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TURKISH JOURNAL of
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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.

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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.

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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.

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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.

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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/ncidodlEID/cid.htm.

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ORIGINAL ARTICLE

Does Gender Have an Effect on Craniofacial Measurements?

Lale Taner, Gamze Metin Gürsoy, Fatma Deniz Uzuner

Department of Orthodontics, Gazi University School of Dentistry, Ankara, Turkey

Cite this article as: Taner L, Metin Gürsoy G, Uzuner FD. Does Gender Have an Effect on Craniofacial Measurements? Turk J Orthod 2019; 32(2): 59-64.

ABSTRACT

Objective: The aim of this cross-sectional study was to evaluate craniofacial structures in terms of different sagittal relations and gender in adolescent individuals.

Methods: Pre-treatment dental models, lateral cephalometric, and hand-wrist radiographs of 223 adolescent subjects (102 male, 121 female) were evaluated. Subjects were divided into the Angle Class I, II, and III (skeletally) subgroups according to the ANB angle. Four angular and 33 linear measurements were used to evaluate the lateral cephalometric radiographs relative to the R1 and R2 coordinate system. The Kolmogorov–Smirnov test was performed to assess the normal distribution of the data. The independent samples t-test and Mann–Whitney U test were used for the comparison of male and female subjects in each group. The values were considered statistically significant at $p<0.05$.

Results: The vertical facial dimension was found to be significantly greater in Class I male subjects than in female subjects (SGo, $p=0.023$; ANS-M, $p=0.036$), and there was a protrusive maxilla (R2ANS, $p=0.038$; R2A, $p=0.016$), while the mandibular sagittal position and the mandibular dimension were similar. The maxilla was placed protrusively (R2ANS, $p=0.001$; R2A, $p=0.002$), while the mandible was found to be larger both in the position and dimension (CoGn, $p=0.003$; R2M, $p=0.014$) in Class II male subjects. Class III male and female subjects were found to have similar maxillary and mandibular vertical and sagittal location and dimensions.

Conclusion: Class I and II subjects showed more gender variation than Class III subjects. The gender-related results of this study declare that treatment planning of malocclusions should be based on gender differences rather than general treatment procedures, which will be useful in achieving successful orthodontic treatment results.

Keywords: Cephalometrics, Class I, Class II, Class III, craniofacial, gender, orthodontics

INTRODUCTION

An accurate diagnosis of malocclusion and related treatment planning are the key of a successful orthodontic treatment. The purpose of orthodontic treatment is to provide acceptable occlusion and function, as well as aesthetics. Subjects with dental and/or skeletal malocclusions may have greater restrictions in terms of the quality of life, discomfort, and social and functional limitations. A detailed identification of hard and soft tissue problems by advancing technology facilitates reaching of the best results for the orthodontist. When the studies evaluating the craniofacial characteristics related to malocclusion are examined, it is observed that the results vary widely (1-4). One of the most important reasons for the variety is the race of samples included in the studies. In addition, the sample of age and gender, the sample size, and methodology differences may be responsible for the divergent outcomes. While the prevalence of malocclusion varies from country to country and among different age and gender groups, the most common malocclusion type in the population has been reported as Angle Class I malocclusions. Class II and Class III malocclusions are the less frequently observed malocclusion types (5-7). The need for orthodontic treatment or a type of malocclusion was noted to be similar between the genders. Gender-related craniofacial differences have been mentioned in the literature, while there is insufficient knowledge about gender variations between the malocclusion types (8-10).

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This study was planned to provide additional information to verify more realistically the possible association between malocclusion and craniofacial morphology. The purpose of the present study was to compare the craniofacial structures in Class I, II, and III Turkish male and female subjects using cephalometric films, and to evaluate the relation of gender in craniofacial morphologic structures.

METHODS

This retrospective study was approved by the Ethical Committee of Gazi University (02.12.2016/14). A total of 2700 patients' pre-treatment lateral cephalograms, hand-wrist radiographs, dental models, and clinical reports were collected from the archives of the Orthodontics Department of the Gazi University. First, subjects who were not in the adolescent period were excluded. Subjects with the skeletal age 10–11.5 years were selected. Later, subjects with no previous loss of primary molars, no history of previous orthodontic or prosthodontic treatment, serial extraction, without acquired or congenitally missing teeth, having no stainless steel crowns or large restorations, facial and/or dental trauma, and no craniofacial anomalies were selected. In addition, subjects without the optimal range of the SNGoGn angle (32±6º) were excluded. Also, all subjects were Caucasian Turkish to avoid ethnic differences in the craniofacial morphology. Finally, the sample consisted of 223 subjects (102 male, 121 female) ranging in the skeletal age between 10 and 11.5 years.

There were three groups constructed and matched according to the ANB angle value:

- Group 1 (n=93): 50 female and 43 male subjects with the skeletal Class 1 (0<ANB angle≤4º) relationship.
- Group 2 (n=90): 51 female and 39 male subjects with the skeletal Class 2 (ANB>4°) relationship.
- Group 3 (n=40): 20 female and 20 male subjects with the skeletal Class 3 (ANB≤0°) relationship.

Hand-wrist radiographs were assessed according to the method of Greulich and Pyle (11), and the skeletal age was calculated.

Four angular and 33 linear measurements were used to evaluate the lateral cephalometric radiographs taken under standardized conditions. The landmarks, reference lines, and measurements are shown in Figure 1.

The measurements were made relative to the R_1 and R_2 coordinate system. R_1 was constructed 7° to the SN plane, and R_2 was constructed perpendicular to R_1 at the Sella, and measurements were made according to a previous study (12). Following measurements based on the selected points were obtained from the cephalometric radiographs.

Linear measurements: CoA, ANS-PNS, CoB, CoGn, CoANS, SGo, GoGn, ArGn, N-ANS, ANS-M, N-M, R_1ANS, R_1PNS, R_1M, R_1A, R_1B, R_1Pg, R_1Gn, R_1Co, R_1Ar, R_1Go, R_1ANT, R_2ANS, R_2PNS, R_2M, R_2A, R_2B, R_2Pg, R_2Gn, R_2Co, R_2Ar, R_2Go, R_2ANT

Angular measurements: SNA, SNB, ANB, SNGoGn

Each cephalometric radiograph was traced, and all parameters were measured by the same investigator. To estimate the method error, 75 randomly selected lateral cephalometric radiographs were retraced and re-measured 2 weeks later by the same examiner.

Statistical Analysis

The method error was assessed with the intraclass correlation coefficient (ICC). The ICC for all measured parameters showed a high reliability and reproducibility of measurements (r>0.95) (Table 1).

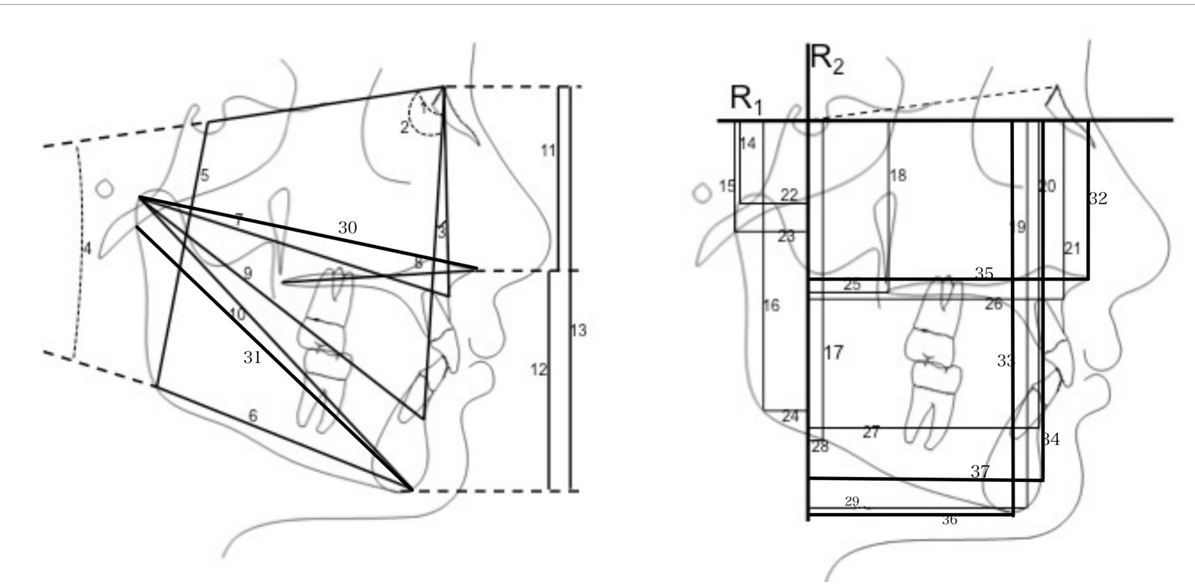

Figure 1. Cephalometric landmarks, reference lines, and measurements used in this study
S, sella; N, nasion; A, skeletal A point; M, menton; B, skeletal B point; ANS, anterior nasal spine; PNS, posterior nasal spine; Go, gonion; Gn, gnathion; Co, condylion; Pg, pogonion; ANT, antegonial notch; Ar, articulare
SNA(1), SNB(2), ANB(3), SNGoGn(4), SGo(5), GoGn(6), CoA(7), ANS-PNS(8), CoB(9), CoGn(10), N-ANS(11), ANS-M(12), N-M(13), R1Co(14), R1Ar(15), R1Go(16), R1ANT(17), R1PNS(18), R1Gn(19), R1B(20), R1A(21), R2Co(22), R2Ar(23), R2Go(24), R2PNS(25), R2A(26), R2B(27), R2ANT(28), R2Gn(29), CoANS(30), ArGn(31), R1ANS(32), R1M(33), R1Pg(34), R2ANS(35), R2M(36), R2Pg(37)

Table 1. Intra-examiner reproducibility for some parameters

Groups	SNA	SN-GoGn	CoPNS	R1Ar	R1Go	R2ANS	R2M
Class 1 (n: 30)	0.997	0.998	0.953	0.988	0.995	0.988	0.997
Class 2 (n: 30)	0.995	0.999	0.974	0.995	0.993	0.965	0.999
Class 3 (n: 15)	0.986	0.995	0.983	0.991	0.999	0.985	0.995

Intraclass correlation coefficient (ICC), r>0.95

Table 2. Gender comparison of maxillary and vertical variables in Class I subjects

	Male (n=43)	Female (n=50)	Male–Female Comparison
	Mean±SD	Mean±SD	p
N-ANS (mm)	52.35±2.9	51.74±2.4	NS†
ANS-M (mm)	66.02±4.6	63.96±4.6	0.036†
N-M (mm)	117.77±5.9	115.22±5.6	0.037†
S-Go (mm)	75.47±4.9	71.6±8	0.023*
SNGoGn (°)	32.35±3.4	32.64±3.1	NS†
ANB (°)	2.1±1.2	2.21±1.1	NS*
SNA (°)	79.67±3.4	79.64±3.6	NS†
ANS-PNS (mm)	53.31±3.2	52.23±2.7	NS†
CoANS (mm)	90.88±4.4	89.56±4.8	NS*
CoA (mm)	86.97±4.4	85.5±4.6	NS†
R_1ANS (mm)	43.97±2.9	44.47±4.2	NS*
R_1A (mm)	49.69±2.9	49.59±3.5	NS*
R_1PNS (mm)	43.87±2.7	42.21±4.8	0.030*
R_2PNS (mm)	20.64±3.2	19.44±3.1	NS†
R_2ANS (mm)	73.51±4.4	71.66±4	0.038†
R_2A (mm)	67.83±4.4	65.62±4.1	0.016†

*Mann–Whitney U test; †Independent t-test; p<0.05

Table 3. Gender comparison of mandibular variables in Class I subjects

	Male (n=43)	Female (n=50)	Male–Female Comparison
	Mean±SD	Mean±SD	p
SNB (°)	77.5±3.3	77.4±3.8	NS†
CoB (mm)	102.19±5.2	99.4±5.3	0.013†
ArGn (mm)	106.35±5.8	104±5.6	NS*
CoGn (mm)	111.53±6.9	109.54±5.1	NS*
GoGn (mm)	73.5±3.7	72.46±4	NS*
R_1Co (mm)	21.79±3	20.69±2.6	NS†
R_1Ar (mm)	31.45±2.9	30.56±3	NS†
R_1Go (mm)	74.85±4.6	73.02±4.5	NS*
R_1ANT (mm)	85.29±5.1	83.13±4.4	0.034†
R_1B (mm)	89.58±5.4	87.45±5.3	NS†
R_1Pg (mm)	102.4±5.8	99.52±5.1	0.013†
R_1Gn (mm)	106.6±6	104.1±5.2	0.035†
R_1M (mm)	107.86±5.8	105.24±5.2	0.025†
R^2Co (mm)	14.6±3	14.67±3.1	NS*
R^2Ar (mm)	15.62±3.3	16.22±3.1	NS*
R^2Go (mm)	6.84±4.7	8.24±4.6	NS†
R^2ANT (mm)	12.33±5.1	11.71±5	NS†
R^2B (mm)	61.9±6.2	59.6±6	NS†
R^2Pg (mm)	62.2±6.8	59.9±6.4	NS†
R^2Gn (mm)	59.88±7.1	57.16±6.7	NS†
R^2M (mm)	55.65±7.4	52.84±6.7	NS†

*Mann–Whitney U test; †Independent t-test; p<0.05

Descriptive statistics of the craniofacial measurements in Class I, Class II, and Class III female and male samples were calculated as the mean and standard deviation. The Kolmogorov–Smirnov test was performed to assess the normal distribution of the data in the sample. The independent samples t-test was used for normal distribution and the Mann–Whitney U Test for non-normal distribution to compare male and female subjects in the groups. The values were considered statistically significant at p<0.05.

RESULTS

Comparison of Class I female and male subjects. There was no difference in the SNGoGn angle between females and males in the Class 1 group. However, the vertical anterior and posterior facial heights were longer in male than in female subjects. Vertical maxillary variables were similar except R1PNS, which was larger in male subjects (Table 2).

Maxillary measurements (R_2ANS, R_2A) were significantly greater in male subjects than females (Table 2).

Mandibular vertical measurements (R_1Gn, R_1Pg, R_1ANT, R_1M) were found significantly higher in male subjects than in female subjects. Also, CoB was found to be longer in males (Table 3).

Comparison of Class II female and male subjects. There was no difference in the SNGoGn angle between females and males in the Class II group. However, a lower facial height and posterior facial height were longer in male than in female subjects. Maxillary variables R_2ANS, R_2A, CoANS, and CoA were found to be significantly larger in male subjects than in female (Table 4).

There were significant differences in the mandibular vertical (R_1Gn, R_1B, R_1Pg, R_1Ar, R_1Go, R_1ANT, R_1M), sagittal (R_2M, R_2Pg, R_2Gn, R_2B, R_2ANT), and dimension measurements (ArGn, CoB, CoGn, GoGn) between female and male subjects, and they were greater in males (Table 5).

Comparison of Class III female and male subjects. There were no significant differences between male and female subjects for sagittal and vertical variables except R_2PNS and R_2ANT, which were larger in males (Tables 6, 7).

Table 4. Gender comparison of maxillary and vertical variables in Class II subjects

	Male (n=39)	Female (n=51)	Male–Female Comparison
	Mean±SD	Mean±SD	p
N-ANS (mm)	52.96±3.3	51.82±3.7	0.002†
ANS-M (mm)	66.74±4.4	64.04±3.5	0.001†
N-M (mm)	118.82±5.2	114.96±5	NS†
S-Go (mm)	75.51±5	72.18±7.6	0.012*
SNGoGn (°)	33.26±3.3	33.56±2.8	NS*
ANB (°)	6.12±1.3	5.91±1.2	NS*
SNA (°)	81.69±3.4	80.81±3	NS†
ANS-PNS (mm)	54.53±3	53.38±3.3	NS†
CoANS (mm)	94.44±4.1	91.31±4.4	0.001†
CoA (mm)	90.72±3.6	87.83±4.5	0.005*
R_1ANS (mm)	44.38±3.2	44.59±3	NS*
R_1A (mm)	50±4.2	49.98±3.6	NS*
R_1PNS (mm)	43.79±2.8	42.56±2.7	NS*
R_2PNS (mm)	21.31±3.9	19.78±2.4	NS*
R_2ANS (mm)	75.41±3.9	72.82±3.4	0.001†
R_2A (mm)	69.86±4.4	67.1±3.6	0.002†

SD, standard deviation
*Mann–Whitney U test; †Independent t-test; p<0.05

Table 5. Gender comparison of mandibular variables in Class II subjects

	Male (n=39)	Female (n=51)	Male–Female Comparison
	Mean±SD	Mean±SD	p
SNB (°)	75.57±3	74.9±2.5	NS†
CoB (mm)	101.21±4.8	97.78±4.1	0.001†
ArGn (mm)	103.49±11.6	101.41±4.1	0.004*
CoGn (mm)	111.54±5.1	108.33±4.8	0.003†
GoGn (mm)	73.18±3.9	70.69±4.4	0.007†
R_1Co (mm)	20.24±3.1	19.07±2.6	NS†
R_1Ar (mm)	31.36±3	29.68±2.8	0.008†
R_1Go (mm)	74.47±4.8	72.39±3.8	0.009*
R_1ANT (mm)	85.58±4.5	82.9±4.3	0.002*
R_1B (mm)	89.05±5	85.95±4.1	0.002†
R_1Pg (mm)	102.72±5.2	99.42±5.1	0.003†
R_1Gn (mm)	106.64±5.3	103.1±4.7	0.002†
R_1M (mm)	107.67±5.3	104.48±4.8	0.003*
R_2Co (mm)	15.91±3.3	15.09±3	NS†
R_2Ar (mm)	16.97±3.3	16.8±3.1	NS†
R_2Go (mm)	9.72±4.6	10.26±4.4	NS†
R_2ANT (mm)	10.56±5.3	8.23±4.8	0.032†
R_2B (mm)	58.64±5.8	56.12±4.2	0.021†
R_2Pg (mm)	58.52±6.5	56.15±4.6	0.048†
R_2Gn (mm)	56.06±6.6	53.41±4.8	0.03†
R_2M (mm)	52.08±7	48.65±5.9	0.014†

SD, standard deviation
*Mann–Whitney U test; †Independent t-test; p<0.05

Table 6. Gender comparison of maxillary and vertical variables in Class III subjects

	Male (n=20)	Female (n=20)	Male–Female Comparison
	Mean±SD	Mean±SD	p
N-ANS (mm)	52.35±3.6	51.45±4.1	NS†
ANS-M (mm)	65.1±5.6	62.72±5.9	NS*
N-M (mm)	117.45±7.7	113.68±6.9	NS†
S-Go (mm)	76.13±11.8	73.88±4.4	NS*
SNGoGn (°)	32.88±3.3	31.23±3.1	NS†
ANB (°)	−2.58±1.6	−1.8±1.3	NS*
SNA (°)	78.43±3.6	79.05±2.8	NS†
ANS-PNS (mm)	51.18±3.3	51.35±3.6	NS†
CoANS (mm)	87.3±6.3	86.2±6	NS†
CoA (mm)	82.18±6.7	81.55±5.2	NS†
R_1ANS (mm)	44.05±3.2	43.08±3.8	NS†
R_1A (mm)	48.53±4.7	47.1±4.9	NS†
R_1PNS (mm)	43.15±3.5	41.68±2.7	NS*
R_2PNS (mm)	19.65±2.1	18±2.1	0.018†
R_2ANS (mm)	70.5±4.6	68.9±4.5	NS†
R_2A (mm)	63.65±3.5	62.43±4.2	NS†

*Mann–Whitney U test; †Independent t-test; p<0.05

Table 7. Gender comparison of mandibular variables in Class III subjects

	Male (n=20)	Female (n=20)	Male–Female Comparison
	Mean±SD	Mean±SD	p
SNB (°)	81.02±3	80.65±2.9	NS†
CoB (mm)	105.43±5.4	101.88±6.7	NS†
ArGn (mm)	109±6.7	106.6±6.8	NS†
CoGn (mm)	111.5±13.3	111.55±10.4	NS*
GoGn (mm)	69.2±11.9	73.3±3.6	NS*
R_1Co (mm)	20.65±3.6	20.2±3.1	NS*
R_1Ar (mm)	30.65±3.3	30.25±3.5	NS†
R_1Go (mm)	77.2±8.3	73.4±4.3	NS*
R_1ANT (mm)	84.5±6.1	82.37±4.3	NS*
R_1B (mm)	90±6.1	86.45±6	NS†
R_1Gn (mm)	107±7.3	102.6±6.8	NS*
R_1Pg (mm)	101.35±7.3	97.28±7	NS*
R_1M (mm)	107.95±7.4	103.98±6.6	NS*
R_2Co (mm)	14.05±2.8	14.05±2.9	NS†
R_2Ar (mm)	15±3.1	15.3±3.4	NS†
R_2Go (mm)	3.35±3.6	5.9±4.8	NS†
R_2ANT (mm)	15±3.8	12.4±3.7	0.035†
R_2B (mm)	65.15±4.3	63.05±6.2	NS*
R_2Pg (mm)	65.7±4.2	64.15±6.3	NS*
R_2Gn (mm)	63.15±4.2	61.53±6.3	NS*
R_2M (mm)	58.5±4.4	56.9±6.1	NS*

*Mann–Whitney U test; †Independent t-test; p<0.05

DISCUSSION

The differential diagnosis of the skeletal pattern and the dental classification of malocclusion are important factors in planning the orthodontic treatment. The diagnosis of possible consequences in an early phase of the skeletal problem can help to prevent the development of more difficult orthodontic problems via target-related therapies. The upper and lower jaws that serve as the base for the teeth should be in the correct position, relative to each other and to the cranial base. In the light of this knowledge, we planned this study to provide and compare data for gender and malocclusion relations and for early prediction of need-oriented treatment. To obtain detailed information, we chose to make the measurements according to a coordinate system and at a specific growing stage. In view of the results of this study, malocclusions may be distinguished at an early stage in relation with gender variations providing possible pre-treatment outcome, which can reduce dental problems and shorten and/or facilitate the orthodontic treatment, especially for Class III patients.

Although there are many studies related to malocclusion types according to ethnic groups, previous reports of gender variations in relation to malocclusion prevalence are inconclusive (3-5, 9, 13).

All subjects in this study had similar optimal vertical growth patterns. This is an important factor to distinguish in order to eliminate possible effects of the vertical growth pattern on the measurements.

Comparison of Class I female and male subjects. In a previous study to determine the craniofacial norms in Anatolian Turkish adults with Class I malocclusion, in line with the findings of our study, researchers found minimal differences between males and females. The maxilla and mandible were located anteriorly regarding the condyle, and lower and upper face heights were longer in males compared to female subjects (14). However, the mean values of the variables were higher than the means of the presented study due to the different development stages of the subjects. Maxilla was found to be more protrusive in males than females whereas the sagittal position of the mandible was similar between the genders in this study. Mandibular length and vertical mandibular measurements were higher in males, and posterior portion of the maxilla (PNS) was located more downward. The results of another study in the same developmental stage, supported some of our outcomes, and the maxillary and mandibular length was found significantly larger in male than female subjects (15). In support, other researchers noted that Turkish adult male patients show larger vertical and sagittal skeletal values than the female patients (16).

Comparison of Class II female and male subjects. Previous studies showed that gender variation had little or no effect on skeletal and dental components of Class II malocclusion (17-20). However, in this present study, many differences were found between male and female subjects for vertical, mandibular, and maxillary variables. Anterior and posterior facial heights were significantly larger in male subjects, although the SNGoGn angle was similar between male and females. Also, the maxilla was located more anteriorly in male subjects, and the maxillary length was larger compared to the female subjects in the present study. In line with our study findings, researchers noted that Chinese males had an anteriorly long face and protruded maxilla compared to females (18, 20). In addition, researchers noted that male subjects had a more retruded mandible compared to female subjects. As a result of that, a straight profile was more common in female subjects (18). On the contrary, the mandible was found larger and located more anteriorly compared to female subjects in this present study.

Comparison of Class III female and male subjects. In a previous study, gender differences in Class III malocclusion were found at 9–12 years of age. The most obvious differences were in the vertical position of the lower incisors, the lower lip in relation to the aesthetic plane, and anterior cranial base dimension (9). Findings in the present study were similar in craniofacial features except the sagittal position of the PNS and ANT points, which were located anteriorly in male subjects. Male and female subjects included in the present study had similar craniofacial features. This result shows that similar treatment procedures may be applied for Class III male and female subjects, but it should not be forgotten that the growth and development in male individuals will be longer and greater when compared to females.

Bacetti et al. (9) explained that the differential outcomes of female and male subjects were due to different development stages at the same chronological age and that gender differences began to become prominent between girls and boys after 12 years. In their study, female subjects were at the age of 13 and had reached a post-pubertal stage in the skeletal development, but the male subjects were still at the pubertal stage.

This reveals the importance of the selection of subjects according to the skeletal age and in similar developmental stages as possible. We limited the range of the skeletal ages of the adolescent subjects in this study to maximize the similar growth potential of the patients. The age of 10–11.5 years is of special importance for beginning functional orthodontic therapies, and the awareness of gender-related craniofacial variations will lead to specific need-oriented treatment plans.

The most spectacular findings in this present study were that the variations between male and female individuals were seen in the same parameters (ANS-M, SGo, R_2ANS, R_2A, CoB, R_1Gn, R_1Pg, R_1ANT, R_1M) for skeletal Class I and Class II anomalies. Vertical and sagittal measurements reveal that the gender-related craniofacial growth in subjects with similar vertical growth patterns result in a more protrusive maxilla and downward position of the mandible in skeletal Class I male and II male subjects than female subjects. Although the skeletal classes were different, the female and male craniofacial variations were similar. However, skeletal Class III subjects showed similar characteristics in female and male subjects, unlike Class I and II individuals. Possible reasons may be the smaller sample size of the Class III group as a limitation of this study.

The prevalence of Class III malocclusion is low in the Turkish population, as well as in other societies, and the fact that both the age interval and the specific vertical ranges were limited, the number of Class III samples is small (5, 7).

CONCLUSION

- Skeletally Class I and II subjects showed more gender variation than Class III subjects.
- Treatment of malocclusions should be based on gender differences rather than general treatment procedures, which will be useful in achieving successful orthodontic treatment results.

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethics Committee of Gazi University (02.12.2016/14).

Informed Consent: Written informed consent was obtained from the patients who participated in this study.

Peer-review: Externally peer-reviewed.

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ORIGINAL ARTICLE

Reliability of Measurements on Plaster and Digital Models of Patients with a Cleft Lip and Palate

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ABSTRACT

Objective: The purpose of this study was to determine (1) the more and less reliable measurements/methods and (2) the influence of knowledge and skill on the inter- examiner, intra-examiner, and inter-method reliability of nasolabial measurements on plaster casts and three dimensional (3D) stereophotogrammetric images of casts in infants with an unrepaired unilateral cleft lip and palate (UUCLP).

Methods: Preoperative extraoral plaster casts from 42 patients with UUCLP were measured with a digital caliper, and the image acquisition of casts was performed with the 3dMDface stereophotogrammetry system (3dMD, Atlanta, GA). Two examiners (one postgraduate student, one lecturer) evaluated 19 nasolabial measurements in two separate sessions.

Results: Intra-rater, inter-rater, and inter-method reliability was lower in measurements of nasal, philtral, and nasal floor width. Almost all of the interclass correlation coefficients (ICC) for measurements performed by the lecturer were above 0.75, whereas the intra-examiner reliability of some measurements performed by the postgraduate student showed low ICC (<0.75).

Conclusion: Measurements of curving slopes, such as nasal width, of small dimensions, such as nostril floor width, and deformity-affected anatomic parts, such as philtrum width, presented a low reliability. Measurements on 3D images showed a higher reliability compared to plaster model measurements performed by the postgraduate student. Therefore, it may be recommended to use 3D digital images of infants with CLP for nasolabial measurements especially if performed in postgraduate settings.

Keywords: Cleft lip and palate, reliability, plaster model, stereophotogrammetry

INTRODUCTION

Cleft lip and palate (CLP) is the second most common congenital anomaly with the incidence of 0.6%–1% (1, 2). The treatment protocol of patients with CLP consists of interventions in special time periods over approximately 18–20 years. Therefore, records are not only used for diagnosis and fabrication of plate for presurgical orthopedic treatment in infancy, but also to evaluate the treatment progress, growth changes, and treatment outcomes over years. Moreover, records are required to communicate and transfer the history of the individual to the forthcoming specialist (3). Briefly, taking and archiving of the records of these cases is much more important than of traditional orthodontic cases.

The assessment and recording of the cleft deformity is performed using different methods. Photography, one of the oldest two-dimensional (2D) recording methods, needs training and effort of the professionals for standardization (4). Furthermore, this technique loses the three-dimensional (3D) nature of the anatomy (5). Facial anthropometry may deliver the most precise data; nevertheless, it unfortunately has shortcomings, such as the difficulty and a long duration during direct measurements on the face, particularly in infants and small children. The other disadvantage is the lack of communication of professionals without the presence of the patient (6).

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Recently, the most frequently used 3D recoding method in cleft clinics is impression taking and cast model production. These methods are superior over photography and direct anthropometry, regarding the 3D evaluation and ease of communication and data transfer between specialists. However, tissue deformation due to the weight of the impression material, the risks of the impression-taking procedure, duration of the model production, the storage requirements, probable data loss due to model fragility, and difficulties in the analyzing of anatomic structures of models are the shortcomings of this method that could not be overcome for years (7-9).

Currently, thanks to the advancements in medical technology, 3D imaging systems including photo-optical, laser-optical scanning (10-12), and stereophotogrammetry (13-15) are introduced to enable the digitalization, even of former cast models and full computer-based management of patient records. Stereophotogrammetry, obtaining images by taking multiple photographs simultaneously, is usually used for facial soft tissue assessments; however, researchers suggest that it is also proper for imaging of plaster casts (16, 17). The inter-method measurement reliability between 3D images and anthropometric assessment (18, 19), as well as 3D virtual models and intraoral stone casts, was satisfying (17). In addition, several studies emphasized that the manipulation of 3D images is easy and uncomplicated (18-20). Certainly, identification of reliable 3D landmarks, and also performing of reproducible measurements, is related with the observer's familiarity (involving knowledge and skill) to 3D images and software programs. As in every manipulation skill, training in 3D image visualization and analysis is required. In a study by Radeke et al. (21), three examiners with different degrees of expertise in dentistry measured the mesio-distal width of each tooth on cast models manually and on 3D images digitally. They concluded that the measurements from software-based methods did not diverge from conventional manual methods if performed even by observer who have a weaker background in dentistry. Nevertheless, the tooth forms assessed in the aforementioned study were more precise compared with abnormal anatomical variations such as a cleft lip and palate. In fact, to the best of our knowledge, none evaluated the effect of experience about the cleft anatomy on the reliability of plaster model and also 3D image assessments. Furthermore, no evaluation of the intra-reliability and shortcomings of lecturer in this topic were evident. Overall, the determination of less reliable measurements and the more reliable method in evaluating patients with craniofacial anomalies will enable to make up a checklist and integrate courses into the educational curriculum in postgraduate settings for the measurements and the method, respectively.

