46	0.341
	IC	29.07±2.79	29.73±2.64	28.78±2.43	0.503	29.29±2.70	29.10±2.57	0.782
Maxillary arch width (Lingual)	IM	32.45±3.32	31.38±3.24	30.55±4.08	0.249	30.86±4.34	31.99±2.75	0.225
	IP (2nd)	28.95±2.60	27.86±3.41	27.70±3.59	0.421	27.81±3.96	28.48±2.43	0.425
	IP (1st)	24.25±2.56	23.49±3.57	23.27±3.10	0.586	23.34±3.55	23.96±2.63	0.440
	IC	24.62±2.74	24.44±2.61	23.71±2.17	0.485	24.28±2.29	24.24±2.72	0.949
Mandibular arch width (Centroid)	IM	44.46±2.49	44.95±4.08	44.04±3.68	0.712	44.90±3.59	44.12±3.32	0.391
	IP (2nd)	36.89±3.37	37.73±3.55	37.40±3.91	0.764	37.28±3.97	37.39±3.25	0.910
	IP (1st)	31.25±2.19	30.33±3.70	30.27±3.40	0.549	30.43±3.68	30.78±2.63	0.664
	IC	23.99±1.88	23.68±1.71	23.19±1.70	0.366	23.91±1.90	23.37±1.63	0.239
Mandibular arch width (Lingual)	IM	36.01±2.59	36.43±3.85	35.60±3.27	0.728	36.09±3.41	35.94±3.13	0.859
	IP (2nd)	31.90±2.89	31.81±4.00	32.32±3.56	0.889	32.22±3.75	31.83±3.24	0.665
	IP (1st)	26.50±2.04	26.54±2.90	26.62±3.08	0.990	26.72±3.21	26.41±2.13	0.653
	IC	20.17±1.78	19.73±1.61	19.84±1.81	0.709	20.29±1.97	19.59±1.41	0.115
Arch depth	Mx	25.79±1.89	25.61±2.54	25.82±2.04	0.945	25.81±1.97	25.67±2.31	0.798
	Md	21.69±2.31	21.44±1.71	20.48±1.52	0.110	21.41±1.85	21.03±1.99	0.452
Arch perimeter	Mx	81.47±5.19	78.98±7.07	77.92±5.36	0.160	80.03±6.13	78.95±5.98	0.147
	Md	77.63±6.62	75.45±7.27	73.26±7.32	0.286	77.35±7.09	73.71±6.93	0.006**
Molar angulation	Mx	157.56±10.17	156.24±9.38	156.80±6.27	0.893	159.77±7.12	154.33±9.14	0.014*
	Md	202.81±10.75	204.16±14.13	206.12±9.20	0.662	202.12±10.03	206.32±12.35	0.036*

IM, Intermolar; IP, Interpremolar; IC, Intercanine; Mx, Maxillary; Md, Mandibular; SD, Standard deviation, [OWA]p values based on One-Way ANOVA results. [Is]p values based on the Independent samples t-test results. *p<0.05; **p<0.01; ***p<0.001
Different letters (a, b, c) in the age variable indicate that there is a significant difference between the groups

in boys than in girls (p<0.05). There was no significant difference in dental arch parameters between the age groups among the controls (p>0.05; Table 2). Meanwhile, the maxillary IM and IP (first and second) arch widths were significantly larger in boys than in girls (p<0.05). Mandibular IM and IP second arch widths and MdAP were also significantly larger in boys than in girls (p<0.05). In contrast, the MdMAg was significantly larger in girls than in boys (p<0.05). In all age groups, maxillary IM and IP arch widths were significantly smaller in individuals with BPC than in controls (p<0.05; Table 3). While maxillary IC arch width differed between patients with BPC and controls in the 12-14-year age group (p<0.05), it did not differ in the other age groups (p>0.05). Mandibular IM arch width of the patients with BPC was significantly larger than that of the controls in all age groups (p<0.05). Similarly, maxillary arch perimeter (MxAP) and MdAP were found to be significantly larger in individuals with BPC than in controls in all age groups (p<0.05). While the MxMAg was significantly smaller in individuals with BPC than in controls in all age groups, the MdMAg was larger (p<0.05). When sexes were evaluated separately, maxillary arch width at both centroid and lingual levels was found to be smaller, and the mandibular arch width was found to be larger in individuals with BPC than in controls in both sexes (p<0.05; Table 4). MxAP and MdAP were also e larger in the individuals with BPC than in controls in both sexes (p<0.05).

DISCUSSION

In this cross-sectional study, the dental arch dimensions and molar angulation were compared among individuals of different age groups and between those with and without bilateral crossbite. Based on our findings, the null hypothesis was partially rejected. The variables did not differ significantly between patients with BPC and controls across all age groups. However, significant differences in several parameters were observed between patients with BPC and controls when separately analyzing different age groups.

Table 2. Comparison of dental arch characteristics according to age groups and genders of control individuals without posterior crossbite

Control		12-14 Age group (N=20)	14-16 Age group (N=20)	16-18 Age group (N=20)	p values[OWA]	Males (N=30)	Females (N=30)	p values[Is]
		Mean±SD	Mean±SD	Mean±SD		Mean±SD	Mean±SD	
Age		13.22[a]±0.53	14.99[b]±0.56	16.61[c]±0.44	<0.001***	15.01±1.54	14.88±1.45	0.208
Maxillary arch width (Centroid)	IM	47.40±2.14	46.20±2.10	47.43±3.44	0.250	47.97±2.76	46.05±2.19	0.004**
	IP (2nd)	41.52±2.17	40.12±1.96	41.26±2.98	0.158	41.74±2.50	40.18±2.17	0.012*
	IP (1st)	36.91±2.38	35.37±1.90	35.75±2.59	0.097	36.66±2.40	35.36±2.17	0.031*
	IC	30.84±2.18	29.83±3.08	29.79±2.15	0.335	30.42±2.11	29.89±2.87	0.420
Maxillary arch width (Lingual)	IM	34.19±2.79	33.18±2.36	34.31±3.27	0.385	34.88±2.86	32.91±2.47	0.006**
	IP (2nd)	32.07±2.29	31.07±2.01	32.04±2.77	0.328	32.49±2.45	30.97±2.09	0.012*
	IP (1st)	27.47±2.00	26.21±1.97	26.92±2.40	0.179	27.49±2.01	26.25±2.15	0.025*
	IC	25.43±1.85	24.05±1.92	24.17±2.15	0.058	24.88±1.95	24.22±2.11	0.209
Mandibular arch width (Centroid)	IM	42.38±2.47	41.16±2.65	42.45±3.45	0.290	43.06±2.64	40.93±2.79	0.004**
	IP (2nd)	36.22±2.38	35.04±2.18	36.69±2.85	0.105	36.75±2.23	35.22±2.63	0.018*
	IP (1st)	31.58±1.76	29.65±1.71	31.23±2.21	0.063	31.30±2.00	30.34±2.04	0.163
	IC	24.10±1.57	23.06±1.64	23.70±1.47	0.112	23.94±1.70	23.30±1.44	0.123
Mandibular arch width (Lingual)	IM	33.17±2.34	32.04±2.52	33.13±3.04	0.322	33.85±2.20	31.71±2.67	0.001**
	IP (2nd)	30.20±2.16	28.72±3.01	30.82±2.62	0.066	30.57±2.85	29.26±2.46	0.022*
	IP (1st)	27.17±3.40	25.67±2.21	26.86±1.96	0.166	27.17±2.80	25.96±2.37	0.077
	IC	20.35±1.45	19.30±1.33	19.89±1.73	0.099	20.22±1.58	19.48±1.45	0.064
Arch depth	Mx	26.86±1.64	26.21±1.41	25.95±1.84	0.201	26.29±1.82	26.38±1.51	0.839
	Md	22.40±1.71	21.63±1.16	21.72±1.40	0.190	21.99±1.51	21.85±1.43	0.713
Arch perimeter	Mx	72.89±3.15	71.26±2.67	71.74±2.81	0.056	73.24±3.36	72.01±3.10	0.147
	Md	64.18±2.75	64.27±2.56	64.23±3.68	0.250	65.37±3.13	64.08±3.09	0.006**
Molar angulation	Mx	162.03±6.07	168.36±5.58	165.19±7.35	0.134	166.52±6.26	163.86±7.14	0.332
	Md	198.45±6.22	195.03±7.91	195.10±10.00	0.328	194.00±8.42	198.39±7.51	0.038*

IM, Intermolar; IP, Interpremolar; IC, Intercanine; Mx, Maxillary; Md, Mandibular; SD, Standard deviation. [OWA]p values based on One-way ANOVA results. [Is]p values based on the Independent samples t-test results. *p<0.05; **p<0.01; ***p<0.001
Different letters (a, b, c) in the age variable indicate that there is a significant difference between the groups

Table 3. Comparison of dental arch characteristics of individuals with and without bilateral posterior crossbite according to age groups (Independent Samples t-test)

		12-14 Age group			14-16 Age group			16-18 Age group			Totally		
		BLC	C	p value	BLC	C	p value	BLC	C	p value	BLC	C	p value
		Mean±SD	Mean±SD		Mean±SD	Mean±SD		Mean±SD	Mean±SD		Mean±SD	Mean±SD	
Maxillary arch width (Centroid)	IM	43.80±3.04	47.40±2.14	<0.001***	43.41±3.20	46.20±2.10	0.002**	43.12±4.12	47.43±3.44	0.001**	43.45±3.44	47.01±2.65	<0.001***
	IP (2nd)	37.71±2.32	41.52±2.17	<0.001***	37.02±3.40	40.12±1.96	0.001**	36.94±3.79	41.26±2.98	<0.001***	37.22±3.19	40.96±2.45	<0.001***
	IP (1st)	32.91±2.39	36.91±2.38	<0.001***	31.98±3.49	35.37±1.90	<0.001***	32.21±3.04	35.75±2.59	<0.001***	32.37±2.98	36.01±2.36	0.042*
	IC	29.07±2.79	30.84±2.18	0.032*	29.73±2.64	29.83±3.08	0.911	28.78±2.43	29.79±2.15	0.171	29.19±2.61	30.15±2.51	<0.001***
Maxillary arch width (Lingual)	IM	32.45±3.32	34.19±2.79	0.048*	31.38±3.24	33.18±2.36	0.042*	30.55±4.08	34.31±3.27	0.003**	31.46±3.59	33.89±2.83	<0.001***
	IP (2nd)	28.95±2.60	32.07±2.29	<0.001***	27.86±3.41	31.07±2.01	0.001**	27.70±3.59	32.04±2.77	<0.001***	28.17±3.22	31.73±2.38	<0.001***
	IP (1st)	24.25±2.56	27.47±2.00	<0.001***	23.49±3.57	26.21±1.97	0.005**	23.27±3.10	26.92±2.40	<0.001***	23.67±3.08	26.87±2.16	<0.001***
	IC	24.62±2.74	25.43±1.85	<0.001***	24.44±2.61	24.05±1.92	0.599	23.71±2.17	24.17±2.15	0.508	24.26±2.51	24.55±2.04	0.483
Mandibular arch width (Centroid)	IM	44.46±2.49	42.38±2.47	0.012*	44.95±4.08	41.16±2.65	0.001**	44.04±3.68	42.45±3.45	0.165	44.48±3.44	42.00±2.90	<0.001***
	IP (2nd)	36.89±3.37	36.22±2.38	0.470	37.73±3.55	35.04±2.18	0.006**	37.40±3.91	36.69±2.85	0.518	37.34±3.57	35.98±2.54	0.018*
	IP (1st)	31.25±2.19	31.58±1.76	0.584	30.33±3.70	29.65±1.71	0.758	30.27±3.40	31.23±2.21	0.296	30.62±3.14	30.82±2.06	0.779
	IC	23.99±1.88	24.10±1.57	0.831	23.68±1.71	23.06±1.64	0.252	23.19±1.70	23.70±1.47	0.321	23.62±1.77	23.62±1.60	0.995
Mandibular arch width (Lingual)	IM	36.01±2.59	33.17±2.34	0.001**	36.43±3.85	32.04±2.52	<0.001***	35.60±3.27	33.13±3.04	0.018*	36.01±3.24	32.78±2.66	<0.001***
	IP (2nd)	31.90±2.89	30.20±2.16	0.052	31.81±4.00	28.72±3.01	0.011*	32.32±3.56	30.82±2.62	0.138	32.01±3.46	29.91±2.72	<0.001***
	IP (1st)	26.50±2.04	27.17±3.40	0.456	26.54±2.90	25.67±2.21	0.292	26.62±3.08	26.86±1.96	0.769	26.55±2.66	26.57±2.64	0.980
	IC	20.17±1.78	20.35±1.45	0.723	19.73±1.61	19.30±1.33	0.365	19.84±1.81	19.89±1.73	0.931	19.91±1.71	19.85±1.55	0.828
Arch depth (First molar)	Mx	25.79±1.89	26.86±1.64	0.052	25.61±2.54	26.21±1.41	0.362	25.82±2.04	25.95±1.84	0.838	25.74±2.14	26.34±1.66	0.088
	Md	21.69±2.31	22.40±1.71	0.273	21.44±1.71	21.63±1.16	0.694	20.48±1.52	21.72±1.40	0.011*	21.20±1.92	21.92±1.46	<0.001***
Arch perimeter	Mx	81.47±5.19	74.89±3.15	<0.001***	78.98±7.07	71.26±2.67	<0.001***	77.92±5.36	71.74±2.81	<0.001***	79.46±6.02	72.63±3.27	<0.001***
	Md	77.63±6.62	67.18±2.75	<0.001***	75.45±7.27	64.27±2.56	<0.001***	73.26±7.32	64.23±3.68	<0.001***	75.41±7.18	65.23±3.29	<0.001***
Molar angulation	Mx	157.56±10.17	162.03±6.07	0.003**	156.24±9.38	168.36±5.58	<0.001***	156.80±6.27	165.19±7.35	<0.001***	156.87±8.64	165.19±6.79	<0.001***
	Md	202.81±10.75	198.45±6.22	0.048*	204.16±14.13	195.03±7.91	<0.001***	206.12±9.20	195.11±10.00	0.001**	204.36±11.43	196.20±8.21	<0.001***

IM, Intermolar; IP, Interpremolar; IC, Intercanine; Mx, Maxillary; Md, Mandibular; SD, Standard deviation, BLC: Bilateral crossbite, C: Control. *p<0.05; **p<0.01; ***p<0.001

Table 4. Comparison of dental arch characteristics of individuals with and without bilateral posterior crossbite according to gender between groups (Independent Samples t-test)

		Females			Males		
		BLC	C	p value	BLC	C	p value
		Mean±SD	Mean±SD		Mean±SD	Mean±SD	
Maxillary arch width (Centroid)	IM	43.66±2.79	46.05±2.19	<0.001***	43.20±4.09	47.97±2.76	<0.001***
	IP (2nd)	37.51±2.31	40.18±2.17	<0.001***	36.90±3.99	41.74±2.50	<0.001***
	IP (1st)	32.71±2.46	35.36±2.17	<0.001***	31.97±3.49	36.66±2.40	<0.001***
	IC	29.10±2.57	29.89±2.87	0.261	29.29±2.70	30.42±2.11	0.085
Maxillary arch width (Lingual)	IM	31.99±2.75	32.91±2.47	0.173	30.86±4.34	34.88±2.86	<0.001***
	IP (2nd)	28.48±2.43	30.97±2.09	<0.001***	27.81±3.96	32.49±2.45	<0.001***
	IP (1st)	23.96±2.63	26.25±2.15	<0.001***	23.34±3.55	27.49±2.01	<0.001***
	IC	24.24±2.72	24.22±2.11	0.975	24.28±2.29	24.88±1.95	0.283
Mandibular arch width (Centroid)	IM	44.12±3.32	40.93±2.79	<0.001***	44.90±3.59	43.06±2.64	0.030*
	IP (2nd)	37.39±3.25	35.22±2.63	0.006**	37.28±3.97	36.75±2.23	0.529
	IP (1st)	30.78±2.63	30.34±2.04	0.550	30.43±3.68	31.30±2.00	0.403
	IC	23.37±1.63	23.30±1.44	0.870	23.91±1.90	23.94±1.70	0.946
Mandibular arch width (Lingual)	IM	35.94±3.13	31.71±2.67	<0.001***	36.09±3.41	33.85±2.20	0.004**
	IP (2nd)	31.83±3.24	29.26±2.46	0.001**	32.22±3.75	30.57±2.85	0.074
	IP (1st)	26.41±2.13	25.96±2.37	0.439	26.72±3.21	27.17±2.80	0.572
	IC	19.59±1.41	19.48±1.45	0.768	20.29±1.97	20.22±1.58	0.883
Arch depth (First molar)	Mx	25.67±2.31	26.38±1.51	0.159	25.81±1.97	26.29±1.82	0.399
	Md	21.03±1.99	21.85±1.43	0.069	21.41±1.85	21.99±1.51	0.193
Arch perimeter	Mx	78.95±5.98	72.01±3.10	<0.001***	80.03±6.13	73.24±3.36	<0.001***
	Md	73.71±6.93	64.08±3.09	<0.001***	77.35±7.09	66.37±3.13	<0.001***
Molar angulation	Mx	154.33±9.14	163.86±7.14	<0.001****	159.77±7.12	166.52±6.26	<0.001***
	Md	206.32±12.35	198.39±7.51	0.004**	202.12±10.03	194.00±8.42	0.001**

BLC, Bilateral posterior crossbite; C, Control; IM, Intermolar; IP, Interpremolar; IC, Intercanine; Mx, Maxillary; Md, Mandibular; SD, Standard deviation.
*p<0.05; **p<0.01; ***p<0.001

Although previous studies have evaluated unilateral posterior crossbite[8,12,13,21] to our knowledge, there is a lack of research focusing on bilateral posterior crossbite. Therefore, this study can be considered as the first to address this gap in the literature. Additionally, research on dimensional differences across age groups is limited, with many studies focusing on a particular age group while overlooking differences across other age groups. In the study by Yang and Chung[18] in 2019, the buccolingual relationship of the molars was examined on tomography images, and some differences were found. However, the age range of participants in their study was broad (6-35 years), and they only included individuals with normal occlusion. Additionally, only the buccolingual angulation of molars was evaluated in their study. It is worth noting that, treatment for posterior crossbite is typically recommended during the early stages of development, particularly during adolescence.[4,8,22] The fact that a wide age range was included in the above study makes it difficult to comment specifically on the adolescence period, when the treatments for this problem are concentrated. In the study by Liu et al.,[23] the age in which rapid maxillary expansion was applied ranged between 5 and 20 years. Therefore, this study examined the dental arch dimensions of individuals aged 12-18 years with permanent dentition, as orthodontic treatment is more frequently performed in such individuals. The fact that the age range in which the posterior crossbite is frequently treated also supports the inclusion of these individuals in this study.[24]

The measurements used in this study were based on those used by McNamara et al.[10], which have been preferred in several previous studies[12,20] and provide comprehensive information about dental arch dimensions. Transverse measurements were performed from both the centroid and lingual regions, and a two-way evaluation was used to obtain a more accurate result. To avoid incomplete interpretation due to tooth rotation and the differences in the buccolingual angulation, measurements were also taken from the lingual region. This study found that transverse widths and buccolingual angulation did not differ between the age groups in either controls or patients with BPC. However, a study by Nanda et al.[25] showed that transverse growth of the maxilla and mandible continued until the age of 18 years, and transverse dimensions at the age of 6 years made up a significant portion of the dimensions at the age of 18 years; with less growth observed after that age.[25] This finding supports the lack of difference in maxillary and mandibular transverse

widths in individuals aged 12-18 years in this study. However, in contrast to the study by Nanda et al.[25], this study found that the same was true for patients with BPC. These findings suggest that, since the upper molars in individuals with BPC are more palatally inclined than those in individuals without BPC, and the lower molars may limit the spontaneous recovery of the upper molars, similar treatments in different age groups will reveal the necessity of correcting the molar angulation. This study found differences in transverse dimensions between males and females in both controls and individuals with BPC. Similar findings in previous studies were thought to be attributed to differences in growth periods and rates between boys and girls,[26] as well as the fact that the face of boys is larger than that of girls.[27]

When the controls and individuals with BPC were compared, the maxillary intermolar width was found to be larger in the controls, whereas the mandibular intermolar width was found to be larger in the individuals with BPC, regardless of age or sex. However, larger maxillary and mandibular anterior-posterior widths were obtained in the individuals with BPC compared to controls. These findings are consistent with those of previous studies[10,20,28] and show that these values are different between individuals with and without BPC regardless of age or sex. Many studies[8,10,12,20,23] on posterior crossbite have focused on treatment-related procedures, and the number of cross-sectional studies remains insufficient. Therefore, this study makes an important contribution to the literature. Although cone-beam computed tomography (CBCT) is considered more effective for examining the buccolingual angulation of the molars,[7,14,15,18] the potential harm of radiation exposure cannot be ignored, and it is recommended to follow the ALARA principle.[29] For this reason, dental models are still used for primary treatment planning and diagnosis instead of CBCT.[1,30] Although the use of dental models may be considered a limitation of the study, their analyses is safer (and thus more ethical) and does not cause any harm to individuals. This study found that the angulation of the molars was greater for the mandible and lower maxilla in individuals with BPC, consistent with the results of McNamara et al.[10] and Geran et al.[20] However, the difference in the angulation between the individuals with BPC and controls was calculated for both younger (12-14 years) and older individuals (16-18 years) in this study. The findings suggest that the molar teeth are upright in both age groups, which is in line with the results by Marshall et al.[31] However, we determined that the difference between the individuals with BPC and controls in the 16-18-year age group was greater than that observed in the 12-14-year age group.

Andrews[32] previously reported a wide range of buccolingual angulation of the first permanent molars in untreated individuals. Although this study showed similar results for both groups, individuals with BPC had a greater variation in this interval. This finding can serve as a reference for recommending posterior crossbite treatment clinically. If the aim of the treatment is to correct molar angulation, different treatment methods may need to be reviewed for individuals with BPC. Because when the existing variation increases, the correction of the molar angulation to their normal positions may become more difficult with treatment. Further clinical studies with different methods should investigate individuals with BPC, and treatment results should be examined based on the analyses performed in this study.

CONCLUSION

The transverse dimension and buccolingual angulation of the molar teeth did not show significant differences between the age groups in both the controls or individuals with BPC. However, the transverse dental arch width and buccolingual angulation of the molars differed between the sexes, regardless of the presence of a posterior crossbite. The difference in molar angulation between individuals with BPC and controls was found to be greater in the older age groups, suggesting that posterior crossbite may affect molar uprighting, with age. Further studies are needed to examine other factors affecting this anomaly, including analyses of different parameters related to BPC, and to identify appropriate treatment methods.

Ethics

Ethics Committee Approval: This study was approved by the Erciyes University Clinical Research Ethics Committee (approval number: 2020/44, date: 15.01.2020).

Informed Consent: Informed consent forms were obtained from all patients included in the study and their parents.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - T.Ö., S.İ.R.; Design - T.Ö., A.Y., S.İ.R.; Supervision - A.Y., S.İ.R.; Funding - T.Ö.; Materials - T.Ö.; Data Collection and/or Processing - T.Ö.; Analysis and/or Interpretation - T.Ö., A.Y., S.İ.R.; Literature Review - T.Ö.; Writing - T.Ö., A.Y.; Critical Review - A.Y., S.İ.R.

Declaration of Interests: The authors have no conflicts of interest to declare.

Funding: The authors declared that this study has received no financial support.

REFERENCES

1. Proffit W, Sarver D, Ackerman J. Orthodontic diagnosis: The problem-oriented approach. Contemporary Orthodontics 5th ed. St Louis: Mosby; 013:150-219. [CrossRef]
2. Lombardo G, Vena F, Negri P, et al. Worldwide prevalence of malocclusion in the different stages of dentition: A systematic review and meta-analysis. *Eur J Paediatr Dent.* 2020;21(2):115-122. [CrossRef]
3. Alhammadi MS, Halboub E, Fayed MS, Labib A, El-Saaidi C. Global distribution of malocclusion traits: A systematic review. *Dental Press J Orthod.* 2018;23(6):40. [CrossRef]
4. Gungor K, Taner L, Kaygisiz E. Prevalence of Posterior Crossbite for Orthodontic Treatment Timing. *J Clin Pediatr Dent.* 2016;40(5):422-424. [CrossRef]

5. Uematsu S, Yoshida C, Takada K. Proportions of malocclusions in Japanese female adolescents over the last 40 years. *Oral Health Prev Dent.* 2012;10(4):373-377. [CrossRef]
6. Petrén S, Bondemark L, Söderfeldt B. A systematic review concerning early orthodontic treatment of unilateral posterior crossbite. *Angle Orthod.* 2003;73(5):588-596. [CrossRef]
7. Alkhatib R, Chung CH. Buccolingual inclination of first molars in untreated adults: A CBCT study. *Angle Orthod.* 2017;87(4):598-602. [CrossRef]
8. Bukhari A, Kennedy D, Hannam A, Aleksejuniene J, Yen E. Dimensional changes in the palate associated with slow maxillary expansion for early treatment of posterior crossbite. *Angle Orthod.* 2018;88(4):390-396. [CrossRef]
9. Eraydin F, Cakan DG, Tozlu M, Ozdemir F. Evaluation of buccolingual molar inclinations among different vertical facial types. *Korean J Orthod.* 2018;48(5):333-338. [CrossRef]
10. McNamara JA Jr, Baccetti T, Franchi L, Herberger TA. Rapid maxillary expansion followed by fixed appliances: a long-term evaluation of changes in arch dimensions. *Angle Orthod.* 2003;73(4):344-353. [CrossRef]
11. Shu R, Han X, Wang Y, et al. Comparison of arch width, alveolar width and buccolingual inclination of teeth between Class II division 1 malocclusion and Class I occlusion. *Angle Orthod.* 2013;83(2):246-252. [CrossRef]
12. Wong CA, Sinclair PM, Keim RG, Kennedy DB. Arch dimension changes from successful slow maxillary expansion of unilateral posterior crossbite. *Angle Orthod.* 2011;81(4):616-623. [CrossRef]
13. Leonardi R, Lo Giudice A, Rugeri M, Muraglie S, Cordasco G, Barbato E. Three-dimensional evaluation on digital casts of maxillary palatal size and morphology in patients with functional posterior crossbite. *Eur J Orthod.* 2018;40(5):556-562. [CrossRef]
14. Almaqrami BS, Alhammadi MS, Tang B, ALyafrusee ES, Hua F, He H. Three-dimensional morphological and positional analysis of the temporomandibular joint in adults with posterior crossbite: A cross-sectional comparative study. *J Oral Rehabil.* 2021;48(6):666-677. [CrossRef]
15. Choi JY, Chaudhry K, Parks E, Ahn JH. Prevalence of posterior alveolar bony dehiscence and fenestration in adults with posterior crossbite: a CBCT study. *Prog Orthod.* 2020;21(1):8. [CrossRef]
16. Dindaroğlu F, Duran GS, Tekeli A, Görgülü S, Doğan S. Evaluation of the Relationship between Curve of Spee, WALA-FA Distance and Curve of Wilson in Normal Occlusion. *Turk J Orthod.* 2016;29(4):91-97. [CrossRef]
17. Andrews LF. The six keys to normal occlusion. *Am J Orthod.* 1972;62(3):296-309. [CrossRef]
18. Yang B, Chung CH. Buccolingual inclination of molars in untreated children and adults: a cone beam computed tomography study. *Angle Orthod.* 2019;89(1):87-92. [CrossRef]
19. Sayania B, Merchant M, Josephs P, Chung CH. Changes in the buccolingual inclination of first molars with growth in untreated subjects: A longitudinal study. *Angle Orthod.* 2017;87(5):681-687. [CrossRef]
20. Geran RG, McNamara JA Jr, Baccetti T, Franchi L, Shapiro LM. A prospective long-term study on the effects of rapid maxillary expansion in the early mixed dentition. *Am J Orthod Dentofacial Orthop.* 2006;129(5):631-640. [CrossRef]
21. Ferro F, Spinella P, Lama N. Transverse maxillary arch form and mandibular asymmetry in patients with posterior unilateral crossbite. *Am J Orthod Dentofacial Orthop*. 2011;140(6):828-838. [CrossRef]
22. Pietilä I, Pietilä T, Pirttiniemi P, Varrela J, Alanen P. Orthodontists' views on indications for and timing of orthodontic treatment in Finnish public oral health care. *Eur J Orthod.* 2007;30(1):46-51. [CrossRef]
23. Liu S, Xu T, Zou W. Effects of rapid maxillary expansion on the midpalatal suture: a systematic review. *Eur J Orthod.* 2015;37(6):651-655. [CrossRef]
24. Celikoglu M, Akpinar S, Yavuz I. The pattern of malocclusion in a sample of orthodontic patients from Turkey. *Med Oral Patol Oral Cir Bucal.* 2010;15(5):791-796. [CrossRef]
25. Nanda R, Snodell SF, Bollu P. Transverse Growth of Maxilla and Mandible. *Semin Orthod.* 2012;18(2):100-117. [CrossRef]
26. Lux CJ, Conradt C, Burden D, Komposch G. Transverse development of the craniofacial skeleton and dentition between 7 and 15 years of age--a longitudinal postero-anterior cephalometric study. *Eur J Orthod.* 2004;26(1):31-42. [CrossRef]
27. DeKock WH. Dental arch depth and width studied longitudinally from 12 years of age to adulthood. *Am J Orthod.* 1972;62(1):56-66. [CrossRef]
28. Allen D, Rebellato J, Sheats R, Ceron AM. Skeletal and dental contributions to posterior crossbites. *Angle Orthod.* 2003;73(5):515-524. [CrossRef]
29. Yeung AWK. The "As Low As Reasonably Achievable" (ALARA) principle: a brief historical overview and a bibliometric analysis of the most cited publications. *Radioprotection.* 2019;54(2):103-109. [CrossRef]
30. Rheude B, Sadowsky PL, Ferriera A, Jacobson A. An evaluation of the use of digital study models in orthodontic diagnosis and treatment planning. *Angle Orthod.* 2005;75(3):300-304. [CrossRef]
31. Marshall S, Dawson D, Southard KA, Lee AN, Casko JS, Southard TE. Transverse molar movements during growth. *Am J Orthod Dentofacial Orthop.* 2003;124(6):615-624. [CrossRef]
32. Andrews LF. Straight Wire: The Concept and the Appliance. San Diego: L.A. Wells; 1989. [CrossRef]

DOI: 10.4274/TurkJOrthod.2022.2022.70

TURKISH JOURNAL of ORTHODONTICS

Original Article

Evaluation of the Difference in the Rate of Canine Retraction Assisted by Piezocision and Discission in Human Subjects: A Preliminary Parallel-Arm Prospective Clinical Study

Srishti Syal[1], Poornima R Jnaneshwar[1], Krishnaraj Rajaram[1], Anupama Tadepalli[2], Ravi Kannan[1]

[1]Department of Orthodontics and Dentofacial Orthopaedics, SRM Dental College, Ramapuram, Chennai, India
[2]Department of Periodontology, SRM Dental College, Ramapuram, Chennai, India

Cite this article as: Syal S, Jnaneshwar PR, Rajaram K, Tadepalli A, Kannan R. Evaluation of the Difference in the Rate of Canine Retraction Assisted by Piezocision and Discission in Human Subjects: A Preliminary Parallel-Arm Prospective Clinical Study. *Turk J Orthod.* 2023; 36(3): 173-179.

