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TURKISH JOURNAL of ORTHODONTICS

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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.

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TYPE OF MANUSCRIPT	WORD LIMIT	ABSTRACT WORD LIMIT	REFERENCE LIMIT	TABLE LIMIT	FIGURE LIMIT
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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

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

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ORIGINAL ARTICLE

Evaluation of Dentoalveolar and Dentofacial Effects of a Mini-Screw-Anchored Pendulum Appliance in Maxillary Molar Distalization

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Cite this article as: Kırcalı M, Yüksel AM. Evalution of Dentoalveolar and Dentofacial Effects of a Mini-Screw-Anchored Pendulum Appliance in Maxillary Molar Distalization. Turk J Orthod 2018; 31(4): 103-9.

ABSTRACT

Objective: The aim of this study was to evaluate the dentoalveolar and dentofacial effects of a mini-screw-anchored pendulum appliance in maxillary molar distalization.

Methods: Twenty patients with the Angle Class II molar relationship (mean age 14.05±2.4 years) were treated with a mini-screw-anchored pendulum appliance for molar distalization. A mini-screw 1.9 mm in diameter and 9 mm in length was used to support the pendulum appliance. The springs of the pendulum appliance were activated at 90° and exerted 250-300 gr force per side. Lateral cephalometric radiographs and dental cast models were obtained from all the patients before and after maxillary molar distalization.

Results: A 0.6° increase in the SNA and SNB angles, and a 0.3° decrease in the SN/GoGn angle were found to be statistically significant. In the maxillary first molars, 4.2-mm significant distalization, 0.6-mm significant intrusion, and 8.9° significant distal tipping were observed. The spontaneous distal drift of the maxillary second premolars was found to be statistically significant. In the maxillary first premolar and incisor positions, significant mesialization was observed; however, the changes in the angles of these teeth were found to be insignificant.

Conclusion: A mini-screw-anchored pendulum appliance is an effective method for maxillary molar distalization that controls the undesired anchorage loss observed in conventional methods.

Keywords: Class II, orthodontic anchorage, orthodontic appliance

INTRODUCTION

Since Kingsley (1) and Angle (2) introduced the headgears as an extra-oral appliance for orthopedic and/or dentoalveolar correction of Class II malocclusions in the late 1800s, these appliances have been used widely for distalization of maxillary molars. Patient cooperation has been the major concern of these extra-oral appliances; therefore, clinicians have investigated several intraoral molar distalization systems for correction of the dentoalveolar Class II malocclusions (3-6).

The pendulum appliance has been used as a fixed intraoral molar distalization device ever since it was introduced by Hilgers et al. (6) in 1992. Conventional pendulum anchors from the palatal tissue and upper premolars during the distalization of maxillary molars. The main disadvantage of this appliance is mesialization of the premolars and proclination of the incisors due to the reciprocal anchorage (6-8).

Since skeletal anchorage devices were introduced, they have been used for eliminating the loss of anchorage during orthodontic treatments (9-11). For this purpose, mini-screws have been widely used because of their easy insertion with non-surgical procedures and loading immediately after insertion (9, 11-13).

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In the literature, mini-screw-anchored pendulum appliance studies have reported the use of one or two mini-screws without dental anchorage in the treatment of Class II malocclusions (9-11, 14). However, the authors, who used only one mini-screw, suggested the use of two mini-screws because of the mini-screw failure (10, 11). The aim of the present study was to evaluate dentoalveolar and dentofacial effects of a pendulum appliance with two occlusal rests on the maxillary first premolars and one mini-screw anchorage in the maxillary molar distalization.

METHODS

The sample size of the present study was estimated using the G*Power Software (v3.1.3; Franz Faul, Universität Kiel, Germany), and a total sample of 20 was required for a power of 95% confidence at the 0.05 significance level. Therefore, 20 patients were included in the present study from the Orthodontic Department of Orthodontics, Gazi University School of Dentistry.