Therefore, the purpose of this study was to determine (1) the more and less reliable measurements/methods and (2) the influence of knowledge and skill on the inter- examiner, intra-examiner, and inter-method reliability of nasolabial measurements on plaster casts and three dimensional (3D) stereophotogrammetric images of casts in infants with unrepaired unilateral cleft lip and palate (UUCLP).

METHODS

This study was carried out on facial models of infants with UUCLP from the archive of the Orthodontic Department of Yeditepe University School of Dentistry. Patient data were handled according to the requirements and recommendations of the Declaration of Helsinki. Ethical approval (no.58/490) was obtained from the institutional review board of Yeditepe University.

Facial plaster models of 42 infants with UUCLP were selected from the archive. The models that were broken or had deficient representation of the anatomical morphology were excluded from the study. Then, the 3D sterephotogrammetric acquisition of the plaster models was performed with the 3dMDface system (3dMD, Atlanta, GA). The stereophotogrammetric system is composed of two modular units of six medical-grade machine vision cameras and a flash system. The models were placed 1 m away from the cameras, and images were captured in 1.5 miliseconds. All 3D images were imported to the 3dMD patient software program (3dMD, Atlanta, GA) for measurements.

Two examiners (R.B.N.Y. and M.A.) performed the measurements. One of the raters (R.B.N.Y.) was a lecturer experienced in patients with CLP and their variable anatomical structures and an active staff member in the cleft clinic over 10 years. She had the experience in handling of both the facial plaster model and 3D stereophotogrammetric images. The second rater (M.A.) was a postgraduate student in the orthodontic department, in the fifth semester. Although, she was theoretically familiar with the cleft lip and palate anatomy and manual measurements of teeth on plaster models, she never performed any measurements on facial plaster models as well as on 3D images of the models. However, she assisted regularly in the cleft clinic upon her first semester and was postgraduate student chef in the cleft clinic. Lecturer gave instruction lessons about not only the use of digital calipers and the 3D software program, but also the definition of the anatomical landmarks to the student. After training, both examiners located the anatomical landmarks and performed the measurements in the nasolabial areas on plaster models and 3D digital images.

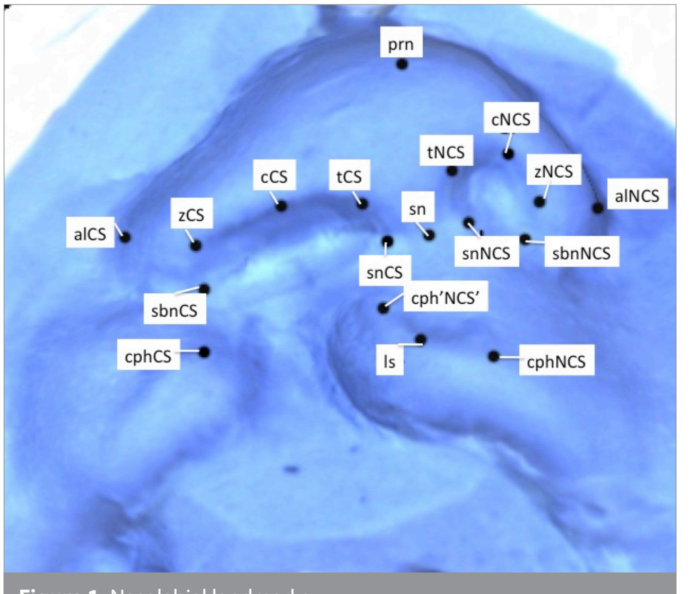

Figure 1. Nasolabial landmarks

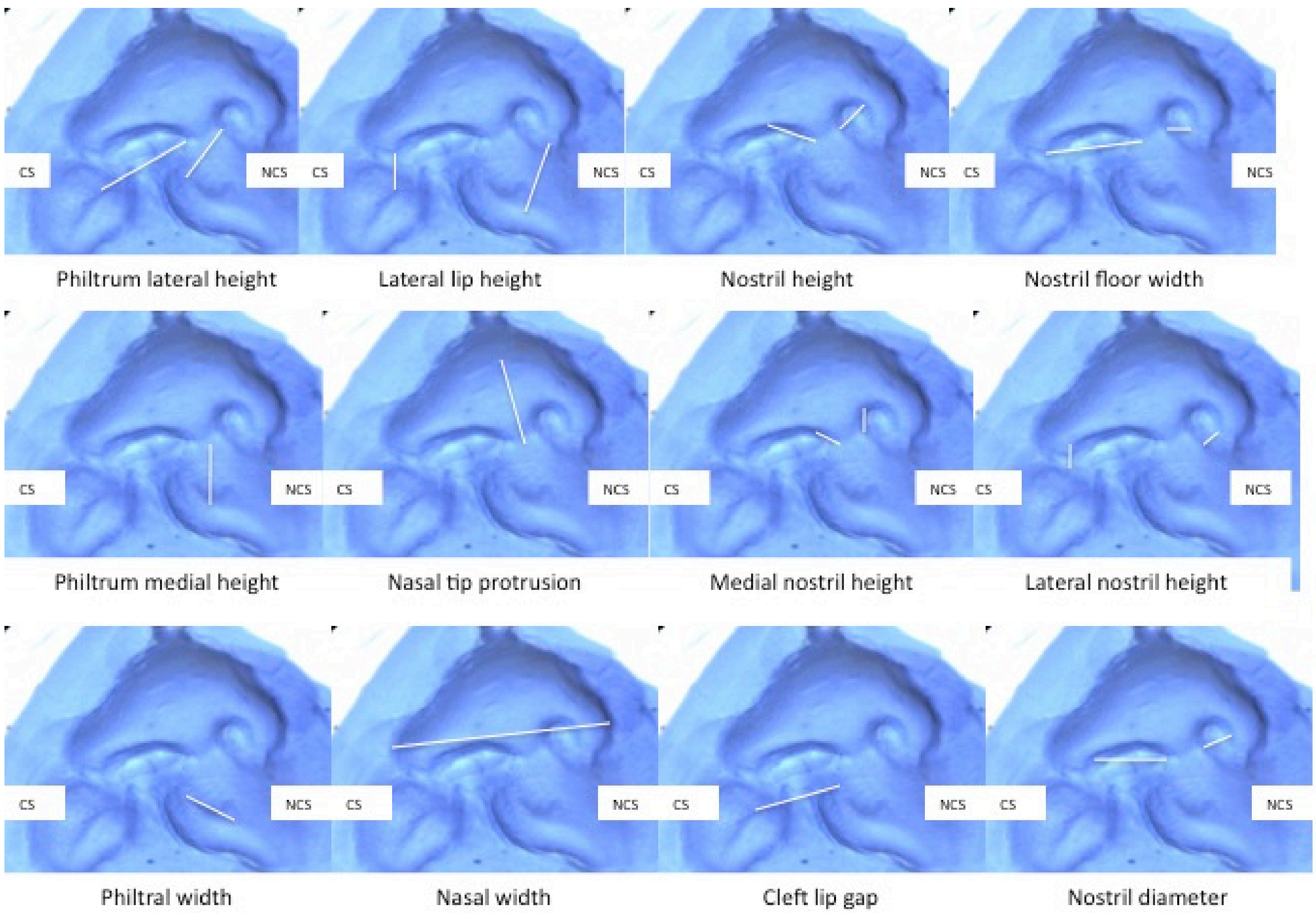

Figure 2. Nasolabial measurements

Table 1. The definition of the nasolabial landmarks

Landmark	Definition
Pronasale (prn)	The most anterior midtip point of the nasal tip
Subnasale (sn)	The midpoint on the nasolabial soft tissue contour between the columella crest and the upper lip
Subnasale CS (snCS)	The point at the margin of the midportion of the columella crest at CS
Subnasale NCS (snNCS)	The point at the margin of the midportion of the columella crest at NCS
Alare CS (alCS)	The most lateral point on the alar contour at CS
Alare NCS (alNCS)	The most lateral point on the alar contour at NCS
Labiale superior (ls)	The midpoint of the vermillion line of the upper lip
Crista philtri CS (cphCS)	The point on crossing of the vermillion line and the elevated margin of the philtrum at CS
Crista philtri NCS (cphNCS)	The point on crossing of the vermillion line and the elevated margin of the philtrum at NCS
Christa philtri' NCS' (cph'NCS')	The point at the noncleft side crossing the vermillion line and the elevated margin of the philtrum, corresponding the same point
Lateral subnasale inferior CS (sbnCS)	The lowest point of the lateral internal outer contour of nostril at CS
Lateral subnasale inferior NCS (sbnNCS)	The lowest point of the lateral internal outer contour of nostril at NCS
Lateral subnasale superior CS (zCS)	The highest point of the lateral internal outer contour of nostril at CS
Lateral subnasale superior NCS (zNCS)	The highest point of the lateral internal outer contour of nostril at NCS
Medial nostril superior CS (tCS)	The highest point of the medial internal outer contour of nostril at CS
Medial nostril superior NCS (tNCS)	The highest point of the medial internal outer contour of nostril at NCS
Nostril top point CS (cCS)	The highest point between lateral subnasale superior and medial nostril superior point on CS
Nostril top point NCS (cNCS)	The highest point between lateral subnasale superior and medial nostril superior point on NCS

CS, cleft side; NCS, noncleft side

Eighteen landmarks were identified to perform 19 linear measurements, consisting of 12 vertical and five horizontal measurements (Figure 1, 2; Table 1, 2). A digital caliper (Opto-Rs 232 simplex/duplex, Sylvac/Fowler, Crissier, Switzerland) was used for the measurements on plaster models, whereas the caliper function of the software program (3dMD, Atlanta, GA) was used for the measurements on 3D digital images.

Table 2. The definition of the nasolabial measurements

Measurements	Definition
Cleft lip gap	Distance between cph'NCS' and cphCS
Philtrum median height	Distance between sn and ls
Philtrum lateral height (CS)	Distance between snCS and cph'NCS'
Philtrum lateral height (NCS)	Distance between snNCS and cphNCS
Philtral width (NCS)	Distance between cph'NCS' and cphNCS
Lateral lip height (CS)	Distance between cphCS and sbnCS
Lateral lip height (NCS)	Distance between cphNCS and sbnNCS
Nasal width	Distance between alCS and alNCS
Nostril floor width (CS)	Distance between sbnCS and snCS
Nostril floor width (NCS)	Distance between sbaNCS and snNCS
Nasal tip protrusion	Distance between sn and prn
Nostril height (CS)	Distance between snCS and cCS
Nostril height (NCS)	Distance between snNCS and cNCS
Medial nostril height (CS)	Distance between snCS and tCS
Medial nostril height (NCS)	Distance between snNCS and tNCS
Lateral nostril height (CS)	Distance between sbnCS and zCS
Lateral nostril height (NCS)	Distance between sbnNCS and zNCS
Nostril diameter (CS)	Distance between snCS and zCS
Nostril diameter (NCS)	Distance between snNCS and zNCS

CS: cleft side, NCS: noncleft side

Statistical Analysis

All plaster models and 3D images were remeasured within a 3-week interval by both examiners. Statistical analyses were performed using the Statistical Package for Social Sciences version 22 (IBM Corp.; Armonk, NY, USA) for Windows. Intraclass correlation coefficients (ICC) were used to determine intra-examiner, inter-examiner agreement for each measurement. ICC has a maximum value of 1 when there is total homogeneity. On the other hand, ICC values above 0.75 and 0.9 are considered as good and excellent, respectively.

RESULTS

The intra-examiner assessment of the plaster model measurements showed that the lecturer was consistent in the repeated measurements (ICC were greater than 0.90 for almost all measurements and had a lower boundary of 0.804), whereas the ICC of the half of the measurements performed by the postgraduate student were greater than 0.75 (Table 3).

The intra-examiner reliability of all the 3D digital measurements of the lecturer was good (ICC greater than 0.75) except for the nasal width. Similarly, the intra-examiner reliability for most of the measurements carried out by the postgraduate student was good. The ICC values of only the philtral width, nasal tip protrusion, noncleft side nostril floor width, and lateral nostril height measurements were below 0.75 (Table 3).

Table 3. Interclass correlation and 95 percent confidence interval for intra-examiner agreement of experienced and inexperienced operator

	Intra-examiner reliability			
	Plaster models		3D images	
	Experienced operator	Inexperienced operator	Experienced operator	Inexperienced operator
Cleft lip gap	0.976 (0.957-0.987)	0.917 (0.850-0.954)	0.997 (0.994-0.998)	0.949 (0.907-0.972)
Philtrum median height	0.929 (0.872-0.961)	0.594 (0.357-0.759)	0.970 (0.946-0.984)	0.882 (0.790-0.935)
Philtrum lateral height (CS)	0.977 (0.958-0.988)	0.891 (0.805-0.940)	0.999 (0.997-0.999)	0.944 (0.898-0.969)
Philtrum lateral height (NCS)	0.955 (0.918-0.976)	0.705 (0.512-0.830)	0.996 (0.993-0.998)	0.783 (0.630-0.877)
Philtral width (NCS)	0.814 (0.680-0.896)	0.466 (0.192-0.672)	0.947 (0.904-0.971)	0.547 (0.294-0.728)
Lateral lip height (CS)	0.957 (0.921-0.977)	0.808 (0.670-0.892)	0.969 (0.943-0.983)	0.866 (0.764-0.925)
Lateral lip height (NCS)	0.927 (0.868-0.960)	0.770 (0.611-0.870)	0.994 (0.988-0.997)	0.915 (0.847-0.953)
Nasal width	0.988 (0.978-0.994)	0.942 (0.894-0.968)	0.509 (0.246-0.702)	0.970 (0.945-0.984)
Nostril floor width (CS)	0.984 (0.970-0.991)	0.935 (0.883-0.965)	0.890 (0.805-0.939)	0.892 (0.808-0.940)
Nostril floor width (NCS)	0.904 (0.829-0.947)	0.574 (0.331-0.746)	0.748 (0.577-0.856)	0.530 (0.272-0.716)
Nasal tip protrusion	0.961 (0.929-0.979)	0.688 (0.488-0.819)	0.995 (0.990-0.997)	0.698 (0.503-0.826)
Nostril height (CS)	0.834 (0.712-0.907)	0.694 (0.497-0.823)	0.997 (0.995-0.998)	0.896 (0.815-0.943)
Nostril height (NCS)	0.946 (0.902-0.971)	0.445 (0.167-0.658)	0.990 (0.982-0.995)	0.914 (0.846-0.953)
Medial nostril height (CS)	0.804 (0.664-0.890)	0.692 (0.495-0.822)	0.966 (0.938-0.982)	0.831 (0.707-0.906)
Medial nostril height (NCS)	0.895 (0.813-0.942)	0.704 (0.512-0.829)	0.929 (0.872-0.961)	0.853 (0.741-0.919)
Lateral nostril height (CS)	0.989 (0.979-0.994)	0.919 (0.854-0.955)	0.987 (0.977-0.993)	0.792 (0.642-0.883)
Lateral nostril height (NCS)	0.920 (0.855-0.956)	0.791 (0.643-0.882)	0.982 (0.966-0.990)	0.691 (0.492-0.821)
Nostril diameter (CS)	0.872 (0.774-0.929)	0.747 (0.575-0.855)	0.998 (0.997-0.999)	0.963 (0.932-0.980)
Nostril diameter (NCS)	0.898 (0.818-0.944)	0.430 (0.149-0.647)	0.996 (0.993-0.998)	0.861 (0.755-0.923)

Table 4. Interclass correlation and 95 percent confidence interval for inter-examiner and inter-method agreement of experienced and inexperienced operator

	Inter-examiner reliability		Inter-method reliability	
	Plaster models	3D images	Experienced operator	Inexperienced operator
Cleft lip gap	0.859 (0.753-0.922)	0.934 (0.880-0.964)	0.961 (0.929-0.979)	0.816 (0.683-0.897)
Philtrum median height	0.648 (0.432-0.794)	0.792 (0.645-0.883)	0.947 (0.904-0.971)	0.576 (0.333-0.748)
Philtrum lateral height (CS)	0.849 (0.736-0.916)	0.903 (0.827-0.947)	0.960 (0.927-0.978)	0.783 (0.631-0.877)
Philtrum lateral height (NCS)	0.760 (0.596-0.864)	0.770 (0.624-0.875)	0.884 (0.795-0.936)	0.653 (0.438-0.797)
Philtral width (NCS)	0.504 (0.239-0.699)	0.388 (0.098-0.616)	0.710 (0.521-0.833)	0.403 (0.117-0.628)
Lateral lip height (CS)	0.772 (0.614-0.871)	0.772 (0.613-0.871)	0.931 (0.875-0.962)	0.646 (0.428-0.792)
Lateral lip height (NCS)	0.824 (0.695-0.901)	0.840 (0.721-0.911)	0.929 (0.872-0.961)	0.691 (0.493-0.821)
Nasal width	0.925 (0.865-0.959)	0.296 (0.005-0.548)	0.270 (0.033-0.528)	0.874 (0.777-0.930)
Nostril floor width (CS)	0.941 (0.893-0.968)	0.901 (0.823-0.945)	0.977 (0.958-0.988)	0.820 (0.690-0.899)
Nostril floor width (NCS)	0.623 (0.397-0.778)	0.382 (0.091-0.612)	0.793 (0.647-0.883)	0.370 (0.078-0.604)
Nasal tip protrusion	0.737 (0.561-0.850)	0.583 (0.342-0.752)	0.790 (0.642-0.881)	0.590 (0.352-0.757)
Nostril height (CS)	0.663 (0.452-0.803)	0.833 (0.710-0.906)	0.841 (0.724-0.912)	0.704 (0.512-0.829)
Nostril height (NCS)	0.783 (0.631-0.877)	0.787 (0.636-0.879)	0.930 (0.873-0.962)	0.680 (0.477-0.815)
Medial nostril height (CS)	0.549 (0.297-0.729)	0.802 (0.660-0.888)	0.722 (0.538-0.840)	0.636 (0.415-0.787)
Medial nostril height (NCS)	0.407 (0.121-0.631)	0.467 (0.189-0.675)	0.753 (0.584-0.859)	0.415 (0.127-0.639)
Lateral nostril height (CS)	0.433 (0.152-0.649)	0.659 (0.447-0.801)	0.954 (0.916-0.975)	0.380 (0.089-0.611)
Lateral nostril height (NCS)	0.353 (0.059-0.591)	0.733 (0.554-0.847)	0.887 (0.800-0.938)	0.245 (0.060-0.508)
Nostril diameter (CS)	0.902 (0.825-0.946)	0.922 (0.859-0.957)	0.982 (0.967-0.990)	0.866 (0.764-0.926)
Nostril diameter (NCS)	0.818 (0.686-0.898)	0.827 (0.700-0.903)	0.806 (0.666-0.891)	0.686 (0.486-0.818)

An inter-examiner agreement was not present for the philtral width, nasal tip protrusion, nostril floor width, and the non-cleft side medial nostril height and cleft-side lateral nostril height measured on both plaster models and 3D digital images. An inter-examiner agreement was identified in more 3D digital measurements compared to those on plaster models (Table 4). Overall, the measurement performed by the lecturer showed a good inter-method agreement (Table 4).

DISCUSSION

Patients with impaired facial appearances such as a cleft lip and palate have a long treatment period, and the follow-ups are frequently difficult to manage; therefore, reliable, user-friendly, and easy-to-achieve documentation methods are necessary (22). Certainly, direct clinical evaluation and anthropometry is the golden standard in documentation (6). However, performing the measurements directly on the face to classify the deformity, to determine the treatment plan, to evaluate the treatment progress, as well as outcomes, is not easy, particularly in infants and children, or patients with mental retardation. Consequently, impression taking has been used more frequently to remodel the facial anatomy. Visually, the plaster models accumulate in the archives of clinicians over years, insomuch that some of the oldest ones have to be trashed. In addition to the storage requirement, fragile cast models are also prone to damage. Nowadays, more and more centers digitize the plaster models and transfer them into software programs to avoid data loss. Additionally, these virtual models allow easier communication between professionals due to the convenience of sharing files (23).

Virtual models may be an advantageous tool in converting the physical archives into digital ones; however, the reliability of the measurements performed on 3D models needs to be evaluated. Fleming et al. (24) compared the reliability of measurements performed on plaster and digital models in their systematic review and concluded that the use of digital models as an alternative to plaster models can be recommended. However, they also added that the reliability is based on various variables. One of the most important factors in the assessment of the performance of any new system, or in other words any invention introduced into a workflow, is the users' experience (21). In addition, after determination of the reliability of measurements and evaluation methods performed by postgraduate students, a lecturer may make up guidelines for the students and integrate courses into the dental educational curriculum. Therefore, the purpose of this study was to determine (1) the more and less reliable measurements/methods and (2) the influence of knowledge and skill on the inter-examiner, intra-examiner, and inter-method reliability of nasolabial measurements on plaster casts and 3D stereophotogrammetric images of casts in infants with UUCLP.

The intra-examiner agreement of all plaster model measurements and all 3D digital measurements (except for the nasal width) performed by the lecturer were good or excellent (ICC equal or greater than 0.75 and 0.9, respectively). For the postgraduate student, most of the digital measurements showed a good reliability, whereas only half of the plaster model measurements showed an ICC above 0.75. The reliability of measurements carried out on plaster models depends on the ability of landmark identification, knowledge about the anatomy, and exact transfer of quantitative data to the computer. Furthermore, the operator has to deal sensitively with the plaster models, to avoid any breakage or deformation of anatomical structures during measurements (25, 26). Similarly, the reliability of measurements on 3D images are bases on a 3D landmark identification, the morphology of the anatomical structure, and image quality. Radeke et al. (21) compared the tooth-width measurements of operators with different levels of experience or even without dentistry background. They concluded that the measurements revealed no statistically significant differences between examiners. However, because the cleft anatomy is much more complicated for an inexperienced examiner, the intra-examiner as well as inter-examiner reliability showed differences between examiners in our study. Overall, another important factor affecting the reliability of measurements in both methods is the examiners experience not only regarding the anatomy of the observed structures, but also in handling of both measurement methods. Othman et al. (27), emphasized that the reproducibility of the identification of landmarks on 3D images by one operator is acceptable, but they concluded that further research of the inter-examiner reproducibility is required. Indeed, the familiarity of the examiner with 3D images and software programs plays a major role in the accuracy and repeatability of the measurements. The familiarity of the experienced examiner with 3D images and also the cleft anatomy may be the reason for the acceptable reliability of measurements.

On 3D facial scans, landmark identification on well-defined borders is easier, and therefore the reproducibility is higher. On the other hand, points located on curving slopes such as the alare point are difficult to determine (20). Accordingly, in our study, we found that the nasal width measurement was not reliable. In addition, it appeared that the experience factor did not matter. The ICC for the philtral width, nostril floor width, and medial nostril height (on NCS) measurements on 3D images done by the student were below 0.75. Anatomical areas, which show individual variations in cleft cases, such as the lateral subnasale inferior (sbnNCS), and areas most affected from the deformity, such as christa philtri (cph’NCS), have to be inspected with attention. The lateral subnasale inferior point, defined as the lowest point of the lateral, internal, and outer contour of the nostril, may be placed on different levels at the vertical plane depending on the shape of the nostril. If the examiner does not have enough experience about the cleft anatomy and the aforementioned anatomical variations, a divergence of measurements may occur (21). The nostril area on the noncleft side in cases with UCLP is also a small area so that validity is more difficult to achieve (28).

The intra-examiner reliability of the measurements performed by the lecturer on virtual models was higher than on the plaster models. Furthermore, the inter-examiner reliability was also higher for 3D images. The caliper manipulation requires experience and training. Sforza et al. (17) mentioned that the tip of the caliper may contact the plaster and afterwards landmarks cancelled the dot, inducing impression in the values of measurements. If measurements are performed on plaster models, the caliper has to be manipulated sensitively so that no anatomical structure is deformed. On the other hand, cancelling the dot on 3D images is not possible. In addition, 3D images enhance accurate measurements by enabling the researcher to rotate and to zoom into the image (29-31). In other words, software programs used in the 3D imaging technology may facilitate the manipulation skill of the operator and may be user-friendly, especially for inexperienced operators. Thus, 3D imaging may be used for training of postgraduate students.

CONCLUSION

- Measurements of curving slopes such as the nasal width, of small dimensions such as nostril floor width, and deformity-affected anatomic parts such as philtrum width presented low reliability.
- The reliability of measurements performed by the experienced examiner was high for both methods, whereas the intra-examiner reliability of some measurements performed by the inexperienced examiner showed low ICC.
- The reliability of a number of 3D digital measurements performed by the inexperienced examiner was found to be higher than plaster model measurements. Therefore, it may be recommended to use 3D digital images of infants with CLP for nasolabial measurements, especially if performed by inexperienced users.

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethics Committee of Yeditepe University (No-58/490).

Informed Consent: Written informed consent was obtained from the patients who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - R.B.N.Y.; Design - R.B.N.Y, D.G., H.I.C.; Data Collection and/or Processing - R.B.N.Y., M.A.; Analysis and/or Interpretation -R.B.N.Y, M.A.; Literature Search - R.B.N.Y.; Writing Manuscript - R.B.N.Y.; Critical Review - D.G., H.I.C.

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ORIGINAL ARTICLE

Comparison of Two Retention Appliances with Respect to Clinical Effectiveness

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ABSTRACT

Objective: The aim of this study was to compare the clinical effectiveness of Essix and Hawley retainers during the retention period.

Methods: A total of 30 subjects whose fixed orthodontic treatment results were evaluated according to the American Board of Orthodontics Phase III Objective Grading system were included in this study. After the removal of orthodontic attachments, the study participants were equally divided into two retention protocols: upper-lower Essix and upper-lower Hawley. The subjects were instructed to wear their retainers full time for 6 months, except during meals, and during nights only for 6 months. The clinical effectiveness of the retainers was evaluated according to the overjet, overbite, maxillary, and mandibular intercanine widths, intermolar widths, arch lengths, irregularity indexes, and lateral cephalometric measurements. All dental model and lateral cephalometric measurements were performed by the same investigator during three periods: pre-treatment, post-treatment, and post-retention.

Results: The overjet, overbite, maxillary, and mandibular intercanine widths; intermolar widths; and arch lengths and lateral cephalometric measurements were not statistically significantly different between the groups and identified time periods. Although the maxillary and mandibular irregularity indexes increased from the post-treatment to post-retention periods, the difference was not statistically significant. Pre-treatment, post-treatment, and post-retention lateral cephalometric measurements were not statistically significantly different between and within the groups.

Conclusion: According to the results of a repeated-measures analysis of variance with two factors, and although an increase was found in the maxillary and mandibular irregularity indexes, the clinical effectiveness of Essix and Hawley retainers was found to be similar during the retention period.

Keywords: Orthodontic treatment, retention, Essix, Hawley, relapse

INTRODUCTION

A long-term stability of the treatment results obtained at the end of active orthodontic treatment is one of the success indicators of orthodontic treatment (1). Stability can only be achieved when the forces derived from the gingival and periodontal tissues, orofacial soft tissues, occlusion, and post-treatment facial growth and development are balanced (2). At this point, it is very important to determine the necessities of the retention phase and the factors that cause a relapse in terms of stability (3).

Relapse is defined as the return of dental and skeletal results, obtained aesthetically and functionally, to the pre-treatment status at the end of the active orthodontic treatment (4). The major requirement to prevent a relapse is time to reorganize the gingival and periodontal tissues and stabilize the altered morphological structure and function and growth-development dependent changes (4, 5). For this reason, retainers are used to prevent a relapse after active orthodontic treatment (6).

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Retainers used in the retention phase are divided into two groups; that is, removable and fixed (4, 7). While the removable retainers are classified as Essix, Hawley, and Positioner, the fixed retainers are classified as polyethylene and fiber-reinforced resin composites; currently, the most preferred multistranded stainless steel wires are those recommended by Zachrisson in 1977 (4, 8-10).

Although there is as yet no consensus as to which retainer is the most effective or how long it needs to be worn, currently, the Essix and Hawley retainers are frequently used in orthodontic practice (6, 11). It has been observed that the comparative studies of Essix and Hawley retainers have evaluated the periodontal health and compliance (12), cost-effectiveness (13), the number of occlusal contacts (14), survival time (15), and clinical effectiveness (16, 17). Some of the studies that evaluated the clinical effectiveness, such as the overjet, overbite, intercanine, and intermolar widths, arch length, and irregularity index, have indicated no significant difference between the two retainers (16, 18, 19). It has also been stated that there is not enough evidence to declare which retainer is more effective (5, 6). In addition, Sheridan et al. (20) reported the retaining component of Hawley retainers is insufficient for anterior teeth due to an inadequate griping with a point contact on the vestibular arch on the labial surface and a mass of acrylic approximating the cervix.

The aim of the present study was to compare the clinical effectiveness of Essix and Hawley retainers, which are frequently used in orthodontic practice, during 1 year of the retention period. The null hypothesis was that the clinical effectiveness of Essix and Hawley retainers does not change with the appliance used.

METHODS

A total of 30 patients who underwent fixed orthodontic treatment with the straight-wire technique using 0.018-inch slot Roth brackets were enrolled in this study. The inclusion criteria were a Class I skeletal pattern, no previous orthodontic treatment, treatment with fixed orthodontic appliances, achievement of optimum occlusion, and treatment that was compatible with the use of a retainer and long-term follow-up, as well as good oral hygiene. The exclusion criteria were the necessity of using a bonded retainer and placement of a contemporary tooth in the retainer due to congenital tooth deficiency, cleft lip and plate, and orthognathic surgery.

This study protocol was approved by Yüzüncü Yıl University School of Medicine, Research Ethics Committee (B.30.2.YYU.0.01.00.00/125). Before debonding, the treatment outcomes were evaluated according to the objective grading system of the American Board of Orthodontics Phase III clinical examination. Informed consent was received from the patients, or their parents, who were to be included in this study after detailed information was given about the study.