Main Points

- This study evaluated the rate of canine retraction assisted by piezocision and dissection in a split mouth clinical study design with the opposite side serving as the control.
- Both corticotomy techniques doubled the rate of tooth movement compared to conventional retraction mechanics, while no difference was observed in the rate of tooth movement between peizocision and decision.
- Discision, although a cost-effective alternative, poses technical difficulties in practice.
- Although patients reported overall satisfaction with the procedure, mild pain and disturbance during the first 24 h was reported with decision.

ABSTRACT

Objective: The objective of the study was to evaluate the rate of orthodontic tooth movement assisted by piezocision and discission in extraction cases.

Methods: Twelve adults (20-35 years) requiring upper premolar extraction for orthodontic treatment were included in this preliminary parallel-arm clinical study. Participants (randomly allocated) in Groups A and B received piezocision and discision-assisted corticotomy cuts at the premolar extraction site, respectively, contralateral side served as the control. Canine retraction was started bilaterally using closed coil NiTi (Nickel titanium) springs. A schedule of fortnightly activation was followed for 3 months. Stage models were made monthly (M0, M1, M2, M3). Models were scanned using a 3-shape intraoral scanner, and the displacement of the canine was measured bilaterally in the stage models. A self-designed questionnaire was used to assess patients pain and satisfaction levels on a visual analogue scale.

Results: The rate of canine retraction at the piezocision site was twice that at the control site in group A (p=0.007). The rate of canine retraction at the dissection site was twice that at the control site in group B (p=0.012). However, there was no significant difference in the rate of retraction between the two surgical techniques. Pain and disturbance were noticed in the discission group at 50 and 67% respectively.

Conclusion: Discision is comparable to piezocision for accelerating orthodontic tooth movement. Although dissection can speed orthodontic treatment, it should be used with caution as it could pose technical and clinical difficulties, particularly in the posterior buccal region of the oral cavity.

Keywords: Corticotomy, piezocision, discision, regional acceleratory phenomenon

Corresponding author: Srishti Syal, e-mail: srishti.syal.bds@gmail.com

Received: April 09, 2022
Accepted: November 26, 2022
Epub: September 20, 2023
Publication Date: September 29, 2023

INTRODUCTION

Accelerated orthodontic tooth movement can be achieved by enhancing the expression of specific inflammatory factors.[1] Several methods have been proposed to achieve accelerated orthodontic tooth movement, including physical or mechanical stimulation, medications, and surgical techniques.[1-4]

Wilcko et al.[5] explained that accelerated rate of tooth movement with periodontally accelerated osteogenic orthodontics is due to a transient catabolic and anabolic phase, which is an attribute of regional acceleratory phenomenon (RAP) as described by Frost in 1983. Vercellotti and Podesta[6] introduced corticotomy assisted by piezosurgical device in conjunction with mucoperiosteal flap elevation. Although, these corticotomies that effectively accelerate orthodontic tooth movement (OTM) are inherently invasive due to the requirement for significant flap elevation. This may potentially lead to postoperative pain, avascular necrosis, and a low patient's acceptance rate.[5-8] Some studies have also reported periodontal problems, such as increased tooth mobility and bone dehiscence, immediately following full-thickness flap elevation.[8-10]

In contrast to previous methods involving cortical resection and flap elevation, the concept of a minimally invasive corticotomy is to activate the inflammatory cascade in the cortical bone by creating an osteoporotic environment conducive to accelerating OTM.[11]

The use of ultrasonic devices is associated with minimal postoperative pain and discomfort because they are less traumatic to the hard and soft tissues. Piezoelectric instruments, which allow for more favorable osseous repair and regeneration, have several advantages: a reduction in intraoperative bleeding and surgical trauma, leading to improved visibility and reduced operating time, resulting in less morbidity for the patient.[12] Corticision, a flapless corticotomy method using scalpel and mallet, introduced by Kim et al.[13] , had the disadvantage of causing dizziness post-surgery due to malleting. Dibart et al.[14] introduced piezocision as a minimally invasive corticotomy procedure.

Piezosurgery knives are available in specific thicknesses, which limits their use in patients with roots in very close proximity. The feasibility of procuring a piezotome in a routine orthodontic setup is impractical.[15] Buyuk et al.[7] used an implant disk saw, which is compatible with a physiodispenser and readily available in dental clinics, for performing corticotomy. This technique has demonstrated satisfactory results in hastening the alignment of crowded teeth.[15]

There is a dearth of literature comparing the above-mentioned techniques in accelerating OTM. Hence, this preliminary prospective clinical study compared the rate of canine retraction assisted by piezocision and decision. The null hypothesis was that there would be no difference between the rate of tooth movement achieved by piezocision and decision.

METHODS

Sample size estimation was performed using G* Power 3 software with power (1-β error prob) of 80% and an α error of 0.05, resulting in a determined sample size of 12 patients (Group A= 6 patients, Group B= 6 patients). The level of statistical significance level was set at p≤0.05.[16] This parallel arm study was approved by the Institute's Scientific Review Board and Ethical Committee of SRM Dental College (approval no: SRMDC/IRB/2019/MDS/No.108A, date: 04.01.2022) and was registered under the Clinical Trial Registry. The study was designed as a preliminary parallel-arm investigation following a split mouth study design, where one quadrant of the maxillary arch served as the corticotomy side and the opposite side serving as the control (Figure 1).

Patients for the study were selected based on specific criteria, including being adults within the age range of 20-35 years, having a full permanent dentition with or without third molars, requiring therapeutic extraction of both maxillary first premolars, having periodontal probing depths less than or equal to 3mm, maintaining adequate oral hygiene, possessing adequate width of attached gingiva, and exhibiting no associated bone loss. Exclusion criteria included systemic diseases that affect bone formation or density, such as osteoporosis, hyperparathyroidism, or vitamin D deficiency, as well as other systemic diseases like blood dyscrasias and a history of smoking. Twelve patients meeting the criteria were enrolled in the study. Informed consent was procured from all participants after having explained the entire treatment protocol to them.

All patients underwent therapeutic orthodontic extraction of all four first premolars followed by fixed mechanotherapy. After initial alignment and leveling, a working archwire (0.019X0.025" stainless steel) was engaged in the upper arch. Orthopantomograms, intraoral photographs and impressions

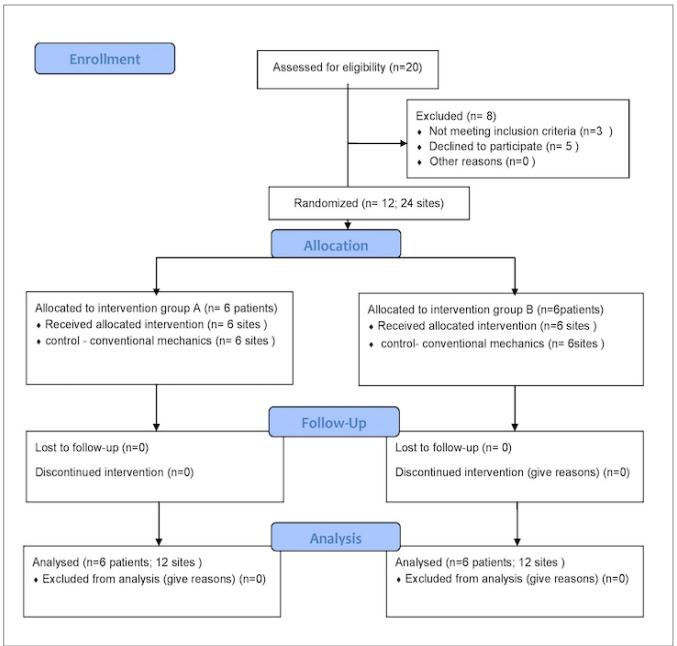

Figure 1. Consort flow diagram

of the upper and lower arches were recorded as presurgical records (M0).

The twelve participants were randomly assigned to one of the groups. Split mouth design with both surgical techniques in the same patient was avoided to prevent the crossover effect of either technique across the quadrants. The test sites received corticotomy assisted by piezocision (group A) or decision (group B). On the contralateral side, canine retraction was carried out using conventional friction mechanics in both groups.

Surgical Intervention

Sterilization and personal protection protocols were followed before and during surgical procedure. Under local anesthesia (2% Lignocaine with 1:80,000 Adrenaline), a minimally invasive vertical microperiosteal incision was executed on the mid-buccal aspect using a surgical scalpel blade no.15C. The incision was approximately 7 mm long, beginning 3 mm from the gingival crest and extending to the alveolar mucosa.

For the Piezocision technique: The guiding soft tissue incision was followed by a cortical penetrating vertical cut made using Piezoelectric BS1-insert at 27-36 khz (9 mm cutting depth, Piezotome, Satelec, Acteon, France) at the center of the site distal to canine. The cut was 7 mm long and 3 mm deep, penetrating the alveolar bone[14] (Figure 2).

In the case of the Dissection technique: Following the guiding soft tissue incision, a cortical penetrating vertical cut executed using a disk saw (3.5 mm radius, Esset KIT-Osstem, Seoul, Korea) operating at 350 rpm, compatible with a physiodispenser (NSK, USA) on the site distal to the canine in the maxillary arch. The cut was 7 mm long and 3.5 mm deep in the bone, positioned distal to the canine within the maxillary arch[7] (Figure 3).

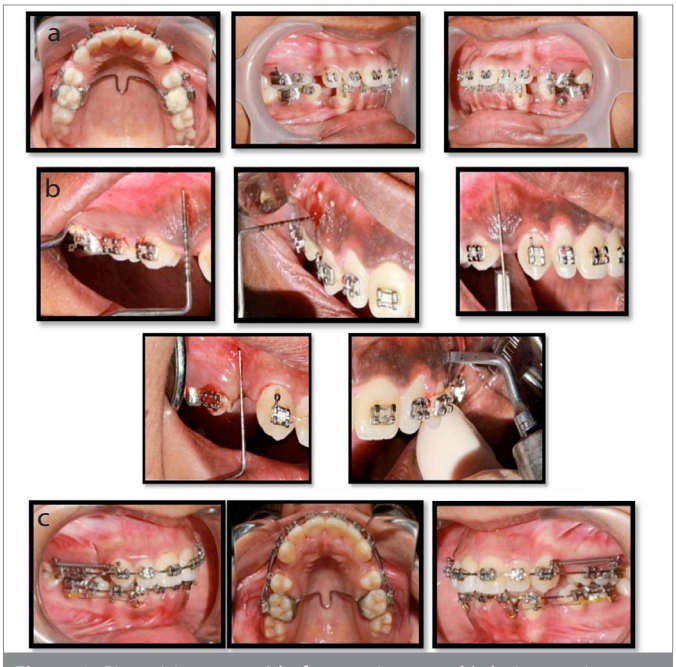

Figure 2. Piezocision case: a) before corticotomy; b) during corticotomy; c) immediate loading of forces with closed NiTi coil spring

The contralateral extraction space located distal to the canine within the maxillary arch served as the control, ensuring the implementation of split mouth design. Immediately after the corticotomy, the sites were irrigated with copious saline solution and gentle pressure was applied using sterile gauze packs to minimize bleeding. After achieving hemostasis, canine retraction was initiated. No sutures or periodontal dressings were placed at the surgical site (Figures 2 and 3). Postsurgery instructions were given, and patients were advised to take paracetamol for the management of postoperative pain if needed.

For each participant after the corticotomy procedure, retraction was initiated for both sites in the maxilla using closed NiTi (Nickel Titanium) coil springs that applied a calibrated force of 120 gms/side for visualising the maxillary canines (Figures 1 and 2).

Activation of the NiTi closed coil spring was performed every 2 weeks during the 3 months follow-up period. Stage impressions were recorded for measuring the rate of canine retraction every month for a follow-up period of three months [M0 (pre-activation), M1, M2, M3].

All stage models were scanned using a 3 Shape Trios intraoral scanner (SHAPE, Copenhagen, Denmark) and saved as standard Triangle Language (.STL) files. The distance from the tip of the maxillary canine to the tip of the mesiobuccal cusp of the maxillary first molar was measured on both the corticotomised and control sites using Maestro 3D software (Figure 4). Cusp tips were chosen as reference points because they offered better visibility and ease of measurement with the three-dimensional analyzing software.[17,18]

A self-designed questionnaire was used to assess patient pain and satisfaction levels on a visual analogue scale during, after, 24, and 48 h after the surgical procedure (Tables 1 and 2).

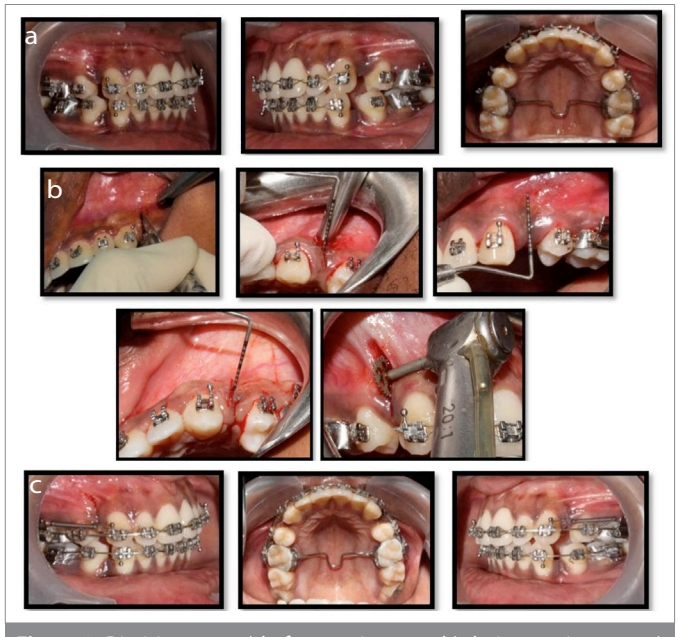

Figure 3. Discision case: a) before corticotomy, b) during corticotomy, c) immediate loading of forces with closed NiTi coil spring

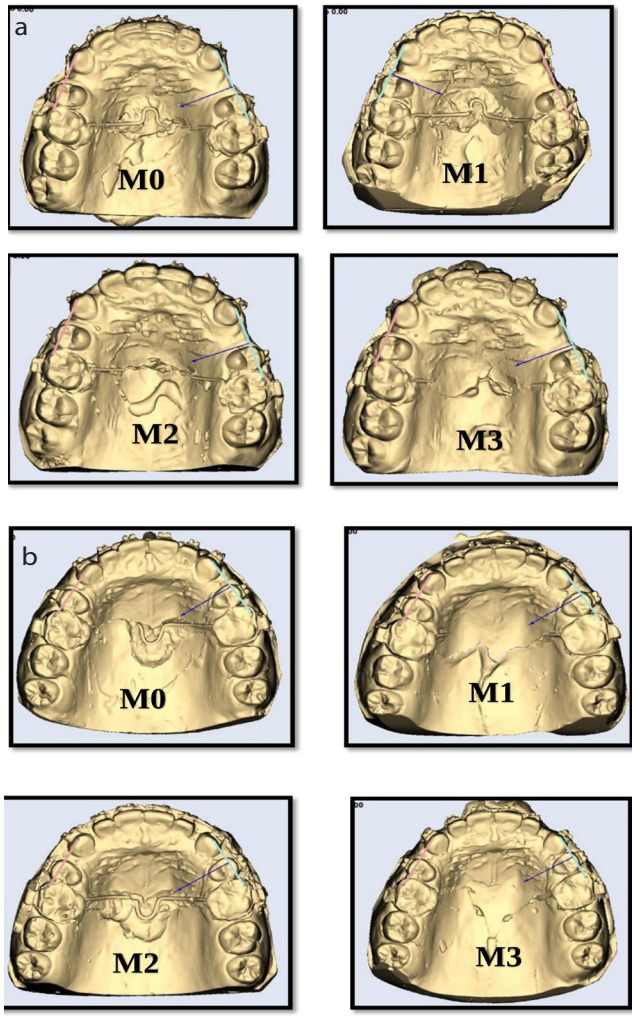

Figure 4. Scanned images of stage models: a) piezocision and b) discision cases

Table 1. Self designed questionnaire interpretation for participants in Group A (piezocision assisted corticotomy)

Pain			
		Piezocision	Control
1	Site	-	-
2	Duration	-	-
3	Intensity	-	-
4	Symptom	-	-
Interference			
		Piezocision	Control
1	Site	-	3
2	Duration	-	Up to 24 hr
3	When	-	Mostly while eating or activity
4	Intensity	-	23%
Satisfaction			
		Piezocision	Control
1	Site of comfort	Equally comfortable	
2	Intensity of comfort	-	
3	Site of discomfort	-	
4	Intensity of discomfort	-	
5	Intensity of satisfaction overall	100%	
6	Overall satisfaction of sites	Equal	

Statistical Analysis

The collected data were analyzed with IBM SPSS Statistics for Windows, Version 23.0 (IBM Corp, Armonk, NY, USA). Test for normality was performed using the Sharpiro-Wilk test. Further Independent Samples Student's t-test was performed to compare piezocision with control, discission with control, and piezocision with discision (Tables 3 and 4).

RESULTS

The rate of distal movement of canines in Group A was greater at the piezocision site compared to the control sites at all stages, demonstrating statistically significant differences for M0-M1 (p=0.025), M1-M2 (p=0.012), M2-M3 (p=0.003) and M0-M3 (p=0.007) (Table 3). The rate of distal movement of canines in group B was higher at discission sites than at the control sites during M0-M1 (p=0.048) and M0-M3 (p=0.012) (Table 3). The rate of canine distalization at both piezocision and discission sites showed no significant difference throughout the 3-month follow-up periods (Table 4). Hence, the two experimentalcorticotomy techniques are equally comparable in terms of accelerating OTM.

Evaluation of the self-designed questionnaire indicated almost complete satisfaction with both the corticotomy combined orthodontic mechanics and the conventional mechanics used. 50% of the participants in Group B noted experiencing pain on the first day with an average intensity of 36.66% on the discission side. On the contrary, participants in Group A experienced no pain. Disturbance during mastication for the first 24 h was observed on the discission side by 67% of the participants. In group A, around 50% of participants found the control site disturbing during eating for the first postoperative 24 h, while all participants experienced neither disturbance nor interference from the piezocision procedure performed (Tables 1 and 2).

DISCUSSION

Factors like hormones, age, occlusal factors, orthodontic forces, health status and bone type affect bone density and remodeling, thereby affecting orthodontic tooth movement

Table 2. Self designed questionnaire interpretation for participants in Group B (discision assisted coticotomy)

Pain			
		Discision	Control
1	Site	50%	-
2	Duration	Up to 24 hr	-
3	Intensity	36.66%	-
4	Symptom	Nil	-
Interference			
		Discision	Control
1	Site	4	1
2	Duration	24-48 hr	Up to 24h
3	When	Mostly during eating, only one during activity	Eating and activity
4	Intensity	30%	35%
Satisfaction			
		Discision	Control
1	Site of comfort	Equal	
2	Intensity of comfort	100%	
3	Site of discomfort	None	Only one patient
4	Intensity of discomfort	-	70% (one patient)
5	Intensity of satisfaction overall	100%	
6	Overall satisfaction of sites	Equal	

Table 3. Intra group comparison for the rate of canine retraction

	Group A (Piezocision)			Group B (Discision group)		
	Piezocision site (mm)	**Control site (mm)**	**p value**	**Discision site (mm)**	**Control site (mm)**	**p value**
M0-M1	1.40+0.20	1.15+0.12	0.025*	1.25+0.28	0.68+0.55	0.048*
M1-M2	1.43+0.44	0.80+0.23	0.012*	1.72+1.10	0.87+0.63	0.13
M2-M3	1.53+0.49	0.70+0.14	0.003*	0.96+0.36	0.23+1.08	0.14
M0-M3	3.97+1.54	1.78+0.42	0.007*	3.95+1.14	1.78+1.31	0.012*

*P value <0.05 - significant
M0- before corticotomy
M1- one month after corticotomy
M2- two months after corticotomy
M3- three months after orticotomy

Table 4. Comparison between rate of canine retraction assisted by piezocision and discision

	Piezocision site (mm)	**Discision site (mm)**	**p value**
M0-M1	1.40+0.20	1.25+0.28	0.32
M1-M2	1.43+0.44	1.72+1.10	0.55
M2-M3	1.53+0.49	0.96+0.36	0.052
M0-M3	3.97+1.54	3.95+1.14	0.97

*p value <0.05 - significant
M0- before corticotomy
M1- one month after corticotomy
M2- two months after corticotomy
M3- three months after orticotomy

(OTM).[19]Age plays a critical role in tooth movement due to its significant relation with bone density, the recruitment of inflammatory markers, and the activation of osteoclasts.[20] Hence, all participants enrolled in this study were between 20 and 35 years. Patients with similar severities of malocclusion requiring extraction of the permanent maxillary first bicuspid were included in this clinical study. To eliminate the potential of uneven occlusal forces arising from a dominant habitual occlusion on one side, the allocation of corticotomy and control sites to the left or right side for each patient was done through randomization.[19] Extractions affect the rate of tooth movement by increasing the activity of inflammatory markers and hence overlap and obscure the effect of corticotomy.[21] In order to minimize this, extractions in this study were performed before bonding brackets to permit recovery of bone architecture and prevent potential inflammation and its obstructing effects. Canine retraction was started only after completion of the alignment and leveling stages. The application of excessive force could lead to many complications such as root resorption.[17] Since literature reports that effective tooth movement is possible with light forces, a force of 120 gms/side was calibrated using a dontrix gauge during activation of closed coil NiTi springs.[22] The maxilla and mandible respond differently to the same force;

loads on maxilla get dissipated to the rest of the cranium, while mandible experiences torsional and bending strain. Different bone mass and geometry account for the difference in response to orthodontic loading in the two bones.[11,19,20] Hence for the present study, corticotomy (test) and control sites were confined to the maxillary arch.

Cortical bone is devoid of blood supply but still considered vital for accelerating OTM. "Mechanical movement theory" has been replaced by Frost's "RAP" which states that there is an increased recruitment of cells involved in bone metabolism at the site of intentional injury. The regional response to surgical insult directly correlates with the magnitude and nature of stimulus.[5] Thickness of cortical bone in the maxillary premolar region is 1.8 mm and corticotomy cut should be more than 1 mm in depth to provide the required stimulus to initiate RAP.[19,23] Uribe et al.[23] concluded that piezotome-corticision-assisted orthodontics could not effectively alleviate mandibular anterior crowding. Their maximum permitted cortical penetration depth was 1mm, which was insufficient to enhance the regional inflammatory process.[23] In this study, the penetration depth was set as 3 mm and length of the cut was 7 mm into the alveolar bone for both piezocision and discision.[5,7,11,15,24] The RAP initiated on the buccal side could readily involve the non-corticotomized palatal side.[5,25] Hence, to minimize the invasive nature of the procedure, discomfort, and operative time for the clinician, corticotomy cuts were made only at the buccal cortex of alveolar bone.[25]

RAP is a transient, ubiquitous post-injury phenomenon that accelerates OTM with its peaks in the first two months.[12,14] Therefore, it is suggested to activate the retraction every two weeks to exploit the exacerbated response. Although RAP lasts for a minimum of four months, its efficacy diminishes with resultant deceleration in the velocity of OTM over time.[17,18,26] In the present study, the rate of canine retraction at the experimental sites was similar to that reported by Aksakalli et al.[18]. Çağlı Karcı and Baka[27] reported only half the amount of canine retraction every month compared to this study. It is not the design of corticotomy that determines the rate of tooth movement but the regional, transient and exaggerated cellular response that is responsible for the acceleration.[5,19] In the present study, piezocision and discission sites demonstrated a statistically comparable rate of canine distalisation. Hence, there was no difference in the rate of canine retraction between the two corticotomy techniques.

The power of the study was 80%; although the sample size was small, it was clear from the results that the rate of canine retraction at both piezocision and discission sites was significantly higher than that at contralateral control sites ($p<0.05$) Table 3. The two experimental sites showed approximately two times faster rates of tooth movement when compared to the control sites. This result is in accordance with previous studies.[6,19] However, it has been reported that microperiosteal flap elevation was associated with faster tooth movement compared to the present study.[5,9,26] When the surgical intervention is adequate to stimulate a rapid alveolar reaction, there is early osteoclastic activation and enhanced turnover of alveolar bone, which is the reason for the acceleration of tooth movement. Corticotomy-assisted OTM demonstrates continuous and steady movement without evidence of a "lag phase", which often corresponds to periodontal ligament hyalinization in conventional OTM. Mucoperiosteal flap elevation by itself is found to be a stimulus for RAP and it could have a synergistic effect to corticotomy.[8,11,28] Although using an implant disk saw for corticotomy can aid in accelerating OTM as demonstrated in this study, the disk saw design, the localized condition of the selected site, and its adjoining structures should be carefully examined and practically correlated. The angulation of the disk to the shaft was at the right angle, which posed technical difficulty in use in the posterior region due to anatomical and access limitations. The vestibular depth decreases posteriorly, and accidental injury to the frenal muscular attachment in the premolar region could be expected even with the most experienced clinical hand. There are increased chances of laceration of buccal frenal attachments with even a slight slippage of the disk saw.

The initial pain or pressure is a common concern expressed by orthodontic patients, for a minimum of 24 hours at every activation.[29] Complete recovery after corticotomy with flap elevation takes nearly seven to ten days with minor postsurgical complications including swelling. Al-Naoum et al.[9] reported that all participants complained of pain while eating for the first two days after surgery, which gradually decreased over time. However, in the current study, 66% of participants experienced pain intermittently for 24 hours with an average intensity of 36.66% on the discission side and disturbance was noticed for two days during mastication. Participants in the piezocision group experienced neither pain nor disturbance. Some participants, however, reported that they found the control sides disturbing for 24 hours compared to the piezocision side. This study suggests that though both procedures are invasive, they are minimally invasive. There was almost a similar level of satisfaction with both corticotomy combined with orthodontic mechanics and conventional mechanics among patients.

The trial was conducted to assess the rate of OTM assisted by corticotomy using piezocision and discission, comparing both with the control side, making it a purely clinical study. This research, however, lacks the analysis of cellular and molecular-level changes occuring due to the regional acceleratory phenomenon (RAP) induced by these procedures. This could serve as a potential scope for future research. This study could not compare augmentation combined with the two procedures because there was no previous research that compared the rate of OTM following piezocision or decision. Exploring this aspect could be a future scope for comparison as augmentation with materials like platelet-rich fibrin and bone-grafts has demonstrated synergistic effects.[16,27]

CONCLUSION

The rates of tooth movement assisted by piezocision and discission were comparable with no statistical difference between the two. Both the corticotomy techniques were found to enhance OTM at twice the pace of conventional mechanics. Although patients reported complete satisfaction with the corticotomy procedures or conventional mechanics, mild pain

and disturbance during the initial 24 hours were reported n the discission group. With piezocision trauma to adjoining structures was minimal, while with discission trauma to adjacent soft tissue structures such as buccal frenal attachments were noted.

Ethics

Ethics Committee Approval: The study was approved by the Institute's Scientific Review Board and Ethical Committee of SRM Dental College (approval no: SRMDC/IRB/2019/MDS/No.108A, date: 04.01.2022).

Informed Consent: Informed consent was procured from all participants after having explained the entire treatment protocol to them.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - S.S., P.R.J., K.R., A.T., R.K.; Design - S.S., P.R.J., K.R., A.T., R.K.; Data Collection and/or Processing - S.S., P.R.J., K.R., A.T., R.K.; Analysis and/or Interpretation - S.S., P.R.J., K.R., A.T., R.K.; Literature Review - S.S., P.R.J., K.R., A.T., R.K.; Writing - S.S., P.R.J., K.R., A.T., R.K.

Declaration of Interests: All authors declare that they have no conflict of interest.

