EISSN 2148-9505

Indexed in PubMed, Web of Science and Scopus

Turkish Orthodontic Society

TURKISH JOURNAL of ORTHODONTICS

Volume 34
Issue 03
September 2021

AVES

turkjorthod.org

TURKISH JOURNAL of
ORTHODONTICS

Publisher
İbrahim KARA

Publication Director
Ali ŞAHİN

Editorial Development
Gizem KAYAN TEKAÜT

Deputy Publication Director
Gökhan ÇİMEN

Publication Coordinators
İrem SOYSAL
Arzu YILDIRIM
Deniz KAYA
Bahar ALBAYRAK
Gamze BİLGEN
Irmak BERBEROĞLU
Ebru BOZ

Finance and Administration
Zeynep YAKIŞIRER ÜREN

Project Coordinators
Sinem Fehime KOZ
Doğan ORUÇ
Emre KARA

Graphics Department
Ünal ÖZER
Deniz Elif DURAN

Contact
Address: Büyükdere Cad. No: 105/9
34394 Mecidiyeköy, Şişli-İstanbul
Phone: +90 212 217 17 00
Fax: +90 212 217 22 92
E-mail: info@avesyayincilik.com

TURKISH JOURNAL of ORTHODONTICS

Aims and Scopes

Turkish Journal of Orthodontics (Turk J Orthod) is an international, scientific, open access periodical published in accordance with independent, unbiased, and double-blinded peer-review principles. The journal is the official publication of Turkish Orthodontic Society and it is published quarterly on 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 and TÜBİTAK 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 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 turkjorthod.org.

OPEN ACCESS

Editor in Chief: Derya Germeç Çakan
Address: Bağdat Cad. No: 238, Göztepe,34728 İstanbul/Turkey
Phone: +90 216 468 08 00
Fax: +90 216 468 08 00
E-mail: info@turkjorthod.org

Publisher: AVES
Address: Büyükdere Cad. 105/9 34394 Mecidiyeköy, Şişli, İstanbul, Turkey
Phone: +90 212 217 17 00
Fax: +90 212 217 22 92
E-mail: info@avesyayincilik.com
Web page: avesyayincilik.com

TURKISH JOURNAL of ORTHODONTICS

Instructions to Authors

Turkish Journal of Orthodontics (Turk J Orthod) is an international, scientific, open access periodical published in accordance with independent, unbiased, and double-blinded peer-review principles. The journal is the official publication of Turkish Orthodontic Society and it is published quarterly on 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.

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 photographs that may reveal the identity of the patients, releases signed by the patient or their legal representative should be enclosed.

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:

1. 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 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 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 December 2017 - http://www.icmje.org/icmje-recommendations.pdf). 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 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 Transfer Form,
- Author Contributions 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 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 1 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).

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 1 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 1 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 1 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.

Table 1. Limitations for each manuscript type

TYPE OF MANUSCRIPT	WORD LIMIT	ABSTRACT WORD LIMIT	REFERENCE LIMIT	TABLE LIMIT	FIGURE LIMIT
ORIGINAL ARTICLE	4500	250 (Structured)	30	6	7 or total of 15 images
REVIEW ARTICLE	5000	250	50	6	10 or total of 20 images
CASE REPORT	1000	200	15	No tables	10 or total of 20 images
LETTER TO THE EDITOR	500	No abstract	5	No tables	No media

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

While citing publications, preference should be given to the latest, most up-to-date publications. If an ahead-of-print publication is cited, the DOI number should be provided. Authors are responsible for the accuracy of references. 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 six authors should be listed followed by "et al." In the main text of the manuscript, references should be cited using Arabic numbers in parentheses. The reference styles for different types of publications are presented in the following examples.

Journal Article: Rankovic A, Rancic N, Jovanovic M, Ivanović M, Gajović O, Lazić Z, et al. Impact of imaging diagnostics on the budget – Are we spending too much? Vojnosanit Pregl 2013; 70: 709-11.

Book Section: Suh KN, Keystone JS. Malaria and babesiosis. Gorbach SL, Barlett JG, Blacklow NR, editors. Infectious Diseases. Philadelphia: Lippincott Williams; 2004.p.2290-308.

Books with a Single Author: Sweetman SC. Martindale the Complete Drug Reference. 34th ed. London: Pharmaceutical Press; 2005.

Editor(s) as Author: Huizing EH, de Groot JAM, editors. Functional reconstructive nasal surgery. Stuttgart-New York: Thieme; 2003.

Conference Proceedings: Bengisson S. Sothemin BG. Enforcement of data protection, privacy and security in medical informatics. In: Lun KC, Degoulet P, Piemme TE, Rienhoff O, editors. MEDINFO 92. Proceedings of the 7th World Congress on Medical Informatics; 1992 Sept 6-10; Geneva, Switzerland. Amsterdam: North-Holland; 1992. pp.1561-5.

Scientific or Technical Report: Cusick M, Chew EY, Hoogwerf B, Agrón E, Wu L, Lindley A, et al. Early Treatment Diabetic Retinopathy Study Research Group. Risk factors for renal replacement therapy in the Early Treatment Diabetic Retinopathy Study (ETDRS), Early Treatment Diabetic Retinopathy Study Kidney Int: 2004. Report No: 26.

Thesis: Yılmaz B. Ankara Üniversitesindeki Öğrencilerin Beslenme Durumları, Fiziksel Aktiviteleri ve Beden Kitle İndeksleri Kan Lipidleri Arasındaki Ilişkiler. H.Ü. Sağlık Bilimleri Enstitüsü, Doktora Tezi. 2007.

Manuscripts Accepted for Publication, Not Published Yet: Slots J. The microflora of black stain on human primary teeth. Scand J Dent Res. 1974.

Epub Ahead of Print Articles: Cai L, Yeh BM, Westphalen AC, Roberts JP, Wang ZJ. Adult living donor liver imaging. Diagn Interv Radiol. 2016 Feb 24. doi: 10.5152/dir.2016.15323. [Epub ahead of print].

Manuscripts Published in Electronic Format: Morse SS. Factors in the emergence of infectious diseases. Emerg Infect Dis (serial online) 1995 Jan-Mar (cited 1996 June 5): 1(1): (24 screens). Available from: URL: http:/ www.cdc.gov/ncidodlElD/cid.htm.

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. 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: Derya Germeç Çakan
Address: Bağdat Cad. No: 238, Göztepe,34728 İstanbul/Turkey
Phone: +90 216 468 08 00
Fax: +90 216 468 08 00
E-mail: info@turkjorthod.org

Publisher: AVES
Address: Büyükdere Cad. 105/9 34394 Mecidiyeköy, Şişli, İstanbul, Turkey
Phone: +90 212 217 17 00
Fax: +90 212 217 22 92
E-mail: info@avesyayincilik.com
avesyayincilik.com

TURKISH JOURNAL of ORTHODONTICS

Contents

TURKISH JOURNAL of ORTHODONTICS

DOI: 10.5152/TurkJOrthod.2021.21060921

Editorial

Call for Emergency Action to Limit Global Temperature Increases, Restore Biodiversity, and Protect Health

Lukoye Atwoli[1], Abdullah H Baqui[2], Thomas Benfield[3], Raffaella Bosurgi[4], Fiona Godlee[5], Stephen Hancocks[6], Richard Horton[7], Laurie Laybourn-Langton[8], Carlos Augusto Monteiro[9], Ian Norman[10], Kirsten Patrick[11], Nigel Praities[12], Marcel G M Olde Rikkert[13], Eric J Rubin[14], Peush Sahni[15], Richard Smith[8], Nicholas J Talley[16], Sue Turale[17], Damián Vázquez[18]

[1]East African Medical Journal
[2]Journal of Health, Population and Nutrition
[3]Danish Medical Journal
[4]PLOS Medicine
[5]The BMJ
[6]British Dental Journal
[7]The Lancet
[8]UK Health Alliance on Climate Change
[9]Revista de Saúde Pública
[10]International Journal of Nursing Studies
[11]CMAJ
[12]Pharmaceutical Journal
[13]Dutch Journal of Medicine
[14]NEJM
[15]National Medical Journal of India
[16]Medical Journal of Australia
[17]International Nursing Review
[18]Pan American Journal of Public Health

Wealthy nations must do much more, much faster

The UN General Assembly in September 2021 will bring countries together at a critical time for marshalling collective action to tackle the global environmental crisis. They will meet again at the biodiversity summit in Kunming, China, and the climate conference (COP26) in Glasgow, UK. Ahead of these pivotal meetings, we—the editors of health journals worldwide—call for urgent action to keep average global temperature increases below 1.5°C, halt the destruction of nature, and protect health.

Health is already being harmed by global temperature increases and the destruction of the natural world, a state of affairs health professionals have been bringing attention to for decades.[1] The science is unequivocal; a global increase of 1.5°C above the pre-industrial average and the continued loss of biodiversity risk catastrophic harm to health that will be impossible to reverse.[2,3] Despite the world's necessary preoccupation with covid-19, we cannot wait for the pandemic to pass to rapidly reduce emissions.

Reflecting the severity of the moment, this editorial appears in health journals across the world. We are united in recognising that only fundamental and equitable changes to societies will reverse our current trajectory.

The risks to health of increases above 1.5°C are now well established.[2] Indeed, no temperature rise is "safe." In the past 20 years, heat related mortality among people aged over 65 has increased by more than 50%.[4] Higher temperatures have brought increased dehydration and renal function loss, dermatological malignancies, tropical infections, adverse mental health outcomes, pregnancy complications, allergies, and cardiovascular and pulmonary morbidity and mortality.[5,6] Harms disproportionately affect the most vulnerable, including among children, older populations, ethnic minorities, poorer communities, and those with underlying health problems.[2,4]

Corresponding author: Laurie Laybourn-Langton, email: laurie.laybourn@ukhealthalliance.org

Global heating is also contributing to the decline in global yield potential for major crops, falling by 1.8-5.6% since 1981; this, together with the effects of extreme weather and soil depletion, is hampering efforts to reduce undernutrition.[4] Thriving ecosystems are essential to human health, and the widespread destruction of nature, including habitats and species, is eroding water and food security and increasing the chance of pandemics.[3,7,8]

The consequences of the environmental crisis fall disproportionately on those countries and communities that have contributed least to the problem and are least able to mitigate the harms. Yet no country, no matter how wealthy, can shield itself from these impacts. Allowing the consequences to fall disproportionately on the most vulnerable will breed more conflict, food insecurity, forced displacement, and zoonotic disease—with severe implications for all countries and communities. As with the covid-19 pandemic, we are globally as strong as our weakest member.

Rises above 1.5°C increase the chance of reaching tipping points in natural systems that could lock the world into an acutely unstable state. This would critically impair our ability to mitigate harms and to prevent catastrophic, runaway environmental change.[9,10]

Global targets are not enough

Encouragingly, many governments, financial institutions, and businesses are setting targets to reach net-zero emissions, including targets for 2030. The cost of renewable energy is dropping rapidly. Many countries are aiming to protect at least 30% of the world's land and oceans by 2030.[11]

These promises are not enough. Targets are easy to set and hard to achieve. They are yet to be matched with credible short and longer term plans to accelerate cleaner technologies and transform societies. Emissions reduction plans do not adequately incorporate health considerations.[12] Concern is growing that temperature rises above 1.5°C are beginning to be seen as inevitable, or even acceptable, to powerful members of the global community.[13] Relatedly, current strategies for reducing emissions to net zero by the middle of the century implausibly assume that the world will acquire great capabilities to remove greenhouse gases from the atmosphere.[14,15]

This insufficient action means that temperature increases are likely to be well in excess of 2°C,[16] a catastrophic outcome for health and environmental stability. Critically, the destruction of nature does not have parity of esteem with the climate element of the crisis, and every single global target to restore biodiversity loss by 2020 was missed.[17] This is an overall environmental crisis.[18]

Health professionals are united with environmental scientists, businesses, and many others in rejecting that this outcome is inevitable. More can and must be done now—in Glasgow and Kunming—and in the immediate years that follow. We join health professionals worldwide who have already supported calls for rapid action.[1,19]

Equity must be at the centre of the global response. Contributing a fair share to the global effort means that reduction commitments must account for the cumulative, historical contribution each country has made to emissions, as well as its current emissions and capacity to respond. Wealthier countries will have to cut emissions more quickly, making reductions by 2030 beyond those currently proposed[20,21] and reaching net-zero emissions before 2050. Similar targets and emergency action are needed for biodiversity loss and the wider destruction of the natural world.

To achieve these targets, governments must make fundamental changes to how our societies and economies are organised and how we live. The current strategy of encouraging markets to swap dirty for cleaner technologies is not enough. Governments must intervene to support the redesign of transport systems, cities, production and distribution of food, markets for financial investments, health systems, and much more. Global coordination is needed to ensure that the rush for cleaner technologies does not come at the cost of more environmental destruction and human exploitation.

Many governments met the threat of the covid-19 pandemic with unprecedented funding. The environmental crisis demands a similar emergency response. Huge investment will be needed, beyond what is being considered or delivered anywhere in the world. But such investments will produce huge positive health and economic outcomes. These include high quality jobs, reduced air pollution, increased physical activity, and improved housing and diet. Better air quality alone would realise health benefits that easily offset the global costs of emissions reductions.[22]

These measures will also improve the social and economic determinants of health, the poor state of which may have made populations more vulnerable to the covid-19 pandemic.[23] But the changes cannot be achieved through a return to damaging austerity policies or the continuation of the large inequalities of wealth and power within and between countries.

Cooperation hinges on wealthy nations doing more

In particular, countries that have disproportionately created the environmental crisis must do more to support low and middle income countries to build cleaner, healthier, and more resilient societies. High income countries must meet and go beyond their outstanding commitment to provide $100bn a year, making up for any shortfall in 2020 and increasing contributions to and beyond 2025. Funding must be equally split between mitigation and adaptation, including improving the resilience of health systems.

Financing should be through grants rather than loans, building local capabilities and truly empowering communities, and should come alongside forgiving large debts, which constrain the agency of so many low income countries. Additional funding must be marshalled to compensate for inevitable loss and damage caused by the consequences of the environmental crisis.

As health professionals, we must do all we can to aid the transition to a sustainable, fairer, resilient, and healthier world. Alongside acting to reduce the harm from the environmental crisis, we should proactively contribute to global prevention of further damage and action on the root causes of the crisis. We must hold global leaders to account and continue to educate others about the health risks of the crisis. We must join in the work to achieve environmentally sustainable health systems before 2040, recognising that this will mean changing clinical practice. Health institutions have already divested more than $42bn of assets from fossil fuels; others should join them.[4]

The greatest threat to global public health is the continued failure of world leaders to keep the global temperature rise below 1.5°C and to restore nature. Urgent, society-wide changes must be made and will lead to a fairer and healthier world. We, as editors of health journals, call for governments and other leaders to act, marking 2021 as the year that the world finally changes course.

Competing interests: We have read and understood BMJ policy on declaration of interests and FG serves on the executive committee for the UK Health Alliance on Climate Change and is a Trustee of the Eden Project. RS is the chair of Patients Know Best, has stock in UnitedHealth Group, has done consultancy work for Oxford Pharmagenesis, and is chair of the Lancet Commission of the Value of Death. None further declared.

Provenance and peer review: Commissioned; not externally peer reviewed.

This editorial is being published simultaneously in many international journals. Please see the full list here: https://www.bmj.com/content/full-list-authors-and-signatories-climate-emergency-editorial-september-2021

REFERENCES

1. Healthy Recovery. *In Support of a Health Recovery*. 2018. Available at: https://healthyrecovery.net.
2. Intergovernmental Panel on Climate Change (IPCC). Summary for policymakers. In: *Global Warming of 1.5°C. An IPCC Special Report on the Impacts of Global Warming of 1.5°C Above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty*. 2018.
3. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Summary for policymakers: the global assessment report on biodiversity and ecosystem services. 2019. Available at: https://ipbes.net/sites/default/files/2020-02/ipbes_global_assessment_report_summary_for_policymakers_en.pdf.
4. Watts N, Amann M, Arnell N, et al. The 2020 report of the Lancet Countdown on health and climate change: responding to converging crises. *Lancet*. 2021;397(10269):129-170. [CrossRef]
5. Rocque RJ, Beaudoin C, Ndjaboue R, et al. Health effects of climate change: an overview of systematic reviews. *BMJ Open*. 2021;11(6):e046333. [CrossRef]
6. Haines A, Ebi K. The imperative for climate action to protect health. *N Engl J Med*. 2019;380(3):263-273. [CrossRef]
7. United Nations Environment Programme, International Livestock Research Institute. *Preventing the Next Pandemic: Zoonotic Diseases and How to Break the Chain of Transmission*. 2020. Available at: https://72d37324-5089-459c-8f70-271d19427cf2.filesusr.com/ugd/056cf4_b5b2fc067f094dd3b2250cda15c47acd.pdf</bok>.
8. Intergovernmental Panel on Climate Change (IPCC). Summary for policymakers. In: *Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems*. 2019.
9. Lenton TM, Rockström J, Gaffney O, et al. Climate tipping points: too risky to bet against. *Nature*. 2019;575(7784):592-595. [CrossRef]
10. Wunderling N, Donges JF, Kurths J, Winkelmann R. Interacting tipping elements increase risk of climate domino effects under global warming. *Earth Syst Dyn Discuss*. 2020:1-21.
11. High Ambition Coalition (HAC). High ambition coalition. Available at: https://www.hacfornatureandpeople.org.
12. Global Climate and Health Alliance. Are national climate commitments enough to protect our health? Available at: https://climateandhealthalliance.org/initiatives/healthy-ndcs/ndc-scorecards/.
13. Carbon Brief. Climate strikers: open letter to EU leaders on why their new climate law is 'surrender'. 2020. Available at: https://www.carbonbrief.org/climate-strikers-open-letter-to-eu-leaders-on-why-their-new-climate-law-is-surrender.
14. Fajardy M, Köberle A, MacDowell N, Fantuzzi A. "BECCS deployment: a reality check". *Grantham Institute Briefing Paper 28*. 2019. Available at: https://www.imperial.ac.uk/media/imperial-college/grantham-institute/public/publications/briefing-papers/BECCS-deployment---a-reality-check.pdf</eref>.
15. Anderson K, Peters G. The trouble with negative emissions. *Science*. 2016;354(6309):182-183. [CrossRef]
16. Climate Action Tracker. Available at: https://climateactiontracker.org.
17. Secretariat of the Convention on Biological Diversity. *Global Biodiversity Outlook 5*. 2020. Available at: https://www.cbd.int/gbo5.
18. Steffen W, Richardson K, Rockström J, et al. Sustainability. Planetary boundaries: guiding human development on a changing planet. *Science*. 2015;347(6223):1259855. [CrossRef]
19. UK Health Alliance on Climate Change. Our calls for action. 2015. http://www.ukhealthalliance.org/cop26/.
20. Climate Action Tracker. Warming projections global update. 2021. Available at: https://climateactiontracker.org/documents/853/CAT_2021-05-04_Briefing_Global-Update_Climate-Summit-Momentum.pdf.
21. United Nations Environment Programme (UNEP). *Emissions Gap Report 2020*. Nairobi, Kenya: UNEP; 2020.
22. Markandya A, Sampedro J, Smith SJ, et al. Health co-benefits from air pollution and mitigation costs of the Paris Agreement: a modelling study. *Lancet Planet Health*. 2018;2(3):e126-e133. [CrossRef]
23. Paremoer L, Nandi S, Serag H, Baum F. COVID-19 pandemic and the social determinants of health. *BMJ*. 2021;372:n129. [CrossRef]

TURKISH JOURNAL of ORTHODONTICS

DOI: 10.5152/TurkJOrthod.2021.20103

Original Article

Skeletal and Dental Effects of Twin-Block Appliances in Patients Treated With or Without Expansion

Muhammed Hilmi Buyukcavus[1], Burak Kale[2]

[1]Department of Orthodontics, Suleyman Demirel University, Faculty of Dentistry, Isparta, Turkey
[2]Department of Orthodontics, Antalya Bilim University, Faculty of Dentistry, Antalya, Turkey

Cite this article as: Buyukcavus MH, Kale B. Skeletal and dental effects of twin-block appliances in patients treated with or without expansion. *Turk J Orthod.* 2021; 34(3): 155-162.

Main Points

- Due to the addition of expansion screws to the twin-block appliance, expansion and functional treatment are simultaneous.
- Including expansion in the twin-block treatment allows dental expansion but not transverse skeletal expansion.
- In addition to eliminating the maxillary transverse deficiency, it is possible to gain space due to an increase in the length of the arch and intercanine and intermolar distances using the twin-block appliance with expansion.

ABSTRACT

Objective: To compare the skeletal and dental effects of twin-block appliances with or without expansion.

Methods: From our archives, patients using twin-block appliances were selected. A total of 20 patients with expansion screws were classified as group 1 (10 male, 10 female; mean age 12.48 ± 1.38 years), and 18 patients without screws as group 2 (8 male, 10 female; mean age 12.81 ± 1.16 years). Cephalometric radiographs at pre-and post-treatment were used to evaluate skeletal and dentoalveolar parametric changes; study models and posteroanterior radiographs were used for transverse evaluation. The initial measurements and the treatment-related mean changes within the study groups were analyzed using the Student's *t*-test.

Results: Changes in maxillary skeletal measurements were not statistically significantly different between groups except for A-VRL ($P > .05$). Mandibular measurements showed an increase in SNB (°) and Co-Gn distance in both groups. However, these changes were similar for both groups ($P > .05$). The maxillary measurements showed that incisors were proclined in the expansion group and retroclined in the non-expansion group. No significant difference was found between the groups in terms of changes in the skeletal transversal measurements ($P > .05$). On the study models, the changes in maxillary intercanine and intermolar widths, and in arch length differed to a statistically significant degree between groups ($P < .05$).

Conclusion: The skeletal effects of 2 different types of twin-block appliances in the transversal direction were similar; it was determined that dental expansion was obtained in the maxilla by adding screws to the twin-block appliances.

Keywords: Twin-block, expansion, posteroanterior, cephalometrics

INTRODUCTION

The twin-block functional orthodontic appliance was developed by William Clark. It is frequently used for functional correction of the mandible in the treatment of Class II Division 1 malocclusion and initially consisted of interconnected acrylic occlusal bite blocks in the form of a simple removable appliance.[1,2] While this basic principle is still applied, the design of the functional appliance has varied over the years for the treatment of skeletal Class II malocclusion, as greater understanding of the appliance and treatment technique are gained. Appliance design has been made easier and become more acceptable to patients by improving and simplifying the appliance without reducing its effectiveness. One of the most important advantages is that the twin-block appliance can be designed in different ways. Hence, the twin-block appliance largely meets the needs of patients of a wide range of ages, from childhood to adulthood, with various types of malocclusions. This is because the

Corresponding author: Muhammed Hilmi Buyukcavus, e-mail: mhbuyukcvs@gmail.com

Received: August 17, 2020
Accepted: February 28, 2021

upper and lower pieces consist of 2 separate parts, and the parts can be individually designed to address the needs of both arches independently.[2]

The systematic review by Cozza et al.[3] searched for answers to 2 key questions. First, is mandibular growth in individuals with Class II anomalies treated with functional appliances more likely than in untreated Class II anomalies? Second, is the average effect of functional appliances on mandibular length clinically significant? Of the 22 articles that met the author's criteria, 66% found total clinically significant growth (mandibular length) with active treatment with functional appliances. The Herbst appliance (0.28 mm/month) was found to have the highest efficiency coefficient among the functional appliances used, followed by the twin-block (0.23 mm/month).

However, many investigators have reported undesirable effects of functional appliances, such as retraction in maxillary incisors and protrusion in mandibular incisors.[4-6] To reduce the protrusion effect of the activator on the mandibular incisors, the researchers made various modifications to the activator. In the Van Beek activator designed for this purpose, the labial surfaces of the lower incisors were covered with acrylic.[7]

It is also possible to expand the maxillary arch by adding active parts to the appliances, such as screws. The design of these parts is advantageous for patients with mandibular retrognathia with transversal constriction of the maxilla. Conventionally, these patients require maxillary expansion after functional treatment, which can result in prolonged duration of orthodontic treatment, reduction in patient cooperation, and loss of time and cost for the physician. The fact that the 2 parts of the twin-block appliances are independent of one another enables the mandible to be extended while simultaneously expanding the maxilla.[8,9]

In the literature, there are limited studies about the transversal effects of functional appliances. Therefore, the aims of our study were to reveal the transversal effects of the twin-block appliance and to compare the short-term skeletal and dental effects of the twin-block appliance with and without expansion.

METHODS

A parallel-group retrospective clinical study was performed. Ethical approval was obtained from the Clinical Research Ethics Committee, Suleyman Demirel University (28.05.2019/186).

Patients were recruited at the Suleyman Demirel University, Faculty of Dentistry, Department of Orthodontics, from 2018 to 2019. Written informed consent was obtained from all patients who applied to our clinic for treatment, each indicating that their radiographs or materials could be used in scientific articles. The following inclusion criteria were applied: (1) Class II malocclusions characterized by a retrognathic mandible (SNB < 76°, ANB > 4°), (2) overjet of 6 mm or more, (3) Class II molar relationships, (4) CVM between stage 2 and 3 in initial records (Lamparski method), (5) treated with a twin-block appliance with or without screws, (6) posteroanterior and lateral cephalometric radiographs and study models taken before and after functional treatment, and (7) landmarks identifiable on all radiographs. Those with a history of orthodontic treatment or craniofacial syndromes, and patients treated with different functional appliances were excluded (Figure 1).

All twin-block appliances were made by the same orthodontic technician. The features of the appliances were: (1) Adam's clasps on the first molars and premolars or deciduous molars, (2) a 3-sided (Bertoni) screw placed and activated in the upper plate (in the expansion group), (3) acrylic blocks constructed at 70° to the occlusal plane, (4) upper vestibule arch placed

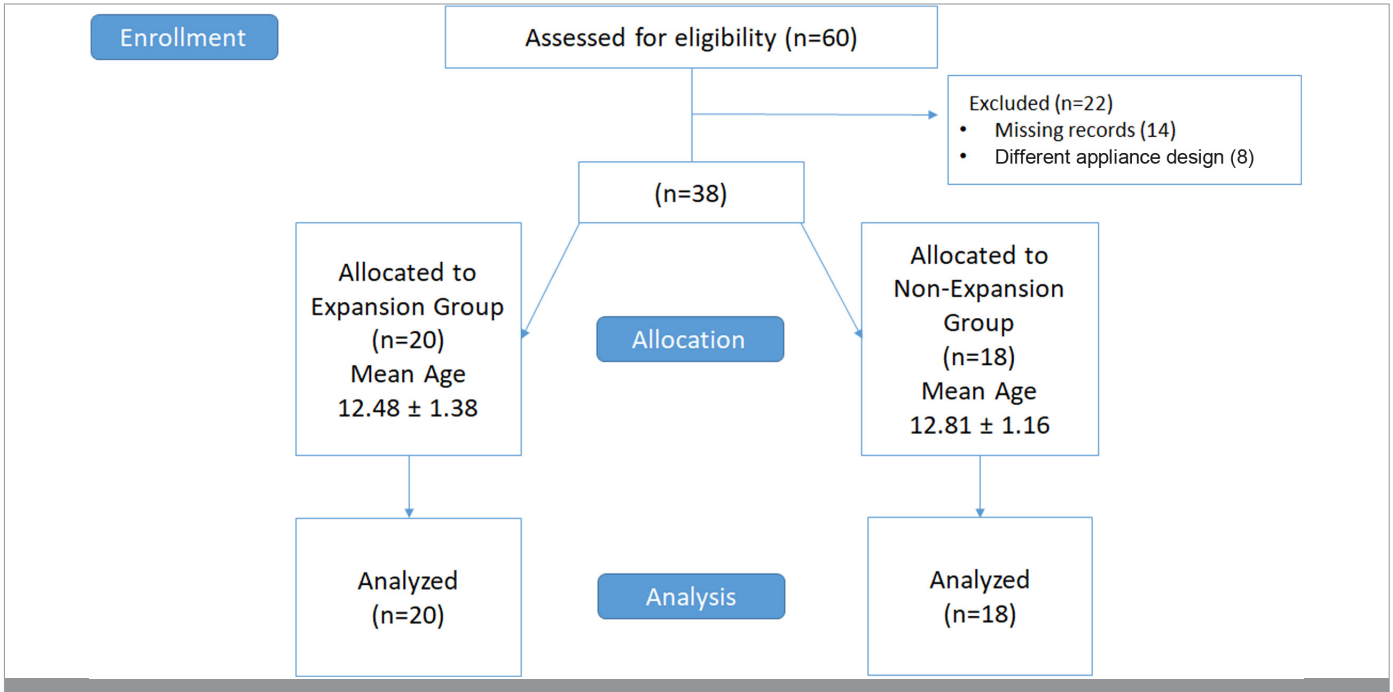


Figure 1. Flow diagram of the groups.

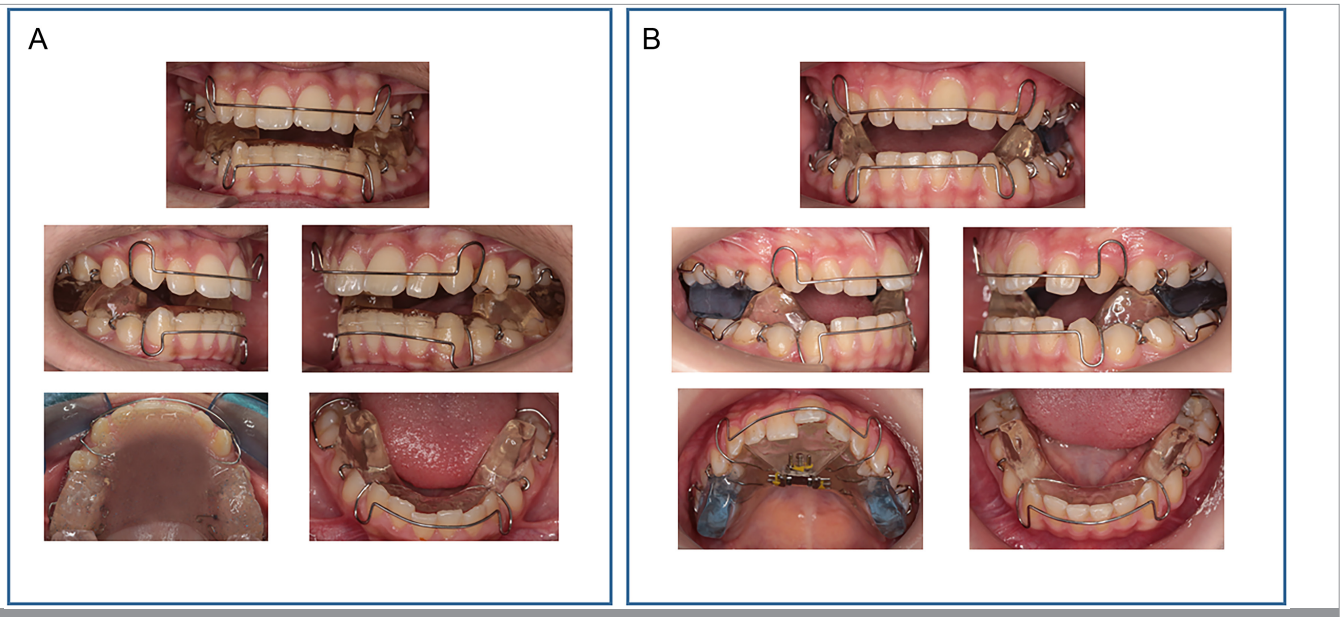


Figure 2. Intraoral view of twin-block appliances without expansion (A) and with expansion (B).

canine-to-canine, and (5) ball-ended clasps on the mandibular incisors. Construction bite registration was obtained in edge-to-edge relation within 2 mm interincisal space (Figure 2).

In patients with transverse deficiency in the maxilla, the mandible was brought forward, while maxillary expansion with screw was performed in the expansion group (Group 1). Patients without transversal deficiency were placed into the non-expansion group (Group 2). In group 1, expansion of the maxilla was performed until posterior crossbite improved.

An appropriate sample size was calculated using the formula recommended by Pandis,[10] for a significance level of 0.05, and a power of 80%, to detect clinically meaningful differences between the groups. A power analysis showed that 31 patients were needed for the study. A total sample of 34 patients (17 per group) was therefore required, although a further 4 patients were recruited to allow for potential attrition. A total of 20 individuals (10 males, 10 females; 12.48 ± 1.38 years) were included in the expansion group, and 18 individuals (8 males, 10 females; 12.81 ± 1.16 years) were included in the non-expansion group, according to the criteria.

All patients were treated by the same clinician during the twin-block treatment (MHB). Since both device types are routinely used in clinical practice, patients were instructed to wear the appliance full-time, except during meals, and for the duration specified on the patient-treatment form. Patient cooperation was evaluated. T0 (pre-treatment) and T1 (post-treatment, i.e., after functional treatment) cephalograms and posteroanterior radiographs were obtained using a standard lateral cephalometric X-ray device (Planmeca ProMax 3D Mid, Planmeca Oy, Helsinki, Finland). Transversal measurements were also performed on the study models pre- and post-treatment.

All lateral cephalometric radiographs were analyzed with Dolphin 3D software (Version 11.8, Dolphin Imaging & Management Solutions, Chatsworth, California, USA) by the single author (BK), who was blinded to the type of appliance. To detect skeletal and dental effects on the radiographs, measurements were also made using reference planes. On each radiograph, a horizontal reference line (HRL) was constructed passing through the tuberculum sella (T) and wing points (W) and a perpendicular line passing through the T as a vertical reference line (VRL) (Figure 3).

Posteroanterior radiographs and study models were used to assess the transversal effects of 2 different twin-block appliances. Dolphin 3D analysis software was used to measure internasal, interfacial (interzygomatic), maxillary (interjugular), and mandibular (intergonial) widths on posteroanterior radiographs. On the study models, intercanine, intermolar, and interpremolar distances and alveolar width were measured with digital calipers, along with maxillary and maxillary arch lengths.

Statistical Analysis

Twenty-five randomly selected lateral cephalometric radiographs were traced 15 days after first measurement by the same clinician. The method error was calculated using the Houston test, which indicated the reliability of the measurements ($r \geq 0.961$). In addition, the results of a paired *t*-test showed that the data were free of systematic error ($P > .05$).

Parametric tests were performed for data analysis because a Shapiro–Wilks test showed normal distribution. The gender distribution in each group was tested using a Pearson chi-square test. Because there was no significant difference between the genders in the chi-square test, the gender factor was ignored in our study ($P > .05$). The changes observed in each group were analyzed using the paired *t*-test, and the initial measurements and the mean changes within the groups were analyzed using a Student's *t*-test. All statistical analyses were performed using the SPSS software package program the Statistical Package for

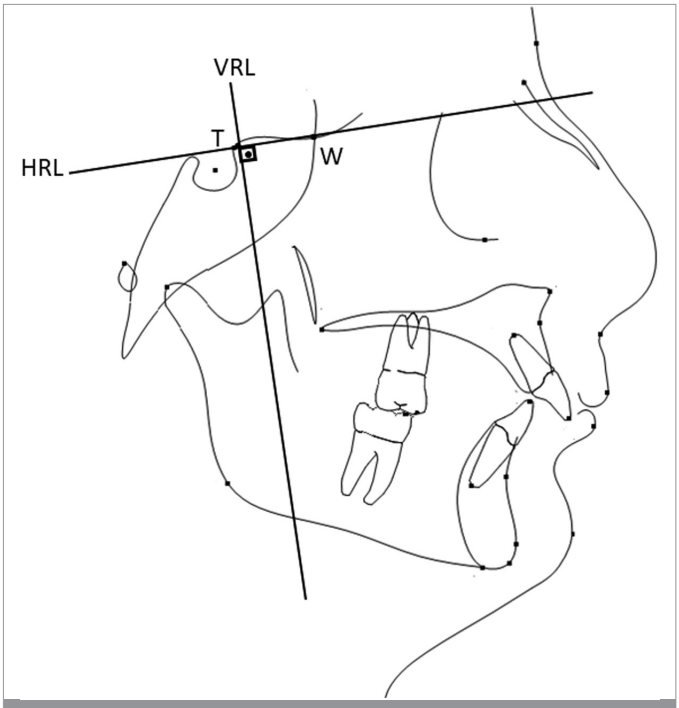


Figure 3. Measurements based on horizontal (HRL) and vertical (VRL) reference lines.