After mechanical removal of the fixed orthodontic appliances with a debonding plier (Dentaurum, Pforzheim, Germany), residual adhesive on the tooth surfaces was cleaned with a 12-bladed tungsten carbide bur (Axis Dental, Irving, Tex) at low speed under water-cooling. Then, tooth surfaces were polished with fluoride-free pumice (Imıpomza, Imıcryl, Konya, Turkey), and alginate impressions were poured to obtain dental models of the upper and lower jaws.

The study participants were divided into two groups, depending on the type of retainers. Fifteen patients (8 extraction and 7 non-extraction) had an upper-lower Essix retainer (Dentsply Raintree Essix, New Orleans, Louisiana, USA), and 15 (7 extraction and 8 non-extraction) received an upper-lower Hawley retainer. Each group consisted of both extraction and non-extraction cases. The retainer type for each patient was randomly allocated by the technician.

Essix retainers were thermoformed from 0.040-inch sheets according to the manufacturer's instructions. The retainer that covered up all occlusal surfaces, including the most distal tooth, was trimmed to provide 1–2 mm buccal and 3–4 mm lingual extensions that pass away from the edge of the gingiva (Figure 1a). A Hawley retainer was constructed from Adams clasps on the first molars, canine-canine teeth labial bows, and acrylic base plates. Adams clasps and labial bows were made from 0.7 mm stainless steel wire (Figure 1b). The patients were instructed to wear their retainers full-time for 6 months except during meals, and then 6 months at night only. 73

The retention characteristics of Essix and Hawley retainers were compared from lateral cephalometric film, and dental models

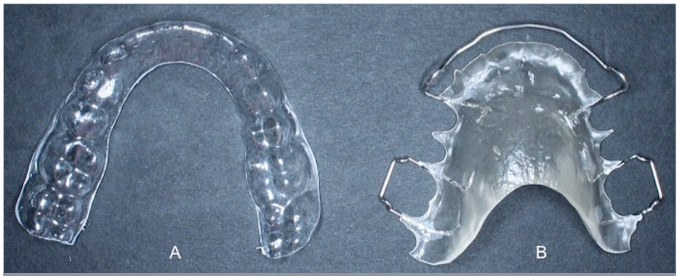

Figure 1. Essix (A) and Hawley (B) retainers used in this study

Table 1. Lateral cephalometric measurements

	Angular and Linear Measurements
1-NA (mm)	Distance between the most labial point of maxillary incisor and the NA line
1-NA (⁰)	Angle formed between the long axis of maxillary incisor and the NA line
1-SN (⁰)	Angle formed by the extension of the long axis of maxillary incisor to the SN plane
1-NB (mm)	Distance between the most labial point of mandibular incisor and the NB line
1-NB (⁰)	Angle formed between the long axis of ma dibular incisor and the NB line
IMPA (⁰)	Angle formed by the extension of long axis of mandibular incisor to the mandibular plane
U1L1 (⁰)	Angle formed by the extensions of long axes of maxillary incisors to the mandibular incisors
SN/GoGn (°)	Angle formed between the mandibular plane (GoGn) and the SN plane

from pre-treatment, post-treatment, and post-retention phases. All cephalometric films were taken for each subject in centric occlusion with a relaxed and closed lip position using the same Sirona Orthophos XG (Bensheim, Germany) imaging system. Additionally, each subject's head was stabilized by positioning the ear rods of the machine in the external auditory meatus with the Frankfurt horizontal plane parallel to the horizontal and sagittal plane at right angles to the path of the X-ray (21). From the cephalometric analyses made using the NemoCeph NX 2005 (Nemotec, Madrid, Spain) program, dental and skeletal changes were evaluated. The angular and linear measurements used in this study are shown in Table 1.

In addition, the overjet, overbite, maxillary and mandibular intercanine widths and intermolar widths, arch lengths, and Little's irregularity indexes were measured on the dental models (Figure 2) (22, 23). The irregularity index defined by Dr. Little was calculated using the linear measurement of displacements in the anatomical contact points of maxillary and mandibular five anterior teeth, parallel to the occlusal plane (23). A digital caliper (Mitutoyo Corp., Kanagawa, Japan) with a 0.01 mm sensitivity was used for the measurements. All cephalometric analyses and dental model measurements were performed by the same investigator (MT).

Statistical Analysis

To assess the measurement precision, investigator reliability and intra-examiner agreement were calculated and found to be high (intraclass correlation coefficient=0.890, $p<0.001$). In addition, the random measurement error was calculated with Dahlberg's formula, and it was observed that, for these linear and angular measurements, the error values ranged from 0.056 to 0.042 (mm) and 0.29° to 0.14°, respectively.

In previous studies, it was observed that the standard deviation (s) ranged from 0.4 to 4. For this reason, it was considered as 2 in our study. In addition, the effect size (d) was assumed to be 1, and the Z value was 1.96 for a 0.05 Type I error rate. Then, the sample size was found to be 15.13 (@15) by using the equation of sample size calculation ($n=Z^2 s^2/d^2$).

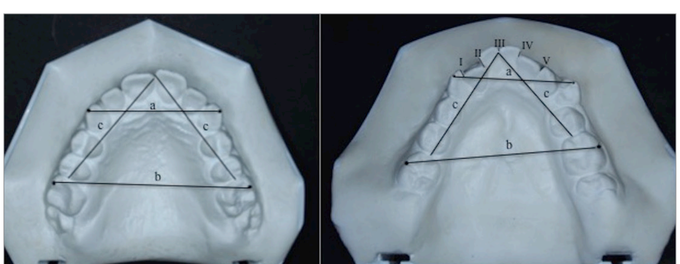

Figure 2. Dental model measurements. Irregularity index (I+II+III+IV+V); a, intercanine width; b, intermolar width; c, arch length

Descriptive statistics for the continuous variables were presented as the mean, standard deviation, and minimum and maximum values, while counts and percentages were used for categorical variables. A repeated measures analysis of variance with two factors (time was the dependent factor, treatment was the independent factor) was used for comparing the groups and periods in terms of continuous variables. To identify the different groups, a Duncan multiple comparison test was calculated. The statistically significant level was considered to be 5%, and the Statistical Package for Social Sciences (SPSS Inc.; Chicago, IL, USA) version 13.0 statistical program was used for all statistical computations.

RESULTS

In the Essix and Hawley groups, the mean age of patients was 17.53±3.89 and 16.54±2.24 years, respectively, and the mean treatment times were 2.90±0.62 and 3.11±0.53 years, respectively. No statistically significant difference was found among the groups in the number, mean age, and mean treatment times of patients (Table 2).

Pre-treatment, post-treatment, and post-retention maxillary and mandibular dental model measurements in the Essix and Hawley groups are shown in Table 3. There was no statistically significant difference between the groups and identified time periods in terms of the overjet, overbite, maxillary and mandibular intercanine widths, intermolar widths and arch lengths. In addition, although the maxillary and mandibular irregularity indexes increased from the post-treatment to the post-retention phase, the difference was not statistically significant.

Pre-treatment, post-treatment, and post-retention lateral cephalometric measurements for the Essix and Hawley groups are presented in Table 4. The lateral cephalometric measurements were not statistically significant between the groups and identified time periods.

DISCUSSION

Studies in the literature have recorded that there is no uniform retainer type recognized for a long-term stability, and the retainers and their wearing times showed variability (24, 25). It has

Table 2. Descriptive statistics

		Number of Patients (n)					
		Extraction	Non-extraction	Mean±SD	Min.	Max.	p
Mean Age	Essix	8	7	17.53±3.89	11.16	23.5	0.402
	Hawley	7	8	16.54±2.24	13.00	19.00	
	Total	15	15	17.03±3.16	11.16	23.5	
Treatment Duration	Essix	8	7	2.90±0.62	2.00	3.75	0.306
	Hawley	7	8	3.11±0.53	1.91	4.00	
	Total	15	15	3.01±0.58	1.91	4.00	

Table 3. Pre-treatment, post-treatment, and post-retention maxillary and mandibular dental model measurements

			Essix (Mean±SD)	Hawley (Mean±SD)	p
	Overjet	Pre-treatment	2.93±2.16a	2.58±1.59a	0.620
		Post-treatment	2.26±0.78a	2.03±0.69a	0.399
		Post-retention	2.37±0.62a	2.33±0.72a	0.850
		p	0.347	0.414	
	Overbite	Pre-treatment	3.16±2.29a	3.30±2.33a	0.877
		Post-treatment	2.27±0.88a	2.51±0.92a	0.485
		Post-retention	2.70±0.87a	2.70±1.24a	0.996
		p	0.256	0.409	
Maxilla	Irregularity Index	Pre-treatment	7.92±4.09a	7.60±3.67a	0.827
		Post-treatment	0.76±0.47b	0.87±0.88b	0.647
		Post-retention	1.23±0.70b	1.56±1.07b	0.322
		p	0.001	0.001	
	Intercanine Width	Pre-treatment	33.84±2.51a	33.84±2.21a	0.997
		Post-treatment	34.21±2.20a	33.98±1.85a	0.764
		Post-retention	34.60±2.37a	34.15±1.71a	0.566
		p	0.667	0.916	
	Intermolar Width	Pre-treatment	49.19±4.71a	49.89±4.19a	0.671
		Post-treatment	48.10±2.78a	48.46±3.27a	0.749
		Post-retention	49.12±2.68a	48.74±3.99a	0.756
		p	0.623	0.582	
	Arch Length	Pre-treatment	66.11±8.19a	66.34±5.63a	0.931
		Post-treatment	62.29±6.45a	63.50±7.09a	0.627
		Post-retention	62.98±5.75a	64.05±6.42a	0.634
		p	0.255	0.468	
Mandibula	Irregularity Index	Pre-treatment	5.68±3.76a	4.50±2.44a	0.322
		Post-treatment	0.83±0.57b	0.98±0.63b	0.484
		Post-retention	1.55±0.97b	1.71±1.15b	0.682
		p	0.001	0.001	
	Intercanine Width	Pre-treatment	25.60±2.50a	26.37±2.31a	0.389
		Post-treatment	25.77±2.05a	26.07±1.58a	0.664
		Post-retention	25.43±2.12a	25.67±1.42a	0.730
		p	0.912	0.593	
	Intermolar Width	Pre-treatment	48.81±2.73a	49.49±4.35a	0.606
		Post-treatment	48.05±1.70a	48.42±3.10a	0.687
		Post-retention	49.02±1.67a	49.34±4.58a	0.794
		p	0.394	0.750	
	Arch Length	Pre-treatment	55.32±5.19a	55.77±5.01a	0.199
		Post-treatment	54.20±5.04a	56.26±5.06a	0.323
		Post-retention	54.18±4.91a	56.06±5.99a	0.292
		p	0.809	0.380	

* Different lowercase letters represent statistically significant differences among the groups

also been stated that relapse occurs independently from the retainer used; therefore, factors such as cost-effectiveness, patient comfort and satisfaction, settling, clinical effectiveness, ease of production, and survival time may be more important in the retainer selection (5, 8). The aim of this study was to compare the clinical effectiveness of the Essix and Hawley retainers that are frequently used in orthodontic practice (5, 16, 17).

There are also conflicting opinions about the wearing times of the retainers. Among these, Ramazanzadeh et al. (11) concluded that, during the 8 months of a retention period for a better incisor alignment in the lower jaw, the retention protocols of 4 months full-time followed by night-only wear is better than 1 week full-time followed by night-only wear. However, Shawesh et al. (26) expressed that, in terms of the incisor irregularity index

Table 4. Pre-treatment, post-treatment, and post-retention lateral cephalometric measurements

			Essix (Mean±SD)	Hawley (Mean±SD)	p
Lateral Cephalometric Measurements	SNA	Pre-treatment	80.77±3.30a	79.31±3.42a	0.244
		Post-treatment	80.24±2.85a	79.26±3.08a	0.376
		Post-retention	80.31±2.94a	79.09±3.30a	0.259
		p	0.862	0.768	
	SNB	Pre-treatment	78.49±3.56a	76.34±3.78a	0.121
		Post-treatment	77.94±3.00a	76.24±3.36a	0.153
		Post-retention	77.87±3.06a	76.50±3.50a	0.345
		p	0.765	0.981	
	ANB	Pre-treatment	2.26±1.97a	2.98±2.02a	0.330
		Post-treatment	2.21±1.91a	2.85±1.88a	0.366
		Post-retention	2.22±1.84a	3.16±1.52a	0.142
		p	0.998	0.904	
	SN/GoGn	Pre-treatment	32.09±5.46a	31.19±4.65a	0.635
		Post-treatment	32.29±5.02a	32.05±5.01a	0.895
		Post-retention	32.33±4.73a	31.65±5.02a	0.705
		p	0.989	0.898	
	1-NA (mm)	Pre-treatment	5.02±2.55a	3.74±1.66a	0.120
		Post-treatment	3.10±2.03b	2.88±1.80a	0.756
		Post-retention	3.19±2.10b	2.91±1.68a	0.699
		p	0.031	0.336	
	1-NA (0)	Pre-treatment	22.76±7.56a	21.34±6.40a	0.586
		Post-treatment	19.67±5.44a	19.14±5.35a	0.790
		Post-retention	19.49±5.98a	19.23±5.43a	0.900
		p	0.278	0.526	
1-SN (0)	Pre-treatment	103.04±7.22a	101.54±5.42a	0.532	
		Post-treatment	99.89±6.74a	98.96±6.67a	0.706
		Post-retention	100.28±6.79a	98.78±6.90a	0.553
		p	0.383	0.445	
1-NB (mm)	Pre-treatment	3.64±1.72a	4.01±1.26a	0.505	
		Post-treatment	3.21±1.53a	3.64±0.92a	0.376
		Post-retention	3.20±1.52a	3.66±0.90a	0.335
		p	0.679	0.562	
1-NB (0)	Pre-treatment	41.36±5.54a	25.72±6.85a	0.465	
		Post-treatment	23.69±5.77a	25.39±4.17a	0.370
		Post-retention	24.17±6.48a	25.26±4.74a	0.606
		p	0.465	0.973	
IMPA (0)	Pre-treatment	90.59±7.91a	96.09±6.55a	0.050	
		Post-treatment	91.51±7.71a	95.64±5.70a	0.111
		Post-retention	91.92±7.74a	95.85±5.94a	0.134
		p	0.886	0.981	

* Different lowercase letters represent statistically significant differences among the groups

and incisor crowding, no significant difference was found between the retention protocols for night-time wear only for 1 year or 6 months full-time followed by 6 months of night-only wear. In addition, Proffit (4) stated that the retention period should be continued for at least 12 months, and by shortening the wearing time to 4–6 months after the post-treatment, it can be used only at night. With this information, in the present study, we also preferred a 1-year retention period with 6 months full-time and then 6 months at night only.

Based on the current studies, Meade and Millett (27) stated that orthodontists commonly recommend an Essix retainer sheet thicknesses of 0.75 mm and 1 mm. In addition, Zhu et al. (28) found no significant difference between the Essix retainers of 0.75 mm and 1 mm thicknesses in terms of survival time, failure rate, and comfort. For this reason, the use of an Essix retainer sheet thickness of 1 mm (0.40 inch) was preferred in our study.

Although there is insufficient evidence to determine which retainer is more effective in studies comparing Essix and Hawley retainers (5, 6), the overjet, overbite, maxillary and mandibular intercanine widths, intermolar widths, arch lengths, and irregularity indexes were evaluated with regard to clinical effectiveness. Lindauer and Shoff (29) compared the overjet, overbite and Little's irregularity index over 6 months of the retention period. They found no statistically significant difference in evaluated parameters between the groups, although increased crowding was observed in the Hawley group for both dental arches. In two separate studies that evaluated the intercanine and intermolar widths, arch length, and irregularity indexes, Barlin et al. (30) found no statistically significant difference between the groups in the 2nd, 6th, and 12th month of the retention period. However, Ramazanzadeh et al. (11) concluded that the upper arch length and the upper-lower irregularity indexes were significantly lower in the Essix group during the 8th month of the retention period. In this study, we also found no significant difference in the overjet, overbite, intercanine and intermolar widths, and irregularity index between the Essix and Hawley groups during 1 year of the retention period.

Rowland et al. (16) compared the clinical effectiveness of Essix and Hawley retainers after the extraction or non-extraction fixed orthodontic treatment for 6 months. In the extraction group, Essix and Hawley retainers were applied to 68 and 66 of these subjects, respectively; in the non-extraction group, Essix and Hawley retainers were applied to 133 and 130 of these subjects, respectively. The authors observed no significant difference in the rotation and intercanine and intermolar widths between the groups, which was consistent with our results. However, in terms of Little's irregularity index, the Essix retainer was found to be more effective in both maxillary and mandibular labial segments than the Hawley retainer, especially in the lower arch. Similarly, Babacan et al. (31) compared the efficiency of Essix and Hawley retainers on mandibular anterior crowding in 40 non-extraction patients, using an irregularity index. At 1 year and 7 months after the treatment, a significant increase in irregularity indexes was found in both groups, but this increase was less in the Essix group. However, it was observed that there was no information about cephalometric measurements and arch lengths in these studies.

Demir et al. (17) compared the clinical effectiveness of Essix and Hawley retainers for a 1-year retention period and after a 2-year follow-up period in 42 patients who had non-extraction fixed orthodontic treatment. Consistent with our results, in all time periods, the authors found no statistically significant difference in intercanine widths and maxillary arch lengths in both groups and mandibular arch lengths in the Essix group. In the Hawley group, although the difference between the after treatment and 2-year follow-up period was statistically significant for mandibular arch length, the difference between other time periods was not significant. In terms of Little's irregularity index, the differences between all time periods in the Hawley group and between the after treatment and 1-year retention period in the Essix group were statistically significant. As a result, they concluded that the arch lengths that increased during orthodontic treatment tended to return to their pre-treatment value after the retention period, but this was significant only in the Hawley group. With Little's irregularity index, although the Essix retainer was more efficient in the mandibular anterior region during the retention period, the two retainers showed similar properties after a 2-year follow-up period. In addition, it was observed that there were slight changes in the cephalometric measurements between the two groups, and the upper-lower incisor inclinations, incisor positions, and arch lengths increased. We suggest that the upper-lower incisor inclinations, incisor positions, and arch lengths did not increase in our study in which extraction and non-extraction treatments were included and may be the reason for these different results.

Consistent with our results, Gómez-Gómez et al. (32) evaluated dental stability from the lateral cephalometric radiographs and found no statistically significant difference between the Essix and Hawley retainers during 6 months of the retention phase. However, in this study, they did not give any information about the pre-treatment cephalometric measurements.

The arch lengths gradually decreased due to the physiological migration of teeth, and anterior crowding may have occurred even in the case of third molar deficiency, especially in the lower arch (33). Additionally, the preservation of pre-treatment arch forms is very important to obtain the best long-term stability since the increased intercanine and intermolar widths during treatment tended to decrease after the retention period (34). For this reason, it has been stated that even if a good and well-functioning occlusion is obtained with orthodontic treatment, relapse may be seen after years of treatment, and patients should be informed of this.

A small sample size, no post-retention follow-up periods, and the investigation of only two retention protocols were the main limitations of this study. For this reason, conducting new studies with larger sample sizes, longer follow-up periods, and different retainer types used after extraction and non-extraction treatment is recommended.

CONCLUSION

- The differences between the Essix and Hawley retainers in the overjet, overbite, maxillary and mandibular intercanine widths, intermolar widths, and arch lengths were not statistically significant.
- Although the maxillary and mandibular irregularity indexes increased from the post-treatment to the post-retention phase, the difference was not statistically significant.
- In terms of pre-treatment, post-treatment, and post-retention lateral cephalometric measurements, no statistically significant difference was found between and within the groups.

Ethics Committee Approval EEthics committee approval was received for this study from the Ethics Committee of Van Yüzüncü Yıl University School of Medicine (B.30.2.YYU.0.01.00.00/125).

Informed Consent: Written informed consent was obtained from the patients who participated in this study.

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ORIGINAL ARTICLE

Effect of Sagittal Dentoskeletal Discrepancies on the Vermilion Height and Lip Area

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ABSTRACT

Objective: A frontal evaluation of the lips could provide important information during a routine clinical evaluation of facial aesthetics. There is a lack of ample evidence in the literature regarding variations in the vermilion height and lip area in various sagittal discrepancies when assessing facial aesthetics. The aim of this cross-sectional study was to evaluate and compare the vermilion height and lip area in dentoskeletal Class I, Class II, and Class III malocclusions.

Methods: Subjects included female patients divided into four groups (Angle's Class I bimaxillary proclination [Class I BMP], Class II Division I [Class II Div 1], Class III and Class I normal [Class I N]) with 36 samples each. Standardized frontal facial photographs were taken at rest and during a posed smile. Thirty-five landmarks on the upper and lower lips were identified for measurements of the vermilion height and lip area. A one-way analysis of variance was used to identify overall differences, and the post-hoc Bonferroni test was applied for multiple comparisons.

Results: Class III showed a significantly smaller upper-lip area and significantly higher ratios of the upper-to-lower lip vermilion height/area. The ratios displayed an increasing trend from the midline to the corners of the mouth. Class I BMP and Class II Div 1 had significantly larger upper and lower-lip areas.

Conclusion: Morphology of the lips is significantly correlated with underlying anteroposterior dentoskeletal discrepancies. During a clinical examination, a critical frontal evaluation of the lips is important as it is apparently indicative of the underlying sagittal discrepancy, especially in skeletal Class III malocclusions.

Keywords: Sagittal discrepancy, lip area, lip proportion, photographic analysis, vermilion height

INTRODUCTION

The face plays a key role in communication and interaction, involving all social relationships among human beings (1). Facial aesthetics is not only one of the most important motives for patients seeking orthodontic treatment, but also a vital objective for the orthodontist (2). The lips and teeth are considered fundamental factors in facial appearance (3). Majority of studies have evaluated facial aesthetics in profile view (3, 4). However, patients tend to judge facial appearances by assessing their frontal view in the mirror (5). Hence studies investigating lip aesthetics in the frontal view are warranted.

More prominent, larger-than-average-size lips have been reported in attractive adolescents (6). The vertical thickness of the lips has been reported to be the most important component of a pleasant smile by both orthodontists and lay persons (7). They concluded that while the vertical thickness of the lower lip was an aesthetic determinant for laypersons, the vertical thickness of the upper lip was an aesthetic determinant for both laypersons and orthodontists. The last two decades of the 20th century showed a trend toward fuller lips among Caucasian female models, closer to the African-Americans (8). Obviously, the vertical lip thickness is an important factor in the determination of attractiveness of the mouth (9).

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The position of the lips is closely related to the teeth and alveolar processes (8). A previous study has reported the upper lip to be correlated positively with the position of maxillary incisors; the more protrusive the incisors, the fuller the upper lip (7). The orthodontic retraction of anterior teeth following four premolar extractions has been shown to significantly decrease the vermilion height and lip area in bimaxillary protrusive patients (5). This obviously implies that the morphology of lips in frontal view is affected by the underlying hard tissue anteroposterior discrepancies. Unfortunately, there is a lack of ample evidence in the literature regarding variations in the vermilion height and lip area in various sagittal discrepancies while assessing facial aesthetics. How do anteroposterior dentoskeletal discrepancies like Class I, Class II, and Class III affect frontal lip morphology? This lacuna in current knowledge has not been addressed so far. Hence, the aim of the present study was to evaluate the lip morphological characteristics in dentoskeletal Class I, Class II, and Class III malocclusions in a population of Dravidian ethnic origin.

METHODS

Approval for the study was obtained from the Institutional Ethics Committee (IEC no: 45/2014/DCC). Subjects were chosen from patients reporting to the Department of Orthodontics and comprised of adult females of Dravidian ethnicity. They were divided into four groups based on the following criteria: Class I BMP—*Angle's Class I malocclusion with bimaxillary proclination*: an ANB angle of 1°–3°, the Wits appraisal 0 to −3 mm, an interincisal angle less than 125^0, Angle's Class I molar relationship, profile showing circumoral convexity with both the lips positioned beyond Ricketts aesthetic plane (10); Class II Div 1—*Angle's Class II Division 1 malocclusion*: an angle ANB >4°, the Wits appraisal greater than −1 mm, an overjet more than 5 mm, Angle's Class II molar relationship, clinically retrognathic, Class II profile (10); Class III—*Angle's Class III malocclusion*: an ANB angle lesser than 1°, the Wits appraisal less ≤−4 mm, Angle's Class III molar relationship, clinically prognathic Class III profile (10); Class I N—*Angle's Class I normal occlusion*: An angle ANB of 1°–3°, the Wits appraisal 0 to −3 mm, an interincisal angle of 130^0–135^0, Angle's Class I molar relationship, clinically orthognathic Class I profile (10). Patients with previous orthodontic treatment, facial asymmetries, or craniofacial anomalies, short upper lip, severe crowding, spacing, incisor displacements, subdivisions (unilateral), transverse discrepancies, impacted tooth, and partial anodontia were excluded from the study. For a minimum difference of 2 mm and a standard deviation of 3, (11) the sample size was deemed to be 36 in each group for obtaining a meaningful significance.

Informed written consent from the parents and the patients was obtained. A review of the literature showed that significant sexual dimorphism exists in the lip morphology (12-14). Female lips are reported to thicken till the age of 14 years, after which they remain the same (15, 16). Therefore, only female subjects aged 18–25 years (mean age±standard deviation: 20.6±2.1 years for Class I BMP; 19.5±1.8 years for Class II Div 1; 21.3±3.2 years for Class III; and 20.1±1.2 years for Class I N) were included.

The frontal photographs were taken at rest and during a posed smile in a normal standing posture with the head fixed by ear rods, with a distance of 1.5 m between the camera lens (SONY DSC-HX400V) and the subject. All photographs were taken by zooming the lens to 10x magnification. The subjects were not allowed to wear any facial cosmetics/make-up. The midsagittal plane of the head was aligned with the center of the camera lens using a tripod stand. To obtain the rest position, subjects were made to stand straight in front of the camera, keeping the ala tragus line parallel to the floor. A custom-made head-holding device with a stand was constructed for this purpose.

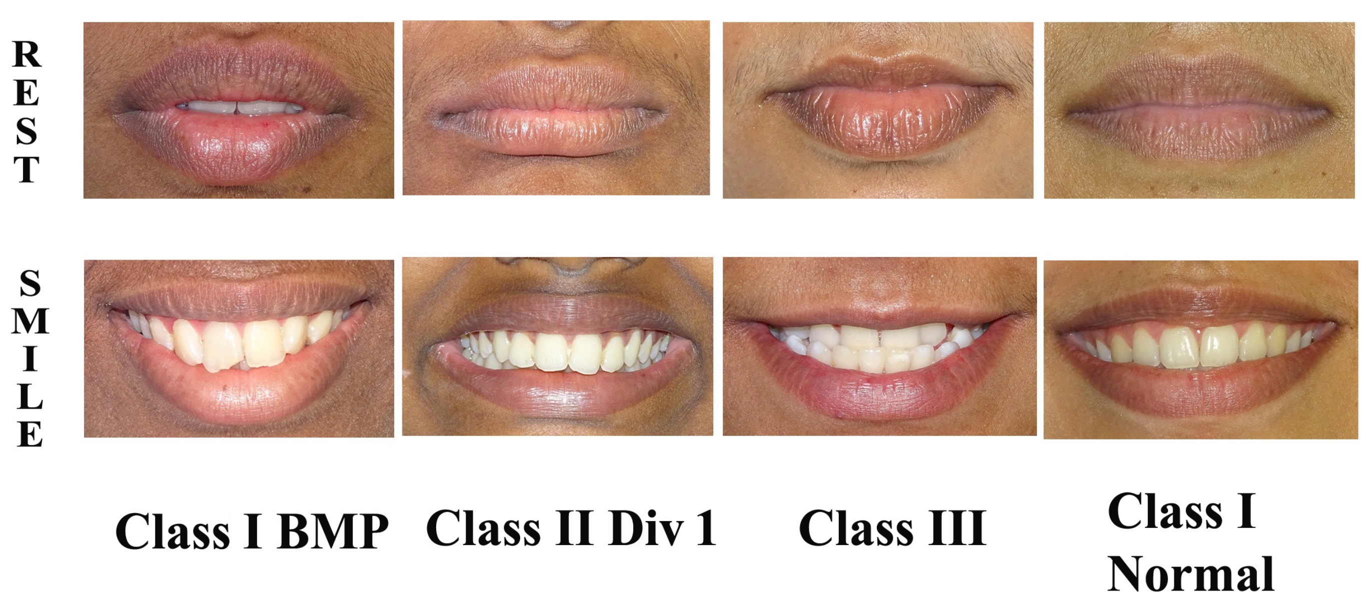

Figure 1. Representative photographs of the lips at rest and during smile

While being photographed, the subjects were asked to keep their teeth slightly apart, and the perioral soft tissues and mandibular posture unstrained at rest. Subjects were asked to say "Mississippi" and then keep the lips in that position. Each subject was coached and asked to achieve the same lip position at least twice in succession before a photograph was taken. To achieve the smiling position, subjects were asked to fully smile and say "cheese" (11), and reproduce the same smile at least twice successively. The subjects easily attained a reproducible maximum smile, and photographs were taken in this position (Figure 1).

All frontal photographs (size 14.81W×9.87H inches and resolution 350 pixels/inch) were copied to the Adobe Photoshop CS3 Extended (version 10.0, Adobe systems 1990), and the lip outlines were drawn and lips shaded. After drawing the vertical and horizontal lines, 35 landmarks were marked as shown in Figure 2. For this purpose, an *X*-axis was drawn parallel to the line connecting the right and left irises through the subnasale point (Sn), whereas the *Y*-axis was drawn perpendicular to the *X*-axis through the Sn point. Two vertical lines were then drawn through the right and left superior vermilion points (9, 11). Both the right and left sides were divided into three equal parts from the superior vermilion point of the lip to the corners of the mouth (6, 14). Four more vertical lines were drawn through landmarks numbered 7, 8, 12, and 13. The landmarks numbered 6–14 and 15–21 were allocated for the upper lip, and 22–28 and 29–35 were allocated for the lower lip. The vermilion height (7–15, 8–16, 9–17, 10–18, 11–19, 12–20, 13–21, 22–29, 23–30, 24–31, 25–32, 26–33, 27–34, and 28–35) and the lip area of both lips was measured using Adobe Photoshop CS3 Extended (version 10.0). Details about the landmarks have been reported earlier (5, 11). To compare the facial size, the distance between the right and left irises of the patient and the control groups were measured. Post-hoc Bonferroni tests confirmed that there were no significant differences in facial size among the four groups. There were no significant variations in the age range either among the groups.