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

REFERENCES

1. Yoshimatsu M, Shibata Y, Kitaura H, et al. Experimental model of tooth movement by orthodontic force in mice and its application to tumor necrosis factor receptor-deficient mice. *J Bone Miner Metab.* 2006;24(1):20-27. [CrossRef]
2. Knop LA, Shintcovsk RL, Retamoso LB, Ribeiro JS, Tanaka OM. Non-steroidal and steroidal anti-inflammatory use in the context of orthodontic movement. *Eur J Orthod.* 2012;34(5):531-535. [CrossRef]
3. Jäger A, Zhang D, Kawarizadeh A, Tolba R, Braumann B, Lossdörfer S, et al. Soluble cytokine receptor treatment in experimental orthodontic tooth movement in the rat. *Eur J Orthod.* 2005;27(1):1-11. [CrossRef]
4. Andrade I Jr, Silva TA, Silva GA, Teixeira AL, Teixeira MM. The role of tumor necrosis factor receptor type 1 in orthodontic tooth movement. *J Dent Res.* 2007;86(11):1089-1094. [CrossRef]
5. Wilcko MT, Wilcko WM, Bissada NF. An Evidence-Based Analysis of Periodontally Accelerated Orthodontic and Osteogenic Techniques: A Synthesis of Scientific Perspectives. *Seminars in Orthodontics.* 2008;14(4):305–316. [CrossRef]
6. Vercellotti T, Podesta A. Orthodontic microsurgery: A new surgically guided technique for dental movement. *Int J Periodontic Restorative Dent.* 2007;27(4):325–331. [CrossRef]
7. Buyuk SK, Yavuz MC, Genc E, Sunar O. A novel method to accelerate orthodontic tooth movement. *Saudi Med J.* 2018;39(2):203–208. [CrossRef]
8. Yaffe A, Fine N, Binderman I. Regional accelerated phenomenon in the mandible following mucoperiosteal flap surgery. *J Periodontol.* 1994;65(1):79-83. [CrossRef]
9. Al-Naoum F, Hajeer MY, Al-Jundi A. Does alveolar corticotomy accelerate orthodontic tooth movement when retracting upper canines? A split-mouth design randomized controlled trial. *J Oral Maxillofac Surg.* 2014;72(10):1880-1889. [CrossRef]
10. Wu J, Jiang JH, Xu L, Liang C, Bai Y, Zou W. A pilot clinical study of Class III surgical patients facilitated by improved accelerated osteogenic orthodontic treatments. *Angle Orthod.* 2015;85(4):616-624. [CrossRef]
11. Kim YS, Kim SJ, Yoon HJ, Lee PJ, Moon W, Park YG. Effect of piezopuncture on tooth movement and bone remodeling in dogs. *Am J Orthod Dentofacial Orthop.* 2013;144(1):23-31. [CrossRef]
12. Cassetta M, Di Carlo S, Giansanti M, Pompa V, Pompa G, Barbato E. The impact of osteotomy technique for corticotomy-assisted orthodontic treatment (CAOT) on oral health-related quality of life. *Eur Rev Med Pharmacol Sci.* 2012;16(12):1735-1740. [CrossRef]
13. Kim SJ, Park YG, Kang SG. Effects of Corticision on paradental remodeling in orthodontic tooth movement. *Angle Orthod.* 2009;79(2):284-291. [CrossRef]
14. Dibart S, Surmenian J, Sebaoun JD, Montesani L. Rapid treatment of Class II malocclusion with piezocision: two case reports. *Int J Periodontics Restorative Dent.* 2010;30(5):487-493. [CrossRef]
15. Yavuz MC, Sunar O, Buyuk SK, Kantarcı A. Comparison of piezocision and discision methods in orthodontic treatment. *Prog Orthod.* 2018;19(1):44. [CrossRef]
16. Yashwant V A, Balu P, Kumar RS, Ammayappan P, Murugaboopathy V. Effectiveness of platelet rich fibrin versus demineralized bone xenograft in periodontally accelerated osteogenic orthodontics. *Angle Orthod.* 2022;92(2):180-188. [CrossRef]
17. Sukurica Y, Karaman A, Gürel HG, Dolanmaz D. Rapid canine distalization through segmental alveolar distraction osteogenesis. *Angle Orthod.* 2007;77(2):226-236. [CrossRef]
18. Aksakalli S, Calik B, Kara B, Ezirganli S. Accelerated tooth movement with piezocision and its periodontal-transversal effects in patients with Class II malocclusion. *Angle Orthod.* 2016;86(1):59-65. [CrossRef]
19. Charavet C, Lecloux G, Bruwier A, et al. Localized Piezoelectric Alveolar Decortication for Orthodontic Treatment in Adults: A Randomized Controlled Trial. *J Dent Res.* 2016;95(9):1003-1009. [CrossRef]
20. Deguchi T, Takano-Yamamoto T, Yabuuchi T, Ando R, Roberts WE, Garetto LP. Histomorphometric evaluation of alveolar bone turnover between the maxilla and the mandible during experimental tooth movement in dogs. *Am J Orthod Dentofacial Orthop.* 2008;133(6):889-897. [CrossRef]
21. Alqadasi B, Xia HY, Alhammadi MS, Hasan H, Aldhorae K, Halboub E. Three-dimensional assessment of accelerating orthodontic tooth movement-micro-osteoperforations vs piezocision: A randomized, parallel-group and split-mouth controlled clinical trial. *Orthod Craniofac Res.* 2021;24(3):335-343. [CrossRef]
22. Iwasaki LR, Haack JE, Nickel JC, Morton J. Human tooth movement in response to continuous stress of low magnitude. *Am J Orthod Dentofacial Orthop.* 2000;117(2):175-183. [CrossRef]
23. Uribe F, Davoody L, Mehr R, et al. Efficiency of piezotome-corticision assisted orthodontics in alleviating mandibular anterior crowding-a randomized clinical trial. *Eur J Orthod.* 2017;39(6):595-600. [CrossRef]
24. Charavet C, Lecloux G, Jackers N, Albert A, Lambert F. Piezocision-assisted orthodontic treatment using CAD/CAM customized orthodontic appliances: a randomized controlled trial in adults. *Eur J Orthod.* 2019;41(5):495-501. [CrossRef]
25. Germeç D, Giray B, Kocadereli I, Enacar A. Lower incisor retraction with a modified corticotomy. *Angle Orthod.* 2006;76(5):882-890. [CrossRef]
26. Aboul-Ela SM, El-Beialy AR, El-Sayed KM, Selim EM, El-Mangoury NH, Mostafa YA. Miniscrew implant-supported maxillary canine retraction with and without corticotomy-facilitated orthodontics. *Am J Orthod Dentofacial Orthop.* 2011;139(2):252-259. [CrossRef]
27. Çağlı Karcı İ, Baka ZM. Assessment of the effects of local platelet-rich fibrin injection and piezocision on orthodontic tooth movement during canine distalization. *Am J Orthod Dentofacial Orthop.* 2021;160(1):29-40. [CrossRef]
28. Baloul SS, Gerstenfeld LC, Morgan EF, Carvalho RS, Van Dyke TE, Kantarci A. Mechanism of action and morphologic changes in the alveolar bone in response to selective alveolar decortication-facilitated tooth movement. *Am J Orthod Dentofacial Orthop.* 2011;139(4 Suppl):S83-S101. [CrossRef]
29. Krukemeyer AM, Arruda AO, Inglehart MR. Pain and orthodontic treatment. *Angle Orthod.* 2009;79(6):1175-1181. [CrossRef]

TURKISH JOURNAL of ORTHODONTICS

DOI: 10.4274/TurkJOrthod.2022.2022.12

Original Article

Evaluation of Maxillary Sinus Volume of Class III Individuals with Different Jaw Positions by Cone-Beam Computed Tomography

Yazgı Ay Ünüvar[1], Emre Köse[2]

[1]Aydın Adnan Menderes University Faculty of Dentistry, Department of Orthodontics, Aydın, Turkey
[2]Aydın Adnan Menderes University Faculty of Dentistry, Department of Oral and Maxillofacial Radiology, Aydın, Turkey

Cite this article as: Ay Ünüvar Y, Köse E. Evaluation of Maxillary Sinus Volume of Class III Individuals with Different Jaw Positions by Cone-Beam Computed Tomography. *Turk J Orthod.* 2023; 36(3): 180-185.

Main Points
- Different sagittal positions of the maxilla have no effect on maxillary sinus volume.
- Males have greater maxillary sinus volume than females.
- Cone-beam computed tomography images can be used to calculate volumes and areas of sinuses using additional software.

ABSTRACT

Objective: To compare maxillary sinus volumes and surface areas among individuals with Class III skeletal patterns, with different sagittal positions of maxilla and Class I patients with normal jaw positions using cone-beam computed tomography (CBCT).

Methods: CBCT images of 168 patients were analyzed retrospectively. The calculated surface areas and sinus volumes of 58 patients with Class I, normal mandibular and maxillary position (0<ANB<4, 84>SNA>80, 82>SNB>78) were compared with 61 patients with Class III retrognathic maxillary and normal mandibular positions (MRs) (ANB<0, SNA<80, 82>SNB>78) and 49 patients with Class III normal maxillary and prognathic mandibular positions (MP) (ANB<0, 84>SNA>80, SNB>82). Also, volume differences between genders and sides were investigated. One-way ANOVA and t-test were used to compare age, gender, skeletal patterns, and maxillary sinus measurements.

Results: CBCT images of 94 females and 74 males were examined. There was no statistically significant difference in the right and left maxillary sinus volume and surface area measurements among Class I, Class III MR, and Class III MP groups (p>0.05). When the maxillary sinus volume and surface area were evaluated according to gender, the right maxillary sinus surface area and volume of males were found to be statistically significantly higher than those of females (p=0.012 and p=0.024). Similarly, the left maxillary sinus surface areas and volumes of males were also found to be significantly higher than those of females (p=0.000 and p=0.002).

Conclusion: Different sagittal positions of the maxilla do not appear to affect maxillary sinus volume, and males tend to have greater maxillary sinus volume than females. CBCT images can be used to calculate intrabony air spaces.

Keywords: Cone-beam computed tomography, Class III malocclusion, maxillary sinus volume

INTRODUCTION

Maxillary sinuses are intrabony air-filled spaces located laterally to the nasal cavity and connected to them through an ostium. They extend inferiorly to the apices of the posterior teeth. They are the first paranasal sinuses to develop. However, there is no consensus on the exact timing of maxillary sinus development. According to the literature, the earliest development occurs during the third week of gestation. The maxillary sinus expands progressively with the resorption of the neighboring nasal capsule and extends into the ossifying maxilla by 20 weeks of gestation. Growth continues through early adulthood and results in an elongated oval shape

Corresponding author: Yazgı Ay Ünüvar, e-mail: yazgi.ay@adu.edu.tr

Received: 13.02.2022
Accepted: 26.11.2022
Epub: September 28, 2023
Publication Date: September 29, 2023

with prominent anterior-posterior expansion.[1,2] During early embryonic growth, three mesenchymal processes contribute to the development of midface structures: the lateral nasal, medial nasal, and maxillary processes. The deep parts of the maxillary process contribute to the formation of the maxillary sinus.[3]

By the end of the 8th year, the maxillary sinus has reached nearly 50% of its final size and its growth rate slows down after the age of 12. However, it continues to grow until reaching adulthood. In adults, the maxillary sinus volume is approximately 15 mL, and its anteroposterior distance and width measure are 34 mm and 23-25 mm, respectively.[2,3]

Due to the proximity of maxillary sinuses to posterior teeth, dentists should be aware of the anatomical features and disorders of the sinonasal region.[4] Knowledge of the symptoms of maxillary sinusitis and the anatomy of the maxillary sinus helps prevent misdiagnosis and complications during surgical procedures.[4,5] Understanding the anatomy and the location of the maxillary sinus is also important for dental implant treatment with sinus lift, endodontic treatment of maxillary posterior teeth and orthodontic mini-implant treatment.[6] Morphometric analysis of the maxillary sinus is valuable for identification when the loss of other skeletons rests occurs.[5,7]

The dimensions of the maxillary sinus can be influenced with tooth loss and aging. Different sinus dimensions may be observed according to gender and malocclusions. The vertical and sagittal growth patterns of the jaws can also impact the development of the maxilla and maxillary sinuses. Some authors argue that there is a difference between maxillary sinus widths and malocclusions, while others claim that there is no difference.[8-11] Considering the complex anatomical structure of the maxillary sinus, diagnostic methods such as computed tomography (CT) and magnetic resonance imaging are considered the gold standard for examining the anatomical and pathologic features of the sinuses. However, their use is limited due to their high cost, limited availability, and the use of the high-dose radiation for CT. Cone-beam CT (CBCT) is an advanced imaging method hat offers the advantage of a lower radiation dose while enabling the examination of paranasal structures and accurate calculation of maxillary sinus volume.[12,13]

The maxillary premolars and molars are usually quite close to or in contact with the maxillary sinus wall. Therefore, the expansion of maxillary sinus after the extraction of first molar tooth, with the downward movement of the alveolar process, plays an important role in orthodontic treatment planning.[14] Due to their placement in the body of the maxilla and their direct relationship with the maxillary posterior teeth, the maxillary sinuses can easily be affected by the anatomical features and dimensional changes of the maxilla. Thus, it has been suggested that the volumetric change of the maxillary sinuses can be more accurate when considering the malocclusion classification and the position of the maxilla. In the present retrospective study, we aimed to compare maxillary sinus volumes among individuals with Class III skeletal patterns with different sagittal positions of the maxilla, and Class I patients with normally positioned jaws using CBCT. The null hypothesis was that there would be no difference in maxillary sinus volume between the Class III and Class I skeletal patterns.

METHODS

The Clinical Research Ethics Committee of Aydın Adnan Menderes University Faculty of Dentistry (approval no: ADÜDHF2021/22, date: 07.07.2021) approved this retrospective study protocol. The design of the study was retrospective, and no additional radiation was given to the patients for this research. CBCT scans were performed and examined for accurate diagnosis of dental problems. An informed consent form was signed by all patients or their parents.

The G-power 3.1.9.4 (Heinric-Heine-Universität Düsseldorf, Germany) program was utilized to calculate the sample size for this study. The study of Aktuna Belgin et al.[4], which bears similarity to our study, was used as a reference for calculating the sample size. From the study data, the effect size was determined to be 0.656. Based on this effect size value, the required sample size was calculated to be 124 participants with 62 participants in each group, considering a power analysis with a double-tailed test. For the analysis, a type I error rate of 0.05 and a study power of 0.95 were assumed.

For this research, CBCT images were analyzed from the archive of Aydın Adnan Menderes University, Faculty of Dentistry, Department of Oral and Maxillofacial Radiology taken between 2015 and 2020. Scans that met our inclusion criteria were selected from among these datasets. Patients with maxillary sinus pathology, a history of sinus operation, previous orthodontic treatment, or orthognathic surgery were excluded from the study. Only artifact-free CBCT images showing bilateral maxillary sinuses and sinuses without mucosal thickening, hypoplasia, and individuals with complete dentate were included in the study. All CBCT images were obtained using a single 360º rotation with a ProMax 3D scanner (Planmeca, Helsinki, Finland). The imaging settings were 8 mA and 90 kV, with an exposure time of 13.5 s. The field of view options were 8×8, 16×10, and 20×10 cm. The images were examined with slice thickness of 0.2 mm.

The anteroposterior skeletal type was determined by ANB measurements, classifying individuals as Class I (0<ANB<4) and Class III (ANB<0). The mandibular and maxillary positions to the cranial base were determined using the SNB and SNA angles, respectively, with reference ranges of 84>SNA>80 and 82>SNB>78.[15-17] As a result, the subjects were divided into three groups: Class I patients with normal mandibular and maxillary positions relative to the anterior cranial base and each other, Class III patients with retrognathic maxillary and normal mandibular positions relative to the anterior cranial base, and Class III patients with normal maxillary and prognathic mandibular position relative to the anterior cranial base. The

Dolphin 3D Imaging program (V.11, Chatsworth, Calif,USA) was used to obtain lateral cephalograms from CBCT images and measure three angular parameters (SNA, SNB and ANB). All data were collected and lateral cephalometric measurements were performed by a single experienced operator (Y.A.Ü.).

A total of 168 patients aged between 18 and 50 (94 female, 74 male) with Class I and III sagittal skeletal patterns were included in this research. The volumes and surface areas of three groups were compared: 58 patients with Class I normal mandibular and maxillary position (0<ANB<4, 84>SNA>80, 82>SNB>78), patients with 61 Class III retrognathic maxillary and normal mandibular position (ANB<0, SNA<80, 82>SNB>78) and 49 patients with Class III normal maxillary and prognathic mandibular position (ANB<0, 84>SNA>80, SNB>82).

Sinus volume and area measurements were conducted using Simplant Pro software (version 13.0, Materialise, Leuven, Belgium) digital imaging program. Volume data was obtained in mm^3 and surface area data in mm^2. To calculate the volume and surface area of the maxillary sinuses from CBCT data, the air value threshold was utilized to determine the maxillary sinus contour and to reveal the volume value, and the drawing/erasure mask and segmentation wizard technique were used. Standardization was achieved by keeping the threshold values constant for all individuals. The left and right maxillary sinuses of each individual were determined by threshold and masking without loss in coronal, axial, and sagittal sections, and the volume and surface area values were recorded by three-dimensional shaping of the maxillary sinuses (Figure 1) Sinus volume and area measurements were performed by a single experienced radiologist (E.K.).

Statistical Analysis

To assess the method error of the measurements, 20% of the images were re-recorded and re-measured 1 month later. The intraclass correlation coefficient, kappa coefficient, and weighted kappa coefficient was used for observer reliability.

Descriptive statistics, including maximum, minimum, mean and standard deviation values for each group were calculated using SPSS for Windows (Statistical Package for Social Sciences, v.11.0, Chicago, Illinois, USA). Statistical significance was set at 0.05. A chi-square test was performed to control for the balanced distribution of gender among the groups. The Shapiro-Wilk test was used to determine the normal distribution of the data. Since the distribution of variables was normal, intergroup comparisons of age, skeletal patterns, and maxillary sinus measurements were performed using one-way ANOVA, and t-test was also used to examine the difference in gender.

RESULTS

The intraclass correlation coefficient results were between 0.928 and 0.941 for all variables assessed, indicating good observer reliability. The gender distribution of the groups is presented in Table 1. A chi-square test was used to ensure a balanced the distribution of sex among the groups. No differences were found between the groups because of the similar male-female composition.

A total of 168 patients, 94 females and 74 males, between the ages of 18 and 50 was included in the study. Descriptive demographic characteristics of the groups are given in Table 2. There was no statistically significant age difference between the groups, and the mean age was 33.00±11.42 for the Class I normal group, 37.77±12.10 for the Class III maxillary retrusion group, and 36.12±11.55 for the Class III mandibular protrusion group (p>0.05). As we used FMA, SNA, SNB, and ANB to form the groups, statistically significant differences in skeletal variables

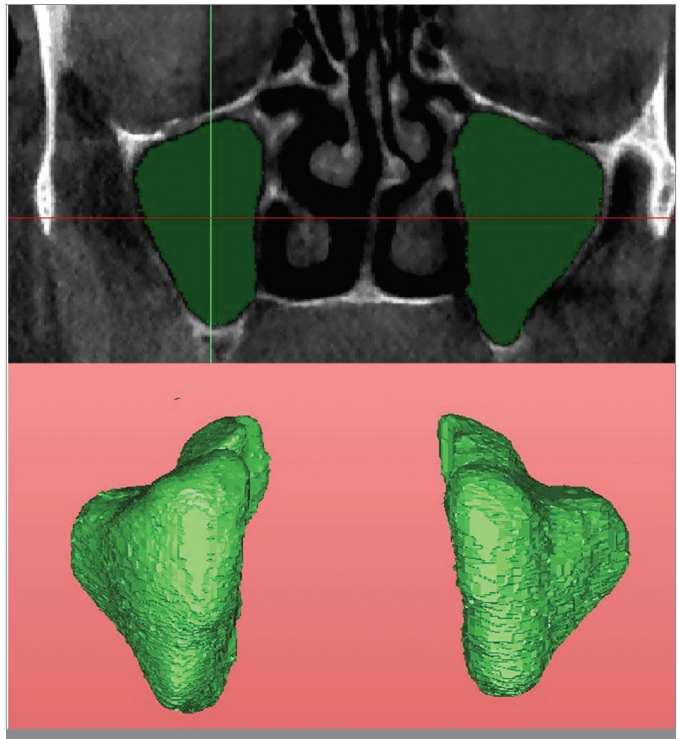

Figure 1. The three-dimensional shaping of the maxillary sinuses

Table 1. The gender distribution of the groups

	Class I normal		Class III maxillary retrusion		Class III mandibular protrusion		Total		p value
	n	%	n	%	n	%	n	%	
Female	31	32.97	34	36.17	29	30.85	94	55.95	0.837
Male	27	36.48	27	36.48	20	27.02	74	44.04	
Total	58	34.52	61	36.30	49	29.16	168	100	

Table 2. Descriptive statistics showing the means, standard deviations, minimum and maximum values of the Class I and Class III groups and results of intergroup comparisons using one-way ANOVA

	Class I normal (n=58)			Class III maxillary retrusion (n=61)			Class III mandibular protrusion (n=49)			p value
	Mean ± SD	Min.	Max.	Mean ± SD	Min.	Max.	Mean ± SD	Min.	Max.	
Age (years)	33.00±11.42	18	50	37.77±12.10	18	50	36.12±11.55	18	50	0.083
SNA(°)	81.86±1.24[a]	80.00	84.00	75.07±1.16[b]	73.80	79.60	82.07±1.45[a]	80.00	84.00	0.000***
SNB(°)	79.14±1.05[a]	78.00	82.00	79.88±1.44[a]	78.50	82.00	84.88±1.36[b]	82.50	86.60	0.000***
ANB(°)	2.72±0.74[a]	1.50	3.90	-4.81±1.24[b]	-7.20	-0.40	-2.81±1.79[b]	-0.60	-6.40	0.000***
Right maxillary sinus volume (mm^3)	16423.03±7260.20	3657.00	43024.00	14830.54±5184.01	3657.00	29157.00	17301.54±6685.61	4616.00	35460.00	0.121
Right maxillary sinus surface area (mm^2)	4216.35±1183.32	1571.00	7849.00	3844.68±827.66	1571.00	5629.00	4256.42±1020.55	1620.00	6771.00	0.059
Left maxillary sinus volume (mm^3)	15892.27±7121.62	4076.00	39281.00	14500.27±5173.68	4076.00	26077.00	17182.38±6605.78	5634.00	35329.00	0.088
Left maxillary sinus surface area (mm^2)	4243.71±1516.78	1599.00	10898.00	3874.88±984.81	1599.00	6113.00	4268.09±1024.91	2110.00	6334.00	0.148

SD, Standard deviation; Min, Minimum; Max, Maximum; *p<0.05; **p<0.01; ***p<0.001; [a,b], Different lower cases in the same row represent statistically significant differences between groups

were expected between the groups.

The distributions of right and left maxillary sinus volume and surface area measurements, as well as comparisons between groups are shown in Table 2. There was no statistically significant difference between the Class I, Class III MR, and Class III MP groups (p>0.05). Therefore, the Class III subgroups were combined and compared with the Class I group. No statistically significant difference was found between the Class I and Class III groups (p>0.05, Table 3).

When evaluating the maxillary sinus volume and surface area according to gender, the right maxillary sinus volume and surface area of males were found to be statistically significantly higher than those of females (p=0.012 and p=0.024). Similarly, the left maxillary sinus volume and surface areas of males were also found to be significantly higher than those of females (p=0.000 and p=0.002) (Table 4).

DISCUSSION

The growth of maxillary sinuses decelerates after 12 years of age and persists until early adulthood.[1,18] The growth mechanism of maxillary sinuses is still not well understood. Proposed factors influencing the alteration of maxillary sinus volume include traction of facial structures, nasal airflow, muscle mass, and brain growth, which may affect cell adherence and migration.[1,19] Due to their morphology, maxillary sinuses are related to zygomatic bone, nasal floor, and maxillary dentition. The most common variations of maxillary sinuses are extensions to the zygomatic bone between the roots of posterior teeth and edentulous areas.[20,21] Therefore, maxillary sinus volume may be affected by neighboring structures. In this study, none of the patients had tooth loss, thickening of the maxillary sinus mucosa, or intraosseous pathology.

In the literature, volumetric changes of maxillary sinuses have been occasionally investigated in relation to factors such as nasal septal deviation, aging, dentition status, sinus pathology, sex, and race.[4,11,22,23] Park et al.[24] calculated the paranasal sinus volumes in an Asian population. While several studies have investigated the relationship between maxillary sinus volume and nasal septal deviation, no consensus has been reached.[1,25] Panou et al.[26] studied changes in maxillary sinus volume in Class III patients undergoing bimaxillary orthognathic surgery. Another orthodontic study involving children, examined how both maxillary sinus volumes increased with rapid maxillary expansion and facemask therapy.[13] In this study, the effect of different sagittal positions of the maxilla on maxillary sinus volume was investigated. Sipahi et al.[27] previously examined the effects of different skeletal malocclusions and nasal septal deviations on maxillary sinus volume, and found no significant difference was found between the groups. Similarly, in the present study, no significant difference in maxillary sinus volume was observed between different sagittal positions of the maxilla.

Table 3. Comparisons of the Class I and Class III groups in terms of maxillary sinus volume and surface area

	Class I (n=58)			Class III (n=110)			p value
	Min.	Max.	Mean ± SD	Min.	Max.	Mean ± SD	
Right maxillary sinus volume (mm^3)	3657	43024	16423.03±7260.20	3657	35460	15931,26±5999.86	0.640
Right maxillary sinus surface area (mm^2)	1571	7849	4216.35±1183.32	1571	6771	4028.09±937.01	0.261
Left maxillary sinus volume (mm^3)	4076	39281	15892.27±7121.62	4076	35329	15695.03±5978.58	0.849
Left maxillary sinus surface area (mm^2)	1599	10898	4243.71±1516.78	1599	6334	4050.04±1017.35	0.326

SD, Standard deviation; Min, Minimum; Max, Maximum

Table 4. Maxillary sinus volume and surface area assessment according to gender

	Female			Male			p value
	Min.	Max.	Mean ± SD	Min.	Max.	Mean ± SD	
Right maxillary sinus volume (mm^3)	3657	29157	14518.53±4820.26	4616	43024	18111.25±7623.16	0.012*
Right maxillary sinus surface area (mm^2)	1571	5629	3877.10±841.34	1620	7849	4367.44±1176.68	0.024*
Left maxillary sinus volume (mm^3)	4076	26077	14131.50±4444.58	5634	39281	17835.74±7748.87	0.000***
Left maxillary sinus surface area (mm^2)	1599	5707	3758.74±870.70	2110	10898	4571.85±1421.43	0.002**

SD, Standard deviation; Min, Minimum; Max, Maximum; *p<0.05; **p<0.01; ***p<0.001

Also, in the present study, the presence of nasal septal deviation and its effect on maxillary sinus volume were not investigated.

In studies examining maxillary sinus volume, males generally tend to have a greater volume than females. Right and left maxillary sinus volumes were calculated differently in some published studies. Although Demir et al.[28] reported no significant difference between the left and right maxillary sinus volume, whereas Prabhat et al.[29] found that the right maxillary sinus volume was greater than the left one. Additionally, Takahashi et al.[30] found a negative correlation between age and maxillary sinus volume. Furthermore, Jun et al.[14] reported variations in maxillary sinus growth across different age groups. In the present study, similar age groups were selected for both genders and maxillary sinus volumes were examined in patients with different maxillary development and without any tooth loss. As seen in previous studies, males had a greater sinus-volume surface area compared to females, although this difference was not statistically significant in the present study. Moreover, it was observed that the right maxillary sinus volume tended to be greater than the left maxillary sinus volume in all groups. Varying results might arise due to factors such as the selected region, sample size, and age groups in different studies.

Maxillary sinus measurements have been performed using various imaging methods, including panoramic radiographs, lateral cephalograms, CBCT, CT, and MR imaging.[31,32] Linear measurements are commonly carried out on lateral cephalograms and panoramic radiographs.[8] However, accurate measurements can be hindered due to different magnifications in each region. For volumetric measurements, three-dimensional imaging methods are more appropriate. Among these, CBCT offers many advantages over CT such as lower radiation dose, cost-effectiveness, precise measurements and improved accessibility.[33] In this study, patients were not exposed to additional radiation doses, and additional software was utilized to calculate maxillary sinus volumes.

CONCLUSION

Maxillary sinus volume can be influenced by various factors. Volumetric studies of maxillary sinuses offer a new perspective in orthodontic practice. A comprehensive analysis of maxillary sinuses can be crucial in orthognathic surgery treatment planning. Future studies can be conducted by considering the dental and skeletal characteristics of the individuals and the condition of the paranasal structures. Different sagittal positions of the maxilla and Class III skeletal patterns do not affect maxillary sinus volume. Additionally, it was observed that males have a greater maxillary sinus volume compared to females. Utilizing CBCT images with additional software can be used to calculate the volumes and areas of sinuses accurately.

Ethics

Ethics Committee Approval: The Clinical Research Ethics Committee of Aydın Adnan Menderes University Faculty of Dentistry (approval no: ADÜDHF2021/22, date: 07.07.2021) approved this retrospective study protocol.

Informed Consent: An informed consent form was signed by all patients or their parents.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - Y.A.Ü., E.K.; Design - Y.A.Ü., E.K.; Supervision - E.K.; Data Collection and/or Processing - Y.A.Ü., E.K.; Analysis and/or Interpretation - Y.A.Ü., E.K.; Writing - Y.A.Ü.; Critical Review - E.K.

Declaration of Interests: The authors have no conflicts of interest to declare.

Funding: The authors declared that this study has received no financial support.