Social Sciences, version 20.0 software (SPSS Inc.; Chicago,IL, USA). at a significance level of $P < .05$.

RESULTS

Table 1 shows the descriptive data of the patients included in the study. No statistically significant differences were found between groups in terms of chronological age, gender distribution and treatment time, as tested by Pearson chi-square and Student's *t*-tests, respectively ($P > .05$). A comparison of the initial values of the groups is shown in Table 2. According to the results of the Student's *t*-test, no significant difference was found between the 2 groups in the initial measurements except for U1-PP (º) and IMPA (º) measurements ($P > .05$). On the other hand, there was a difference in the initial values of both groups in transversal measurements in maxillary interpremolar and intercanine widths and arch length ($P < .05$). The patients in both groups had a skeletal Class II malocclusion due to mandibular retrognathism with normal vertical growth patterns.

Table 3 shows the statistical comparison of the mean changes that occurred in groups using the independent *t*-test. Maxillary measurements showed decreased SNA (º) in both groups, while Co-A distance increased in both groups. A-HRL and A-VRL measurements increased in both groups due to forward and downward movement at point A ($P < .001$). However, there were no statistically significant differences between groups, except A-VRL ($P > .05$). Mandibular measurements showed an increase in SNB (º) and Co-Gn distance in both groups ($P < .001$). At the B and Pg points, B-HRL, B-VRL, Pg-HRL, and Pg-VRL measurements increased in both groups due to forward and downward movement. However, no statistically significant differences were found between groups ($P > .05$). Those changes in the maxilla and the mandible caused an improvement in the maxillo–mandibular relationships.

When the maxillary dentoalveolar measurements were compared, a statistically significant increase in U1-PP (º), U1-VRL, and U1-HRL measurements was found in the expansion group, and a statistically significant decrease was found in the non-expansion group ($P < .001$). the changes in U1-PP and U1-VRL were significantly different between groups ($P < .05$). When mandibular dentoalveolar measurements were compared, the increase in IMPA were similar in both groups ($P > .05$). Both overjet and overbite decreased due to dentoalveolar changes. However, there was no statistically significant difference between groups ($P > .05$).

When the transversal measurements were evaluated, no statistically significant differences were found in the measurements on posteroanterior radiographs, both in non-expansion group and intergroup ($P > .05$). Transverse measurements on the study models showed no statistically significant differences between interdental widths, intragroup and between groups, and in alveolar width measurements in the mandible ($P > .05$). Regarding maxillary measurements, the treatments in the groups resulted in changes that were statistically significant ($P < .05$); intercanine, intermolar widths, and arch length changes between groups were statistically significant ($P < .05$).

DISCUSSION

Class II malocclusions are one of the most common types of malocclusion treated by orthodontists.[11,12] These malocclusions may occur as a result of various skeletal and dental combinations[13]; however, it has been reported that they are mostly caused by mandibular retrognathism.[14] Functional appliances are often used in the treatment of Class II Division 1 malocclusions caused by mandibular retrognathia.[15] The objectives of functional orthopedic treatment for skeletal Class II malocclusions are the formation of an orthognathic profile and the reduction of mandibular retrognathia,

Table 1. Comparison of the chronological age, CVM periods, gender distributions, and treatment time between groups

	Gender Distribution (Male/Female)	Chronological Age Mean±SD (Years)	CVMPeriod Number (%)	Treatment Time Mean±SD (Years)
Group 1 ($N = 20$)	10/10	12.48 ± 1.38	CS 2 (8) 40 CS 3 (12) 60	1.09 ± 0.19
Group 2 ($N = 18$)	8/10	12.81 ± 1.16	CS 2 (8) 45 CS 3 (10) 55	1.07 ± 0.23
P	.852*	.922†	.947*	.716†

Group 1: Twin-Block Group with expansion; Group 2: Twin-Block Group with non-expansion;
*Results of Pearson chi-square test; †Results of Student's *t*-test.
CVM, cervical vertebral maturation period; SD, standard deviation; *N*, number.

Table 2. Comparison of in-group changes with paired t-test and initial values between groups with student's t-test

	Group 1 (Expansion)			Group 2 (Non-expansion)			
	T0	T1		T0	T1		
Cephalometric Measurements	Mean ± SD	Mean ± SD	*P*	Mean ± SD	Mean ± SD	*P*	P′
SNA (°)	80.13 ± 3.83	78.82 ± 3.47	.000	79.31 ± 2.79	78.5 ± 2.54	.000	.428
SNB (°)	74.94 ± 2.18	77.62 ± 2.09	.000	73.69 ± 2.67	76.45 ± 2.39	.000	.524
ANB (°)	5.19 ± 0.97	1.2 ± 0.71	.000	5.62 ± 0.81	2.26 ± 0.73	.000	.328
Co-A (mm)	81.67 ± 2.85	82.59 ± 2.63	.000	82.94 ± 3.53	83.75 ± 3.66	.000	.224
Co-Gn (mm)	105.11 ± 4.54	110.01 ± 4.77	.000	102.69 ± 6.01	107.44 ± 5.97	.000	.137
Wits (mm)	5.39 ± 1.40	1.87 ± 1.03	.000	5.88 ± 1.18	2.28 ± 1.22	.000	.704
A: VRL (mm)	54.83 ± 5.46	54.85 ± 5.29	NS	54.63 ± 5.83	55.1 ± 5.41	.000	.230
B: VRL (mm)	43.28 ± 7.85	46.52 ± 7.42	.000	43.5 ± 8.16	46.6 ± 7.88	.000	.241
Pg: VRL (mm)	45.33 ± 7.44	48.25 ± 7.16	.000	47.02 ± 8.46	49.61 ± 8.03	.000	.285
U1: VRL (mm)	47.88 ± 4.66	50.07 ± 4.93	.000	48.56 ± 2.86	47.85 ± 2.75	.000	.092
L1: VRL (mm)	56.44 ± 4.35	57.77 ± 4.21	.000	54.81 ± 5.44	56.02 ± 4.92	.000	.874
A: HRL (mm)	50.39 ± 5.71	50.98 ± 5.34	.000	51.13 ± 5.27	51.75 ± 6.08	.000	.842
B: HRL (mm)	85.83 ± 5.25	89.58 ± 5.01	.000	83.94 ± 4.22	87.71 ± 3.84	.000	.225
Pg: HRL (mm)	93.22 ± 5.02	97.07 ± 4.87	.000	96.08 ± 6.41	99.99 ± 6.62	.000	.958
U1: HRL (mm)	26.63 ± 2.02	25.96 ± 1.44	.000	26.39 ± 2.28	27.14 ± 3.11	.000	.552
L1: HRL (mm)	34.17 ± 2.08	34.68 ± 1.82	NS	33.81 ± 2.05	34.54 ± 2.6	NS	.167
SN/PP (°)	9.33 ± 1.37	9.45 ± 1.45	.000	9.5 ± 1.51	9.56 ± 1.23	.000	.618
SN/GoGn (°)	29.35 ± 3.69	31.54 ± 3.31	.000	30.78 ± 4.63	32.74 ± 5.07	.000	.416
FMA (°)	24.56 ± 4.1	25.54 ± 3.94	.000	25.67 ± 4.43	26.5 ± 4.38	.000	.772
U1/PP (°)	106.94 ± 7.75	109.31 ± 6.84	.000	110.67 ± 4.32	109.54 ± 4.97	.000	.019
IMPA (°)	95.19 ± 9.92	98.67 ± 10.03	.000	96.28 ± 5.83	99.99 ± 6.09	.000	.0.11
Overjet (mm)	6.71 ± 0.53	2.44 ± 0.47	.000	7.94 ± 1.54	2.91 ± 1.33	.000	.141
Overbite (mm)	5.01 ± 1.85	1.59 ± 1.06	.000	5.19 ± 1.97	2.13 ± 1.05	.000	.487
Posteroanterior measurements							
Internasal width	27.63 ± 2.41	27.68 ± 2.19	NS	26.85 ± 2.35	26.88 ± 2.21	NS	.514
Interfacial width	96.65 ± 9.01	97.61 ± 8.74	.000	94.35 ± 10.71	94.9 ± 11.27	NS	.348
Maxillary width	56.95 ± 3.93	57.37 ± 4.06	.000	58.18 ± 3.12	58.26 ± 2.89	NS	.068
Mandibular width	80.06 ± 6.43	80.42 ± 6.69	NS	78.91 ± 3.52	79.15 ± 3.14	NS	.209
Dentoalveolar measurements							
Max. intercanine width	32.13 ± 3.08	33.82 ± 3.14	.000	33.07 ± 1.81	32.81 ± 1.92	.000	.496
Max. interpremolar width	34.73 ± 1.61	36.39 ± 2.05	.000	36.86 ± 2.76	36.92 ± 3.81	NS	.041
Max. intermolar width	44.97 ± 3.22	47.23 ± 3.18	.000	48.89 ± 2.83	48.83 ± 3.01	NS	.033
Max. alveolar width	55.79 ± 3.27	57.01 ± 4.11	.000	59.45 ± 3.02	60.13 ± 4.28	.000	.067
Max. arc length	38.21 ± 2.03	38.72 ± 2.74	NS	39.83 ± 2.27	39.75 ± 2.84	NS	.044
Mand. intercanine width	27.06 ± 1.37	27.64 ± 1.16	NS	24.83 ± 1.90	25.39 ± 1.76	.000	.902
Mand. interpremolar width	33.61 ± 2.26	34.2 ± 2.35	.000	29.77 ± 1.44	30.28 ± 1.87	.000	.247
Mand. intermolar width	41.62 ± 2.57	41.76 ± 2.99	NS	41.24 ± 2.22	41.32 ± 2.83	NS	.465
Mand. alveolar width	56.12 ± 1.98	56.24 ± 2.13	NS	55.94 ± 2.83	56.03 ± 2.96	.000	.819

P, results of paired t-test comparing the in-group changes; P′, results of Student's t-test comparing the initial values of the groups;
SD, standard deviation; NS, non-significant.

to achieve normal occlusion and facial profile improvement.[16] With the use of the twin-block appliance, developed by Clark and applied separately to the maxilla and mandible, it was observed that patients were able to perform functions such as eating and speaking more easily.[17] The most important advantages of this appliance are that the patient can wear the appliance even while eating, and in patients with transversal problems, it can bring the mandible forward at the same time.

Table 3. Statistical comparison of the mean changes between the groups with independent t-test

	Group 1 (Expansion)	Group 2 (Non-Expansion)	
	Mean ± SD	Mean ± SD	*P*
Cephalometric measurements			
SNA (°)	−1.31 ± 1.40	−0.81 ± 1.24	.072
SNB (°)	2.68 ± 0.78	2.55 ± 0.72	.828
ANB (°)	−3.99 ± 1.75	−3.36 ± 1.37	.622
Co-A (mm)	0.92 ± 2.16	0.81 ± 2.71	.064
Co-Gn (mm)	4.89 ± 1.81	4.75 ± 2.67	.169
Wits (mm)	−3.52 ± 1.02	−3.6 ± 1.92	.704
A – VRL (mm)	0.02 ± 2.77	0.47 ± 1.51	.016
B – VRL (mm)	3.24 ± 1.76	3.10 ± 1.93	.590
Pg – VRL (mm)	2.92 ± 1.83	2.59 ± 1.78	.433
U1 – VRL (mm)	2.19 ± 1.87	−0.71 ± 1.63	.029
L1 – VRL (mm)	1.33 ± 0.79	1.21 ± 1.03	.070
A – HRL (mm)	0.59 ± 1.18	0.62 ± 1.26	.682
B – HRL (mm)	3.75 ± 2.35	3.77 ± 2.19	.142
Pg – HRL (mm)	3.85 ± 1.23	3.91 ± 1.89	.094
U1 – HRL (mm)	−0.67 ± 1.13	0.75 ± 0.84	.025
L1 – HRL (mm)	0.51 ± 0.49	0.73 ± 0.54	.086
SN/PP (°)	0.12 ± 0.87	0.06 ± 1.16	.637
SN/GoGn (°)	2.19 ± 0.97	1.96 ± 1.27	.560
FMA (°)	0.98 ± 0.52	0.83 ± 0.48	.326
U1/PP (°)	2.37 ± 1.81	−1.13 ± 2.34	.019
IMPA (°)	3.48 ± 0.59	3.71 ± 0.63	.738
Overjet (mm)	−4.27 ± 0.53	−5.03 ± 1.01	.118
Overbite (mm)	−3.42 ± 1.54	−3.06 ± 1.61	.059
Posteroanterior measurements			
Internasal width	0.05 ± 0.41	0.03 ± 0.35	.707
Interfacial width	0.66 ± 0.32	0.55 ± 0.11	.498
Maxillary width	0.42 ± 1.12	0.08 ± 0.15	.070
Mandibular width	0.36 ± 0.31	0.24 ± 0.21	.543
Dentoalveoler measurements			
Max. intercanine width	1.69 ± 0.76	−0.26 ± 0.83	.036
Max. interpremolar width	1.66 ± 1.05	0.06 ± 0.82	.054
Max. intermolar width	2.26 ± 1.43	-0.06 ± 0.39	.018
Max. alveolar width	1.22 ± 1.30	0.68 ± 1.17	.136
Max. arc length	0.51 ± 0.37	−0.08 ± 0.43	.042
Mand. intercanine width	0.58 ± 0.95	0.56 ± 0.35	.871
Mand. interpremolar width	0.59 ± 0.74	0.51 ± 0.39	.876
Mand. intermolar width	0.14 ± 0.28	0.08 ± 0.40	.606
Mand. alveolar width	0.12 ± 0.41	0.09 ± 0.23	.754

Group 1, Twin-Block Group with expansion; Group 2, Twin-Block Group with non-expansion.
SD, standard deviation; P, results of independent *t*-test.

The T point, where the sella tursica intersects with the total anterior clinoid process, and the midpoint of the intersection of the anterior skull base of the large wings of the sphenoid bone (Wing point -W)were reported to be the most stable points that are not affected by growth and development.[18] In this study, HRL and VRL planes were used to differentiate the effects of orthodontic treatment from growth and development.

The effects of 2 types of twin-block appliances on maxilla were evaluated by analyzing SNA angle and Co-A, A-VRL, and A-HRL distance. In both groups, the SNA angle decreased; Co-A, A-VRL, and A-HRL increased with treatment. The decrease in SNA angle agrees with other studies.[19] The majority of researchers argue that twin-block appliances limit the sagittal development of the maxilla.[20] It is stated that the mandible is brought forward with functional appliances and forces are applied in the opposite direction to the maxilla, and the growth of the maxilla in the sagittal direction is limited. This effect on the maxilla was called the "headgear effect" by some researchers.[20] There are also studies that report that twin-block appliances have little or no effect on sagittal development of the maxilla.[5,21]

The position of the maxilla was evaluated with the A-VRL distance in the horizontal direction and the A-HRL distance in the vertical direction. In our study, the A-VRL distance was significantly increased in both groups. Cozza et al.[22] reported that the A-point moved forward by 0.97 mm in the group treated with the activator appliances, but that the development of the maxilla was inhibited because it was significantly lower than the 2.23 mm increase in the control group.[22] Our findings are consistent with those of Cozza et al.

In our study, similar increases were observed in mandibular effective length (Co-Gn) in both treatment groups. Mandibular effective length increased by 4.89 mm in the expansion group and by 4.75 mm in the non-expansion group. The increase observed in all mandibular skeletal measurements in both groups showed that both types of appliances increased mandibular development. Although an increase in the SNB angle was seen in both groups, it was not statistically significant. In studies conducted with twin-block appliances, it has been reported that the mandibular effective length increases by between 4.1 and 6.5 mm.[23] They reported that statistically significant increases in the SNB angle with functional treatment are evidence of stimulation of mandibular growth.[21] However, Cozza et al.[22] reported that the SNB angle is a weak determinant of the effects of functional orthopedic treatment in their systematic review that aimed to determine the changes caused by functional appliances on the mandible.[22]

Maxillo–mandibular relationships were evaluated by analyzing the ANB angle and Witts measurement. The decrease in the ANB angle is due to the combination of a decrease in SNA angle and an increase in SNB angle, in accordance with previous studies.[21,24] Wits measurements showed a statistically significant decrease in both groups. In our study, the rotational change of the maxilla relative to the cranial base was evaluated by SN/PP measurements. Although there was a slight increase in SN/PP measurements

in both groups, there was no statistically significant difference between the groups. In both groups, the maxilla was slightly rotated clockwise. The rotational changes of the mandible relative to the cranial base were evaluated using the SN/GoGn and FMA angles. There was no statistically significant increase in the SN/GoGn and FMA angles in either group. In clinical studies with functional appliances, some investigators reported an increase of 0.30-1.80 in the mandibular plane angle (SN/GoGn),[17,20] while others did not find a change.[25,26]

In dentoalveolar measurements, it was found that the maxillary incisors were significantly retroclined in the non-expansion group; this effect has been reported in many studies with functional appliances.[15,23] Others reported that the labial arch in the twin-block appliances caused a headgear effect on the maxillary incisors and led to lingual inclination. Toth and McNamara[5] reported that this retusion and lingual bending seen in the maxillary incisors in the twin-block appliances was caused by the effect of lip muscles in contact with the maxillary teeth.[5] In the expansion group, the maxillary incisors were proclined due to the anterior part of the screw. When the effect of the appliances in both groups on the mandibular incisors was examined, it was found that there was statistically significant protrusion of mandibular incisors in both groups. When the groups were compared, it was found that the appliances caused a similar amount of protrusion of mandibular incisors. The amount of overjet in both groups decreased. In the expansion group, the overjet decreased by 4.27 mm and in the non-expansion group by 5.03 mm.

To our knowledge, the current study is the first to compare the transversal effects of twin-block appliances. Transversal measurements on posteroanterior radiographs did not reveal any significant difference in either appliance type. Therefore, it may be concluded that expansion with twin-block appliances has minimal skeletal effects and more dental effects. Measurements showed a clinically insignificant increase only between molar distances in the maxilla, but this increase was not significant when the groups were compared.

When the measurements taken from the study models were examined, increased intermolar and interpremolar distances and maxillary arch lengths were detected. Although the expansion screw of the twin-block appliance is in the upper part, an increase in the distance between the mandibular posterior teeth was observed (but remained minimal) due to the contacts in the mandible. Even though maxillary expansion increases the distance between the premolar and molar, the increase in the alveolar base may be meaningless, and the expansion may only be dental. In addition, the distance between the canines increased, but was found to be statistically insignificant. This may be due to the part of the labial arch in the canine region. The increase in arch length may be related to the protrusion of incisors in the mandible and the opening of the anterior part of the screw in the maxilla.

Cone-beam computed tomography (CBCT) has been developed for maxillofacial imaging and can provide accurate and reliable measurements in orthodontics. CBCT images have several advantages over conventional lateral cephalometric films that have been reported in previous studies. Our study provides an opportunity for clinicians to compare the findings obtained in CBCT studies. Therefore, the findings of this retrospective clinical study should be considered within the limits of the 2-dimensional radiographic design used for evaluation.

Another limitation of our study was the absence of a control group, which would have allowed us to differentiate between outcomes of clinical treatment and changes due to growth and development. However, since skeletal Class II malocclusions are often severe malocclusions in orthodontics that require early treatment, it is unethical to assign these patients to a control group and not provide them treatment.[26,27] Therefore, our study did not include a control group.

CONCLUSION

- Both types of twin-block appliances were effective treatments for skeletal Class II malocclusion. Overjet and overbite decreased significantly.
- There was no significant difference in terms of protrusion of lower incisors between the 2 types of twin-block appliances. In the expansion group, the maxillary incisors protruded significantly; in the non-expansion group, they were retruded.
- The skeletal effects of both twin-block appliances in the transverse direction were similar; dental expansion was achieved in the maxilla by adding screws to the twin-block appliances.

Ethics Committee Approval: The study was approved by the Clinical Research Ethics Committee, Suleyman Demirel University (Approval No: May 28, 2019/187).

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.H.B.; Design - M.H.B.; Supervision - M.H.B., B.K.; Funding - M.H.B.; Materials - M.H.B.; Data Collection and/or Processing - M.H.B.; Analysis and/or Interpretation - B.K.; Literature Review - M.H.B., B.K.; Writing - M.H.B., B.K.; Critical Review - M.H.B., B.K.

Acknowledgments: We sincerely thank the assistants of the orthodontic department of the Suleyman Demirel University for their help in clinical cases and their collection of data.

Conflict of Interest: The authors have no conflict of interest to declare.

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

REFERENCES

1. Clark WJ. The twin block technique. A functional orthopedic appliance system. *Am J Orthod Dentofacial Orthop*. 1988;93(1):1-18. [CrossRef]
2. Clark WJ. *Twin-Block Functional Therapy*. London: Mosby-Wolfe; 1995.
3. Cozza P, Baccetti T, Franchi L, De Toffol L, McNamara JA, Jr. Mandibular changes produced by functional appliances in Class II malocclusion: a systematic review. *Am J Orthod Dentofacial Orthop*. 2006;129(5):599.e1-599 e12. [CrossRef]

4. Pancherz H. A cephalometric analysis of skeletal and dental changes contributing to Class II correction in activator treatment. *Am J Orthod*. 1984;85(2):125-134. [CrossRef].
5. Toth LR, McNamara JA, Jr. Treatment effects produced by the twin-block appliance and the FR-2 appliance of Frankel compared with an untreated Class II sample. *Am J Orthod Dentofacial Orthop*. 1999;116(6):597-609. [CrossRef]
6. Hägglund P, Segerdal S, Forsberg CM. The integrated Herbst appliance–treatment effects in a group of adolescent males with Class II malocclusions compared with growth changes in an untreated control group. *Eur J Orthod*. 2008;30(2):120-127. [CrossRef]
7. Altenburger E, Ingervall B. The initial effects of the treatment of Class II, division 1 malocclusions with the van Beek activator compared with the effects of the Herren activator and an activator-headgear combination. *Eur J Orthod*. 1998;20(4):389-397. [CrossRef]
8. 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]
9. 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]
10. Pandis N. Sample calculations for comparison of 2 means. *Am J Orthod Dentofacial Orthop*. 2012;141(4):519-521. [CrossRef]
11. Sayin MO, Türkkahraman H. Malocclusion and crowding in an orthodontically referred Turkish population. *Angle Orthod*. 2004;74(5):635-639. [CrossRef]
12. Gelgör IE, Karaman AI, Ercan E. Prevalence of malocclusion among adolescents in central Anatolia. *Eur J Dent*. 2007;1(3):125-131. [CrossRef]
13. Harvold EP, Vargervik K. Morphogenetic response to activator treatment. *Am J Orthod*. 1971;60(5):478-490. [CrossRef].
14. Freitas MR, Santos MA, Freitas KM *et al.* Cephalometric characterization of skeletal Class II, division 1 malocclusion in white Brazilian subjects. *J Appl Oral Sci*. 2005;13(2):198-203. [CrossRef]
15. Basciftci FA, Uysal T, Büyükerkmen A, Sari Z. The effects of activator treatment on the craniofacial structures of Class II division 1 patients. *Eur J Orthod*. 2003;25(1):87-93. [CrossRef]
16. Baltromejus S, Ruf S, Pancherz H. Effective temporomandibular joint growth and chin position changes: activator versus Herbst treatment. A cephalometric roentgenographic study. *Eur J Orthod*. 2002;24(6):627-637. [CrossRef]
17. Banks P, Wright J, O'Brien K. Incremental versus maximum bite advancement during twin-block therapy: a randomized controlled clinical trial. *Am J Orthod Dentofacial Orthop*. 2004;126(5):583-588. [CrossRef]
18. Arat ZM, Türkkahraman H, English JD, Gallerano RL, Boley JC. Longitudinal growth changes of the cranial base from puberty to adulthood. A comparison of different superimposition methods. *Angle Orthod*. 2010;80(4):537-544. [CrossRef]
19. Hägg U, Rabie AB, Bendeus M et al. Condylar growth and mandibular positioning with stepwise vs maximum advancement. *Am J Orthod Dentofacial Orthop*. 2008;134(4):525-536. [CrossRef]
20. 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]
21. Tümer N, Gültan AS. Comparison of the effects of monoblock and twin-block appliances on the skeletal and dentoalveolar structures. *Am J Orthod Dentofacial Orthop*. 1999;116(4):460-468. [CrossRef]
22. Cozza P, De Toffol L, Colagrossi S. Dentoskeletal effects and facial profile changes during activator therapy. *Eur J Orthod*. 2004;26(3):293-302. [CrossRef]
23. Schaefer AT, McNamara JA Jr, Franchi L, Baccetti T. A cephalometric comparison of treatment with the Twin-block and stainless steel crown Herbst appliances followed by fixed appliance therapy. *Am J Orthod Dentofacial Orthop*. 2004;126(1):7-15. [CrossRef]
24. Türkkahraman H, Sayin MO. Effects of activator and activator headgear treatment: comparison with untreated Class II subjects. *Eur J Orthod*. 2006;28(1):27-34. [CrossRef]
25. Pangrazio-Kulbersh V, Berger JL, Chermak DS *et al.* Treatment effects of the mandibular anterior repositioning appliance on patients with Class II malocclusion. *Am J Orthod Dentofacial Orthop*. 2003;123(3):286-295. [CrossRef]
26. 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]
27. Papadopoulos MA. Meta-analyses and orthodontic evidence-based clinical practice in the 21st century. *Open Dent J*. 2010;4:92-123. [CrossRef]

TURKISH JOURNAL of ORTHODONTICS

DOI: 10.5152/TurkJOrthod.2021.20091

Original Article

Contamination of Low Frictional Elastomeric Ligatures by *Streptococcus mutans*: A Prospective RT-PCR and AFM Study

Caglar Dagdeviren[1], Aysegul Gulec[1], Fahriye Eksi[2], Mustafa Saglam[2], Mehmet Kahraman[3]

[1]Department of Orthodontics, Dentistry Faculty, Gaziantep University, Gaziantep, Turkey
[2]Department of Microbiology, Medical Faculty, Gaziantep University, Gaziantep, Turkey
[3]Department of Chemistry, Art and Science Faculty, Gaziantep University, Gaziantep, Turkey

Cite this article as: Dagdeviren C, Gulec A, Eksi F, Saglam M, Kahraman M. Contamination of low frictional elastomeric ligatures by *Streptococcus mutans*: A prospective RT-PCR and AFM study. *Turk J Orthod.* 2021; 34(3): 163-169.

Main Points

- The type of ligation did not appear to affect the plaque and GI values.
- *S. mutans* colonization showed variations in low-friction elastomeric ligatures, independent of surface roughness.
- Only ring-shaped low-friction elastomeric ligatures were similar to the steel ligature in terms of *S. mutans* colonization.

ABSTRACT

Objective: To compare *Streptococcus mutans* colonization between low-friction elastomeric ligatures and to correlate microbial colonization levels with the surface roughness status.

Methods: The study included 160 premolars of 10 patients. During the study period, which consisted of 4 sessions each lasting 4 weeks, the ligature types Slide™ Low-Friction Ligature (Leone, Firenze, Italy), Tough-O Energy™ (Rocky Mountain Orthodontics, Denver, USA), and Sili Ties™ (Dentsply Sirona, Surrey KT13 0NY, UK), and steel ligatures (American Orthodontics, Sheboygan, USA) as a control, were fixed to the premolar teeth by clockwise rotation among the jaw quadrants. The plaque index (PI) and gingival index (GI) were obtained before bonding (T0), 6 weeks after bonding (T1), and subsequently every 4 weeks (T2, T3, T4). Presence of *S. mutans* was analyzed by real-time polymerase chain reaction at T1, T2, T3, T4. Surface roughness was evaluated with Atomic Force Microscopy (AFM) before ligation (Ra0) and after (Ra1) ligation. The paired t-test, ANOVA, repeated measures of ANOVA, and the Kruskal–Wallis test were used for the statistical analysis.

Results: *S. mutans* colonization was significantly higher on the Slide group ($P < .05$). The lowest Ra0 was seen in Slide and the highest was seen in the Tough-O Energy group. There was no correlation between *S. mutans* colonization and Ra1 parameters of elastomeric groups ($P > .05$).

Conclusion: *S. mutans* colonization showed variations in low-friction elastomeric ligatures independent of surface roughness. Ring-shaped low-friction elastomeric ligatures were not different from the steel ligature in terms of *S. mutans* colonization.

Keywords: Real-time polymerase chain reaction, atomic force microscopy, microbiology, surface roughness, low-friction elastomeric ligatures

INTRODUCTION

During orthodontic treatment, maintaining oral hygiene becomes difficult due to the placement of bands, brackets, and ligatures in the oral cavity.[1] It was previously reported that permanent orthodontic treatment led to dense plaque formation and an increase in cariogenic and periodontal bacterial growth.[2] Throughout treatment, the presence of plaque at the gingival border was accepted as the main etiological factor in periodontal diseases, whereas increased plaque accumulation around orthodontic brackets is known to result in white-spot lesions

Corresponding author: Aysegul Gulec, e-mail: ayseguldt@yahoo.com

Received: August 4, 2020
Accepted: March 6, 2021

and in severe cases of tooth decay, which negatively affect the quality of life.[3,4] Enamel demineralization, which results in white-spot formation, is observed due to the increase in the number and volume of acid-producing bacteria, and the decrease in pH because of the glucose metabolized by these cariogenic bacteria.[5,6] *Streptococcus mutans* is one of the bacteria that play an important role in the onset of carious lesions.[7]

Current product development efforts have resulted in the development of low-friction elastomeric ligatures to reduce the friction of orthodontic sliding mechanics.[8] The efforts to reduce friction between orthodontic wires and braces have played a role in the development of elastomeric ligatures with altered surface structures. A difference in the colonized bacteria around the brackets can be anticipated in connection with this altered surface structure. The effect of different ligation methods on microbial colonization has been a topic that researchers have been working on for a long time, but bacterial colonization on low-friction elastomeric ligatures was investigated in relatively few studies, where Slide™ elastomeric ligatures as low-friction elastomeric ligatures were compared with conventional elastomeric ligatures using microbial culture techniques.[9-14] Nowadays, the number of elastomeric ligatures showing low friction has increased in the market. However, there are no studies comparing different low-friction elastomeric ligatures concerning microbial colonization. Thus, the aim of this study was to compare *S. mutans* colonization among 3 different low-friction elastomeric ligatures that are available commercially—Slide™ Low Friction Ligature (Leone, Firenze, Italy), Tough-O Energy™ (Rocky Mountain Orthodontics, Denver, USA), and Sili Ties™ (Dentsply Sirona, Surrey KT13 0NY, UK)—with steel ligatures (American Orthodontics, Sheboygan, USA) as a control, using real-time polymerase chain reaction (RT-PCR), as this is a simple, fast, and accurate method to identify specific bacterial species and their quantities.[15] The effect of the ligature types on periodontal status was also investigated. The secondary aim of the study was to investigate the surface structures of these ligature types via atomic force microscopy (AFM), which uses a very high-resolution scanning force microscope in which surface roughness can be detected, and to associate these surface structures with bacterial colonization.[16]

METHODS

This study was approved by the Ethics Committee of Gaziantep University, (April 26, 2017/169), and was registered in ClinicalTrials.gov: NCT04185987. The power analysis sample size determination revealed that for an alpha level of 0.05, and a power of 0.8, a minimum of 9 subjects in each group was required. (G*Power version 3.0.10, Franz Faul, Universitat Kiel, Germany). Systemically healthy patients who had permanent dentition, no dental plaque, had good oral hygiene, and who did not use antibiotics or smoke for at least 2 months before the initiation of the study were invited to participate in the study during a routine bonding visit in the orthodontics department of the Dentistry Faculty of Gaziantep University. The exclusion criteria were: absence, decay, or restoration in upper or lower premolars, and the presence of any prosthetic restorations and other orthodontic attachments except brackets, tubes, and ligature wires in the mouth. The study, which was planned to include 3 different trademarked brands of low-friction elastomeric ligatures with steel ligatures as a control simultaneously present in the mouths of the patients during the treatment process, started with 10 patients (4 female and 6 male) with a mean age of 13.58 ± 0.79 years (min:12.3; max:14.6). Informed consent was obtained from all patients and their parents. The study groups are presented in Table 1.

Patients were bonded with 22′ slot for MBT brackets (Mini Master brackets; AO, Wisconsin, USA) and 0.014 NiTi wires (TriTanium™ Wire; AO, Wisconsin, USA) were attached to the brackets via steel ligatures by the same clinician (C.D.). These 0.014″ NiTi wires were kept in place throughout the study. A 2-week time period was given to the patients for getting used to brushing, at the end of which steel ligatures were removed from the patients and all ligature groups were fixed to the brackets of the patients. The teeth to be examined were defined as left and right, upper and lower, and first and second premolar teeth. During the study period, which consisted of 4 sessions each lasting 4 weeks, all ligature types were fixed to the related premolar teeth by clockwise rotation among the jaw quadrants. Rotations were also performed between the first and the second premolars of the same region. The study design is presented in Table 2. Intraoral pictures of the patients based on the study design are shown in Figure 1. The pictures of the ligature types are shown in Figure 2.

Plaque index (PI)and gingival index (GI) were measured, prior to bonding (T0), 6 weeks after bonding (T1), and subsequently every 4 weeks (T2; T3; T4), as the clinical parameters of dental plaque accumulation.[17,18] The periodontal evaluation was carried out only on the related premolar tooth by the same trained clinician (C.D.). A total of 160 ligature samples were collected from the patients at T1, T2, T3, and T4 by the same clinician (C.D), and were kept at −80°C in a transport medium until microbial analysis. Real-time PCR analysis was performed for the investigation of the presence of *S. mutans*. DNeasy Blood & Tissue Kit(Qiagen, Hilden, Germany) was used for DNA isolation, according to the manufacturer's instructions.[19] Following extraction, forward and reverse primers (forward; 5'-CCGGTGACGGCAAGCTAA-3', reverse; 5'-TCATGGAGGCGAGTTGCA-3') of *S. mutans* (Metabion International

Table 1. Study groups

Groups	Type of elastomeric ligature	Manufacturer	*N*
I	Slide™ Low-Friction Ligature	Leone, Firenze, Italy	40
II	Tough-O Energy™ Ligature	Rocky Mountain Orthodontics, Denver, USA	40
III	Sili Ties™ Ligature	Dentsply Sirona, Surrey KT13 0NY, UK	40
IV	Twisted End Steel Ligature	American Orthodontics, Sheboygan, USA	40

Table 2. Study design

Time period	Tooth number	Ligature type	Time period	Tooth number	Ligature type
2-6 weeks after bonding	15	Group I	6-10 weeks after bonding	14	Group IV
	25	Group II		24	Group I
	35	Group III		34	Group II
	45	Group IV		44	Group III
10-14 weeks after bonding	15	Group III	14-18 weeks after bonding	14	Group II
	25	Group IV		24	Group III
	35	Group I		34	Group IV
	45	Group II		44	Group I

AG Planegg, Germany) were designed and provided to investigate the presence of the bacteria and determine the bacterial load within the isolated eluates. The ATCC 25175 and ATCC 35668 strains of *S. mutans* were used as positive controls. The standards were optimized for usage in the RT-PCR study. Primarily, a master mix was prepared with RT2 SYBR Green PCR master mix kit (Qiagen, Hilden Germany) for RT-PCR. For each sample, a mixture was prepared with 12.5 µL RT2 SYBR Green PCR master mix, 0.5 µL forward primer, and 0.5 µL reverse primer 6 5 µL H_2O. The template isolated from the 5 µL samples (sample DNA) was added on this master mix prepared, the PCR tubes were capped, and RT-PCR analysis was performed using the Rotor-Gene Q instrument (Hilden Germany).