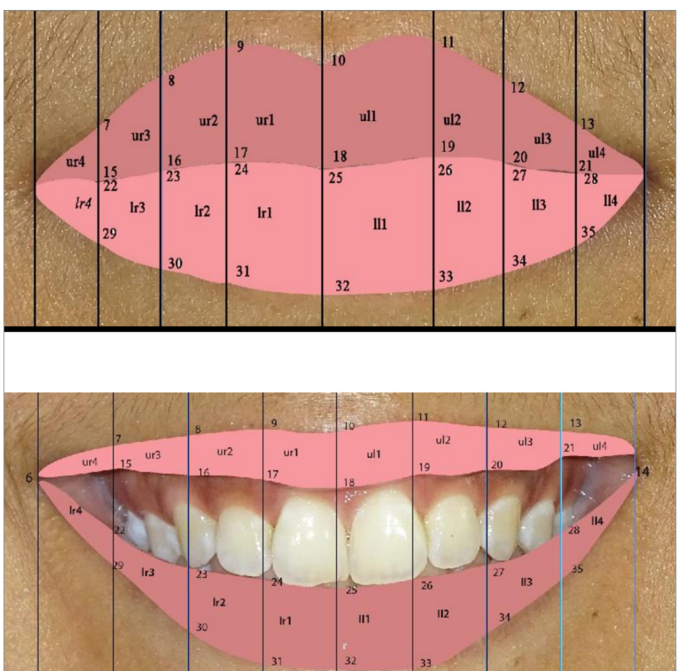

Figure 2. Lips at rest and during smile with landmarks

Statistical analysis: All the data were statistically evaluated with the SPSS software (SPSS Inc. Released 2009. PASW statistics for Windows, Version 18, Chicago, IL). The normality of the data was tested using the Koglomorov–Smirnov test. All the variables followed normal distribution. One-way analysis of variance (ANOVA) was used to identify overall differences in mean values of vertical vermilion ratios and lip-area ratios in the four groups. The level of significance was set at $p<0.05$. When differences between groups were found to be significant, the post-hoc Bonferroni test for multiple comparisons was applied. To test intra-observer reliability, ten photographs of each sample were traced and digitized on two separate occasions, three weeks apart. All intraclass correlation coefficients for the vermilion height and lip-area measurements were greater than or equal to 0.88, signifying a negligible error.

RESULTS

Table 1 shows the mean and standard deviation of the upper and lower total lip area with ANOVA, and Table 2 depicts multiple comparisons of the above among the four groups at rest and during smile. The upper lip total area in Class III was found to be lesser by 11cm^2 than the Class I BMP, by 9cm^2 than Class II Div 1, and by 5cm^2 than Class I N group. These differences were found to be highly significant ($p<0.001$). Similar highly significant differences were also apparent during smile.

A comparison of the upper and lower segment vermilion heights at rest and during smile is given in Figure 3. This graphic representation shows a consistent decrease in the vermilion height of the upper lip in Class III malocclusions. This is obvious across all segments of the upper lip during rest as well as smile.

The Class I BMP and Class II Div 1 groups displayed significantly higher values for both upper and lower total lip areas when com-

Table 1. Mean and standard deviation values for upper and lower total lip areas at rest and during smile with analysis of variance (ANOVA)

					ANOVA	
	Class I BMP (cm²)	Class II Div 1 (cm²)	Class III (cm²)	Class I N (cm²)	F	sig
ruta	22.61±3.97	20.83±3.36	11.52±3.62	16.48±3.27	69.141	0.000
rlta	27.28±3.99	24.87±4.10	22.96±5.65	20.57±3.84	14.676	0.000
suta	24.27±3.21	22.71±3.37	12.20±4.24	17.57±3.57	82.081	0.000
slta	33.29±4.54	30.68±5.02	28.82±6.68	25.97±4.50	12.365	0.000

ruta: rest upper total area, rlta: rest lower total area, suta: smile upper total area, slta: smile lower total area

Table 2. Multiple comparisons of upper and lower total lip areas at rest and during smile

Dependent Variable	Multiple Comparison		Sig.
Rest upper total area (ruta)	Class I BMP	Class II D1	0.221
		Class III	0.000
		Class I N	0.000
	Class IID1	Class I BMP	0.221
		Class III	0.000
		Class I N	0.000
	Class III	Class I BMP	0.000
		Class II DI	0.000
		Class I N	0.000
	Class I N	Class I BMP	0.000
		Class II D1	0.000
		Class III	0.000
Rest lower total area (rlta)	Class I BMP	Class II D1	0.140
		Class III	0.000
		Class I N	0.000
	Class II D1	Class I BMP	0.140
		Class III	0.432
		Class I N	0.000
	Class III	Class I BMP	0.000
		Class II DI	0.432
		Class I N	0.146
	Class I controls	Class I BMP	0.000
		Class II D1	0.000
		Class III	0.146
Smile upper total area (suta)	Class I BMP	Class II D1	0.420
		Class III	0.000
		Class I N	0.000
	Class II D1	Class I BMP	0.420
		Class III	0.000
		Class I N	0.000
	Class III	Class I BMP	0.000
		Class II DI	0.000
		Class I N	0.000
	Class I N	Class I BMP	0.000
		Class II D1	0.000
		Class III	0.000
Smile lower total area (slta)	Class I BMP	Class II D1	0.222
		Class III	0.003
		Class I N	0.000
	Class II D1	Class I BMP	0.222
		Class III	0.816
		Class I N	0.001
	Class III	Class I BMP	0.003
		Class II DI	0.816
		Class I N	0.139
	Class I N	Class I BMP	0.000
		Class II D1	0.001
		Class III	0.139

pared to Class III and Class I N groups at rest and during smile ($p<0.001$). However, no statistically significant differences were observed between these two (Class I BMP and Class II Div 1).

The ratios of upper-to-lower lip vermilion height and area during rest and smile with ANOVA are given in Table 3. These ratios were obtained by dividing the lower-lip values by the corresponding upper ones with respect to both lip areas and vermilion heights at different points. This was done during rest and smile to yield the "rest vermilion ratio (rvr)," "smile vermilion ratio (svr)," "rest area ratio (rar)," "smile area ratio (sar)," "rest total area ratio (rtar)," and "smile total area ratio (star)". Results show highly significant differences ($p<0.001$). A multiple comparison revealed that the skeletal Class III group was significantly different. The value of all the ratios in skeletal Class III were found to be significantly higher ($p<0.001$). No significant variations were observed in the ratios for Class I BMP, Class II Div 1, and Class I controls. Figure 4 depicts the ratios of the upper-to-lower vermilion height and lip area at rest and during smile.

DISCUSSION

The importance of evaluating aesthetics in the frontal view has been well emphasized with an increasing number of orthodontists shifting their focus from the sagittal plane to the frontal, while evaluating patients for orthodontic treatment (17). The mouth being the center of communication in the face, the aesthetic appearance of the oral region during rest, speech, and smile is a conspicuous part of facial attractiveness (11).

Photographs provide a conventional documentation of the soft tissues of the face and are considered extremely reliable, as facial landmarks can be located consistently (18, 19). Though various soft tissue facial analyses based on standardized diagnostic photographs are available (18), none of them focus on morphology and proportions of the lips in frontal view. Whether lip frontal morphology and proportions are affected by underlying sagittal dentoalveolar discrepancies have thus far, to the best of our knowledge, not been evaluated. The present study focuses on the frontal evaluation and comparison of the upper- and lower-lip morphology in skeletal Class I BMP, Class II Div 1, Class III, and Class I N subjects.

Our investigation revealed statistically highly significant decrease in the upper-lip area of the skeletal Class III group, as compared to others at rest and during a posed smile. The decrease in the vermilion height of the upper lip in skeletal Class III is also obvious at rest and during smile (Figure 3). Clinically, this was observed to be a remarkable identifying feature during a regular extraoral examination of the face and lips. This is in contrast to the observations by Rafiqul Islam et al., who in an evaluation of the lip morphology of skeletal Class III cases following orthognathic surgery reported that the pre-treatment areas of the upper and lower lips in Class III were significantly larger than Class I controls (17).

The Class I BMP group in our study showed a statistically highly significant increase in both the upper and lower-lip areas and

Table 3. Upper-to-lower-lip vermilion height and lip-area ratios during rest and smile with analysis of variance (ANOVA)

RATIO	Class I BMP	Class II Division I	Class III	Class I Controls	ANOVA	
					F	Sig.
At Rest						
rvr_1 (22-29/7-15)	1.33±..36	1.09±.34	3.13±1.02	1.18±.40	91.963	0.000
rvr_2 (23-30/8-16)	1.32±.22	1.28±.27	2.66±.74	1.30±.25	88.392	0.000
rvr_3 (24-31/9-17)	1.19±.17	1.26±.20	1.65±.50	1.21±.19	18.462	0.000
rvr_4 (25-32/10-18)	1.39±.16	1.44±.21	1.99±.56	1.41±.25	25.921	0.000
rvr_5 (26-33/11-19)	1.16±.15	1.26±.25	1.61±.37	1.21±.18	22.758	0.000
rvr_6 (27-34/12-20)	1.30±.23	1.29±.23	2.36±1.22	1.38±.20	23.406	0.000
rvr_7 (28-35/13-21)	1.35±.34	1.14±.36	3.25±1.33	1.30±.39	65.686	0.000
rar_1 (lr4/ur4)	1.14±.35	.90±.40	3.14±1.37	1.18±.51	63.441	0.000
rar_2 (lr3/ur3)	1.25±.22	1.16±.24	2.58 ±1.10	1.25±.37	46.033	0.000
rar_3 (lr2/ur2)	1.23±.17	1.29±.24	1.96±.60	1.27±.22	34.753	0.000
rar_4 (lr1/ur1)	1.26±.14	1.39±.16	1.96±.44	1.26±.22	52.611	0.000
rar_5 (ll1/ul1)	1.21±.13	1.30±.22	1.75±.47	1.24±.19	27.869	0.000
rar_6 (ll2/ul2)	1.20±.20	1.33±.20	2.20±.98	1.31±.18	28.325	0.000
rar_7 (ll3/ul3)	1.27±.28	1.09±.37	2.57±.93	1.46±.31	53.736	0.000
rar_8 (ll4/ul4)	1.20±.36	.98±.38	2.87±.83	1.23±.47	91.463	0.000
rtar (rlta/ruta)	1.22±.14	1.21±.21	2.11±.50	1.26±.21	74.288	0.000
During Smile						
svr_1 (22-29/7-15)	1.62±.26	1.69±.60	4.03±2.25	1.80±.50	34.458	0.000
svr_2 (23-30/8-16)	1.55±.28	1.52±.32	2.61±1.07	1.70±.30	27.232	0.000
svr_3 (24-31/9-17)	1.33±.20	1.35±.22	1.90±.61	1.41±.21	20.475	0.000
svr_4 (25-32/10-18)	1.35±.24	1.37±.22	2.09±.69	1.42±.24	30.220	0.000
svr_5 (26-33/11-19)	1.31±.20	1.31±.21	1.89±.49	1.44±.20	29.289	0.000
svr_6 (27-34/12-20)	1.49±.24	1.43±.33	2.76±.91	1.62±.23	53.929	0.000
svr_7 (28-35/13-21)	1.59±.33	1.64±.50	5.19±3.58	1.81±.46	33.272	0.000
sar_1 (lr4/ur4)	1.51±.43	1.4±.71	4.12±2.1	1.33±.41	49.936	0.000
sar_2 (lr3/ur3)	1.57±.23	1.43 ±.31	2.75±1.06	1.7±.41	35.643	0.000
sar_3 (lr2/ur2)	1.4±.21	1.42±.26	2.2±.63	1.54±.21	36.820	0.000
sar_4 (lr1/ur1)	1.29±.18	1.32±.17	2.10±.46	1.40±.23	65.080	0.000
sar_5 (ll1/ul1)	1.28±.17	1.31±.18	2.16±.35	1.39±.20	110.05	0.000
sar_6 (ll2/ul2)	1.33±.20	1.35±.22	2.31±.58	1.49±.21	63.228	0.000
sar_7 (ll3/ul3)	1.42±.22	1.46±.29	3.1±1.19	1.77±.35	58.720	0.000
sar_8 (ll4/ul4)	1.47±.30	1.35±.48	4.58±2.34	1.53±.32	59.544	0.000
star (slta/suta)	1.38±.14	1.36±.22	2.51±.60	1.51±.19	91.828	0.000

rvr: rest vermilion ratio, svr: smile vermilion ratio, rar: rest area ratio, sar: smile area ratio, rtar: rest total area ratio, star: smile total area ratio, ruta: rest upper total area, rlta: rest lower total area, suta: smile upper total area, slta: smile lower total area

vermilion heights as compared to Class III and Class I controls. This agrees with a previous observation by Nety Trisnawaty et al. (5). The probable reason for this could be that flared incisors have a tendency to roll the upper and lower lips out, exposing more of the mucocutaneous lip and increasing the vermilion height and lip area (7).

Skeletal Class II individuals with increased overjet have been reported to have upper lips more protrusive than lower by Chihiro Tanikawa et al. (4). They hypothesized that the upper lip may be looked upon as thicker (or vertically longer) because the upper-lip vermilion receives, in theory, less vertical pressure from the lower-lip vermilion (4). The present study also supports the above hypothesis as a significant increase in the size of the upper lip was observed in skeletal Class II cases (Table 2).

On computing the upper-to-lower-lip ratios for all the four groups, our study revealed that the ratios were significantly increased in the skeletal Class III for both the vermilion height and lip area at rest and during smile. The increase in ratio was three times greater at rest and four times greater during smile at extreme right and left corners of the mouth when compared with Class I (Figure 4). This is similar to the observation by Rafiqul Islam et al. who attributed an increased lip ratio to the everted

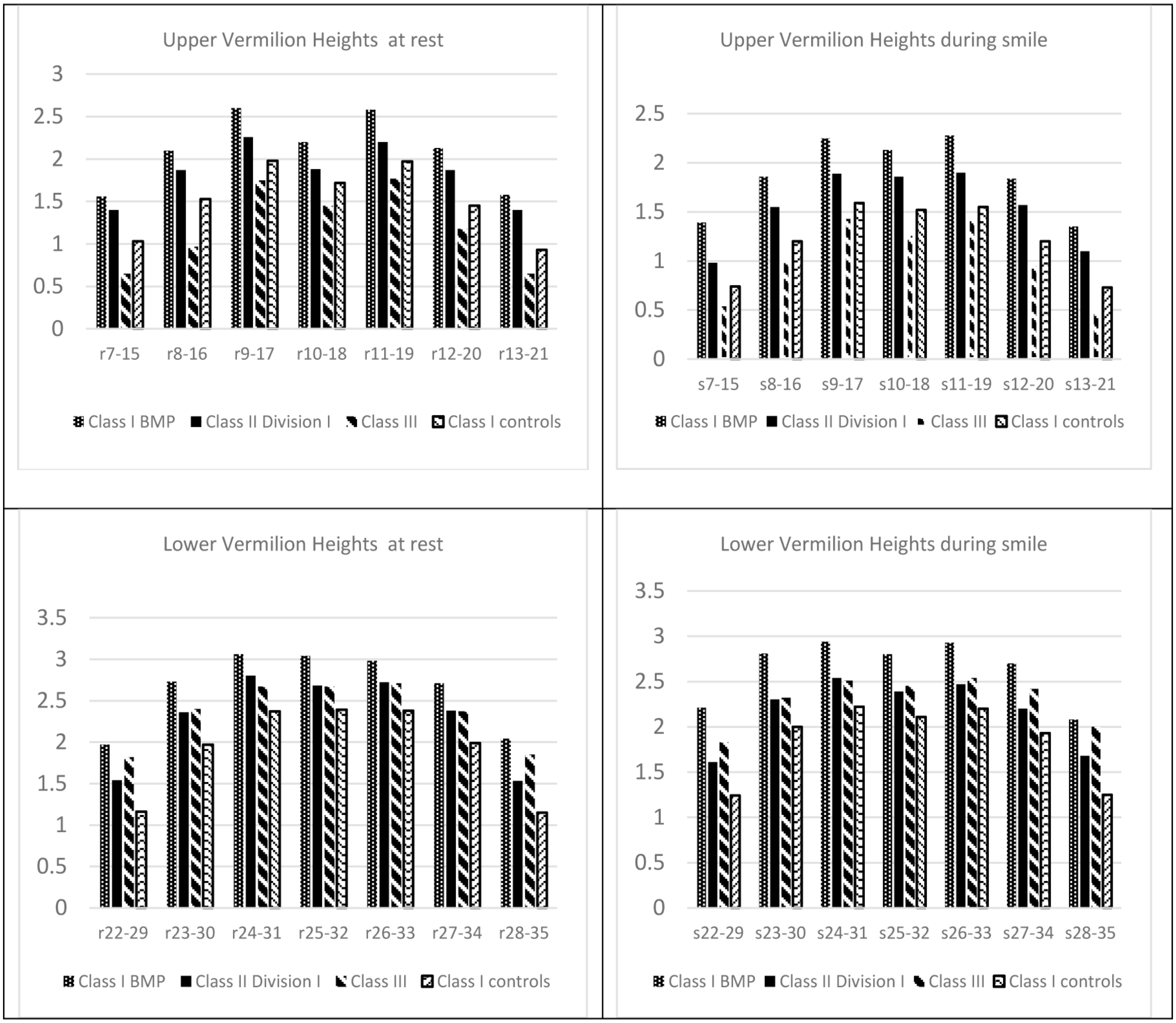

Figure 3. Comparison of the upper- and lower-segment-wise vermilion heights at rest and during smile
r: rest, s: smile

lower lip seen in cases of reverse overbite and skeletal Class III malocclusions; this would increase the lower-lip area resulting in loss of the upper and lower-lip balance (17). However, the results of our investigation do not show any significant change in the lower lip of Class III group when compared to Class I controls. The upper lip on the other hand showed a significant decrease in the upper-lip area and vermilion height in Class III group, which resulted in the increased lip ratios. In individuals with skeletal Class III malocclusion, the lower-lip vermilion, positioned more forward than its opponent, pushes the upper-lip vermilion backward, and a part of the upper-lip vermilion rolls inwards (4). Previous investigations reporting retrusive upper lips and protrusive lower lips in skeletal Class III malocclusions have all evaluated lips in the lateral/profile view only (4, 20).

A closer look at Figure 4 revealed interesting features. Both the vermilion height- and segment-wise lip-area ratios increased progressively from the midline to the extreme right and left corners of the mouth for the Class III group. Such a pattern was not observed for the Class I or Class II Div 1 subjects. The vermilion height ratios at the mouth corners were three times greater than the midline at rest and four times greater during smile in the Class III group. This was due to the fact that the observed decrease in the upper vermilion height was more towards the corners of the mouth.

Clinical Implications

The close association between sagittal dentoskeletal discrepancies and the vermilion height/lip area is obvious from the findings of this study. Considering the trend toward preferences for increased lip fullness, techniques to gain the arch length and non-extraction treatments are catching on. The use of expansion appliances, lip bumper, lingual arch, the Schwarz plate, and various molar distalization appliances are now supplanting premo-

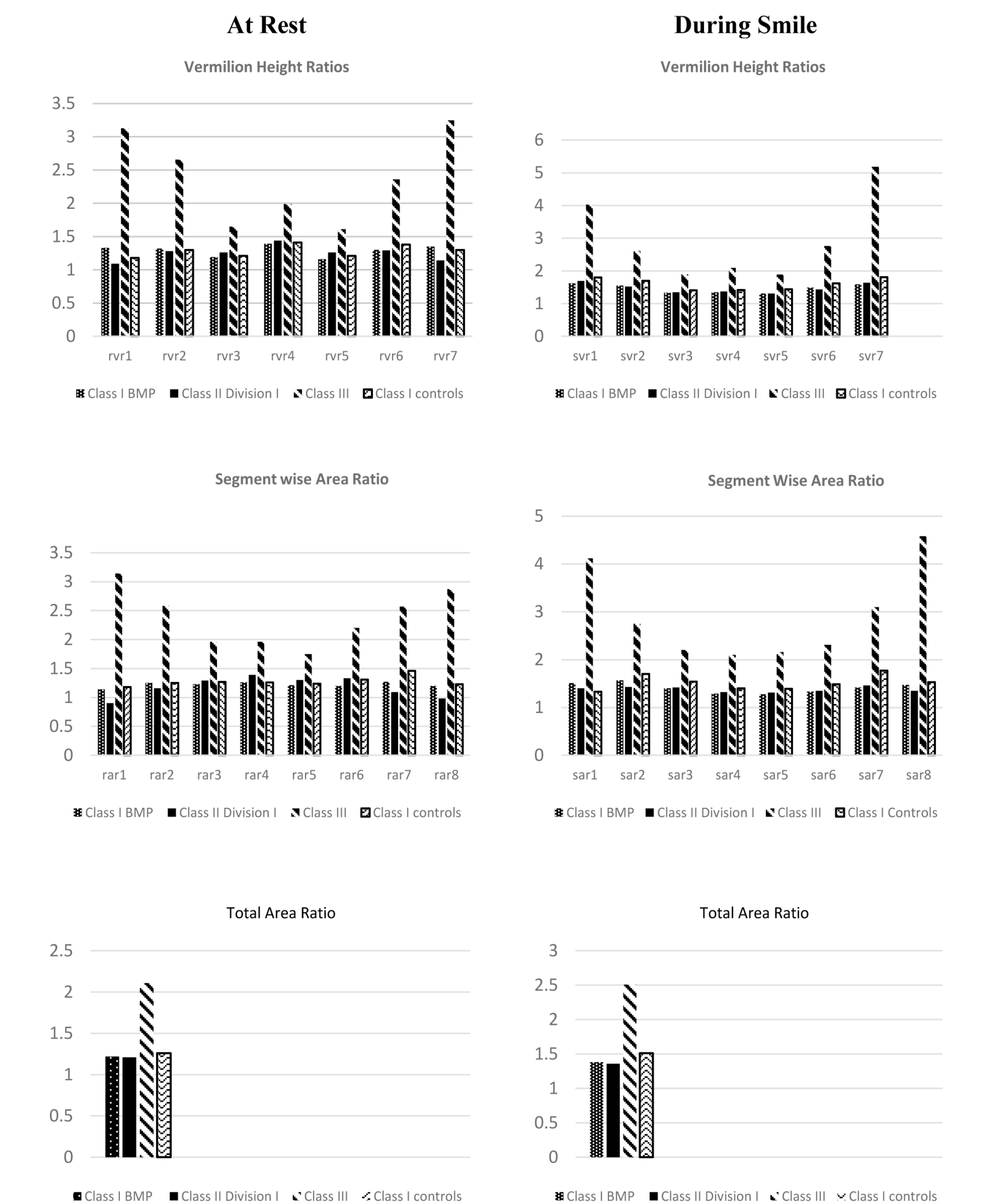

Figure 4. Comparison of vertical vermilion height and lip-area ratios at rest and during smile
rvr: rest vermilion ratio, svr: smile vermilion ratio, rar: rest area ratio, sar: smile area ratio

lar extractions (8). As morphologic characteristics of lips reflect underlying sagittal skeletal discrepancies, they could also serve as additional diagnostic indicators during a clinical examination of the face.

Limitation of the Study

The effect of vertical skeletal discrepancies and Class II Division 2 malocclusion on frontal lip morphology was not included. This needs to be evaluated in further studies. Only females were included, considering the effect of sexual dimorphism on the lip morphology. Males may also have similar lip ratios, which were not evaluated in this study.

CONCLUSION

- Morphologic characteristics of lips showed significant differences among skeletal Class I, Class II, and Class III malocclusions at rest and during smile.
- Skeletal Class III cases displayed a significantly smaller upper-lip area, as compared to the Class I BMP, Class II Div 1, and Class I N group.
- Class I BMP and Class II Div 1 displayed significantly larger upper and lower lip areas.
- Ratios of the upper-to-lower-lip areas and vermilion heights showed significantly higher values for skeletal Class III. The ratios displayed an increasing trend from the midline to the corners of the mouth.

  No statistically significant differences were observed in the lip-area ratios and vermilion height ratios for Class I BMP, Class II Div 1, and Class I N.

Ethics Committee Approval: Ethics committee approval was received for this study from the Institutional Ethics Committee of Government Dental College (IEC no: 45/2014/DCC).

Informed Consent: Written informed consent was obtained from the patients who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – S.Sundareswaran; Design - S.Sundareswaran; Data Collection and/or Processing - A.J., S.Srinivas; Analysis and/or Interpretation -A.J., S.Sundareswaran; Literature Search - A.J., S.Srinivas; Writing Manuscript - A.J., S.Sundareswaran, S.Srinivas; Critical Review - S.Sundareswaran.

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

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ORIGINAL ARTICLE

Comparative Evaluation of Conventional and OnyxCeph™ Dental Software Measurements on Cephalometric Radiography

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ABSTRACT

Objective: Cephalometry can be measured with traditionally conventional analysing methods (hand tracing), as well as using computers. Many dental softwares have been developed for this purpose. The reliability of these programs are often compared with the conventional method. The aim of the present study was to compare the conventional method of manual cephalometric analysis with a computerized one, OnyxCeph ™ (Image Instruments, Chemnitz, Germany) dental software.

Methods: Lateral cephalometric radiographs of 150 patients (75 males and 75 females) age range 12-34 were traced by two methods. Conventional method and computerized (OnyxCeph) cephalometric analysis method. 2 maxillar, 3 mandibular, 2 maxillo-mandibular, 3 vertical, 7 dental and 1 soft tissue parameters; 10 angular, 8 linear totally 18 cephalometric parameters were measured. Intra-class correlation coefficients were performed for both methods to assess the reliability of the measurements.

Results: The results 9 of 18 parameters were found statistically significant. They were Cd-A distance, Cd-Gn distance, Go-Me distance, GoGnSN angle, ANS-Me distance, upper incisor-NA distance, lower incisor-NB distance, lower incisor-NB angle, overbite distance.

Conclusion: Despite some discrepancies in measured values between hand-tracing cephalometric analysis method and the OnyxCeph cephalometric analysis method, statistical differences were minimal and only Cd-A, Cd-Gn, Go-Me, ANS-Me, GoGnSN° were clinically important for cephalometric analysis OnyxCeph was evaluated as an efficient method to replace conventional method.

Keywords: Cephalometrics, manual tracing, onyxceph, computerized cephalometric program, reliability

INTRODUCTION

Cephalometric radiography is important diagnostic method that determines the morphology, development, and diagnosis in dental or skeletal abnormalities. It is used for treatment planning, evaluating the results of treatment, relationship between dental and cranial structures and identification of malocclusion (1-3). Three different methods are used to evaluate the cephalometric radiographs. The conventional cephalometric analysis is one of the methods, which is performed by tracing radiographic landmarks on acetate overlays and measuring linear and angular values. The second one is a computer-aided cephalometric analysis method, which uses scanners or digital cameras for exporting cephalometric images to measurement programs and anatomical structures marked with a mouse cursor on a computer monitor. The third method is a fully digital method, which transmits digital radiographs directly to a computer database, and a cephalometric program determines the anatomical structures and completes the cephalometric analysis by measuring distances and angles through automation (4-9).

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However, cephalometric analysis has some limitations. It produces errors during radiographic image acquisition or cephalometric tracing. Cephalometric errors can be categorized into projection errors (acquisition), identification errors, and measurement errors (2, 5, 10-13). Projection errors under magnification and distortion titles contain patient positioning errors, exposure position, differences in exposure parameters, collimation, bath conditions, and differences in film shooting methods. Errors during the digitization of the image are also considered (2, 5, 6, 11, 14-18). A study by Gaddam et al. (19) investigated the projection errors in lateral cephalometric radiographs. Ten skulls and 8 cephalometric parameters were evaluated, and head rotations from 0° to −20° at 5° intervals in the vertical axis were performed. They concluded that according to the head rotation, angular measurements had fewer projection errors than linear measurements. Further evidence was from a study by Yoon et al. (20), which evaluated 17 skulls and 8 parameters to identify potential projection errors of lateral cephalometric radiographs according to the head rotation. Each skull was rotated from 0° to ±15° at 1° intervals in the vertical axis. The results were consistent with those of Gaddam et al. (19). Measurement errors were affected by the measuring device (ruler, protractor, etc.), technique (recording or archiving of measurements), or investigator (limitation in visual performance or fault in measuring) (2, 5, 6, 11, 18, 21). These errors mostly have been eliminated by the spread of digital analyzing methods (11). Landmark identification errors are the most common and important errors in the analysis. These errors involve radiographic image quality (sharpness, blur, contrast, and noise), differences depending on the researchers (intra-observer: light, time constraints, psychological conditions; inter-observer: their experience or perspective differences), precision of landmark identification, and reproducibility of the location. Errors less than 0.5 mm are considered acceptable anatomical landmark errors (2, 5, 6, 8, 11, 15-18, 21, 22-25). The landmarks are located on the outline of the cranium, which are comparatively easy to identify, whereas the internal structures were more difficult to identify because of the summation of superimposed anatomical details (14).

Computerized systems for cephalometric analysis were routinely performed, and many analysis programs have been developed to date (26). Various studies have been compared to a variety of computer-aided cephalometric analysis programs using the conventional cephalometric analysis method for reliability and reproducibility in literature (11, 12, 23, 27). However, no clear consensus has been achieved regarding the standard method. McClure et al. (28) evaluated 19 landmarks on 6 patients with an age range of 21–30 years to compare identification errors with the conventional analysis method and the Dolphin Imaging software. It was emphasized that even the statistically significant differences between the two methods of image acquisition were unlikely to attain clinical significance. Cavdar et al. (29) compared the conventional cephalometric analysis using Jiffy Orthodontic Evaluation (JOE®) and QuickCeph® computerized cephalometric programs and used 90 lateral cephalograms with 18 parameters. The authors justified that the computer-aided method may be preferable because of the benefits, such as time gain, archiving, and enhancement of radiographs. Akın et al. (30) compared intra and interexaminer reliability of 19 parameters obtained from 60 lateral cephalometric radiographs using the conventional and QuickCeph computerized cephalometric analysis methods. It was determined that computerized cephalometric analysis did not increase the measurement error compared to the conventional method. Rusu et al. (31) assessed 39 lateral cephalograms with three different computerized programs: Planmeca Romexis, Orthalis, and AxCeph. They reported that Romexis and AxCeph give more reliable results than Orthalis.