REFERENCES

1. Lee S, Fernandez J, Mirjalili SA, Kirkpatrick J. Pediatric paranasal sinuses-Development, growth, pathology, & functional endoscopic sinus surgery. *Clin Anat.* 2022;35(6):745-761. [CrossRef]
2. Değermenci M, Ertekin T, Ülger H, Acer N, Coşkun A. The Age-Related Development of Maxillary Sinus in Children. *J Craniofac Surg.* 2016;27(1):e38-e44. [CrossRef]
3. Panje WR, Ceilley RI. The influence of embryology of the mid-face on the spread of epithelial malignancies. *Laryngoscope.* 1979;89(12):1914-1920. [CrossRef]
4. Aktuna Belgin C, Colak M, Adiguzel O, Akkus Z, Orhan K. Three-dimensional evaluation of maxillary sinus volume in different age and sex groups using CBCT. *Eur Arch Otorhinolaryngol.* 2019;276(5):1493-1499. [CrossRef]
5. Emre K, Sessiz R. The effect of nasal septum deviation on maxillary sinus volume and gender determination. *Selcuk Dent J.* 2019;6(4):184-188. [CrossRef]
6. Favato MN, Vidigal BC, Cosso MG, Manzi FR, Shibli JA, Zenóbio EG. Impact of human maxillary sinus volume on grafts dimensional changes used in maxillary sinus augmentation: a multislice tomographic study. *Clin Oral Implants Res.* 2015 Dec;26(12):1450-1455. [CrossRef]
7. Uthman AT, Al-Rawi NH, Al-Naaimi AS, Al-Timimi JF. Evaluation of maxillary sinus dimensions in gender determination using helical CT scanning. *J Forensic Sci.* 2011;56(2):403-408. [CrossRef]
8. Endo T, Abe R, Kuroki H, Kojima K, Oka K, Shimooka S. Cephalometric evaluation of maxillary sinus sizes in different malocclusion classes. *Odontology.* 2010;98(1):65-72. [CrossRef]
9. Oktay H. The study of the maxillary sinus areas in different orthodontic malocclusions. *Am J Orthod Dentofacial Orthop.* 1992;102(2):143-145. [CrossRef]
10. Kilic C, Kamburoglu K, Yuksel SP, Ozen T. An Assessment of the Relationship between the Maxillary Sinus Floor and the Maxillary Posterior Teeth Root Tips Using Dental Cone-beam Computerized Tomography. *Eur J Dent.* 2010;4(4):462-467. [CrossRef]
11. Möhlhenrich SC, Heussen N, Peters F, Steiner T, Hölzle F, Modabber A. Is the Maxillary Sinus Really Suitable in Sex Determination? A Three-Dimensional Analysis of Maxillary Sinus Volume and Surface Depending on Sex and Dentition. *J Craniofac Surg.* 2015;26(8):e723-e726. [CrossRef]
12. Szabo BT, Aksoy S, Repassy G, Csomo K, Dobo-Nagy C, Orhan K. Comparison of hand and semiautomatic tracing methods for creating maxillofacial artificial organs using sequences of computed tomography (CT) and cone beam computed tomography (CBCT) images. *Int J Artif Organs.* 2017;40(6):307-312. [CrossRef]
13. Pamporakis P, Nevzatoğlu Ş, Küçükkeleş N. Three-dimensional alterations in pharyngeal airway and maxillary sinus volumes in Class III maxillary deficiency subjects undergoing orthopedic facemask treatment. *Angle Orthod.* 2014;84(4):701-707. [CrossRef]
14. Jun BC, Song SW, Park CS, Lee DH, Cho KJ, Cho JH. The analysis of maxillary sinus aeration according to aging process; volume assessment by 3-dimensional reconstruction by high-resolutional CT scanning. *Otolaryngol Head Neck Surg.* 2005;132(3):429-434. [CrossRef]
15. Wu BW, Kaban LB, Peacock ZS. Correlation of Cephalometric Analyses With Clinical Impression in Orthognathic Surgery Patients: Harvold and Steiner Analyses. *J Oral Maxillofac Surg.* 2019;77(11):2308-2317. [CrossRef]
16. Camcı H, Salmanpour F. Cephalometric Evaluation of Anterior Cranial Base Slope in Patients with Skeletal Class I Malocclusion with Low or High SNA and SNB Angles. *Turk J Orthod.* 2020;33(3):171-176. [CrossRef]
17. Küchler EC, Reis CLB, Carelli J, et al. Potential interactions among single nucleotide polymorphisms in bone- and cartilage-related genes in skeletal malocclusions. *Orthod Craniofac Res.* 2021;24(2):277-287. [CrossRef]
18. Lawson W, Patel ZM, Lin FY. The development and pathologic processes that influence maxillary sinus pneumatization. *Anat Rec (Hoboken).* 2008;291(11):1554-1563. [CrossRef]
19. Kossowska E, Gasik C. Results of surgical treatment of choanal atresia. *Rhinology.* 1979;17(3):155-160. [CrossRef]
20. Fatu C, Puisoru M, Rotaru M, Truta AM. Morphometric evaluation of the frontal sinus in relation to age. *Ann Anat.* 2006;188(3):275-280. [CrossRef]
21. Marquez S, Lawson W, Schaefer S, Laitman J. Anatomy of the nasal accessory sinuses. Minimally invasive surgery of the head, neck, and cranial base Philadelphia: Lippincott Williams & Wilkins; 2002:153-193. [CrossRef]
22. Cho SH, Kim TH, Kim KR, et al. Factors for maxillary sinus volume and craniofacial anatomical features in adults with chronic rhinosinusitis. *Arch Otolaryngol Head Neck Surg.* 2010;136(6):610-615. [CrossRef]
23. Köse E, Canger EM, Bulut DG. Cone Beam Computed Tomographic Analysis of Paranasal Variations, Osteomeatal Complex Disease, Odontogenic Lesion and Their Effect on Maxillary Sinus. *Meandros Medical and Dental Journal.* 2018;19(4):310-316. [CrossRef]
24. Park IH, Song JS, Choi H, et al. Volumetric study in the development of paranasal sinuses by CT imaging in Asian: a pilot study. *Int J Pediatr Otorhinolaryngol.* 2010;74(12):1347-1350. [CrossRef]
25. Aydin S, Taskin U, Orhan I, et al. The analysis of the maxillary sinus volumes and the nasal septal deviation in patients with antrochoanal polyps. *Eur Arch* Otorhinolaryngol. 2015;272(11):3347-3352. [CrossRef]
26. Panou E, Motro M, Ateş M, Acar A, Erverdi N. Dimensional changes of maxillary sinuses and pharyngeal airway in Class III patients undergoing bimaxillary orthognathic surgery. *Angle Orthod.* 2013;83(5):824-831. [CrossRef]
27. Sipahi DB, Beycan K, Yalçınkaya ŞE. Three-Dimensional evaluation of the volume and septum morphology of maxillary sinus in ındividuals with skeletal Angle Class I, II And III. *Selcuk Dent J.* 2018;6(4):216-221. [CrossRef]
28. Demir UL, Akca ME, Ozpar R, Albayrak C, Hakyemez B. Anatomical correlation between existence of concha bullosa and maxillary sinus volume. *Surg Radiol Anat.* 2015;37(9):1093-1098. [CrossRef]
29. Prabhat M, Rai S, Kaur M, Prabhat K, Bhatnagar P, Panjwani S. Computed tomography based forensic gender determination by measuring the size and volume of the maxillary sinuses. *J Forensic Dent Sci.* 2016;8(1):40-46. [CrossRef]
30. Takahashi Y, Watanabe T, Iimura A, Takahashi O. A Study of the Maxillary Sinus Volume in Elderly Persons Using Japanese Cadavers. *Okajimas Folia Anat Jpn.* 2016;93(1):21-27. [CrossRef]
31. Daraze A, Hoteit M, Youness H. Maxillary sinus size in different gender and sagittal skeletal classes: orthodontics and forensic interests. *Internations Journal of Oral and Dental Sciences.* 2016;2(1):27-34. [CrossRef]
32. Saccucci M, Cipriani F, Carderi S, et al. Gender assessment through three-dimensional analysis of maxillary sinuses by means of cone beam computed tomography. *Eur Rev Med Pharmacol Sci.* 2015;19(2):185-193. [CrossRef]
33. Van Dessel J, Nicolielo LF, Huang Y, et al. Accuracy and reliability of different cone beam computed tomography (CBCT) devices for structural analysis of alveolar bone in comparison with multislice CT and micro-CT. *Eur J Oral Implantol.* 2017;10(1):95-105. [CrossRef]

TURKISH JOURNAL of ORTHODONTICS

DOI: 10.4274/TurkJOrthod.2022.2022.65

Original Article

Relationship of the Fusion Stage of Spheno-Occipital Synchondrosis with Midpalatal and Zygomaticomaxillary Sutures on Cone-Beam Computed Tomography Scans of Patients Aged Between 7 and 21 Years

Niloufar Tashayyodi[1], Zahra Dalili Kajan[2], Farzane Ostovarrad[2], Negar Khosravifard[2]

[1]Department of Maxillofacial Radiology, School of Dentistry, Guilan University of Medical Sciences, Rasht, Iran
[2]Dental Sciences Research Center, Department of Maxillofacial Radiology, School of Dentistry, Guilan University of Medical Sciences, Rasht, Iran

Cite this article as: Tashayyodi N, Dalili Kajan Z, Ostovarrad F, Khosravifard N. Relationship of the Fusion Stage of Spheno-Occipital Synchondrosis with Midpalatal and Zygomaticomaxillary Sutures on Cone-Beam Computed Tomography Scans of Patients Aged Between 7 and 21 Years. *Turk J Orthod.* 2023; 36(3): 186-193 .

Main Points
- The grades I-III of SOS predicts the higher percentage of MPS opening and the higher chance of opening of ZMS.
- With each one year increase in age, MPS opening percentage decreased by 1.07% in the anterior half and by 1.30% in the posterior half.
- There was a correlation between the fusion of SOS (cranial compartment) and ZMS (facial suture) in all age groups.

ABSTRACT

Objective: This study assessed the relationship of the fusion stage of spheno-occipital synchondrosis (SOS) with midpalatal (MPS) and zygomaticomaxillary (ZMS) sutures on cone-beam computed tomography (CBCT) scans of 7 to 21-year-old patients.

Methods: This cross-sectional study evaluated the CBCT scans of 176 patients between 7 and 21 years presenting to a maxillofacial radiology clinic. The fusion stage of SOS was determined using a five-stage classification system. The percentage of opening depth of MPS was measured on two middle coronal cuts in the anterior and posterior half of the palate. To assess ZMS, suture fusion was evaluated in four age groups in the axial cut visualizing its maximum length. Data were analyzed using the Kruskal-Wallis, Mann-Whitney U, and Bonferroni tests and regression models.

Results: The percentage of MPS opening significantly decreased in both the anterior and posterior halves with age ($p<0.002$). With an increase in SOS grade, the percentage of MPS opening in both the anterior and posterior halves significantly decreased ($p<0.001$). By an increase in the ZMS stage, the SOS grade significantly increased ($r=0.565$, $p<0.001$).

Conclusion: The MPS opening percentage in the anterior and posterior halves decreased with age, with a greater reduction in the posterior half. A significant inverse correlation exists between the SOS fusion stage and the percentage of MPS opening. In SOS grades I-III, the mean percentage of MPS opening was 100% in all age groups (with the highest frequency of ZMS stage I), indicating a higher chance of success for orthodontic treatments such as rapid maxillary expansion in these individuals.

Keywords: Sphenoid bone, occipital bone, cranial sutures, cone-beam computed tomography, orthodontics

INTRODUCTION

Synchondrosis refers to a cartilaginous joint between two bones. Spheno-occipital synchondrosis (SOS) is a longitudinal suture extending from the clivus to the pharyngeal surface of the cranial base, fusing the sphenoid and occipital bones.[1] Due to the effect of SOS on the elongation of the cranial base and the provision of space for dentoalveolar growth and development, SOS is an important area in growth and development of the craniofacial

Corresponding author: Zahra Dalili Kajan, e-mail: zahradalili@yahoo.com

Received: April 20, 2022
Accepted: December 22, 2022
Epub: September 28, 2023
Publication Date: September 29, 2023

skeleton.[2,3] The development of SOS shifts the maxilla anteriorly and inferiorly, resulting in an increase in facial height and depth.[4-7] Cranial base growth's effect on the maxillomandibular complex makes it an interesting topic of research for orthodontists.[8] In patients with craniofacial syndrome, the initiation of ossification of SOS causes severe midface hypoplasia.[5] Some researchers believe that the cranial base serves as a guide for the development of the maxilla, midface, and inferior facial complex. Spheno-occipital synchondrosis is of particular interest among synchondroses because it can be observed on lateral skull radiographs taken during the adolescence period.[9] On the other hand, intersphenoid synchondrosis is ossified immediately after birth, whereas ethmoid synchondrosis is ossified at 7 years of age.[10] Due to the ossification of SOS at a relatively later stage in life compared with synchondroses of the skull base, SOS is commonly used for age estimation in forensic medicine.[11,12]

Age estimation is particularly important in orthodontics to determine the pubertal status of patients. Recently, SOS has attracted the attention of researchers as a beneficial index for age estimation alone or in combination with other skeletal age indices, especially for legal and forensic purposes.[8,13-17] It appears that the SOS fusion stages can serve as an efficient index for the assessment of development and puberty because the time of SOS fusion and cervical vertebral maturation stages are closely correlated. Thus, assessment of SOS fusion may help in orthodontic treatment planning and decision-making regarding surgical or nonsurgical treatment plans.[3,13] Clinically, orthodontic treatments such as rapid maxillary expansion (RME) affect the zygomaticomaxillary (ZMS) and frontomaxillary sutures as well as SOS. Thus, the level of the maturation and fusion of the sutures adjacent to the midpalatal suture (MPS) can affect the success rate of maxillary expansion.[18] A previous study on early treatment of Class III patients with RME and maxillary protraction indicated that a combination of these modalities increased the SOS width by 0.5 to 1 mm and yielded more favorable results. Therefore, it may be concluded that combined application of RME and maxillary protraction would have a higher success rate if performed before the complete fusion of the SOS.

Orthodontists can guide/modify facial growth and development to further benefit their patients. However, comprehensive knowledge about the normal growth pattern and the underlying mechanisms is required.[19] Precise knowledge about the fusion pattern of MPS and SOS at different ages can greatly help orthodontists and oral and maxillofacial surgeons in treatment planning and decision-making. Maxillary expansion procedures affect not only the MPS but also other sutures. Thus, the expansion status highly depends on the maturity status of other sutures such as the SOS. Also, SOS may serve as a suitable index for the estimation of skeletal age.[2] This study aimed to assess the relationship of the fusion stage of SOS with MPS and ZMS on cone-beam computed tomography (CBCT) scans of patients aged between 7 and 21 years.

METHODS

This cross-sectional study was conducted on 176 CBCT scans of patients aged between 7 and 21 years referred to an oral and maxillofacial radiology clinic in Rasht, Iran between 2019 and 2021. The study protocol was approved by the Ethics Committee of Gulian University of Medical Sciences (IR.GUMS.REC.1400.413). The minimum sample size was calculated as 50 in each group assuming four age groups with a mean midpalatal suture (MPS) score of 93.36 in the age group <10 years, 79.86 in those 10-15 years, 65.56 in those 15-20 years, and 53.83 in those between 20 and 25 years, study power of 0.95, error rate of 0.05, and standard deviation of 50.20 according to a previous study[20] using PASS 11. During this period (2019-2021), the number of eligible and available cases in the age range of 7 to 10 years was 26.

CBCT scans taken for purposes not related to this study, such as assessment of paranasal sinuses or the midface that visualized the maxilla, base of skull, and spheno-occipital region, were selected for this study. Images with motion artifacts, CBCT scans of patients with a mass or fracture at the aforementioned sites, and CBCT scans of patients with systemic diseases or syndromic conditions with significant effects on bone density or cortex of maxillofacial bones were excluded. After the selection of eligible CBCT scans of patients by convenience sampling, they were divided into four groups based on the age range of the patients as follows:

Group I: 7-10-years-old (n=26), Group II: 11-14-years-old (n=50), Group III: 15 to 17-years-old (n=50), and Group IV: 18 to 21-years-old (n=50).

All CBCT scans were obtained in full mode by a NewTom (SRL, Verona, Italy) CBCT scanner with patients in the standing position. The exposure settings were automatically adjusted by the scanner and software. Two oral and maxillofacial radiologists with over 10 years of clinical experience independently assessed the ossification pattern of SOS on reconstructed sagittal images with 1 mm slice thickness and 2 mm slice interval at the midline. The SOS and clivus area were clearly visible on the reconstructed sagittal images. In the case of disagreement between the two observers, the images were evaluated by an independent third radiologist. Also, 20 CBCT images were randomly selected and re-evaluated by the examiners after a 2-week interval to assess intraobserver reliability.

The fusion stages of SOS were classified using a 5-point classification scale introduced by Bassed et al.[13] (Figure 1A-E):

Stage I: The joint is completely open.

Stage II: The superior part of the joint is fused.

Stage III: Half of the joint length is fused.

Stage IV: The joint is completely fused and a scar line is evident.

Stage V: The joint is completely fused and there is no scarring.

To assess the MPS, axial images with a 1 mm slice thickness that visualized the MPS path properly were selected. A reconstruction line was drawn posterior to the nasopalatine foramen extending to the transverse palatine suture. Based on the predetermined area by reconstruction line in software, coronal images were reconstructed with 1 mm slice thickness and 2 mm slice interval with 100 mm image width. Next, the cuts were divided into two groups (anterior and posterior half), and the two middle cuts in each group were selected. In each cut, if the MPS depth was entirely open, the percentage of opening was reported as 100%, and if part of it was open, the entire suture height and the depth of the opening were measured to 0.1 mm accuracy, and then the value was reported as the percentage of opening in the respective cut by dividing the depth of suture opening to the entire suture height. Subsequently, the mean percentage of suture opening was calculated for each of the anterior and posterior halves based on the mean values of the two middle cuts (Figure 2).

The opening percentage of the MPS depth in all cuts was calculated using the following formula:

$$\frac{\textit{MPS opening depth}}{\textit{Visible entire MPS depth (from the palate to the base of nasal cavity)}}$$

To assess the ZMS, axial images with 1 mm slice thickness were evaluated. Among the axial cuts, the cut with the greatest length of the ZMS was evaluated and assigned to one of the following four groups (Figure 3A-D):

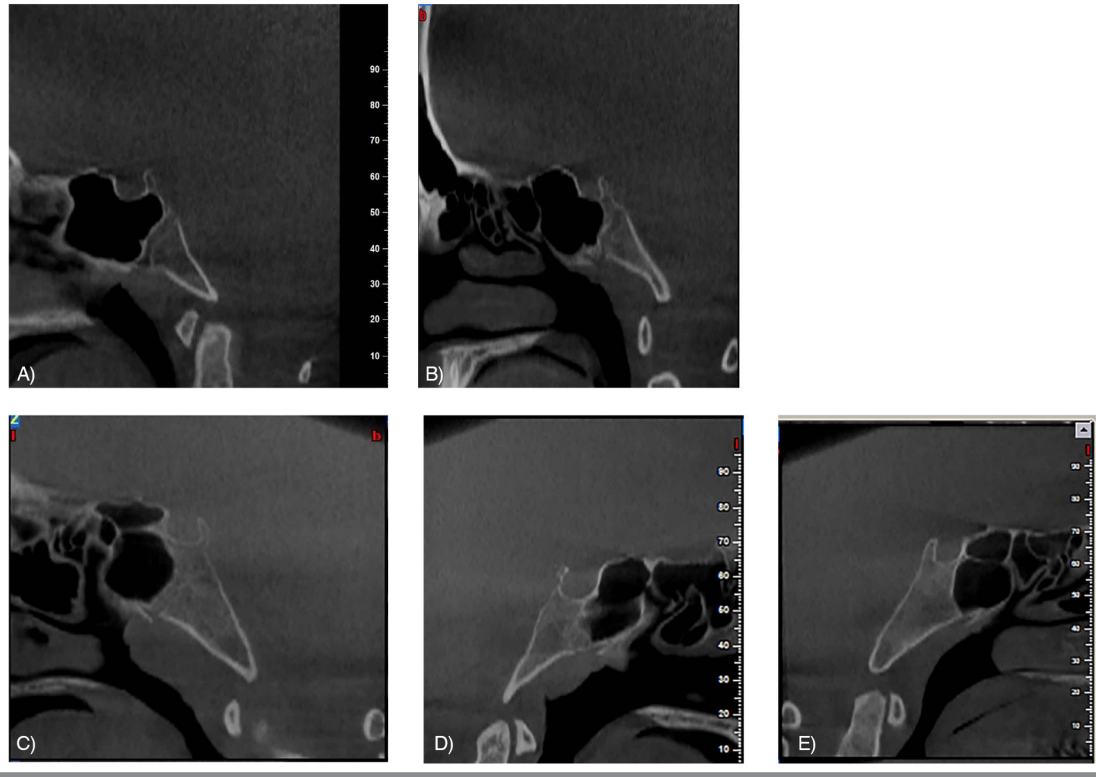

Figure 1. Fusion stages of SOS: A) Stage 1 (the joint is completely open); B) Stage 2 (superior part of the joint is fused); C) Stage III (half of the joint length is fused); D) Stage IV (the joint is completely fused and a scar line is evident), E) Stage V (the joint is completely fused and there is no scarring)

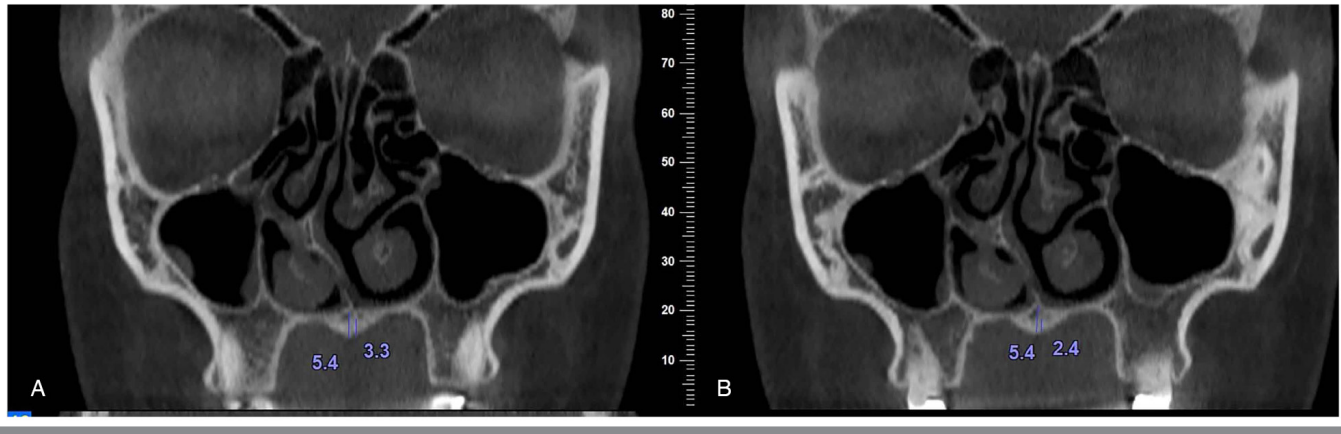

Figure 2. The measurement of the total height of MPS and opening portion in the coronal images of anterior MPS

I) The suture is completely open.

II) Over half of the suture length is open.

III) Less than half of the suture length is open.

IV) The suture is completely fused.

The percentage of the opening of MPS and the fusion stage of ZMS were determined by a postgraduate student (N.T.) of oral and maxillofacial radiology under the supervision of an oral and maxillofacial radiologist (Z.D.K.) irrespective of the observers (F.O. and N.K.H.) who evaluated the SOS.

Statistical Analysis

The normal distribution of data was evaluated using the Shapiro-Wilk test. The homogeneity of variances was analyzed using Levene's test. Accordingly, the Spearman correlation test, linear and ordinal regression models, Kruskal-Wallis test, Mann-Whitney U test, and Bonferroni adjustment were applied for statistical analysis of the data using SPSS version 26. The significance was set at ≤0.05.

RESULTS

CBCT scans of 81 males (46%) and 95 females (54%) were evaluated. Of all, 26 (14.8%) were between 7and10 years. Other age groups included 50 patients (28.4%) each. The mean age of all participants was 14.93±4.16 years. The intraobserver agreement for the evaluation of SOS was calculated as 92%.

Table 1 presents the mean percentage of MPS opening in the anterior and posterior halves in different age groups. The Kruskal-Wallis test showed that the mean percentage of MPS opening in the anterior and posterior halves significantly differed among the three age groups (p=0.005 and p=0.004, respectively). The mean percentage of MPS opening decreased in the anterior and posterior halves with age; the percentage of opening in the posterior half was lower than that in the anterior halves in all age groups. Pairwise comparisons of the age groups regarding the anterior half of MPS showed no significant difference in the percentage of opening between 11 and 14 and 15-17-years-old (p>0.999). However, the difference between 18 and 21 and 11-14-years-old (p=0.006) and 18-21 and 15-17-years-old (p=0.040) was statistically significant. Pairwise comparisons of the age groups regarding the percentage of opening of MPS in the posterior half showed a significant difference only between 18-21-year-olds and 11-14-year-olds (p=0.003). Other differences were not found significant (p>0.05).

Table 2 presents the frequency of different grades of SOS fusion in each age group. A significant difference was noted in frequency of all grades, except for grade III, among different age groups such that higher grades had a higher frequency in older age groups (p<0.05).

Table 3 presents the frequency of ZMS grades in different age groups. The frequency of ZMS grades I and III significantly differed in different age groups (p<0.05).

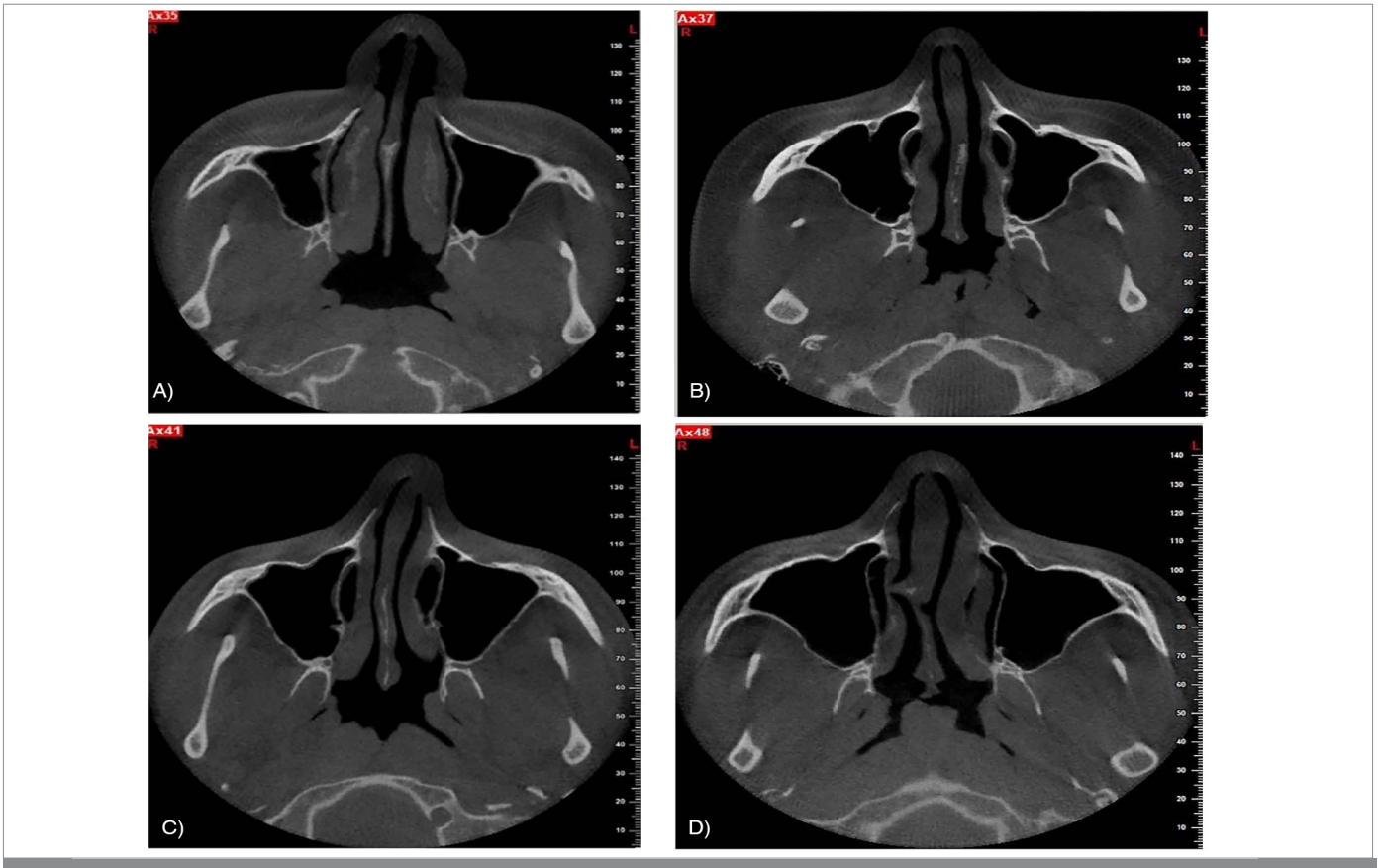

Figure 3. Fusion stages of ZMS: A) Stage 1 (suture is completely open); B) Stage II (over half of the suture length is open); C) Stage III (less than half of the suture length is open); D) Stage IV (suture is completely fused)

Table 1. Mean percentage of MPS opening in the anterior and posterior halves in different age groups

	Percentage of MPS** opening			p value*
Age groups	11-14	15-17	18-21	
	(n=50)	(n=50)	(n=50)	
Anterior half	98±9.90	96.08±13.60	87.88±22.29	0.005
Posterior half	95.42±16.66	91.12±20.88	74.34±22.37	0.004

*Kruskal-Wallis test; p≤0.05, **MPS: Mid Palatal suture.

Table 2. Frequency of different SOS fusion grades in each age group

SOS**	Age groups				p value*
	7-10	11-14	15-17	18-21	
	n (%)	n (%)	n (%)	n (%)	
1	26 (60)	14 (35)	2 (5)	0 (0)	<0.001
2	15 (5.6)	16 (88.9)	1 (5.6)	0 (0)	<0.001
3	0 (0)	7 (53.8)	5 (38.5)	1 (7.7)	0.116
4	0 (0)	5 (13.9)	18 (50)	13 (36.1)	0.028
5	1 (1.5)	6 (9.1)	23 (34.8)	36 (54.5)	<0.001

*Chi-square test; p≤0.05, **SOS: Spheno-Occipital Synchondrosis

Table 3. Frequency of ZMS grades in different age groups

ZMS** grade	Age group				p value*
	7-10	11-14	15-17	18-21	
	n (%)	n (%)	n (%)	n (%)	
1	26 (27.1)	39 (40.6)	21 (21.9)	10 (10.4)	<0.001
2	0 (0)	9 (20.5)	18 (40.9)	17 (38.6)	0.190
3	0 (0)	1 (3.4)	11 (37.9)	17 (58.6)	0.001
4	0 (0)	0 (0)	0 (0)	5 (100)	-

*Chi-square test; p≤0.05, **ZMS: Zygomaticomaxillary Suture

Table 4 presents the mean percentage of MPS openings in the anterior and posterior halves based on the SOS grade. As indicated, the mean percentage of MPS opening in the anterior and posterior halves was the same in SOS grades I, II, and III. In SOS grades IV and V, however, the mean percentage of MPS opening in the posterior half was lower than that in the anterior half.

Table 5 compares the frequency of SOS grade based on ZMS grade. As shown, only in SOS grade III the difference in the frequency of different ZMS grades was not significant (p=0.058).

The results also showed that, by an increase in SOS grade, the frequency of individuals with higher ZMS grades significantly increased (p<0.05).

SOS grade showed no significant correlation with the percentage of MPS opening in the anterior half in any age group (>0.05). Note that all 26 patients in the age group of 7-10 years had 100% MPS opening percentage in the anterior half. SOS grade had a significant inverse correlation with the MPS opening percentage in the posterior half in 11-14-year-olds (p=0.004), such that lower SOS grades showed a higher percentage of MPS opening in the posterior half (Table 6). In general, SOS grade had a significant inverse correlation with the MPS opening percentage in the posterior half, such that by an increase in SOS grade, the percentage of MPS opening decreased in the posterior half.

Table 4. Mean percentage of MPS opening in the anterior and posterior halves based on the SOS grade

SOS*	MPS**	
	Posterior half	Anterior half
	Mean ± SD	Mean ± SD
1	100±0	100±0
2	100±0	100±0
3	100±0	100±0
4	82.15±26.93	94.31±16.35
5	88.49±20.84	91±19.75

*SOS: Spheno-occipital Synchondrosis
** MPS: Mid Palatal Suture

Irrespective of age group, a significant inverse correlation was noted between SOS and MPS (r=-0.269, p<0.001 in the anterior half and r=-0.296, P<0.001 in the posterior half). Lower SOS grades showed a higher percentage of MPS opening (anterior and posterior halves).

Separate assessment of the correlation of SOS grade and MPS opening percentage (anterior and posterior halves) in males and

Table 5. Comparison of the frequency of SOS grade based on the ZMS grade

SOS** grade	ZMS*** grade				p value*
	1	2	3	4	
	n (%)	n (%)	n (%)	n (%)	
1	37 (94.9)	2 (5.1)	0 (0)	0 (0)	<0.001
2	17 (94.4)	1 (5.6)	0 (0)	0 (0)	<0.001
3	8 (61.5)	4 (30.8)	1 (7.7)	0 (0)	0.058
4	12 (34.3)	17 (48.6)	5 (14.3)	1 (2.9)	0.001
5	20 (30.3)	19 (28.8)	23 (34.8)	4 (6.1)	0.004

*Chi-square test; **SOS: Spheno-occipital Synchondrosis; ***ZMS: Zygomaticomaxillary Suture, p≤0.05

Table 6. Association of SOS grade with MPS fusion and ZMS grade

Associated of SOS* grade and			
Age groups	11-14	15-17	18-21
MPS** fusion in anterior half	r=-0.229	r=-0.255	r=0.074
	p=0.117	p=0.077	p=0.612
MPS fusion in posterior half	r=-0.408	r=-0.086	r=0.138
	p=0.004	p=0.558	p=0.338
ZMS*** fusion	r=0.300	r=0.251	r=0.149
	p=0.040	p=0.082	p=0.305

*SOS: Spheno-Occipital Synchondrosis; **MPS: Mid-Palatal Suture; ***ZMS: Zygomaticomaxillary Suture

females revealed a significant inverse correlation between these two variables in males (p=0.002 in the anterior half and p<0.001 in the posterior half), indicating a higher percentage of MPS opening in lower SOS grades in males.