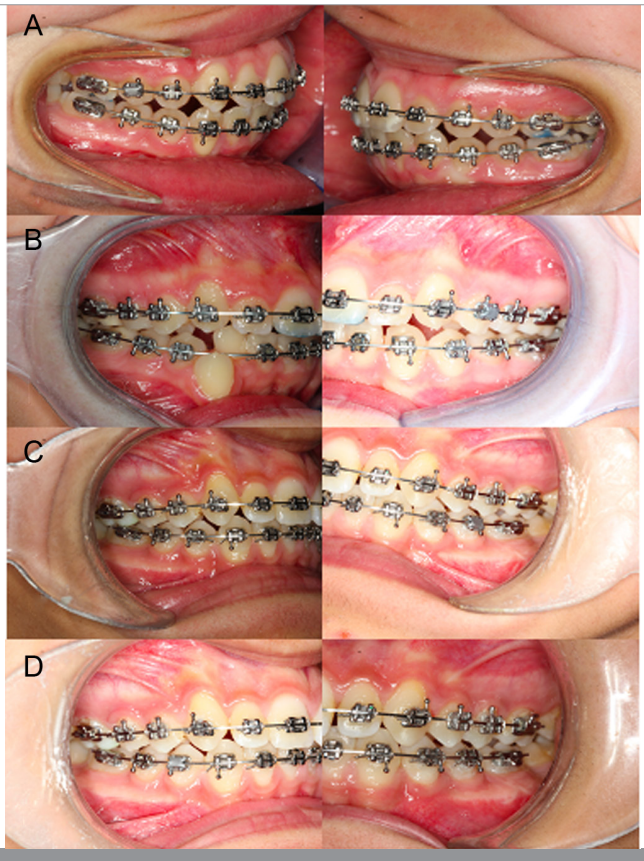


Figure 1. The intraoral pictures of the patients based on the study design. (A) First month, (B) Second month, (C) Third month, and (D) Fourth month

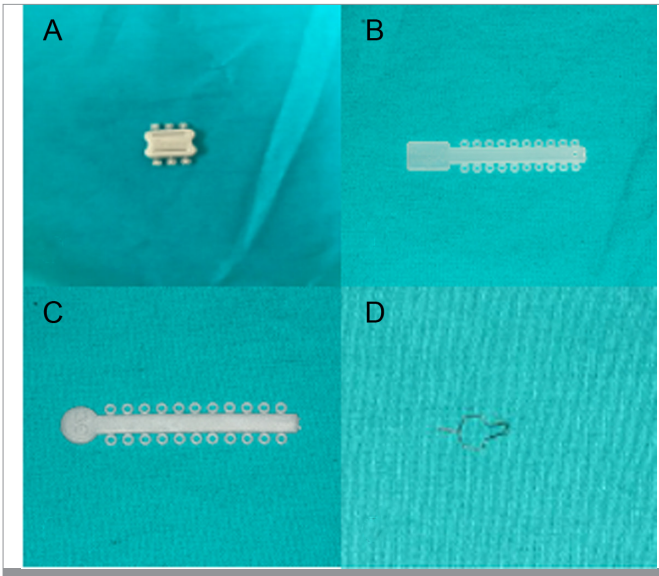


Figure 2. Ligature groups. (A) Slide™ Low-Friction Ligature (B) Tough-O Energy™ Ligature (C) Sili Ties™ Ligature (D) Twisted End Steel Ligature

For surface roughness analysis, three-dimensional surface roughness (R_a) of the 3 different types of elastomeric ligatures was analyzed by AFM (Bruker, Santa Barbara, CA) with its own specific software Nanoscope™ version-5.31R1. R_a represents the arithmetic mean of the absolute values of the profile of the scanned surface in micrometers (µm), (40 µm × 40 µm). The baseline forms of the elastomeric ligatures (R_a0) and the forms after 4-weeks of use (R_a1) were presented separately, and the surface roughness was measured on 6 different regions and calculated in nanometers.

STATISTICAL ANALYSIS

Compliance of the data with normal distribution was tested using the Shapiro–Wilk test. The comparison of the non-normally distributed data between more than 2 independent groups was performed using the Kruskal–Wallis test, and all pairwise multiple comparison tests and normally distributed data were analyzed using one-way analysis of variance (ANOVA). The comparison between 2 different time points was performed using the paired samples *t*-test, and between more than 2-time points was performed using repeated measures of ANOVA and LSD multiple comparison tests. The correlations between surface roughness and microbial colonization were tested using Spearman's correlation coefficient. The Statistical Package for Social Sciences version 22.0 software (IBM Corp.; Armonk, NY, USA) was used for statistical analysis. A *P* value of $<.05$ was considered significant.

RESULTS

Descriptive statistical data on time-dependent means of PI and GI values and inter-group comparisons are presented in Table 3. PI and GI values at all-time points during the treatment were higher compared to the ones at baseline in all groups ($P < .001$).

Table 3. Descriptive statistical data on time-dependent means of PI and GI values and inter-group comparisons

			T0	T1	T2	T3	T4	
	Group	*n*	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	*P* within groups
Plaque index (PI)	I	10	0.44 ± 0.19[abcd¥]	2.20 ± 0.36	2.25 ± 0.33	2.39 ± 0.26	2.37 ± 0.20	<.001[€]
	II	10	0.56 ± 0.1 [abcd¥]	2.33 ± 0.23	2.32 ± 0.11	2.48 ± 0.13	2.28 ± 0.12	<.001[€]
	III	10	0.40 ± 0.22 [abcd¥]	2.19 ± 0.36	2.33 ± 0.76	2.25 ± 0.08	2.27 ± 0.20	<.001[€]
	IV	10	0.46 ± 0.09 [abcd¥]	2.25 ± 0.45	2.18 ± 0.48	2.14 ± 0.09	2.19 ± 0.26	<.001[€]
	P between groups[*]		NS	NS	NS	NS	NS	
Gingival index (GI)	I	10	0.58 ± 0.23 [abcd¥]	2.09 ± 0.54	2.19 ± 0.33	2.22 ± 0.31	2.15 ± 0.49	<.001[€]
	II	10	0.53 ± 0.18 [abcd¥]	2.14 ± 0.64	2.30 ± 0.67	2.28 ± 0.40	2.20 ± 0.54	<.001[€]
	III	10	0.60 ± 0.33 [abcd¥]	2.51 ± 0.78	2.50 ± 0.49	2.48 ± 0.13	2.35 ± 0.87	<.001[€]
	IV	10	0.48 ± 0.45 [abcd¥]	2.01 ± 0.66	2.25 ± 0.92	2.12 ± 0.18	2.11 ±0.73	<.001[€]
	P between groups*		NS	NS	NS	NS	NS	

*ANOVA; [€]Repeated measures of ANOVA; [¥]LSD multiple comparison test.
T0, Prior to bonding; T1, 6 weeks after bonding; T2, T3, T4 subsequently every 4 weeks; $P \leq ,05$;.
[a]significantly different from T1, [b]significantly different from T2, [c]significantly different from T3, [d]significantly different from T4.
SD, standard deviation.

Table 4 displays the total count of *S. mutans* colonization on the ligature surfaces and intergroup comparisons. *S. mutans* colonization on Group I ligature was significantly higher compared to all other groups ($P = .016$). No significant difference was observed between other elastomeric ligature groups or between these groups and the control group ($P > .05$).

Table 5 shows the intergroup and intragroup comparisons of surface roughness analysis. According to R_a0 values, the lowest roughness was seen in Group I and the highest roughness was seen in Group II. When the R_a1 values of all groups were compared, the lowest roughness was observed in Group III, and the highest roughness was observed in Group II. Intra-group comparisons of R_a0 and R_a1 revealed that the R_a1 of Group I was significantly higher compared to the R_a0 ($P = .012$), whereas no statistically significant difference was found between Group II and Group III ($P > .05$, Figure 3).

There was no correlation between the total *S. mutans* colonization and R_a1 parameters of the elastomeric ligature groups ($P > .05$) (Table 6).

DISCUSSION

The literature clearly shows that fixed orthodontic treatment increases plaque formation, bacterial colonization, and enamel

Table 4. Total count of *S. mutans* colonization on the ligature surfaces and inter-group comparisons

	Groups					*P* (between groups)					
***S.mutans* colonization**	**Group I n = 40 Mean ± SD**	**Group II n = 40 Mean ± SD**	**Group III n = 40 Mean ± SD**	**Group IV n = 40 Mean ± SD**	***P* (within groups)**	**I-II**	**I-III**	**I-IV**	**II-III**	**II-IV**	**III-IV**
	10.8± 3.74	6.65 ± 2.81	6.09± 2.47	5.85± 3.02	.016[£]	.025*	.008*	.005*	.674	.553	.863

*All pairwise multiple comparison tests; [£]Kruskal–Wallis test.
SD, standard deviation.

Table 5. Intergroup and intragroup comparisons of surface roughness analysis

	Groups			*P* (between Groups)			
	Group I n = 6 Mean ± SD	**Group II n = 6 Mean ± SD**	**Group III n = 6 Mean ± SD**	***P***	**I-II**	**I-III**	**II-III**
R_a0 (μm)	0.06 ± 0.01	0.21 ± 0.03	0.1 ± 0.02	.001[€]	0.001[β]	0.004 [β]	0.001[β]
R_a1(μm)	0.17 ± 0.05	0.23 ± 0.01	0.1 ± 0.03	.001[€]	0.026[β]	0.046 [β]	0.010[β]
P (within groups)	.012*	0.412	0.765				

*Paired *t*-test; [€]Repeated measurements of ANOVA; [β]LSD multiple comparison test; $P \leq .05$.
SD, standard deviation.

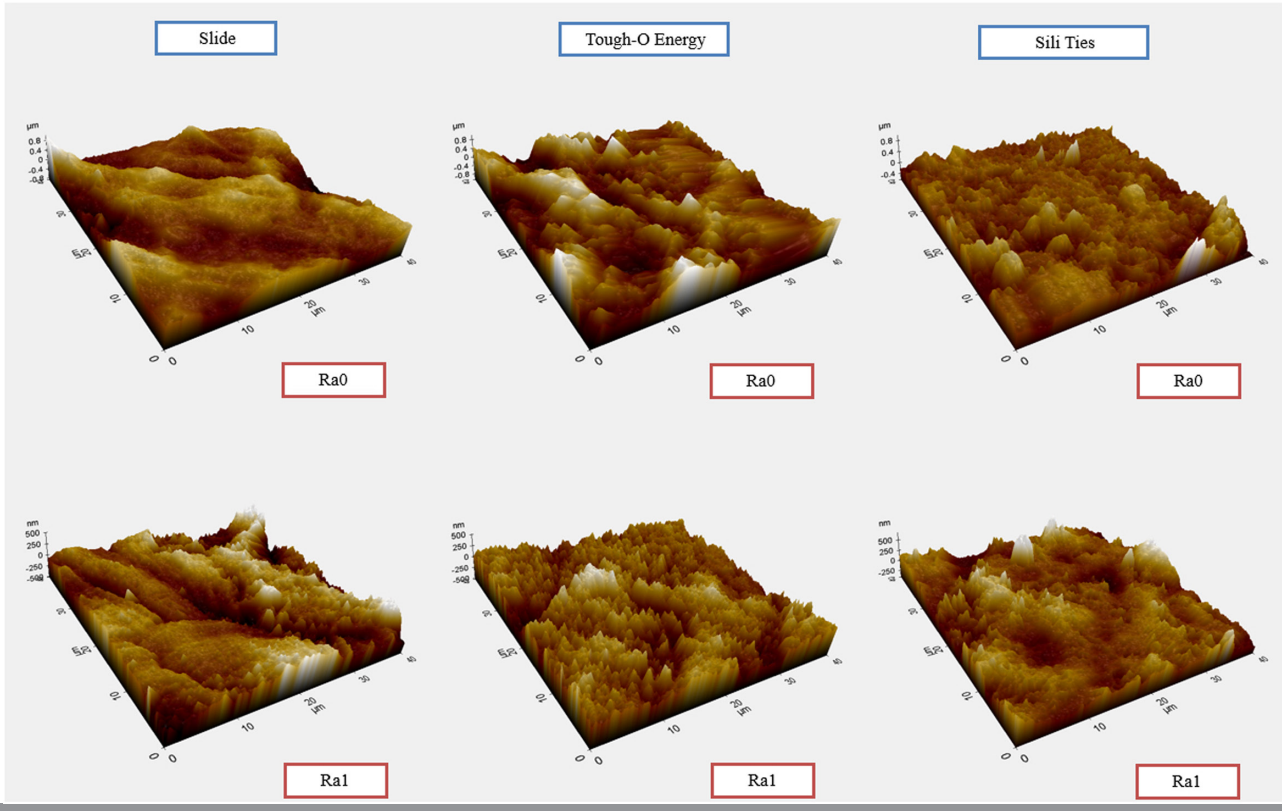


Figure 3. AFM images of ligature groups

Table 6. Correlation between the total *S. mutans* colonization and R_a1 parameters of elastomeric ligature groups

	Group I		Group II		Group III	
S mutans	*P*	Correlation coefficient	*P*	Correlation coefficient	*P*	Correlation coefficient
	.623	-0.257	.111	–0.714	.704	0.200

Spearman's rank correlation analysis.

decalcification.[5] Many studies have investigated the effects of ligation techniques on dental plaque retention and microbial flora, but only a few focused on the low-friction elastomeric ligatures; none of them investigated the surface properties of elastomeric ligatures as an additional factor.[12-14,20,21] To meet the deficit to some extent, 3 different low-friction elastomeric ligatures were compared in the present study in terms of microbial colonization, periodontal status, and surface morphology.

Three different commercially available brands of elastomeric ligatures as low-friction ligatures made up the material of this study. Slide™ is a product that is manufactured with a special polyurethane mix by injection molding. Although its application is similar to that of conventional elastic ligatures, the shape of the ligature is rather bulky. Once ligated on the bracket, it creates a passive ligation on the slot with a lower frictional force that leaves the archwire free to slide. Tough-O Energy™ and Sili Ties™ ligatures are ring-shaped, in the same way as conventional elastomeric ligatures, but less frictional force occurs between the archwire and ligatures due to their production techniques, which is the distinguishing property of these 2 elastomeric ligatures. Based on the study design, 3 different brands of elastomeric ligatures, as well as steel ligatures as a control group, were present in the mouth at the same time. Together with the advantage of keeping the number of participating subjects relatively low, this design reduced the duration of follow-up and minimized the possible hygiene motivation loss of the patient. Clockwise rotation of the ligature groups around the jaw quadrants at each control visit aimed to prevent the brushing habits of the patient from affecting the results. The aim of the rotation between the first and the second premolars in the same region was to avoid the possible effects of microorganisms remaining from the previous session.

PI and GI measurements used for the evaluation of periodontal health revealed lower values before bonding compared to all other measurements. This finding is consistent with those of previous studies reporting that the orthodontic fixed treatment increased plaque accumulation.[11,22,23] There was no statistically significant difference between groups at any of the time points, showing that the oral hygiene motivation of the patients remained stable during the study.

In the present study for microbial evaluation, RT-CR, which can detect a small number of cariogenic bacteria in patients who

are likely to experience enamel demineralization, was used. The number of studies evaluating the effects of ligation methods on microbial flora using PCR is quite low.[24,25] To eliminate the difficult and time-consuming laboratory procedures of culture techniques, the highly sensitive RT-PCR technique was preferred.

A consortium of multiple microorganisms acts collectively, and possibly synergistically, to initiate and expand the caries lesion.[26] S. *mutans* is not the sole cause of caries lesions, but is still a frequently investigated microorganism because it plays an important role in the onset of these lesions.[11,27] Total *S. mutans* counts showed that microbial accumulation on the Slide™ elastomeric ligatures was higher compared to all other groups of ligatures. In the study of Bhagchandani et al.,[12] using culture techniques for microbial examination, 4 different types of ligatures and steel ligature as a control were compared in terms of microbial colonization. The highest microbial colonization was observed on Slide™ elastomeric ligatures, similar to our study. Investigators have concluded that this may be due to the complicated, rough, and high-volume structure of those groups of ligatures. In another study, Akgün et al.[13] compared Slide™ elastomeric ligatures and conventional elastomeric ligatures concerning aerobic and anaerobic bacterial growth and plaque accumulation using microbiological culture methods, and observed no difference. The comparison of low-friction elastomeric ligatures between themselves rather than with conventional elastomeric ligatures and the bacteria type examined reveal the difference of this study from that of Akgün et al.[13]

Interestingly, no difference was observed between the ring-shaped low-friction elastomeric ligature types, or between these groups and the steel ligature control group, with regard to *S. mutans* count. This finding is compatible with the findings of the study of Türkkahraman et al.[11] comparing conventional ring-shaped elastomeric ligatures and steel ligatures in terms of microbial colonization using culture techniques, which revealed no significant difference between these 2 types of ligatures but a higher number of microorganisms on elastomeric ligatures. However, in many studies in the literature, elastomeric ligatures have been reported to have more microbial colonization than steel ligatures.[28-30] In contrast to the current knowledge, microbial colonization on the surfaces of a new group of ligatures, low-friction elastomeric ligatures, was assessed in the present study. Within its limitations, this is the most important aspect in which this study contributed to literature. The fact that no difference was observed between ring-shaped low-friction elastomeric ligatures and steel ligatures in terms of microbial colonization could lead to these types of ligatures being preferred more.

In our study, the surface properties of low-friction elastomeric ligatures were measured by AFM at baseline and after usage. The measurement of surface roughness via AFM was also previously performed in orthodontics.[31] When the baseline surface structures of all groups were compared, the lowest roughness was observed in Slide™ ligatures and the highest roughness was observed in Tough-O Energy™ ligatures. After usage, AFM analysis revealed that the greatest change in surface roughness was observed in the Slide group, and the other elastomeric ligature groups showed an insignificant change in surface roughness. Condo et al.[32] investigated the morphological changes observed in the structures of conventional elastomeric ligatures and Slide™ elastomeric ligatures using scanning electron microscope (SEM), both before and after usage. The study reported a significant difference in the internal and external diameters and the thicknesses of conventional elastomeric ligatures. They reported morphological irregularities in the sizes of Slide™ ligatures. The authors concluded that wing lengths were increased due to the effect of elastomeric deformation observed at the wings of Slide™ ligatures, which might have resulted in impaired contact between the wire and the ligature. The possibility of statistical evaluation as a result of the measurements performed by AFM allowed us to obtain more quantitative results compared with those studies conducted using SEM.

One of the parameters to be investigated in the present study was the correlation between the surface roughness of elastomeric ligatures and bacterial growth. No correlation was observed between the total *S. mutans* count observed on the surface of the elastomeric groups and R_a1 parameters. In the study by Guimares et al.[33] investigating the surface and mechanical properties of elastomeric ligatures, surface roughness analyses were performed on SEM images. According to the results of their study, the amount of change observed in surface roughness was more than the amount of change observed in mechanical properties. In the study where surface roughness was not evaluated statistically, this increase observed in roughness was concluded to have been caused by plaque accumulation. Although no significant correlation was observed in the present study either, it was found that more microorganisms accumulated on elastomeric ligatures in proportion to the increase in roughness.

Together with the periodontal status and surface structures, this study provides information on the quantitative analysis of *S. mutans* in patients using low-friction elastomeric ligatures. The ring-shaped low-friction elastomeric ligatures did not differ from the steel ligature in terms of *S. mutans* colonization. Keeping in mind that no relation could be established between elastomeric ligature surface roughness and *S. mutans* count, a feasible explanation for this result may be the dimensional differences of the ligatures. Slide™ ligatures may have more *S mutans* due to their unique and bulky shape. The main limitations of this study are the limited number of patients, bacteria investigated, and surface roughness samples, due to the financial constraints.

CONCLUSION

According to our findings with the limitations of in vivo studies:

- Plaque and gingival index values do not appear to be affected by ligation type.
- Slide™ ligatures demonstrated a higher quantity of *S. mutans* colonization compared to other low-friction ligatures.
- No difference was observed between Tough-O Energy™ and Sili Ties™ ligatures and steel ligatures, with regard to *S. mutans* colonization.

- No correlation was observed between the surface roughness of low-friction elastomeric ligatures and the total *S. mutans* count.

Ethics Committee Approval: This study was approved by Ethics committee of Gaziantep University, (Approval No: 2017/169).

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 - A.G., C.D.; Design - A.G., C.D.; Supervision - A.G.; Funding - C.D.; Materials - C.D.; Data Collection and/or Processing - C.D., F.E., M.S., M.K.; Analysis and/or Interpretation - F.E, M.S., M.K.; Literature Review - C.D., A.G.; Writing - C.D.; Critical Review - A.G.

Conflict of Interest: The authors have no conflict of interest to declare.

Financial Disclosure: This work was supported by Gaziantep University Research Projects (Grant number DHF.UT.17.06).

REFERENCES

1. Petti S, Barbato E, Simonetti D'Arca A. Effect of orthodontic therapy with fixed and removable appliances on oral microbiota: A six-month longitudinal study. *New Microbiol*. 1997;20(1):55-62.
2. Papaioannou W, Gizani S, Nassika M, Kontou E, Nakou M. Adhesion of Streptococcus mutans to different types of brackets. *Angle Orthod*. 2007;77(6):1090-1095. [CrossRef]
3. Chapman JA, Roberts WE, Eckert GJ, Kula KS, González-Cabezas C. Risk factors for incidence and severity of white spot lesions during treatment with fixed orthodontic appliances. *Am J Orthod Dentofacial Orthop*. 2010;138(2):188-194. [CrossRef]
4. Ren Y, Jongsma MA, Mei L, van der Mei HC, Busscher HJ. Orthodontic treatment with fixed appliances and biofilm formation--a potential public health threat? *Clin Oral Investig*. 2014;18(7):1711-1718. [CrossRef]
5. Mitchell L. Decalcification during orthodontic treatment with fixed appliances--an overview. *Br J Orthod*. 1992;19(3):199-205. [CrossRef]
6. Beyth N, Redlich M, Harari D, Friedman M, Steinberg D. Effect of sustained-release chlorhexidine varnish on Streptococcus mutans and Actinomyces viscosus in orthodontic patients. *Am J Orthod Dentofacial Orthop*. 2003;123(3):345-348. [CrossRef]
7. van Houte J. Role of micro-organisms in caries etiology. *J Dent Res*. 1994;73(3):672-681. [CrossRef]
8. Baccetti T, Franchi L. Friction produced by types of elastomeric ligatures in treatment mechanics with the preadjusted appliance. *Angle Orthod*. 2006;76(2):211-216. [CrossRef]
9. Sukontapatipark W, el-Agroudi MA, Selliseth NJ, Thunold K, Selvig KA. Bacterial colonization associated with fixed orthodontic appliances. A scanning electron microscopy study. *Eur J Orthod*. 2001;23(5):475-484. [CrossRef]
10. Alves de Souza R, Borges de Araújo Magnani MB, Nouer DF et al. Periodontal and microbiologic evaluation of 2 methods of archwire ligation: ligature wires and elastomeric rings. *Am J Orthod Dentofacial Orthop*. 2008;134(4):506-512. [CrossRef]
11. Türkkahraman H, Sayin MO, Bozkurt FY *et al.* Archwire ligation techniques, microbial colonization, and periodontal status in or (doi thodontically treated patients. *Angle Orthod*. 2005;75(2):231-236. [CrossRef]
12. Singh A, Varshney S, Varshney K et al. Microbial colonization around orthodontic ligature ties: an in-vivo study. *APOS Trends Orthod*. 2013;3(3):72. [CrossRef]
13. Akgun OM, Altug H, Karacay S et al. Effect of 2 elastomeric ligatures on microbial flora and periodontal status in orthodontic patients. *Am J Orthod Dentofacial Orthop*. 2014;145(5):667-671. [CrossRef]
14. Rangarajan S, Mogra S, Shetty VS, Shetty S, Jose NP. Comparison of contamination of low-frictional elastomeric rings with that of conventional elastomeric rings by Streptococcus mutans - an in-vivo study. *J Clin Diagn Res*. 2015;9(4):ZC26-ZC29. [CrossRef]
15. Yano A, Kaneko N, Ida H, Yamaguchi T, Hanada N. Real-time PCR for quantification of Streptococcus mutans. *FEMS Microbiol Lett*. 2002;217(1):23-30. [CrossRef]
16. Oura K, Lifshits VG, Saranin AA, Zotov AV, Katayama M. *Surface Science: an Introduction*. Springer Science & Business Media; 2013 .
17. Silness J, Löe H. Periodontal disease in pregnancy II. correlation between oral hygiene and periodontal condition. *Acta Odontol Scand*. 1964;22(1):121-135. [CrossRef]
18. Löe H, Silness J. Periodontal disease in pregnancy I. Prevalence and severity. *Acta Odontol Scand*. 1963;21(6):533-551. [CrossRef]
19. Loesche WJ. Role of Streptococcus mutans in human dental decay. *Microbiol Rev*. 1986;50(4):353-380. [CrossRef]
20. Arnold S, Koletsi D, Patcas R, Eliades T. The effect of bracket ligation on the periodontal status of adolescents undergoing orthodontic treatment. A systematic review and meta-analysis. *J Dent*. 2016;54:13-24. [CrossRef]
21. Sawhney R, Sharma R, Sharma K. Microbial colonization on elastomeric ligatures during orthodontic therapeutics: an overview. *Turk J Orthod*. 2018;31(1):21-25. [CrossRef]
22. Forsberg CM, Brattström V, Malmberg E, Nord CE. Ligature wires and elastomeric rings: two methods of ligation, and their association with microbial colonization of Streptococcus mutans and lactobacilli. *Eur J Orthod*. 1991;13(5):416-420. [CrossRef]
23. Alexander SA. Effects of orthodontic attachments on the gingival health of permanent second molars. *Am J Orthod Dentofacial Orthop*. 1991;100(4):337-340. [CrossRef]
24. Baka ZM, Basciftci FA, Arslan U. Effects of 2 bracket and ligation types on plaque retention: A quantitative microbiologic analysis with real-time polymerase chain reaction. *Am J Orthod Dentofacial Orthop*. 2013;144(2):260-267. [CrossRef]
25. Yadav N, Sidhu M, Grover S, Malik V, Dogra N. Cronicon evaluating and comparing periodontal and microbial parameters in orthodontic patients with elastomeric modules and self ligating brackets-A PCR study. *EC Dent Sci*. 2017;14:105-113.
26. Simón-Soro A, Mira A. Solving the etiology of dental caries. *Trends Microbiol*. 2015;23(2):76-82. [CrossRef]
27. Abraham KS, Jagdish N, Kailasam V, Padmanabhan S. Streptococcus mutans adhesion on nickel titanium (NiTi) and copper-NiTi archwires: A comparative prospective clinical study. *Angle Orthod*. 2017;87(3):448-454. [CrossRef]
28. Garcez AS, Suzuki SS, Ribeiro MS et al. Biofilm retention by 3 methods of ligation on orthodontic brackets: A microbiologic and optical coherence tomography analysis. *Am J Orthod Dentofacial Orthop*. 2011;140(4):e193-e198. [CrossRef]
29. Harikrishnan P, Subha TS, Kavitha V, Gnanamani A. Microbial adhesion on orthodontic ligating materials: microbiol. *Advances in Microbiology*. 2013;3(1):108-114.
30. Rohit K, Mahalakshmi K, Murali RV, Padmavathy K, Balasubramanian S. Evaluation of Streptococcus Mutans Biofilm Retention by Three Different Types of Ligations on Orthodontic Brackets: An InVitro Scanning Electron Microscopic Study. *IOSR J Dent Med Sci*. 2014;13(6):70-74.
31. Lee TH, Huang TK, Lin SY et al. Corrosion resistance of different nickel-titanium archwires in acidic fluoride-containing artificial saliva. *Angle Orthod*. 2010;80(3):547-553. [CrossRef]
32. Condò R, Casaglia A, Armellin E, Condò SG, Cerroni L. Traditional elastic ligatures versus slide ligation system. A morphological evaluation. *Oral Implantol*. 2013;6(1):15-24. [CrossRef]
33. Guimarães GS, de Morais LS, de Souza MMG, Elias CN. Superficial morphology and mechanical properties of in vivo aged orthodontic ligatures. *Dent Press J Orthod*. 2013;18(3):107-112. [CrossRef]

TURKISH JOURNAL of ORTHODONTICS

DOI: 10.5152/TurkJOrthod.2021.20079

Original Article

Plaque Removal Efficacy of 3 Cleaning Methods for Removable Orthodontic Appliances: A Crossover Randomized Clinical Trial

Homa Farhadifard, Sepideh Sohilifar, Anahita Bakhshaei

Department of Orthodontics, Faculty of Dentistry, Hamadan University of Medical Sciences, Hamadan, Iran

Cite this article as: Farhadifard H, Sohilifar S, Bakhshaei A. Plaque removal efficacy of 3 cleaning methods for removable orthodontic appliances: A crossover randomized clinical trial. *Turk J Orthod.* 2021; 34(3): 170-175.

Main Points

- The microbial plaque was mostly collected in the case of using the brushing method alone.
- The use of denture cleansing tablets is recommended to enhance oral hygiene when using ROAs.
- Combination of brushing and cleansing tablets decreased the microbial biofilm.

ABSTRACT

Objective: The mechanical plaque removal methods for removable orthodontic appliances (ROAs) may damage the surface of the appliance and may not effectively eliminate the entire microbial plaque. This study aimed to compare the efficacy of brushing+denture cleansing tablets, brushing+propolis mouthwash, and brushing only, for plaque removal from the surface of each orthodontic appliance.

Methods: This crossover randomized clinical trial evaluated 32 patients aged 7-15 years with ROAs. The patients were randomly assigned to 3 groups of brushing (control), brushing + denture cleansing tablets (intervention group 1), and brushing + propolis mouthwash (intervention group 2). The plaque removal methods were switched among the groups during 3 periods, each of 1-month duration. One month after practicing a certain protocol, the plaque disclosing agent was applied on the surface of the appliance. The photographs of the appliances were analyzed by Image J software to calculate the surface area occupied by the residual microbial plaque.

Results: The ratio difference between the surface area of residual plaque to the surface area of the entire appliance was significant between the intervention group 1 and the control group ($P < .001$), while it was not significant between the intervention group 2 and the control group ($P = 0.105$). Moreover, this difference between the intervention groups 1 and 2 was statistically significant ($P < .001$).

Conclusion: The simultaneous use of toothbrush with denture cleaning tablets decreased the microbial biofilm on the surface of ROAs to a better extent, compared to the results with brushing alone. Thus, it appears that the use of denture cleaning tablets may be suitable for effective cleaning of ROAs.

Keywords: Denture cleaning tablets, microbial plaque, orthodontic appliances, propolis mouthwash

INTRODUCTION

Fixed orthodontic treatment with the use of bands and brackets decreases the efficacy of oral hygiene measures in the prevention of plaque accumulation. In contrast, removable orthodontic appliances (ROAs) allow for adequate oral hygiene and decrease the risk of dental and periodontal problems.[1] Although the use of ROAs is more limited compared with the past, they are still used for particular indications, especially in mixed dentition and in conjunction with other orthodontic treatments.[2]

Corresponding author: Anahita Bakhshaei, e-mail: ana.bakhshaei@gmail.com

Received: July 4, 2020
Accepted: March 6, 2021

Orthodontic appliances change the microbial ecosystem of the oral cavity by inducing bacterial growth and increasing the risk of conditions such as halitosis, periodontal disease, and caries. Moreover, being unable to clean dental plaque on the concave and hard-to-reach areas of ROAs by toothbrush can lead to the roughness of the acrylic surface and will surge plaque accumulation. In addition, using a toothbrush along with toothpaste can even result in more abrasion of the acrylic base when compared to using a toothbrush with only water or cleaning tablets.[3] Therefore, some studies have considered this method obsolete and suggest chemical cleaning tablets for this purpose.[4]

To the best of our knowledge, limited published information is available regarding the efficient cleaning of resin ROAs. Thus, researchers are still seeking an ideal method for cleaning resin ROAs to minimize complications and promote the oral hygiene and satisfaction of patients.[3]

Dentipur tablets (Dentipur®, Helago-Pharma GmbH, Parchim, Germany) are among the materials used to improve acrylic denture hygiene. Its manufacturers claim that the advantages of these tablets, compared with toothpastes and other products, include their fast action (within 3 minutes), easy use (immersion), and not causing wear of the acrylic surfaces. Chemical cleaning tablets reduce the adhesion of microbial plaque to the surface of resin ROAs by releasing reactive oxygen species, and eliminate the microbial plaque from the surface of the appliance.[3]

Propolis is a natural substance derived from a plant resin that is collected by honeybees. The ethanolic extract of propolis is probably more effective than its aqueous extract to control oral biofilm and prevent the progression of dental caries.[5] Propolis is highly effective against Gram-positive bacteria, especially Staphylococcus aureus, and Gram-negative bacteria such as Salmonella.[6] Therefore, we decided to use propolis mouthwash to assess its effectiveness in removal of plaque accumulated on ROAs.

This study aimed to assess and compare the efficacy of 3 methods—brushing, brushing + denture cleaning tablets, and brushing + propolis mouthwash—for cleaning of ROAs, to find an efficient method for optimal plaque removal.

METHODS

The present study was conducted from May 2019 to January 2020. This crossover randomized clinical trial was approved by the University ethics committee (REC.1397.513) and registered in the Registry of Clinical Trials (CT20190106042253N2).

The patients were randomly selected among 7-15-year-olds presenting to the Dental Clinic of Hamadan University of Medical Sciences School of Dentistry, who were under orthodontic treatment with a removable appliance for a minimum of 1 and a maximum of 3 months. According to the prior studies[7,8] in the field of microbial culture of dental plaque in ROAs, and comparing the measured biofilm level after using different cleaning methods, and using Giradueau et al.'s study[9] with $\sigma^2_x = 0.02$, $\mu^{(1)}-\mu^{(2)} = 0.03$, $1-\rho = 0.09$, $Z_{\alpha/2} = 0.84$, and $Z_\beta = 1.96$, the appropriate sample size for this study was considered as 32. However, assuming an attrition rate of 20%, it was estimated that 37 patients were required to achieve 80% power to detect a difference between treatment methods, with an α level of .05.

The patients were randomized into 3 groups using balanced block randomization, and were assigned to each of these groups for the first month: brushing alone (control group), brushing + denture cleansing tablets (Dentipur®, Helago-Pharma GmbH, Parchim, Germany) (intervention group 1), or brushing + propolis mouthwash (intervention group 2). For the next 2 months, the allocation of interventions was switched for the patients in the 3 groups such that all patients received all 3 interventions by the end of 3 months.

Prior to the commencement of the study, the removable appliances were used by patients for a minimum of 1 month. During this period, the patients were requested to clean the appliance with a toothbrush and toothpaste every night.