OnyxCeph™ dental Picture Archiving Communication Systems was developed for archiving, diagnostics, treatment planning, and patient education. This software program is based on two-dimensional (2D) and 3D data processing. Image import, image adjust (classify and crop image), cephalometric analysis and measurements, mirror image, model base (adjust models and attach base), segmentation (separation and completion) Ricketts Visual Treatment Objective, superimposition, image edit, data export, copy/save/send/show/print image, treatment simulation, slide show, online/offline reports are possible with this 2D and 3D image data (32).

Davoudian (32) examined and compared the reliability and reproducibility of digitization using the OnyxCeph imaging software with conventional techniques through 21 parameters in 30 lateral cephalograms. It was determined that all measurements showed good reliability in both methods except for the nasolabial angle in the manual method.

Although researchers have studied several software programs based on computerized cephalometry, there are few studies based on the OnyxCeph software (32). The aim of the present study was to compare the conventional cephalometric analysis method and a computerized cephalometric analysis method with the OnyxCeph dental software.

METHODS

In this retrospective study, lateral cephalometric radiographic images were gathered from a total of 150 participants (75 females and 75 males) with an age range of 12–34 years. The inclusion criteria were patients without any missing teeth based on the records for the period 2013–2016 in the archives of the Marmara University School of Dentistry, Department of Radiology. The exclusion criteria were participants with systemic disease, which may adversely affect their bone development; pathological conditions, such as cysts and tumors; and a history of a trauma or injury in the oral and maxillofacial regions. Ethical approval was obtained from the ethics committee of the Marmara University School of Medicine (Protocol 092015128 2015/9:128).

All lateral cephalometric radiographs were acquired from the same orthopantomogram (Promax, Planmeca Oy, 0080 Helsinki, Finland) using standard radiographic techniques (75 kV, 4.1 seconds, 10 mA).

Based on the cephalometric measurements, patients were grouped as those undergoing conventional techniques and digital techniques (Onyx Ceph™). In the conventional method, the digital images were resized to a 1:1 scale using Adobe Photoshop (Adobe Systems, San Jose, California, USA) and printed on an A4 paper using a laser printer (HP Laserjet P2035n). For standardizing the analysis, there were no changes in the settings of resolution, contrast, and brightness before printing in the digital cephalometric radiographs.

For the conventional technique, 150 digital radiographs were manually traced on an A4 paper placed over the printed image. A 0.3 mm 2H lead pencil to trace all the required landmarks, a ruler to draw lines, and a protractor to measure angles were used. Bilateral structures were averaged to make a single landmark.

For the digital technique, direct digital cephalometric radiographs were recorded in the Joint Photographic Experts Group format and transferred to the OnyxCeph3™ 3.1.54 (Image Instruments, Chemnitz, Germany) dental analysis software for a cephalometric analysis. Digital measurements were evaluated using a 23-inch Acer 1920×1080-pixel HP Reconstruction PC monitor. The identified anatomical points were marked in the program with an indicator on the mouse control. Before marking the anatomical points, a ruler on the cephalostat was calibrated in the program, and thus standardization was provided in all cephalometric radiographs. Measurements were drawn automatically by the program after the marking the anatomical points.

All the tracings were performed by the same maxillofacial radiologist. No more than 10 radiographs were traced per day to avoid examiner fatigue. To assess reliability, 30 randomly selected radiographs were retraced by the same investigator using the conventional cephalometric analyzing method. A time interval of more than 2 months elapsed between first and second analyses.

The commonly used dental, skeletal, and soft tissue parameters in a cephalometric analysis were selected and the linear and angular measurements shown in Figure 1 were produced. A total of 18 anatomical landmarks with 5 planes and 8 linear and 10 angular measurements were evaluated. In these measurements, there were 2 maxillary parameters, 3 mandibular parameters, 2 maxillomandibular parameters, 3 vertical parameters, 7 dental parameters, and 1 soft tissue parameters (Table 1).

Cephalometric radiographs were divided into 3 groups (classes I, II, and III) according to the Angle classification, which is used for the classification of malocclusions. The ANB angle of 0° to 4° is class 1; ANB angle >4° is class 2; and ANB angle <4° is class 3. The conventional and digital methods were compared based on this classification.

The OnyxCeph dental software program was used to analyze lateral cephalometric radiographs after the anatomic landmarks were marked. The measurements can be evaluated using several

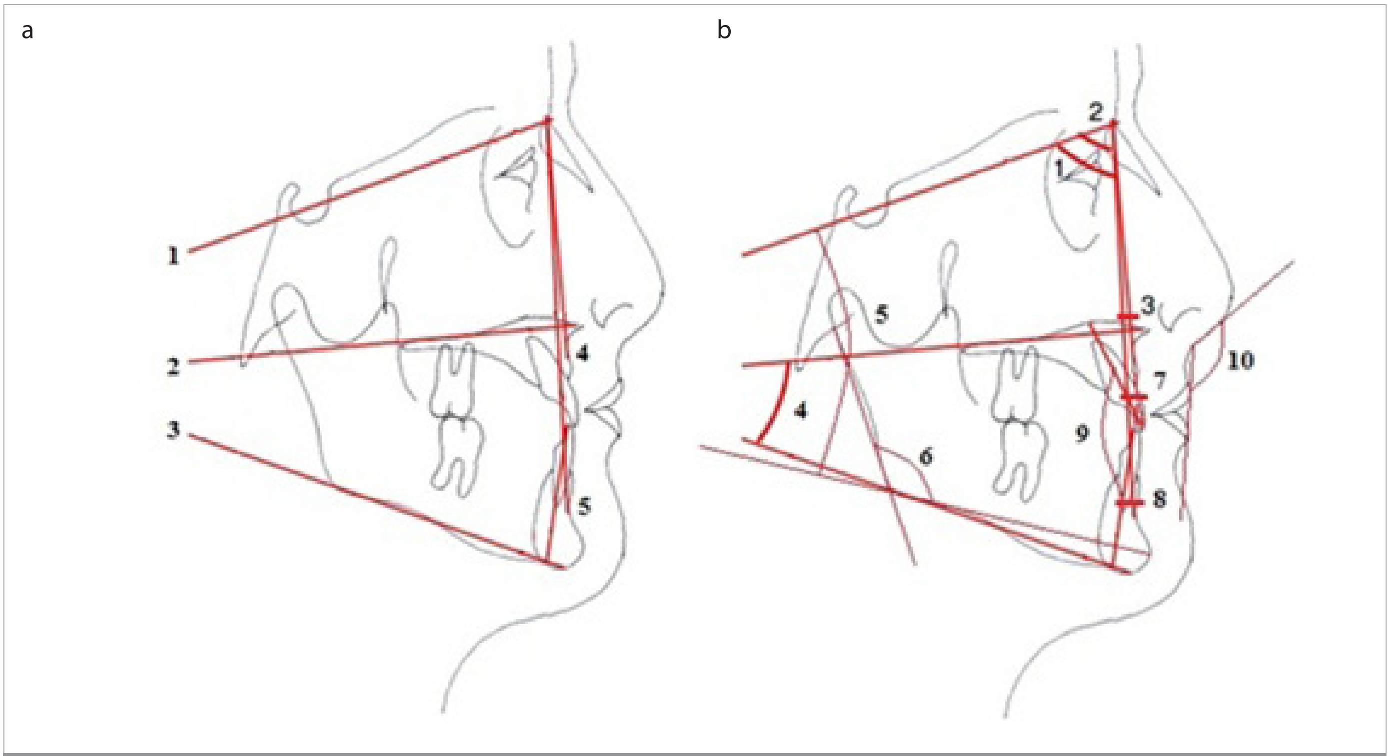

Figure 1. a, b. (a): 1. SN plane: Plane is passing through Sella and Nasion points. 2. PP (Palatal plane): Plane is passing through ANS and PNS points. 3. MP (Mandibular plane): Plane is passing through Gonion and Menton points. 4. NA plane: Plane is passing through Nasion and A points. 5. NB plane: Plane is passing through Nasion and B points. (b): 1.SNA°: Angle determined by points S, N, and A. 2. SNB°: Angle determined by points S, N, and B. 3. ANB°: Angle determined by points A, N, and B. 4. PP-MP°: Angle formed between palatal and mandibular planes. 5. GoGnSN°: Angle formed between GoGn and SN lines. 6. ArGoGn°: Angle formed between GoAr and GoGn lines. 7. U1NA°: Angle formed by the intersection of the maxillary incisor axis to the plane between points N and A. 8. L1NB°: Angle formed by the intersection of the mandibular incisor axis to the plane between points N and B. 9. İnterinsizal°: Angle formed by the intersection of the mandibular incisor axis to the maxillary incisor axis. 10. Nazolabial°: Angle determined by points columella, SN and UL

Table 1. Measurements used for this study

Go-Me (mm)	**Distance between Go and Me points**
SNB (°)	Angle determined by points S, N, and B
Maxillomandibular parameters	
ANB (°)	Angle determined by points A, N, and B
PP-MP (°)	Angle formed between palatal and mandibular planes
Vertical parameters	
GoGnSN (°)	Angle formed between GoGn and SN lines
ANS-Me (mm)	Distance between ANS and Me
ARGoGn (°)	Angle formed between GoAr and GoGn lines
Dental parameters	
U1-NA (mm)	Perpendicular distance from the tip of the maxillary incisor to the plane between points N and A
U1-NA (°)	Angle formed by the intersection of the maxillary incisor axis to the plane between points N and A
L1-NB (mm)	Perpendicular distance from the tip of the mandibular incisor to the plane between points N and B
L1-NB (°)	Angle formed by the intersection of the mandibular incisor axis to the plane between points N and B
Interincisal angle (°)	Angle formed by the intersection of the mandibular incisor axis to the maxillary incisor axis
Overjet (mm)	Horizontal distance between the tips of maxillary and mandibular central incisors
Overbite (mm)	Vertical distance between the tips of maxillary and mandibular central incisors
Soft tissue parameters	
Nasolabial angle (°)	Angle determined by points columella, SN and UL

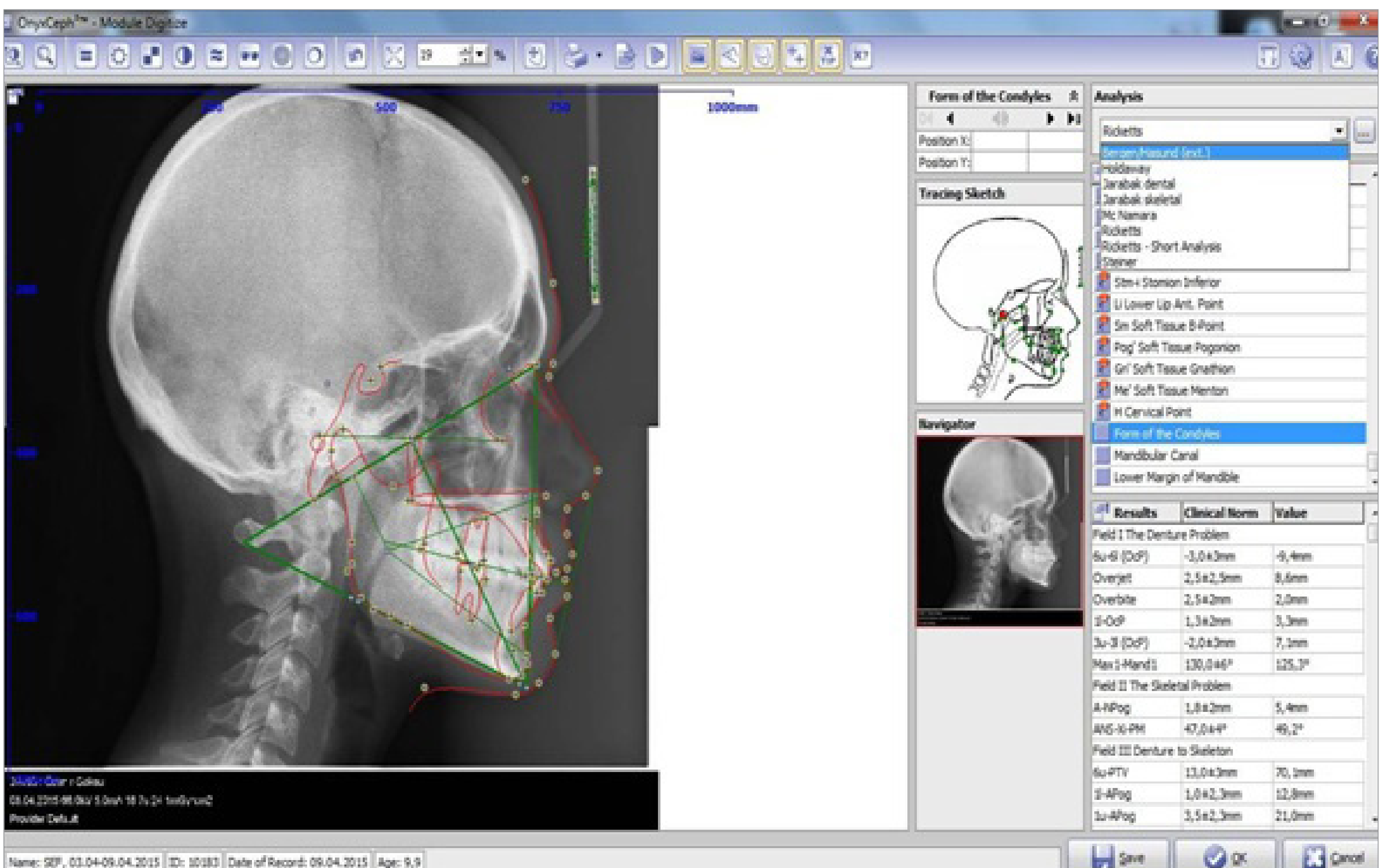

Figure 2. OnyxCeph dental software program. Measurements can be evaluated using several analysis methods

analysis methods (Figure 2). The measured values were based on the drawing, deviation ratio according to the norm values. These rates are in different color tones. Green color indicates class 1 deviation, red color class 2, and blue color class 3.

Pretreatment, intermediate stages, end of treatment analysis of the cases were evaluated using the OnyxCeph dental software program. Changes in the middle and final stages were determined by the dynamic nature of the visual assessment of the

OnyxCeph dental software program. Thus, the alterations of the facial appearance can be easily interpreted during and after treatment.

Statistical Analysis

The statistical analyses were performed using the software Statistical Package for Social Sciences version 22.0 (IBM Corp.; Armonk, NY, USA). Shapiro Wilks test was used for evaluating the normal distribution of parameters. It was determined that the parameters were in accordance with the normal distribution. Descriptive statistical methods were used for each measurement (mean, standard deviation frequency). A student's t-test was used for the evaluation of the digital and conventional measurements based on gender. A paired sample t-test was used to evaluate the statistical significance and compare differences between the digital and conventional measurement values. A p value of <0.05 was considered significant.

RESULTS

The total of 150 individuals' (75 females and 75 males) cephalometric radiograph images were assessed in this study. The age ranged from 12.5 years to 33.7 years, the average age was 17:56±3:59 years.

According to the statistical analysis, the average of the digital and conventional measurements and measuring differences are shown in Table 2. There was a statistically significant difference between averages of Cd-A distance, which is one of the maxillary parameters (p=0.001; p<0.01). The agreement between the two measurement methods was 48.9% (intra-class correlation coefficient [ICC]: 0.489; 95% confidence interval [CI]:0.357–0.602).

There was a statistically significant difference between the averages of Cd-Gn distance, which is one of the mandibular parameters

Table 2. Difference between digital and conventional measurement averages in all patients

	Digital Mean±SD	Conventional Mean±SD	Difference Mean±SD	p
SNA (°)	79.99±4.6	79.95±9.78	0.05±0.71	0.950
Cd-A (mm)	83.38±5.65	79.3±6.2	4.08±0.49	0.001**
Cd-Gn (mm)	119.2±77.31	105.5±8.88	13.7±6.37	0.033*
Go-Me (mm)	69.31±6.27	63.56±4.99	5.74±0.46	0.001**
SNB (°)	77.16±4.5	76.92±10.11	0.24±0.75	0.752
ANB (°)	2.85±3.2	3.3±2.87	−0.44±0.22	0.055
PP-MP (°)	25.06±5.99	25.41±6.2	−0.35±0.40	0.383
GoGnSN (°)	33.59±6.29	31.32±11.49	2.27±0.92	0.014*
ANS-Me (mm)	66.33±6.54	63.47±6.45	2.85±0.27	0.001**
ArGoGn (°)	124.31±7.71	124.6±15.63	−0.29±1.26	0.820
U1-NA (mm)	4.96±3.39	4.26±2.96	0.7±0.22	0.002**
U1-NA (°)	23.68±7.22	23.44±7.34	0.24±0.48	0.626
L1-NB (mm)	5.35±2.95	4.74±2.52	0.61±0.21	0.006**
L1-NB (°)	27.45±6.31	26.39±7.7	1.06±0.50	0.036*
Interincisal angle (°)	125.64±8.84	123.78±17.07	1.85±1.24	0.138
Overjet (mm)	3.84±3.09	3.84±2.38	0±0.17	0.988
Overbite (mm)	1.77±2.07	2.16±2.2	−0.39±0.15	0.011*
Nasolabial angle (°)	103.08±12.57	104.06±14.62	−0.98±1.13	0.385

Paired sample t-test; SD: Standard Deviation * p<0.05 ** p<0.01

Table 3. Distribution of cephalometric parameters according to the difference (md) * in conventional and digital measurements in all patients

md < 0.5	0.5 < md < 1.0	1.0 < md < 1.5	1.5 < md < 2.0	2.0 < md
SNA°	U1NA (mm)	L1NB°	Interincisal angle°	Cd-A (mm)
SNB°	L1NB (mm)			Cd-Gn (mm)
ANB°	Nasolabial angle°			Go-Me (mm)
PP - MP°				GoGnSN°
ArGoGn°				ANS - Me (mm)
U1NA°				
Overjet (mm)				
Overbite (mm)				

*md (measurement difference): millimeter for linear measurements, degree for angular measurements (p=0.033; p<0.05). The agreement between the two measurement methods was 0.6% (ICC: –0.006; 95% CI: –0.165–0.154). There was a statistically significant difference between the averages of Go-Me distance, which is one of the other mandibular parameters (p=0.001; p<0.01). The agreement between the two measurement methods was 50.7% (ICC: 0.570; 95% CI: 0.378–0.617).

There was a statistically significant difference between the averages of the PP-MP angle, which is one of the maxillomandibular parameters (p=0.383; p>0.05). The agreement between the two measurement methods was 67.6% (ICC: 0.676; 95 % CI: 0.579–0.754).

There was a statistically significant difference between the averages of other vertical parameters GoGnSN angle (p=0.014; p<0.05). The agreement between the two measurement methods was 26.6% (ICC: 0.266; 95% CI: 0.111–0.408). There was a statistically significant difference between the average of the other vertical parameters ANS-Me distance (p=0.001; p<0.01). The agreement between the two measurement methods was 87% (ICC: 0.870; 95% CI: 0.825–0.904).

There was a statistically significant difference between the averages of U1-NA distance, which is one of the dental parameters (p=0.002; p<0.01). The agreement between the two measurement methods was 63.9% (ICC: 0.639; 95% CI: 0.533–0.725). There was a statistically significant difference between the average of the other dental parameters L1-NB distance (p=0.006; p<0.01). The agreement between the two measurement methods was 53.6% (ICC: 0.536; 95% CI: 0.412–0.641). There was a statistically significant difference between the average of the other dental parameters L1-NB angle (p=0.036; p<0.05). The agreement between the two measurement methods was 62.1% (ICC: 0.621; 95% CI: 0.512–0.710). There was a statistically significant difference between the average of the other dental parameters overbite distance (p=0.011; p<0.05). The agreement between the two measurement methods was 62.4% (ICC: 0.624; 95% CI: 0.516–0.713).

Considering the differences between the conventional and digital measurements in Table 3, values less than 0.5 mm for dimensional parameters and the degree for angular parameters are follows: SNA angle, SNB angle ANB angle, PP-MP angle ArGoGn

Table 4. Method error assessment for repeated conventional measurements in 30 patients

		95% CI		
	ICC	Lower	Upper	p
SNA (°)	0.999	0.998	0.999	0.001**
Cd-A (mm)	0.994	0.988	0.997	0.001**
Cd-Gn (mm)	0,998	0.996	0.999	0.001**
Go-Me (mm)	0.999	0.997	0.999	0.001**
SNB (°)	0.997	0.994	0.999	0.001**
ANB (°)	0.999	0.998	1.000	0.001**
PP-MP (°)	0.997	0.994	0.999	0.001**
GoGnSN (°)	0.999	0.997	0.999	0.001**
ANS-Me (mm)	0.998	0.995	0.999	0.001**
ArGoGn (°)	0.996	0.992	0.998	0.001**
U1-NA (mm)	0.991	0.982	0.996	0.001**
U1-NA (°)	0.999	0.998	1.000	0.001**
L1-NB (mm)	0.991	0.982	0.996	0.001**
L1-NB(°)	0.997	0.994	0.999	0.001**
Interincisal angle (°)	0.998	0.995	0.999	0.001**
Overjet (mm)	0.994	0.988	0.997	0.001**
Overbite (mm)	0.992	0.984	0.996	0.001**
Nasolabial angle (°)	0.997	0.994	0.999	0.001**

ICC: Intra-class Correlation Coefficient, CI: Confidence Interval ** p<0.01

Table 5. Compatibility between classifications according to ANB in digital and conventional measurements

	ANB Digital			
ANB Conventional	Class I	Class II	Class III	Total
Class I	56 (37.3%)	17 (11.3%)	13 (8.7%)	86 (57.3%)
Class II	12 (8%)	40 (26.7%)	3 (2%)	55 (36.7%)
Class III	1 (0.7%)	0 (0%)	8 (5.3%)	9 (6%)
Total	69 (46%)	57 (38%)	24 (16%)	150 (100%)

McNemar p=0.003

angle, U1NA angle, overbite distance, and overjet distance. Parameters with a difference value between 0.5 and 1.0 included U1NA distance, L1NB distance, and nasolabial angle. The only parameter with a difference value between 1.0 and 1.5 was the L1NB distance. The only parameter with a difference value between 1.5 and 2.0 was the interincisal angle. Parameters with a difference value more than 2.0 were ANS-Me distance, Cd-A distance, Cd-Gn distance, Go-Me distance, and GoGnSN angle.

Randomly selected 30 cephalometric radiographs were repeated using the conventional techniques to control individual drawings and the level of measurement error for the assessment of the measurements used. Each parameter of recurrence coefficients (r^2) was calculated. The results are shown in Table 4. For each measurement method, the error and the upper and lower limits of 95% CI were determined and provided in the table. The ICC for all samples was found to be close to 1.00. The results of the ICC analysis regarding the method showed an insignificant error and did not affect the results of conventional measurement.

In total, 56 patients were defined as class 1, 40 patients as class 2, and 8 patients as class 3 by the conventional and digital measurement as shown in table 5. Accordingly, there was no statistically significant compliance of digital and conventional measurements depending on the ANB angle between the classes ($p=0.003$; $p<0.01$). Overall, 69 patients (46%) were class 1, 57 patients (38%) were class 2, and 24 patients (16%) were class 3 in the digital measurement, while 86 patients (57.3%) were class 1, 55 patients (36.7%) were class 2, and 9 patients (6%) were class 3 in the conventional measurement. The kappa coefficient was 47.8% between the two measurement methods.

DISCUSSION

The cephalometric radiography analysis was divided into conventional or digital analysis. In the conventional cephalometric analysis, numerous measurements could be waste of time. Currently, those time problems are eliminated by a software that allows a precise measurement of improved digital cephalometric analysis systems (7, 9, 12, 16, 25, 29, 33-37). Numerous studies have investigated the differences between computer-aided cephalometric analysis programs and conventional cephalometric analysis in terms of reliability, accuracy, repeatability, and time (9, 12, 17, 25, 29, 30, 34, 36-38). In our study, the digital cephalometric analysis method (OnyxCeph) was compared to the conventional cephalometric analysis. We found that that digital method was faster and consistent with the other researches. In a study by Iseri et al. (39), 14 parameters were identified in 50 cephalometric radiographs, which was measured twice and compared for accuracy, repeatability, and time using the conventional analysis methods and computer-aided analysis method. There were no statistically significant differences between the average of primary and secondary measurements in both methods. However, the computer-aided method provided significantly higher time gain, which was 7 times faster than conventional methods.

Uysal et al. (40) assessed inter- and intra-examiner reproducibility in the conventional cephalometric and Dolphin cephalometric analyses methods. It was reported that although the computer-aided cephalometric analysis method was not effective to reduce inter- and intra-examiner error, it was preferable in terms of time gain for clinicians.

Inter-examiner errors were greater than intra-examiner errors; hence, to minimize errors, all the measurements in this study were measured by one examiner as in other studies (8, 16, 17, 25, 29, 32, 33, 38, 41, 42). In Naoumova and Lindman's study (33), 30 patients (12 males and 18 females) with identified 25 landmarks were compared using the conventional cephalometric analysis methods with the digital cephalometric analysis method (FACAD, Ilexis AB, Linköping, Sweden). This study was conducted by a single researcher. The researchers' reproducibility correlation coefficients of all variables were above 0.95 for the conventional method and above 0.8 for FACAD. In our study, the ICC was examined for only the conventional method, and the ICC for all variables were above 0.9. The reproducibility of the individual researcher was high.

Several studies have found the main source of error in cephalometric analysis to be the identification of the landmarks (9, 14, 27). As the consensus of many researchers, the Frankfurt horizontal plane showed low coefficient of repeatability. Since it is difficult to detect as stated in many studies, any parameters including a reference from the Po or Or were not used in our study(6, 7, 9, 12, 34, 40).. Moreover, measurements including references points Cd , Cd-A and the Cd-Gn distance was used in our study and there was no statistically significant difference between the conventional cephalometric and OnyxCeph cephalometric measurement.

The nasolabial angle, which is a commonly used parameter in cephalometric analysis, was indicated as an angle which is difficult to determinate and shows a low reproductibility as tated in many studies (6, 12, 34, 40, 43). Unlike other studies, the nasolabial angle did not show significant differences between the conventional cephalometric analysis and digital cephalometric analysis (OnyxCeph) method in our study. The reason for the high reproducibility of the nasolabial angle could be explained by the easily determined soft tissue and appropriate radiographic contrast.

If complex parameters with multiple anatomical landmarks have low reproducibility, it is considered clinically insignificant (16). The GoGnSN angle contained in our study comprised 4 different cephalometric points and showed a statistically significant difference. However, in the light of previous information, these statistical differences are not considered reliable to achieve a clinical decision.

The ANB angle is used for the classification of malocclusion and for revealing the relationship between the upper and lower jaw in a sagittal direction (44). The ANB angle showed statistically significant differences between the conventional and digital techniques in our study. Although a complex parameter that contains multiple anatomical points that we can make the comment the reason for the high reproducibility in present study of the

ANB angle is the ease of detection landmarks of A, B and N. Akin et al. compared conventional and digital measurement methods with two different researchers. The ANB angle was found to be highly reliable for both researchers (30).

It has been suggested that the problem about repeatability is not related the measurement techniques, such as digital or conventional; it might be related to the parameters to be measured whether angular or linear (16). It was concluded that linear measurements have a higher error rate from angular measurements due to the distortion on the image (13). Kumar et al. (36) compared the conventional and digital tracing methods using Burstone analysis. They stated that differences in the measurements of linear parameters were greater than those of the angular parameters as the reason of that errors in calibration were not affected angular values; it changed the linear values. In a study by Tikku et al. (46), which compared the conventional and digital cephalometric measurement methods, a total of 26 parameters (13 linear and 13 angular) were assessed. Only the occlusal plane angle had a statistically significant difference between two methods. From this view point, it has been commented that linear measurements cause a higher statistically difference than angular measurements.

It was reported that in a clinical situation, a reproducibility that is within 2° or 2 mm would probably not make a difference in the treatment and is insignificant for a clinical decision (13, 32). Our study is also consistent with similar studies, which showed a statistically significant difference in 9 parameters between the conventional and digital cephalometric analysis (OnyxCeph), where 7 of them are linear parameters (Cd-A, Cd-Gn, Go-Me, ANS-Me, U1NA, L1NB, and overbite) and 2 of them were angular parameters (GoGnSN°, L1NB°).

CONCLUSION

Although the parameters that showed a statistically significant difference between conventional and digital method were available (Cd-A, Cd-Gn, Go-Me, GoGnSN°, ANS-Me, U1NA, L1NB, L1NB°, Overbite), the differences within 2° or 2 mm were insignificant for a clinical decision. The parameters that showed clinically significant differences were Cd-A, Cd-Gn, Go-Me, ANS-Me, GoGnSN°. It was concluded that considering many advantages of computer-aided cephalometric analysis, OnyxCeph software is preferable. Nevertheless, further studies are necessary to conclude the reliability and reproducibility of digitization using OnyxCeph imaging software.

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethics Committee of the Marmara University School of Medicine (Protocol 092015128 2015/9:128).

Informed Consent: Written informed consent was obtained from the patients who participated in this study.

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ORIGINAL ARTICLE

Is It Possible to Protract the Maxilla by Surgically Assisted Rapid Maxillary Expansion and Intermaxillary Class III Elastics?

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ABSTRACT

Objective: The purpose of the present study was to evaluate skeletal and soft tissue changes with surgically assisted rapid maxillary expansion (SARME) and intermaxillary Class III elastics.

Methods: A total of 15 patients (mean age: 19.58 years) were included in the study. Each patient underwent SARME with the use of Class III elastics (500 g) applied through miniscrews to stimulate maxillary advancement. Lateral cephalograms and posteroanterior radiographs obtained before treatment (T1), after SARME and elastic use (T2), and after treatment (T3) were analyzed to determine the changes in each phase of treatment. Planimeter was used to evaluate facial soft tissue changes. Wilcoxon signed-rank test was used to evaluate the changes that occur during treatment.

Results: SARME provided permanent and efficient maxillary expansion at both skeletal and dental levels ($p<0.01$). Maxillary skeletal (ANS-Ver and U1i-Ver; $p<0.01$) and soft tissue (Pr-Ver, Sn-Ver, and ULA-Ver; $p<0.01$) variables and superior upper labial area (Area 1; $p<0.05$) increased due to maxillary dental and skeletal changes. Superior lower labial area (Area 3; $p<0.05$) decreased as a result of slight increase in facial height and changes in maxillary–mandibular incisor relationship at the end of the treatment.