Separate assessment of the correlation of SOS grade and ZMS fusion grade in different age groups revealed a direct significant correlation between the SOS grade and ZMS fusion grade only in 11-14-year-olds (p=0.040) such that by an increase in fusion grade of ZMS, the SOS grade also increased (Table 6). In general, ZMS had a direct significant correlation with SOS (r=0.565, p<0.001). A separate assessment of the correlation of SOS grade and ZMS fusion grade in males and females revealed that in both males and females, the correlation between the SOS and ZMS fusion grades was significant (p<0.001). In both males and females, by increasing the ZMS fusion grade, the SOS grade increased as well.

Assessment of the simultaneous effect of age and gender on MPS opening in the anterior and posterior halves revealed that age had a significant effect on MPS opening in the anterior and posterior halves; such that with each one-year increase in age, the MPS opening percentage decreased by 1.07% in the anterior half and by 1.30% in the posterior half. In both regression models, age was a more significant variable than gender with respect to changes in MPS opening percentage in the anterior and posterior halves. Age had a significant effect on both SOS and ZMS fusion grades. Each one-year increase in age increased the SOS grade (grade 1 to 2, 2 to 3, 3 to 4, and 4 to 5) by 0.56 and the ZMS grade (grade 1 to 2, 2 to 3, 3 to 4) by 0.47 units. At the same age, the SOS grade in males was an averagely -0.58 units lower than that in females. Also, at the same age, ZMS grade in males was averagely 0.46 units higher than that in females.

DISCUSSION

Preoperative assessment of the fusion of MPS and other craniofacial sutures involved in treatment is imperative for correct treatment planning and minimizing complications of expansion treatment. Thus, this study aimed to assess the relationship of the fusion pattern of SOS with MPS and ZMS on CBCT scans of 7 to 21-year-old patients.

Kajan et al.[18] assessed MPS maturation by CBCT to determine the percentage of MPS opening in different age groups before the transverse maxillary expansion. They observed that the percentage of MPS opening decreased with age, and the difference in this regard was significant among different age groups in the middle and posterior thirds; however, the difference was not significant in the anterior third. In the present study, the percentage of opening of MPS decreased with age, and this difference was significant among different age groups in both the anterior and posterior halves. In 7 to 10-year-olds, the MPS opening was 100%. It is worth noting that the definitions for the anterior and posterior halves in this study were different from those in the study by Kajan et al.[18] The definitions used in this study were set to enhance the clinical generalizability of the results.

There is a narrow bony bridge in the posterior part of the suture, which was ossified with age. Fast ossification and fusion of sutures occur in three decades of life. In the present study, the lowest percentage of MPS opening was recorded in both the anterior and posterior halves in the oldest age group in our study (18 to 21 years) and the lowest percentage of MPS opening was recorded in 20-25-year-olds (oldest age group) in the study by Kajan et al.[18]. In this study, the percentage of

MPS opening in the anterior and posterior halves was 100% in some patients between 18 and 21 years. This finding was in line with that of Kajan et al.[18] and Kwak et al.[21] Accordingly, Kwak et al.[21] discussed that age should not be considered as the only determining factor for surgically assisted RME because conventional RME may be performed in some adults. CBCT can greatly help in patients with a surgical treatment plan for maxillary expansion. An important finding of the present study was that after the age of 18 years, the percentage of MPS opening in the anterior half showed a significant difference with the value in younger individuals. This age threshold is important and should be considered in orthodontic treatment planning. In patients older than 14 years, the percentage of MPS opening in the posterior half was even lower than that in the anterior half in patients under 18 years of age. This finding indicates that fusion of the intermaxillary suture initiates sooner in the posterior half, and the V-shaped opening of MPS in the process of RME[22] agrees with the pattern of fusion of MPS observed in the present study.

On the other hand, due to the late fusion of SOS compared with other sutures and its role in increasing the facial height and depth, the grade of SOS fusion is an interesting topic of research.[11] Can et al.[1] assessed the chronological age based on SOS fusion by CT in 10 to 25-year-olds in a Turkish population. They used a classification similar to that used in this study and found a significant correlation between aging and the grade of SOS fusion. The maximum age for SOS fusion grade I was 13 years in females and 17 years in males, while the youngest age for grades IV and V was 15 years in females and 14 years in males. Dalili Kajan et al.[23] assessed SOS fusion in 9-22-year-olds by CT and found the maximum frequency of SOS fusion grade I in 9-11 and 13-year-olds, irrespective of gender. The maximum frequency of grade II was noted in 12 and 14-year-olds. The maximum frequency for grades III, IV and V was noted in 15, 16, and 17-22-year-old individuals. They also reported a significant correlation between age and SOS fusion grade in both males and females. In the present study, the maximum SOS fusion grade was grade I in 7-10-year-olds, grade II in 11-14, and grade 5 in 15-17, and 18-21-year-olds. In general, the increase in SOS grade with age had a stepwise pattern. Moreover, the number of individuals with a higher SOS grade increased in older age groups in the present study, and the difference in this respect was significant among different age groups for all grades except for grade III. Furthermore, the oldest age group with SOS grade I in the present study was 15-17-year-olds while the youngest age group with SOS grade V was 7-10-year-olds. This finding was different from the results of Can et al.[1] which may be because they assessed SOS in patients older than 10 years. Furthermore, factors such as sample size, population distribution, ethnicity, and socioeconomic status can affect SOS fusion. Different methodologies may also be responsible for variations in the results.

Loose sutures around the zygoma allow the maxilla to adequately respond to protrusive orthodontic forces in protraction with a face mask in developing patients.[24] Surgically assisted RME is used for maxillary expansion in adults, which is invasive and costly and is associated with postoperative complications;[25] however, application of orthodontic forces causes stress in the sutures surrounding the maxilla.[26] Growth modification of the maxilla depends on the degree of maturation of circummaxillary sutures and SOS.[26] ZMS is the longest and thickest circummaxillary suture that has the greatest resistance to orthopedic forces following RME and maxillary protrusion.[27] Significant opening of SOS in response to the MPS expansion has also been reported[4,28] suggesting its remodeling during RME. An interesting finding of the present study was the significant inverse correlation of SOS grade and MPS opening irrespective of age, and the direct correlation of SOS fusion and ZMS fusion, indicating a more appropriate response to RME in younger age groups; this correlation was significant in males. In the current study, the maximum frequency of SOS grades I-III in 7-10 and 11-14-year-olds indicated that application of orthopedic forces would be effective in these age groups, and those between 15 and 17 years are categorized as borderline group. The findings regarding ZMS and SOS fusion grades in 18-21-year-olds indicated a lower chance of obtaining a favorable response to orthopedic forces following RME in this age group, and this group is a better candidate for surgically assisted RME/LeFort osteotomy or miniscrew-assisted rapid palatal expansion.

Higher SOS grades were significantly correlated with a lower percentage of MPS openings in this study. Also, ZMS and SOS fusion were significantly correlated. Ok et al.[29] evaluated the correlation of SOS, MPS, and ZMS in 7 to 30-year-olds in Turkey. They used a qualitative index for MPS in the horizontal dimension, which has poor clinical application and does not indicate the precise depth of opening (to predict the degree of possible opening with RME). They reported that higher SOS grades were significantly correlated with the higher frequency of ZMS and MPS grades.

In the present study, age emerged as a more influential parameter than gender in ZMS, SOS, and MPS fusion status and had a significant correlation with them. For each one-year increase in age, MPS opening percentage decreased by 1.07% in the anterior half and by 1.30% in the posterior half. Additionally, each one-year increase in age increased the SOS grade by 0.56 and ZMS grade by 0.47 units. These findings are consistent with Dalili Kajan et al.[23] 's research, which also reported a significant effect of age on SOS.

CONCLUSION

The fusion of SOS and ZMS was significantly correlated with all age groups irrespective of gender. In SOS grades I-III, the mean percentage of MPS opening was 100% in all age groups (with the highest frequency of ZMS"1"), indicating a higher chance of success for orthodontic treatments such as RME and maxillary protraction in these individuals. Irrespective of age, SOS had a significant inverse correlation with MPS. Aging decreased the mean percentage of MPS opening; this reduction was greater in the posterior half.

Acknowledgment

We are grateful to acknowledge Dr Mohammad Ebrahim Ghafari (Dental Sciences Research Center, Guilan University of Medical

Sciences, Rasht, Iran) for his assistance in analyzing the statistical data.

Ethics

Ethics Committee Approval: The study protocol was approved by the Ethics Committee of Gulian University of Medical Sciences (IR.GUMS. REC.1400.413).

Informed Consent: Informed consent was obtained.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - Z.D.; Design - Z.D.; Data Collection and/or Processing - N.T.; Analysis and/or Interpretation - N.T., Z.D.; Writing - N.K.; Critical Review N.T., Z.D.

Declaration of Interests: There are no known conflicts of interest associated with this publication.

Funding: There has been no significant financial support for this work that could have influenced its outcome.

REFERENCES

1. Can IO, Ekizoglu O, Hocaoglu E, Inci E, Sayin I, Kaya KH. Forensic age estimation by spheno-occipital synchondrosis fusion degree: computed tomography analysis. *J Craniofac Surg.* 2014;25(4):1212-1216. [CrossRef]
2. Strzecki A, Osiewacz S, Szczepańska J, Pawłowska E. Effect of rapid maxillary expansion on the morphology of spheno-occipital synchondrosis in rats : A micro-CT study. *J Orofac Orthop.* 2019;80(5):266-273. [CrossRef]
3. Fernández-Pérez MJ, Alarcón JA, McNamara JA Jr, et al. Spheno-Occipital Synchondrosis Fusion Correlates with Cervical Vertebrae Maturation. *PLoS One.* 2016;11(8):e0161104. [CrossRef]
4. Bazargani F, Feldmann I, Bondemark L. Three-dimensional analysis of effects of rapid maxillary expansion on facial sutures and bones. *Angle Orthod.* 2013;83(6):1074-1082. [CrossRef]
5. Goldstein JA, Paliga JT, Wink JD, Bartlett SP, Nah HD, Taylor JA. Earlier evidence of spheno-occipital synchondrosis fusion correlates with severity of midface hypoplasia in patients with syndromic craniosynostosis. *Plast Reconstr Surg.* 2014;134(3):504-510. [CrossRef]
6. Silvestrini-Biavati A, Angiero F, Gambino A, Ugolini A. Do changes in spheno-occipital synchondrosis after rapid maxillary expansion affect the maxillomandibular complex? *Eur J Paediatr Dent.* 2013;14(1):63-67. [CrossRef]
7. Leonardi R, Cutrera A, Barbato E. Rapid maxillary expansion affects the spheno-occipital synchondrosis in youngsters. A study with low-dose computed tomography. *Angle Orthod.* 2010;80(1):106-110. [CrossRef]
8. Macey-Dare LV. The early management of Class III malocclusions using protraction headgear. *Dent Update.* 2000;27(10):508-513. [CrossRef]
9. Okamoto K, Ito J, Tokiguchi S, Furusawa T. High-resolution CT findings in the development of the sphenooccipital synchondrosis. *AJNR Am J Neuroradiol.* 1996;17(1):117-120. [CrossRef]
10. Alhazmi A, Vargas E, Palomo JM, Hans M, Latimer B, Simpson S. Timing and rate of spheno-occipital synchondrosis closure and its relationship to puberty. *PLoS One.* 2017;12(8):e0183305. Erratum in: *PLoS One.* 2018;13(1):e0191703. [CrossRef]
11. Sinanoglu A, Kocasarac HD, Noujeim M. Age estimation by an analysis of spheno-occipital synchondrosis using cone-beam computed tomography. *Leg Med (Tokyo).* 2016;18:13-19. Erratum in: *Leg Med (Tokyo).* 2017;27:43. [CrossRef]
12. Hayashi I. Morphological relationship between the cranial base and dentofacial complex obtained by reconstructive computer tomographic images. *Eur J Orthod.* 2003;25(4):385-391. [CrossRef]
13. Bassed RB, Briggs C, Drummer OH. Analysis of time of closure of the spheno-occipital synchondrosis using computed tomography. *Forensic Sci Int.* 2010;200(1-3):161-164. [CrossRef]
14. Pate RS, Tingne CV, Dixit PG. Age determination by spheno-occipital synchondrosis fusion in Central Indian population. *J Forensic Leg Med.* 2018;54:39-43. [CrossRef]
15. Yang JH, Cha BK, Choi DS, Park JH, Jang I. Time and pattern of the fusion of the spheno-occipital synchondrosis in patients with skeletal Class I and Class III malocclusion. *Angle Orthod.* 2019;89(3):470-479. [CrossRef]
16. Dillon ME. Comparison of spheno-occipital synchondrosis closure, cervical vertebrae maturation and hand-wrist maturation as skeletal maturation indicators [dissertation]. Minnesota, University of Minnesota; 2018. [CrossRef]
17. Demirturk Kocasarac H, Altan AB, Yerlikaya C, Sinanoglu A, Noujeim M. Correlation between spheno-occipital synchondrosis, dental age, chronological age and cervical vertebrae maturation in Turkish population: is there a link? *Acta Odontol Scand.* 2017;75(2):79-86. [CrossRef]
18. Kajan ZD, Nasab NK, Eghrari N. Quantitative Evaluation of Midpalatal Suture Opening and Its Relation with Zygomaticomaxillary Suture Status in Patients Aged 7-25 Years Using Cone Beam Computed Tomography Images: In an Iranian Population. *Contemp Clin Dent.* 2018;9(Suppl 1):S89-S94. [CrossRef]
19. Akhlaghi M, Valizadeh B, Gharedaghi J. Closure time of spheno-occipital suture in the male cadavers referred to legal medicine organization. *Acta Med Iranica.* 2008;46(2):105-108. [CrossRef]
20. Franchi L, Baccetti T, Lione R, Fanucci E, Cozza P. Modifications of midpalatal sutural density induced by rapid maxillary expansion: A low-dose computed-tomography evaluation. *Am J Orthod Dentofacial Orthop.* 2010;137(4):486-488; discussion 12A-13A. [CrossRef]
21. Kwak KH, Kim SS, Kim YI, Kim YD. Quantitative evaluation of midpalatal suture maturation via fractal analysis. *Korean J Orthod.* 2016;46(5):323-330. [CrossRef]
22. Olmez H, Akin E, Karaçay S. Multitomographic evaluation of the dental effects of two different rapid palatal expansion appliances. *Eur J Orthod.* 2007;29(4):379-385. [CrossRef]
23. Dalili Kajan Z, Hadinezhad A, Khosravifard N, Gholinia F, Rafiei E, Ghandari F. Fusion patterns of the spheno-occipital synchondrosis in the age range of 9-22: A computed tomography analysis. *Orthod Craniofac Res.* 2021;24(3):405-413. [CrossRef]
24. Westwood PV, McNamara JA Jr, Baccetti T, Franchi L, Sarver DM. Long-term effects of Class III treatment with rapid maxillary expansion and facemask therapy followed by fixed appliances. *Am J Orthod Dentofacial Orthop.* 2003;123(3):306-320. [CrossRef]
25. Tausche E, Hansen L, Hietschold V, Lagravère MO, Harzer W. Three-dimensional evaluation of surgically assisted implant bone-borne rapid maxillary expansion: a pilot study. *Am J Orthod Dentofacial Orthop.* 2007;131(4 Suppl):S92-S99. [CrossRef]
26. Cordasco G, Matarese G, Rustico L, et al. Efficacy of orthopedic treatment with protraction facemask on skeletal Class III malocclusion: a systematic review and meta-analysis. *Orthod Craniofac Res.* 2014;17(3):133-143. [CrossRef]
27. Angelieri F, Franchi L, Cevidanes LHS, Hino CT, Nguyen T, McNamara JA Jr. Zygomaticomaxillary suture maturation: A predictor of maxillary protraction? Part I - A classification method. *Orthod Craniofac Res.* 2017;20(2):85-94. [CrossRef]
28. Gardner GE, Kronman JH. Cranioskeletal displacements caused by rapid palatal expansion in the rhesus monkey. *Am J Orthod.* 1971;59(2):146-155. [CrossRef]
29. Ok G, Sen Yilmaz B, Aksoy DO, Kucukkeles N. Maturity evaluation of orthodontically important anatomic structures with computed tomography. *Eur J Orthod.* 2021;43(1):8-14. [CrossRef]

TURKISH JOURNAL of ORTHODONTICS

DOI: 10.4274/TurkJOrthod.2022.2022.23

Original Article

Bond Strength and Surface Roughness of Two Ceramics After Metal Bracket Debonding

Luciana P.B. Arcas[1], Kusai Baroudi[1,2], Caroline A.B. de Matos[1], Fabiana C. Ribeiro[1], Laís R. Silva-Concílio[1], Marina Amaral

[1]Department of Dentistry, Faculty of Dentistry University of Taubaté, Taubaté, Brazil
[2]RAK College of Dental Sciences, RAK Medical & Health Sciences University, Ras al Khaimah, United Arab Emirates

Cite this article as: Arcas LPB, Baroudi K, de Matos CAB, Ribeiro FC, Silva-Concílio LR, Amaral M. Bond Strength and Surface Roughness of Two Ceramics After Metal Bracket Debonding. *Turk J Orthod.* 2023; 36(3): 194-198.

Main Points
- Orthodontic brackets can be bonded to ceramic crown surfaces.
- When bonded to metallic brackets, the bond strength of resin-matrix ceramics is higher than that of lithium disilicate.
- The use of diamond burs for the removal of the remaining adhesive of the resin matrix ceramics is highly recommended.
- Polishing of the ceramic surface after bracket debonding is mandatory.

ABSTRACT

Objective: The aims of this study were to compare the bond strength between metallic brackets and two different glass ceramics and to evaluate the ceramic surface roughness after different finishing protocols.

Methods: The surface roughness of lithium disilicate and resin matrix ceramic samples was measured (initial). All samples were treated with hydrofluoric acid and silane and bonded to metallic brackets with orthodontic cement adhesive. Shear bond strength tests were performed using a universal testing machine (n=12). The surface roughness was measured again (intermediate, n=6) after removing the remaining cement adhesive from the ceramic surfaces with a diamond or 24-blade bur after polishing the ceramic surfaces (final, n=6).

Results: The resin matrix ceramic had the highest bond strength. The rotatory instrument used for the removal of cement adhesive did not affect the surface roughness of the resin matrix ceramic or lithium disilicate (p=0.985 and p=0.504, respectively), but did affect the evaluation time (p<0.001) for both restorative materials. The intermediate roughness was the highest. For the resin matrix ceramic, polishing promoted a final surface roughness similar to the initial condition; however, changes in the surface shape of this ceramic could be visibly observed when using a 24-blade bur.

Conclusion: The bond strength of metallic brackets bonded on resin-matrix ceramics is higher than bonding on lithium disilicate. The use of diamond burs for the removal of the remaining adhesive from the resin matrix ceramics is highly recommended.

Keywords: Ceramics, adhesives, orthodontic brackets, debonding, surface roughness

INTRODUCTION

Bonding orthodontic brackets to restored dental surfaces is a routine clinical practice. Glass ceramics, such as lithium disilicate and feldspathic ceramic, are esthetic ceramics used for partial restorations, veneers, full monolithic crowns, and metal layering.[1,2] No consensus has been reached about the bond strength of metallic brackets to the ceramic surface needed for orthodontic purposes,[3] and the clinical rate of debonding between bracket and ceramic surfaces is approximately 10% after two years.[4] Damage caused ceramic surfaces after bracket debonding also needs to be investigated more thoroughly.[5-7] No protocol for bonding is described in the literature; research has mainly focused on the surface finishing of ceramic materials after bracket debonding.

Corresponding author: Marina Amaral, e-mail: marina.amaral@unitau.br

Received: May 11, 2022
Accepted: July 6, 2022
Epub: September 20, 2023
Publication Date: September 29, 2023

The surface characteristics of ceramic restorations are modified by adhesive processes during both bonding and debonding of orthodontic brackets.[8] The acid etching performed before bonding, as well as the adhesive penetration, may modify surface roughness, gloss, color, hue and shade of ceramics, despite the method or type of ceramic used for finishing the surface.[8,9] The extent of the damage to the ceramic surface must be quantified so the clinician can analyze the final results of the treatment.

Several studies have investigated techniques for minimizing the damage to the surface of the ceramic surface after bracket removal.[6,10] Tungsten carbide burs, multiplied burs, polishing disks, diamond polishing pastes, and ceramic polishing kits are usually employed, which may result in different surface patterns.[11,12] However, these tools seldom lead to a ceramic with a conditions similar to the original.

The composition ceramics are also associated with different mechanical strengths and translucencies after orthodontic procedures.[13] Lithium disilicate is composed of lithium silicate crystals embedded in a glass matrix and presents a flexural strength higher than that of feldspathic ceramics. Another promising restorative material is resin matrix ceramic, also called hybrid ceramic, fabricated by computer-aided design/computer-aided manufacturing (CAD/CAM) systems. This ceramic is composed of a polymer (14%)-infiltrated ceramic (86%) network.[1,14] The resin matrix ceramic mimics the properties of natural teeth; for example, it acts like a monobloc when adhesively bonded to tooth tissues and decreases the wear by antagonists. Additionally, this type of ceramic is also less brittle and more tough than glass ceramics and presents an elastic modulus similar to that of dentin. Surface finishing procedures and their effects on the material properties have also been previously been investigated.[14]

The bonding of ceramic and metallic orthodontic brackets to ceramic surfaces is performed by etching the ceramic surface with hydrofluoric acid and then applying silane.[15-17] Acid etching may damage the ceramic surface,[17] decreasing the strength of the ceramic and changes in translucency.[13] Thus, the present investigation compared the bond strength between metallic brackets and the surfaces of two ceramics, as well as to investigate the surface roughness caused by rotatory instruments used for the removal of remnant orthodontic adhesive from ceramic surfaces. The null hypothesis was that there is no difference in bond strength and surface roughness between the two tested ceramics after the metal brackets were debonded and rotatory instruments were used to remove the remaining adhesive.

METHODS

Two ceramics were evaluated: lithium silicate (IPS e.max CAD, IvoclarVivadent, Schaan, Lieschtenstein) and a resin matrix ceramic (Vita Enamic, VITA Zahnfabrik, Bad Säckingen, Germany). Six CAD/CAM blocks of each material were sectioned (6.5×12×2 mm) with a precision saw (IsoMet, Buehler, Lake Bluff, USA). The flat square samples were embedded into a chemically cured acrylic resin (JET, Clássico, Cotia, Brazil) with one surface exposed. The samples were polished with silicon carbide papers (3M, Maplewood, USA) of increasing grit sizes (800, 1200, and 2000 grit).

All samples were subjected to a roughness test using a contact profilometer (Surftest SJ 310, Mitutoyo, Tokyo, Japan). Three parallel readings (ʎc 0.25 mm) were performed at the future site for bracket bonding. The mean roughness value (Ra) of each sample was recorded.

Bonding of Brackets

Metallic brackets (Edgewise Standard 022; Morelli, Sorocaba, Brazil) were used. Two metallic brackets were bonded to each ceramic surface (n=12)[15] following the protocols described below:

• Lithium disilicate: etching with 10% hydrofluoric acid for 20 s, washing with water spray for 40 s, drying, and silane application (Prosil, FGM, Joinville, Brazil).

• Resin matrix ceramic: etching with 5% hydrofluoric acid for 60 s, washing with water spray for 120 s, drying, and silane application (Prosil, FGM, Joinville, Brazil).

• Metallic bracket: cleaning with 70% alcohol, primer application (Monobond N, IvoclarVivadent, Schaan, Lieschtenstein).

After bonding, orthodontic adhesive cement (Orthocem, FGM, Joinville, Brazil) was applied to the base of the bracket, which was positioned on the treated ceramic surface. The bracket was pressed by hand onto the ceramic surface until there was no visible space between the bracket and the substrate, which is also how it should be placed in the clinical setting. Excess adhesive was removed. The assembly was light-cured for 30 s per bracket (Bluephase N, IvoclarVivadent, Schaan, Lieschtenstein); the light detector was placed as closely as possible to the buccal side of the bracket without touching it. Samples were stored in distilled water at 37 °C for seven days.

The samples were attached to a universal testing machine (MBIO, BioPDI, Sao Carlos, Brazil) with the adhesive interface parallel to the load application direction. An increasing load (1 mm/min) was applied at the adhesive interface until failure (bracket debonding) occurred. All brackets were debonded (n=12) from the ceramic surfaces. The maximum load applied for failure was recorded (N). The bond strength (σ, Mpa) was calculated as σ=L/A, where L is the maximum load (N) and A is the adhesive interface (mm^2). The residual composite remaining were assessed using the Adhesive Remnant Index (ARI). This index was proposed by Årtun and Bergland[18] and was initially used to assess the fracture characteristics of the bracket and enamel. The same scores were used whether the substrate was a ceramic or resin.[2,18-20] Failure was classified as: (0) no adhesive cement remained on the ceramic, (1) less than half of the adhesive cement remained on the ceramic, (2) more than half of the adhesive cement remained on the ceramic, and (3) all adhesive cement remained on the ceramic.

After bracket debonding, the respective sites were subjected to adhesive removal using one of two rotatory instruments (n=6)[12]: diamond bur (2135 F, Microdont, Sao Paulo, Brazil) or 24-blade bur (FG 24, Orthometric, Marilia, Brazil) to complete the resin composite restorations. These burs were attached to a high-speed hand piece (extra torque 605C; Kavo, Sao Paulo, Brazil), slipped onto the ceramic surface parallel to the roughness reading pathway, and used until all remaining adhesives were removed.

After finishing, all samples were subjected to intermediate roughness measurements, as described previously. Three parallel readings were performed at the bracket-debonding site. The Ra of each sample was recorded.

Sites from bracket debonding were polished with a specific system (Exa-Cerapol AR; Viking, KG Sorensen, Cotia, Brazil) indicated for all ceramic types. Each site was polished for 30 s, with each step of the system (three steps total) proceeding in a single direction (parallel to the direction of the roughness reading).

All samples were subjected to final roughness measurements after polishing as described previously. Three parallel readings were performed at the bracket debonding site. The Ra of each sample was recorded.

Statistical Analysis

Shear bond strength data were subjected to statistical analysis by the Mann-Whitney U test (α=0.05), with Minitab Statistical Software, Minitab Ltd., UK.

Roughness data were subjected to a two-way analysis of variance (ANOVA) for repeated data, comparing the effect of the rotatory instrument and evaluation time (initial, intermediate, and final) (α=0.05) for each ceramic material.

RESULTS

Ceramic material had a significant effect on the bond strength of metallic brackets (p=0.03). The resin matrix ceramic exhibited a higher bond strength than the lithium disilicate ceramic (Table 1). All samples were classified as ARI 3, indicating that alll the adhesive remnant left on the ceramic surface after bracket debonding.

The rotatory instrument used to remove the adhesive did not affect the surface roughness of either the lithium disilicate or resin matrix ceramics (p=0.985 and p=0.504, respectively), but it did affect the evaluation time (Initial Ra x Intermediate Ra x Final Ra, p<0.001) (Table 2). For both materials, the intermediate roughness was the highest. For resin matrix ceramics, it was possible to obtain roughness values similar to the initial condition at the final measurement; however, lithium disilicates presented higher roughness values at the final condition than at the initial condition.

DISCUSSION

This study evaluated the shear bond strength and surface roughness of two ceramics used for monolithic restoration after the bonding and debonding of metallic orthodontic brackets. The metallic brackets bonded to the resin matrix ceramic presented a higher bond strength than that of bonded to lithium disilicate (Table 1).

Resin matrix ceramics have a high fracture toughness and an elastic modulus similar to orthodontic adhesives.[14] The similarities between elastic moduli are an important factor when the shear bond strength test is used,[21] and may be the reason that the highest bond strength values were obtained for this material. Additionally, the presence of polymers in the resin matrix ceramic favors adhesion to other polymers, such as the orthodontic adhesive used in this study.[1]

The bond strength values obtained in this study are below the values indicated as ideal for orthodontic tensile strength (minimum 5 MPa).[22] Failure analysis revealed adhesive failure at the adhesive-metallic bracket interface (ARI 3) that was similar to what has been reported in the literature.[23] An MDP-primer was used at the bracket bonding surface (mesh), but brackets presented a flat surface, which may have been inadequate to provide the retention of the adhesive to the metallic surface.

Additionally, differences in shape, mesh type, and surface treatment of bracket bases vary according to the brands available on the market, and affect bracket retention on various restorative surfaces.[24]

Despite the development of different bracket bases and their pre-blasting, which provide greater mechanical retention and less chance of debonding during orthodontic treatment,[20] excessive shear strength can damage the substrate during debonding. The failure of adhesion between the bracket and adhesive (ARI 3) is the safest in terms of not damaging the substrate.[2] However, it is certain that the occurrence of this damage will depend on the protocol used to remove the residual adhesive cement.[20,25]

Both ceramics exhibited an increase in roughness values after the removal of the remaining adhesive with rotatory instruments, but only the resin matrix ceramic recovered the initial roughness values after polishing. Thus, the null hypothesis was rejected.

Table 1. Mean shear bond strength values on different ceramic materials

Shear bond strength	Mean (SD)	Median	n
Lithium disilicate	1.138 MPa (1.258)	0.819 MPa	12
Resin matrix ceramic	2.644 MPa (1.681)	2.315 MPa	12
p-value	0.0304		

MPa, Mean bond strength values; SD, standard deviation; Mpa, median, Mann-Whitney test (α=0.05)

Table 2. Mean roughness values, standard deviation of each material, and statistical significance for evaluated factors

	Rotatory instrument	Initial Ra (mm)	Intermediate Ra (mm)	Final Ra (mm)	p value*
		Mean±standard deviation	Mean±standard deviation	Mean±standard deviation	
Lithium Disilicate	Diamond bur	0.119 B±0.02	3.269 A±0.62	2.058 A±0.45	p<0.001***
	24-blade bur	0.135 B±0.01	3.554 A±2.44	1.738 AB±0.63	
p value†	0.986				0.790‡
Resin matrix ceramic	Diamond bur	0.209 B±0.11	2.804 A±0.73	0.378 B±0.16	p<0.001***
	24-blade bur	0.222 B±0.06	2.336 B±1.31	0.416 B±0.10	
p value†	0.496				0.519‡

Initial Ra (Before bracket bonding); Intermediate Ra (after removal of remaining adhesive with rotatory instruments); Final Ra (after polishing). Ra, Mean roughness two-way ANOVA for each material (α=0.05). Different uppercase letters indicate statistical difference in the respective column. *p value representing comparison between evaluation timepoints in each material; †p-value representing comparison of both rotatory instruments for each material; ‡p value representing interaction between factors (evaluation moment; rotatory instrument)

The type of rotatory instruments tested for the removal of the remaining adhesive did not affect the surface roughness in the intermediate time before polishing. However, the 24-blade bur caused visible wear on the surface of the resin-matrix ceramic. The lithium disilicate did not exhibit any visible changes. Because it is not always clinically possible to identify the ceramic used for restoring the patient's teeth, it is preferable to use finishing diamond burs when removing the remaining adhesive from the ceramic surface. After polishing, the resin matrix ceramic presented a surface roughness similar to the initial condition, but lithium disilicate presented roughness values higher than those in the initial condition (Table 2). A stone grinding bur and abrasive disks of silicone or alumina may also be alternatives for polishing ceramics after bracket debonding.[6,12]

The polishing protocol used in this study-promoted roughness values similar to the initial conditions for the resin matrix ceramic. This category of ceramics is marketed for easier adjustment, repair, and milling than hard machining ceramics such as lithium disilicate.[1] Several polishing systems and protocols may be effective for resin matrix ceramics.[14] However, lithium disilicate presents high surface roughness, is brittle and is resistant to wear,[1] thereby requiring more specific finishing procedures. A lack of surface gloss was observed for lithium disilicate after all procedures (final condition).