After briefing the patients and their parents about the study and obtaining their written informed consent, an experienced clinician assessed the oral hygiene of patients by measuring their plaque index. The inclusion criteria were (I) requiring resin maxillary orthodontic appliances, and (II) plaque index < 30%. Immunocompromised patients and patients with systemic diseases, or those with improper use of the appliance, poor oral hygiene, and inappropriate cleaning of the appliance, were excluded.

The patients were told that they must use their maxillary appliance for a minimum of 10 hours during a 24-hour period and must adhere to the hygienic measures as instructed. The patients received instructions regarding oral hygiene and cleaning of their orthodontic appliance, both verbally and written in the form of a brochure.

The patients in all of the groups were requested to brush their teeth and their appliances with a medium toothbrush of any commercial brand using the Bass technique, 2 or 3 times a day, with any toothpaste containing 1400 ppm fluoride. Also, they were instructed to correctly use dental floss once a day. It is noteworthy that parents were responsible for performing or supervising the brushing of teeth and cleaning of the appliance, in case a child was not able to follow the instructions.

To instruct the patients and their parents on the correct technique of cleaning of the appliance, the clinician first demonstrated by cleaning the maxillary appliance with a medium toothbrush. To assess the cooperation level of patients, the parents were provided with a questionnaire to record the duration of usage of the appliance over 24 hours. They were requested to fill out the questionnaire and bring it back at the following session. The questionnaire was used for patients' screening; therefore, patients with inadequate appliance wear time were excluded from the study.

In the brushing group, the patients were instructed to brush their orthodontic appliance with a toothbrush.

Patients in the intervention group 1 were provided with 1 pack of Dentipur tablets and a screw-top container to place the appliance and the tablet in. The composition of these tablets includes VP|VA copolymer, sodium lauryl sulfate, sodium lauryl sulfoacetate, aroma, CI 73015, potassium caroate, sodium carbonate, citric acid, and glucose. The patients were instructed to brush their teeth with a toothbrush and toothpaste every night, immerse their orthodontic appliance in a slurry prepared by dissolving a denture cleansing tablet in water for 3 minutes, thoroughly brush the appliance with a clean toothbrush and rinse it under running water.

In the intervention group 2, the patients were provided with a bottle of propolis mouthwash (propolis mouthwash, Soren Tech Toos®, Mashhad, Iran) containing 30% ethanolic extract of propolis. The patients were requested to brush their appliance with a toothbrush and immerse their appliance in the mouthwash for 3 minutes every night.

In the present study, the patients practiced all 3 methods in a consecutive, random fashion. At the 1-month recall session, patient cooperation (using the appliance for a minimum of 10 hours in every 24 hours, continuous use of the appliance, and correct hygiene measures) was evaluated. Next, a plaque disclosing agent (Lactona®, Bergen opZoom, Netherlands) was applied on the internal surface of the appliance (the surface in contact with the tissue) by a cotton swab before the commencement of the study and after each follow-up. The appliances were then rinsed, dried, and photographed in a vertical position using a camera (Canon© 40-D, Tokyo, Japan) with a macro100 lens at every appointment, including the baseline. All photographs were captured at a 50-cm distance perpendicular to the appliance at 6.5 fps speed with a 20-mm diaphragm using a 20-megapixel CCD. Afterward, the maxillary appliance was cleaned with a toothbrush, disinfected, and delivered to the patient. The patients were then assigned to another intervention group for the next month. This process was repeated at the end of the second month and the third month as well, such that all patients had practiced all 3 interventions at the end of the third month.

The photographs were analyzed by ImageJ software (ImageJ, LOCI, University of Wisconsin, USA). ImageJ software is open-source JAVA-based software for image processing, manufactured by the National Institute of Health (Figure 1). It is of note that the evaluator was blinded for the calculation of the surface area occupied by the residual plaque on the appliance (in mm^2).

The surface area of the new microbial plaques on the appliance, which was pink, was calculated by the software. The ratio of the surface area of the microbial plaque to the entire surface area of the appliance was also calculated and analyzed.

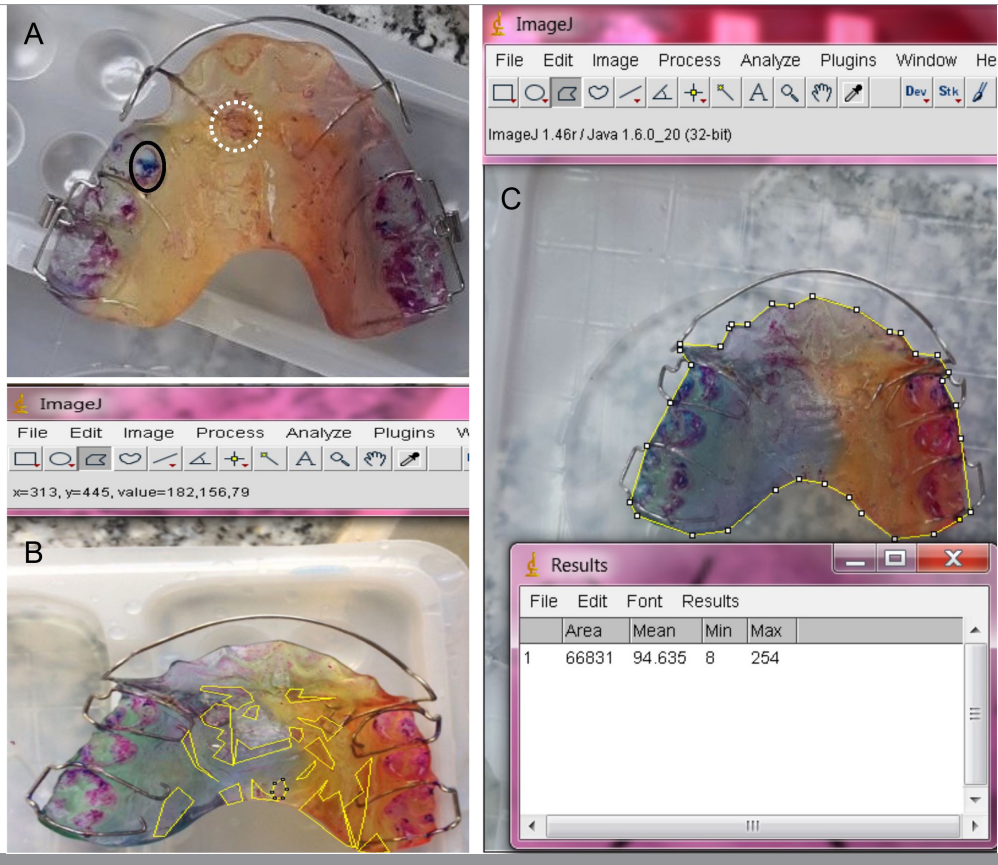


Figure 1. Plaque's Image analysis by the Image J software: (a) Dotted white line: new plaque, continues black line: old plaque

Table 1. The mean ratio of biofilm surface area to the entire surface area of the orthodontic appliance in the 3 groups (n = 32)

Group	Mean	Standard Deviation	Minimum	Maximum
Brushing	0.3209	0.20	0.03	0.69
Brushing +denture cleansing tablets	0.0678	0.05	0.01	0.20
Brushing + propolis mouthwash	0.2441	0.15	0.18	0.55

Table 2. Pairwise comparisons of the groups regarding the amount of biofilm on the surface of orthodontic appliances

Cleaning Method 1	Cleaning Method 2	Mean Difference	*P**
Brushing	Brushing + denture cleansing tablets	.2531	<.001
	Brushing + propolis	.0767	.105
Brushing + denture cleansing tablets	Brushing + propolis	−.1763	<.001

*Tukey's test.

Table 3. The effect of age or duration of usage of orthodontic appliance during the day or at night, on the amount of biofilm

Variable	*F*	*P**
Gender	0.04	0.833
Age	0.31	0.578
Duration of usage during the day	1.72	0.198
Duration of usage at night	1.11	0.298

*mixed-model analysis.

All statistical analyses were carried out using SPSS Version 21 (SPSS Inc., IL, USA). The data of different groups and all of the follow-ups were merged as one.

Normal distribution of data was evaluated using the Kolmogorov–Smirnov test. Considering the normal distribution of data, one-way ANOVA followed by the Tukey's test was applied to compare the groups regarding the ratio of biofilm surface area to the entire surface area. The effect of age, gender, and duration of usage of the orthodontic appliance on the results was also analyzed using the mixed-model analysis. To assess the intra-observer reliability, 13 photographs (20%) were analyzed again after 2 weeks by the same experienced observer. Based on these measurements, the intra-observer correlation coefficient was calculated to be 0.81.

RESULTS

At the beginning of this study, 51 patients were assessed for eligibility, and 37 of them were included in the study. Among these 37 participants, 3 were excluded due to poor cooperation in using the appliance and 2 were excluded due to their absence at the recall session (Figure 2). The number of evaluated photographs was 37, 32, and 34 in the 3 groups of denture cleansing tablets + brushing, propolis mouthwash+ brushing, and brushing, respectively. It is of note that only 32 patients completed the study and were allocated to each of these 3 groups. (Table1)

As shown in Table 2, 16 males and 16 females with a mean age of 11.22 ± 1.91 years remained in the study. The initial plaque index of all patients was 27%. Also, the duration of appliance usage by the patients was 6.61 ± 2.24 and 7.02 ± 1.84 hours, during the day and at night, respectively.

The mean ratio of the biofilm surface area to the entire surface area of the orthodontic appliance was 0.3209 ± 0.20, 0.0678 ± 0.05, and 0.2441 ± 0.15 in the brushing, brushing + denture cleansing tablets, and brushing + propolis groups, respectively.

One-way ANOVA showed a statistically significant difference in the biofilm surface area between the 3 groups ($P < .001$). Thus, pairwise comparisons were carried out using the Tukey's test. As shown in Table 2, the amount of biofilm on orthodontic appliances was significantly lower in the group that followed brushing + denture cleansing tablets compared with the other 2 groups ($P < .001$).

Although the amount of biofilm on orthodontic appliances was lower in the brushing + propolis mouthwash group compared with the brushing group, this difference did not reach statistical significance ($P = .105$).

As shown in Table 3, according to the mixed-model analysis, the age, gender or duration of usage of the orthodontic appliance during the day or at night had no significant effect on the results.

DISCUSSION

ROAs often interfere with the natural cleaning of the oral cavity. The clasps, retainers, and other components of the appliance cause food impaction and microbial plaque accumulation and lead to dental caries and periodontal disease. A study demonstrated greater adhesion of Streptococcus mutans to surfaces in children with ROAs, compared with those without an orthodontic appliance.[10]

In the present study, a plaque disclosing agent, which was an active solution lacking any erythrosine, was used to assess the efficacy of cleaning methods. This solution stains the old plaque dark blue and the new plaque pink. The use of a plaque disclosing agent is the most common method applied for research purposes, because its accuracy has been previously confirmed.[7] ImageJ software was used in this study for the accurate calculation of the plaque surface area stained by the disclosing agent.[8]

In this study, the old plaque was only detected in concave areas of the appliance. According to Madléna,[11] 2-3% of all deposits remained on the orthodontic appliances after cleaning with cleansing tablets. Normally, these tablets have optimal efficacy when used from the first day. It appears that the old plaque

remains in depressions due if the cleanser tablets are not used from the first day of using the appliance.

One major concern in the use of cleansing tablets is the corrosion of soldered areas. Nonetheless, it seems that the susceptibility to corrosion mainly depends on problems during soldering. In this study, none of the orthodontic appliances had soldered areas, and no change occurred in the appearance of the appliances.[3]

The current results are in line with those of Diedrich et al.[10] They compared the efficacy of 3 cleaning methods for ROAs, namely brushing with toothpaste, the use of denture cleaning tablets, and the use of an ultrasonic device. They reported that a toothbrush and toothpaste adequately cleaned the accessible surfaces. According to their study, denture cleaning tablets and the ultrasonic device had higher efficacy for cleaning the hard-to-reach areas. Nonetheless, none of the 3 methods could completely eliminate the microbial plaque.[4] It appears that the clasps, expansion screws, marginal borders, and surface irregularities are inaccessible with the toothbrush. Moreover, rough acrylic surfaces would enhance plaque accumulation such that the presence of porosities deeper than 0.2 µm would cause microbial adhesion.[12] The microporosities of the material can serve as a microbial source, and microorganisms mainly spread in the acrylic base. Moreover, a combination of toothbrush and toothpaste would cause further wear of the appliance surface compared with water or self-acting tablets.[13] Diedrich et al.[10] reported that brushing alone was not acceptable, and denture cleaning tablets should be used along with brushing. They showed that the tablets released oxygen and cleaned the appliance in the sensitive and hard-to-reach areas by enzymatic proteolysis. Organic residues are oxidized in an alkaline solution and thus the surface of the appliance is disinfected. According to Moore et al.,[14] Miller's and Kleenite were more effective cleaning solutions. Brushing and immersion in a cleaning solution containing potassium dichloroisocyanurate, trisodium phosphate, and sodium lauryl sulfate (with the commercial name of Mersene) was less effective. Dentipur tablets, similar to Mersene, contain sodium lauryl sulfate; however, it is present in the form of copolymer. Sodium lauryl sulfate is a detergent utilized for solubilizing proteins in microbiological laboratories.[14]

The current results were in contrast to those of Tarbet et al.,[15] regarding dentures. They compared the cleaning efficacy of precise brushing with toothpaste and immersion in solutions of denture cleansing, and concluded that precise brushing with toothpaste was more effective for plaque removal from the denture surface. In this study, the patients cleaned the entire surface of the appliance with a toothbrush after immersion in the slurry of denture cleansing tablets; however, in the study by Tarbet et al.,[15] patients only used the tablets. The absence of mechanical load for cleaning of the appliance may explain the inefficacy of tablets in their study. Moreover, the differences in the structure and composition of the acrylic denture and ROAs as well as the differences in the composition of tablets, may explain the controversy in the results. Dodwad et al.[16] evaluated the efficacy of propolis as an oral irrigating solution for the prevention of plaque formation and the promotion of gingival health. As they have mentioned in their study, the exact mechanism of the antimicrobial action of propolis is not known exactly; though flavonoids and cinnamic acids seem to be the main compounds responsible. They evaluated 30 patients who were randomly assigned to 3 groups of 10, namely the propolis mouthwash, negative control, and saline groups. The positive control group used 0.2% chlorhexidine. The results revealed that chlorhexidine was more effective than propolis and saline for the prevention of plaque formation. Propolis was found to be slightly superior to chlorhexidine in promoting the gingival score. Their results were similar to our findings regarding the lower efficacy of propolis than other antibacterial agents for the prevention of plaque formation. It seems that the lower efficacy of propolis mouthwash may be due to the lack of sodium lauryl sulfate as a component, and the dependency of its plaque-inhibiting action on natural components.[17]

To the best of the authors' knowledge, the cleaning effect of propolis and its derivatives on ROAs has not been evaluated before. Thus, a precise comparison of the current results with other studies regarding this topic is not possible.

The mixed-model analysis showed that age, gender, and duration of usage of the appliance had no significant effect on the cleaning efficacy of the 3 interventions. This finding maybe explained by the fact that parents were responsible for the cleaning of the orthodontic appliance of their children.

Not being able to precisely monitor patient cooperation was a limitation of this study. To minimize this problem, a questionnaire was designed to assess the cooperation of patients in using the appliance. Another limitation of this study was the inter-individual differences in the composition of biofilm, personal hygiene, and the dimensions and morphology of the orthodontic appliances. To overcome this problem, the study had a crossover design and all patients alternatively practiced all the cleaning methods.

CONCLUSION

According to the results of this study, the simultaneous use of brushing and denture cleaning tablets compared with brushing alone decreased the biofilm on the surface of ROAs. Thus, it appears that the use of denture cleaning tablets may be suitable for effective cleaning of orthodontic appliances.

Ethics Committee Approval: This study was approved by Ethics committee of Hamadan University, (Approval No: IR.UMSHA.REC.1397.513) and registered in the Iranian Registry of Clinical Trials (IRCT20190106042253N2).

Informed Consent: Written informed consent was obtained from all participants who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - H.F., S.S.; Design - H.F., S.S.; Supervision - H.F., S.S.; Material- H.F., S.S.; Data Collection and/or Processing - A.B.; Analysis and/or Interpretation - S.S., A.B.; Literature Review- A.B., H.F., S.S.; Writing - A.B.; Critical Review - H.F., S.S.

Conflict of Interest: The authors have no conflict of interest to declare.

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

REFERENCES

1. Levrini L, Novara F, Margherini S, Tenconi C, Raspanti M. Scanning electron microscopy analysis of the growth of dental plaque on the surfaces of removable orthodontic aligners after the use of different cleaning methods. *Clin Cosmet Investig Dent*. 2015;7:125-131. [CrossRef]
2. Littlewood SJ, Tait AG, Mandall NA, Lewis DH. The role of removable appliances in contemporary orthodontics. *Br Dent J*. 2001;191(6):304-309. [CrossRef]
3. Eichenauer J, Serbesis C, Ruf S. Cleaning removable orthodontic appliances: A survey. *J Orofac Orthop*. 2011;72(5):389-395. [CrossRef]
4. Ahuja V, Ahuja A. Apitherapy-a sweet approach to dental diseases. Part II: Propolis. *JoAOR*. 2011;2(2):1-8. [CrossRef]
5. Rahman MM, Richardson A, Sofian-Azirun M. Antibacterial activity of propolis and honey against staphylococcus aureus and Escherichia coli. *Afr J Microbiol Res*. 2010;4(18):1872-1878.
6. Batoni G, Pardini M, Giannotti A, *et al*. Effect of removable orthodontic appliances on oral colonisation by mutans streptococci in children. *Eur J Oral Sci*. 2001;109(6):388-392. [CrossRef]
7. da Silva CH, Paranhos Hde F. Silva CHLd, Paranhos HdFO. Efficacy of biofilm disclosing agent and of three brushes in the control of complete denture cleansing. *J Appl Oral Sci*. 2006;14(6):454-459. [CrossRef]
8. Paranhos Hde F, da Silva CH. Comparative study of methods for the quantification of biofilm on complete dentures. *Braz Oral Res*. 2004;18(3):215-223. [CrossRef]
9. Giraudeau B, Ravaud P, Donner A. Sample size calculation for cluster randomized cross-over trials. *Stat Med*. 2008;27(27):5578-5585. [CrossRef]
10. Diedrich P. Microbial colonization and various cleaning procedures for orthodontic appliances. *Fortschr Kieferorthop*. 1989;50(3):231-239. [CrossRef]
11. Madléna M. The importance and possibilities of proper oral hygiene in orthodontic patients. In: *Orthodontic: Basical Aspects and Clinical Consideration*. Rijeka: INTECH; 2012:69-110.
12. Lima EM, Moura JS, Del Bel Cury AA, Garcia RC, Cury JA. Effect of enzymatic and naocl treatments on acrylic roughness and on biofilm accumulation. *J Oral Rehabil*. 2006;33(5):356-362. [CrossRef]
13. Gonser F, Kiesow A, Sarembe S, Petzold M. Bewertung durch zahnburstenreinigung hervorgerufener oberflachenveranderungen bei prothesenkunststoffen. *Dtsch Zahnarztl Hypn*. 2008;63(10):689.
14. Moore TC, Smith DE, Kenny GE. Sanitization of dentures by several denture hygiene methods. *J Prosthet Dent*. 1984;52(2):158-163. [CrossRef]
15. Tarbet WJ, Axelrod S, Minkoff S, Fratarcangelo PA. Denture cleansing: a comparison of two methods. *J Prosthet Dent*. 1984;51(3):322-325. [CrossRef]
16. Dodwad V, Kukreja BJ. Propolis mouthwash: a new beginning. *J Indian Soc Periodontol*. 2011;15(2):121-125. [CrossRef]
17. Murray MC, Worthington HV, Blinkhorn AS. A study to investigate the effect of a propolis-containing mouthrinse on the inhibition of de novo plaque formation. *J Clin Periodontol*. 1997;24(11):796-798. [CrossRef]

TURKISH JOURNAL of ORTHODONTICS

DOI: 10.5152/TurkJOrthod.2021.20162

Original Article

Effects of Rapid Maxillary Expansion on the Temporomandibular Joint: A Bone Scintigraphy Study

Gulay Dumanli Gok[1], Nuri Mert Topbasi[2], Bulent Baydas[3], Hatice Uslu[4], Ismail Ceylan[5], Ibrahim Yavuz[6], Ilhan Metin Dagsuyu[2], Mustafa Filik[7]

[1]Department of Orthodontics, Biruni University, Istanbul, Faculty of Dentistry, Turkey
[2]Private Practice, Istanbul, Turkey
[3]Department of Orthodontics, Uludağ University, Faculty of Dentistry, Bursa, Turkey
[4]Department of Nuclear Medicine, İstanbul Medeniyet University, Faculty of Medicine, Istanbul, Turkey
[5]Department of Orthodontics, Ataturk University, Faculty of Dentistry, Erzurum, Turkey
[6]Department of Orthodontics, Erciyes University, Faculty of Dentistry, Kayseri, Turkey
[7]Department of Nuclear Medicine, Ataturk University, Faculty of Medicine, Erzurum, Turkey

Cite this article as: Dumanli Gok G, Topbasi MN, Baydas B, *et al*. Effects of rapid maxillary expansion on the temporomandibular joint: A bone scintigraphy study. *Turk J Orthod.* 2021; 34(3): 176-181.

Main Points

- An increase in metabolic activity occurs in the TMJ region during RME.
- The increase in metabolic activity in the TMJ region decreases over time following the RME procedure.
- Mandibular condyles have adapted over time to the forces exerted by RME in the region of theTMJ.

ABSTRACT

Objectives: The purpose of this study is to assess the effects of rapid maxillary expansion (RME) on metabolic activity in the temporomandibular joints (TMJs) of young adult patients using scintigraphy.

Methods: The images of the TMJs were obtained from the retrospective scintigraphic images taken from 17 adult females (between 16.1 and 18.8 years of age, mean age of 17.3 $\pm$ 0.86 years) who had non-functional bilateral posterior crossbite, deep palatal vault, and dental crowding, and had been treated with RME. Bone scintigraphs were collected at 3 time intervals: at the beginning of treatment (T1), during the opening of the mid-palatal suture (T2), and at the end of screw activation (T3). Alteration in bone activity in the TMJ regions were evaluated in sagittal and transaxial slices. To determine the differences between the intervals, repeated analysis of variance and Bonferroni multiple comparison tests were applied.

Results: In the right and left TMJ regions, significantly increased metabolic activity was exhibited between T1 and T2 ($P < .001$). At the time of opening the maxillary mid-palatal suture, the metabolic activity increased by approximately 60% compared to the initial status. At the end of the active expansion period (T3), the change in metabolic activity was approximately 20% lower compared to T2.

Conclusions: Metabolic activity intensified in the regions of interest in the TMJ during RME. After mid-palatal suture opening, the activity noticeably decreased (T2-T3). This decrease in bone activity suggests that the TMJ complex adapts to RME forces.

Keywords: Scintigraphy, maxillary expansion, temporomandibular joint, adaptive remodeling

INTRODUCTION

Rapid maxillary expansion (RME) is a treatment modality performed by heavy forces that can split the mid-palatal suture at a rate of 0.2-0.5 mm/day. RME is capable of effectively treating buccal crossbite and transversal maxillary deficiency. The 2 halves of the maxilla can be pushed reciprocally in young individuals during RME.[1] Although the precise purpose of RME is to treat maxillary arch deficiencies, its reactions are not restricted to the maxillary bone. Since the maxilla is related with 10 bones in the facial skeletal system, RME has the potential to affect directly or indirectly the structures that are associated with the maxilla, such as the mandible, nasal cavity,

Corresponding author: Gulay Dumanli Gok, e-mail: drgulaygok@gmail.com

Received: December 24, 2020
Accepted: April 18, 2021

pharyngeal system, and the pterygoid process of the sphenoid bone.[2-4]

It has been shown that the major impediment to RME comes not only from the mid-palatal suture, but also from the other sutures of the maxilla and surrounding structures.[5] Of these neighboring structures, the zygomatic and sphenoid bones and the temporomandibular joint (TMJ) are particularly affected during RME.[6-8] Additionally, the rapid separation of the maxillary halves and the intensity of the forces applied to the jaw may cause functional loading and adaptive remodeling of the condyles, by altering the mandibular position and changing the occlusion.[9-11]

The effect of RME on TMJ has been considerably studied using traditional radiological imaging, cone beam computed tomography (CBCT), and magnetic resonance imaging (MRI) as diagnostic tools.[10,12,13] While CBCT is the chosen method for thorough analysis of alterations in TMJ skeletal structures, MRI is the preferred imaging modality for observing the soft tissues of the TMJ.[14] In a comprehensive literature review, Torres et al.[15] identified 3 significant findings about RME effects on TMJ. They showed that RME modifies the condyle-fossa relationship, does not modify the position or shape of the articular disc, and maintains intercondylar symmetry. However, neither CBCT nor MRI are adequate for early visualization of the effects of RME on the TMJ. Clinical studies using MRI have reported that the first mark of condylar remodeling is observed after 18 weeks of RME, but no information was provided about the duration of the expansion effect.[10] Following this pattern, it is accepted that in order for bone changes to be visible in radiography, there has to be approximately 30-50% demineralization.[16] Also, radiologic and other structural imaging modalities frequently fail to distinguish minor bone alterations. However, bone scintigraphy is capable of imaging skeletal metabolic activity and is commonly used to distinguish unusual vascularity or osteogenesis in the bone system, even if there is only an approximately 10% increase in osteoblastic activity above normal.[17] Due to its ability to detect metabolic changes, scintigraphy may be more illuminating, before noticeable structural changes appear on different radiographic methods.[18]

The questions that arise here are: How do condyles respond to functional and orthopedic forces of this magnitude? Does the high expansion force of RME influence the TMJ complex? If so, how long does the effect continue? Accordingly, in the present study, the early effects of the expansion procedure on TMJ were examined via scintigraphy. This paper aimed to extend and deepen this growing body of literature regarding the effects of RME on the TMJ by showing scintigraphic activation areas in the condyles depending on the stages of RME.

METHODS

The retrospective records of TMJ were obtained from the subjects who had participated in our 2006 study.[19] In the previous study, TMJ evaluation had not been planned, and the Clinical Research Ethics Committee's approval (decision number: 2018/23-19) was granted to conduct this retrospective study. Measurements were obtained from the images of the TMJ regions.

The records were collected from 17 skeletal Class I, normodivergent young adult females between the ages of 16.1 and 18.8 years (mean age: 17.3 $\pm$ 0.86 years). These patients had non-functional bilateral posterior crossbite, deep palatal vault, and dental narrowness, and they were treated with RME at the Department of Orthodontics, Faculty of Dentistry, Ataturk University.

The exclusion criteria were trauma, pathological orifice and jaw lesions, periodontal diseases, previous orthodontic treatment, and any evidence of TMJ disease. All potential benefits and risks were described to the patients and their families, and informed consent forms were signed. Only individuals who had a mid-palatal suture opening that was detected radiographically were included in the study. The skeletal maturation stage of all patients was 10-11, as reported by Fishman.[20] Biederman's RME appliance with a Hyrax screw (602-813, Dentaurum, Ispringen, Germany) was used, with an activation protocol of 2 times each day (0.5 mm) for an average of 20 days. Expansion was considered sufficient when the maxillary lingual cusp of the permanent first molar contacted the mandibular facial cusp of the permanent first molar.

99mTechnetium-Methylene Diphosphonate (99mTc-MDP) was used to obtain single-photon emission computed tomography (SPECT) images before RME (T1), during the splitting of the mid-palatal suture (T2), and at the end of screw activation (T3), to assess bone activity in the TMJ regions in each period. Patients were administrated an intravenous infusion of 0.4 mCi/kg (15 MBq/kg) 99mTc-MDP. Then, imaging was performed 3 hours after infusion of the radiotracer. The SPECT system was a single-headed gamma camera framework (GE 3200 XCT General Electric Medical System Ltd, St Albans, Herts, England) and images were taken with a low-energy, all-purpose, high-resolution collimator. In a 256 $\times$ 256 matrix, SPECT images were acquired for 25 seconds per frame over 360 rotations, with a 1.33 zoom. This produced 2 pixel-sized sagittal, transaxial and coronal images (Figures 1-4). Ten pixel-sized circular regions of interest (ROI) were marked on the medial slices of the sagittal and transaxial images.

Scintigraphic examinations can be affected by fluid intake, hunger–satiety situations, or general fitness.[21] To overcome this limitation, the relative uptake of 99mTc-MDP was calculated by dividing the activity counts on the TMJ regions by the background activity counts determined from the symphysis area. All results were stated as a mean ratio of uptake in the ROI to that of the sagittal and coronal mandibular symphysis. Since the condylar region and the zygomatic bone are superposed in the coronal plane, coronal measurements were calculated for only the symphysial area. In all slices, these quantitative assessments were executed using the Genie processing program (Genie, Version 2.6S, General Electric Medical System Ltd, Milwaukee, Wisconsin). To distinguish the accuracy of the selected TMJ regions and the reliability of positions, the scintigraphs were evaluated 3 times and the average values were considered.

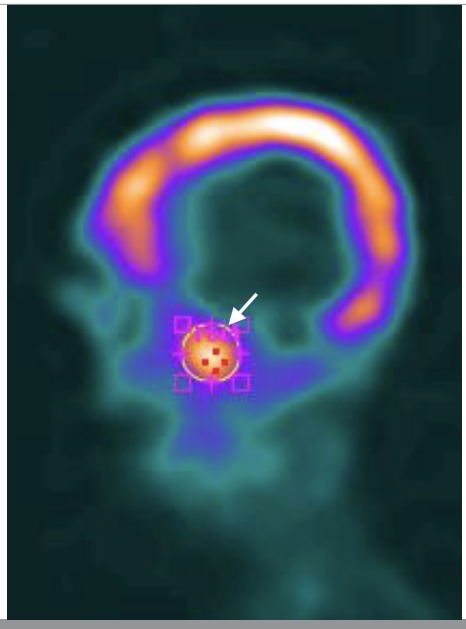


Figure 1. The regions of interest were examined on the sagittal slice of the left condyle (white arrow).

Statistical Analysis

All descriptive statistics were calculated for each interval. To compare the measurements after initial screening, repeated analysis of variance (ANOVA) and Bonferroni multiple comparison tests were executed, the *F* values of which were found to be statistically significant. Data management and analysis were performed using SPSS for Windows, Version 10.0 (SPSS Inc, Chicago, IL), and $P = .05$ was considered statistically significant. Post hoc power analysis was performed using the online ClinCalc Post Hoc power calculator (https://clincalc.com/stats/Power.aspx).

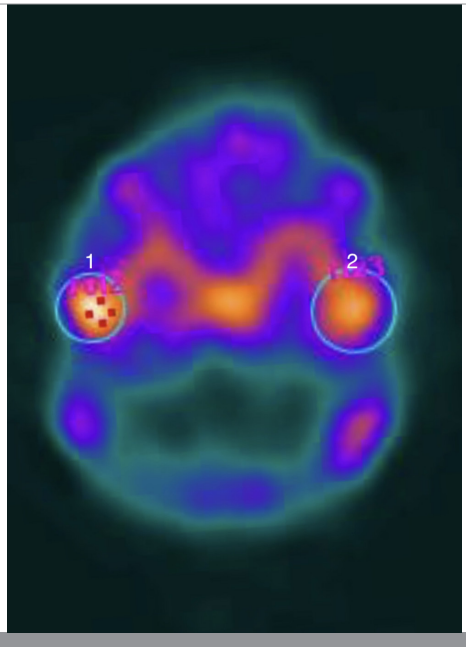


Figure 2. The regions of interest were examined on the transaxial slice of the condyles (A) Left condyle (B) Right condyle.

Figure 3. The regions of interest were examined on the sagittal slice of the symphysis area (white arrow).

RESULTS

The results of this study show that there was a condylar reaction to RME in young adult females. The descriptive statistics and ANOVA results are shown in Tables 1 and 2. Bonferroni multiple comparison test results are presented in Tables 3 and 4.

The right and left TMJ regions showed significant intensification of metabolic activity between the T1 and T2 periods. In the course of opening the maxillary mid-palatal suture (i.e., at the end of the 20-day-long active treatment), the metabolic

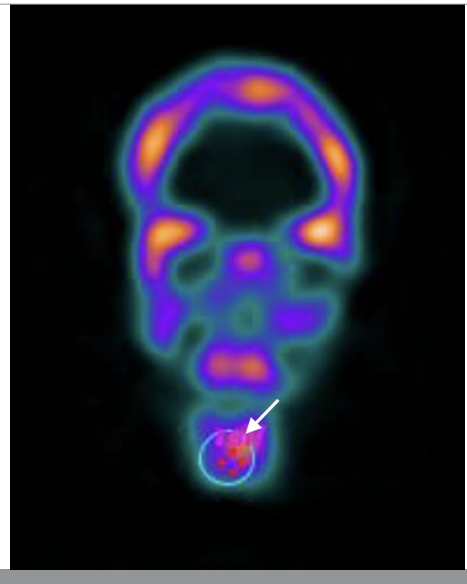


Figure 4. The regions of interest were examined on the coronal slice of the symphysis area (white arrow).

Table 1. Descriptive statistics and the results of the repeated measures analysis of variance (Sagittal Slice)

	T1		T2		T3		
N = 17	Mean	SD	Mean	SD	Mean	SD	*F*
Regions							
Right joint	0.53	0.13	0.86	0.25	0.75	0.10	28.52***
Left joint	0.60	0.15	0.89	0.21	0.75	0.10	23.67***

***$P < .001$.
SD, standard deviation.

Table 2. Descriptive statistics and the results of the repeated measures analysis of variance (Transaxial Slice)

	T1		T2		T3		
N = 17	Mean	SD	Mean	SD	Mean	SD	*F*
Regions							
Right joint	0.56	0.17	0.90	0.29	0.78	0.15	32.66***
Left joint	0.63	0.18	0.91	0.21	0.76	0.12	26.52***

***$P < .001$.
SD, standard deviation.

Table 3. The results of the bonferroni multiple comparison test (Sagittal Slice)

	T1-T2	T1-T3	T2-T3
Regions			
Right joint	−0.33***	−0.22***	0.11
Left joint	−0.29***	−0.14**	0.15*

*$P < .05$, **$P < .01$, ***$P < .001$.
SD, standard deviation.

Table 4. The results of the bonferroni multiple comparison test (Transaxial Slice)

	T1-T2	T1-T3	T2-T3
Regions			
Right joint	−0.34***	-0.22***	0.12*
Left joint	−0.27***	-0.13***	0.14**

*$P < .05$, **$P < .01$, ***$P < .001$.
SD, standard deviation.

activity increased by approximately 60% compared to the initial status. Metabolic activity decreased between the T2 and T3 periods. At the end of the active expansion (T3), metabolic activity intensification showed an approximately 20% reduction compared to T2, and this reduction was statistically significant. The difference between the values for metabolic activity between the first and last time points was still statistically significant (Tables 1-4).

In this study, post hoc power analysis was analyzed for collected data. The calculated power for the cellular activity detected varied by 92.9% and 100% between the measurements over time. The power calculated was largely above 80%, indicating that the sample size was reliable for this study.