Conclusion: The results suggest that the improvement in the facial profiles of the patients is related to the significant increase in the bony and dental support of the upper lip region together with the contribution of the superior lower lip area.

Keywords: Class III elastics, maxillary retrusion, SARME, miniscrews

INTRODUCTION

Rapid maxillary expansion (RME) had been the gold standard for maxillary expansion in children and adolescents. However, it was reported that RME in adult patients can cause buccal tipping and extrusion of the posterior teeth, buccal root resorption, palatal tissue necrosis, pain, and other gingival complications (1-4).

In adult patients with both maxillary transverse deficiency and retrusion, the general treatment approach is primarily to perform surgically assisted rapid maxillary expansion (SARME) to correct the transversal problem and then to perform Le Fort I osteotomy to address the anteroposterior deficiency. With these approaches, patients must undergo two separate surgeries under general anesthesia. Undergoing multiple surgical procedures can increase the risk of complications, as well as prolong recovery time (5-7). It has been suggested in some studies that segmental Le Fort 1 osteotomies can be a more appropriate alternative to patients with transversal and/or sagittal discrepancies. This surgical method is considered to be useful, but some stability problems and complications were also reported (8-10).

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According to previous studies, corticotomy-assisted maxillary protraction can also be efficient to stimulate maxillary forward movement in younger individuals (11, 12). Although several studies have been published on the effects of either SARME, RME, or SARME-aided maxillary protraction with face masks or temporary anchorage devices for use of intermaxillary elastics (13-16), to the best of our knowledge, no study has been published evaluating the use of intermaxillary Class III elastics simultaneously with SARME in adult patients to facilitate maxillary advancement.

Hence, it was considered worthwhile to examine the effects of simultaneous implementation of SARME and intermaxillary Class III elastics on maxillary expansion and advancement.

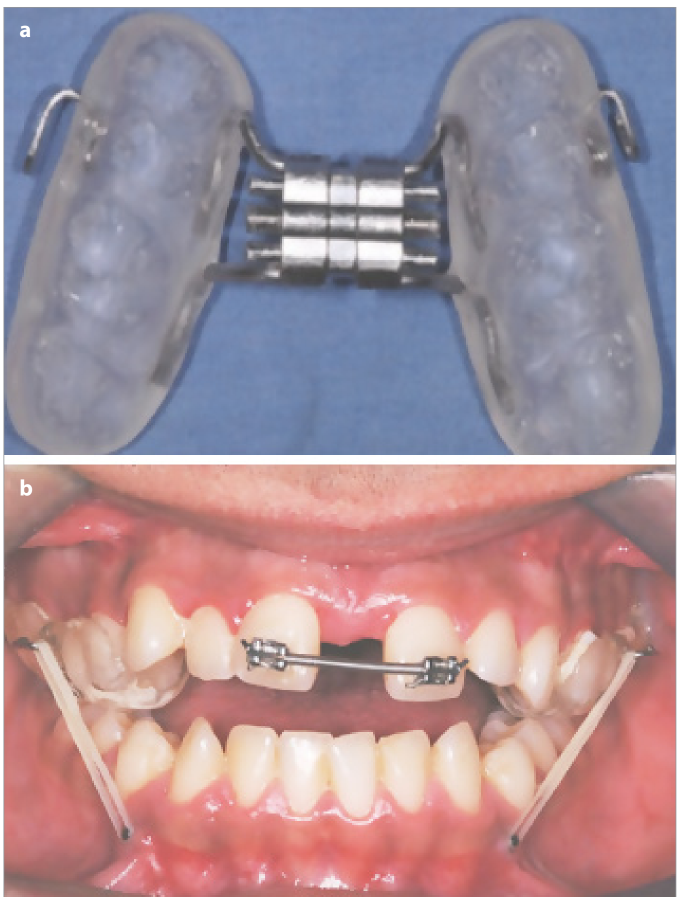

Figure 1. a, b. Modified Hyrax appliance used for expansion (a). Application of intermaxillary Class III elastics through expansion appliance and miniscrews placed between mandibular canine and premolar teeth (b).

METHODS

Subjects

The study was approved by the ethics committee of Ankara University (IRB approval no.: B.30.3.ANK.0.21.63.00/824-02/9-8/126-2592). Informed consent was obtained from all patients prior to participation in the study. Sample size was calculated using the G*power 3.0.10 program (Universität Düsseldorf, Germany). Considering an alpha significance level of 0.05 and a statistical power of 0.80, the study required at least 14 patients. A total of 15 (1 female and 14 male) patients were included in the study (Table 1). The mean age of the patients was 19.58 years. The patients included in the study were either in the latest growth stages or had completed growth according to the Greulich–Pyle hand–wrist atlas (17). They were all borderline orthognathic surgery subjects with skeletal Class III malocclusion and severe transverse maxillary deficiency with maxillary retrognathia.

1. Inclusion criteria were as follows:
2. posterior bilateral crossbite with skeletal involvement,
3. presence of Class III malocclusion associated with maxillary retrusion,
4. absence of congenital anomalies,
5. healthy periodontal status,
6. no history of orthodontic or surgical treatments prior to expansion.

Treatment Protocol

An occlusal-coverage modified Hyrax-type palatal expander was used in all patients. Stainless steel hooks 1 mm in thickness were embedded into the vulcanite on the buccal region of the palatal expander between premolar teeth (Figure 1).

All patients underwent SARME under general anesthesia performed by the same surgical team. The incisions were bilaterally performed at the depth of the vestibule. The mucoperiosteum was then elevated, and the maxillary bone was exposed from the pyriform aperture anteriorly to the pterygomaxillary fissure posteriorly. The pterygoid plates were separated from the maxilla. An additional vertical incision parallel to the labial frenulum was performed, and the maxilla was separated by malleting a thin osteotome through the suture between the maxillary central incisors.

While still under anesthesia, each patient received AbsoAnchor® Golf Head-type miniscrews (diameter 1.6 mm and length 8 mm; Dentos Inc., Taegu, South Korea) bilaterally between the roots of their mandibular canines and first premolars in attached gingiva and at an angle of 45° to the occlusal plane, as well as Hyrax-type expansion appliances. After 24 h postoperatively, ex-

Table 1. Chronological ages of the patients and mean treatment times between treatment periods

Chronological Ages	Minimum Age (year)	Maximum Age (year)	Mean Age (year)	Treatment Duration (year)
Pretreatment (T1)	15.25	27.75	19.58	0.25
Post-SARME and elastics (T2)	15.50	28.00	19.83	1
Post-treatment (T3)	16.58	28.83	20.83	1.25
Total (year)				

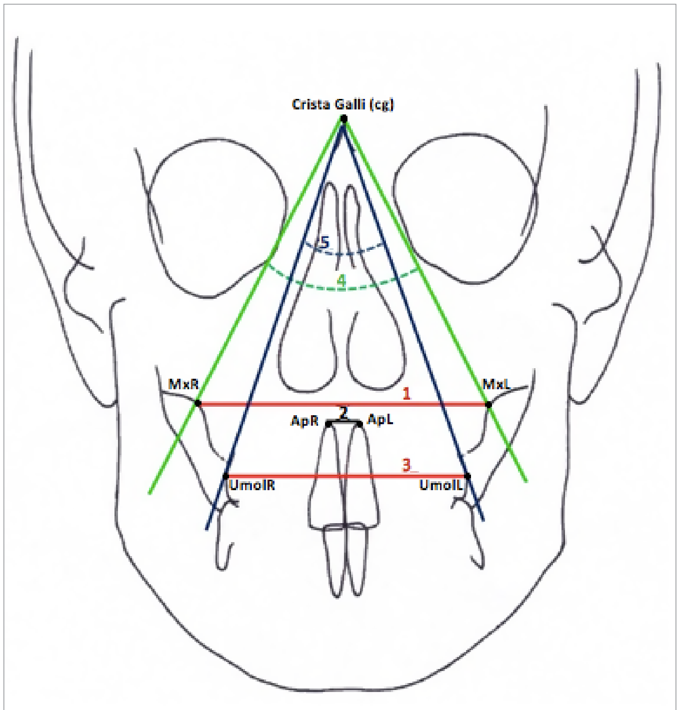

Figure 2. Posteroanterior measurements: 1: MxR-MxL (basal maxillary width), 2: ApR-ApL (linear distances between right and left maxillary central incisor apices), 3: UmolR-UmolL (maxillary dentoalveolar width), 4: MxR/Cg/MxL (angle between crista galli and maxillary base points), 5: UmolR/Cg/UmolL (angle between crista galli and maxillary molar points).

pansion and maxillary advancement processes were initiated by attaching intermaxillary Class III elastics exerting 500 g of force to the miniscrews (Figure 1). The patients and their parents were instructed to activate the screws one turn in the morning and one turn in the evening (0.25 mm per turn). After expansion was complete, two braces were attached to the first incisors, and a 0.016 inch×0.016 inch Nitinol arch wire was applied. Close coil springs were placed between those incisors to prevent retrusion and unrestrained tipping of the incisors. Following this period, the expansion appliances were kept in place passively for 90 days postoperatively, and elastics application was continued.

The patients were then initiated to fixed appliance treatment, and intermaxillary elastics (150 g force) were continued to be applied between the maxillary molar–premolar teeth and the miniscrews. No precaution was taken except working with wide arch wires to preserve maxillary expansion. Three out of 30 miniscrews failed during treatment and were promptly replaced.

Radiological Evaluation

Pretreatment (T1), post-SARME and elastic use (T2), and post-treatment (T3) posteroanterior radiographs and lateral cephalograms were obtained for each patient. Five measurements were also made from posteroanterior radiographs to analyze the transversal changes (Figure 2). A constructed horizontal line was traced in a clockwise direction 7° from the sella-nasion line. This line was considered as the horizontal reference (HR) plane, and perpendicular to the HR plane through the sella point was ac-

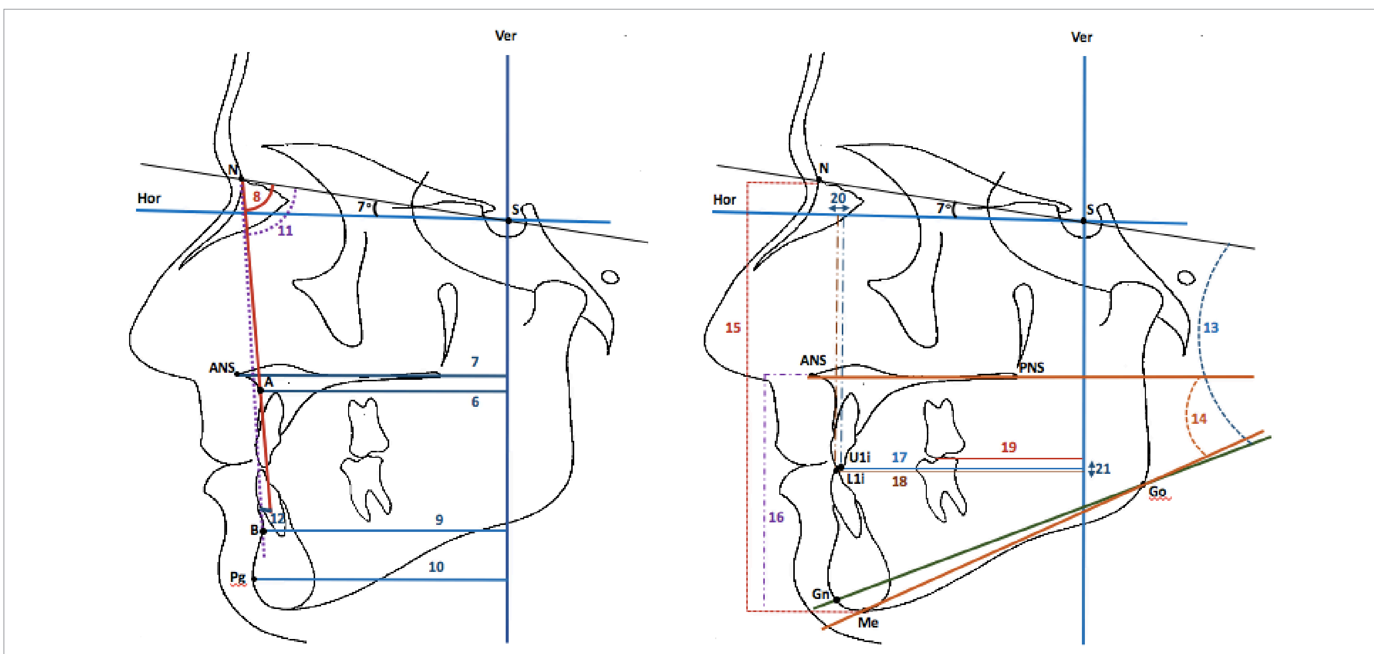

Figure 3. Maxillary skeletal measurements: 6: A-Ver (distance between point A and vertical reference plane), 7: ANS-Ver (distance between anterior nasal spine and vertical reference plane), 8: SNA (posteroinferior angle between anterior cranial base and nasion-point A line). *Mandibular skeletal measurements:* 9: B-Ver (distance between point B and vertical reference plane), 10: Pg-Ver (distance between pogonion and vertical reference plane), 11: SNB (posteroinferior angle between anterior cranial base and nasion-point B line). *Maxillomandibular skeletal measurements:* 12: ANB (angle between nasion-point A and nasion-point B lines). Vertical skeletal measurements: 13: SN/Go-Gn (angle between anterior cranial base and mandibular plane), 14: ANS-PNS/Go-Me (angle between palatal plane and mandibular plane), 15: N-Me (total anterior facial height), 16: ANS-Me (anterior lower facial height). *Dentoalveolar measurements:* 17: U1i-Ver (distance between incisal edge of the upper central incisor and vertical reference plane), 18: L1i-Ver (distance between incisal edge of the lower central incisor and vertical reference plane), 19: U6-Ver (distance between upper first molar and vertical reference plane), 20: overjet, 21: overbite.

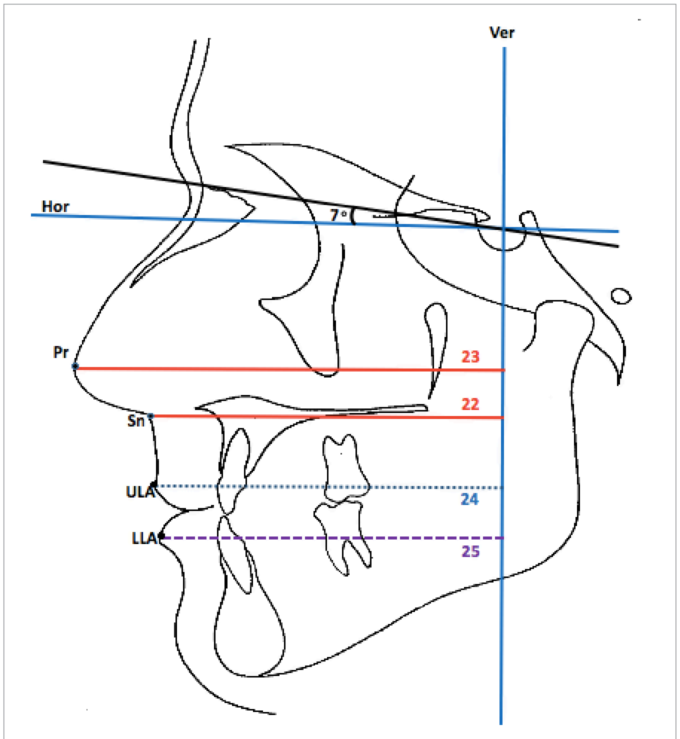

Figure 4. Soft tissue measurements: 22: Sn-Ver (distance between subnasale point and vertical reference plane), 23: Pr-Ver (distance between pronasale point and vertical reference plane), 24: ULA-Ver (distance between the most anterior point of the upper lip and vertical reference plane), 25: LLA-Ver (distance between the most anterior point of the lower lip and vertical reference plane)

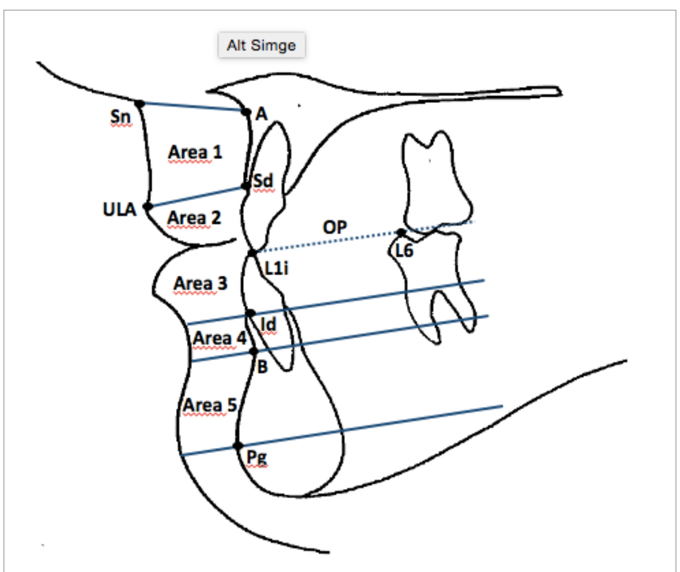

Figure 5. Planimetric area measurements: The upper lip was divided into two parts (Areas 1 and 2). 26: Area 1: superior upper labial area; the area between point A, subnasal, upper lip anterior, and supradental point. 27: Area 2: inferior upper labial area; the area below supradental and upper lip anterior line. The lower lip was divided into three parts (Areas 3, 4, and 5) from the incisal edge of the mandibular central incisor (L1i), infradentale (Id), point B, and pogonion point. Lines dividing the lower lip area were constructed parallel to the mandibular occlusal plane. 28: Area 3: superior lower labial area, 29: Area 4: middle lower labial area, 30: Area 5: inferior lower labial area

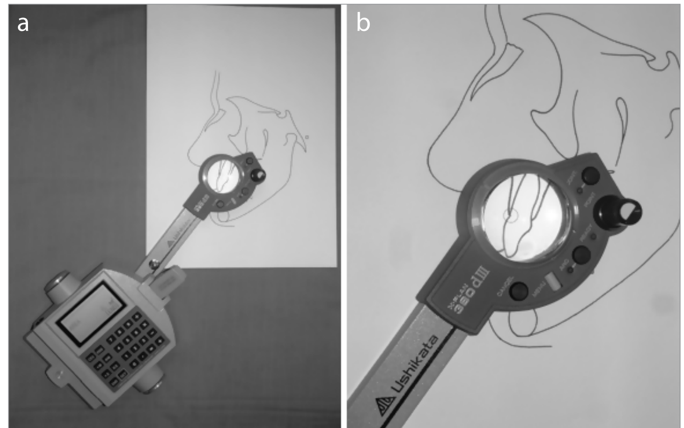

Figure 6. a, b. (a) Digital planimeter. (b) Measurement of the areas using the digital planimeter (18)

cepted as the vertical reference plane (Ver). The presented cephalometric hard tissue (Figure 3) and soft tissue (Figure 4) measurements were made from lateral cephalograms using PorDios (Purpose on Request Digitizer Input Output System, trademark of the Institute of Orthodontic Computer Science, Aarhus, Denmark) cephalometric analysis program.

Changes in labial areas were evaluated by dividing the lip region into five sections (Figure 5) (18). Labial area measurements were also made from cephalometric charts using a digital planimeter (Ushikata X-PLAN380 dll/460 dll, Tokyo, Japan). To achieve this, the cephalometric films were transferred onto paper using a 0.3 mm pencil, and the specified areas were marked (Figure 6).

Statistical Analysis

Statistical analyses were performed using the Statistical Package for Social Sciences (IBM Corp.; Armonk, NY, USA) version 20.0. Descriptive statistics were calculated for all measurements, as well as the between-stage changes. The correlation coefficients were calculated to assess the reliability of the method. Wilcoxon signed-rank test was used to compare T2–T1, T3–T2, and T3–T1 changes of cephalometric and posteroanterior measurements.

RESULTS

Lateral cephalometric and posteroanterior radiographs of eight patients were randomly selected. All measurements were digitized twice by the same observer at an interval of 1 month to determine intraobserver variability. The reliability of the method was high, with correlation coefficients ranging between 0.81 and 1.

Changes in Posteroanterior Radiographic Measurements

Posteroanterior radiographs obtained during the expansion phase (T1–T2) revealed significant increases in the MxR-MxL, UMolR-UMolL, and ApR-ApL distances ($p<0.01$) and MxR/Cg/MxL ($p<0.01$) and UmolR/Cg/UmolL angles ($p<0.05$), which indicate tipping of the maxillary segments and of the maxillary molars. Although significant decreases were observed in the dental parameters ($p<0.05$) during the T3–T2 period, permanent maxillary expansion was provided at both the skeletal and dental levels at the end of the treatment period ($p<0.01$; Table 2).

Table 2. Mean pretreatment (T1) values of posteroanterior parameters and the changes occured during SARME and elastic use (A; T2-T1); between SARME and elastic use and posttreatment periods (B; T3-T2); pretreatment and posttreatment periods (C; T3-T1) by Wilcoxon Sign Test

	T1	T2-T1		T3-T2		T3-T1	
Parameters	**X ±Sx**	**D ± Sd**	**Test**	**D ± Sd**	**Test**	**D ± Sd**	**Test**
Posteroanterıor Measurements							
1. MxR-MxL (mm)	65.22±1.00	3.18±0.59	**	-0.12±0.37		3.07±0.59	**
2. ApR-ApL (mm)	6.82±0.35	3.58±0.64	**	-2.37±0.63	*	1.21±0.40	*
3. UmolR-UmolL (mm)	60.48±1.40	6.78±0.81	**	-1.91±0.75	*	4.87±0.67	**
4. MxR/cg/MxL (°)	58.2±1.31	3.43±0.66	**	-0.58±0.50		2.84±0.60	**
5. UmolR/cg/UmolL (°)	42.76±0.98	4.58±0.59	*	-3.22±0.64	*	1.36±0.52	**

X: mean value, Sx: the error of mean; D: mean values of differences, Sd: Standard deviation
*p<0.05; **p<0.01; ***p<0.001.

Table 3. Mean pretreatment (T1) values of cephalometric skeletal/dentoalveolar parameters and changes occurring during SARME and elastic use (A; T2-T1); between SARME and elastic use and posttreatment periods (B; T3-T2); pretreatment and posttreatment periods (C; T3-T1) by Wilcoxon Sign Test

	T1	T2-T1		T3-T2		T3-T1	
PARAMETERS	**X±Sx**	**D±Sd**	**Test**	**D±Sd**	**Test**	**D±Sd**	**Test**
MAXILLARY SKELETAL MEASUREMENTS							
6. A-Ver (mm)	68.08±1.30	0.20±0.41		0.14±0.38		0.34±0.58	
7. ANS-Ver (mm)	75.91±1.40	1.11±0.48	*	1.10±0.30	**	2.21±0.53	**
8. SNA (°)	78.65±1.04	0.14±0.30		−0.47±0.33		−0.33±0.33	
MANDIBULAR SKELETAL MEASUREMENTS							
9. B-Ver (mm)	65.81±2.02	−1.24±0.56	*	0.98±0.73		-0.26±1.07	
10. Pg-Ver (mm)	66.66±2.37	−1.62±0.61	*	1.52±0.85		-0.10±1.13	
11. SNB (°)	79.36±1.04	−0.64±0.23	*	0.12±0.31		−0.52±0.42	
MAXILLO–MANDIBULAR SKELETAL MEASUREMENTS							
12. ANB (°)	−0.71±0.66	0.78±0.26	*	−0.59±0.34		0.19±0.35	
VERTICAL SKELETAL MEASUREMENTS							
13. SN/Go-Gn (°)	38.25±1.26	1.57±0.52	*	−1.09±0.56		0.47±0.72	
14. ANS-PNS/Go-Me (°)	28.52±1.52	0.94±0.40	*	0.52±0.28		1.46±0.40	**
15. N-Me (mm)	1.37±0.49 ±.27	2.86±0.55	**	0.01±0.59		2.87±0.78	**
16. ANS-Me (mm)	78.87±1.95	2.17±0.52	**	1.07±0.52		3.25±0.56	**
DENTOALVEOLAR MEASUREMENTS							
17. U1i-Ver (mm)	70.42±1.54	0.35±0.43		2.06±0.71	**	2.41±0.78	**
18. L1i-Ver (mm)	70.9±1.70	−0.98±0.47		0.79±0.76		−0.19±1.01	
19. U6-Ver (mm)	37.91±1.25	1.21±0.41	*	2.33±0.74	*	3.54±0.82	**
20. Overjet (mm)	−0.62±0.53	1.05±0.31	**	1.80±0.53	**	2.85±0.68	**
21. Overbite (mm)	−0.67±0.47	−1.17±0.44	*	2.32±0.57	**	1.14±0.56	

X: mean value, Sx: error of mean; D: mean values of differences, Sd: Standard deviation
*p<0.05; **p< 0.01; ***p< 0.001.

Changes in Lateral Cephalometric Measurements

Maxillomandibular Changes

The ANS-Ver value increased significantly in all treatment periods, indicating anterior movement of the anterior nasal spine. Significant changes were also observed in SNB, B-Ver, and Pg-Ver values and ANB in the T2–T1 period ($p<0.05$; Table 3).

Vertical Changes

Significant increases were observed in the ANS-PNS/Go-Me angle, then in the N-Me and ANS-Me values, ($p<0.01$), and in the Go-Gn/SN angle ($p<0.05$), indicating the posterior rotation of the mandible and the increase of the anterior facial height (Table 3).

Dental Changes

The incisal edge of the maxillary central incisor moved anteriorly in the T3–T2 and T3–T1 periods (U1i-Ver; $p<0.01$), whereas the sagittal position of the mandibular incisor (L1i-Ver) did not change significantly. Maxillary first molar also moved anteriorly in all time points (U6-Ver). Both overjet and overbite increased at the end of the treatment ($p<0.01$; Table 3).

Table 4. Mean pretreatment (T1) values of soft tissue parameters and changes occurring during SARME and elastic use (A; T2-T1); between SARME and elastic use and posttreatment periods (B; T3-T2); pretreatment and posttreatment periods (C; T3-T1) by Wilcoxon Sign Test

	T1	T2-T1		T3-T2		T3-T1	
PARAMETERS	X±Sx	D±Sd	Test	D±Sd	Test	D±Sd	Test
SOFT TISSUE MEASUREMENTS							
22. Sn-Ver (mm)	87.85±1.51	0.79±0.38	*	1.01±0.43	*	1.80±0.61	**
23. Pr-Ver (mm)	105.97±1.46	1.04±0.51	*	1.06±0.35	**	2.10±0.71	**
24. ULA-Ver (mm)	88.39±1.77	−0.90±0.61		2.34±0.71	**	1.45±0.57	*
25. LLA-Ver (mm)	87.41±1.93	−1.11±0.48	*	1.68±0.65	*	0.57±0.91	
SOFT TISSUE AREA MEASUREMENTS							
26. AREA 1 (mm^2)	220.61±48.10	7.21±27.52		27.26±46.75	*	30.48±42.62	
27. AREA 2 (mm^2)	114.04±36.51	−2.49±24.80		−8.75±19.91		−11.25±23.79	
28. AREA 3 (mm^2)	178.52±26.11	9.43±24.28		-16.14±23.65	*	−6.7±20.37	
29. AREA 4 (mm^2)	134.02±65.67	13.64±61.28		−4.34±68.91		9.29±35.91	
30. AREA 5 (mm^2)	218.73±53.34	12.58±31.54		8.47±38.41		21.05±21.05	

X: mean value, Sx: error of mean; D: mean values of differences, Sd: Standard deviation
*p< 0.05; **p< 0.01; ***p< 0.001.

Table 5. Summary of the relationship between linear soft tissue and skeletal tissue changes of maxillary–mandibular components and upper–lower lip areas between posttreatment and pretreatment periods (T3-T1)

		Hard Tissue		Soft Tissue	
Area	D		D		D
Maxillary Variables					
AREA 1 (mm^2)	30.48*	SNA (°)	−0.33	Pr-Ver (mm)	2.1
		A-Ver (mm)	0.34	Sn-Ver (mm)	1.81
		ANS-Ver (mm)	2.21**		
AREA 2 (mm^2)	−11.25	U1i-Ver(mm)	2.41**	ULA-Ver (mm)	1.45*
Mandibular and Maxillomandibular Variables					
AREA 3 (mm^2)	−6.7	L1i-Ver (mm)	−0.2	LLA-Ver (mm)	0.57
		ANS-Me (mm)	3.24**		
AREA 4 (mm^2)	9.29	B-Ver (mm)	−0.26		
AREA 5 (mm^2)	21.05	Pg-Ver (mm)	−0.10		

D: mean values of differences; *p< 0.05; **p< 0.01; ***p< 0.001

Soft Tissue Changes

The tip of the nose (Pr-Ver) and the subnasale point (Sn-Ver) moved forward in all observation stages (Table 4). The anterior movement of the upper lip (ULA-Ver) was also significant in the T3–T2 ($p<0.01$) and T3–T1 ($p<0.05$) periods (Table 4). The lower lip (LLA-Ver) moved significantly at the posterior direction during the expansion period ($p<0.05$; T2–T1), whereas an anterior movement was observed during the fixed treatment (T3–T2) period ($p<0.05$; Table 4).

Changes in Lip Area Measurements

Area 1 (superior upper lip area) did not change significantly between T2 and T1, whereas significant increases were observed in the T3–T2 and T3–T1 periods ($p<0.05$; Table 4). Area 3 (superior lower lip area) significantly decreased between T3 and T2 ($p<0.05$; Table 4).

The summary of the correlation between linear soft and skeletal tissue changes of maxillary–mandibular components and upper–lower lip areas between pre- and posttreatment periods (T3–T1) is presented in Table 5. It could be summarized that the increase in Area 1 is related with the forward movement of ANS and maxillary incisors, whereas the decrease in Area 3 could be correlated with the increase in anterior facial height (ANS-Me).