The patients who fulfilled the following inclusion criteria were included in the study: (1) the ANB angle between 0° and 5°, (2) decreased or optimum vertical facial growth pattern (SN/GoGn≤38°), (3) Angle Class II malocclusion with at least 4 mm Class II molar relationship, (4) a minimal crowding in the mandibular arch (≤2 mm) and a moderate crowding in the maxillary arch (≤5 mm), (5) fully erupted maxillary second molars, and (6) no craniofacial anomalies or previous orthodontic treatment. All the patients and parents were informed about the orthodontic procedures throughout the study and signed an informed consent form. The study was approved by the Gazi University Ethics Committee (23.06.2014/321).

The study group comprised 13 females and 7 males (mean chronological age 14.05±2.4 years) and treated using the mini-screw anchored pendulum appliance for molar distalization.

Treatment Protocol

Before treatment, all the patients were examined to evaluate the presence and position of the maxillary third molar. Two of the patients had extracted their maxillary third molars previously; two of them had no third molar germs. Seven patients had third molars below the trifurcation line of second molars, and to achieve less resistance during distalization, these teeth were extracted. Nine of the patients had third molars above the trifurcation line of second molars, and they were not expected to affect the distalization; therefore, these teeth were not extracted.

The mini-screws (Spider screw, HDC Company, Sarcedo, Italy) used in the present study are self-drill screws and are 1.9 mm in diameter and 9 mm in length. The mini-screws were placed in the paramedian area of the anterior palate under local anesthesia, approximately 4-5 mm posterior to the incisive papilla and 4-5 mm lateral to the median palatal suture (Figure 1a). Following the insertion of the mini-screw, maxillary first molars were banded, and a plaster model was obtained. A pendulum appliance with a Nance button on the palatal surface, two occlusal rests on maxillary first premolars, and two springs from the Nance button to the sheets of molar bands were constructed on the plaster models. The acrylic part of the Nance appliance corresponding to the area of the mini screw was removed.

After the appliance, adaptation was clinically checked, and occlusal rests were bonded to the first premolars to maintain the stability of the appliance. The appliance was connected and fixed to the mini-screw with the help of cold-curing methyl methacrylate free acrylic resin (Ufi Gel Hard; Voco GmbH, Cuxhaven, Germany). The springs were activated at 90° for approximately 250 gr of distalization force and inserted into the sheets of maxillary first molar bands (Figure 1b, c).

The patients were examined every 4 weeks, and the activation of the springs was checked during these appointments. Reactivation was performed when needed. The distalization was continued until the Angle Class I molar relationship was achieved in all the patients, and then the pendulum appliance was removed (Figure 2, 3). The Nance button as a reinforcement appliance was fixed using the same protocol as that used for the mini screw.

Lateral cephalograms and dental cast models were taken before the mini-screw insertion (T0) and after the Angle Class I molar relationship was achieved (T1). All cephalometric radiographs were traced and superimposed by the same operator. A local superimposition was done on the best fit of the palatal curvature and maxillary trabecular structures to evaluate the maxillary dentoalveolar changes by treatment. The maxillary horizontal reference plane (x) was drawn along the ANS-PNS plane and the maxillary vertical reference plane (y) was perpendicular to the ANS-PNS plane at the PNS point. Thirteen angular and 14 linear