DISCUSSION

The effects of RME on the TMJ complex are generally investigated using 2D radiological methods,[12] MRI,[10] and CBCT imaging. The development of CBCT, which offers lower-dose scanning and higher-resolution imaging, has created the opportunity to visualize the complicated hard tissue of TMJ. Thus, much of the literature on CBCT imaging of TMJ after RME has focused particularly on evaluating the condyle-fossa relationship spatially. Although there are studies which report that RME improves the relationship of asymmetric condyle-fossa in functional crossbite cases,[12] there are publications showing that it does not cause any change positionally in functional crossbite[22] or non-functional maxillary transversal deficiency cases.[13] Although MRI is considered to have the ability to visualize unmineralized soft tissue of the TMJ,[23] it is inadequate for early visualization of RME effects on the TMJ. Ruf and Pancherz[23] stated that the first sign of condylar remodeling is revealed by MRI after 6-12 weeks of Herbst treatment. Following this pattern, one well-known study of the effect of RME on the TMJ is an often-cited publication by Arat et al.[10] They reported that a sign of condylar remodeling is bone marrow edema seen in MRI in the 18th week of expansion, but they did not specify whether this was ineffective or detrimental. Thus, a question remains as to whether RME influences the condyles negatively or positively.

Bone scintigraphy studies have focused on the effects of functional orthopedic treatment (FOT) to the adaptive growth of condylar cartilage and bone responses to treatment,[24] or biomechanically generated bone activity in the neighboring tissues of mid-palatal suture during and after RME.[25] However, there is no useful information about the effects of RME on the TMJ area before structural changes are visible on radiographs. In the present study, given its ability to identify functional changes, we used scintigraphy imaging to measure bone activity of the TMJ area, which has not been investigated before. Also, scintigraphic studies of the TMJ in the literature focus on the imaging of changes in the sagittal direction of the condyle. However, our study is the first to evaluate transversal forces on the condyle.

In terms of functional treatment, a scintigraphic study by Paulsen et al.[24] reported that new bone formation was initiated by Herbst treatment in a patient who had an asymmetric mandibular condylar growth. Among the potential stimulatory mechanisms that cause adaptive remodeling is the muscle hypothesis, according to which the stimulation arises from lateral pterygoid muscle hyperactivity.[26] However, recent studies have indicated that the viscoelastic properties that are associated with protracted retrodiscal tissue, fibrous capsule, and the glenoid fossa provide adaptive remodeling of the condyle and glenoid fossa, rather than hyperactivity in muscles.[27] Importantly, the treatment mechanism of FOT differs significantly from RME. The FOT mechanism is very similar to a simulated joint between the maxilla and the

mandible, and it positions the mandible in a protruded position by continuous (Herbst) or intermittent (activator) force. FOT improves occlusion by the simulation of growth at the mandibular condyle, protruding mandibular incisors, and distalizing maxillary molar teeth. To distalize molars, the adequate force ranges from approximately 150 g to 250 g.[20] Conversely, RME produces an interrupted force with levels ranging from 0.007 to 11.59 kg.[28] Thus, compared to FOT, RME's stress level is high, and the type of force is different. Moreover, Zimring and Isaacson[5] reported that reaction forces associated with maxillary suture expansion dissipate within the craniofacial skeleton at least 6 weeks after RME, but our study indicates that they start to dissipate within the median palatal suture splitting—within approximately 3 weeks.

One hypothesis for RME effects on the condyle is that RME forces lead to the mandible reposing itself further back, which can exert extra pressure from the condyle toward the glenoid fossa. Thus, the mandible is forced into establishing a different pattern, which alters functional condylar loading.[10] In a CBCT study of patients of ages similar to the group used in our study, McLeod et al.[13] reported that RME did not significantly affect condyle position in cases of non-functional maxillary narrowness. However, the fact that the position of the condyle did not change does not mean that the condyle was not subjected to compressive forces. In the present study, metabolic activity showed significant increase up to the splitting of the mid-palatal suture. After the opening of the mid-palatal suture, activity exhibited a remarkable decrease. The present study showed decreasing RME forces in the TMJ, from the early stages of expansion. Our findings can be interpreted as evidence that transversal or rotational forces caused cellular activity intensification in the condylar region from the early period of RME. The decrease in cellular activity after the end of the screw activation period shows that the condyles have adapted to the expanding forces immediately after the splitting of the mid-palatal suture, and the TMJ complex tends to return to normal situation. The TMJ region is an anatomically restricted area that is surrounded by glenoid fossa and fibers. It was assumed that if the pressure persisted, RME forces could damage the TMJ; however, the result of this basic investigation can help in understanding the effects of temporary pressure on the condylar region by showing that residual forces of RME do not affect TMJ regions for a long time.

Overall, although our study had some strengths, it also had limitations. First, when considering that patients reach their growth spurt at 12-13 years of age (females) or at 14-15 years of age (males),[29] and that the gain is skeletal in nature with RME before the peak in growth spurt, while it is more dentoalveolar in nature during or after the peak in growth spurt, it can be thought that the average age of selected samples in this study is high. However, this age group was selected because of the harmful effect of radiotracers, especially for children.[30] Moreover, only those patients whose mid-palatal suture opening had been seen radiographically were included in our study, and this disadvantage was ruled out. Meanwhile, this preference is also advantageous. Given that the radiotracer is taken up by the tissues intensely in childhood and the amount of radiotracer uptake diminishes with maturation,[18] if younger patients were included in the study, it would be difficult to determine whether the detected cellular activity in the TMJ originated from RME or young tissues with high cellular activity. Further, to perform the present study only on females was a reasonable choice. If both sexes had been included in the present study, it would have been complicated to determine whether the observed cellular activity originated from RME or from the tissues, at different stages of maturity in females and males. Second, in our study, the different screws and screw activation procedures were not compared. Considering the high residual loads of RME, future studies should assess the effects of RME on TMJ regions by examining other RME procedures with memory screws or with a slow maxillary expansion protocol that produces less tissue resistance.

CONCLUSION

The conclusions drawn from the present study can be summarized as below:

- The results of this study demonstrate a condylar reaction to RME.
- There was statistically significant increase in metabolic activity while splitting the mid-palatal suture. At the end of the active expansion, the increased metabolic activity showed a decreasing trend.
- Mandibular condyles adapt to transversal and rotational residual loads and tend to return to their normal condition shortly after mid-palatal suture opening.

Ethics Committee Approval: Ethical committee approval was received from the Ethics Committee of Biruni University, (Approval No: 2018/23-19).

Informed Consent: Verbal informed consent was obtained from all participants who participated in this study.

Peer Review: Externally peer-reviewed.

Author Contributions: Concept - B.B., G.D.G.; Design - B.B., G.D.G.; Supervision - B.B.; Materials - B.B.; Data Collection and/or Processing - B.B., I.C., I.Y., I.M.D.; Analysis and/or Interpretation - H.U., M.F.; Literature Review - G.D.G., N.M.T.; Writing - G.D.G., N.M.T.; Critical Review - B.B.

Conflict of Interest: The authors have no conflict of interest to declare.

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

REFERENCES

1. Wertz RA. Skeletal and dental changes accompanying rapid midpalatal suture opening. *Am J Orthod*. 1970;58(1):41-66. [CrossRef]
2. Bishara SE, Staley RN. Maxillary expansion: clinical implications. *Am J Orthod Dentofacial Orthop*. 1987;91(1):3-14. [CrossRef]
3. Izuka EN, Feres MFN, Pignatari SSN. Immediate impact of rapid maxillary expansion on upper airway dimensions and on the quality of life of mouth breathers. *Dent Press J Orthod*. 2015;20(3):43-49. [CrossRef]
4. Timms DJ. Some medical aspects of rapid maxillary expansion. *Br J Orthod*. 1974;1(4):127-132. [CrossRef]

5. Zimring JF, Isaacson RJ. Forces produced by rapid maxillary expansion. 3. Forces present during retention. *Angle Orthod*. 1965;35:178-186. [CrossRef]
6. Holberg C. Effects of rapid maxillary expansion on the cranial base--an FEM-analysis. *J Orofac Orthop*. 2005;66(1):54-66. [CrossRef]
7. Martina R, Cioffi I, Farella M *et al.* Transverse changes determined by rapid and slow maxillary expansion - a low-dose CT-based randomized controlled trial. *Orthod Craniofac Res*. 2012;15(3):159-168. [CrossRef]
8. Bell RA. A review of maxillary expansion in relation to rate of expansion and patient's age. *Am J Orthod*. 1982;81(1):32-37. [CrossRef]
9. Melgaço CA, Neto JC, Jurach EM, Nojima MdCG da, Nojima LI. LIImmediate changes in condylar position after rapid maxillary expansion. *Am J Orthod Dentofac Orthop*. 2014;145(6):771-779. [CrossRef]
10. Arat FE, Arat ZM, Tompson B, Tanju S, Erden I. Muscular and condylar response to rapid maxillary expansion. Part 2: magnetic resonance imaging study of the temporomandibular joint. *Am J Orthod Dentofacial Orthop*. 2008;133(6):823-829. [CrossRef]
11. Fuentes MA, Opperman LA, Buschang P *et al.* Lateral functional shift of the mandible: Part I. Effects on condylar cartilage thickness and proliferation. *Am J Orthod Dentofacial Orthop*. 2003;123(2):153-159. [CrossRef]
12. Kecik D, Kocadereli I, Saatci I. Evaluation of the treatment changes of functional posterior crossbite in the mixed dentition. *Am J Orthod Dentofacial Orthop*. 2007;131(2):202-215. [CrossRef]
13. McLeod L, Hernández IA, Heo G, Lagravère MO. Condylar positional changes in rapid maxillary expansion assessed with cone-beam computer tomography. *Int Orthod*. 2016;14(3):342-356. [CrossRef]
14. Garcia MdM, Machado KFS, Mascarenhas MH. Ressonância magnética e tomografia computadorizada da articulação temporomandibular: além da disfunção. *Radiol Bras*. 2008;41(5):337-342. [CrossRef]
15. Torres D, Lopes J, Magno MB *et al.* Effects of rapid maxillary expansion on temporomandibular joints. *Angle Orthod*. 2020;90(3):442-456. [CrossRef]
16. Stevenson AG. Bone scanning as an aid to diagnosis and treatment planning in oral surgery. *Br J Oral Surg*. 1978;15(3):231-239. [CrossRef]
17. Craemer TD, Ficara AJ. The value of the nuclear medical scan in the diagnosis of temporomandibular joint disease. *Oral Surg Oral Med Oral Pathol*. 1984;58(4):382-385. [CrossRef]
18. Murray IPC, Ell PJ, eds. *Nuclear Medicine in Clinical Diagnosis and Treatment*. Edinburgh: Churchill Livingstone; 1998.
19. Baydas B, Yavuz I, Uslu H, Dagsuyu IM, Ceylan I. Nonsurgical rapid maxillary expansion effects on craniofacial structures in young adult females. A bone scintigraphy study. *Angle Orthod*. 2006;76(5):759-767. [CrossRef]
20. Fishman LS. Radiographic evaluation of skeletal maturation. A clinically oriented method based on hand-wrist films. *Angle Orthod*. 1982;52(2):88-112. [CrossRef]
21. Stace sm, Huggett sm, Denton bk, Harries am. The value of patient hydration prior to bone scintigraphy. *J Diagn Radiogr Imaging*. 2003;5(1):13-18. [CrossRef]
22. Leonardi R, Caltabiano M, Cavallini C *et al.* Condyle fossa relationship associated with functional posterior crossbite, before and after rapid maxillary expansion. *Angle Orthod*. 2012;82(6):1040-1046. [CrossRef]
23. Ruf S, Pancherz H. Temporomandibular joint growth adaptation in Herbst treatment: a prospective magnetic resonance imaging and cephalometric roentgenographic study. *Eur J Orthod*. 1998;20(4):375-388. [CrossRef]
24. Paulsen HU, Rabøl A, Sørensen SS. Bone scintigraphy of human temporomandibular joints during Herbst treatment: A case report. *Eur J Orthod*. 1998;20(4):369-374. [CrossRef]
25. Arat ZM, Gökalp H, Atasever T, Türkkahraman H. 99mTechnetium-labeled methylene diphosphonate uptake in maxillary bone during and after rapid maxillary expansion. *Angle Orthod*. 2003;73(5):545-549. [CrossRef]
26. McNamara JA. Neuromuscular and skeletal adaptations to altered function in the orofacial region. *Am J Orthod*. 1973;64(6):578-606. [CrossRef]
27. Voudouris JC, Kuftinec MM. Improved clinical use of Twin-block and Herbst as a result of radiating viscoelastic tissue forces on the condyle and fossa in treatment and long-term retention: growth relativity. *Am J Orthod Dentofacial Orthop*. 2000;117(3):247-266. [CrossRef]
28. Işeri H, Tekkaya AE, Oztan O, Bilgiç S. Biomechanical effects of rapid maxillary expansion on the craniofacial skeleton, studied by the finite element method. *Eur J Orthod*. 1998;20(4):347-356. [CrossRef]
29. WA M, Tanner JM. Puberty, ed. *Human Growth; a Comprehensive Treatise. Falkner F TJ*. New York: Plenum Publishing; 1986:171-209.
30. Kutanzi KR, Lumen A, Koturbash I, Miousse IR. Pediatric exposures to ionizing radiation: carcinogenic considerations. *Int J Environ Res Public Health*. 2016;13(11):1057. [CrossRef]

TURKISH JOURNAL of ORTHODONTICS

DOI: 10.5152/TurkJOrthod.2021.21075

Original Article

Prioritized Commitment-Based Clinical Assessment: A New Method for Assessment of Orthodontic Treatment Outcomes

Seyed Mohammadreza Safavi[1], Arash Farzan[2], Farnaz Younessian[3], Alireza Akbarzadeh Baghban[4]

[1]Department of Orthodontics, Dental Research Center, Research Institute of Dental Sciences of Shahid Beheshti University of Medical Sciences, Tehran, Iran
[2]Department of Orthodontics, Zanjan University of Medical Sciences, School of Dentistry, Zanjan, Iran
[3]Department of Orthodontics, Nova Southeastern University, College of Dental Medicine, Fort Lauderdale, Florida, USA
[4]Department of Basic Sciences, Shahid Beheshti University of Medical Sciences, School of Rehabilitation Sciences, Tehran, Iran

Cite this article as: Mohammadreza Safavi S, Farzan A, Younessian F, Akbarzadeh Baghban A. Prioritized commitment-based clinical assessment: A new method for assessment of orthodontic treatment outcomes. *Turk J Orthod.* 2021; 34(3): 182-188.

Main Points

- A new prioritized commitment-based clinical assessment index can be used as a CCA method.
- The treatment priorities are similar between orthodontists considering patients' chief complaints.
- The available orthodontics outcome assessment methods should be improved by considering patient concerns and priorities, and clinicians' commitments achieved during treatment.

ABSTRACT

Objective: Quality assessment is an essential part of orthodontic treatment. Most of the current indices are essentially based on occlusal assessment. However, an ideal occlusion is only one aspect of an ideal treatment. The aim of this article is to introduce a new prioritized commitment-based clinical assessment (PCCA) method and present its reliability and linear correlation test in comparison with the comprehensive clinical outcome assessment (CCA).

Methods: One hundred treated cases were scored with the conventional assessment tool—the CCA—and the newly developed assessment tool—the PCCA—with 2 calibrated examiners at 2 different time intervals. These cases were randomly selected including equal numbers of the main malocclusions managed with fixed conventional edgewise appliances within the past 3 years and had complete pre-treatment and post-treatment routine records. The intraclass correlation coefficient (ICC) was used to assess the intra-examiner repeatability of the total scores of both methods. Pearson's correlation coefficients were computed to assess the linear relationships between the CCA and PCCA scores.

Results: The intra-examiner reliability assessed for CCA and PCCA showed high repeatability for both examiners (ICC: 0.93 and 0.945, respectively). The inter-examiner reliability values for CCA and PCCA, assessed by ICC, were 0.84 and 0.96, respectively. The linear correlation between the 2 methods, assessed by comparing the mean score of each case by the 2 examiners was significant, at 0.01.

Conclusion: The PCCA method can be used for quality assessment in treated orthodontic patients. The preliminary test of the new method presented good inter- and intra-observer agreements and a significant linear correlation with the CCA method.

Keywords: Dental occlusion, calibration, malocclusion, orthodontic appliances, outcome assessment

INTRODUCTION

Since the introduction of orthodontics as a dental specialty, the pioneers of the profession made efforts to establish methods of classifying deviations from the so-called "ideal occlusion" and set treatment goals to achieve that. According to Kingsley, articulation of the teeth was considered as the second priority, following the facial appearance. However, in the early 20th century, Angle established a new concept stating that the optimal facial esthetics always coincided with ideal occlusion; therefore, strict rules to achieve ideal occlusal relationships were established and accepted until just the last decades.[1]

Corresponding author: Arash Farzan, e-mail: dr.arash.farzan@gmail.com

Received: June 28, 2020
Accepted: February 22, 2021

Although a concept shift has occurred, most of the available popular outcome assessment indices are based essentially on the previous concept of considering the final occlusion to assess the quality of final treatment outcome, and contain strict quantitative scoring systems involving intra-arch/inter-arch teeth positions compared with an ideal occlusion measured on dental casts. The most well-known assessment indices are the occlusal index,[2] the peer assessment rating (PAR) index,[3] and the American Board of Orthodontics Objective Grading System (ABO-OGS).[4]

Among these indices, the ABO-OGS, thanks to several comprehensive field tests by orthodontic experts, provides one of the most valid and reliable treatment outcome assessments.[4] This index includes several criteria on dental casts and some other important aspects of treatment, like the clinician's ability in case management, and final fulfillment of pre-treatment objectives. On the other hand, it has been found that only 32% of the cases treated by a group of orthodontists achieved scores less than 20 in the model analysis section, which usually would pass the board examination.[5] Later on, the comprehensive clinical assessment (CCA) was established at Indiana University as a complement to the ABO-OGS, with the aim of developing a more comprehensive outcome method. The CCA considers the following criteria to provide a clinical score, more representative of quality of treatment in a semi-quantitative manner: facial esthetics, dental esthetics, vertical control, arch forms, periodontium management, root structure preservation, and treatment efficacy.[6] However, it does not consider individualized priorities of these criteria at each specific case, nor does it assess the pre-treatment objectives.

On the other hand, considering the special social, economic, cultural, mental, and cosmetic concerns of each individual, compromised occlusion is an inevitable part of orthodontic treatments; therefore, in selected cases, compromising some aspects of ideal occlusion in order to reduce treatment costs and risks and fully satisfy patient compliance seems logical. Additionally, it seems also logical to consider some other aspects of a suitable treatment other than occlusion for assessing its success in a bolder fashion.[7]

The present methods of assessing treatment outcomes do not put enough emphasis on aspects of an ideal treatment other than occlusion,[8] and generally compare treatment outcome with an ideal condition. Since the achievement of an ideal treatment outcome is almost impossible in many patients, in the current investigation, we attempted to develop a new quality assessment method that is based essentially on the clinician's commitments in a prioritized manner at the start of the treatment —the prioritized commitment-based assessment (PCCA)—and compared it to the available CCA for a preliminary overview of its applicability.

METHODS

Development of a New Quality Assessment Method

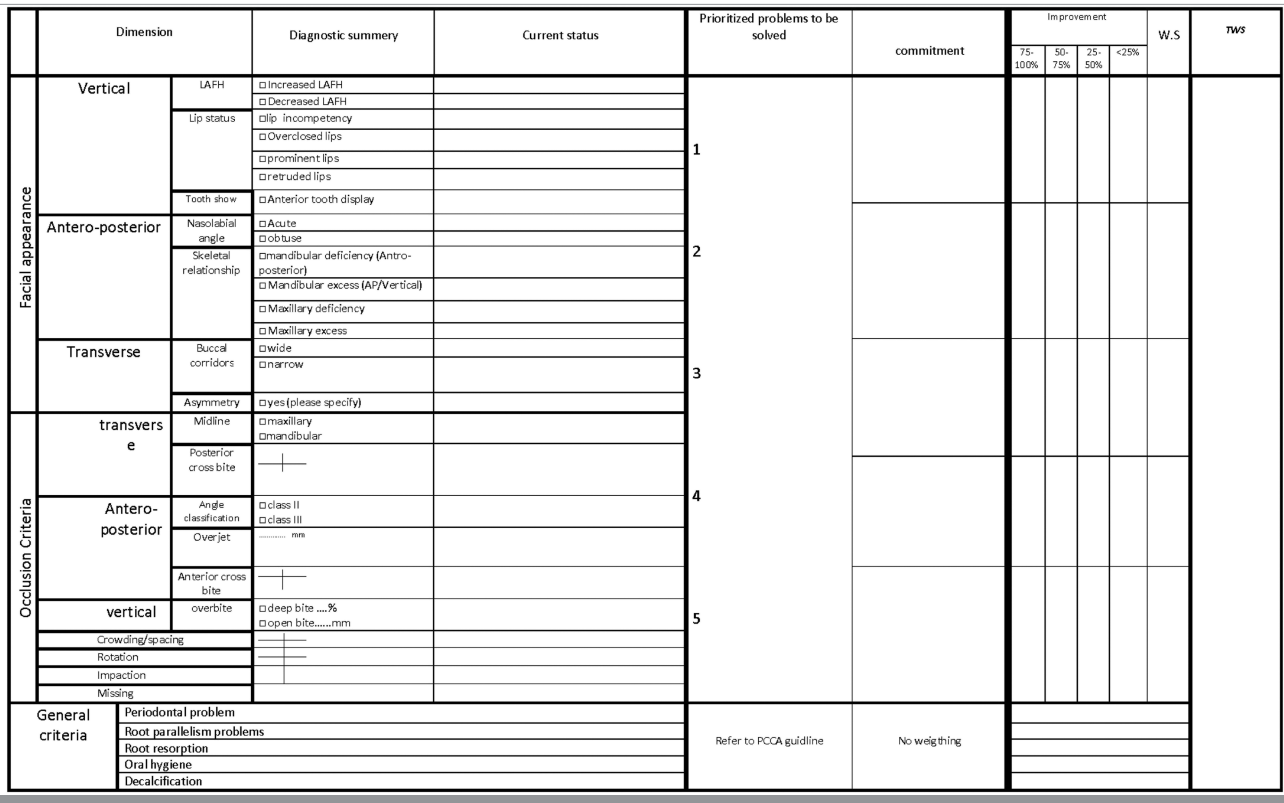
A new treatment quality assessment method was designed using pre-treatment and post-treatment records of patients, namely extra-oral and intra-oral standard photographs, dental casts, panoramic radiographs, lateral cephalograms, and treatment progress notes. The standards considered for intra-oral photographs were that they be of good quality without any distortion and blurring of the images, with as much as possible of soft tissue retraction, and 5 standard views (upper and lower jaw occlusal views, front, left, and right teeth in occlusion views). The standards needed for extra-oral photographs were that they be of good quality without any distortion and blurring of the images in at least 4 standard views of face and neck and the upper parts of shoulders (frontal at rest, frontal at smile, profile, and three-quarter in rest).

The decision number of the ethics committee of the Research Institute for Dental Sciences of Shahid Beheshti University of Medical Sciences was EC1392-117. Informed consent was obtained from all the subjects whose documents were evaluated in the study, and the privacy of the records was strictly maintained by the investigators. To evaluate the quality of treatments received with the prioritized commitment-based clinical assessment (PCCA), we designed a customized problem/diagnosis list of problems that are common and frequently seen in most of the orthodontic patients. The list has 2 main parts: (1) facial appearance in vertical, antero-posterior, and transverse dimensions and (2) occlusion in transverse, antero-posterior, and vertical dimensions, which are shown in Figure 1.

The method is mainly designed to work prospectively; however, it can be used to assess the quality of finished cases having the aforementioned records available, particularly with predetermined treatment objectives and clinician's commitments available. The general pool of possible orthodontic problems was obtained by evaluating electronic databases of the orthodontic department and determining commonly faced problems. A thorough diagnosis is required with this method. The current status of each of the criteria listed in the table should be recorded in the "current status" column. After recognition of the major problems of each individual patient from a general problem list, the clinician attempts to prioritize them. To reduce the difference among examiners, we suggest following rules of thumb to be considered in prioritization:

- Address the chief complaint of the patient as one of the first 2 priorities. For example, if the patient's chief complaint is "just straighten my upper teeth," the crowding/rotation may be the first priority. However, if the patient complains about "separated lips," lip incompetency should be addressed as the first priority.
- Address the criteria that are the most deviated from the norms as higher priorities.
- Of the problems evident in the case, if there is a problem not listed in the table, the clinician can add it to the table on their own. Then the clinician records his/her commitment regarding each criterion. This would include maintaining the current status or improving it.

In the assessment of facial appearance, the vertical dimension contains 3 criteria: the lower anterior facial height (LAFH), the lip status during rest (competency/incompetency), and tooth



	Dimension		Diagnostic summery	Current status	Prioritized problems to be solved	commitment	Improvement 75-100%	Improvement 50-75%	Improvement 25-50%	Improvement <25%	W.S	TWS
Facial appearance	Vertical	LAFH	□Increased LAFH		1							
			□Decreased LAFH									
		Lip status	□lip incompetency									
			□Overclosed lips									
			□prominent lips									
			□retruded lips									
		Tooth show	□Anterior tooth display									
	Antero-posterior	Nasolabial angle	□Acute		2							
			□obtuse									
		Skeletal relationship	□mandibular deficiency (Antro-posterior)									
			□Mandibular excess (AP/Vertical)									
			□Maxillary deficiency									
			□Maxillary excess									
	Transverse	Buccal corridors	□wide		3							
			□narrow									
		Asymmetry	□yes (please specify)									
Occlusion Criteria	transvers e	Midline	□maxillary □mandibular									
		Posterior cross bite			4							
	Antero-posterior	Angle classification	□class II □class III									
		Overjet	..... mm									
		Anterior cross bite										
	vertical	overbite	□deep bite ....% □open bite.....mm		5							
	Crowding/spacing											
	Rotation											
	Impaction											
	Missing											
General criteria	Periodontal problem				Refer to PCCA guidline	No weigthing						
	Root parallelism problems											
	Root resorption											
	Oral hygiene											
	Decalcification											

Figure 1. Table designed for prioritized commitment-based clinical assessment. It includes a problem diagnosis list containing common and frequently seen problems regarding facial appearance, occlusion criteria, and general criteria. It also has dedicated columns for the current status of each criterion according to available records, the priority, the orthodontist's commitment regarding each criterion, the weight of each diagnosed problem according to its priority, the final status at treatment completion, the weighted score, and the total weighted score.

display. In the antero-posterior dimension, it includes the nasolabial angle and skeletal relationships. We considered 90-100° nasolabial angle norms for male and 100-110° nasolabial angle norms for female patients. In the transverse dimension, it includes the buccal corridors and asymmetry. LAFH is measured considering the equation G-ANS/ANS-Me = 1, and evaluated on both photographs and lateral cephalogram. Lip separations of 4 mm or more at rest are considered abnormal.[9] Over-closed lips, prominent lips, and retruded lips are also addressed in the list of problems. These conditions should be evaluated mainly on standard photographs, but lateral cephalograms can also be used. Anterior tooth display or tooth-show is addressed in the smile (at least a quarter of the crown should be visible in the smile, and 2 mm gingival show is generally the upper limit for an esthetically acceptable smile).[10] The nasolabial angle (between 90° and 110°, with acute values acceptable for males and obtuse ones for females) is evaluated on photographs and cephalometry. Maxillary deficiency/excess is a complementary problem addressed as an upper lip problem and is evaluated on photographs and lateral cephalograms. The same is done for chin deficiency/excess. Buccal corridors are evaluated on frontal photographs. Asymmetry is measured on standard photographs, considering the relationship between the A-Pog line and the midsagittal line. If any evident asymmetry is evident and needs to be corrected by orthodontic treatment (like asymmetry due to a lateral functional shift), it would be scored 1, and if no visible asymmetry is present, it would score 0.

In the occlusion section, the evaluation is divided into transverse, antero-posterior, and vertical dimensions as well. Crowding/spacing, rotation, impaction, and missing teeth are also included in this part (Figure 1).

Midline and posterior crossbite are listed in the transverse section of the table. The midline for maxillary arch is recorded as the degree of millimetric deviation from the facial midline. The posterior crossbite is evaluated on dental casts and the teeth involved in this situation are mentioned in the table. Angle classification, overjet, and anterior crossbite are listed in the section regarding antero-posterior part. The Angle classification is recorded for canines and first molars. The overjet is recorded as the millimetric distance between the labial surfaces of incisors. The anterior crossbite is mentioned by the teeth involved in the situation. Overbite is listed in the vertical section, and is recorded by millimetric distance between the incisal edges of incisors.

Crowding is the most prevalent and usually the most important factor in the list of problems. It is measured by comparing the space available and space required, for simplicity. Having a commitment of "correcting the crowding" is not an accurate statement. The clinician should precisely determine the objective, for example "correcting the crowding to 0" or "accept 2-3 mm crowding in the lower incisor area," in a Cl III compromised treatment case. As mentioned before, in some cases, the ideal occlusal relationship according to available occlusal indices cannot

be achieved due to various obstacles. Rotation seems to be somehow overlapped by crowding; however, in some adjunctive orthodontic cases (e.g., pre-prosthetic orthodontic preparation), the problem is better addressed as a distinct one. Impaction and missing teeth are also mentioned in occlusion section by pointing the tooth/teeth involved in the situations.

The main problems are prioritized in the designed table (Figure 1), mostly up to a maximum of 5 main problems. This way, most important problem would have the first priority and the highest weightage of 5. The subsequent important problems would receive 2, 3, 4, and 5 priorities and weightages of 4, 3, 2, and 1 in the list, respectively

We developed a semi-quantitative scoring system. Determination of the score of each item depends on the treatment alterations that are intended for the course of treatment. After determining the score, it is written in the table; according to the priority of the commitment, the weighted score is then calculated: the scores of the first, second, third, fourth, and fifth priorities are multiplied by 5, 4, 3, 2, and 1 respectively.

We also considered some general criteria for each case which have neither weightages nor priorities and should be maintained/improved in all the cases (Figure 1):

- Periodontal problems as a consequence of orthodontic treatment: the gingival condition is evaluated and photographed, and 1 or 2 points deducted for moderate and severe gingivitis, respectively. If new bone loss or exacerbation of previous periodontitis is evident, 3 points are deducted.
- Root parallelism problems: scoring systems for these criteria are designed on a per-quadrant basis because any problematic mechanics in each quadrant can lead to these kinds of problems.
- Root resorption remains a challenging issue in orthodontics.
- Oral hygiene is evaluated based on progress notes; if more than 3 warning clinical notes are found, 1 point is deducted.
- Decalcification is evaluated on photographs as stated in the CCA method.[6]
- Finally, the "total weighted score" is calculated by the sum of total weighted scores and general criteria scores (Figure 1).

Test of the New Assessment Method

The new model was tested on 100 comprehensive orthodontically treated cases at the Orthodontic Department of Shahid Beheshti Medical University. These cases were randomly selected on each type of malocclusion including an equal 25 cases of Cl I, Cl II div 1, Cl II div 2, and Cl III routine malocclusions managed with fixed conventional edgewise appliances within the past 3 years, and had complete pre-treatment and post-treatment records. The sample records consisted of standardized initial and final study casts, panoramic and lateral cephalometric radiographs, and extra-oral and intra-oral standard photographs, in addition to the orthodontist's notes of each treatment session. To limit the confounding variables, cases with any congenital or systemic disorders or cleft lip/palate were excluded. In addition, cases managed with concomitant orthognathic surgical or any interdisciplinary approach were not included. All the selected cases were treated by orthodontic postgraduate students under the supervision of the department's instructing professors.

All the cases were scored using both CCA and PCCA methods with 2 calibrated examiners at 2 separate time intervals. Initially, 20 patients were selected to be scored by both examiners, due to intra-rater calibration procedure.

STATISTICAL ANALYSIS

To assess the intra-examiner repeatability, a subsample of 20 cases was selected and scored by examiners twice with a 4-week interval. The intraclass correlation Coefficient (ICC) was used to assess the intra-examiner repeatability of the total scores. All the cases were assessed by a postgraduate student (author AF) and an orthodontist (author FY) using CCA and PCCA scoring systems. The inter-examiner agreement was assessed also by ICC, the Bland–Altman test, and paired *t*-test for all the cases. Pearson's product-moment correlation coefficients were computed to assess the linear relationships between CCA and PCCA scores. SPSS 18 software (SPSS Inc. Release 2009. PASW Statistics for Windows, Version 18.0. Chicago: SPSS Inc.) was used for statistical calculations.

RESULTS

One hundred completed fixed orthodontic treatment cases were evaluated using 2 methods of CCA and PCCA by the 2 calibrated examiners at 2 different time intervals. To avoid any possible bias in interpretation of the data, there was a 4-week time interval between the 2 methods. The mean score of each case by each examiner, using either set up of quality assessment modalities, was calculated.

The linear correlation between the 2 methods was assessed by comparing the mean score of each case by the 2 examiners, and was considered significant at 0.01 (Pearson's correlation = 0.752). Summarized data and descriptive statistics for the cases are presented in Table 1. ICC for intra-examiner and inter-examiner reliability and paired *t*-test values for inter-examiner reliability for the 2 methods are presented in Table 2. The Bland–Altman results are shown in Figure 2. The *P*-value by paired *t*-test between average CCA and average PCCA was .017. *P*-values $<$ .05 were assumed significant.

DISCUSSION

Setting objectives for orthodontic treatment can generally be based on 2 different presumptions: 1) convert all the observed malocclusions to an ideal occlusion. Therefore, for assessing the orthodontic practice and clinicians' skills, one should set a gold standard with ideal occlusion, and any deviation from that would be considered a sort of inadequacy in practice. In this perspective, the main objective is to treat the malocclusion; the other factors important in providing medical services—patient concerns, treatment duration, costs versus benefits etc.—take the second place.

Table 1. Summarized data and descriptive statistics for the cases measured by authors FY and AF

	PCCA-FY (*n* = 100)	PCCA-AF (*n* = 100)	CCA-FY (*n* = 100)	CCA-AF (*n* = 100)	Average PCCA	Average CCA
Mean	1.11	1.26	0.74	0.66	1.18	0.70
Minimum	0	0	0	0	0	0
Maximum	15.00	15.00	7.00	8.00	15.00	7.50
Range	15.00	15.00	7.00	8.00	15.00	7.50
Std. Deviation	2.48	2.60	1.05	1.14	2.52	1.05

PCCA, prioritized commitment-based assessment; CCA, comprehensive clinical assessment; FY/AF, examiners' initials.

Table 2. Intraclass correlation coefficient (ICC) and paired t-test values for CCA and PCCA

	ICC	*P* (Paired *t*-Test)
Intra-examiner reliability for PCCA (FY)	0.94	-
Intra-examiner reliability for PCCA (AF)	0.95	-
Intra-examiner reliability for CCA (FY)	0.92	-
Intra-examiner reliability for CCA (AF)	0.94	-
Inter-examiner reliability (PCCA)	0.96	.028
Inter-examiner reliability (CCA)	0.84	.208

PCCA, prioritized commitment-based assessment; CCA, comprehensive clinical assessment; FY/AF, examiners' initials.

2) Clinicians should openly accept the fact that in nearly 70% of the cases, an ideal occlusion could not be achieved according to available gold standards.[5] Therefore, they should try to focus on a method to assess the treatment outcomes and clinicians' skills with a more realistic approach, rather than simply assign a majority of them to a so-called "failed" group. This can be done by considering the fulfillment of a prioritized commitment-based problem list at the end of treatment. Orthodontists should roughly classify their patients at the beginning of the service to 2 groups: 1) patients for whom the ideal occlusion can be achieved; 2) patients for whom the ideal occlusion is not achievable. For the first group, performing assessment according to an ideal gold standard seems logically acceptable. However, for the latter group, it is better to consider the proposed method of assessment of a prioritized commitment-based problem list as an adjunctive assessment tool. Therefore, in our opinion, the treatment outcome assessment in such cases should be based on 2 fundamental points in addition to well-designed routine standard assessment methods: (1) the clinician's commitments, and (2) the fulfillment of the commitments according to their determined priority.