Both lithium disilicate and the resin matrix ceramic were etched with hydrofluoric acid, followed by silane application, as recommended by the respective manufacturers. This surface treatment is also indicated in the literature for the bonding of metallic brackets to ceramic restorations.[15,17] However, even after polishing, the color and gloss of the resin matrix ceramic were still affected by bonding/debonding the brackets, which resulted in an opaque surface. This study did not evaluate color alterations, but previous studies have shown that there was an increase in the translucency of resin matrix ceramics after bonding/debonding of brackets[13] and color alteration in lithium disilicate ceramic.[9] Alternative treatments for the ceramic surface, such as phosphoric acid etching[26] and Er-YAG laser application,[27] have been suggested. They reported bond strength values sufficient for orthodontic tensile strength, resulting in less damage and a low chipping rate of the ceramic surface after bracket debonding.[26,27] Air abrasion of the surface of the glass ceramics was not indicated in this study. Despite presenting the best bond strength results,[16] air abrasion promoted high values of surface roughness and color alteration in the ceramics.[11]

As mentioned before, it may be clinically difficult to obtain information or identify the ceramic system used, leading to the need for investigation of one standard protocol of rotatory instruments and polishing procedures for ceramic surface finishing after orthodontic bracket debonding. The 24-blade burs are indicated for the removal of adhesive from the tooth surface,[28] but they may damage the restorative materials, particularly polymeric materials, as demonstrated in this study. Additionally, ceramics with stains and glazes on their surfaces may present different results.

CONCLUSION

Metallic brackets bonded to the resin matrix ceramic presented higher shear bond strength values than the brackets bonded to lithium disilicate. Polishing after bracket debonding, resulted in a surface roughness similar to the initial condition, but the removal of the remaining adhesive of the resin matrix ceramics should be performed with diamond burs, as it was not possible to obtain roughness values similar to the initial condition after the use of orthodontic 24-blade burs.

Ethics

Ethics Committee Approval: This research dismisses the ethics committee approval since it does not use human or part of them in the experiments.

Informed Consent: NA.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - M.A., C.A.B.M., F.C.R.; Design - M.A., L.R.S.-C.; Data Collection and/or Processing - M.A., C.A.B.M., F.C.R.; Analysis and/or Interpretation -L.P.B.A., L.R.S.-C.; Literature Review - K.B., L.R.S.-C.; Writing - L.P.B.A., K.B., M.A.

Declaration of Interests: The authors have no conflicts of interest to declare.

Funding: The authors declared that this study has received no financial support.

REFERENCES

1. Gracis S, Thompson VP, Ferencz JL, Silva NR, Bonfante EA. A new classification system for all-ceramic and ceramic-like restorative materials. *Int J Prosthod.* 2015;28(3):227-235. [CrossRef]
2. Ebert T, Elsner L, Hirschfelder U, Hanke S. Shear bond strength of brackets on restorative materials: Comparison on various dental restorative materials using the universal primer Monobond® Plus. *J Orofac Orthop.* 2016;77(2):73-84. [CrossRef]
3. Alakus Sabuncuoglu F, Erturk E. Shear bond strength of brackets bonded to porcelain surface: in vitro study. *J Istanb Univ Fac Dent*. 2016;12;50(1):9-18. [CrossRef]
4. Zachrisson YO, Zachrisson BU, Büyükyilmaz T. Surface preparation for orthodontic bonding to porcelain. *Am J Orthod Dentofacial Orthop.* 1996;109(4):420-430. [CrossRef]
5. Kao EC, Boltz KC, Johnston WM. Direct bonding of orthodontic brackets to porcelain veneer laminates. *Am J Orthod Dentofacial Orthop.* 1988;94(6):458-468. [CrossRef]
6. Lee DH, Mai HN, Thant PP, et al. Effects of different surface finishing protocols for zirconia on surface roughness and bacterial biofilm formation. *J Adv Prosthodont*. 2019;11(1):41-47. [CrossRef]
7. Zubizarreta-Macho Á, Triduo M, Alonso Pérez-Barquero J, Guinot Barona C, Albaladejo Martínez A. Novel Digital Technique to Quantify the Area and Volume of Cement Remaining and Enamel Removed after Fixed Multibracket Appliance Therapy Debonding: An In Vitro Study. *J Clin Med.* 2020;9(4):1098. [CrossRef]
8. Jarvis J, Zinelis S, Eliades T, Bradley TG. Porcelain surface roughness, color and gloss changes after orthodontic bonding. *Angle Orthod.* 2006;76(2):274-277. [CrossRef]
9. Moradinezhad M, Moradi M, Shamohammadi M, Hormozi E, Ghorani A. Porcelain color alteration after orthodontic bonding using three different surface preparation methods. *Dent Res J (Isfahan).* 2018;15(3):180-184. [CrossRef]
10. Janiszewska-Olszowska J, Szatkiewicz T, Tomkowski R, Tandecka K, Grocholewicz K. Effect of orthodontic debonding and adhesive removal on the enamel - current knowledge and future perspectives - a systematic review. *Med SciMonit*. 2014;20:1991-2001. [CrossRef]
11. Herion DT, Ferracane JL, Covell DA Jr. Porcelain surface alterations and refinishing after use of two orthodontic bonding methods. *Angle Orthod.* 2010;80(1):167-174. [CrossRef]
12. Marchi R De, Marchi, LM De, Terada RSS, Terada HH. Comparison between two methods for resin removing after bracket debonding. *Dental Press J Orthod.* 2012;17(6):130-136. [CrossRef]
13. Kurtulmus-Yilmaz S, Cengiz E, Ongun S, Karakaya I. The Effect of Surface Treatments on the Mechanical and Optical Behaviors of CAD/CAM Restorative Materials. *J Prosthodont*. 2019;28(2):496-503. [CrossRef]
14. Özarslan MM, Büyükkaplan UŞ, Barutcigil Ç, Arslan M, Türker N, Barutcigil K. Effects of different surface finishing procedures on the change in surface roughness and color of a polymer infiltrated ceramic network material. *J Adv Prosthodont.* 2016;8(1):16-20. [CrossRef]
15. Golshah A, Mohamadi N, Rahimi F, Pouyanfar H, Tabaii ES, Imani MM. Shear Bond Strength of Metal Brackets to Porcelain Using a Universal Adhesive. *Med Arch*. 2018;72(6):425-429. [CrossRef]
16. Özarslan MM, Üstün Ö, Buyukkaplan US, Barutcigil Ç, Türker N, Barutcigil K. Assessment the Bond Strength of Ceramic Brackets to CAD/CAM Nanoceramic Composite and Interpenetrating Network Composite after Different Surface Treatments. *Biomed Res Int.* 2018;2018:1871598. [CrossRef]
17. Bishara SE, Ajlouni R, Oonsombat C, Laffoon J. Bonding orthodontic brackets to porcelain using different adhesives /enamel conditioners: a comparative study. *World J Orthod.* 2005;6(1):17-24. [CrossRef]
18. Årtun J, Bergland S. Clinical trials with crystal growth conditioning as an alternative to acid-etch enamel pretreatment. *Am J Orthod.* 1984;85(4):333-340. [CrossRef]
19. Kilponen L, Varrela J, Vallittu PK. Priming and bonding metal, ceramic and polycarbonate brackets. *Biomater Investig Dent.* 2019;6(1):61-72. [CrossRef]
20. Henkin FS, Macêdo ÉO, Santos KD, Schwarzbach M, Samuel SM, Mundstock KS. In vitro analysis of shear bond strength and adhesive remnant index of different metal brackets. *Dental Press J Orthod.* 2016;21(6):67-73. [CrossRef]
21. Braga RR, Meira JB, Boaro LC, Xavier TA. Adhesion to tooth structure: a critical review of "macro" test methods. *Dent Mater.* 2010;26(2):38-49. [CrossRef]
22. Di Guida LA, Benetti P, Corazza PH, Della Bona A. The critical bond strength of orthodontic brackets bonded to dental glass-ceramics. *Clin Oral Investig.* 2019;23(12):4345-4353. [CrossRef]
23. Asiry MA, AlShahrani I, Alaqeel SM, Durgesh BH, Ramakrishnaiah R. Effect of two-step and one-step surface conditioning of glass ceramic on adhesion strength of orthodontic bracket and effect of thermo-cycling on adhesion strength. *J Mech Behav Biomed Mater.* 2018;84:22-27. [CrossRef]
24. Dalaie K, Mirfasihi A, Eskandarion S, Kabiri S. Effect of bracket base design on shear bond strength to feldspathic porcelain. *Eur J Dent.* 2016;10(3):351-355. [CrossRef]
25. Ehrmann E, Medioni E, Brulat-Bouchard N. Finishing and polishing effects of multiblade burs on the surface texture of 5 resin composites: microhardness and roughness testing. *Restor Dent Endod.* 2018;44(1):e1. [CrossRef]
26. Stella JP, Oliveira AB, Nojima LI, Marquezan M. Four chemical methods of porcelain conditioning and their influence over bond strength and surface integrity. *Dental Press J Orthod.* 2015;20(4):51-56. [CrossRef]
27. Juntavee N, Juntavee A, Wongnara K, Klomklorm P, Khechonnan R. Shear bond strength of ceramic bracket bonded to different surface-treated ceramic materials. *J Clin Exp Dent.* 2018;10(12):1167-1176. [CrossRef]
28. Ferreira JTL, Borsatto MC, Saraiva MCP, Matsumoto MAN, Torres CP, Romano FL. Evaluation of Enamel Roughness in Vitro After Orthodontic Bracket Debonding Using Different Methods of Residual Adhesive Removal. *Turk J Orthod.* 2020;33(1):43-51. [CrossRef]

DOI: 10.4274/TurkJOrthod.2022.2022.66

TURKISH JOURNAL of ORTHODONTICS

Systematic Review

Changes in the pH and the Flow Rate of Saliva During Orthodontic Treatment with Fixed Orthodontic Appliances: A Systematic Review

Reda Jakavičė, Alvyda Žarovienė

Department of Orthodontics, Lithuanian University of Health Sciences, Kaunas, Lithuania

Cite this article as: Jakavičė R, Žarovienė A. Changes in the pH and the Flow Rate of Saliva During Orthodontic Treatment with Fixed Orthodontic Appli-ances: A Systematic Review. *Turk J Orthod.* 2023; 36(3): 199-207.

Main Points
- The aim of the study was to evaluate changes in salivary flow and pH in different periods of orthodontic treatment with fixed appliances.
- Most studies have stated that stimulated salivary flow rate and pH tend to increase.
- According to the data, unstimulated salivary flow rate changes, while unstimulated saliva pH decreases.

ABSTRACT

This systematic review aimed to assess salivary flow and pH changes at various stages of orthodontic treatment with fixed appliances. A comprehensive searches in electronic databases, including Medline, ResearchGate, Web of Science, SAGE Journals, Cochrane Oral Health Group's Trials Register, and ScienceDirect, without any publication date restrictions until January 2022 was conducted. The Pre-ferred Reporting Items for Reporting Systematic Reviews and Meta Analyses (PRISMA 2020 version) protocol was adopted and the risk of bias assessments were performed using the Cochrane ROBINS-I tool for non-randomized studies. Out of 4902 articles, 25 were fully evaluated, and seven studies that met the inclusion criteria were included in the review. The results showed that orthodontic treatment with fixed orthodontic appliances increased the stimulated salivary flow rate during various stages of treatment. However, the unstimulated salivary flow rate showed different changes. Furthermore, stimulated salivary pH increased, whereas unstimulated salivary pH significantly decreased, depending on the specific period of orthodontic treatment. Overall, fixed orthodontic appliances have an impact on salivary flow rate and pH during different stages of treatment. Nevertheless, the current literature is insufficient to draw definitive conclusions. More well-designedrandomized studies with larger sample sizes are necessary to confirm these findings.

Keywords: Saliva, fixed orthodontic treatment, fixed orthodontic appliances, dental brackets

INTRODUCTION

Orthodontic treatment effectively improves people's quality of life by restoring regular and stable occlusion, optimal chewing function, and dentofacial aesthetics.[1] However, the use of fixed orthodontic devices can have adverse effects on soft tissues, teeth, and saliva.[2] Nowadays, ensuring good oral hygiene with fixed orthodontic appliances remains a significant challenge, as the areas around brackets are difficult to clean and prolonged plaque retention, which may cause white enamel spot lesions and gingivitis.[3,4] Saliva typically consist of water (99%), and organic and non-organic elements (1%).[5] During orthodontic treatment, plaque stagnation can lead to changes in the qualitative and quantitative indicators of saliva. The concentration of cariogenic bacteria, such as *Streptococcus mutans* and *Lactobacillus*, may increase due to the increased plaque retention, which promotes the development of active tooth decay.[6,7] Changes in the quality of saliva are often observed in its pH, buffer capacity and the viscosity of saliva.[8] Saliva pH, as a qualitative indicator of saliva, is particularly important for oral and dental health. The optimal saliva pH in healthy individuals typically ranges from 6.7 to 7.3.[9] However, in some

Corresponding author: Reda Jakavičė, e-mail: reda.vaiciunaite@gmail.com

Received: April 21, 2022
Accepted: October 09, 2022
Epub: September 28, 2023
Publication Date: September 29, 2023

cases, orthodontic treatment can lead to a decrease in salivary pH with changes in oral microbes.[10] A decreased saliva pH can increase the risk of demineralization of dental hard tissues and inflammation of the gums.[11]

During orthodontic treatment with fixed orthodontic devices, the quantitative indicator of saliva, i.e., which is the amount of saliva excreted, also undergoes changes. The statistical mean of average unstimulated saliva output is typically between 0.25-0.35 mL/min, while the non-pathological mean volume of stimulated saliva output ranges from 1-3 mL/min.[12] A decrease in saliva secretion, can lead to dry mouth, known as xerostomia. Decreased salivation may be associated with tooth decay, demineralization of dental hard tissues, and gingival inflammation. Fiyaz et al.[13] found that the saliva flow of selected patients with tooth decay was almost twice that of the control group, without caries.

However, some patients may experience an increase in saliva output during orthodontic treatment, and hypersalivation is diagnosed when saliva levels rise above the reference range.[14] Meanwhile, increased but non-pathological salivation can have benefits, such as improving mouth cleansing and enhancing the antimicrobial properties of saliva, leading to better anti-caries resistance. The study suggests that hypersalivation during orthodontic treatment may be associated with increased patient sensitivity due to the presence of fixed orthodontic devices.[11] Therefore, understanding how the qualitative and quantitative parameters of excreted saliva may change during the duration of orthodontic treatment is crucial. Numerous studies with diverse patient samples have explored the relationship between the use of fixed orthodontic appliances and alterations in salivary parameters, yielding different conclusions.[2,11,15-19] The primary objective of this systematic review was to assess the methodological quality, analyse and summarize the currently available information on changes in salivary flow and pH in different periods of orthodontic treatment with fixed appliances. The null hypothesis tested was that there would be no significant difference between baseline and during orthodontic treatment regarding these salivary parameters.

METHODS

Protocol and Registration

A systematic review was conducted in line with the PRISMA 2020 version statement (Preferred Reporting Items for Systematic Reviews and Meta-Analyses), as illustrated in Figure 1. The protocol was registered with PROSPERO (registration number CRD42022300434).

Eligibility Criteria

According to the Participants Intervention Comparison Outcome Study design schema (PICOS), the study included prospective trials (S) on patients undergoing orthodontic treatment (P) with fixed orthodontic appliances (I). In these studies, changes in quantitative and qualitative indices of saliva were observed at different times of treatment (C). The outcome of this systematic review included changes in salivary flow and pH at different time points during long-term orthodontic treatment (O).

The criteria for the study inclusion were full-text studies, clinical studies with humans, patients treated with fixed orthodontic appliances, and stimulated and unstimulated saliva samples collected before orthodontic treatment, and at different time points during orthodontic treatment. Additionally, the studies needed to present the exact mean values of salivary flow rate and pH were presented in the studies. Exclusion criteria were all case reports, case series, systematic reviews, and animal and *in vitro* studies. Furthermore, studies comparing saliva parameters between different orthodontic appliances or studies involving patients treated with orthodontic removable appliances were also excluded. The number of sample sizes was not a criterion for exclusion.

Search Strategy

The systematic search was conducted in six electronic databases, which included Medline, ResearchGate, Web of Science, SAGE Journals, Cochrane Oral Health Group's Trials Register, and ScienceDirect. The databases were searched using the specified keywords both separately and in different combinations. The search strategy used for PubMed was as follows: (saliva OR salivary) AND (fixed orthodontic appliances OR fixed orthodontic treatment OR orthodontic braces OR orthodontic brackets OR dental braces OR dental brackets OR brackets OR braces). This search strategy was appropriately adapted for ResearchGate, SAGE Journals, Web of Science, Cochrane Oral Health, and ScienceDirect electronic databases. The selection of studies was carried out independently by two investigators. Any discrepancies between the investigators were resolved through discussion. It's important to note that the librarian was not consulted during this process.

Study Selection

Before beginning the search in the selected databases, the search strategy was discussed and developed by two analyzers, and thereafter the study selection was carried out by two researchers. Search filters were applied to refine the results and duplicates entries were removed. Initially, the titles and abstracts of the identified studies were analyzed. Following this initial screening, complete articles were selected for a more comprehensive review and analysis, based on the predefined eligibility criteria. If the articles met the inclusion criteria for the review, the entire content of those articles was read to make the final decision regarding their suitability for inclusion in the systematic review.

Data Extraction

The characteristics and data of the included studies that met the eligibility criteria were extracted by two reviewers. Two independent reviewers performed data extraction using spreadsheets (Microsoft Excel Version 16.49, Redmond, WA, USA). The following variables were recorded for each reviewed article: author, country, year of publication, type of study,

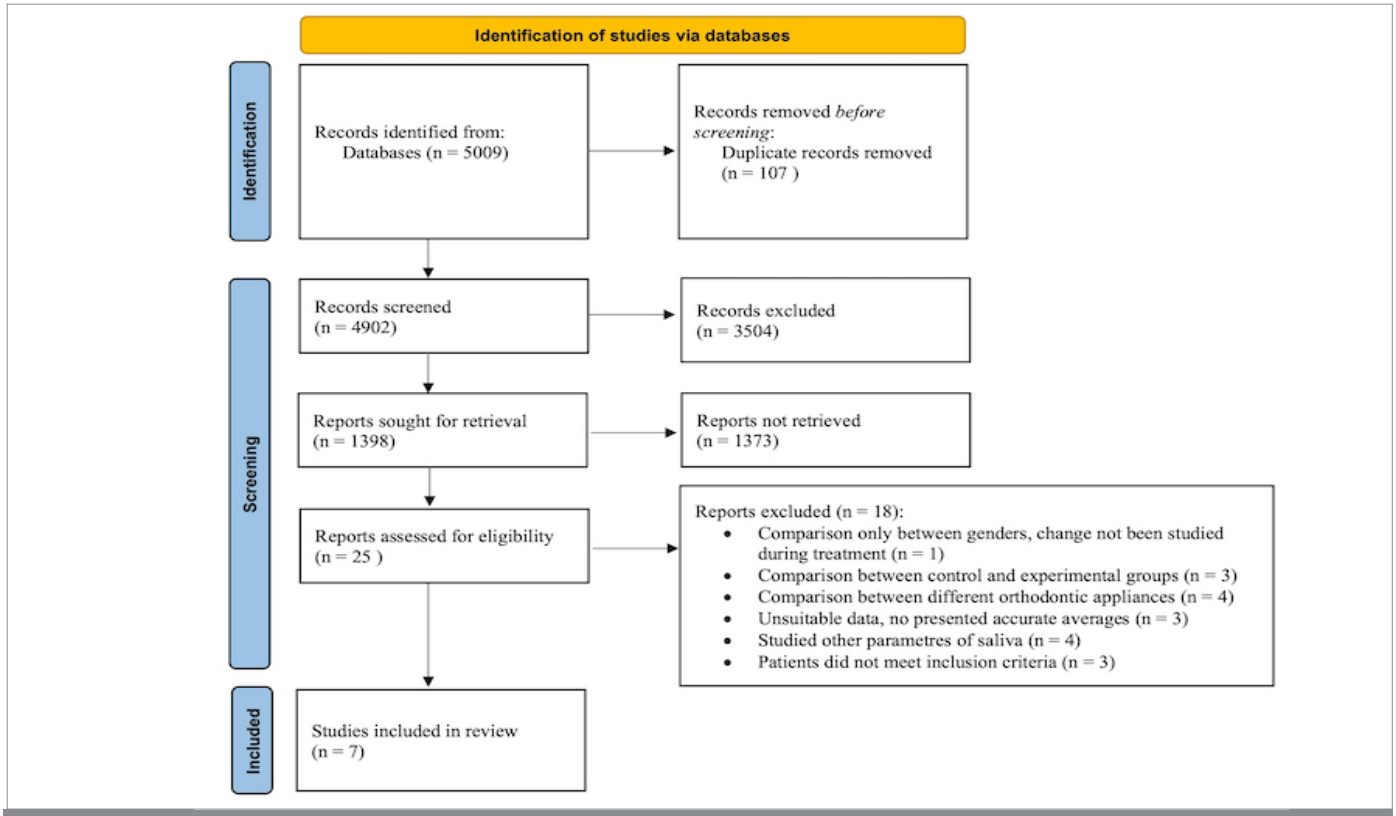

Figure 1. Identification of studies via databases

characteristics of study participants such as sample size, sex, age, intervention type (fixed orthodontic appliances), type of saliva samples, evaluation methods (methods of saliva measurements and timing on evaluation), and treatment outcomes (changes in salivary flow rate and pH in different time points). To assess the agreement between the two reviewers' data extraction, Kappa statistics were utilized after the initial selection of articles.

RESULTS

Study Characteristics

The characteristics of the included studies are summarized in Table 1.

Participants in the included studies consisted of a total of 242 patients treated with fixed orthodontic appliances. The sample sizes of the studies varied, ranging from 21 to 60 patients. Additionally, the age of the participants in the studies ranged from 10 to 34 years, with male patients being 84 and female 98. in the study conducted by Alshahrani et al.[11], the gender of 60 patients was not separated or specified in the data.

Intervention: Most studies did not indicate which bracket systems were used; only two studies identified Edgewise braces[2,19] and one study utilized self-ligating braces.[17] In all studies, the most popular method of saliva collection was the spitting method into a sterile tube. The samples were collected at different times of the day between 8 am and 3.30 pm.[2,15-19] However, one study did not specify the exact time of day for sample collection.[11] Out of the included studies, four studies, collected, unstimulated saliva samples,[2,11,15,16] while the other three studies used stimulated saliva obtained through paraffin wax or orthodontic elastic bands.[17-19]

Quality Assessment

To assess the quality of studies, the ROBINS-I tool for non-randomized studies was used, and the data are summarized in Table 2.[20] The risk of bias within the non-randomized studies from the two trials was evaluated to have an overall moderate bias due to certain discrepancies in confounding and measurement of outcome domains.[2,17] Three additional non-randomized studies[11,15,19] were found to have an overall serious risk of bias. The other two studies[16,18] were determined to present a critical risk of bias. The most problematic domains associated with bias were the lack of blinding, inadequate assessment of confounding factors, and imprecise outcome measurements.

Study Selection

The protocol for this systematic review followed the guidelines presented in the PRISMA 2020 version statement (Figure 1). For reference management, Mendeley Desktop 1.19.8 software (Mendeley Ltd, London, UK) was used. The electronic database search initially identified 5009 records. After duplicate removal, 4902 records remained, which were then screened for relevance. Screening of titles and abstracts resulted in the exclusion of 3504 studies. Additionally, 1373 full-text reports were not accessible among the 25 full-text articles we assessed for eligibility, 18 studies were subsequently excluded.[3,6,8,10,12,21-43] Finally, 7 studies

Table 1. Summary of the characteristics of included studies

	Authors	Study design	The study sample: Patients (M/F); Age Range/Mean (years)	Types of saliva samples	Intervention: Types of orthodontic appliances	Methods of measurements and timing of evaluation	Eligible outcome
1	Alshahrani et al.,[11] Saudi Arabia	PCT	60 (-); 18-30 /21.7	Unstimulated	Fixed orthodontic appliances (bracket system not specified)	Spitting method (into a 2 mL gradu-ated tube) pH digital meter. The saliva samples were collected between 8 and 11 am. Follow-up: before and 2 months.	Variations in saliva flow rate and pH at different stages of orthodontic treatment
2	Arab et al.,[15] Iran	PCT	30 (6/24); 12-18/-	Unstimulated	Fixed orthodontic appliances: *Straight wire 0.022-inch bracket slot system (AO, Sheboygan, WI, USA)	Spitting method (into a sterile test tube for 10 min.). pH meter strips. The saliva samples were collected between 10 and 12 am. Follow-up: before treatment: 6, weeks.	Variations in saliva flow rate and pH at different stages of orthodontic treatment
3	Altaee et al.[16] Iraq	PCT	34 (15/19); 16-32/23.60±5.46	Unstimulated	Fixed orthodontic appliances (bracket system not specified)	Spitting method (into a clean graduated glass tube for 10 min.) pH test paper. The saliva samples were collected between 1-3.30 pm. Follow-up: before and 1 month	Variations in saliva flow rate and pH at different stages of orthodontic treatment
4	Kouvelis et al.,[17] Greece	PCT	30 (17/13); 12-18/ 13.97±2.07	Stimulated (by a paraffin pellet)	Fixed orthodontic appli-ances (self-ligating metallic labial bracket system + InnovationR and Sentalloy 0.014-inch wire)	Spitting method (made by using sterile urine boxes). pH indicator strips. The saliva samples were collected between 9 and 12 am. Follow-up: before, 4 and 12 weeks.	Variations in saliva flow rate and pH at different stages of orthodontic treatment
5	Sanchez and Honores[18] Peru	PCT	44 (23/21); 10-34/17.27	Stimulated (by Orthodontic elastic bands)	Fixed orthodontic appliances (bracket system not specified).	Spitting method (in glass test 10 mL tubes for 5 min.) The saliva samples were collected between 9am and 12 pm. Follow-up: before and 1 month.	Variations in saliva flow rate at different stages of orthodontic treatment
6	Peros et al.,[19] Croatia	PCT	23 (9/14); 12-17/14.04±1.52	Stimulated (by paraffin wax)	Fixed orthodontic appliances: *Labial bracket system with metal wire ligatures (Forestadent, Pforzheim, Germany). *Archwires: started with 0.012-inch NiTi, followed with 0.016-inch NiTi after 6 weeks and 0.016-inch x 0.022-inch NiTi for the next 6 weeks	Spitting method (into a sterile plastic graduated cup for 10 min.) pH digital meter. Follow-up: before, 6, 12, and 18 weeks	Variations in saliva flow rate and pH at different stages of orthodontic treatment

The PCT, prospective controlled clinical trial; M, males; F, females.

were included in a systematic review.[2,11,15-19] An overview of the search results and the screening process is summarized in the study flow chart (Figure 1).

Results of Individual Studies

The results of the seven included studies are summarized and presented in Table 3. Figure 2 demonstrates changes in the stimulated and unstimulated salivary flow rate during orthodontic treatment periods, while Figure 3 demonstrates changes in the stimulated and unstimulated salivary pH.

Unstimulated Salivary Flow Rate

Three of the included studies analyzed the unstimulated salivary flow rate.[11,15,16] Due to the observed different in age groups and the fact that saliva production decreases with age, the results of unstimulated salivary flow rate were separated into two groups.