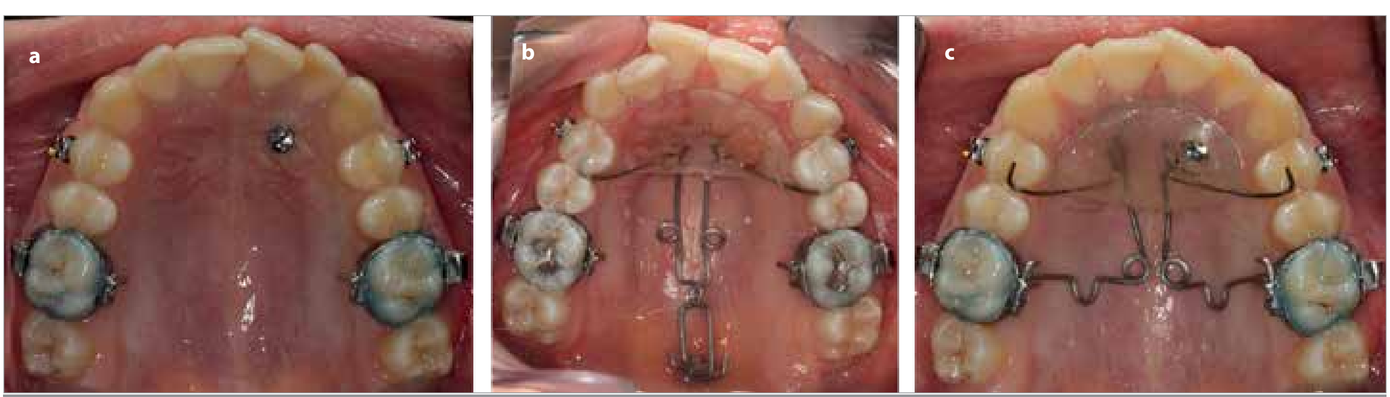

Figure 1. a-c. Placement of the mini-screw, activation of springs, and intraoral view of the pendulum appliance

measurements were evaluated on each lateral cephalometric radiograph (Figure 4, 5). The dental cast models were scanned using a 3D scanner (3Shape, Copenhagen, Denmark), and digital cast models were obtained. The model analyses were done using the 3Shape OrthoAnalyzer™ (3Shape A/S) program, and two angular and two linear measurements were evaluated on each digital cast models (Figure 6).

Statistical Analysis

The data obtained from the subjects were evaluated using the Statistical Package for Social Sciences version 20 (IBM Corp.; Armonk, NY, USA). Descriptive statistics were calculated for age, duration of treatment, and cephalometric measurements at T0 and T1. The normality of the distribution of the variables was examined using the Shapiro-Wilk test. Changes during the treatment were analyzed using the paired *t*-test for normally distributed variables and the Wilcoxon test for not normally distributed variables. $p<0.05$, $p<0.01$, and $p<0.001$ were considered statistically significant.

RESULTS

Table 1 represents the initial age, cephalometric and dental cast measurements of the patients, and the changes of these variables with the treatment.

Figure 2. Intraoral images of a patient before distalization

Figure 3. Intraoral images of a patient after distalization

The 0.7° increase in the SNA angle and 0.6° increase in the SNB angle was found to be statistically significant (p<0.01). The 0.3° anterior rotation of the mandible (SN/GoGn) was statistically significant (p<0.05).

In the upper first molars, a 4.2 mm significant distalization (p<0.001), 0.6 mm significant intrusion (p<0.05), and 8.9° significant distal tipping (p<0.001) were observed with treatment. Moreover, in the upper second molars, a 3.5 mm significant distalization (p<0.001), 0.5 mm significant intrusion (p<0.05), and 8.3° significant distal tipping (p<0.001) were achieved.

A 2.2 mm significant decrease in the sagittal position of the upper second premolar (p<0.001) and the 3.4° decrease in the U5/ANS-PNS angle were found to be statistically significant (p<0.001).

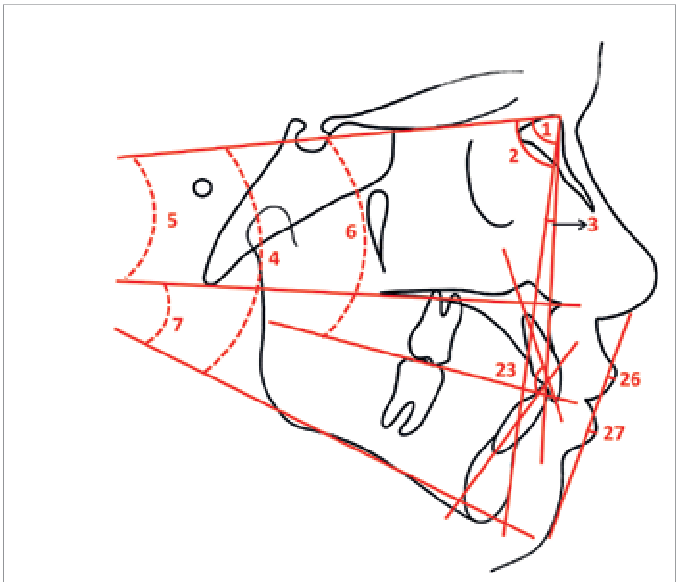

Figure 4. Cephalometric measurements evaluated in the present study: 1, SNA; 2, SNB; 3, ANB; 4, SN/GoGn; 5, SN/ANS-PNS; 6, SN/OP; 7, ANS-PNS/GoMe; 23, U1/L1; 26, UL-S Line; 27, LL-S Line