DISCUSSION

SARME is the primary surgical approach for adults with maxillary transverse deficiency (19). Some previous studies reported that SARME can also be applied in younger individuals to stimulate maxillary protraction (11-13). Küçükkeleş et al. (13) applied face mask together with Le Fort I osteotomy in adolescent patients to enhance the protraction effect. They compared the results of this approach with RME+face mask and claimed that Le Fort I+face mask results in significantly more advancement. There are also studies examining the effects of temporary anchorage devices for maxillary protraction (14-16). However, to our knowledge, there is no study evaluating the effects of intermaxillary Class III elastics simultaneously with SARME in adult patients. Therefore, the purpose of the present study was to evaluate whether simultaneous maxillary expansion and advancement could be achieved with a single surgical procedure and an intraoral anchorage system.

An occlusal-coverage bonded palatal expander was used for all patients in the present study. Toygar Memikoğlu et al. (20) claimed that although satisfactory treatment results can be achieved with both bonded and banded palatal expanders, dentoalveolar response is more with banded appliances. Therefore, a bonded appliance that was acrylic-coated on the occlusal surfaces was used to prevent dental effects.

In the present study, posteroanterior radiographs obtained during the expansion phase indicated tipping of the maxillary segments and of the maxillary molars, respectively. During fixed treatment, decreases were observed in these parameters. The statistically nonsignificant decrease in the MxR/Cg/MxL angle also demonstrates that the expansion achieved in our study was stable at the skeletal level. Based on these results, it can be concluded that the primary goal of the present study was successfully achieved as permanent maxillary expansion was provided at both the skeletal and dental levels. These findings are consistent with previous long-term studies on RME and SARME (21, 22)

According to the results of the present study, there were no significant differences in parameters associated with the position of point A, whereas ANS moved forward 1.11 mm in the T2–T1 period (Table 3). Vardimon et al. (23) attributed high relapse rates following maxillary expansions with 90-day retention to the new bone being immature and easily resorbed under pressure. These bony changes have a direct effect on the position of point A. We also left the devices for an average of 3 months for retention. Therefore, the inability to cephalometrically evaluate advancement of point A during the expansion period could be attributed to the appearance of immature bone not showing sufficient radiopacity in that region. However, when we reevaluated maxillary parameters at the end of the treatment, the movement of point A was still insignificant although ANS moved forward 2.21 mm in total ($p<0.01$; Table 3). In our study groups, the pterygoid processes were separated during surgery, which hypothetically should facilitate the forward movement of the maxilla. Studies by Biederman (24) and Liou (25) revealed that surgical weakening of the pterygoid processes may have caused their resorption during expansion, or the maxilla may have expanded in a more parallel direction instead of a V-shape. In fact, the 6.78 mm increase between the maxillary molars (UmolR-UmolL) and the 3.58 mm increase between the maxillary central incisors (ApR-ApL) demonstrate that the posterior region expanded more than the anterior region (Table 2). We believe that these findings corroborate why point A did not show as much advancement as expected in the long term. The position of point A may also be influenced by local remodeling associated with the proclination of upper incisors (26, 27). It should be noted that significant protrusion of upper incisors was observed in the present study (Table 3). The insignificantly mild retrusion of point A observed in our study may also be explained by the proclination of upper incisors with backward movement of incisor root apexes.

Although these changes in maxillary skeletal parameters may introduce uncertainty regarding the success of maxillary advancement, we observed favorable changes in the profiles of patients included in the study. Based on soft tissue measurements, significant increases were observed in the pronasale and subnasale points. Changes in both of these parameters can be associated with forward movement of the anterior nasal spine. Although we observed a statistically nonsignificant retrusion in the upper lip during the expansion and protraction period, protrusion in the fixed treatment period was significantly consistent with maxillary incisor movement. Previous studies have shown that lip thickness and position can be affected by incisor movement (28, 29). Consistent with these changes, Area 1, representing the superior upper lip area, increased significantly in the T3–T2 and T3–T1 periods. In a study using similar methods to analyze soft tissue changes following bimaxillary surgery, Altug-Atac et al. (18) reported substantial increases in Pr and Sn points, but in contrast to our findings observed a decrease in Area 1. They attributed this to compression of the lip area due to significant forward movement of the maxilla and point A caused by Le Fort I surgery. Although advancement of the maxilla as a whole may compress soft tissue in patients undergoing orthognathic surgery, the more restricted movement in our study and the aforementioned immature structure may explain why we observed an increase in Area 1 (Table 4).

In our assessment of the lower lip position, although lower lip significantly retruded during the expansion and protraction period, a slight protrusion was observed during the fixed orthodontic treatment period. This change in lower lip position may be due to the position of lower incisor showing mild retrusion between T2 and T1 and protrusion between T3 and T2 periods or may be associated with increases in the vertical facial dimensions occurring during the expansion and protraction period. Area 3, representing the superior lower lip, decreased significantly between T3 and T2. The soft and flexible structure of the lower lip makes it easily affected by tooth movements and musculature (30). In addition to the changes observed in the vertical dimension, we believe that the lip may show backward movement due to the favorable changes in overjet and overbite at the end of the treatment. According to our results, correction of the dental relationship in particular resulted in curling of the superior aspect of the lower lip, which created favorable profile changes in our patients (Table 5).

Another treatment option for adult patients with skeletal Class III malocclusion who are not willing to undergo Le Fort-maxillary advancement surgery is camouflage treatment. The results of the present study could also be interpreted as a camouflage due to the protrusion of maxillary incisors during the fixed orthodontic treatment stage. Additionally, we observed maxillary molar mesialization all through the treatment stages. One of the most favorable findings of the study could be defined as achieving the mesial movement of maxillary dental arch without any undesirable mandibular incisor retrusion. It is well-known that the undesirable movement of mandibular incisors inside the narrow symphysis of the mandibles of Class III subjects could solely cause additional dental complications. Therefore, the application of Class III elastics through miniscrews should get all the credit in avoiding these unfavorable dental movements.

Figure 4. a-e. Photos of a patient treated with SARME/intermaxillary Class III elastic procedure and fixed orthodontic treatment. (a) Pretreatment (T1) extraoral photos. (b) Posttreatment (T3) extraoral photos. (c) Pretreatment (T1) intraoral photos. (d) Post-SARME and elastic use (T2) intraoral photos. (e) Posttreatment (T3) intraoral photos

CONCLUSION

The patients included in our study were borderline orthognathic surgical cases. A successful maxillary expansion was achieved in all subjects at the skeletal level. There was no need for a secondary and more likely a bimaxillary surgery in any of the subjects with the application of Class III elastics and SARME (Figure 7). Significant forward movement of the ANS and midfacial soft tissues provided a positive answer to our null hypothesis of whether SARME and Class III elastics applied simultaneously can stimulate maxillary advancement.

Nevertheless, if this procedure is considered in patients with maxillary transverse deficiency and retrusion, patient selection must be conducted carefully, and the patient and their family should be informed of the possibility of a second surgery.

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethics Committee of Ankara University (IRB approval no.: B.30.3.ANK.0.21.63.00/824-02/9-8/126-2592).

Informed Consent: Written informed consent was obtained from the subjects who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - A.T.A.; Design - A.T.A.; Data Collection and/or Processing - E.B.Ş., K.C.E., H.A.K.; Analysis and/or Interpretation - E.B.Ş., E.C.; Literature Search - E.B.Ş., E.C., A.T.A., U.T.M.; Writing Manuscript - E.B.Ş., E.C.; Critical Review - A.T.A., U.T.M.

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

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ORIGINAL ARTICLE

Effect of Oral Submucous Fibrosis on Jaw Dimensions

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ABSTRACT

Objective: The disuse of the jaws owing to the restricted movement of the mandible in advanced cases of oral submucous fibrosis (OSMF) may have an effect on the morphologic features of the jaw bones. The purpose of the present study was to determine the jaw bone measurements in patients with OSMF and to compare the measurements in normal subjects and Caucasian norms.

Methods: The lateral cephalograms of 59 subjects (43 males and 16 females) with OSMF and 44 normal subjects (23 males and 21 females) in the age group of 18–45 years were collected. The jaw measurements were performed using Burstone analysis, and the relevant linear measurements of jaw sizes included were N-A, N-B, N-ANS, ANS-PNS, ANS-Gn, Ar-Go, and Pg-Go. The sex-wise comparison was performed using unpaired t-test, and measurements were compared with other studies using Z test.

Results: In the present study, sex-wise comparison was found to be significant with greater jaw measurements in males than in females in patients with OSMF. Overall, the measurements were less or equal in patients with OSMF than in normal subjects except for N-ANS and Pg-Go. When study measurements were compared with Burstone measurements, differences were significant with greater and less measurements.

Conclusion: Overall, the jaw measurements were less or equal in patients with OSMF than in normal subjects except for mandibular body length and middle third facial height that may need further evaluation.

Keywords: Oral submucous fibrosis, burstone analysis, lateral cephalograms, linear jaw measurements

INTRODUCTION

Oral submucous fibrosis (OSMF) is a chronic premalignant condition that affects various portions of the oral cavity, as well as the pharynx. The prevalence of OSMF is higher in southeast Asia, South Africa, and Middle East regions. OSMF causes progressive fibrosis of submucosal tissues and juxta-epithelial inflammatory reactions leading to stiffness of the oral mucosa. In severe cases, the mouth opening may become restricted partially or completely (1, 2).

The disuse of the jaws owing to the restricted movement of the mandible may have an effect on the morphologic and biomechanical features of the jaw bones, joints, and muscles (3-5). One of the factors that influence the form and structure of the bone is its mechanical loading. It is well documented that if a bone or muscle is not used for a large interval of time, then disuse atrophy may occur. Contrarily, hyperfunction or increased demand due to increased masticatory forces should lead to hypertrophy. The bone undergoes continuous formation and resorption to achieve its function. In the adult skeleton, the bony homeostasis is maintained when these two processes are in balance. Thus, the remodeling of the bone in response to mechanical loading on the bone can regulate bone resorption, and formation maintains its form/shape and bone mass (amount of bone). The significant restriction of jaw movement or immobilization may stimulate resorption and suppress bone formation (3-8).

In view of this, the present study was conducted in patients with OSMF to assess the amount or size of the maxillary and mandibular jaw bones with regard to their linear measurement to determine whether the reduction

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in jaw bone movements due to fibrosis has any influence on the size of the jaw bones. This may predict whether mandibular jaw hypomobility can be a forerunner of altered jaw dimensions in patients with OSMF.

Accordingly, the present study intended to determine the linear measurements of the maxilla and mandible in patients with OSMF with their sex-wise comparisons. In addition, the measurements in patients with OSMF were compared with the linear measurements of the maxilla and mandible in normal subjects and Caucasian norms.

METHODS

The study was approved by the ethics committee. The study was conducted in the Department of Oral Medicine and Radiology, Sharad Pawar Dental College and Hospital, DMIMS DU, Sawangi-M, Wardha, Maharashtra, India. The study participants were recruited from the outpatient department of the hospital. A total of 59 clinically diagnosed cases of patients with OSMF were included in the study based on their clinical findings and relevant habit history.

For measurements, the lateral cephalograms were obtained. The measurements were performed using Burstone hard tissue analysis of cephalometrics (9, 10) on skeletal profile. The lateral cephalometric radiographs were collected in a standardized manner in centric occlusion with the Frankfort horizontal plane (HP) oriented horizontally using a Planmeca ProLine CC machine (Windows Vista (R) SP1, 32 bit; Helsinki, Finland). The study intended to measure the maxillary and mandibular jaw sizes, and the linear measurements relevant to the study were measured. The measurements included in the study were N-A (linear), N-B (linear), N-ANS (linear), ANS-Gn (linear), ANS-PNS (linear), Ar-Go (linear), and Pg-Go (linear). The baseline used in Burstone analysis is the HP constructed by drawing a line intersecting at N 7° from the Sella-Nasion plane; the measurements in this analysis are made either parallel to or perpendicular to this plane. The various included landmarks (Figures 1, 2) relevant to the study were (10-14):

- Nasion (N)—the most anterior point of the nasofrontal suture in the midsagittal plane,
- Anterior nasal spine (ANS)—the anterior-most midsagittal point on the tip of the sharp bony process of the maxilla,
- Subspinale (A)—the deepest midsagittal point on the concavity between ANS and prosthion,
- Supramentale (B)—the deepest point in the midsagittal plane on the concavity between infradentale and pogonion,
- Posterior nasal spine (PNS)—the most posterior point on the contour of the palate,
- Articulare (Ar)—the intersection of the sphenoid and the posterior border of the condyle,
- Gonion (Go)—constructed by bisecting the posterior ramal plane and mandibular plane,
- Gnathion (Gn)—constructed by bisecting the facial plane and tangent to the lower border of the mandible.

N-A measurement describes the position of the apical base of the maxilla in relation to nasion. To measure this, perpendicular to the HP is dropped from N (N perpendicular), and horizontal distance parallel to the HP is measured from point A.

N-B measurement describes the position of the apical base of the mandible in relation to nasion. It is obtained by measuring the distance between point B and nasion perpendicular (N perpendicular) parallel to the HP.

N-ANS measurement describes the distance between N and ANS measured perpendicular to the HP providing the middle third facial height.

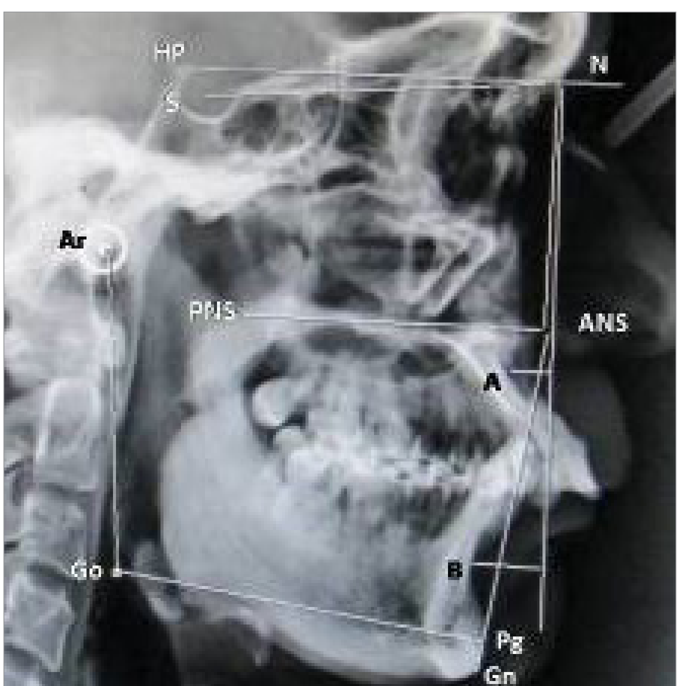

Figure 1. Cephalometric landmarks and plane in Burstone analysis

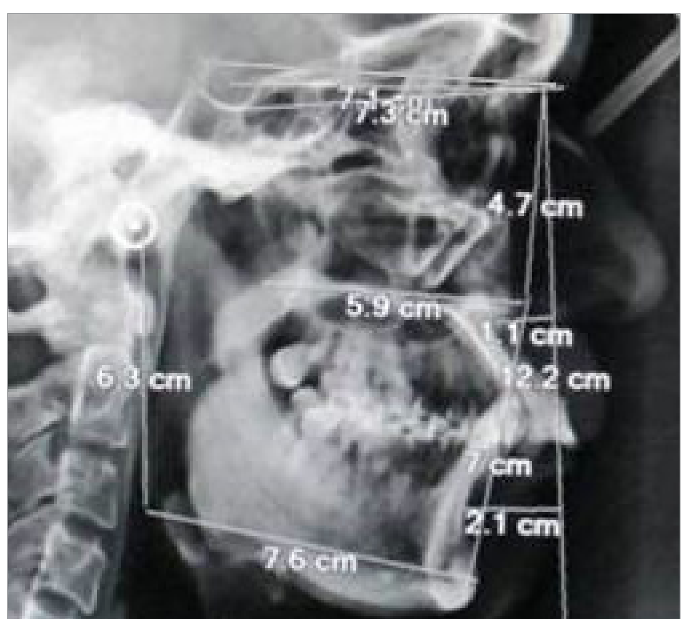

Figure 2. Jaw bone measurements in Burstone analysis

ANS-Gn measurement describes the distance between ANS and Gn measured perpendicular to the HP providing the lower third facial height.

ANS-PNS measurement describes the distance between these two points measuring the total effective maxillary length.

Ar-Go measurement describes the linear distance between articulare and gonion providing the mandibular ramal length.

Pg-Go measurement describes the linear distance between gonion and pogonion providing the mandibular body length.

The measurements were recorded in millimeters. The recorded measurements were tabulated and subjected for statistical analysis.

Statistical analysis was performed using Statistical Package for Social Sciences version 21.0 (IBM Corp.; Armonk, NY, USA). Z test was used for comparison between the studies. Student's unpaired t-test was used for sex-wise comparison. A P (probability) value ≤0.05 was considered as statistically significant.

RESULTS

In the present study, sex-wise comparison was found to be significant (P values: N-A: 0.001, N-B: 0.009, ANS-Gn: 0.003, ANS-PNS: 0.002, Pg-Go: 0.01, and Ar-Go: 0.0001) in patients with OSMF for all the measurements except for N-ANS. The measurements were greater in OSMF males than in OSMF females (Table 1).

When the measurements in patients with OSMF were compared with normal subjects, there were significant differences in measurements for N-ANS (significant Z values: 5.76 and 2.67), ANS-Gn (significant Z values: 7.31 and 5.28), Ar-Go (significant Z values: 10.1 and 9.18), and Pg-Go (significant Z values: 0.31 and 12.32) in both males and females, respectively. When the measurements were compared, the values were less in OSMF females than in normal females except for Pg-Go measurements. Overall, OSMF males had less measurement than normal males except for N-ANS and Pg-Go (Table 2).

When the measurements in patients with OSMF were compared with Burstone measurements in the Caucasian population, differences in values were significant (significant Z values: N-A: 5.89

Table 1. Sex-wise comparisons of mean values of linear jaw measurements in patients with OSMF

	Student's unpaired t-test						
	Sex	**N**	**Mean**	**Std. deviation**	**Std. error of the mean**	**t-Value**	**p**
N-A	Male	43	1.17	3.01	0.06322	5.51	0.001, S
	Female	16	0.9	1.01	0.10898		
N-B	Male	43	5.1	4.91	0.16707	2.68	0.009, S
	Female	16	4.40	4.81	0.36021		
N-ANS	Male	43	56.6	1.21250	0.18491	0.58	0.56, NS
	Female	16	54.3	1.69601	0.42400		
ANS-Gn	Male	43	66.6	0.53006	0.08083	3.08	0.003, S
	Female	16	61.4	0.66448	0.16612		
ANS-PNS	Male	43	54.1	0.44262	0.06750	3.27	0.002, S
	Female	16	50.1	0.34852	0.08713		
Pg-Go	Male	43	80.1	0.57645	0.08791	2.68	0.010, S
	Female	16	75.5	0.61331	0.15333		
Ar-Go	Male	43	56.0	0.49923	0.07613	4.18	0.0001, S
	Female	16	48.4	0.85851	0.21463		

Table 2. Comparisons of mean values of linear jaw measurements between patients with OSMF and normal subjects

	Male			Female		
	Normal	**OSMF**	**Z value**	**Normal**	**OSMF**	**Z value**
N-A	2.15±1.05	1.17±3.01	0.42	1.22±1.41	0.9±1.01	1.92*
N-B	5.51±0.50	5.1±4.91	1.06	5.41±0.35	4.4±4.81	1.59
N-ANS	48.4±0.80	56.6±1.21	5.76*	55.9±0.23	54.3±1.69	2.67*
ANS-Gn	69.0±0.95	66.6±0.53	7.31*	83.7±0.68	61.4±0.66	5.28*
ANS-PNS	55.9±0.40	54.1±0.44	0.4	59.0±0.49	50.1±0.34	2.78*
Pg-Go	59.4±1.40	80.1±0.57	10.1*	55.3±1.01	75.5±0.61	9.18*
Ar-Go	56.7±0.79	56±0.49	0.31*	69.0±1.32	48.4±0.85	12.42*

*Indicates significant Z value.

Table 3. Comparisons of mean values of linear jaw measurements between the present study and Burstone measurements

	Male			Female		
	Burstone	Present study	Z value	Burstone	Present study	Z value
N-A	0±3.7	1.17±3.01	5.89*	−2±3.7	0.9±1.01	7.44*
N-B	−5.3±6.7	5.4±4.91	8.12*	−6.9±4.3	4.4±4.81	13.34*
N-ANS	54.7±3.2	56.6±1.21	2.17*	50±2.4	54.3±1.69	5.73*
ANS-Gn	68.6±3.8	66.6±0.53	1.96*	61.1±3.3	61.4±0.66	0.34
ANS-PNS	57.7±2.5	54.1±0.442	5.36*	52.6±3.5	50.1±0.34	2.75*
Pg-Go	83.7±4.6	80.1±0.576	2.92*	74.8±5.8	75.5±0.61	0.46
Ar-Go	52±4.2	56±0.499	3.55*	46.2±5.8	48.4±0.85	1.45

*Indicates significant Z value

and 7.44, N-B: 8.12 and 13.34, N-ANS: 2.17 and 5.73, and ANS-PNS: 5.36 and 2.75) in males and females except for ANS-Gn, Ar-Go, and Pg-Go in females. The values in patients with OSMF were greater for N-A, N-B, N-ANS, and Ar-Go and less for ANS-Gn, ANS-PNS, and Pg-Go than those in the Caucasian population in both males and females (Table 3).

DISCUSSION

The present study assessed the linear measurements of the jaw bones (maxilla and mandible) to determine jaw bone sizes in patients with OSMF. The study conducted sex-wise comparisons and comparisons with measurements in normal subjects and Burstone study. In the present study, the measurements were significantly higher in males than in females in patients with OSMF, suggesting greater dimensions of the jaw bone in males than in females.

Overall, the measurements were equal or less in patients with OSMF than in normal subjects except for N-ANS and Pg-Go (Table 2). Thus, the middle third facial height and mandibular body length were greater in patients with OSMF than in normal subjects. The total effective maxillary length and lower third facial height were smaller, and mandibular ramal length was more or less equal in OSMF males than in normal males. The middle third facial height, total effective maxillary length, lower third facial height, and mandibular ramal length were smaller in OSMF females than in normal females.

There was a significant difference between Burstone measurements in the Caucasian population and present study measurements in patients with OSMF except for ANS-Gn, Ar-Go, and Pg-Go in females. The values in patients with OSMF for measurements were greater for N-A, N-B, N-ANS, and Ar-Go and less for ANS-Gn, ANS-PNS, and Pg-Go than those in the Caucasian population in both males and females. Thus, the comparisons revealed the variable positions of the apical base of the maxilla and mandible in relation to nasion, greater middle third facial height, and ramal length, whereas less lower facial height and total effective maxillary and mandibular length in the Caucasian population (10) (Table 3).

India is one of the most populous countries with regional variations, and demographic and sociocultural characteristics of the communities are too complex and thus incomparable. The normal measurements of a particular locality may not be considered normal for other regions. Hence, the present study also included comparisons of measurements in patients with OSMF with jaw measurements in the normal population simultaneously, and it was observed that the overall measurements were either relatively equal or less than the normal population.

The structure and amount of the bone are determined by genetic blueprint and by various regulatory factors. The ability of the bone to alter its structure and to adapt to mechanical loads entails that mechanical forces can regulate bone turnover or remodeling; increased loads should increase formation, and unloading should have the opposite effect. The action of these factors, hormones, and cytokines on osteoclasts was proposed to be mediated by osteoblast-lineage cells, which possess the cognate receptors intimately linking osteoblast–osteoclast interaction to bone turnover (3-5). It may be anticipated that the restricted jaw movements or immobilization of the jaws in patients with OSMF may stimulate resorption and suppress formation. Although multiple factors probably may be involved in the maintenance of bone homeostasis, the active factor is seen presently in the form of restricted jaw bone movements in patients with OSMF.

The study was conducted to assess the influence of restricted jaw movements on the maxillary and mandibular jaw sizes. The findings in the present study may provide the baseline data for future studies. The variable observations when the jaw measurements in patients with OSMF were compared with normal subjects and the Caucasian population recommend further studies using broader sample size correlating with interincisal width and history of reduced mouth opening, i.e., the degree and years of partial or complete immobilization of the jaws, to reach a definite conclusion.

CONCLUSION

- In patients with OSMF, the measurements were significantly greater in males than in females
- Overall, the measurements were equal or less in patients with OSMF than in normal subjects except for middle third facial height and mandibular body length.
- The comparisons between Burstone measurements and present study measurements in OSMF revealed greater middle third facial height and ramal length, whereas less lower

facial height and total effective maxillary and mandibular length in the Caucasian population.

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethics Committee of Sharad Pawar Dental College and Hospital.

Informed Consent: Written informed consent was obtained from the patients who participated in this study.

Peer-review: Externally peer-reviewed.

Conflict of Interest: The author has no conflict of interest to declare.

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REVIEW

Fixed Orthodontic Retainers: A Review

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ABSTRACT

Orthodontic retention is defined as maintaining teeth in optimal aesthetic and functional position after treatment. Despite the necessity of retention phase and the factors influencing the stability of the teeth after orthodontic treatment was discussed by the orthodontist for a long time, it is accepted that a retention phase is essential for stability of orthodontic treatment results nowadays. Therefore, the application of a suitable retention method is important both for prevention of relapse after orthodontic treatment and for increasing patient satisfaction. Removable appliances had been used for many years for retention purposes. Later, fixed retainers were introduced to prevent relapse as having a number of advantages, such as better aesthetics, no need for patient cooperation, effectiveness, and suitability for lifelong retention. However, their need for precise bonding technique, fragility, and tendency to cause periodontal problems by weakening oral hygiene are some of their disadvantages.

Keywords: Orthodontic retention, tooth stability, relapse, fixed retainer, lifelong retention

INTRODUCTION

Orthodontic retention is defined as maintaining teeth in optimal aesthetic and functional position after treatment (1). Retention is a treatment phase in which clinicians have not come to a consensus and rather shapes through years as the clinician gains experience (2). The necessity of retention phase has even been a debate among orthodontists for years (3). In the 19th century, the most important factor for stability of the teeth after orthodontic treatment was believed to be occlusion. Approaching the 20th century, Lundstrom (4) claimed that the most important factor for stability is apical base, whereas McCauley (5) emphasized the importance of canine and molar relationship. In 1944, Tweed (6) reported that incisor inclination plays a role, and that upright incisors help in maintaining better stability during retention. Nowadays, there is a strong acceptance that a retention phase is crucial for stability of treatment results. Furthermore, lifelong retention is advised in some cases (7).

Removable appliances have been used for many years for retention purposes. In the 1970s, fixed retainers were introduced to prevent relapse in the lower incisor area (8). These retainers that are bonded to the lingual faces of the teeth are increasingly preferred by orthodontists for being both aesthetic and easy to wear by patients for long-term use (9,10)146 boys. In a study published in 2002, it was reported that one-third of orthodontists preferred fixed lingual retainer in the mandible, whereas 5% preferred fixed retainers in the maxilla (11). In another study published in 2011, it was reported that fixed retainers are preferred by 42% of orthodontists in the mandible and 11% of orthodontists in the maxilla (12).

Clinical and Research Consequences

Fixed retainers are most commonly used in the orthodontic retention phase as they have a number of advantages, such as better aesthetics, no need for patient cooperation, effectiveness, and suitability for lifelong retention (13). However, their need for precise bonding technique, fragility, and tendency to cause periodon-

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tal problems by weakening oral hygiene are some of their disadvantages.

In 1965, Newman (14) presented the direct bonding technique of orthodontic attachments. Later, in 1973, Kneirim (15) introduced the use of fixed retainers for orthodontic retention purposes for the first time. The wires that are used in the manufacturing of fixed retainers are categorized into generations since they have been introduced (16). These are the following:

- 1st generation: These are 0.025–0.036 inch blue elgiloy or stainless steel round wires. These are bonded only to lingual surfaces of canines, and loops are bended at each end to increase retention.
- 2nd generation: These are 0.032 inch triple-stranded wires and can be bonded to lingual surfaces of all anterior teeth. These multi-stranded wires substituted plain wires as they have higher elasticity that allows physiological movement of the teeth (17).
- 3rd generation: These are 0.032 inch stainless steel or 0.030 inch gold-coated plain wires. Their ends are sandblasted with aluminum oxide to increase mechanic retention. They are bonded to canines only (18).
- 4th generation: These are 0.0215 inch 5-stranded wires that can be bonded to all anterior teeth.
- 5th generation: These are 0.032 inch, blue elgiloy plain wires that are sandblasted at the ends and bonded to canines only.

At the beginning, plain round or rectangular orthodontic wires were used as fixed retainers (1). In 1977, Zachrisson (19) presented the advantages of using multi-stranded wires as bonded retainers. Then, in 1982, Artun and Zachrisson (20) introduced the technique of bonding multi-stranded wires to canines only. Later, Zachrisson (21) applied triple-stranded wires to all anterior teeth in his studies. However, in his paper where he discussed his experience with fixed retainers for 20 years, he reported that 0.0215 inch 5-stranded wires serve better results based on failure rates observed in follow-up sessions (21) (Figure 1).

In the last 10 years, multi-stranded wires became more popular for bonded fixed retainers (1). Meanwhile, resin fiberglass bands were introduced as an alternative (22, 23). However, although they were more aesthetic and smaller in size, their higher long-term failure rates and inability to allow physiological tooth movements reduced their popularity as a choice for bonded fixed retainers (Figure 2).

In recent years, bonded retainers can be manufactured using CAD–CAM systems. The studies in this area are limited as this is a very new technology. The techniques and types of wires used for manufacturing bonded retainers using CAD–CAM technology vary for each firm. In one of the techniques used, the retainers are produced by bending of prefabricated wires by the handle of a machine. The SureSmile retainer (OraMetrix, Richardson, TX, USA) that is produced by this technique uses copper–nickel–titanium wires (24). Another technique is producing bonded retainers by carving out of a block of wire. The Memotain retainer (CA-Digital, Mettmann, Germany) that is produced by this technique is manufactured from nickel–titanium wires of 0.014×0.014 inch thickness (25) (Figure 3).

Fixed bonded retainers are generally used in two ways. First, thicker 0.032 inch wires are bonded to canines only. Although stainless steel wires are mostly preferred in this technique, Liou et al. (26) reported successful results for nickel–titanium wires as well. Second, retainers made of 0.0175–0.0215 inch wires are bonded to each tooth usually from canine to canine. The indications for these two techniques differ from one another (1).