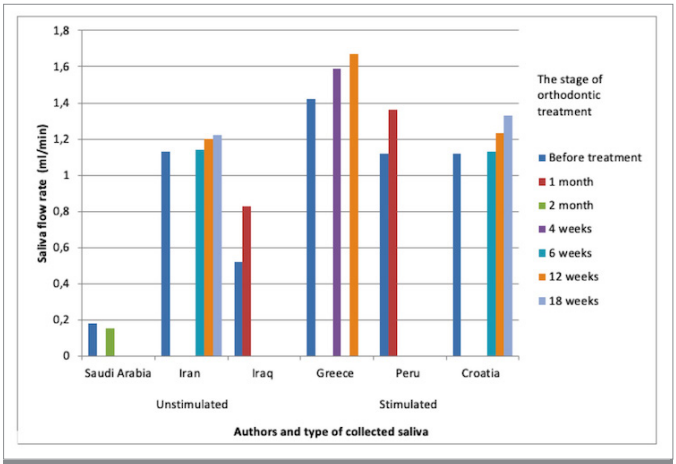

Figure 2. Changes in the salivary flow rate

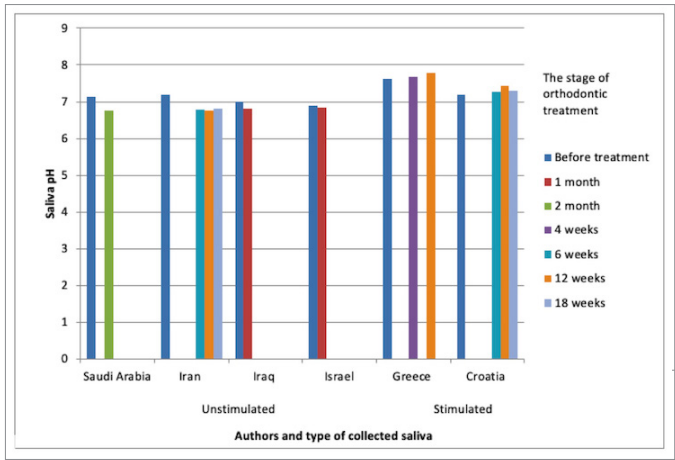

Figure 3. Changes in the salivary pH

Table 2. Risk of bias of the included studies

Studies	Confounding	Selection bias	Classification of interventions	Intended interventions	Missing data	Measurement of outcomes	Reported result	Overall
Peros et al.[19]	Low	Low	Low	Low	Low	Serious (no method error, not blinded assessor	Low	Serious
Altaee et al.[16]	Critical (difference in age, sex between groups, pH in total before treatment)	Moderate	Low	Moderate (treatment details partially provided)	Low	Serious (no method error, not blinded assessor)	Moderate	Critical
Sánchez at al.[18]	Critical (difference in age and sex between groups)	Moderate	Low	Moderate (treatment details partially provided)	Low	Serious (no method error, not blinded assessor)	Low	Critical
Arab et al.[15]	Serious (difference in sex between groups)	Moderate	Low	Low	Low	Serious (no method error, not blinded assessor)	Low	Serious
Zogakis et al.[2]	Moderate	Low	Low	Low	Low	Moderate (not blinded assess)	Low	Moderate
Alshahrani et al.[11]	Serious (difference in age, unknown difference in sex)	Moderate	Low	Moderate (treatment details partially provided)	Low	Serious (no method error, not blinded assessor)	Low	Serious
Kouvelis et al.[17]	Moderate	Low	Low	Low	Low	Moderate (not blinded assessor)	Low	Moderate

Table 3. A summary of the results of the included studies (salivary flow rate and pH measurements)

	Authors	Stage of orthodontic treatment	The type of collected saliva	Saliva flow rate (mL/min)	Saliva pH	Conclusions
1	Alshahrani et al.[11], Saudi Arabia	Before treatment 2 months of treatment	Unstimulated	0.18 0.15	7.14±0.29 6.75±0.29	Statistically significant reductions in salivary flow and pH
2	Arab et al.[15], Iran	Before treatment 6 weeks of treatment Twelve weeks of treatment 18 weeks of treatment	Unstimulated	1.13±0.42 1.14±0.25 1.20±0.33 1.22±0.42	7.18±0.35 6.78±0.23 6.76±0.28 6.81±0.31	The salivary flow increased but did not change significantly, while the saliva pH significantly decreased during orthodontic treatment
3	Altaee et al.[16], Iraq	Before treatment 1 month of treatment	Unstimulated	0.52 0.83	7.01±0.53 6.8±0.63	A statistically significant increase in the salivary flow rate. Significant decrease in the salivary pH
4	Kouvelis et al.[17], Greece	Before treatment 4 weeks of treatment Twelve weeks of treatment	Stimulated	1.42 1.59 1.67	7.63 7.67 7.78	A statistically significant increase in the salivary flow rate. However, the salivary pH did not change significantly
5	Sanchez et al.[18], Peru	Before treatment 1 month of treatment	Stimulated	1.12 1.36	Not studied	A statistically significant increase in salivary flow. Salivary pH not studied
6	Peros et al.[19], Croatia	Before treatment 6 weeks of treatment Twelve weeks of treatment 18 weeks of treatment	Stimulated	1.12 1.13 1.23 1.33	7.18 7.27 7.42 7.30	A significant increase in salivary flow rate and pH was found
7	Zogakis et al.[2], Israel	Before treatment 4-6 weeks of treatment	Unstimulated	Not studied	6.9 6.83	No statistically significant reduction in salivary pH

The first age group included participants aged 16-32 years.[11,16] Alshahrani et al.[11] reported that the unstimulated salivary flow rate was significantly higher one week before orthodontic treatment than after 2 months of orthodontic treatment ($p<0.05$). According to the results, the mean unstimulated saliva flow rate before treatment was 184.57±53.41 µL/min, compared to 149.12±50.57 µL/min of flow rate after 2 months of treatment.[11] In contrast, Altaee et al.[16] stated that the unstimulated saliva flow rate of participants increased significantly during the 1-month orthodontic treatment period, from 0.52±0.1 mL/min to 0.83±0.16 mL/min ($p<0.05$). The second age group included participants aged 12-18 years.[15] Arab et al.[15] analyzed younger patients before orthodontic treatment and at 6, 12, 18 weeks of orthodontic treatment with fixed appliances and revealed that the unstimulated salivary flow rate increased significantly after every 6 weeks of treatment ($p<0.05$). In detail, the salivary flow rate before starting fixed orthodontic treatment (1.13±0.42 mL/min) had a significantly lower mean than after 18 weeks of treatment (1.22±0.42 mL/min).[15] Evaluating the unstimulated salivary flow rate of these three studies, a general conclusion cannot be drawn due to the different results observed between the studies.

Stimulated Salivary Flow Rate

Three studies evaluated the status of stimulated salivary flow rate parameters.[17-19] In the study by Sánchez and Honores[18] the average stimulated salivary flow rate changed significantly from 1.12 mL/min to 1.36 mL/min after a month of bracket placement. However, these results should be interpreted with caution due to the wide range of age groups involved (10-34 years). Nonetheless, similar results were reported by researchers in two other studies over time.[17,19] Kouvelis et al.[17] showed a significantly greater stimulated salivary flow rate after 12 weeks (1.67 mL/min) of treatment compared to before treatment (1.42 mL/min). Peros et al.[19] also showed a significant increase in stimulated salivary flow rate with values increasing from 1.12 mL/min before treatment to 1.33 mL/min after 18 weeks of treatment. Regarding changes between the genders, it was noticeable that the stimulated salivary flow rate of females increased by 0.22 from baseline to 1 month (from 1.16 mL/min to 1.38 mL/min), while that of men increased by 0.25 (from 1.06 mL/min to 1.31 mL/min) during the same period of treatment.[18] Concerning the status of stimulated salivary flow rate, the results of the studies showed a significant increase during different periods of long-term orthodontic treatment.

Unstimulated Salivary pH

Four of the included studies analyzed the unstimulated salivary pH in different periods of treatment with fixed orthodontic appliances.[2,11,15,16] Evaluating the records of patients who underwent such treatment revealed that unstimulated salivary pH significantly decreased after various periods of orthodontic

treatment.[11,15,16] Alshahrani et al.[11] reported a decrease in salivary pH by 0.39±0.29 during a 2- month period ($p<0.05$), while Altaee et al.[16] showed a decrease in pH by 0.21±0.13 during a 1-month period ($p<0.05$). The findings from the study by Arab et al.[15] also showed a significant reduction in unstimulated salivary pH from 7.18±0.35 to 6.76±0.28 during a 12-week period; however, from 12 to 18 weeks, salivary pH increased to 6.8±0.3.[15] In the study conducted by Zogakis et al.[2], the reduction in unstimulated salivary pH was 0.07, but it was not significant compared to the values before and 4-6 weeks of orthodontic treatment ($p>0.05$). Regarding the status of unstimulated salivary pH , the results of three studies revealed a significant decrease during different periods of orthodontic treatment, while in one study, the decrease in salivary pH was not significant.

Stimulated Salivary pH

Two authors investigated stimulated salivary pH.[17,19] Kouvelis et al.[17] and Peros et al.[19] published results of stimulated salivary pH. Kouvelis et al.[17] studied stimulated salivary pH at different time points: before treatment - 7.63, 4 weeks of treatment - 7.67, and 12 weeks of treatment - 7.78. The salivary pH of stimulated saliva increased by 0.15 during the 12-week period, but the difference was not statistically significant ($p>0.05$).[17] On the other hand, Peros et al.[19] reported that the measurements of stimulated salivary pH increased significantly compared the initial examination (7.18) during the 12-week period of treatment (7.42). However, there was a reduction of stimulated salivary pH by 0.12 during the 12- to 18-week period.

DISCUSSION

Salivary Flow Rate

No single conclusion was reached when evaluating the unstimulated salivary flow rate.[11,15,16] Other authors have also obtained variable results. Li et al.[33] found an increase in the non-stimulated salivary flow rate during the first month, followed by a return to the norm after 3 months. Three other authors[10,21,34] presented one month and half-year results of unstimulated salivary flow, where a significant increase was observed; however, in one study, the authors did not provide accurate measurements of salivary flow, and results were presented in the ranges (<3.5 mL, 3.5-5 mL., >5 mL).[21] Considering an even longer treatment period, such as one year, Alessandri Bonetti et al.[8] found an increased salivary flow rate, but these results were not statistically significant. Different results may have been obtained because most study groups were not divided into smaller age groups, and adults were not separated from children. It is known that children's saliva secretion is more intensive compared to adults and decreases over time.[35,36] Another important factor that may affect the results is the evaluation of salivation over a long period of time,since orthodontic treatment itself takes an average of about 19.9 months.[37] Therefore, it is essential to evaluate the salivary flow rate over a long period, and the results may change over time due to adaptive processes happening in the human body.

Some authors compared changes between genders. Females' unstimulated salivary flow rate increased during 1 month of treatment by 0.13 (from 0.51 mL/min to 0.64 mL/min), while men's salivary flow rate increased by 0.2 (from 0.51 mL/min to 0.71 mL/min) during the same period of treatment. Thus, the unstimulated salivary flow rate was greater in males than females as shown in a study by Altaee et al.[16] However, Alessandri Bonetti et al.[8] found no significant difference between the sexes over a period of one year.

Concerning stimulated salivary flow rate, as observed in the results of the present systematic review, all authors reported an increase in stimulated salivary flow rate at different treatment periods compared to baseline, even between different age groups.[17-19] Similar findings were found by other authors: Lara-Carillo et al.[12] found an increased stimulated salivary flow rate in patients after 1 month of orthodontic treatment. Increased rates were also found in patients treated with fixed orthodontic appliances one and three months later.[38,39] In one study, a significant increase in the stimulated salivary flow rate was also established even six months after the placement of fixed orthodontic appliances.[21] This confirms the statement that bonded brackets create a mechanical stimulus to receptors in the brain, promoting increased salivary secretion.

Comparing changes between genders, an increased stimulated salivary flow rate was obtained with a greater change in males compared to females, where the initial flow rate was higher in the female group.[18] These results may be inaccurate due to the inclusion of various age groups (10-34 years). Lara-Carillo et al.[12] also compared results between genders and found increased stimulated saliva flow in both gender groups, but with a higher initial flow rate in the male group. On the other hand, Kado et al.[40] evaluated stimulated salivary flow between genders of pre-orthodontic patients and found a significantly higher flow rate in males than in females. These results were explained by the smaller size of salivary glands in females compared to males the influence of hormonal patterns.[12]

Salivary pH

A reduction in unstimulated salivary pH during orthodontic treatment was found in all included studies that evaluated the pH of unstimulated saliva.[11,15,16] These results are consistent with those reported by Kanaya et al.[39], who found a decreased pH associated with an increased number of acidogenic bacteria, such as *Streptococcus mutans*, *Lactobacilli*.[39] When the pH decreases sharply and reaches the critical value (pH 5.5), the balance between demineralization and remineralization is pushed toward mineral loss and demineralization. Jurela et al.[10] also found a decrease in salivary pH of patients treated with braces and associated this decrease with an increased plaque index. This may be explained by the fact that plaque buildup is a mass of bacteria that produce acid and results in reduction in salivary pH.

Comparing the results of stimulated salivary pH, an increase in pH was observed during the 12-week period.[2,17,19] Lara-

Carillo et al.[12] also showed an increase in pH after one month of orthodontic treatment, while Maret et al.[6] demonstrated that 6 months with orthodontic appliances increased salivary pH. Specifically, Maret et al[6]. compared the salivary pH of children with fixed orthodontic appliances (pH=7.49) to a control group of children (pH=7.37) without orthodontic treatment, showing a statistically significant difference in pH levels. These results agree with the study by Ivanovic et al.[30], where the pH of saliva statistically significantly increased 12 weeks after wearing fixed braces compared to the control group of respondents who were not treated orthodontically. A higher pH value indicates higher basicity. However, it is essential to note that fixed appliances remain in the mouth for an extended period, and oral prophylaxis measures, such as oral hygiene practices, diet advice, and topical fluoride application, should be considered to maintain oral health.

Moreover, certain unexplored variables can significantly influence the oral environment. The utilization of probiotics, parabiotics, postbiotics, and natural compounds has demonstrated the ability to modify clinical and microbiological parameters in periodontal patients, a which may also have an impact during orthodontic treatment. All these variables should be considered in future clinical trials.[41,42]

Study Limitations

This systematic literature review analyzed the currently available information on changes in salivary flow and pH during orthodontic treatment with fixed orthodontic appliances. The quality of the included studies was mainly medium, which means that the results of these studies should be interpreted with caution. Some studies provided limited details of their methods, making quality assessment difficult. The main limitations of the included studies were; blinding, assessment of confounding factors, non-homogeneous study designs, and small sample sizes. Additionally, in some studies, children and adults were not separated into different groups, and the evaluation of salivary parameters was not consistently performed at the same time as orthodontic treatment. Some studies had short follow-up periods, limiting the ability to assess long-term outcomes. The accuracy of saliva parameters might have been influenced by the different collection times of saliva, emphasizing the importance of standardized saliva collection protocols in future research. To gain a more comprehensive understanding of the long-term effects, future research should consider following the participants for extended evaluation periods. The limited number of studies evaluating the same procedures, outcomes, and evaluation periods precluded the performance of meta-analyses. Due to resource limitations, full texts of non-English-language articles identified during the searches were not retrieved, potentially resulting in the omission of relevant evidence. It is important to note that this study was not funded, and the authors declare that there are no conflicts of interest.

CONCLUSION

Orthodontic treatment with fixed orthodontic appliances increases the salivary flow rate during various periods of orthodontic treatment. However, the changes in salivary pH differ depending on whether the saliva is stimulated or unstimulated. Stimulated salivary pH tends to increase during orthodontic treatment, while unstimulated salivary pH tends to decrease. Although the published results are promising, they are not sufficient to confirm final changes in quantitative and qualitative indices of saliva during orthodontic treatment with fixed appliances. Further well-conducted multicenter randomized studies with a large sample are needed to confirm this statement to establish more robust evidence.

Ethics

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - R.J., A.Ž.; Design - R.J., A.Ž.; Supervision - R.J., A.Ž.; Data Collection and/or Processing - R.J., A.Ž.; Analysis and/or Interpretation - R.J., A.Ž.; Writing - R.J., A.Ž.; Critical Review - R.J., A.Ž.

Declaration of Interests: The authors have no conflicts of interest to declare.

Funding: No financial assistance was received to support this study.

REFERENCES

1. Zarzycka-Kogut K, Pucek M, Szymańska J.Orthodontic Treatment – Complications and Preventive Measures. *Polish Journal of Public Health.* 2014;124(2):103-106. [CrossRef]
2. Zogakis IP, Koren E, Gorelik S, Ginsburg I, Shalish M. Effect of fixed orthodontic appliances on nonmicrobial salivary parameters. *Angle Orthod.* 2018;88(6):806-811. [CrossRef]
3. Mei L, Chieng J, Wong C, Benic G, Farella M. Factors affecting dental biofilm in patients wearing fixed orthodontic appliances. *Prog Orthod.* 2017;18:4. [CrossRef]
4. Demling A, Heuer W, Elter C, et al. Analysis of supra- and subgingival long-term biofilm formation on orthodontic bands. *Eur J Orthod.* 2009;31(2):202-206. [CrossRef]
5. Llena-Puy C. The rôle of saliva in maintaining oral health and as an aid to diagnosis. *Med Oral Patol Oral Cir Bucal.* 2006;11(5):E449-E455. [CrossRef]
6. Maret D, Marchal-Sixou C, Vergnes JN, et al. Effect of fixed orthodontic appliances on salivary microbial parameters at 6 months: a controlled observational study. *J Appl Oral Sci.* 2014;22(1):38-43. [CrossRef]
7. Mummolo S, Marchetti E, Giuca MR, et al. In-office bacteria test for a microbial monitoring during the conventional and self-ligating orthodontic treatment. *Head Face Med.* 2013;9:7. [CrossRef]
8. Alessandri Bonetti G, Incerti Parenti S, Garulli G, Gatto MR, Checchi L. Effect of fixed orthodontic appliances on salivary properties. *Prog Orthod.* 2013;14:13. [CrossRef]
9. Ramya AS, Uppala D, Majumdar S, Surekha Ch, Deepak KG. Are salivary amylase and pH - Prognostic indicators of cancers? *J Oral Biol Craniofac Res.* 2015;5(2):81-5. [CrossRef]
10. Jurela A, Sudarević K, Budimir A, Brailo V, Lončar Brzak B, Janković B. Clinical and Salivary Findings in Patients with Metal and Crystalline Conventional and Self-Ligating Orthodontic Brackets. *Acta Stomatol Croat.* 2019;53(3):224-230. [CrossRef]

11. Alshahrani I, Hameed MS, Syed S, Amanullah M, Togoo RA, Kaleem S. Changes in essential salivary parameters in patients undergoing fixed orthodontic treatment: A longitudinal study. *Niger J Clin Pract.* 2019;22(5):707-712. [CrossRef]
12. Lara-Carrillo E, Montiel-Bastida NM, Sánchez-Pérez L, Alanís-Tavira J. Effect of orthodontic treatment on saliva, plaque and the levels of Streptococcus mutans and Lactobacillus. *Med Oral Patol Oral Cir Bucal.* 2010;15(6):e924-e929. [CrossRef]
13. Fiyaz M, Ramesh A, Ramalingam K, Thomas B, Shetty S, Prakash P. Association of salivary calcium, phosphate, pH and flow rate on oral health: A study on 90 subjects. *J Indian Soc Periodontol.* 2013;17:454-460. [CrossRef]
14. Miranda-Rius J, Brunet-Llobet L, Lahor-Soler E, Farré M. Salivary Secretory Disorders, Inducing Drugs, and Clinical Management. *Int J Med Sci.* 2015;12(10):811-824. [CrossRef]
15. Arab S, Nouhzadeh Malekshah S, Abouei Mehrizi E, Ebrahimi Khanghah A, Naseh R, Imani MM. Effect of Fixed Orthodontic Treatment on Salivary Flow, pH and Microbial Count. *J Dent (Tehran).* 2016;13(1):18-22. [CrossRef]
16. Altaee ZH, Al-Ajeely MH, Abdulateef YM. Prevalence, Effect of fixed orthodontic appliance on some factors and elements of saliva. *Sulaimani Dent J.* 2015;2(2):89-93. [CrossRef]
17. Kouvelis G, Papadimitriou A, Merakou K, Doulis I, Karapsias S, Kloukos D. A Prospective Cohort Study Assessing the Impact of Fixed Orthodontic Appliances on Saliva Properties and Oral Microbial Flora. *Oral Health Prev Dent.* 2021;19(1):67. [CrossRef]
18. Sánchez BE, Honores CM. Effect of orthodontic fixed appliances on salivary flow and viscosity. *Revista Mexicana de Ortodoncia.* 2015;3(3):185-189. [CrossRef]
19. Peros K, Mestrovic S, Anic-Milosevic S, Slaj M. Salivary microbial and nonmicrobial parameters in children with fixed orthodontic appliances. *Angle Orthod.* 2011;81(5):901-906. [CrossRef]
20. Sterne JA, Hernán MA, Reeves BC, et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. *BMJ.* 2016;355:i4919. [CrossRef]
21. Anu V, Madan Kumar PD, Shivakumar M. Salivary flow rate, pH and buffering capacity in patients undergoing fixed orthodontic treatment - A prospective study. *Indian J Dent Res*. 2019;30(4):527-530. [CrossRef]
22. Papadimitriou A, Kouvelis G, Fanaropoulou T, et al. Effects of Self-ligating Orthodontic Appliances on the Periodontal Health of Adolescents: A Prospective Cohort Study. *Oral Health Prev Dent.* 2021;19(1):129-135. [CrossRef]
23. Silva Andrade A, Marcon Szymanski M, Hashizume LN, Santos Mundstock K, Ferraz Goularte J, Hauber Gameiro G. Evaluation of stress biomarkers and electrolytes in saliva of patients undergoing fixed orthodontic treatment. *Minerva Stomatol.* 2018;67(4):172-178. [CrossRef]
24. Topaloglu-Ak A, Ertugrul F, Eden E, Ates M, Bulut H. Effect of orthodontic appliances on oral microbiota--6 month follow-up. *J Clin Pediatr Dent.* 2011;35(4):433-6. [CrossRef]
25. Pereira IF, Brasileiro CB, Kleperon NP, et al. Comparative study of oral and salivary parameters in patients with and without loss of bone mass. *Braz Oral Res.* 2018;32:e54. [CrossRef]
26. Kado I, Hisatsune J, Tsuruda K, Tanimoto K, Sugai M. The impact of fixed orthodontic appliances on oral microbiome dynamics in Japanese patients. *Sci Rep.* 2020;10(1):21989. [CrossRef]
27. Jurela A, Repic D, Pejda S, et al. The effect of two different bracket types on the salivary levels of S mutans and S sobrinus in the early phase of orthodontic treatment. *Angle Orthod.* 2013;83(1):140-5. [CrossRef]
28. Lombardo L, Ortan YÖ, Gorgun Ö, Panza C, Scuzzo G, Siciliani G. Changes in the oral environment after placement of lingual and labial orthodontic appliances. *Prog Orthod.* 2013;14:28. [CrossRef]
29. Mummolo S, Tieri M, Nota A, et al. Salivary concentrations of Streptococcus mutans and Lactobacilli during an orthodontic treatment. An observational study comparing fixed and removable orthodontic appliances. *Clin Exp Dent Res.* 2020;6(2):181-187. [CrossRef]
30. Ivanovic T, Stojanovic L, Ivanovic D, Nikolic P, Milosavljevic Z, Milinkovic M. Effects of the fixed orthodontic therapy on biochemical and microbiological parameters of saliva. *Srp Arh Celok Lek.* 2020;148(5-6):270-274. [CrossRef]
31. Kukreja P, Hugar SM, Hallikerimath S, Sogi S, Badakar C, Thakkar P. Evaluation of the Effect of Fixed and Removable Appliances on Salivary Parameters (Salivary Flow Rate pH and Buffering Capacity) in Children Aged 5-12 Years: An In Vivo Study. *Int J Clin Pediatr Dent.* 2021;14(6):774-778. [CrossRef]
32. Al-Haifi HAA, Ishaq RAA, Al-Hammadi MSA. Salivary pH changes under the effect of stainless steel versus elastomeric ligatures in fixed orthodontic patients: a single-center, randomized controlled clinical trial. *BMC Oral Health.* 2021;21(1):544. [CrossRef]
33. Li Y, Hu B, Liu Y, Ding G, Zhang C, Wang S. The effects of fixed orthodontic appliances on saliva flow rate and saliva electrolyte concentrations. *J Oral Rehabil.* 2009;36(11):781-785. [CrossRef]
34. Vanishree T, Panchmal GS, Shenoy R, Jodalli P, Sonde L, Kundapur N. Changes in the Oral Environment after Placement of Fixed Orthodontic Appliance for the Treatment of Malocclusion - a Descriptive Longitudinal Study. Oral Health Prev Dent. 2017;15(5):453-459. [CrossRef]
35. Sonesson M, Eliasson L, Matsson L. Minor salivary gland secretion in children and adults. *Arch Oral Biol.* 2003;48(7):535-539. [CrossRef]
36. Kudo F, Sawai A, Kuroyanagi R. Study of the unstimulated salivary flow rates by saliva collected by spitting method in children. *Pediatr Otorhinolaryngol Jpn.* 2014;35(1):17-20. [CrossRef]
37. Tsichlaki A, Chin SY, Pandis N, Fleming PS. How long does treatment with fixed orthodontic appliances last? A systematic review. Am *J Orthod Dentofacial Orthop.* 2016;149(3):308-318. [CrossRef]
38. Chang HS, Walsh LJ, Freer TJ. The effect of orthodontic treatment on salivary flow, pH, buffer capacity, and levels of mutans streptococci and lactobacilli. *Aust Orthod J.* 1999;15(4):229-234. [CrossRef]
39. Kanaya T, Kaneko N, Amaike C, Fukushima M, Morita S, Miyazaki H, et al. The effect of orthodontic appliances on levels of Streptococcus mutans, Streptococcus sobrinus and microbial flora in saliva. *Int Congr Ser.* 2005;1284:189-190. [CrossRef]
40. Kado I, Kunimatsu R, Yoshimi Y, Medina CC, Yamada S, Tanimoto K. Surveillance of salivary properties of pre-orthodontic patients in relation to age and sex. *Sci Rep.* 2021;11(1):6555. [CrossRef]
41. Butera A, Gallo S, Maiorani C, Preda C, Chiesa A, Esposito F, et al. Pascadopoll M. et al. Manadement of Ginaival Bleedina in Periodontal Patients with Domiciliar Use or loothpastes Containina AvaluronicAcid, Lactoferrin, or Paraprobiotics: A Randomized Controlled Clinical Trial. *Applied Sciences.* 2021:11(18):8586. [CrossRef]
42. Butera A, Gallo S, Pascadopoli M, Taccardi D, Scribante A. Home Oral Care of Periodontal Patients Using Antimicrobial Gel with Postbiotics, Lactoferrin, and Aloe Barbadensis Leaf Juice Powder vs. Conventional Chlorhexidine Gel: A Split-Mouth Randomized Clinical Trial. *Antibiotics (Basel).* 2022;11(1):118. [CrossRef]
43. Teixeira H, Kaulfuss S, Ribeiro J, Pereira B, Brancher J, Camargo E. Calcium, amylase, glucose, total protein concentrations, flow rate, pH and buffering capacity of saliva in patients undergoing orthodontic treatment with fixed appliances. *Dental Press J Orthod.* 2012;17(2):157-161. [CrossRef]

TURKISH JOURNAL of ORTHODONTICS

DOI: 10.4274/TurkJOrthod.2022.2022.4

Systematic Review

The Evaluation of Maxillary Sinus Dimensions in Different Craniofacial Patterns: A Systematic Review and Meta-Analysis

Ramyaja Chunduru, Pamila Rachel, Vignesh Kailasam, Sridevi Padmanabhan

Department of Orthodontics and Dentofacial Orthopedics, Sri Ramachandra Institute of Higher Education and Research (SRIHER), Tamil Nadu, India

Cite this article as: Chunduru R, Rachel P, Kailasam V, Padmanabhan S. The Evaluation of Maxillary Sinus Dimensions in Different Craniofacial Patterns: A Systematic Review and Meta-Analysis. *Turk J Orthod.* 2023; 36(3): 208-215.

Main Points
- Maxillary sinus dimensions differ in different craniofacial patterns.
- The maxillary sinus dimensions are greater in Class II skeletal malocclusion and in hyper-divergent male individuals.
- Knowledge about sinus dimensions is critical in orthodontics during placement of mini-implants, mesialisation of molars, and intrusion of posterior teeth.

ABSTRACT

This systematic review was intended to evaluate the maxillary sinus dimensions in vertical and sagittal craniofacial patterns and to assess if there was a difference among the craniofacial patterns. A systematic search was performed in seven databases till February 2021. The risk of bias was performed with modified Newcastle Ottawa scale. Meta-analysis was performed using random effects model. Twelve studies were included in the review and 8 in the meta-analysis. Compared to Class I malocclusion, the maxillary sinus area is greater in Class II and lesser in Class III malocclusion. On comparing normo-divergent growth pattern, the maxillary sinus area is lesser in hypo-divergent and greater in hyper-divergent individuals. Most of the studies were graded as satisfactory. The measurements are greater in hyper-divergent Class II malocclusion and in males.

Keywords: Maxillary sinus, growth patterns, malocclusion, systematic review

INTRODUCTION

Maxillary sinus is an air-filled, pyramidal-shaped structure present in the body of the maxilla.[1] The size and shape of the maxillary sinus determine the facial appearance.[2] Proffit et al.[3] showed that long-face adults had 2 to 3 times smaller occlusal forces than those with a normal face. The lighter bite force in hyper-divergent and large gonial angle patients results in an increase in sinus volume.[4] However, Oksayan et al[5] and Yassaei et al.[6] have shown that maxillary sinus dimensions are reduced in hyper-divergent individuals and vice versa. Goymen et al.[7] and Bassil-Nassif et al.[8] found no difference in the sinus dimensions among individuals with various mandibular growth patterns. The literature available regarding the relationship of the size of the maxillary sinus and sagittal malocclusion is conflicting.[9-11]

The size of the maxillary sinus is important in the field of dentistry during placement of implants, mini-screws, augmentation procedures, mesialisation of second molars in place of first molars, and intrusion of maxillary molars.[4]

As there are controversies in the literature on the relationship of the maxillary sinus dimensions in different growth patterns and with skeletal sagittal malocclusion, a systematic review is warranted.

Corresponding author: Vignesh Kailasam, e-mail: vignesh.k@sriramachandra.edu.in

Received: January 10, 2022
Accepted: May 15, 2022
Epub: September 29, 2023
Publication Date: September 29, 2023

Therefore, the aim is to evaluate the maxillary sinus dimensions in vertical and sagittal craniofacial patterns and to assess if there is a difference in the maxillary sinus dimensions among these craniofacial patterns.

METHODS

The review question was "Is there a difference in the maxillary sinus dimensions in the craniofacial patterns?"

Eligibility Criteria:

The inclusion and exclusion criteria were:

Inclusion Criteria:

Population: General population.

Intervention: Maxillary sinus dimensions using 2D and #D radiographs.

Comparison: Maxillary sinus dimensions in individuals with different sagittal malocclusions and mandibular growth patterns.

Outcome: Maxillary sinus dimensions.

Type of studies: All studies.

Exclusion Criteria

Any existing pathological condition in the sinus such as tumours or cysts, previous orthodontic treatment, facial asymmetry, craniofacial syndromes, cleft lip and palate.

All types of studies were included.

Information sources, search strategy, and study selection

Electronic searches were conducted until February 28th 2021, across 7 databases: PubMed, OVID, Cochrane library, LILACS, Scopus, Web of Sciences, and Embase. The search strategy included the use of MeSH (Medical Subject Headings), keywords, Boolean operators "AND" and "OR", for each database. The key words for PUBMED were "maxillary sinus", "malocclusion" and its variants, "normo-divergent", hypo-divergent and hyper-divergent and its variants. They were suitably modified for other databases.

The Initial screening of articles identified in the databases searched involved independent screening of title and abstract by 2 reviewers (R.C and P.R) on the basis of the research question and against the inclusion and exclusion criteria. In articles where the title and abstract failed to provide sufficient information, the full text was reviewed, to assess for relevance. They were then retrieved from these potentially eligible studies. To ensure that no relevant studies were missed, the reference list of the remaining articles was hand-searched. The duplicates from various databases were removed using the Mendeley software. Any discrepancies with regards to the eligibility of an article were resolved by discussion with a third reviewer (V.K.) when necessary.

Data Extraction

The data extraction of the included articles was performed independently and in duplicate by two authors. A pre-determined and standardized table was used for data extraction and study characteristics were tabulated. An attempt to contact the authors was made for any missing information.

Outcome

The outcome for which the data would be sought is the maxillary sinus height, length, width, area, and volume.

Risk of bias and quality assessment of the studies:

The risk of bias for individual studies was evaluated using the "Modified Newcastle Ottawa scale" adapted for cross-sectional studies.[12] Any disagreements over the risk of bias were resolved by discussion, with the involvement of a third reviewer.