In the present study, we introduced a new assessment method for treatment outcomes based essentially on the clinician's commitment at treatment initiation and their priorities in each individual case. According to the study design, that is, developing a new assessment tool and performing preliminary tests for evaluating the validity and reliability of the method, and also considering similar studies, we randomly selected 25 cases for each type of malocclusion (Cl I, Cl II div1, Cl III div2, and Cl III). Evaluating the reliability of a newly developed method needs several statistical assessments, since each statistical test may have its advantages and disadvantages. The preliminary test of the PCCA regarding its correlation with another comprehensive assessment method, the CCA, using ICC, was relatively good. Furthermore, the preliminary test of reproducibility showed excellent reliability. However, considering Bland–Altman and paired *t*-test, we did not have a perfect correlation between the 2 methods. This may refer to the fact that the CCA itself is not assumed as a perfect gold standard for assessing orthodontic treatment outcome.[6] Regarding the results of the paired *t*-test considering the large number of cases, any little difference between assessment methods may induce a significant statistical difference; however, for clinical use, relying on the ICC test seems appropriate.

The first index with a comprehensive study on its validity and reliability was the PAR index.[3] This index is totally based on assessing dental casts and includes no factor for assessing other aspects of orthodontic treatment. For the occlusion assessment, the index was not perfectly precise in discriminating between the minor malpositions of the teeth that are found in ABO case reports.[4] Therefore, an ABO committee was formed to design a more precise method of objective quality assessment. As a result of 3 phases of examination, the ABO-OGS was introduced, and is now being used as the standard of board qualification in ABO.[4]

The ABO uses one of the most valid and reliable methods for assessing treatment quality.[4,11] The ABO-OGS, by means of a specifically designed measuring gauge, objectively gives scores to treated cases. Final dental casts and panoramic radiographs are considered in the process of evaluation. This outcome assessment index can be assumed as a high standard occlusal index, considering its precise millimetric scores given to each of the 7 occlusal criteria.[4] The board qualification process also includes a clinical management part, which considers skeletal, dental and facial analyses separately and is based on pre-treatment and post-treatment measurements and pre-treatment objectives. In the case of fulfillment of any objective, no score is deducted; otherwise, a point will be deducted. However, this section seems somehow brief compared to the occlusal assessment part. For

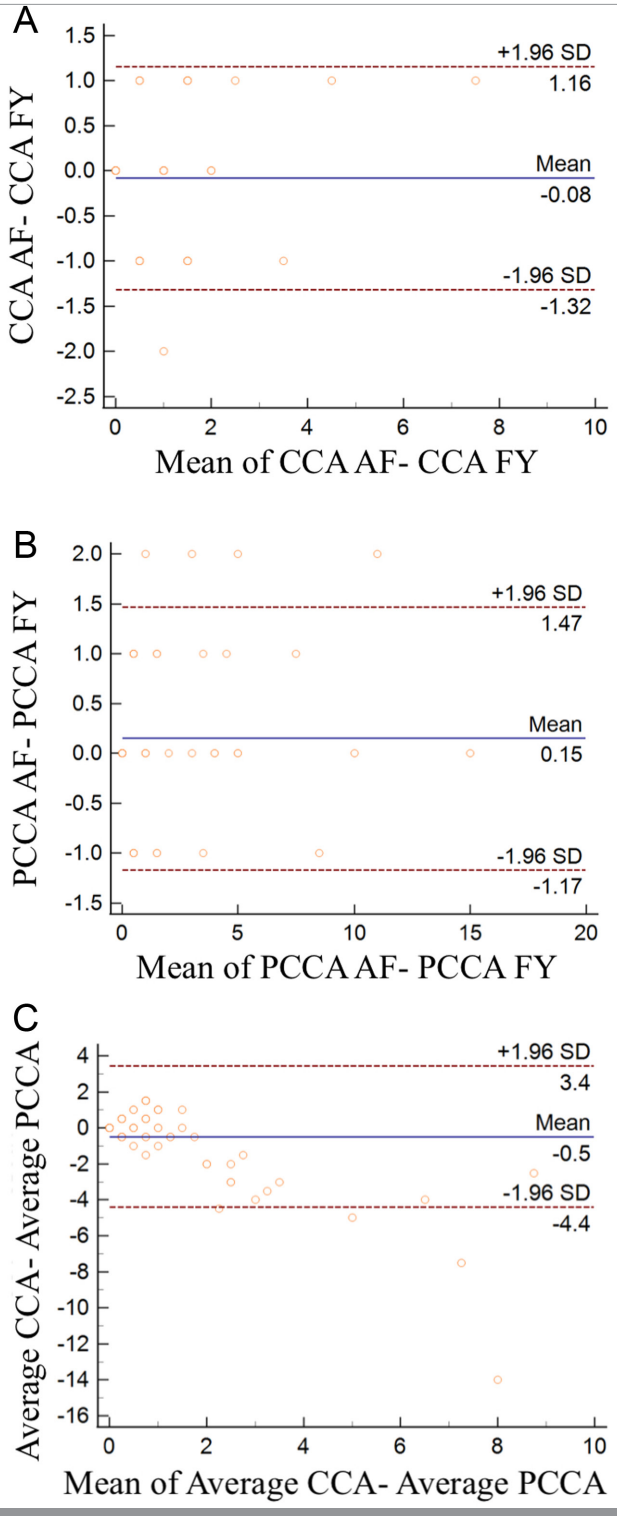


Figure 2. Bland–Altman test graphs. (A) CCA for evaluators AF and FY. (B) PCCA for evaluators AF and FY. (C) Average for CCA and PCCA.

example, it lacks an appropriate consideration of soft tissue changes as a consequence of orthodontic treatments, since only the E-line is being considered in the facial analysis. The case management section also uses a simple scoring method (0 or 1), lacking a weighting method to discriminate between higher treatment priorities from the lower ones. The PCCA concept may be especially used to improve this part of the board qualification process and help it achieve greater validity and reliability in assessing treatment outcomes.

The CCA was designed at Indiana University as a clinical complement to the ABO-OGS.[6] It includes several factors and raises a more comprehensive point of view for outcome evaluation. However, this method lacks a condition-specific approach or a differential weighting scale applicable in clinical practice. For example, either a deterioration in the patient's profile or the mistake of leaving bonding resin remnants on enamel surface lead to maximum of 2 points deducted from the total score of an orthodontic case. Who can claim that these faults are of the same importance?

On the other hand, some authors have questioned the rationale of determining an ideal occlusal situation, stating that different malocclusions should be assumed as normal variations rather than pathologic disorders, and that the orthodontists should improve some characteristics of such variations in terms of esthetics or function.[12,13] Therefore, conducting the assessment is based essentially on an ideal standard occlusion without proper consideration of other of clinical expertise like ethics, life experience, patient satisfaction, work habits, and the ability to handle stressful situations, response to criticism, and ability to participate as part of health-care team.[14] Therefore, it seems necessary to also properly include other aspects of an ideal treatment into outcome assessment methods, since the perfect occlusal outcome by itself cannot be an indicator of optimal treatment. We should assess the quality of treatment, or skills of the clinician in setting, and the prioritization of appropriate objectives for each patient individually and then the clinician's ability to reach these commitments.

A compromised treatment option with less than ideal occlusal outcome may be preferred over an ideal plan with considerable treatment duration, costs, and risks.[15] However, we do not claim that the idealistic occlusal indexes should not be used anymore or that they are of little value for assessing the outcomes. In fact, they should be applied to all cases, but one should also consider more comprehensive clinical management assessments.

The PCCA also uses a case-specific weighting system. A certain problem in different cases does not necessarily indicate the same level of importance. Therefore, the different weightages for each row of prioritized problems in the list provide a more accurate way for addressing problems and commitments in treatment outcome assessment. We suggest assessing the treatment outcome considering the first 5 priorities, based on the fact that after assessing the electronic database of the department, we faced a minimum of one problem (e.g., crowding in mild Cl II malocclusion) and a maximum of 7-8 problems; however it seems that the main problems in the most severe cases can be summarized to 5.

Another specific benefit of this quality assessment system includes the possibility for its use in the early mixed dentition for phase I treatment quality assessment. Since there are some specific goals in early phase of treatments that are not included in the routine overall goals for comprehensive treatments, most

of the mentioned grading systems exclude the mixed dentition patients to restrict the confounding variables and increase the reliability of the method.[3,4] However, with the ability to adjust the objectives of each phase in the PCCA method, it is possible to implement it for these interim treatment modalities as well.

It is clear that the presented method is not a perfect one; although the preliminary test of the method showed excellent results. As we go toward a more subjective assessment method, its reliability may decrease. The main problem with the PCCA is the possible differences between clinicians in determining treatment priorities in similar conditions. This problem was the case in our study, but interestingly, minor differences in setting treatment priorities between 2 examiners had a nonsignificant effect on the inter-examiner agreement. However, strict adherence to the soft tissue paradigm, the patient's chief complaints, and the most deviant aspects of each case of malocclusion might decrease the level of possible heterogeneity in this regard. We also found a good linear correlation between PCCA and CCA (but not an excellent one). We believe this finding only shows different points of view of these methods in assessing the cases.

Future efforts should be made to find a solution to increase the clinicians' agreement on developing prioritized problem lists, identifying patients' needs, and providing the best approach to address them. This may need several well-conducted clinical trials and meta-analysis studies to develop specific guidelines considering the costs versus the benefits of any treatment modality for various clinical conditions.

As final words, we look at the PCCA as an adjunctive tool for assessing orthodontic treatment outcome, but not as the only one. The patients may be satisfied when the chief complaint is treated, but this does not necessarily mean that the patient is free of further possibly progressive risks of poor oral health.

CONCLUSION

The preliminary test on a new PCCA index presented good inter- and intra-observer agreements in comparison with the currently available comprehensive clinical outcome assessment method.

Ethical Committee Approval: Ethical committee approval was received from the Ethics Committee of Shahid Beheshti University of Medical Sciences, (Approval No: EC1392-117).

Informed Consent: Written informed consent was obtained from all participants who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - S.M.S., A.F.; Design- S.M.S., A.F., F.Y.; Data Collection and/or Processing - A.F.; Analysis and/or Interpretation - A.A.B.; Writing - A.F., F.Y.

Conflict of Interest: The authors have no conflict of interest to declare.

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

REFERENCES

1. Sarver DM, Ackerman JL. Orthodontics about face: the re-emergence of the esthetic paradigm. *Am J Orthod Dentofacial Orthop*. 2000;117(5):575-576. [CrossRef]
2. Summers CJ. The occlusal index: a system for identifying and scoring occlusal disorders. *Am J Orthod*. 1971;59(6):552-567. [CrossRef]
3. Richmond S, Shaw WC, O'Brien KD, *et al.* The development of the PAR Index (Peer Assessment Rating): reliability and validity. *Eur J Orthod*. 1992;14(2):125-139. [CrossRef]
4. Casko JS, Vaden JL, Kokich VG, *et al.* Objective grading system for dental casts and panoramic radiographs. American Board of Orthodontics. *Am J Orthod Dentofacial Orthop*. 1998;114(5):589-599. [CrossRef]
5. Abei Y, Nelson S, Amberman BD, Hans MG. Comparing orthodontic treatment outcome between orthodontists and general dentists with the ABO index. *Am J Orthod Dentofacial Orthop*. 2004;126(5):544-548. [CrossRef]
6. Pinskaya YB, Hsieh TJ, Roberts WE, Hartsfield JK. Comprehensive clinical evaluation as an outcome assessment for a graduate orthodontics program. *Am J Orthod Dentofacial Orthop*. 2004;126(5):533-543. [CrossRef]
7. Ackerman MB, Rinchuse DJ, Rinchuse DJ. ABO certification in the age of evidence and enhancement. *Am J Orthod Dentofacial Orthop*. 2006;130(2):133-140. [CrossRef]
8. Sachdeva RC. SureSmile technology in a patient-centered orthodontic practice. *J Clin Orthod*. 2001;35(4):245-253.
9. Nanda R. *Biomechanics and Esthetic Strategies in Clinical Orthodontics*. Amsterdam: Elsevier Health Sciences; 2005.
10. Graber LW, Vanarsdall Jr RL, Vig KW. *Orthodontics: Current Principles and Techniques*. Amsterdam: Elsevier Health Sciences; 2005.
11. Lieber WS, Carlson SK, Baumrind S, Poulton DR. Clinical use of the ABO-Scoring Index: reliability and subtraction frequency. *Angle Orthod*. 2003;73(5):556-564. [CrossRef]
12. Ackerman MB. Six keys for making orthodontics a sustainable dental specialty. *Angle Orthod*. 2013;83(6):1102-1103. [CrossRef]
13. Ackerman MB. Selling orthodontic need: innocent business decision or guilty pleasure? *J Med Ethics*. 2010;36(5):275-278. [CrossRef]
14. McCartney RD. Assessing a physician's true worth. *Internist*. 1995;36(4):8-10.
15. Safavi S, Namazi A. Evaluation of mandibular incisor extraction treatment outcome in patients with Bolton discrepancy using peer assessment rating index. *J Dent*. 2012;9(1):27-34.

TURKISH JOURNAL of ORTHODONTICS

DOI: 10.5152/TurkJOrthod.2021.20087

Original Article

Assessment of the Diagnostic Skills of General Dentists in Different Types of Orthodontic Malocclusions

Hanife Nuray Yilmaz[1], Elvan Onem Ozbilen[1], Gulden Karabiber[2]

[1]Department of Orthodontics, Faculty of Dentistry, Marmara University, Istanbul, Turkey
[2]Department of Orthodontics, Faculty of Dentistry, Medeniyet University, Istanbul, Turkey

Cite this article as: Nuray Yilmaz H, Onem Ozbilen E, Karabiber G. Assessment of the diagnostic skills of general dentists in different types of orthodontic malocclusions. *Turk J Orthod.* 2021; 34(3): 189-198.

Main Points

- Except for the Class II camouflage case, the answers indicating the need for orthodontic treatment were higher in all malocclusions.
- Only patients indicated as surgery patients by the orthodontists were chosen for orthognathic surgery by the general dentists, in Class II cases.
- The answers indicating orthognathic surgery were high for both surgery and facemask patients, in Class III cases.
- The general dentists chose both unesthetic profile and irregular teeth as reasons for surgery, except for the open bite camouflage case.
- The general dentists chose protruded mandible for the Class III case, and retruded mandible for the Class II case, as reasons for orthognathic surgery.

ABSTRACT

Objective: One of the biggest problems in publicly funded dental clinics is the patient waiting list. The appropriate referral plays a key role in avoiding an increase in the number of patients on this waiting list. This study aimed to assess general dentists' diagnostic skills and approaches for different malocclusions.

Methods: A questionnaire was prepared using photos of 8 patients previously treated for different malocclusions. One hundred twenty general dentists (83 female, mean age: 24 ± 1.18 years; 37 male, mean age: 24 ± 1.95 years) participated in the survey and were asked to decide whether the patient needed orthodontic treatment or orthognathic surgery, and to provide the reason for surgery (irregular teeth, or both unesthetic profile and irregular teeth), and the cause of the unesthetic profile (mandibular protrusion, mandibular retrusion, maxillary protrusion, maxillary retrusion).

Results: The answers suggesting the need for orthodontic treatment were significantly higher for all malocclusions except for the Class II camouflage case. Of the Class III cases, the general dentists chose orthognathic surgery for both surgery and facemask cases (93.1%, 66.4% respectively). For the severe open bite case, orthognathic surgery was chosen with a ratio of 81.2%, and orthognathic surgery was decided as not necessary for the mild open bite case (74.8%). Among the surgery cases, mandibular retrusion for the Class II case (94.6%), mandibular protrusion for Class III case (95.4%), and maxillary retrusion for the severe open bite case (44.6%) were the maximum reported reasons.

Conclusion: The distinction between camouflage and surgical treatment was better made by dentists in Class II and open bite cases than in Class III cases.

Keywords: Diagnosis, referral, malocclusion

INTRODUCTION

Malocclusion is a term that defines the deviations from the ideal occlusal relationship. However, unlike the clinicians, patients usually demand orthodontic treatment primarily for esthetic reasons, rather than for the actual malocclusion. For many centuries, facial attractiveness has been desired as a physical character in almost all societies.[1] Therefore, a treatment plan should improve facial esthetics to meet the patient's expectations and correct the malocclusion, along with any dysfunction. While treating patients with skeletal discrepancies, treatment options may include camouflage, functional treatment, or orthognathic surgery, depending on the patient's

Corresponding author: Elvan Onem Ozbilen, e-mail: elvanonem89@gmail.com

Received: July 11, 2020
Accepted: February 28, 2021

age, the severity of the malocclusion, facial esthetics, and the patient's demand.

Measuring the amount of malocclusion and treatment needed is important for public health, since the malocclusion and its unesthetic outcomes may affect the quality of life, such as psychological development, social skills, etc.[2,3] In particular, when public funds cover the orthodontic treatment in certain countries, that information becomes very critical to ensure that all social classes have equal access to oral health care. One of the biggest problems in publicly funded dental clinics is the patient waiting lists. An appropriate referral plays a key role in avoiding a longer waiting list, which is time-consuming for both patients and the clinicians. A study conducted by O'Brien et al.[4] showed that up to 45% of the orthodontic referrals could be classified as inappropriate.

Many orthodontic indices and methods have been developed as measuring tools to identify the treatment need and give priority to those who have a greater need for orthodontic treatment.[5,6] The Index of Orthodontic Treatment Need (IOTN), which is the most common index, was developed by Brook and Shaw,[6] and then the esthetic component (AC) of the IOTN was added by Richmand et al.[7] to classify patients into 3 broad groups: no need for treatment; possible treatment need/borderline need; and definite treatment need. Several studies show that IOTN and AC are reliable indices in the decision-making process.[8,9] However, there are also missing parts of that index—for example, open bite and reverse overjet photos are not included. On the other hand, Hunt et al.[10] reported in their cohort study that the current use of the AC cutoff score does not reflect lay people's dental esthetic expectations. Moreover, although Grzywacz[11] reported a significant agreement in the AC ratings between the professionals and 12-year-old children, they suggested moving the grade III-IV cases to "borderline need," which are normally in the "no treatment needed" grade, would be more realistic. In the present study, instead of the IOTN-AC index, we prepared a questionnaire with different malocclusion photos, ranging from mild to severe, to assess the diagnostic skills and treatment approaches of general dentists, and evaluate whether they can diagnose the orthodontic problem considering the severity of malocclusion and the patients' age, and direct patients correctly for orthodontic treatment to our publicly funded hospital.

METHODS

In the present study, a questionnaire was prepared using the photos of 8 previously treated patients (Figures 1-3), which were selected from the archive of Marmara University, Department of Orthodontics, Istanbul, Turkey, and their ideal treatments were planned by 3 orthodontists according to photographic, model, and radiological analyses as Class II functional treatment, Class II orthognathic surgery, Class II camouflage treatment, Class III facemask treatment, Class III orthognathic surgery, Class III camouflage treatment, camouflage treatment for mild open bite, and orthognathic surgery for severe open bite. The color images were converted into grayscale using Adobe Photoshop (CS2 Version 9.0, Adobe Systems Incorporated, San Jose, CA, USA). The cephalometric values of the patients are given in Table 1. The study was approved by Marmara University, Faculty of Dentistry, the Ethical

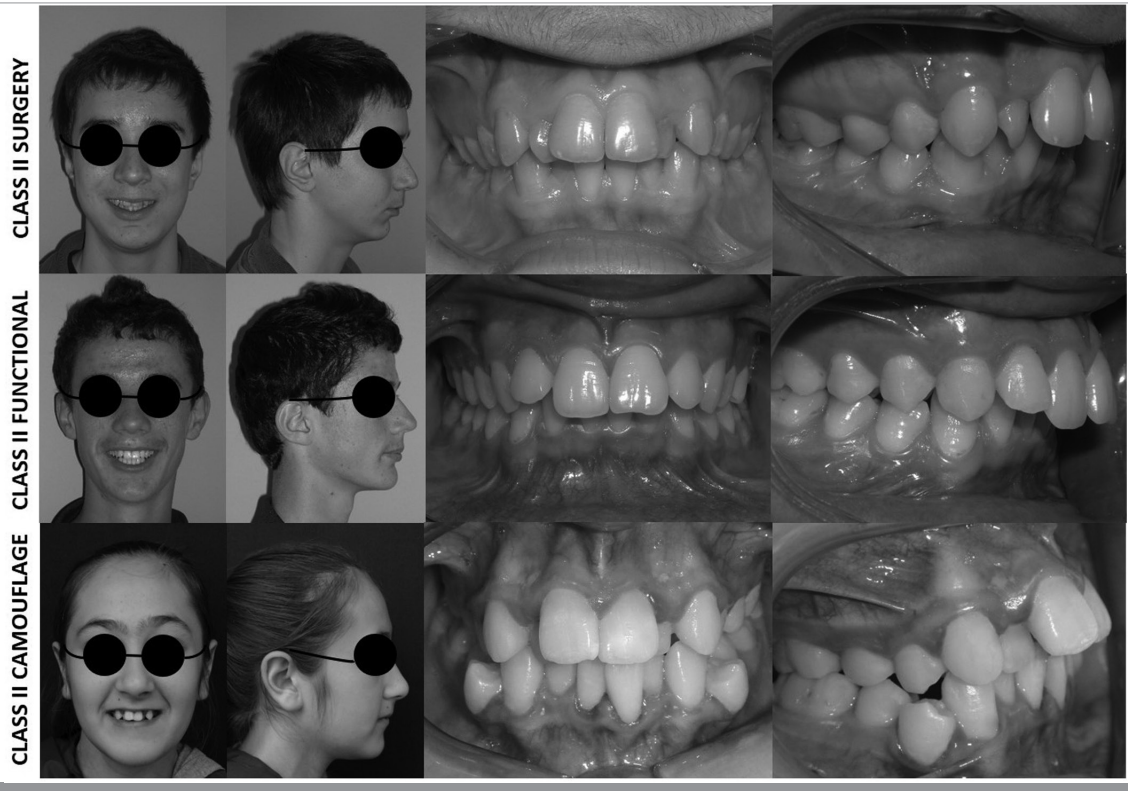


Figure 1. The extraoral and intraoral pictures of the patients with Class II malocclusion.

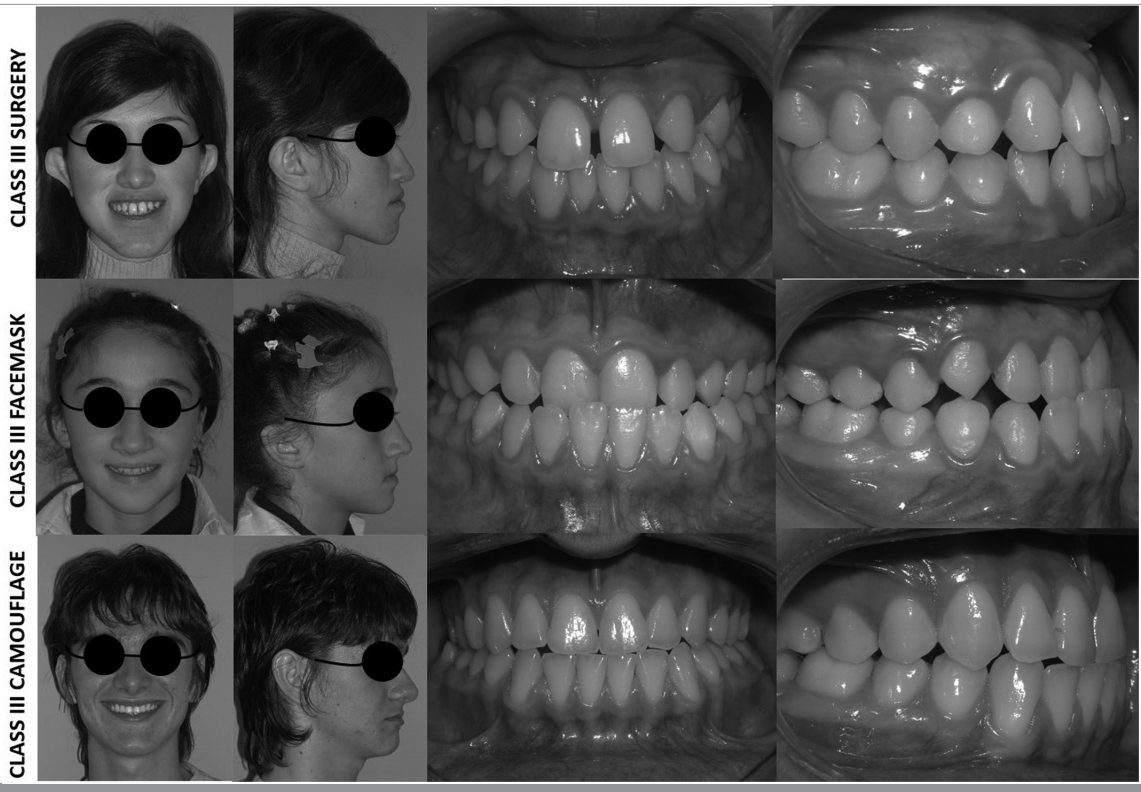


Figure 2. The extraoral and intraoral pictures of the patients with Class III malocclusion.

Committee of Clinical Research (June 1, 2020, 2020/25, Istanbul, Turkey). Informed consents were signed by all of the patients whose photographs were used for the questionnaire and by the dentists willing to participate in this study.

One hundred twenty recently graduated general dentists (83 female, mean age 24 ± 1.18; 37 male mean age 24 ± 1.95) took part in the survey, and they were asked to evaluate each patient's photos together with the age and decide whether the patient needed orthodontic treatment or not. If the answer was "yes," they were asked whether the patient needed orthognathic surgery or not; if the answer was "yes" for this question too, they were asked the identify the reason (irregular teeth or both unesthetic profile and irregular teeth) for which the patients need surgical treatment; and finally, the last question asked them to identify the reason, if the profile was unesthetic (mandibular protrusion, mandibular retrusion, maxillary protrusion, or maxillary retrusion) (Figure 4).

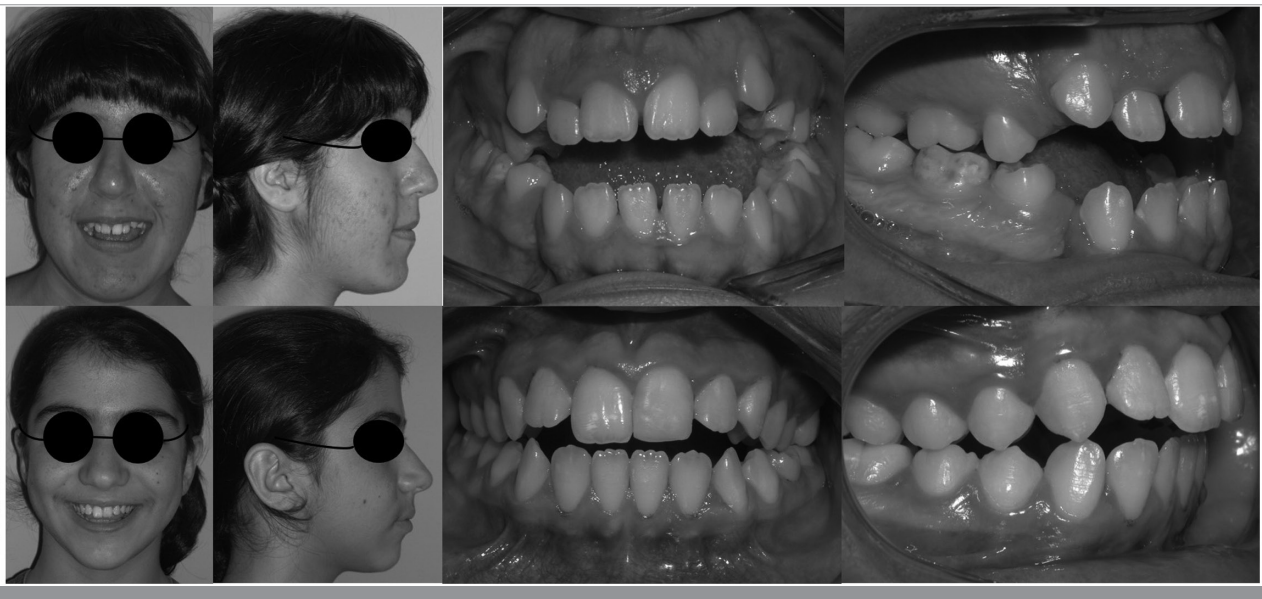


Figure 3. The extraoral and intraoral pictures of the patients with open bite malocclusion.

Table 1. Cephalometric measurements for the patients

		Vertical Parameters			Sagittal Parameters				Dental Parameters		
Cases	Age (years)	∑ (°)	FMA (°)	Maxillary height (°)	SNA (°)	SNB (°)	N⊥A (mm)	ACB/Corpus	U1-SN (°)	IMPA (°)	Holdaway ratio
Class II surgery	18	400	29	60	78	71	-2	78/78	101	98	8/4
Class II camouflage	14	388	27	59	87	81	2	66/70	113	93	5/5
Class II functional	15	392	23	59	79	75	1	76/80	108	90	4/6
Class III surgery	19	397	29	60	82	86	-3	71/82	115	74	3/0.5
Class III facemask	10	394	30	59	81	83	-2	71/79	105	85	4/2
Class III camouflage	17	392	22	59	80	82	-1	71/78	105	91	4/2
Open bite surgery	18	412	37.5	65	79	76	2	73/79	106	81	8/2.5
Open bite camouflage	13	408	39	63	82	78	2	72/75	100	91	6/3

Statistical analysis was performed using IBM SPSS Statistics 22 (IBM SPSS, Turkey). The chi-square test was performed to compare the data, and the significance level was set at $P < .05$.

RESULTS

Among all cases, according to the first question asking whether orthodontic treatment was needed, the only treatment for which there was no significant difference between the answers was the Class II camouflage treatment case (treatment was needed, 57.5%; not needed, 42.5%; $P > .05$). For all the other cases, the ratio of answers describing the need for treatment was significantly higher (Table 2).

When the need for orthognathic surgery was evaluated, all the results were statistically significant. In more detail, among the Class II cases, only the patient indicated as a surgery patient by the orthodontists was chosen for orthognathic surgery by the general dentists (66.7%) (Figure 5). For Class II camouflage or functional treatment cases, the percentages of those who reported that there was no need for orthognathic surgery were 94.2% and 80.9% respectively (Table 2, Figures 6 and 7). Of the Class III cases, patients indicated as requiring orthognathic surgery and facemask treatment, the answers regarding the need for orthognathic surgery were chosen (93.1%, 66.4% respectively) (Table 2, Figures 8 and 9), and for the camouflage case, the answer was that there was no need for orthognathic surgery (62.2%) (Table 2, Figure 10). In the presence of open bite malocclusion, the severe case which required orthognathic surgery was answered as "orthognathic surgery needed" (81.2%) (Figure 11), and the mild case for which camouflage treatment was enough, was described as not needing orthognathic surgery (74.8%) (Table 2, Figure 12).

1. Does this patient need orthodontic treatment?
   a. Yes
   b. No
   If the answer is "no", please skip to the other page.
2. Does this patient need orthognathic surgery?
   a. Yes
   b. No
   If the answer is "no", please skip to the other page.
3. For which of the following reasons does this patient need orthognathic surgery?
   a. Unaesthetic profile and the alignment of the teeth
   b. Unaesthetic alignment of the teeth
   If the answer is "b", please skip to the other page.
4. What is the reason for unaesthetic profile?
   a. Forward position of mandible
   b. Backward position of mandible
   c. Forward position of maxilla
   d. Backward position of maxilla

Figure 4. An example of the questionnaire

There was no statistically significant difference only for the open bite camouflage case, with respect to the answers given to the question of whether orthognathic surgery was needed because of irregular teeth, or both an unesthetic profile and the irregular teeth. In all the other groups, both unesthetic profile and irregular teeth were chosen as reasons for orthognathic surgery (Table 2).

Mandibular retrusion for the Class II case (94.6%), mandibular protrusion for the Class III case (95.4%), and maxillary retrusion for the severe open bite case (44.6%) were mostly reported (Table 2) as the reason for orthognathic surgery.

DISCUSSION

Many external (hair color, make-up) and internal (skin, teeth and lip color) factors may affect the individual's concept of beauty.[12,13] Therefore, the color images were converted into grayscale in the present study. Black and white photographs have the

Table 2. Evaluation of the answers given for the questionnaire

	Class II Camouflage n (%)	Class II Surgery n (%)	Class II Functional n (%)	Class III Surgery n (%)	Class III Camouflage n (%)	Class III Facemask n (%)	Open bite Camouflage n (%)	Open bite Surgery n (%)
Need for orthodontic treatment	69 (57.5)	111 (78.3)	94 (78.3)	116 (96.6)	103 (85.8)	115 (95.8)	111 (92.5)	112 (93.3)
No need for orthodontic treatment	51 (42.5%)	9 (7.5)	26 (21.7)	4 (3.3)	17 (14.2)	5 (4.2)	9 (7.5)	8 (6.7)
[1]*P*	NS	**	**	**	**	**	**	**
Need for orthognathic surgery	4 (5.8)	74 (66.7)	18 (19.1)	108 (93.1)	39 (37.8)	77 (66.4)	28 (25.2)	91 (81.2)
No need for orthognathic surgery	65 (94.2)	37 (33.3)	76 (80.9)	8 (6.9)	64 (62.2)	39 (33.6)	83 (74.8)	21 (18.8)
[1]*P*	**	**	**	**	**	**	**	**
Unesthetic profile and irregular teeth	4 (100)	74 (100)	16 (88.9)	108 (100)	38 (97.4)	76 (98.7)	16 (57.1)	83 (91.2)
Irregular teeth	0 (0)	0 (0)	2 (11.1)	0 (0)	1 (2.6)	1 (1.3)	12 (42.9)	8 (8.8)
[1]*P*	*	**	**	**	**	**	NS	**
Protruded mandible	0 (0)	0 (0)	2 (12.5)	103 (95.4)	22 (57.9)	48 (63.1)	3 (18.8)	28 (33.8)
Retruded mandible	4 (100)	70 (94.6)	8 (50)	0 (0)	0 (0)	2 (2.7)	3 (18.8)	9 (10.8)
Protruded maxilla	0 (0)	3 (4.05)	6 (37.5)	1 (0.9)	1 (2.6)	0 (0)	5 (31.2)	9 (10.8)
Retruded maxilla	0 (0)	1 (1.4)	0 (0)	4 (3.7)	15 (39.5)	26 (34.2)	5 (31.2)	37 (44.6)
[1]*P*	**	**	*	**	**	**	NS	**

[1]Chi-square test.
*$P < .05$, **$P < .01$.
NS, not significant.