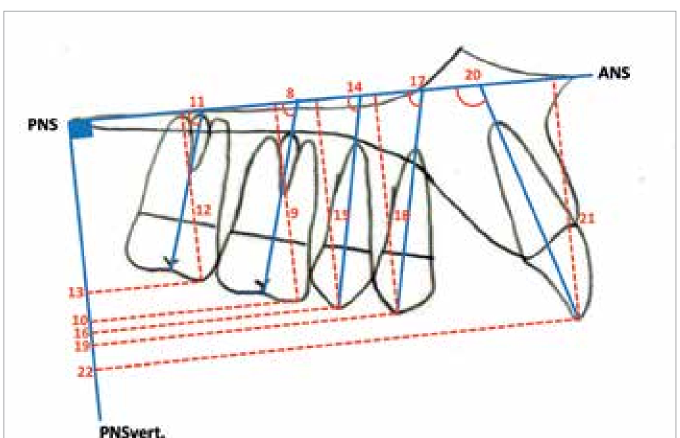

Figure 5. Maxillary dentoalveolar cephalometric measurements evaluated in the present study: 8, U6/ANS-PNS; 9, U6-ANS-PNS; 10, U6-PNS vert.; 11, U7/ANS-PNS; 12, U7-ANS-PNS; 13, U7-PNS vert.; 14, U5/ANS-PNS; 15, U5-ANS-PNS; 16, U5-PNS vert.; 17, U4/ANS-PNS; 18, U4-ANS-PNS; 19, U4-PNS vert.; 20, U1/ANS-PNS; 21, U1-ANS-PNS; 22, U1-PNS vert

The vertical position of the upper first premolar was found to be significantly decreased by 0.5 mm (p<0.01) and the sagittal position of the upper first premolar was found to be significantly increased by 0.4 mm (p<0.05). However, the 0.8° decrease in the U4/ANS-PNS angle was found to be insignificant.

The changes in the upper incisor angle (U1/ANS-PNS) and upper incisor vertical position (U1-ANS-PNS) were found to be insignificant. The sagittal position of the upper incisors (U1-PNSvert) significantly increased (p<0.01).

The changes in the overjet and interincisal angle were found to be insignificant; however, the overbite significantly increased (p<0.05).

In the dental cast measurements, the distance between the mesiobuccal and distobuccal cusps of the upper first molars significantly increased by 2.4 mm and 3.3 mm, respectively (p<0.001). Insignificant mesiopalatal rotations in the upper first molars were observed after the treatment.

DISCUSSION

In skeletal Class I cases with mesialized maxillary molars or mild to moderate skeletal Class II cases, pendulum has been used with less patient cooperation for maxillary molar distalization (7, 8, 14-16). However, the main disadvantage of this appliance is mesialization of anchorage teeth (6-8, 14-16). Many studies demonstrated that mini-screw supported pendulum appliances provide rigid anchorage during maxillary molar distalization. In the mentioned studies, usually two mini-screws were used to increase the anchorage of the pendulum appliance (9-11, 17-19). Some authors used only one mini-screw; however, they suggested the use of two mini-screws to prevent the mini-screw failure (10, 11). In the present study, the pendulum appliance was sup-