Data synthesis: For each article that met the validity criteria, data were extracted and compiled into a table of evidence. The studies that evaluated the sinus dimensions in sagittal malocclusion and the growth patterns were grouped individually. Those studies that evaluated the sinus dimensions in both sagittal and vertical craniofacial patterns were placed in both groups. Analysis was prepared according to the Cochrane Handbook for Systematic Reviews.[13] Data for meta-analysis were analyzed in Review Manager (RevMan) 5.3.[14] An inverse variance method of pooling the data with a random-effects model was used for the meta-analysis. Heterogeneity was assessed with I^2 statistics.

Certainty of Evidence

The certainty of evidence was assessed by two reviewers using Grading of Recommendations, Assessment, Development and Evaluation (GRADE) Approach.[15]

RESULTS

The search selection process is depicted in the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis) 2020 flowchart (Figure 1). The search of the seven electronic databases reported 2868 records. In addition, 1 article was selected through citation search. After the removal of duplicates, 2644 articles were eliminated after reading the titles and abstracts. Of the 19 full-text documents, 7 studies were excluded. The reasons for exclusion are presented in Figure 1. Twelve studies were included in the systematic review and 8 in the meta-analysis.

Study Characteristics

The study characteristics of the studies included are given in Table 1. Among the 12 studies, 9 evaluated the maxillary sinus dimensions in sagittal malocclusion (Class I, Class II, and Class III).[6,9-11,16-20] Five studies assessed the maxillary sinus dimensions in different growth patterns.[5-7,16,21]

Risk of Bias in Studies

The quality assessment for the included studies was done using the Modified Newcastle Ottawa scale, adopted for cross-sectional studies (Table 2). Eleven studies were graded satisfactory, and

1 was graded unsatisfactory.[9] Most of the studies were graded satisfactory only, due to the lack of control of the confounding factors, and lack of standardization of the growth pattern when the sagittal malocclusion was compared and vice versa.

Maxillary Sinus Dimensions

Among the 9 studies, 4 studies concluded that there was no significant difference in the maxillary sinus dimensions in the sagittal plane (Table 3). Meta-analysis was possible for 5 studies.[6,9,10,17,19] (Figures 2-4). Among the five studies, four studies found no significant difference in the sinus area or volume among the vertical growth patterns.[5,7,16,21] Table 4 provides the details of the studies. Among the vertical patterns, the maxillary sinus height alone was smaller in hypo-divergent individuals. Other dimensions such as the length and the width were not statistically significant. The sinus area is greatest in the hyper-divergent individuals. However, the sinus volume showed no significant difference (Figures 5 and 6). Among the 13 studies, five studies revealed that males had greater sinus dimensions than females.[6,11,16,17,21] The GRADE approach indicated "low" overall certainty of evidence.

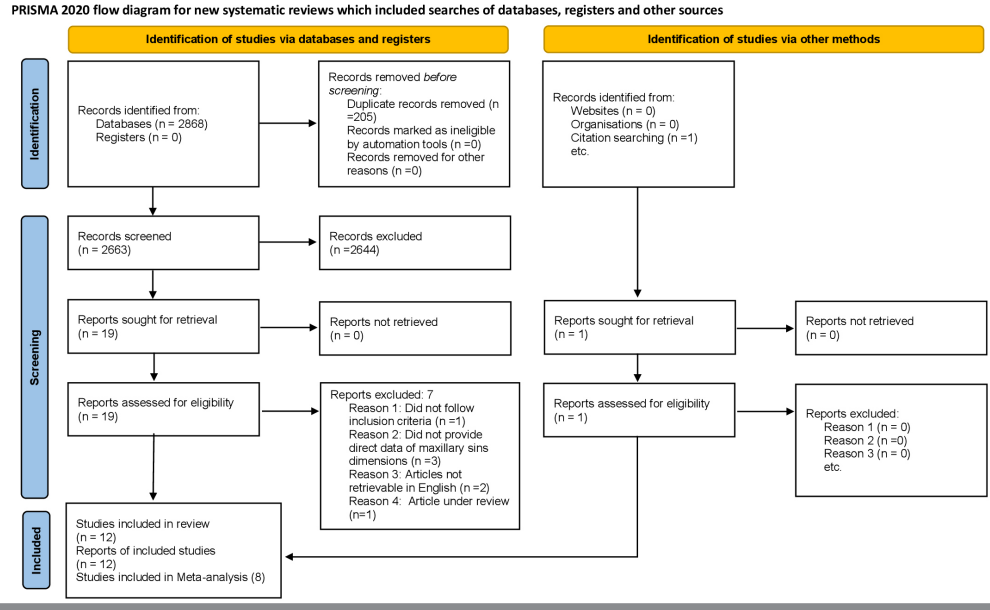

Figure 1. Search results flow diagram

Table 1. Characteristics of the included studies

Author	Study design	Age	Sample size	Radiograph	Malocclusion	Parameter
Oktay[9] 1992	Cross-sectional	6-30	189	OPG	Sagittal (Class I, Class II and Class III)	(MSA)
Endo et al .[10] 2010	Retrospective	12-16	120	LC	Sagittal	MSL, MSH, UMSA, LMSA, TMSA
Al-Ani et al.[21] 2011	Retrospective	18-25	60	LC	Vertical (Normo, Hypo and Hyper-divergent)	MSL, MSA, TMSA
Urabi and Al-Nakib[11] 2012	Cross-sectional	18-25	120	LC	Sagittal	MSL, MSH, UMSH, LMSA, TMSA
Dhiman et al.[19] 2015	Cross-sectional	16-25	240	LC	Sagittal	TMSA
Qadir and Mushtaq[17] 2017	Cross-sectional	15-35	90	LC	Sagittal	MSL, MSH, UMSA, LMSA, TMSA
Oksayan et al.[5] 2017	Retrospective	29.9±10.9	60	CBCT	Vertical	MSV, MSL, MSH, MSW
Andiappan[20] 2020	Retrospective	16-25	96	LC	Sagittal	MSA
Paluch et al.[18] 2018	Retrospective	4.4-19.3	122	LC and PA	Sagittal	MSLL; SMRPA, and SMLPA
Yassaei et al.[6] 2018	Descriptive	15-20	111	LC	Sagittal and Vertical	MSH, MSL, MSA
Goymen et al.[7], 2019	Retrospective	18-27	60	LC and PA	Vertical	MSA, MSH, MSW
Shrestha et al.[16] 2021	Cross-sectional	21-64 years	100	CBCT	Sagittal and Vertical	MSV

MSH, maxillary sinus height; MSL, maxillary sinus length; MSA, maxillary sinus area; MSW, maxillary sinus width; MSV, maxillary sinus volume; TMSA, total maxillary sinus area; UMSA, upper maxillary sinus area; LMSA, lower maxillary sinus area; LC, lateral cephalogram; OPG, orthopantomogram

Table 2. Risk of bias using MNCOS tool

Author	Selection				Comparability	Outcome		
	Representative	Sample	Ascertainment	Non-respondent	Study design or analysis	Assessment	Statistical test	Total risk of bias
Oktay[9] 1992	C	B	A*	NA	B	B**	A*	4- Unsatisfactory
Endo et al.[10] 2010	A*	B	A*	NA	B	B**	A*	5- Satisfactory
Al-Ani et al.[21] 2011	A*	B	A*	NA	B	B**	A*	5- Satisfactory
Urabi and Al-Nakib[11] 2012	A*	B	A*	NA	B	B**	A*	5- Satisfactory
Dhiman et al.[19] 2015	A*	B	A*	NA	B	B**	A*	5- Satisfactory
Oksayan et al.[5] 2017	A*	B	A*	NA	B	A**	A*	5- Satisfactory
Qadir and Mushtaq[17] 2017	A*	B	A*	NA	B	B**	A*	5- Satisfactory
Yassaei et al.[6] 2018	B*	A*	A*	NA	B	A**	A*	6- Satisfactory
Andiappan[20] 2019	A*	B	A*	NA	B	B**	A*	5- Satisfactory
Goymen et al.[7] 2019	A*	A*	A*	NA	B	A**	A*	6- Satisfactory
Paluch et al.[18] 2020	B*	B	A*	NA	B	B**	A*	5- Satisfactory
Shrestha et al.[16] 2021	A*	A*	A*	NA	B	B**	A*	6- Satisfactory

Table 3. Maxillary sinus dimensions in sagittal malocclusion

Author	Parameter				Outcome
		Class I	Class II	Class II	
Oktay[9]	MSA	95.39±2.9	102.2±3.5	97.4±4.3	No significant effect
Endo et al.[10]	MSA	1500.1±236.3	1501.6±239.7	1509.2±201.5	No significant effect
	MSH	45.5±5.1	45.4±5.2	46.05±4.2	
	MSL	44.9±2.5	45.5±2.7	44.9±2.7	
Urabi and Al-Nakib[11]	MSA	1361.8	1406.9	1315.5	No significant effect
	MSH	43.3	42.7	42.8	
	MSL	43.3	44.4	43.7	
Qadir and Mushtaq[17]	MSA	1702.5±224.8	1721.8±227.3	1698.4±193.2	Length is greater in Class II
	MSH	41±4.6	40.9±4.8	41.5±3.2	
	MSL	41.5±2.6	42±2.4	40.9±2.4	
Yassaei et al.[6]	MSA	836.4±139.3	812.9±125.8	928.0±134	Height and area are greater in Class III
	MSH	40.8±3.7	38.6±4.1	41.3±4.3	
	MSL	35±3.7	35.5±4.1	36±3.5	
Andiappan[20]	MSA	1728	1286.8	1244.6	Increased in Class I
Dhiman et al.[19]	MSA	1337.5±100.1	1679.7±93.2	1183.9±117	Area greater in Class II
Shreshta et al.[16]	MSV	19,889.7±6844	28,680.3±6827.6	18091±9060.5	Greatest in Class II
Paluch et al.[18]	MSA	Class I - Class II = -4.5, Class I - Class III = -140.8, Class II - Class III = -136.3			Area in Class III greater

MSH, maxillary sinus height; MSL, maxillary sinus length; MSA, maxillary sinus area; MSW, maxillary sinus width; MSV, maxillary sinus volume

DISCUSSION

This systematic review was done to assess the maxillary sinus dimensions in various craniofacial patterns and to assess if the different craniofacial patterns have an influence on the sinus dimensions.

The proximity of the sinus floor with the root apex has its importance in the field of orthodontics.[4] Apart from the orthodontic side effects such as root resorption and pulp vitality,[22] the movement of the tooth against the cortical bone is another challenging problem to address.[23] Hence, the evaluation of the maxillary sinus dimensions among various craniofacial patterns is relevant for orthodontic treatment.

Among the 12 studies, Oktay[8] was graded as unsatisfactory because of the lack of skeletal classification of malocclusion and lack of availability of the statistical information. Only Shreshta et al.[16] and Goymen et al.[7] provided the justification for the sample

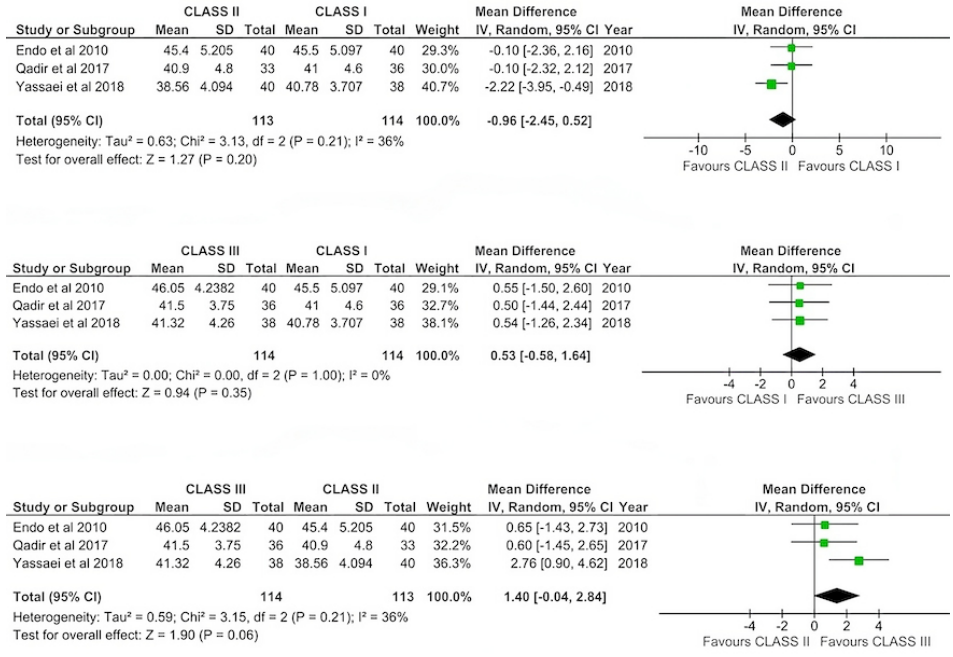

Figure 2. Forest plot comparing the maxillary sinus height between Class I, Class II and III sagittal malocclusion.
df, degrees of freedom; CI, confidence interval

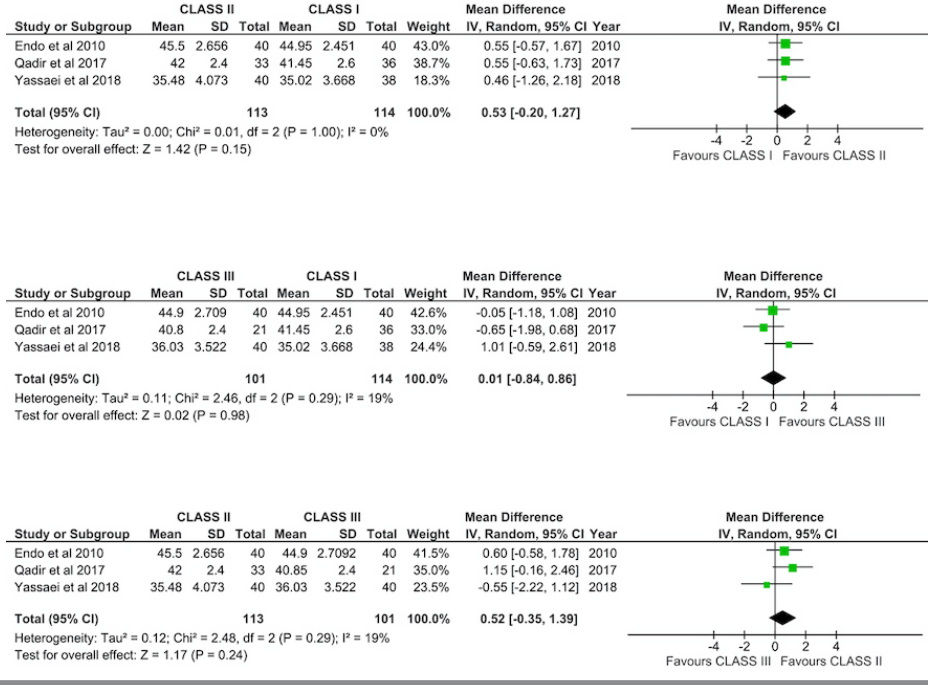

Figure 3. Forest plot comparing the maxillary sinus length between Class I, Class II and Class III sagittal malocclusion.
df, degrees of freedom; CI, confidence interval

size. The rest of the studies were graded as satisfactory due to lack of sample size calculation, lack of controlling the confounding factors such as age and sex,[6,9,18,21] and standardization of the growth pattern when the sagittal malocclusion was compared and vice versa.

The Class I and normodivergent data were considered normative in order to compare the dimensions between the groups. Prognathic maxilla associated with a Class II malocclusion could contribute to a greater sinus area. In the vertical dimension, the maxillary sinus area was greatest in the hyper-divergent followed by normodivergent and hypo-divergent growth patterns. The meta-analysis revealed no significant difference in the sinus volume between the growth patterns. Maxillary sinus size tends to be greater in males than in females.[24-27]

Study Limitations

Lack of published data with standardization of the growth pattern among the subjects classified into Class I, Class II or Class III, age and ethnicity.

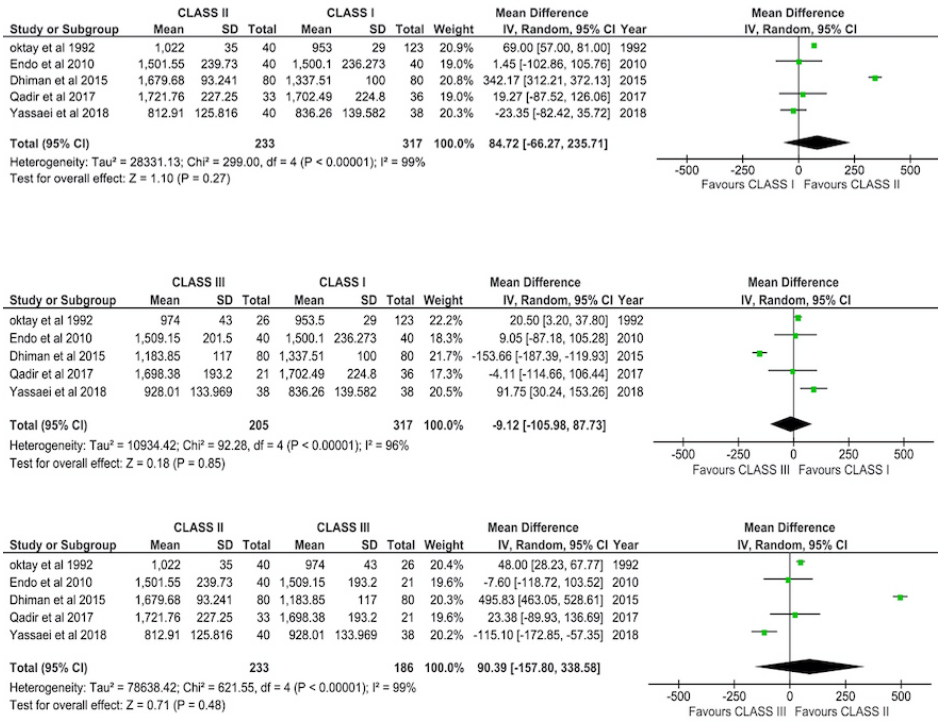

Figure 4. Forest plot comparing the maxillary sinus area between Class I, Class II and Class III sagittal malocclusion.
df, degrees of freedom; CI, confidence interval

Table 4. Maxillary sinus dimensions in vertical malocclusion

Author		Parameter			Outcome
		Hypo	Normo	Hyper	
Goymen at al.[7]	MSA	76.3±3.4	78.3±2	81.9±2.3	No significant difference
	MSH	37.5±1	38.4±0.6	37.7±0.8	
	MSW	32.8±0.7	33.9±0.6	35.1±0.7	
Shreshta et al.[16]	MSV	19042.94±75	20483.48±834	21305.89±7623.14	No effect
Al ani et al.[21]	MSA	1436.21±275.6	1524.41±260	1598±279.64	Height is greater in hyper-divergent
	MSH	37.15±4.57	40.18±4.33	42.1±4.4	
	MSL	38.47±3.93	37.81±3.47	37.8±3.4	
Oksayan et al.[5]	MSH	37.375±5.858	37.51±6.874	34.7±6.8	Length in low angle greater. Other dimensions show no difference
	MSL	37.7±4.769	35.6±5.95	35.6±4	
	MSW	28.34±4.603	27.48±5.627	26.5±5.0	
	MSV	15.2±4.51	13.8±5.412	12.7±4.5	
Yassaei et al.[6]	MSA, MSH and MSL	Correlation coefficient: SN- GoGn - R= -0.31, -0.071 and -0.376			MSA Is more in hypo-divergent group, MSH is more in hyper-divergent group, MSL is more in hypo-divergent group

MSH, maxillary sinus height; MSL, maxillary sinus length; MSA, maxillary sinus area; MSW, maxillary sinus width; MSV, maxillary sinus volume

CONCLUSION

Qualitative analysis of 12 studies done using the Modified Newcastle Ottawa (adapted for cross-sectional studies) scale reported 11 studies as being "satisfactory" and one study as "unsatisfactory". The GRADE approach indicated "low" overall certainty of evidence. Craniofacial form affects sinus dimensions with the vertical dimension appearing more critical.

Other Information

Protocol and Registration

This systematic review was conducted and reported following the PRISMA2020 guidelines (Preferred Reporting Items for Systematic Reviews and Meta-analysis).[28] The proposal was registered on the International Prospective Register of Systematic Reviews titled "Evaluation of maxillary sinus dimensions in

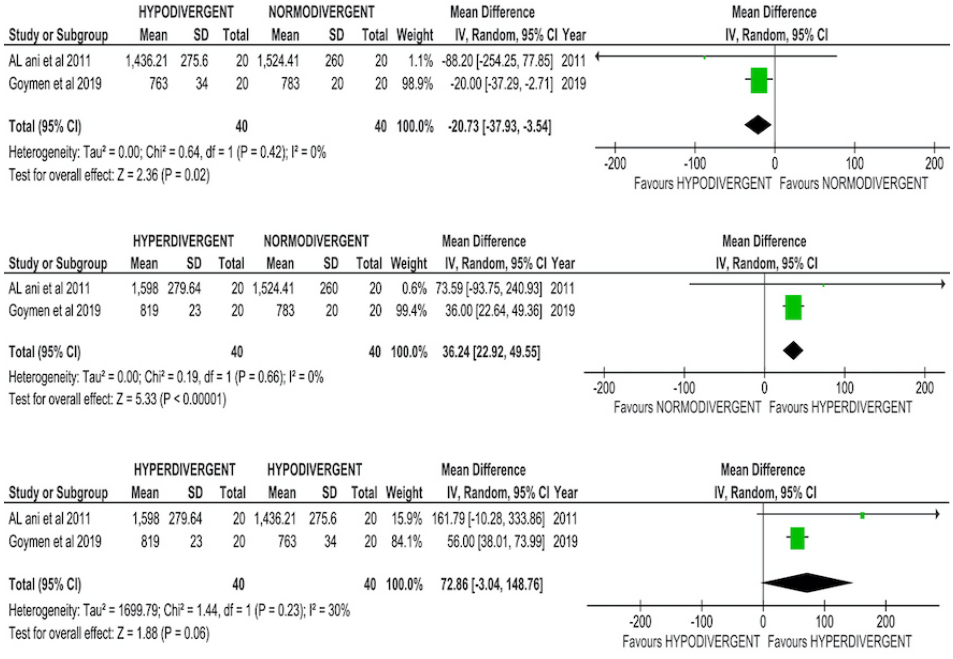

Figure 5. Forest plot comparing the maxillary sinus area between normo-divergent, hypo-divergent and hypo-divergent growth pattern. df, degrees of freedom; CI, confidence interval

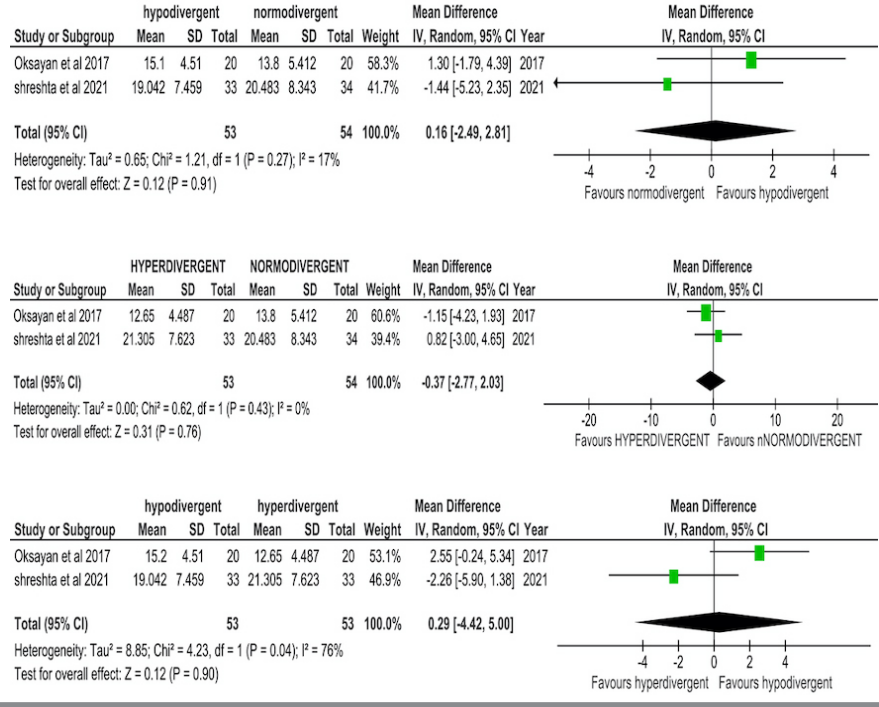

Figure 6. Forest plot comparing the maxillary sinus volume between normo-divergent, hypo-divergent and hyper-divergent growth pattern. df, degrees of freedom; CI, confidence interval

different craniofacial patterns: A systematic review and meta-analysis" (CRD42021229438).

Ethics

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - R.C., P.R., V.K., S.P.; Design - R.C., P.R.; Data Collection and/or Processing - R.C., P.R.; Analysis and/or Interpretation - R.C., P.R., V.K., S.P.; Writing - R.C., V.K., S.P.; Critical Review - V.K., S.P.

Declaration of Interests: The authors have no conflicts of interest to declare.

Funding: The authors declared that this study has received no financial support.

REFERENCES

1. Killey HC, Kay LW. The maxillary sinus and its dental implications. Bristol: J. Wright; 1975. [CrossRef]
2. Alberti PW. Applied surgical anatomy of the maxillary sinus. *Otolaryngol Clin North Am.* 1976;9(1):3-20. [CrossRef]
3. Proffit WR, Fields HW, Nixon WL. Occlusal forces in normal- and long-face adults. *J Dent Res.* 1983;62(5):566-570. [CrossRef]
4. Ahn NL, Park HS. Differences in distances between maxillary posterior root apices and the sinus floor according to skeletal pattern. *Am J Orthod Dentofacial Orthop.* 2017;152(6):811-819. [CrossRef]
5. Okşayan R, Sökücü O, Yeşildal S. Evaluation of maxillary sinus volume and dimensions in different vertical face growth patterns: a study of cone-beam computed tomography. *Acta Odontol Scand.* 2017;75(5):345-349. [CrossRef]
6. Yassaei S, Emami A, Mirbeigi S. Cephalometric association of mandibular size/length to the surface area and dimensions of the frontal and maxillary sinuses. *Eur J Dent.* 2018;12(2):253-261. [CrossRef]
7. Goymen M, Buyuknacar GB, Gulec A. Effect of Vertical Growth Pattern on Maxillary and Frontal Sinus Sizes. *European Journal of Therapeutics.* 2019;25(3):197-200. [CrossRef]
8. Bassil-Nassif N, Bouserhal J, Garcia R. Volumes faciaux et typologie verticale : étude comparative tridimensionnelle [Facial volumes and vertical facial type: a three dimensional comparative study]. *Orthod Fr.* 2010;81(2):127-137. [CrossRef]
9. Oktay H. The study of the maxillary sinus areas in different orthodontic malocclusions. *Am J Orthod Dentofacial Orthop.* 1992;102(2):143-145. [CrossRef]
10. Endo T, Abe R, Kuroki H, Kojima K, Oka K, Shimooka S. Cephalometric evaluation of maxillary sinus sizes in different malocclusion classes. *Odontology.* 2010;98(1):65-72. [CrossRef]
11. Urabi AH, Al-Nakib LH. Digital lateral cephalometric assessment of maxillary sinus dimensions in different skeletal classes. *J Univ Baghdad.* 2012;24(1):35-38. [CrossRef]
12. Herzog R, Álvarez-Pasquin MJ, Díaz C, Del Barrio JL, Estrada JM, Gil Á. Are healthcare workers' intentions to vaccinate related to their knowledge, beliefs and attitudes? A systematic review. *BMC Public Health.* 2013;13:154. [CrossRef]
13. Higgins JP, Thomas J, Chandler J, et al. Cochrane Handbook for Systematic Reviews of Interventions. John Wiley & Sons; 2019. [CrossRef]
14. Review Manager (RevMan) [Computer program]. Version 5.4. The Cochrane Collaboration, 2020. [CrossRef]
15. Ryan R, Hill S. How to GRADE the quality of the evidence. Cochrane Consumers and Communication Group, Version 3.0; 2016. [CrossRef]
16. Shrestha B, Shrestha R, Lin T, et al. Evaluation of maxillary sinus volume in different craniofacial patterns: a CBCT study. *Oral Radiol.* 2021;37(4):647-652. [CrossRef]
17. Qadir M, Mushtaq M. Maxillary sinus size and malocclusion: Is there any relation. *Int J Applied Dent Scie.* 2017;3(4):333-337. [CrossRef]
18. Paluch Z, Warnecki R, Nowak-Polak D, Kluczewska E. Morphometric differentiation of the maxillary sinus in craniofacial skeletal patterns. *Forum Ortodon.* 2020;16(2):91-100. [CrossRef]
19. Dhiman I, Singla A, Mahajan V, Jaj HS, Seth V, Negi P. Reliability of frontal sinus with that of maxillary sinus in assessment of different types of skeletal malocclusions. *J Indian Orthod Soc.* 2015;49(2):96-103. [CrossRef]
20. Andiappan A. Assessment of Frontal and Maxillary Sinus Area in Various Skeletal Malocclusions and their correlation with other Craniofacial Patterns: A Lateral Cephalometric study. [Doctoral dissertation]. Madurai: Best Dental Science College; 2019. [CrossRef]
21. Al-Ani RA, Al-Mashhadany SM, Al-Chalabi HM. The Size of Maxillary Sinus in Subjects with Different Vertical Discrepancies (A Lateral Cephalometric Study). *Iraqi Orthod J.* 2011;7(1):30-34. [CrossRef]
22. Talic NF. Adverse effects of orthodontic treatment: A clinical perspective. *Saudi Dent J.* 2011;23(2):55-59. [CrossRef]
23. Kuroda S, Tanaka E. Risks and complications of miniscrew anchorage in clinical orthodontics. *Jpn Dent Sci Rev.* 2014;50(4):79-85. [CrossRef]
24. Cohen O, Warman M, Fried M, et al. Volumetric analysis of the maxillary, sphenoid and frontal sinuses: A comparative computerized tomography based study. *Auris Nasus Larynx.* 2018;45(1):96-102. [CrossRef]
25. Möhlhenrich SC, Heussen N, Peters F, Steiner T, Hölzle F, Modabber A. Is the Maxillary Sinus Really Suitable in Sex Determination? A Three-Dimensional Analysis of Maxillary Sinus Volume and Surface Depending on Sex and Dentition. *J Craniofac Surg.* 2015;26(8):e723-e726. [CrossRef]
26. Maspero C, Farronato M, Bellincioni F, et al. Three-Dimensional Evaluation of Maxillary Sinus Changes in Growing Subjects: A Retrospective Cross-Sectional Study. *Materials (Basel).* 2020;13(4):1007. [CrossRef]
27. Hopkin GB, Houston WJ, James GA. The cranial base as an aetiological factor in malocclusion. *Angle Orthod.* 1968;38(3):250-255. [CrossRef]
28. Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *PLoS Med.* 2009;6(7):e1000100. [CrossRef]