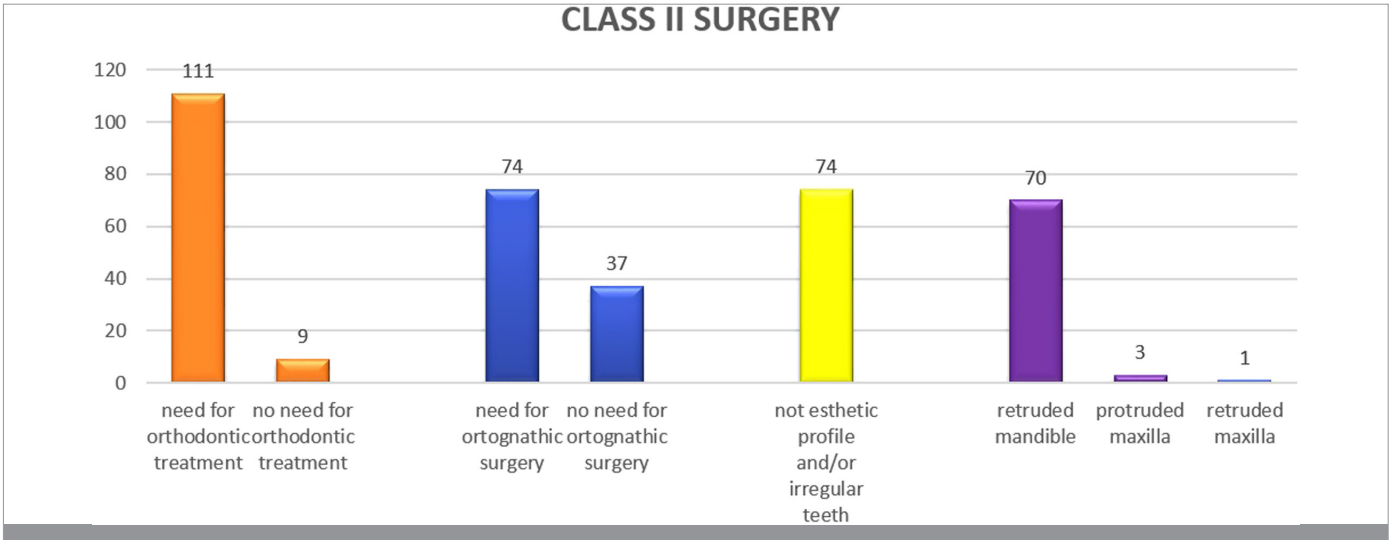


Figure 5. Distribution of the answers given to the Class II orthognathic surgery case by the general dentists

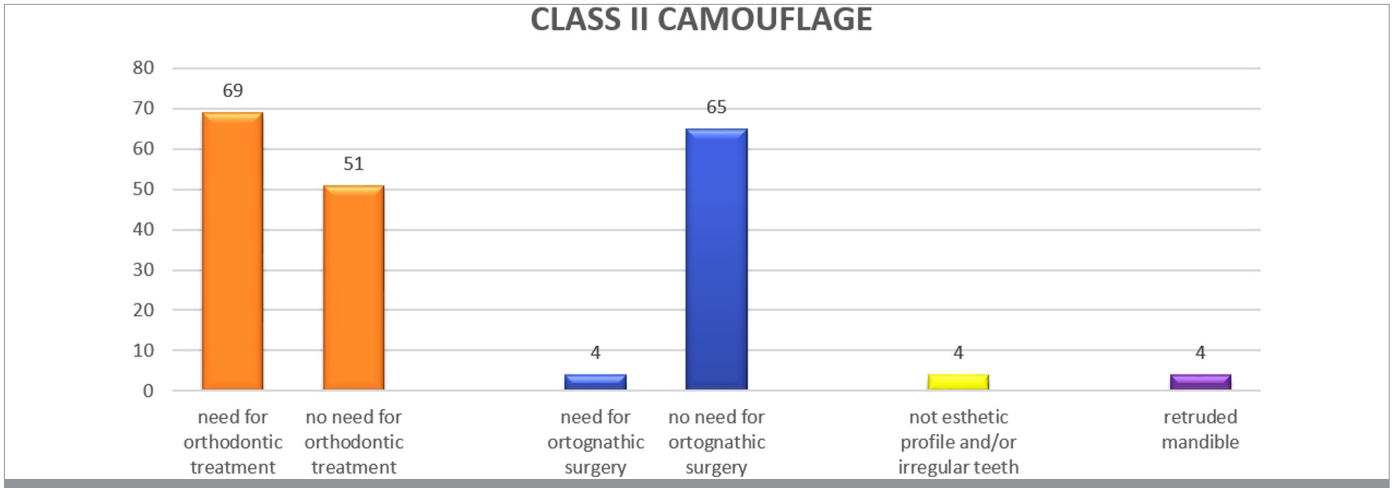


Figure 6. Distribution of the answers given to the Class II camouflage treatment case by the general dentists

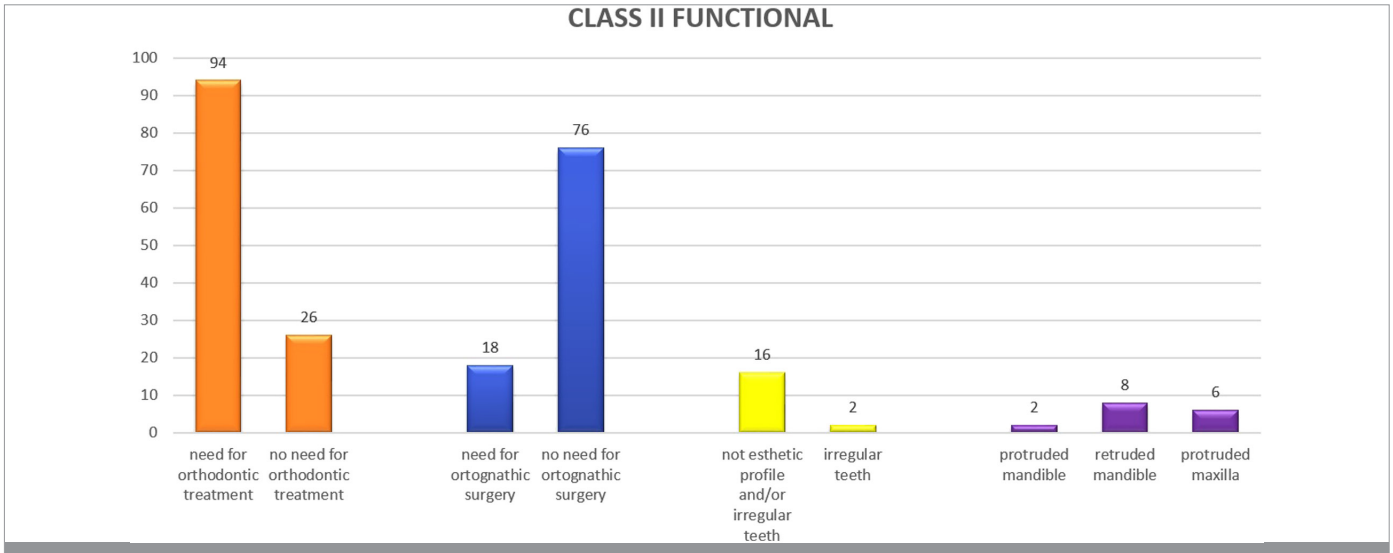


Figure 7. Distribution of the answers given to the Class II functional treatment case by the general dentists

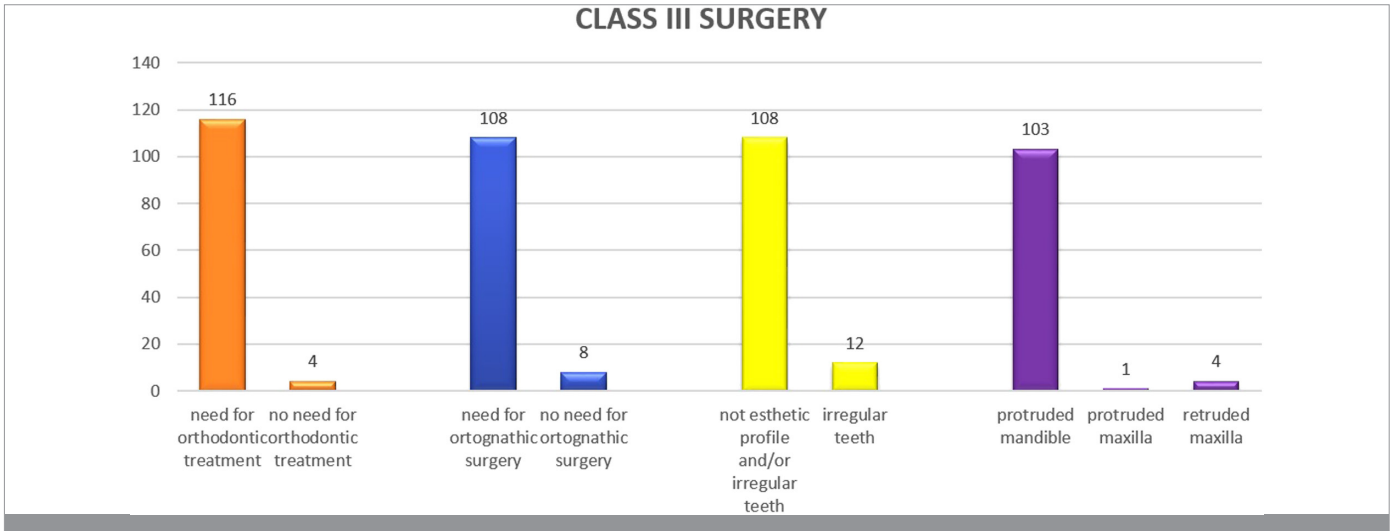


Figure 8. Distribution of the answers given to the Class III orthognathic surgery case by the general dentists

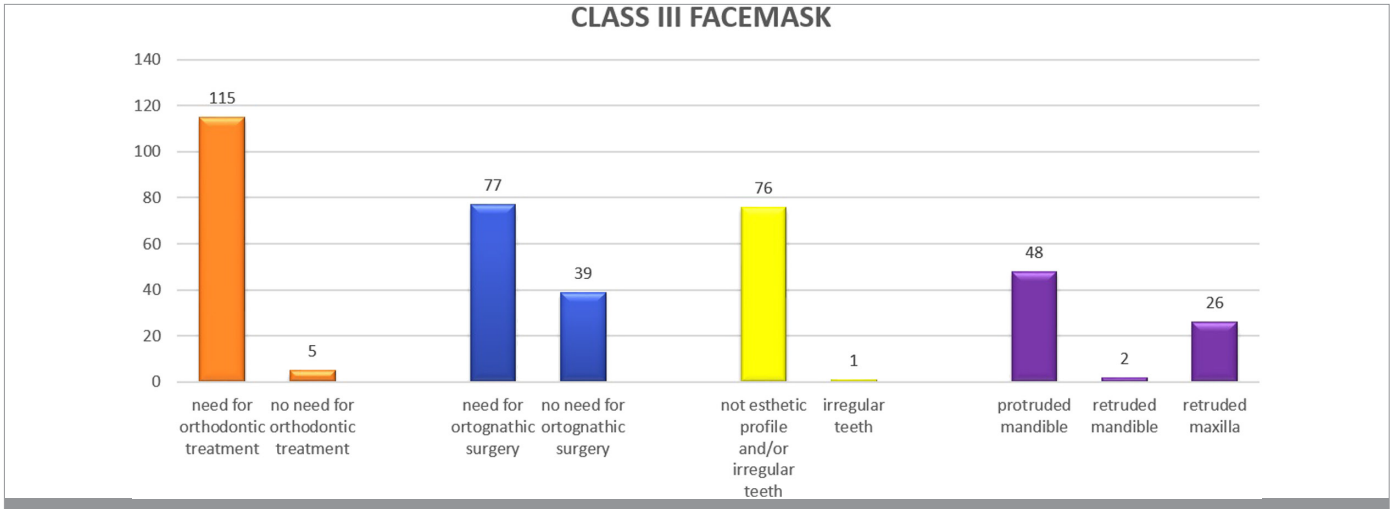


Figure 9. Distribution of the answers given to the Class III facemask treatment case by the general dentists

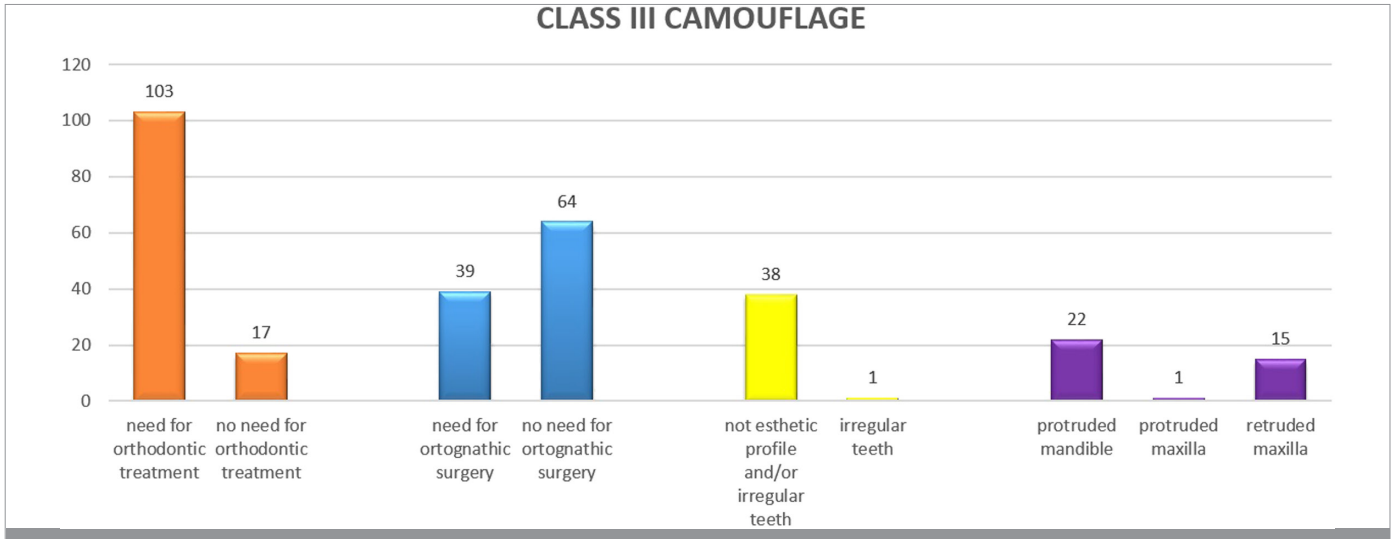


Figure 10. Distribution of the answers given to the Class III camouflage treatment case by the general dentists

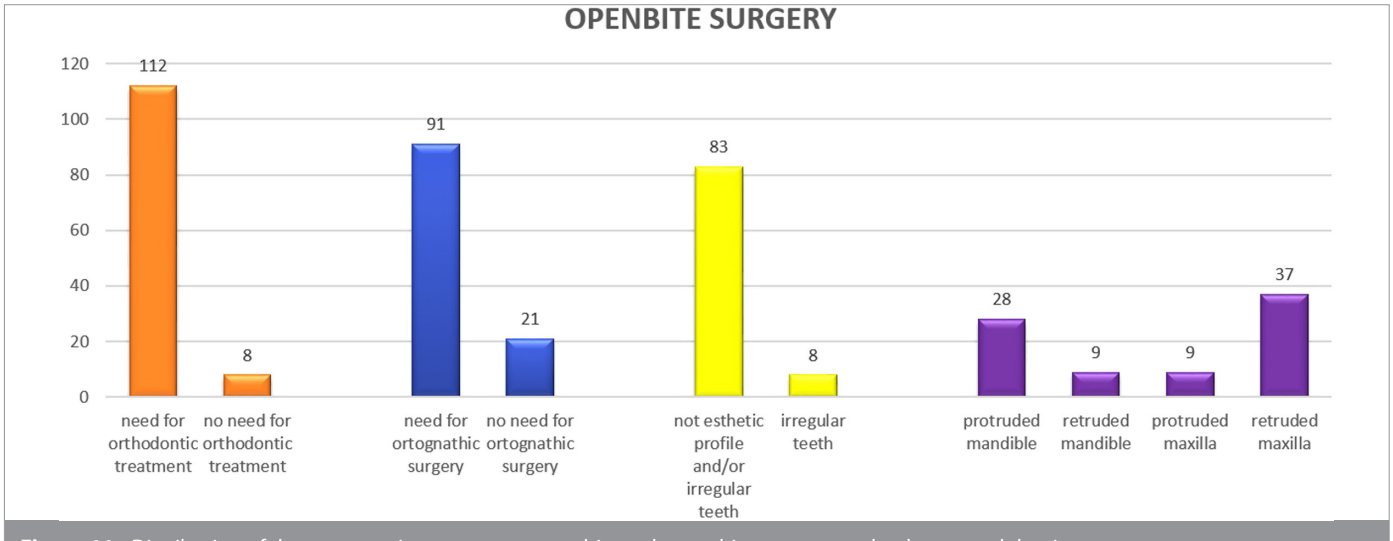


Figure 11. Distribution of the answers given to severe open bite orthognathic surgery case by the general dentists

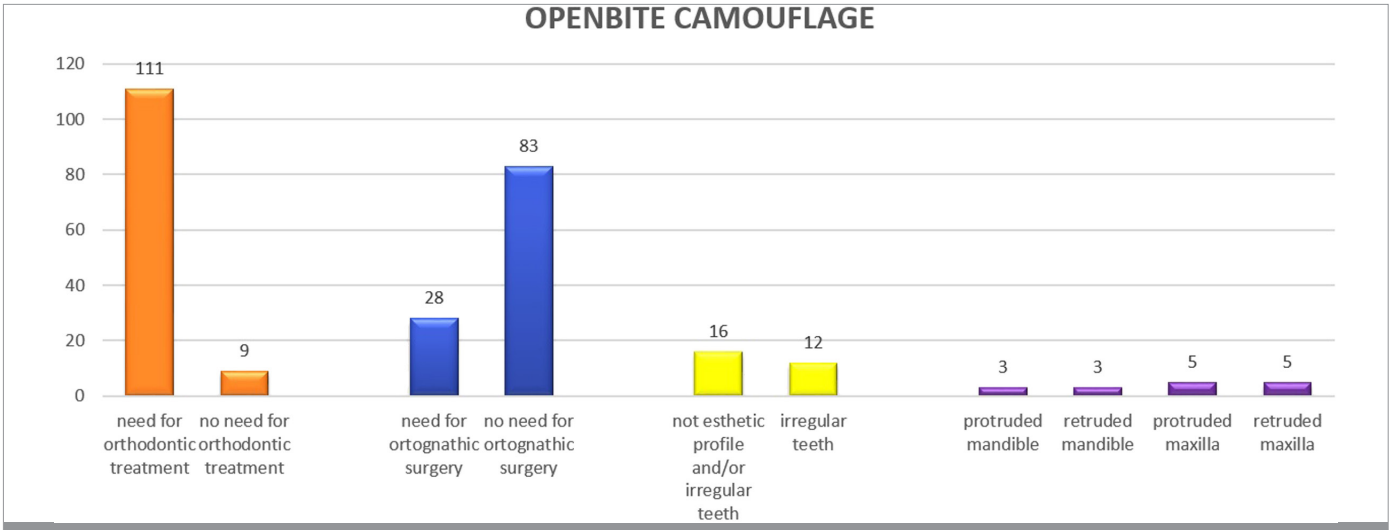


Figure 12. Distribution of the answers given to mild open bite camouflage treatment case by the general dentists

advantages of objectivity and simplification of facial esthetics by discarding those factors, and ensures that the participants can answer only by focusing on the profile and the malocclusion without being affected by other characteristics.

In dentistry, orthodontic patients are usually referred to orthodontists for treatment. In some countries, the government covers orthodontic treatment financially only in public hospitals, which creates long waiting lists. To ensure equity in all social classes and to minimize waiting lists, appropriate referral plays an important role. O'Brien et al.[4] showed that up to 45% of the orthodontic referrals could be classified as inappropriate. It is suggested that referral guidelines can help general dentists to select suitable patients for referral to a specialist.[14] However, O'Brien et al.[15] reported that referral guidelines did not significantly influence the behavior of the general dental practitioners. Orthodontic referrals usually come from pediatric and general dentists. While orthodontists receive additional education to diagnose and treat different dental and skeletal malocclusions, the education of general dentists in orthodontics is only limited in dental school.[16] All practitioners are advised to know treatment possibilities and the correct timing of application for orthodontic malocclusions.[17] In West Sussex, 52% of the general dentists could diagnose orthodontic treatment needed; however, only 20% of them were able to decide the appropriate referral time.[18] Similar to their results, Chew and Aw[19] reported that the majority of the referred patients did need treatment; however, many of these patients were too young for the orthodontic treatment. In their sample, about 40% of the subjects were in the mixed dentition stage when referred, and only about 16% of these children were indicated for interceptive treatment in the mixed dentition stage.[19] Many other studies show a high level of agreement in terms of an accurate orthodontic diagnosis among pediatric dentists, general dentists, and orthodontists.[20-22] Petersen and Dahlström[23] also concluded that general dentists and orthodontists rated IOTN from intraoral photographs in a similar way.

On the contrary, in a study that evaluates orthodontic knowledge of undergraduates in British dental schools, 75% did not expect their new graduates to be able to plan orthodontic treatment. They believed that undergraduate education should be focused on the diagnosis of a malocclusion, rather than treatment planning.[24] In another study, a poor agreement was found in profile identification between the clinicians, and the first-year dental students, third-year dental students, and patient groups.[25] Heath et al.[26] reported that perceptions of case complexity were similar between orthodontists, general dentists, orthodontic residents, and dental students for patients in mild cases, however orthodontic training influences the ability to recognize case complexity in moderate to severe cases. Their results also showed that most professionals believe that they had inadequate orthodontic training during their undergraduation studies. Similarly to Heath et al.[26] another study showed that the perceived treatment needs for normal occlusion to mild maxillary protrusion were not related to the level of expertise; however, for moderate to severe maxillary protrusion, the perceived treatments were different among dental students, residents, and orthodontists.[27] In the present study, we believed that the recently graduated general dentists would be able to diagnose dental and skeletal malocclusions with all their complexities as the orthodontists do, and decide on the treatment type according to the severity of discrepancy, patients' age, and the jaw that was the source of the problem.

One hundred twenty general dentists participated in our survey. Although the ratios of male and female participants were different, studies have shown that there was no significant difference between the male and female participants regarding their perceptions.[23,28]

In the literature, there are studies reporting the differences between professionals and lay people in the perception of dental esthetics using the AC assessments.[10] Furthermore, the fact that the IOTN-AC index does not include the open bite and reverse overjet photos is a major omission. Therefore, in our study, a special questionnaire was used instead of the ICON-AC index, in order to assess whether general dentists are able to diagnose the malocclusions directly according to the type of malocclusion,

severity, and patients' age, instead of trying to compare patients to 10 photos, as in the ICON-AC index.

According to our results, for all cases except the Class II camouflage case, answers describing the need for orthodontic treatment were significantly higher; which coincided with the orthodontists' plan in the present study and also with the literature findings.[20-22] Among the Class II cases, only the patient indicated as requiring surgery by the orthodontists was chosen for orthognathic surgery by the general dentists (66.7%); camouflage and functional treatment patients were indicated for orthodontic treatment at only 94.2%, and 80.9%, respectively. This result might be explained by the increased knowledge about the functional treatment in Class II cases among the general dentists in the present study, as it was reported by Aldrees et al.,[20] that pediatric and general dentists suggested functional appliances more than the orthodontist did for early treatment. Of the Class III patients, the need for orthognathic surgery was chosen for both patients indicated as orthognathic surgery and facemask treatment, with a ratio of 93.1% and 66.4% respectively. These results might be explained by the literature findings of studies conducted in different countries, showing that the profiles in the range of Class II patterns are more favorable than the Class III pattern.[28,29] This trend was also observed in those who needed surgical treatment. Profiles with mandibular prognathism have a more limited acceptable range. Soh et al.[30] reported that overjet was the major occlusal trait that influenced perceptions of dental esthetics; the greater the reverse overjet, the lower the dental esthetic ratings given. Hamdan et al.[31] concluded that Class III malocclusion has a greater esthetic impairment compared to the open bite, and Abu Alhaija and Al-Khateeb[32] also reported that severe reverse overjet is esthetically more unacceptable. Furthermore, in their study, Aldrees et al.[20] showed that compared with the orthodontists, the pediatric dentists and general dentists did not select facemasks with a high frequency. These situations might be the reason why the general dentists in our study recommended orthognathic surgery more for the Class III patients than the Class II patients, and also for those who could be treated with a facemask appliance. In the presence of open bite malocclusion, general dentists preferred orthognathic surgery for severe cases, and the camouflage treatment for mild cases, with ratios of 81.2% and 74.8% respectively. Our findings coincided with the literature findings which showed that mild open bite that could be treated orthodontically was more acceptable for both laypeople and dental professionals; according to given scores, while mild open bite was in the "no need for treatment or borderline need" category, severe open bite that was beyond the orthodontic limits was considered as esthetically unacceptable.[32]

General dentists reported that an unesthetic profile and irregular teeth were the reasons necessitating orthognathic surgery, except for the mild open bite case in the present study. Among the orthognathic surgery cases, mandibular retrusion was determined as a reason for Class II malocclusion by the orthodontists, which coincided with the general dentists' results (94.6%). In addition, Class III malocclusion occurred due to maxillary retrusion; however, general dentists chose mandibular protrusion as the reason for orthognathic surgery (95.4%).

In the present study, only Class II, Class III, and open bite cases were used for assessment among the group of recently graduated general dentists who would start to refer orthodontic patients to specialists as a part of their future clinical lives. However, it is also known that the ability to diagnose a case may increase with experience. Therefore, further studies with larger sample sizes from different levels of expertise would also contribute to the literature.

CONCLUSION

- No significant difference for the Class II camouflage case was found in terms of the need or not for orthodontic treatment.
- For Class III patients, the general dentists indicated the need for orthognathic surgery for both the orthognathic surgery patients and the facemask treatment patients.
- While the general dentists chose camouflage treatment for the mild open bite case, they chose orthognathic surgery for the severe open bite cases.
- Both the unesthetic profile and irregular teeth were chosen as the reasons for orthognathic surgery. Mandibular retrusion for Class II patients (94.6%), mandibular protrusion for Class III patients (95.4%), and maxillary retrusion for open bite surgery cases (44.6%) were the most reported.

Ethics Committee Approval: Ethical Committee approval was received from the Ethics Committee of Marmara University, (Approval No: 2020/25).

Informed Consent: Written informed consent was obtained from all participants who participated in this study.

Peer Review: Externally peer-reviewed.

Author Contributions: Concept - H.N.Y., E.Ö.Ö.; Design - H.N.Y., E.Ö.Ö.; Supervision - H.N.Y., E.Ö.Ö.; Data Collection and Processing - H.N.Y., E.Ö.Ö., G.K.; Analysis and Interpretation - E.Ö.Ö., G.K.; Literature Review- G.K.; Writing and Critical Review - E.Ö.Ö., H.N.Y., G.K.

Conflict of Interest: The authors have no conflict of interest to declare.

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

REFERENCES

1. Eisenthal Y, Dror G, Ruppin E. Facial attractiveness: beauty and the machine. *Neural Comput*. 2006;18(1):119-142. [CrossRef]
2. Kiyak HA. Does orthodontic treatment affect patients' quality of life? *J Dent Educ*. 2008;72(8):886-894. [CrossRef]
3. Nobile CGA, Pavia M, Fortunato L, Angelillo IF. Prevalence and factors related to malocclusion and orthodontic treatment need in children and adolescents in Italy. *Eur J Public Health*. 2007;17(6):637-641. [CrossRef]
4. O'Brien K, McComb JL, Fox N, Bearn D, Wright J. Do dentists refer orthodontic patients inappropriately? *Br Dent J*. 1996;181(4):132-136. [CrossRef]
5. Koochek AR., Yeh MS, Rolfe B, Richmond S. The relationship between Index of Complexity, Outcome and Need, and patients' perceptions

of malocclusion: a study in general dental practice. *Br Dent J*. 2001;191(6):325-329. [CrossRef]
6. Brook PH, Shaw WC. The development of an index of Orthodontic Treatment Priority. *Eur J Orthod*. 1989;11(3):309-320. [CrossRef]
7. Richmond S, Shaw WC, O'Brien KD et al. The relationship between the Index of Orthodontic Treatment Need and consensus opinion of a panel of 74 dentists. *Br Dent J*. 1995;178(10):370-374. [CrossRef]
8. Oshagh M, Salehi P, Pakshir H, Bazyar L, Rakhshan V. Associations between normative and self-perceived orthodontic treatment needs in young-adult dental patients. *Korean J Orthod*. 2011;41(6):440-446. [CrossRef]
9. Otuyemi OD, Kolawole KA. Perception of orthodontic treatment need: opinion comparisons of patients, parents and orthodontists. *Afr J Oral Health*. 2005;2(1-2):42-51. [CrossRef]
10. Hunt O, Hepper P, Johnston C, Stevenson M, Burden D. The aesthetic component of the index of orthodontic treatment need validated against lay opinion. *Eur J Orthod*. 2002;24(1):53-59. [CrossRef]
11. Grzywacz I. The value of the aesthetic component of the Index of Orthodontic Treatment Need in the assessment of subjective orthodontic treatment need. *Eur J Orthod*. 2003;25(1):57-63. [CrossRef]
12. Stephen ID, McKeegan AM. Lip color affects perceived sex typicality and attractiveness of human faces. *Perception*. 2010;39(8):1104-1110. [CrossRef]
13. Wuerpel EH. A classic revisited. Ideals and idealism by Edmund H. Wuerpel, 1931. *Angle Orthod*. 1981;51(1):6-23. [CrossRef]
14. Ferguson JW, Langford JW, Davenport PJ. Making the best use of consultant orthodontic services. Part 1: Determining which patients require referral. *Dent Update*. 1997;24(1):15-17.
15. O'Brien K, Wright J, Conboy F et al. The effect of orthodontic referral guidelines: a randomised controlled trial. *Br Dent J*. 2000;188(7):392-397. [CrossRef]
16. Christensen GJ. Orthodontics and the general practitioner. *J Am Dent Assoc*. 2002;133(3):369-371. [CrossRef]
17. Ngan P, Fields H. Orthodontic diagnosis and treatment planning in the primary dentition. *ASDC J Dent Child*. 1995;62(1):25-33.
18. Jackson OA, Cunningham SJ, Moles DR, Clark JR. Orthodontic referral behaviour of West Sussex dentists. *Br Dent J*. 2009;207(9):E18. [CrossRef]
19. Chew MT, Aw AKL. Appropriateness of orthodontic referrals: self-perceived and normative treatment needs of patients referred for orthodontic consultation. *Commun Dent Oral Epidemiol*. 2002;30(6):449-454. [CrossRef]
20. Aldrees AM, Tashkandi NE, AlWanis AA, AlSanouni MS, AlHamlan NH. Orthodontic treatment and referral patterns: A survey of pediatric dentists, general practitioners, and orthodontists. *Saudi Dent J*. 2015;27(1):30-39. [CrossRef]
21. Berk NW, Bush HD, Cavalier J *et al.* Perception of orthodontic treatment need: opinion comparisons of orthodontists, pediatric dentists, and general practitioners. *J Orthod*. 2002;29(4):287-291. [CrossRef]
22. Pietilä T, Pietilä I, Väätäjä P. Early screening for orthodontic treatment. Differences in assessments made by a consultant orthodontist and three public health dentists. *Commun Dent Oral Epidemiol*. 1992;20(4):208-213. [CrossRef]
23. Petersen B, Dahlström L . Perception of treatment need among orthodontic patients compared with professionals. *Acta Odontol Scand*. 1998;56(5):299-302. [CrossRef]
24. Rock WP, O'Brien KD, Stephens CD. Orthodontic teaching practice and undergraduate knowledge in British dental schools. *Br Dent J*. 2002;192(6):347-351. [CrossRef]
25. Tufekci E, Jahangiri A, Lindauer SJ. Perception of profile among laypeople, dental students and orthodontic patients. *Angle Orthod*. 2008;78(6):983-987. [CrossRef]
26. Heath EM, English JD, Johnson CD, Swearingen EB, Akyalcin S. Perceptions of orthodontic case complexity among orthodontists, general practitioners, orthodontic residents, and dental students. *Am J Orthod Dentofacial Orthop*. 2017;151(2):335-341. [CrossRef]
27. Kuroda S, Fuji A, Sugie M, et al. Relationship between orthodontic expertise and perception of treatment needs for maxillary protrusion: comparison of dental students, residents, and orthodontists. *Am J Orthod Dentofacial Orthop*. 2010;137(3):340-345. [CrossRef]
28. Imani MM, Sanei E, Niaki EA, Shahroudi AS. Esthetic preferences of orthodontists, oral surgeons, and laypersons for Persian facial profiles. *Am J Orthod Dentofacial Orthop*. 2018;154(3):412-420. [CrossRef]
29. Kuroda S, Sugahara T, Takabatake S *et al.* Influence of anteroposterior mandibular positions on facial attractiveness in Japanese adults. *Am J Orthod Dentofacial Orthop*. 2009;135(1):73-78. [CrossRef]
30. Soh J, Chew MT, Chan YH. Perceptions of dental esthetics of Asian orthodontists and laypersons. *Am J Orthod Dentofacial Orthop*. 2006;130(2):170-176. [CrossRef]
31. Hamdan AM, Singh V, Rock W. Perceptions of dental aesthetics of Class III and anterior open bite malocclusions: a comparison between 10-to 11-year-old schoolchildren and orthodontists. *Angle Orthod*. 2012;82(2):202-208. [CrossRef]
32. Abu Alhaija ES, Al-Khateeb SN. Attractiveness ratings of anterior open bites and reverse overjets using the aesthetic component of the Index of Orthodontic Treatment Need. *Eur J Orthod*. 2005;27(2):134-139. [CrossRef]

TURKISH JOURNAL of ORTHODONTICS

DOI: 10.5152/TurkJOrthod.2021.21157

Review

In-house Aligners: Why We Should Fabricate Aligners in Our Clinics?

Murat Tozlu[1], Fulya Ozdemir[2]

[1]Department of Orthodontics, Gelisim University, Faculty of Dentistry, İstanbul, Turkey
[2]Department of Orthodontics, Marmara University, Faculty of Dentistry, İstanbul, Turkey

Cite this article as: Tozlu M, Ozdemir F. In-house aligners: Why we should fabricate aligners in our clinics? *Turk J Orthod.* 2021; 34(3): 199-201.

Main Points

- As the availability and efficiency of aligner fabrication technology evolves, and with the increasing demand of patients, it seems that most orthodontists are going to use aligners in everyday operations.
- In-house production of aligners has 3 big advantages for the clinician: price, delivery timing, and doctor's time.
- A large amount of time-consuming tasks in producing aligners may be delegated to a dedicated dental staff.

ABSTRACT

As digital dentistry is evolving, contemporary orthodontics is embracing clear aligners as a tool more than ever before. On the other hand, aligners are being marketed to patients by aligner companies in every way that is possible. The demand of the end user and the pursuit of the orthodontist toward less chair time has made aligners popular in the last decade. As the price for having all machinery needed to fabricate aligners has decreased, orthodontists may choose to fabricate aligners in-house. In-house fabrication will bring advantages in the price, delivery time, and doctor's time if it is done correctly.

Keywords: Clear aligners, 3D printing, fabrication

INTRODUCTION

As we are all being educated on esthetics by all kinds of media, there is an increasing demand for esthetic corrections of the face and teeth. Besides the demand for esthetic teeth, there is also a demand for more esthetic options in orthodontic corrections. With the help of recent advances in dental technology, orthodontic treatment of mild to moderate degree can be performed successfully with clear aligners. As dentistry and orthodontics go digital, the methods used to design and fabricate aligners have changed drastically, including the utilization of new CAD-CAM technology to make production easier. On one hand, the availability of 3D technology has increased, while on the other hand, the price for the 3D technology utilized for the production of aligners has decreased, so much so that the aligners can be produced in-house or, in other words, in our own clinics.