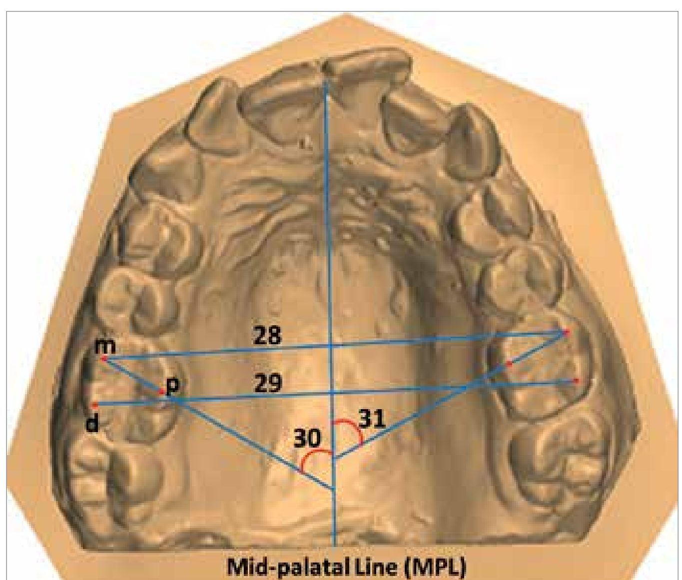

Figure 6. Maxillary dental cast model measurements evaluated in the present study: 28, UL6 m-UR6 m; 29, UL6d-UL6d; 30, UL6 mp/MPL; 31, UR6 mp/MPL (m, mesiobuccal cusp; d, distobuccal cusp; p, palatal cusp)

ported with one mini-screw to avoid the anchorage loss, and the appliance was fixed to maxillary first premolars with two occlusal clasps to eliminate the failure of the mini-screw; therefore, mobility or loss of mini-screws was not observed during the distalization period.

In the orthodontic literature, it was reported that the anterior palatal plate has sufficient bone thickness for mini-screw insertion (13, 20, 21). Some authors suggested paramedian palatal suture as a safe zone for mini-screw insertion in the adolescents (22-24) because of the growth pattern of maxilla, whereas some others reported any objection about the median palatal suture for the mini-screws (12, 20). In the present study, all the subjects were adolescents and young adults, and the mini-screws were inserted into the paramedian palatal suture.

The length of the mini-screw is one of the important factors during insertion into the anterior palatal area. The shorter mini-screws decrease the stability of the mini-screw; however, the longer mini-screws might damage the roots of the teeth, incisive canal, or nasal cavity (20, 25). In the literature, the length of the mini-screw inserted into the palatal area range between 8 and 14 mm (10, 13, 19, 22, 23). Nienkemper et al. (20) reported similar and satisfying stability results with the mini-screws that were 9 mm and 11 mm in length. Considering the previous studies, the mini-screws that are 9 mm in length were used in the present study.

In the mini-screw-anchored pendulum appliance studies, it was reported that 200-250 gr force could be obtained with the 60° or 90° activation of springs, and the average distalization period

Table 1. Changes in age and cephalometric and dental cast measurements

PARAMETER		Pre-treatment		Post-treatment		Treatment Difference		
	N	Mean	SD	Mean	SD	Mean	SD	p
Age (years)	20	14.05	2.4	14.75	2.3	0.7	0.3	
SNA (°)	20	78.7	3.7	79.3	3.6	0.6	0.8	0.003 **
SNB (°)	20	75.8	3.5	76.4	3.7	0.6	0.8	0.004 **
ANB (°)	20	2.9	1.4	3	1.5	0.1	0.5	0.666 NS
SN/GoGn (°)	20	33.3	3.6	33	3.6	-0.3	0.6	0.033 *
SN/ANS-PNS (°)	20	9.8	3.5	9.9	3.4	0.1	1	0.832 NS
SN/OP (°)	20	16.6	3.5	16.7	3.1	0.1	1.4	0.746 NS
ANS-PNS/GoMe (°)	20	26.1	4	25.7	3.9	-0.4	0.9	0.120 NS
U6/ANS-PNS (°)	20	81.6	5.9	72.7	6.4	-8.9	3.1	0.001 ***
U6-ANS-PNS (mm)	20	24.9	2.8	24.3	2.9	-0.6	1	0.019 *
U6-PNS vertical (mm)	20	22.2	2.9	18	3.1	-4.2	0.8	0.001 ***
U7/ANS-PNS (°)	20	66.6	4.8	58.3	4.2	-8.3	-11	0.001 ***
U7-ANS-PNS (mm)	20	18.5	4.2	18.1	4.3	-0.4	0.7	0.010 *
U7-PNS vertical (mm)	20	9.3	3.6	5.8	3.5	-3.5	0.9	0.001 ***
U5/ANS-PNS (°)	20	83.2	3.9	79.8	3.9	-3.4	1.6	0.001 ***
U5-ANS-PNS (mm)	20	25.9	2.9	26	2.8	0.1	0.5	0.287 NS
U5-PNS vertical (mm)	20	28.1	3.8	26	3.8	-2.1	0.6	0.001 ***
U4/ANS-PNS (°)	20	91.6	5	90.8	5.2	-0.8	1.7	0.066 NS
U4-ANS-PNS (mm)	20	27.5	2.6	27.1	2.9	-0.4	0.7	0.008 **
U4-PNS vertical (mm)	20	36.7	4.1	37.1	4.2	0.4	0.8	0.020 *
U1/ANS-PNS (°)	20	110.1	5.7	110.4	6.5	0.3	1.6	0.444 NS
U1-ANS-PNS (mm)	20	30.2	2.7	30.5	2.8	0.3	0.8	0.097 NS
U1-PNS vertical (mm)	20	54.4	3.5	55	3.5	0.6	0.7	0.002 **
U1/L1 (°)	20	128.3	9	127.9	9.9	-0.4	2.9	0.540 NS
Overjet (mm)	20	3.5	2.2	3.6	2	0.1	0.6	0.172 NS
Overbite (mm)	20	3	1.4	3.3	1.4	0.3	0.9	0.465 NS
UL-S line (mm)	20	-0.8	2.1	-0.9	2	-0.1	1.1	0.759 NS
LL-S line (mm)	20	-0.2	2.6	-0.1	2.5	0.1	1	0.359 NS
UL6 m-UR6 m (mm)	20	50	3.3	52.3	2.7	2.3	1,2	0.001 ***
UL6d-UR6d (mm)	20	53.5	3.3	55.8	3.2	2.3	1	0.001 ***
UL6 mp/MPL (°)	20	50.7	6.8	50.1	5.1	-0.6	5.7	0.659 NS
UR6 mp/MPL (°)	20	53.1	6.5	52.6	5	-0.5	5.6	0.693 NS