The indications for bonding fixed retainers to only canines were defined by Lee (27) as follows:

Figure 1. 5-stranded wire retainer bonded to all anterior teeth from canine to canine

Figure 2. Resin fiberglass band retainer bonded to all anterior teeth from first premolar to first premolar

Figure 3. Memotain retainer bonded to all anterior teeth from canine to canine

- cases with severe rotations and crowding in the lower incisors,
- cases in which lower inter-canine width is changed,
- cases treated with lower incisor proclination,
- cases with mild crowding that are treated without extractions,
- cases with deep overbite.

The indications for bonding fixed retainers to all teeth were defined by Zachrisson (28) as follows:

- cases in which median diastema is closed,
- cases with diastemas between the anterior teeth,
- adult patient with a potential for migration of the teeth after orthodontic treatment,
- cases with tooth loss or large diastemas in the maxilla before treatment,
- cases treated with mandibular incisor extraction,
- cases with severely rotated teeth before treatment,
- cases in which the position of a palatinally impacted canine is corrected.

The fixed retainers that are bonded to only canines are generally indicated when the anterior segment is moved toward the anteroposterior or lateral directions. If there is a risk of relapse for each tooth separately, then it will be wiser to bond the retainer to each tooth (1).

Clinical Evaluation of Fixed Retainers
Failure types, failure rates, and effects on periodontal health are the investigated issues in clinical studies related with bonded retainers.

Failure Types of Fixed Retainers
The reasons for failure of bonded fixed retainers include separation of tooth–adhesive interface, separation of wire–adhesive interface, breakage of retainer wire, and unwanted torque movements of the teeth caused by a retainer wire (29-33). It is reported that most of the failures are observed within the first 6 months of retainer use.

The most common failure type is separation of tooth–adhesive interface (29). The reported rate of this failure type in metal retainers is 3.5%–53%, whereas this rate changes from 11% to 51% in fiber retainers (30-33). The reason for separation of tooth–adhesive interface is almost always related with extreme biting forces caused by eating hard foods. Therefore, patients wearing fixed retainers should abstain from biting hard foods directly. On the other hand, breakage of retainer wire is usually related with metal fatigue that is observed in long-term retainer use.

It is mentioned that the reason for separation of retainer wires from adhesive materials may result from either inadequate use of adhesive materials during the bonding stage or loss of adhesive material from composite surface due to abrasion in long-term use. Larger amounts of adhesive usage is recommended to increase the resistance to abrasion (1).

The less common failure types are opening of spaces between the teeth and sometimes displacement of the teeth or occurrence of dehiscence due to unexpected torque movements although there is no separation of retainer from tooth surface (9,31,34–36)2077 female. Despite failure of fixed retainers is a multifactorial problem, disharmony between retainer wire and tooth surface, errors in wire placement or bonding technique and mechanical properties of retainer wires play an important role in failures (34). It is reported that passive adaptation of retainer wire to tooth surface, avoiding contamination of saliva during bonding, and abstaining from biting hard foods will increase the success rate of fixed retainers.

Failure Rates of Fixed Retainers
A number of studies investigating various types of retainer wires, adhesive materials, and bonding techniques used for fixed retainers can be found in the literature. There is a wide range for failure rates examined for each different type of fixed retainers. For stainless steel retainers, which are bonded to canines only, the failure rates are reported to be 13%–37.7% (27, 37–39). On the other hand, the failure rates are reported to be 9%–14% when they are bonded to six lower incisors (40, 41).

The failure rates for multi-stranded retainers that became popular in recent years for their advantages are reported to be 8.8%–46% (32, 33, 38, 42, 43). For resin fiberglass retainers, the failure rate was observed between 11% and 71%, and the risk of failure for maxilla was reported to be higher than that for mandible for all examined fixed retainer types (32, 33, 44).

Effects of Fixed Retainers on Periodontal Health
The biggest concern for bonded fixed retainers in long-term use is whether they make it more difficult to maintain oral hygiene and cause negative effects on periodontal health (8, 20, 37, 38, 45-48). However, no consensus is found about this subject when the literature is reviewed. There are studies that show that bonded fixed retainers cause increased plaque and calculus accumulation or gingival inflammation. There are also other studies that show no negative effect.

Artun (20) compared the effects of different types of fixed retainer wires on caries formation and periodontal health and reported that although fixed retainers cause more plaque accumulation, they do not cause caries. Levin et al. (45) showed that bonded fixed retainers cause increased plaque accumulation, gingival recession, and bleeding on probing. Pandis et al. (8) reported that as a result of long-term tissue irritation, bonded fixed retainers cause an increase in pocket depth, marginal gingival recession, and calculus accumulation. However, these results were related with long-term wearing of fixed retainers rather than the materials used (20). It was remarked that the interproximal area beneath bonded fixed retainers was difficult to clean, thus more calculus was accumulated in this area (8, 46).

On the other hand, there are many studies that argue against these opinions. These studies revealed that even long-term wearing of fixed retainers caused no gingival tissue damage in most patients (37, 38, 47, 48).

Rody et al. (47) placed fixed retainers in the mandibular anterior teeth and reported that although there is an increase in plaque accumulation, periodontal health is not affected. Booth et al. (37) reported acceptable gingival values in the mandibular anterior teeth after long-term wear of fixed retainers. Another study reported a decrease in bone level and remarked that it was due to orthodontic treatment rather than type of retention protocol (49).

CONCLUSION

Even though there are controversial studies in the literature, it is evident that bonded fixed retainers complicate maintaining oral hygiene. In light of this information, it is crucial to inform patients about the importance of brushing and flossing in details. They should also avoid biting hard foods, be motivated to protect their dental health, and be encouraged not to miss their periodic check-ups during the retention phase of orthodontic treatment (50).

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CASE REPORT

Accidental Swallowing of a Molar Band

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ABSTRACT

Accidental ingestion or aspiration of foreign bodies is considered as a medical emergency in dentistry. Despite their rare occurrence, accidental ingestions are associated with various complications and morbidity, thereby necessitating prevention of their incidence along with early and effective management. Herein, we report a case of accidental swallowing of an orthodontic molar band in a patient with unilateral cleft lip and palate and its management.

Keywords: Accidental ingestion, molar band, cleft lip, palate

INTRODUCTION

Accidental ingestion or aspiration of foreign bodies (e.g., dental material, appliances, or instruments) is one of the serious complications encountered in clinical dentistry. It may result in airway obstruction and thus cause severe breathlessness or internal hemorrhage due to perforation of the gastrointestinal tract, leading to death (1-3).

According to a review by Tamura et al. (4), dental foreign bodies accounted for 3.6%-27.7% of all foreign bodies ingested or aspirated, with ingestion being more prevalent than aspiration. When comparing different dental specialties, orthodontic appliances are the second most common dental foreign body to be ingested (5). The various factors responsible for higher incidence of aspiration of orthodontic appliances are the relative small size of orthodontic appliances, presence of saliva, limited accessibility in the posterior region of the jaws, and supine position of the patient (2, 6). Furthermore, the morphology and muscles of the soft palate in addition to the velopharyngeal seal can play a major role in the occurrence of such aspirations. Patients with cleft palate have a short soft palate with velopharyngeal insufficiency. Ha et al. (7) reported that individuals with repaired cleft palate have shorter and thinner levator muscles than those of healthy individuals. Therefore, orthodontists should be more careful when performing clinical procedures in cleft palate patients.

The present case report describes accidental swallowing of a molar band in a patient with unilateral cleft lip and palate (UCLP) and its management.

CASE PRESENTATION

A 15-year-old boy with repaired UCLP was under treatment at a postgraduate cleft lip palate clinic. His medical history was noncontributory and revealed a negative family history of cleft. He had unilateral left-sided cleft lip and palate in which the scar tissue of the repaired lip extended from the base of the nose to the upper lip on the left side, a deformed alar dome of the left side, a deviated nasal septum to the right side, abnormal columella, and an obliterated philtral dimple. The other intraoral findings included Angle's Class II subdivision malocclusion on the left side, crossbite from the upper left central incisor to the upper left canine, and constricted maxillary arch. Lateral cephalogram tracing and intraoral photographs of the patient revealed a short

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soft palate (Figure 1). Maxillary arch expansion for correction of the crossbite with quad-helix appliance followed by fixed orthodontic appliance therapy was planned. After 3 months of maxillary arch expansion, upper and lower arch bonding was performed with 0.022×0.028-inch slot Roth prescription bracket system (Figure 2).

During routine follow-up, the patient reported to the clinic with the complaint of a loosened upper right molar band. While recementing the molar band, it slipped into his oral cavity. To prevent the molar band from entering the oropharynx, the patients' head was turned downward and he was asked to cough. Despite repeated coughing, the band could not be retrieved. Subsequently, the oral cavity and oropharynx were visually inspected under good illumination. Failure to locate the band led to suspicion of ingestion or aspiration of the molar band. However, the patient did not show any signs and symptoms of airway obstruction. The patient was immediately taken to the medical emergency department. A posteroanterior chest X-ray was performed (Figure 3), and it revealed that the molar band was lodged in the neck region but the position was not fully clear. Subsequently, a lateral cervical spine X-ray was taken to confirm the location. It was

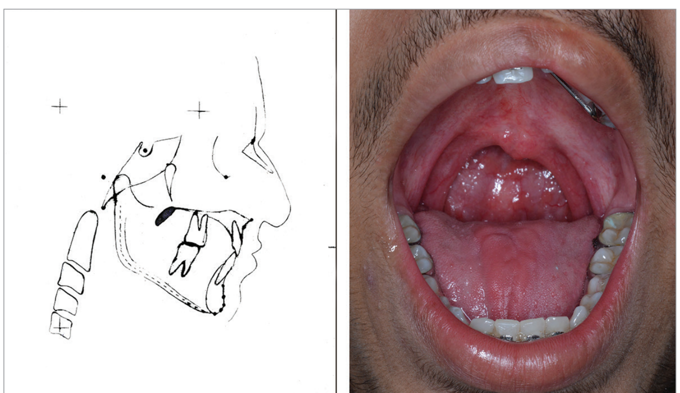

Figure 1. Lateral cephalogram tracing and clinical intraoral photograph showing a short soft palate

found that the molar band was located in the cervical part of the esophagus (Figure 4). As the patient was asymptomatic, endoscopic examination and retrieval of the molar band was planned by gastroenterologist. The molar band was successfully retrieved with an endoscope (Figure 5), and the patient was discharged on the same day without any complication.

DISCUSSION

Ingestion or aspiration of a dental foreign body is a potential complication in dentistry. Owing to higher incidence of accidental ingestion observed in clinical orthodontics, a standard guideline for the prevention and management of this complication is a must during orthodontic procedures (2, 3, 8-10).

- Guidelines for prevention:

A. General guidelines:
1. Mobile phones should be switched off in the clinic to prevent distraction.
2. A textured latex glove should be used for better grip on dental appliances and instruments.
3. High-speed suction with a pharyngeal tip should be mandatory, especially while operating in the posterior regions of the jaw.
4. High-viscosity impression material should be used.
5. Extra precaution should be taken when treating very young, special need, and cleft patients.
6. Patients should be instructed to report immediately in case of breakage of appliance.
7. All staff, including the operating dentist, should be trained and updated in basic life support and first aid skills.

B. Specific guidelines:
1. All the components of removable appliances should be made smooth and inspected for any sign of fracture at every appointment.
2. Radio-opaque acrylic should be used to facilitate easy visualization and location in case of ingestion or aspiration.

Figure 2. Mid-treatment intraoral photograph showing a 0.018-inch SS wire in the upper and lower arches

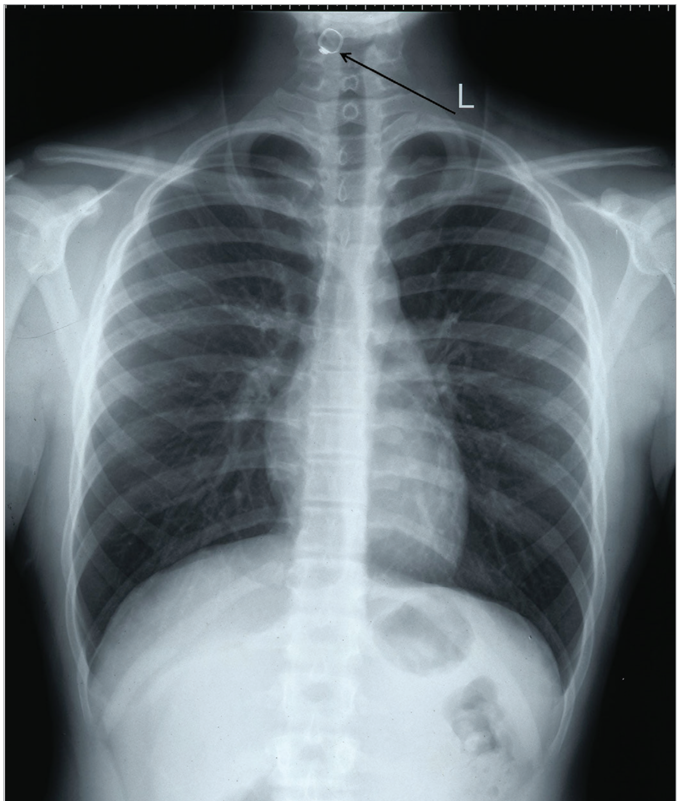

Figure 3. Posteroanterior radiograph showing the swallowed object in the neck region

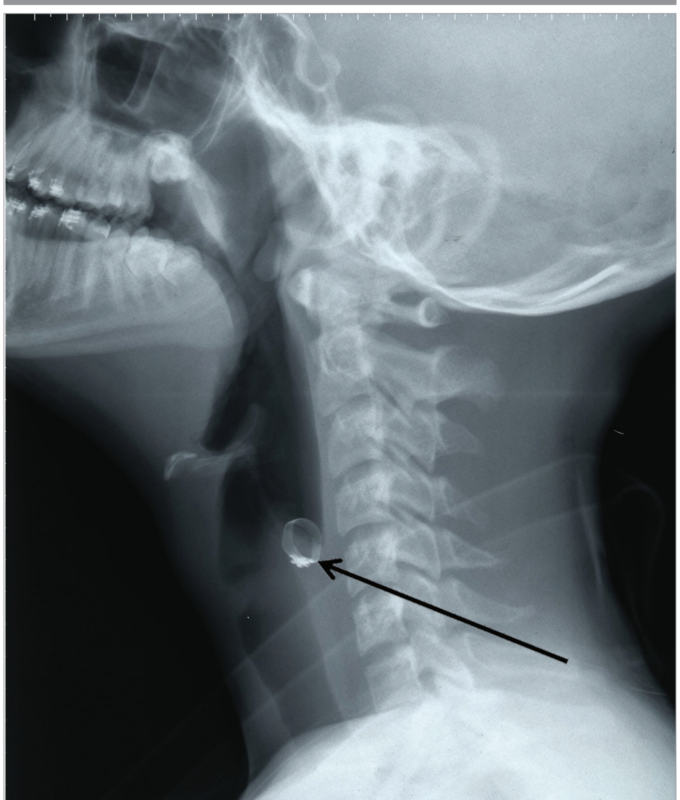

Figure 4. Lateral cervical spine radiograph showing the swallowed object in the cervical part of the esophagus

3. The transpalatal arch, quad-helix, molar band, and expansion appliance keys should be tied and secured with floss while performing intraoral adjustments.

Figure 5. Image showing the molar band retrieved from the esophagus

4. Gauze pads should be used as a barrier while adjusting appliances or cutting the distal end of wires.
5. The cutting ends of distal end cutters should be checked for trapped wires and wiped off with gauze after every cut.
6. Distal end cutters should be periodically checked for signs of failure of "safety hold" and accordingly replaced.
7. The distal ends of arch wires should be cinched, if possible.
8. Temporary anchorage devices should be secured to the main appliance with a ligature wire.

- Management:

Despite all precautions, mishaps occasionally occur. Therefore, clinicians must be capable of providing early and effective management to minimize patient discomfort and complications. Management depends upon the type, size, and location of the foreign body as well as whether it has been ingested or aspirated.

In case a foreign body accidentally slips into the oral cavity during dental procedures, the head of the patient should be turned sideways or downwards and he/she should be asked to cough to prevent the foreign body from entering the oropharynx. Next, the oral cavity and oropharynx of the patient should be thoroughly examined under light. If the object is visible, forceps or high-speed suction should be used to retrieve it. If the object is not visible, ingestion or aspiration should be suspected. The patient should be observed for any sign or symptom of airway obstruction. If present, the Heimlich maneuver should be attempted to dislodge the foreign body. Upon failure to dislodge, every attempt should be made to maintain the airway. The patient should be immediately taken to the emergency department for radiographic localization and further management.

If the patient shows signs of respiratory distress, emergency airway should be established immediately. Once the airway is maintained, the foreign body can be retrieved using an endoscope. However, if on radiographic examination (chest and/or abdominal X-ray) the object is found to be ingested, the patient should be advised not to panic and eat a diet rich in cellulose. Serial radiographs should be taken for localization, and the patient should be closely monitored until the object is excreted. If the foreign body is not excreted and found to be impacted in esophagus, it should be retrieved using Foley's catheter (for small blunt objects) or an endoscope (for large sharp objects). Failure to retrieve the foreign body by endoscopy or in cases where the patient shows symptoms of gut perforation (fever, vomiting, abdominal pain, and distention) may require surgical intervention.

CONCLUSION

This case report presents successful retrieval of an accidentally swallowed molar band from the cervical part of the esophagus in a patient with UCLP. Owing to a short soft palate, the risk of ingestion or aspiration of a foreign body is relatively higher in patients with cleft palate. This necessitates extra precaution during the treatment of these patients. Dentists and, in particular, orthodontists must be capable of preventing the incidence of such ingestions and familiar with early and effective management.

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Peer-review: Externally peer-reviewed.

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CASE REPORT

Nonextraction Treatment of a Class III Malocclusion Case Using Mini-Screw-Assisted Lower Molar Distalization

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ABSTRACT

Mini-screw assisted lower molar distalization was planned for a present mild Class III malocclusion case. Two mini-screws were inserted into the available inter-root area: one on the left, and the other on the right side in the posterior region in the mandible. Distalization of lower molars, premolars and canines were achieved. Orthodontic treatment lasted approximately 2.5 years with 1 year of molar distalization. Minimal relapse was seen in the postretention period. Dentoalveolar changes with mini-screw assisted lower molar distalization are reported in the present case.

Keywords: Mini-screw, lower molar distalization, Class III malocclusion

INTRODUCTION

Camouflage treatment of mild Class III malocclusion may include distalization of mandibular dentition besides a number of other treatment modalities. Mostly, intermaxillary elastics with fixed appliances have been used for this purpose (1). However, Class III elastic wear causes unwanted side effects, such as maxillary incisor proclination, maxillary molar and mandibular incisor elongation and it also tends to widen maxillary molars, roll their crowns lingually besides requiring patient compliance (2).

To prevent these undesirable effects, absolute anchorage systems have been applied for either en-masse distalization of mandibular dentition or molar distalization (3-10). In the present case report, we introduce a nonextraction and nonsurgical treatment of Class III malocclusion using mini-screw-assisted mandibular molar distalization.

CASE PRESENTATION

The patient was a 18-year-old Turkish man who had a sightly concave profile, symmetric face and retrusive lips with an acute nasolabial angle. Intraoral examination revealed Angle Class III molar relationship, anterior crossbite and moderate crowding in both arches. Overjet was -2mm and overbite was 0.5mm (Figure 1).

Lateral cephalometric analysis indicated mild skeletal Class III relationship with maxillary retrusion, optimum mandibular plane angle and normal upper and lower incisor positions (Table 1).

Treatment Plan and Procedure

In the present case, the extraction of mandibular third molars and mini-screw supported lower molar distalization was planned to provide Angle Class I molar relationship and solve crowding. Bone anchorage was provided

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Table 1. Skeletal, dental, and soft-tissue measurements prior to treatment (T0), at the end of treatment (T1), and after a postretention period (T2)

	T0	T1	T2
SNA (°)	78	78	78
SNB (°)	79	79	79
ANB (°)	-1	-1	-1
S-Go (mm)	91	91	91
ANS-Me (mm)	75	75	75
SNGoGn (°)	31	32	32
U1-NA (mm)	5	8	7
U1/PP (°)	115	131	128
L1-NB (mm)	5	6	6.5
IMPA (°)	89	91	93
Overjet (mm)	-2	2	0.5
Overbite (mm)	0.5	1	1
Upper lip-SL (mm)	-4	-2	-2
Lower lip-SL (mm)	0	-1	-1
Nasolabial (°)	117	109	110

by two mini-screws (1.6×8mm Metin mini-screws (MTN), Medifarm, Ankara, Turkey] placed into an available inter-root area. On the right side, one of the mini-screws was inserted between the first molar and second premolar, whereas on the left side it was inserted between the premolars (Figure 2).

A segmented archwire bent from 0.017×0.025″ stainless steel archwire was inserted between the slot of the mini-screw and an auxiliary tube of the second molar. Force (200g) was applied via a compressed open coil for second molar distalization. After the second molar distalization, the first molars were distalized using mini-screws as second molars, then premolars were distalized on the continuous archwire with closed coils while the first molars were kept in place using mini-screws (Figure 3).

In the maxillary arch, protrusion of incisors was planned to align the anterior teeth and correct cross-bite. Lateral cephalograms of the patient were obtained prior to (T0) and at the end of full-fixed orthodontic treatment (T1), 1.8 years after fixed orthodontic treatment (T2; Figure 4).

Treatment Results

Orthodontic treatment lasted approximately 2.5 years, with 1 year of molar distalization. At the end of the full-fixed treatment,

Figure 1. Intraoral and extraoral photographs of the patient prior to treatment (T0)

Figure 2. Placement of two mini-screws between available posterior interroot area in mandibula

Figure 3. Intraoral photograph of the patient showing the distalization phase

Figure 4. Lateral cephalograms of patient were taken at prior to treatment (T0), at the end of treatment (T1), after postretention period (T2)

crowding was eliminated and Class I canine and super Class I molar relationship with 2mm of overjet and 1mm of overbite was obtained (Figure 5). Slight advancement in profile was achieved owing to the protrusion of upper lip position (Figure 6). Local su-

Figure 5. Intraoral and extraoral photographs of the patient at the end of treatment (T1)

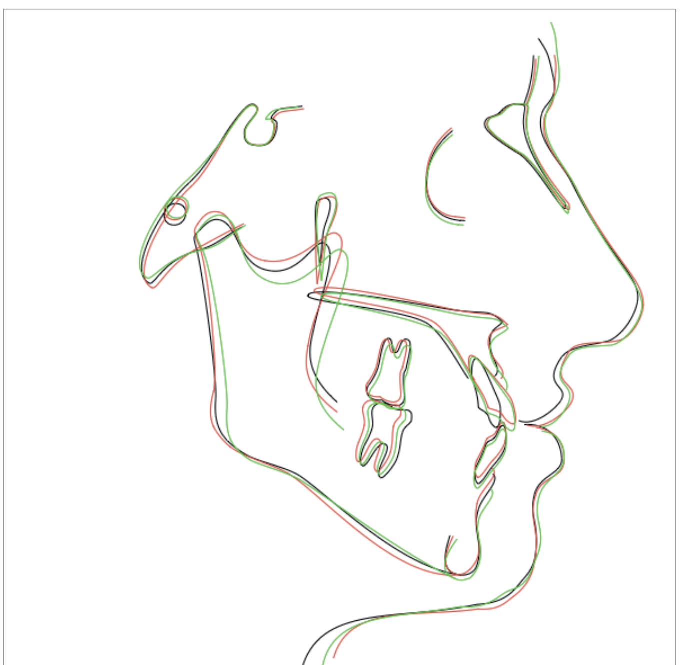

Figure 6. Total cephalometric superimpositions

perimpositions revealed prominent protrusion of upper incisors, slight protrusion of lower incisors, and distalization of lower molars (Figure 7, 8; Table 1). Minimal relapse was seen in the postretention period (Figure 9).

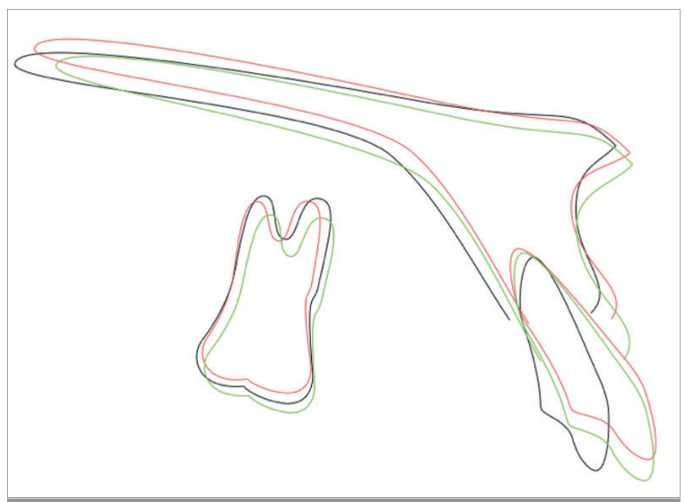

Figure 7. Local maxillary superimpositions

DISCUSSION

The severity of the skeletal problem, growth pattern, facial profile and patient requirements are important in managing skeletal Class III malocclusions (7). In this mild skeletal Class III case, we preferred camouflage treatment. After treatment, his facial profile slightly improved owing to the protrusion of the upper lip.

Another treatment option, in this case, was to extract four premolars; however, this would lead to more retrusive lips, which could have worsened the profile. Another camouflage treatment option was to extract one mandibular incisor. However, the patient rejected either extractions. Therefore, mini-screw assisted mandibular molar distalization was preferred to correct the Class III malocclusion without teeth extractions, and positive overjet was achieved with the protrusion of maxillary incisors.

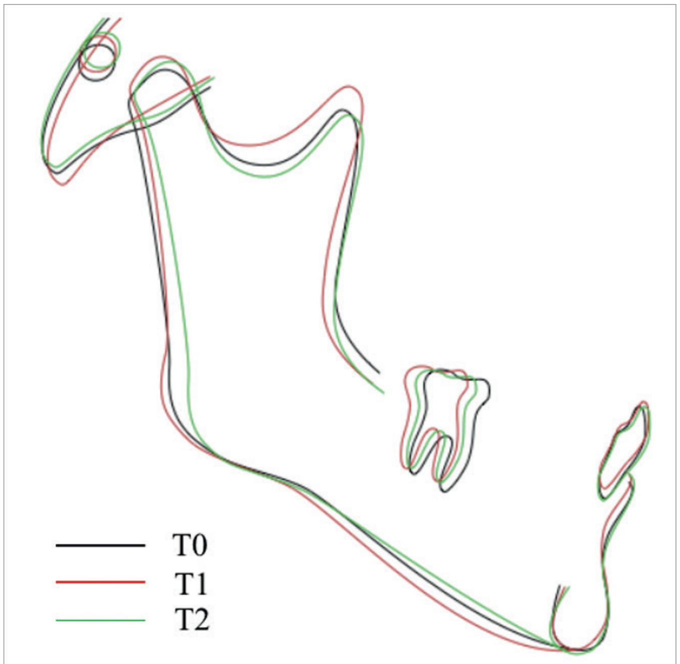

Figure 8. Local mandibular superimpositions. 1: LMcs. Sagital linear change of molar mesiobuccal cusp tip

Class III elastic, which is one of the most widely used mechanisms for Class III correction, has disadvantages, such as the need for patient cooperation, tipping movement, anchorage loss and extrusion of maxillary molars (2). Here, extrusion and mesialization of maxillary molars would have increased the arch discrepancy and caused an open-bite tendency. However, with this system, direction of distalization force was passing through the center of resistance of molars, which avoided extrusion. Thus, mini-screw-assisted distal movement of the mandibular posterior teeth eliminated these undesirable effects.

In the previously reported mechanotheraphy, mini-screws or mini-implants were inserted into different areas for mandibular molar distalization (3-10). Some authors placed mini-plates or mini-screws into the anterior border of mandibular ramus and performed either en-masse distalization of mandibular dentition or tooth distalization (3-6). The posterior alveolar bone is an alternative site for posterior anchorage. Chung et al. inserted a C-shaped mini-implant into the maxillary molar area for Class III elastic usage through this implant (8). Later, Chung et al. inserted C-implants between the mandibular first molar and sec-

Figure 9. Intraoral and extraoral photographs of the patient after postretention period (T2)

ond premolar, like in our system, as close as possible to the first molar root. In this system, second molars were distalized using a sliding jig connected to the main archwire that transferred the elastic forces to second molars applied from the mini-screws (9). Jing et al. (10) vertically implanted the mini-screws into external oblique ridge areas of the bilateral mandibular ramus between the first mandibular and second molar for en-masse distalization. This area reportedly offers more simple and stable force systems (11). Here, a mini-screw was inserted into the available mandibular posterior inter-root area. The implant site was based on cortical bone thickness, bone hardness, anatomic structures, and soft-tissue functional movements. The quantity and quality of the cortical bone greatly influenced the failure force of mini-screw implants (12, 13). Different from in the other studies, the present system of posterior inter-root area can be used for mini-screw insertion. Also, there is no need for full-fixed systems or to wait for leveling at the beginning of the treatment. Distalization can be immediately started. Further, this system differs in that the lower second molar is distalized by the frictionless system; it distalizes with the arch and does not slide on the archwire.

In the present case, mandibular molars distalized 3 mm of each side of the arch. In the literature, molar distalization amounts with the assistance of mini-implants or mini-plates vary between 2-6 mm. Sugawara et al. (3) achieved mandibular molar distalization of 3.5 mm at the crown level and 1.8 mm at the root level, and the average amount of relapse was 0.3 mm at both the crown and root apex levels. Poletti et al. (4) reported 4mm of molar distalization with a tipping of 10°. A case report stated that a mandibular dentition was distalized 5 and 2 mm on the left and right sides, respectively. Jing et al. (10) reported 4 mm of distalization without undesirable tipping.

The relapse amount in distalized mandibular molars during the postretention period, in this case, was 1mm. There are different reports about correlations between tipping and relapse. Chung et al. (9) stated that the larger the amount of tooth movement and the more the teeth are tipped, the greater is the relapse. However, Sugawara et al. (3) found no significant correlations between the amount of relapse and tipping ratio and the amount of tooth movement.

CONCLUSION

Thus, mini-screw supported mandibular molar distalization can be proposed as an effective treatment alternative for avoiding routine teeth extractions in borderline Class III cases.

Informed Consent: Written informed consent was obtained from the patient who participated in this study.

Peer-review: Externally peer-reviewed.

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