IN-HOUSE PRODUCTION STEPS: FILAMENT VS. RESIN

A 3D model can be obtained using either a filament or a resin material. When using the filament, models are produced using FDM (Fused Deposition Modeling) printers. The main advantage of the filament model is that it is 10 times more economical than the resin model.[1] Another important advantage of the filament model is that it can be used immediately after the printing process. As for the resin models, postprocessing is needed after the printing process. It includes alcohol washing and light curing of the model. Resin models are built with resin rising in a resin tank, and because of this, the surface of the model is covered with resin following the procedure. Washing

Corresponding author: Murat Tozlu, e-mail: tozlumurat@gmail.com

Received: December 28, 2020
Accepted: August 15, 2021

removes the resin from the outer surface of the 3D model, which takes approximately 15 minutes. A clinician may do the cleaning in 3 ways: she/he may rinse the model manually by using a plastic box to shake the model in a rinsing solution, with the cap tightly closed. Second, she/he may use an ultrasonic cleaner manufactured for the dentistry or jewelry industry. Third, she/he may use a cleaner manufactured specifically for aligner production. All 3 methods can be utilized for successful cleaning.

Curing and Labeling

The resin model is built by light curing of the resin, layer by layer. Therefore, following the printing process, the resin model is not absolutely cured. There is a need for a final light curing. For final curing, the models should be cured for approximately 30 minutes under ultraviolet light. After final curing, the models are ready for the aligner forming procedure. All models should be labeled before exporting the STL files from the software because models at different stages of treatment of various patients may be printed on the same table simultaneously. Labeling is an easy procedure: a custom text is placed in a convenient site on the model to be embossed or engraved at a chosen depth and font size with the help of the software. However, the formed aligners would not have labels if the labeling number were not on the teeth; so while trimming and polishing, there is a risk of putting the aligner in the wrong box. (The clinician may put the label on a surface of a tooth, but this causes difficulty while removing the aligner and may also cause discomfort because of the irregular surface of the label.) Therefore, the person trimming the aligners should put the aligners on the models that they belong to but should not totally fit the aligner to the model. Fitting and removing the aligner multiple times on the model before packaging may deform the aligner.

Plastic Foils to Fabricate Aligners

There are a few types of plastic foils fabricated for aligner production. These are polyurethane derivatives, PET (polyethylene terephthalate), and PET-G derivatives. Companies are focused on improving the qualities of the plastic foils in terms of elasticity, durability, and resistance to coloring and microcracking under force and oral environment. There is no consensus among the orthodontists regarding the number of days before the patient begins to wear the next aligner. Some orthodontists claim that they use some kind of tooth movement acceleratory device or method to enable their patients change aligners every 3 days.[2] Some ask their patients to change the aligners every 7, 10, or 15 days depending on their daily wear time. Studies confirm that the aligners exert force on the teeth for 48 hours, and after that, the force decreases rapidly to a minimum. When the patient changes the aligner, the same cycle continues. The elasticity of the material is experimented in vitro in many studies.[3,4] However, till now there is no study in the literature that compares the effect of material composition of the plastic foil on treatment efficiency or treatment duration.

In-house production of aligners has 3 big advantages for the clinician: (1) price, (2) delivery time, and (3) doctor's time.

THE FIRST ADVANTAGE OF IN-HOUSE ALIGNERS

When the clinician produces her/his own aligners, the price of the aligners is very economic compared with the price of the aligners bought from companies. If the clinician is producing her/his own aligners, the cost of 1 single aligner comprises the cost of a 3D model print plus the plastic foil cost. When it comes to costly software, the numbers of software to be used for the purpose of aligner fabrication are increasing, which means that prices are going to decrease rapidly in the near future. Furthermore, besides buying a license for a year, monthly or case-based choices for payment are available. Also, the prices of 3D printers are more attainable every year, again due to an increase in the availability of 3D printers. Besides expensive printers, there are a vast number of more reachable models. Lastly, the thermoplastic aligner forming machine is already present in a lot of clinics, where the orthodontists are already into fabricating orthodontic appliances.

THE SECOND ADVANTAGE OF IN-HOUSE ALIGNERS

Duration is the second advantage, which means that the clinician can deliver the aligners very fast. After the digital scanning of patients' teeth, digital setup takes approximately 30 minutes for a moderate case. In an easy case where the molars do not move, it takes about 15 minutes for setup.

The advantage of the procedure is that some of the most time-consuming steps can readily be delegated to a staff member, following a short education. There is an increase in the number of software available in the market. The principles and work sequence are nearly the same for all these software packages. The first step is the preparation of the model, which includes loading of the models, orientation, cutting excess data, filling the gaps in the models, and marking the teeth. This is a procedure that should always be carried out in the same way, without any need for orthodontic expertise by dental staff. The second step is the digital setup where the clinician constructs the treatment plan (aligns the teeth on the arch form suitable for the patient, determines the movement sequence and speed, puts the necessary attachments, and determines the need for IPR, elastic wear, etc.). The last step is the exporting of the digital setup models, which includes labeling and deciding the height of the models, which can also be done by a dental staff. As technology evolves, in the upcoming versions of the aligner software, the first and third stages, carried out in the same way, such as model preparation and exporting will be done by the software. In the near future, besides self-segmentation and exporting, autoalignment is going to be a new feature of the aligner software.

With the use of a DLP printer, it takes approximately an hour to get 3 models at a time. Postprocessing takes about 30 minutes. Vacuum or pressure forming of the aligners takes about 5 minutes for each aligner. To summarize, a clinician can deliver the aligners to patient in the same day taking impressions.

THE THIRD ADVANTAGE OF IN-HOUSE ALIGNERS

Contrary to general belief, when aligners are fabricated in the clinic, the clinician spends less time compared to ordering the aligners from a company. When produced in-house, it takes a total clinician time of 15 to 30 minutes for obtaining the series of digital setup models for the case. Next is the printing of the 3D models and the forming of the aligners from thermoplastic foils, which will be handled by the clinic staff. Forming and trimming of the aligner from the plastic foil is a standard procedure, which can be easily done successfully by an educated staff member. 3D printers have user-friendly manuals, and the printing procedure can also be done by the staff. When compared with the aligners produced by a company outside of the clinic, 1 big advantage of in-house aligners is that the clinician quickly makes the aligning and staging which is in his mind instead of writing a recipe to the company technician, who is most of the time not even a dental technician. Depending on the company, sometimes this technician may not even know the basic rules of dental alignment. If the clinician is making her/his own digital setup, there will be no digital setup evaluation process sent by the company or modifications that should be evaluated repeatedly. Another big disadvantage when working with companies is that the clinician cannot decide when the digital setup would be ready for a submitted case. Even if the company has a message system that alerts the clinician that the digital setup plan is ready to be evaluated, it may not be a suitable time for the clinician. Also, it is not guaranteed that the digital setup treatment plan sent by the company will be the final one. As a whole, the clinician has a complete time control on the procedure when an in-house aligner system is used.

While constructing a system for fabricating the aligners in-house, for the safety of all the steps and for the continuity of the system, the clinician should learn and practice all the steps in detail—including the tips and tricks—and have full control on the procedure. At any stage of the fabrication, when something does not work, it should be the clinician who will be diagnosing and solving the problem in order to conduct a healthy procedure.

Peer Review: Externally peer-reviewed.

Author Contributions: Concept – M.T., F.O.; Design – M.T., F.O.; Resources – M.T., F.O.; Writing Manuscript – M.T., F.O.; Critical Review – M.T., F.O.

Conflict of Interest: The authors have no conflict of interest to declare.

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

REFERENCES

1. Groth C, Kravitz ND, Jones PE, Graham JW, Redmond WR. Three-dimensional printing technology. *J Clin Orthod*. 2014;48(8):475-485.
2. Ojima K, Dan C, Kumagai Y, Schupp W. Invisalign treatment accelerated by photobiomodulation. *J Clin Orthod*. 2016;50(5):309-317.
3. Kwon JS, Lee YK, Lim BS, Lim YK. Force delivery properties of thermoplastic orthodontic materials. *Am J Orthod Dentofacial Orthop*. 2008;133(2):228-334. [CrossRef]
4. Gerard Bradley T, Teske L, Eliades G, Zinelis S, Eliades T. Do the mechanical and chemical properties of InvisalignTM appliances change after use? A retrieval analysis. *Eur J Orthod*. 2016;38(1):27-31. [CrossRef]

TURKISH JOURNAL of ORTHODONTICS

DOI: 10.5152/TurkJOrthod.2021.20116

Review

Staging Orthodontic Aligners for Complex Orthodontic Tooth Movement

Shivam Mehta[1], Dolly Patel[2], Sumit Yadav[3]

[1]Department of Developmental Sciences/Orthodontics, Marquette University School of Dentistry, Milwaukee, Wisconsin, USA
[2]Department of Orthodontics, AMC Dental College, Ahmedabad, Gujarat, India
[3]Division of Orthodontics, University of Connecticut Health, Farmington, Connecticut, USA

Cite this article as: Mehta S, Patel D, Yadav S. Staging orthodontic aligners for complex orthodontic tooth movement. *Turk J Orthod.* 2021; 34(3): 202-206.

Main Points

- It is favorable to modify the location of elastics by changing the teeth used for elastic wear as treatment progresses, for distalization with aligner therapy.
- Torquing of maxillary incisors, amount of crowding, overbite, overjet, and amount of retraction of maxillary and mandibular incisors are the factors that play an important role in staging OTM for space closure with aligners.
- The tendency for underperformance of aligners for intrusion, extrusion, and rotational correction can be overcome by performing overcorrection during the staging of OTM.

ABSTRACT

The recent trend in orthodontics has shown an increased shift toward aligner therapy. For years, orthodontists have used fixed preadjusted appliances for orthodontic treatment. Even though fixed appliances have been highly efficient in the treatment of orthodontic malocclusions, they are not as esthetic as clear aligners. The purpose of this article is to review the staging of orthodontic tooth movement (OTM) with aligner therapy.

Keywords: Aligner therapy, preadjusted edgewise appliance, complex orthodontic tooth movement

INTRODUCTION

Orthodontic treatment has experienced a shift in the market, with an increasing demand for aligners.[1-3] The main benefit of aligner therapy is the superior esthetics and the use of appliances that are removable, compared to fixed orthodontic appliances. This makes it an attractive option for adult orthodontic patients. However, a limitation of aligner therapy is the lack of predictable and efficient orthodontic treatment for complex malocclusion. Aligners have been reported to be less effective in certain orthodontic tooth movements (OTMs) such as torquing, extraction space closure, intrusion, and rotations.[1,4,5]

Aligner therapy works by sequentially moving the teeth in small amounts with consecutive aligners to reach to the final orthodontic outcome. The technique of moving the teeth with successive thermoplastic appliances worn consecutively by the patient was contributed to the orthodontic community by Kesling.[6] However, in the late 1990s, with the launch of Invisalign aligners by AlignTechnology, aligners gained more popularity and changed the landscape of the orthodontic market. Using CAD/CAM in the production technology, aligners could be manufactured at a much faster pace than before. However, there have been controversies in the utility of aligners in the treatment of severe or complex malocclusions. Some proponents of aligner therapy have suggested the use of aligners for complex tooth movements such as orthodontic space closure, distalization, and intrusion. However, some others suggest using it for orthodontic treatment of mild malocclusion.[7,8]

Corresponding author: Shivam Mehta, e-mail: shivam.mehta@marquette.edu

Received: August 9, 2020
Accepted: March 6, 2021

An important aspect in the success of aligner therapy is the staging of the OTM with the aligners. Owing to the lack of literature on the staging of OTM with aligners, most clinicians base their interpretations on expert opinions. Thus, there is an unmet need for more information on the topic of staging OTM with aligners. With an increasing number of orthodontic aligner manufacturers jumping into the orthodontic market, and the constantly evolving nature of aligner materials, attachments, and mechanics, it is important to evaluate the current information regarding aligners and staging for complex tooth movements. Thus, this review is conducted to establish the staging of OTM and how to maximize the efficiency of OTM with aligners.

Staging of OTM

Staging of OTM refers to the breakdown of the intended movement of teeth in a sequential manner with aligners. The importance of this concept lies in understanding OTM principles and their application. Aligners serve as a tool to achieve OTM, but the basic principles of OTM remain the same as in fixed preadjusted appliances. The current review will address some of the core principles of OTM with fixed preadjusted edgewise appliances (PEA) and aligners, and clinical modifications to achieve efficient OTM with aligners.

General Concepts

The staging of OTM refers to the sequential movement of the teeth with the aligner trays. The tooth that is moved the most is known as the leading tooth. It is the staging of the leading tooth that determines the total number of aligner trays. The degree of movement of a tooth with each tray determines its velocity in terms of staging. While staging the OTM, some teeth may require only linear movements, other teeth may require only rotational movement, while some may require both linear and rotational tooth movements. Thus, the linear and rotational velocities of the teeth may be staged separately. All the teeth included in the staging with aligner therapy are moved simultaneously. This concept is similar to that with PEA, where all the teeth that are bracketed move with the insertion of the wire. Although, the degree of movement of the teeth may be different, It has been reported in the literature that slowing down the tooth movements may lead to better tracking and predictability of treatment with aligners.[8-10] The leading tooth is the tooth that requires the most stages or aligner trays to achieve the predicted tooth movement. Thus, the staging of OTM with aligners can be carried out such that the velocity of tooth movement for the teeth other than the leading tooth can be slowed down to achieve better expression of tooth movement.

Distalization with Aligner Therapy

Distalization with aligners can be achieved with the sequential movement of the posterior teeth. For example, if the second molars are present, then the second molars are distalized first, followed by the first molars, followed by the premolars, and so on.[11] Newton's third law states that there is an equal and opposite reaction to an applied force, and this applies to both fixed preadjusted appliances and aligners.[12] It is important to understand that just as in a conventional distalization appliance such as pendulum, distal jet, etc., the proclination of anteriors may occur due to the forward direction of force on the anterior teeth (opposite to the distalizing force on the posteriors).[13]

The concept of reinforced anchorage states that when multiple teeth are pitted against a single tooth, the magnitude of the side effects is diluted because the force gets distributed over multiple teeth.[14] The model of sequential distalization takes advantage of this principle. Thus, when the second molars are distalized, the first molars and all the teeth anterior to it on both sides act as the anchor unit.[15] This leads to fewer side effects on the anterior teeth. In addition, the wearing of elastics, and change in position of the elastics as the orthodontic treatment progresses, help in reinforcing anchorage. It has been shown that the maxillary first molar can be distalized effectively with aligners in combination with intermaxillary elastics by 2.25 mm, without significant effects on the vertical dimension.[11] When sequential orthodontic distalization is done for second molars and first molars, the Class II elastics can be worn from the mandibular first molars to the maxillary second premolars to serve as an additional anchorage to prevent flaring of the maxillary anterior teeth.[11,16] The position of the elastics can be changed to a normal Class II elastic from the mandibular molar to the maxillary canine when the second premolars and first premolars are distalized. Thus, rather than just applying distal force on all the maxillary teeth at the same time, proper planning and staging of force application and direction can help in preserving anchorage and treating Class II malocclusions, with esthetic results.

Space Closure with Aligner Therapy

Space closure mechanics with aligners need detailed planning because of the complexity of OTM involved in space closure. Aligners apply intermittent forces, as they are removable orthodontic appliances. Thus, tipping is easily accomplished with aligners, but bodily movement is difficult.[17] Orthodontic space closure often requires translation movement of the teeth in order to achieve parallel root positioning of teeth adjacent to the extraction space. Furthermore, it is important to maintain the torque of the maxillary anterior teeth in extraction cases.[18] However, the torquing control with aligners is poor. It has been reported that imprecision in the torquing aspects of maxillary incisors ranges from 0.5° to 8.5°.[19] This is a wide range, and an imprecision of 8.5° may lead to considerable lingual tipping of the maxillary anteriors. Inadequate torque control in extraction cases can lead to consequences such as poor esthetics, running out of overjet before complete space closure, increased maxillary incisor gingival display due to lingual tipping, and extrusion.[19,20]

The use of the torquing auxiliaries follows the same principle as that of progressing to a heavy archwire such as a 19 × 25 SS wire in fixed preadjusted appliances, to fill the slot before space closure and incisor retraction. In a PEA, the torquing of the archwire due to the couple generated from the interaction of the bracket and wire slot helps in maintaining incisor torque during the retraction. The same concept should be applied to the aligner system as well. However, it has been reported that the moment/force (M/F) ratios achieved with aligners are not the same as with fixed orthodontic appliances.[21] Previously, it has been reported that the accuracy for the torquing movements

with aligners was less than 51.5%.[22] However, in more recent studies, there are conflicting findings on the accuracy of the torquing movement with aligners. While some authors have reported torquing accuracy to be as high as 72.9%, others have reported lower accuracy for torquing movements, at around 56%.[19,23] Thus, to produce adequate torquing of incisors with aligners, the authors recommend prescribing overcorrection during the staging of orthodontic treatment. For the incisors, power ridges can be added to enhance the torque.[19] However, it should be noted that due to the couple generation, power ridges and torquing lead to some intrusive effects on the maxillary incisors. Additionally, the attachments when bonded to maxillary anteriors can lead to unesthetic appearance and can be an issue with adult patients.[24] The torquing of the incisors can be staged to take effect at the same time as the incisor retraction takes place. In clinical experience, the authors usually start the torquing 2-3 trays before the incisor retraction. This additional torquing of maxillary incisors can help to prevent the uncontrolled lingual tipping during retraction and avoid issues such as running out of overjet prior to the completion of space closure. Additionally, the authors, in their clinical practice, also modify the prescription with an additional distal crown tip on the posterior teeth—the second premolars and first molars and second molars—if present (in first bicuspid extraction case), before the space closure. The purpose of this feature is to reduce the mesial tipping of the molars during the space closure. These prescriptions of additional torquing of maxillary incisors and the distal crown tip of the maxillary posterior teeth during the staging of space closure can help in decreasing the roller coaster effect, namely posterior open bite, incisor extrusion, and anterior deep bite during the retraction.

Cases with moderate to severe crowding, such as blocked-out canine or discrepancies exceeding 8 mm may be considered a better option to resolve with extraction therapy with aligners, as a significant amount of extraction space will be used in resolving the crowding. A recent study reported that mild to moderate crowding of less than 6 mm was successfully resolved with non-extraction therapy with aligners, without excessive proclination of the incisors. However, non-extraction orthodontic treatment for patients with crowding of more than 6 mm led to excessive proclination of the incisors.[25] Thus, with sound clinical judgment and appropriate diagnosis, extractions may be indicated in the treatment of patients with severe crowding, using aligners. Typical extraction patterns in orthodontic treatment include maxillary and mandibular first or second premolars.[14,26] As the average size of maxillary first and second premolars is 7-8 mm, the extraction leads to space of approximately 15 mm in the upper arch. In a case with 10 mm crowding, if extractions are performed, the amount of space remaining after the crowding is resolved is less than 5 mm. The control of torquing of anterior teeth may be expected to be better in such small spaces than in a case with mild crowding requiring 15 mm of space closure with retraction of anterior teeth. However, in such cases, there are still challenges regarding alignment, rotational correction, and mesiodistal tipping movements with aligners, which can be managed to a satisfactory degree by building overcorrection into the aligners during the staging process.[4,23]

The staging of OTM for extraction cases should be performed after taking into consideration the overbite, overjet, and dental and skeletal malocclusion. Patients with Class II Division 1 malocclusion tend to have proclination of the maxillary anteriors, increased overjet, and deep overbite.[14] In such cases, the overbite correction should be performed simultaneously while staging the orthodontic space closure.[27] If there is an increased Curve of Spee in the lower arch, the Curve of Spee should be flattened by extrusion of posteriors, intrusion of anteriors, or a combination of the 2 (most common approach).[28] Bite turbos can be used with aligners to enhance the bite-opening effect with a combination of intrusion of mandibular anteriors and extrusion of posteriors. At the same time, the maxillary space closure should be staged to retract the canines and the incisors.[28] There is a tendency for the canines to have a distal crown tip while performing retraction of canines, which leads to a mesial root tip. This tendency can be counteracted by adding the anti-tip attachments while staging the retraction. The anti-tip attachments can help to generate moment to cause distal root tipping of the maxillary canines while the force is delivered to the canines to move them distally.[27] However, the complete expression of the mesio-distal tip programmed into the aligner system is not always achieved. The imprecision of the canine mesiodistal tip has been reported to range from 0.6° to 5°.[19] Thus, it may be helpful to build-in an additional distal root tip or mesial crown tip in the canine while staging the retraction of the maxillary canine. The authors recommend adding 5° to 10° of mesial crown tip in the canine to be expressed throughout the staging of the canine retraction. In extraction cases, a critical aspect in the staging of OTM is the use of elastics. It has been suggested that elastics worn from the initial stage of OTM can help to reduce the treatment time and achieve better correction of overjet and anteroposterior discrepancies such as Class II subdivision malocclusions.[29]

Intrusion and Extrusion with Aligner Therapy

An analogy of intrusion and extrusion mechanics with fixed preadjusted appliances can help to understand the biomechanics with aligners. It has been reported that segmental arch mechanics with PEA can lead to true intrusion of incisors, ranging from 1.5 mm to 1.9 mm.[30] However, with a continuous archwire, true intrusion is rarely achieved because of the difficulty in guiding the intrusion force through the center of resistance of the incisors. The Burstone intrusion arch may help to direct the force distal to the lateral incisor so that it is closer to the center of resistance of the maxillary incisors.[31] However, the general consensus is that an intrusion greater than 1-2 mm is difficult to achieve without the use of a temporary anchorage device (TAD).[14,30-32]

With aligner therapy, it has been reported that anterior intrusion is inefficient.[3,23] Recent studies have reported maxillary incisor intrusion to be around 33%.[23] The main mechanics for the overbite correction in patients with deep overbite has been found to be the proclination of mandibular teeth.[33] The combination of intrusion of maxillary incisors and extrusion of mandibular molars also plays a role in resolving the deep overbite with aligner therapy.[33] Thus, the authors recommend building all 3 aspects into the staging, such as proclination of teeth, maxillary and mandibular incisor intrusion, and extrusion of posterior

teeth, to achieve effective bite-opening in patients with deep overbite. However, some posterior intrusion usually occurs with aligner therapy, and thus posterior open bite is a typical side effect observed with aligner therapy.[34] This may occur due to the intrusion of posterior teeth due to the thick layer of thermoplastic appliance between the maxillary and mandibular posterior teeth, resulting in a "bite-block" effect. However, in most cases, it is not a major concern and can be corrected easily with elastics. In cases with mild anterior open bite, the posterior intrusion can be helpful in closing the bite and achieving proper overbite.[35] Thus, aligners have a contrasting effect on bite closure, compared to fixed appliances which tend to open the bite slightly with continuous archwire mechanics.[9,35]

On the other hand, recent studies have suggested that extrusion of incisors is a more predictable movement than intrusion.[23,34,36] Traditionally, aligners were considered to be poor at performing extrusive movements, but with evolving mechanics and a better understanding of aligner mechanics, extrusion can now be achieved more predictably.[10,23,36] Some studies have suggested that when the intrusion of posterior teeth was planned with aligners, anterior teeth extrusion occurred as a side effect.[33] Thus, in order to close an anterior open bite, if a significant posterior intrusion is desired with aligners, then a treatment plan with TAD must be taken into consideration.[37,38] For Non-TAD-based mechanics, the tendency for incisor extrusion should be recognized and should be included in the staging. Aligners may be helpful in closing a dental open bite where the patient does not present with adequate incisor display, by incisor extrusion.

Rotational Correction with Aligner Therapy

Rotational movements are not easily achieved with fixed braces or aligners. In a preadjusted appliance, the engagement of the wire into the bracket helps to generate the couple necessary to generate rotational movement.[39] With aligners, such a couple is difficult to achieve. The rotational accuracy of the tooth movement is reported to be low with aligners.[23] The highest accuracy for rotation with aligners has been reported for maxillary central and lateral incisors, which is still less than 51%.[10,23] Thus, this tendency of underperformance of aligners for rotational correction of teeth should be taken into consideration while staging OTM. Specific resin attachments to generate the opposite forces with aligners for rotational correction may help in achieving better rotational control for canines and premolars.[4] The correction of the rotations of mandibular molars is found to be more accurate with aligners than premolars. One reason for this can be that the mandibular molars are not as rounded as premolars and have more surface area, therefore the aligners can fit the tooth better to deliver the required forces. Furthermore, the higher the degree of rotation of the tooth, the harder it is to achieve the complete rotational correction.[22,23] To overcome this tendency, it has been suggested to do overcorrection of the rotated teeth by 10% (11/10 rule) or by a 5° overcorrection beyond ideal position, to achieve better results with rotational movements using aligners.[40] Thermopliers can be a useful adjunct in aligner cases with significant rotations.[40] Recent studies have found that the accuracy of rotational correction with aligners is higher for maxillary premolars than maxillary canines.[41] In addition, the directionality of rotation, especially for canines, has also been reported to have an effect on the accuracy of the rotational correction. For example, for maxillary canines, mesial rotation can be performed relatively better and with higher accuracy of 52%, compared to the distal rotation, which has a lower accuracy of 37%.[23] Thus, a higher degree of overcorrection can be prescribed for rotational movements of maxillary canines than premolars, and specifically for distal rotation. Overall, it is a general consensus that the accuracy of the rotational correction is poor, and thus overcorrection even greater than 10% may be required to achieve complete derotation.[15] The authors recommend the overcorrection to be about 20%, and that slowing down the rotational movements to about 1° per aligner tray while staging can achieve better rotational correction, as it has been shown in previous studies stating that increasing the amount of rotational movement to more than 1.5° per aligner tray leads to decreased accuracy.[22] Additionally, when staging the OTM for correction of rotations, overcorrections should be built-in toward the end of the treatment so that other predictable movements have been achieved. When the overcorrection trays are used for rotational correction, the aligner trays often stop tracking, and thus building the overcorrection during the end of treatment ensures successful completion of OTM for other teeth.

OTM depends on multiple factors. Various parameters such as the crown anatomy, root length, dilacerations, the density of alveolar bone, age, and sex of the patient can influence the OTM. In this review, comprehensive information regarding how aligners can be used for complex OTMs is presented. However, clinicians have to consider patient-related factors and use sound clinical judgment and skills while performing the staging and formulating the treatment plans.

CONCLUSION

The staging of OTM with aligners can help achieve better orthodontic treatment outcomes. The limitations of aligner therapy must be taken into consideration while staging the orthodontic treatment, in order to limit the side effects. Tipping of teeth may be more easily achieved with the use of aligners than by torquing. Thus, the torque control should be initiated from initial aligner trays while staging orthodontic treatment. Overcorrection for rotations may help to achieve better correction. The principles of OTM do not change with the type of appliance used. If such principles are comprehended, and the modifications in the execution of the appliance are made, better treatment outcomes can be achieved.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - S.M.; Design - S.M.; Supervision - S.M., D.P., S.Y.; Materials - S.M., D.P., S.Y.; Data Collection and/or Processing - S.M., D.P., S.Y.; Analysis and/or Interpretation - S.M., D.P., S.Y.; Literature Review - S.M., D.P., S.Y.; Writing - S.M.; Critical Review - S.M., D.P., S.Y.

Conflict of Interest: The authors have no conflict of interest to declare.

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

REFERENCES

1. Weir T. Clear aligners in orthodontic treatment. *Aust Dent J*. 2017;62(suppl 1):58-62. [CrossRef]
2. Karkhanechi M, Chow D, Sipkin J, *et al.* Periodontal status of adult patients treated with fixed buccal appliances and removable aligners over one year of active orthodontic therapy. *Angle Orthod*. 2013;83(1):146-151. [CrossRef]
3. Malik OH, McMullin A, Waring DT. Invisible orthodontics part 1: invisalign. *Dent Update*. 2013;40(3):203-4, 207. [CrossRef]
4. Chan E, Darendeliler M.A. The Invisalign appliance today: a thinking persons orthodontic appliance. *Semin Orthod*. 2017;23(1):12-64. [CrossRef]
5. Pavoni C, Lione R, Laganà G, Cozza P. Self-ligating versus Invisalign: analysis of dento-alveolar effects. *Ann Stomatol*. 2011;2(1-2):23-27.
6. Kesling HD. Coordinating the predetermined pattern and tooth positioner with conventional treatment. *Am J Orthod Oral Surg*. 1946;32:285-293. [CrossRef]
7. Krieger E, Seiferth J, Marinello I, *et al.* Invisalign® treatment in the anterior region: were the predicted tooth movements achieved? *J Orofac Orthop*. 2012;73(5):365-376. [CrossRef]
8. Lagravère MO, Flores-Mir C. The treatment effects of Invisalign orthodontic aligners: a systematic review. *J Am Dent Assoc*. 2005;136(12):1724-1729. [CrossRef]
9. Boissere W, Morton J, Ojima K. *Aligner Orthodontics: Diagnostics, Biomechanics Planning and Treatment*. Hanover: Quintescence Publishing; 2015:26-30.
10. Kravitz ND, Kusnoto B, BeGole E, Obrez A, Agran B. How well does Invisalign work? A prospective clinical study evaluating the efficacy of tooth movement with Invisalign. *Am J Orthod Dentofacial Orthop*. 2009;135(1):27-35. [CrossRef]
11. Ravera S, Castroflorio T, Garino F, et al. Maxillary molar distalization with aligners in adult patients: a multicenter retrospective study. *Prog Orthod*. 2016;17:12. [CrossRef]
12. Rossini G, Parrini S, Castroflorio T, Deregibus A, Debernardi CL. Efficacy of clear aligners in controlling orthodontic tooth movement: a systematic review. *Angle Orthod*. 2015;85(5):881-889. [CrossRef]
13. Angelieri F, de Almeida RR, Janson G, Castanha Henriques JF, Pinzan A. Comparison of the effects produced by headgear and pendulum appliances followed by fixed orthodontic treatment. *Eur J Orthod*. 2008;30(6):572-579. [CrossRef]
14. Proffit WR, Fields HW. *Contemporary Orthodontics*, 4th edition. St. Louis: Mosby; 2007:686-718.
15. Simon M, Keilig L, Schwarze J, Jung BA, Bourauel C. Forces and moments generated by removable thermoplastic aligners: incisor torque, premolar derotation, and molar distalization. *Am J Orthod Dentofacial Orthop*. 2014;145(6):728-736. [CrossRef]
16. Caruso S, Nota A, Ehsani S, et al. Impact of molar teeth distalization with clear aligners on occlusal vertical dimension: a retrospective study. *BMC Oral Health*. 2019;19(1):182. [CrossRef]
17. Zhang XJ, He L, Guo HM, et al. Integrated three-dimensional digital assessment of accuracy of anterior tooth movement using clear aligners. *Korean J Orthod*. 2015;45(6):275-281. [CrossRef]
18. Parashar A, Aileni KR, Rachala MR, *et al.* Torque loss in en-masse retraction of maxillary anterior teeth using miniimplants with force vectors at different levels: 3D FEM study. *J Clin Diagn Res*. 2014;8(12):ZC77-ZC80. [CrossRef]
19. Lombardo L, Arreghini A, Ramina F, Huanca Ghislanzoni LT, Siciliani G. Predictability of orthodontic movement with orthodontic aligners: a retrospective study. *Prog Orthod*. 2017;18(1):35. [CrossRef]
20. Barlow M, Kula K. Factors influencing efficiency of sliding mechanics to close extraction space: a systematic review. *Orthod Craniofac Res*. 2008;11(2):65-73. [CrossRef]
21. Elkholy F, Panchaphongsaphak T, Kilic F, Schmidt F, Lapatki BG. Forces and moments delivered by PET-G aligners to an upper central incisor for labial and palatal translation. *J Orofac Orthop*. 2015;76(6):460-475. [CrossRef]
22. Simon M, Keilig L, Schwarze J, Jung BA, Bourauel C. Treatment outcome and efficacy of an aligner technique--regarding incisor torque, premolar derotation and molar distalization. *BMC Oral Health*. 2014;14:68. [CrossRef]
23. Haouili N, Kravitz ND, Vaid NR, Ferguson DJ, Makki L. Has Invisalign improved? A prospective follow-up study on the efficacy of tooth movement with Invisalign. *Am J Orthod Dentofacial Orthop*. 2020;158(3):420-425. [CrossRef]
24. Thai JK, Araujo E, McCray J, Schneider PP, Kim KB. Esthetic perception of clear aligner therapy attachments using eye-tracking technology. *Am J Orthod Dentofacial Orthop*. 2020;158(3):400-409. [CrossRef]
25. Duncan LO, Piedade L, Lekic M, Cunha RS, Wiltshire WA. Changes in mandibular incisor position and arch form resulting from Invisalign correction of the crowded dentition treated nonextraction. *Angle Orthod*. 2016;86(4):577-583. [CrossRef]
26. Tweed CH. Indications for the extraction of teeth in orthodontic procedure. *Am J Orthod Oral Surg*. 1944-1945;42:22-45. [CrossRef]
27. Li W, Wang S, Zhang Y. The effectiveness of the Invisalign appliance in extraction cases using the ABO model grading system: a multicenter randomized controlled trial. *Int J Clin Exp Med*. 2015;8(5):8276-8282.
28. Boyd RL. Complex orthodontic treatment using a new protocol for the Invisalign appliance. *J Clin Orthod*. 2007;41(9):525-47; quiz 523.
29. Lombardo L, Colonna A, Carlucci A, Oliverio T, Siciliani G. Class II subdivision correction with clear aligners using intermaxillary elastics. *Prog Orthod*. 2018;19(1):32. [CrossRef]
30. Ng J, Major PW, Heo G, Flores-Mir C. True incisor intrusion attained during orthodontic treatment: a systematic review and meta-analysis. *Am J Orthod Dentofacial Orthop*. 2005;128(2):212-219. [CrossRef]
31. Burstone CR. Deep overbite correction by intrusion. *Am J Orthod*. 1977;72(1):1-22. [CrossRef]
32. Goel P, Tandon R, Agrawal KK. A comparative study of different intrusion methods and their effect on maxillary incisors. *J Oral Biol Craniofac Res*. 2014;4(3):186-191. [CrossRef]
33. Khosravi R, Cohanim B, Hujoel P, *et al.* Management of overbite with the Invisalign appliance. *Am J Orthod Dentofacial Orthop*. 2017;151(4):691-699.e2. [CrossRef]
34. Dai FF, Xu TM, Shu G. Comparison of achieved and predicted tooth movement of maxillary first molars and central incisors: first premolar extraction treatment with Invisalign. *Angle Orthod*. 2019;89(5):679-687. [CrossRef]
35. Moshiri S, Araújo EA, McCray JF, Thiesen G, Kim KB. Cephalometric evaluation of adult anterior open bite non-extraction treatment with Invisalign. *Dent Press J Orthod*. 2017;22(5):30-38. (PubMed: [CrossRef]) (PubMed Central: [CrossRef]) [CrossRef]
36. Grünheid T, Loh C, Larson BE. How accurate is Invisalign in nonextraction cases? Are predicted tooth positions achieved? *Angle Orthod*. 2017;87(6):809-815. [CrossRef]
37. Giancotti A, Germano F, Muzzi F, Greco M. A miniscrew-supported intrusion auxiliary for open-bite treatment with Invisalign. *J Clin Orthod*. 2014;48(6):348-358.
38. Turley PK. Evolution of esthetic considerations in orthodontics. *Am J Orthod Dentofacial Orthop*. 2015;148(3):374-379. [CrossRef]
39. Sander C, Sander FM, Sander FG. The derotation of premolars and canines with NiTi elements. *J Orofac Orthop*. 2006;67(2):117-126. [CrossRef]
40. Boyd RL. Predictability of successful orthodontic treatment using Invisalign. *The Greater Philadelphia Society of Orthodontists page*. 2002. (Available at: http://www.gpso.org/events/2003_outline.pdf) Accessed September 1, 2007.
41. Charalampakis O, Iliadi A, Ueno H, Oliver DR, Kim KB. Accuracy of clear aligners: A retrospective study of patients who needed refinement. *Am J Orthod Dentofacial Orthop*. 2018;154(1):47-54. [CrossRef]