p<0.05*; p<0.01**; p<0.001***; NS: nonsignificant
m: mesiobuccal cusp; d: distobuccal cusp; p: palatal cusp; MPL: midpalatal line

ranged between 6.8 and 8.2 months (9-11, 19). In the present study, an average of 250 gr force was applied with the 90° activation of the pendulum springs, and the mean distalization period was found to be 8.4 months.

The significant increase in the SNA angle was found to be statistically significant ($p<0.05$). Kırcelli et al. (10) reported that a remodeling at the point A might be induced by the pressure of the acrylic Nance part of the bone-anchored pendulum appliance during maxillary molar distalization.

In the mandible, the anterior rotation was observed with a 0.6° significant increase in the SNB angle ($p<0.01$) and a 0.3° significant decrease in the SN/GoGn angle ($p<0.05$). This slight anterior rotation was because of the significant intrusion on the maxillary molars with the mini-screw-supported pendulum appliance. Escobar et al. (9) reported posterior rotation in the mandibular plane with bone-supported pendulum because of the inclination and rotation of the molars that create premature contacts with a tendency to open the bite.

In the maxillary first molars, a 4.2±0.8 mm distal movement and 8.9±3.1° distal tipping were found to be statistically significant ($p<0.001$). In the previous skeletally anchored pendulum studies, the distal movement of the maxillary first molars was reported to range between 2.9 mm and 6.4 mm, and distal tipping was reported between 8.8° and 11.3° in line with the results of the present study (9-11, 18, 19). Byloff and Darendeliler (8) demonstrated 10°-15° uprighting bends on the pendulum springs to prevent the tipping and achieve more bodily distal movement of the maxillary first molars; however, in the present study, a complete bodily distal movement could not be achieved despite performing the uprighting bends as reported by the authors.

On the maxillary second molars, a 3.5 mm significant distal movement ($p<0.001$) and 8.3° significant distal tipping ($p<0.001$) were observed after distalization. Kinzinger et al. (26) reported that the tipping of the maxillary first molar was much greater when the second molar was still at the budding stage. Similarly, if the maxillary third molar was still in the budding stage, tipping of the erupted second molar was greater. Therefore, the author suggested the germectomy of the third molars to achieve a more bodily distalization of both molars. In the present study, if the maxillary third molars were above the trifurcation line of the second molars, they were extracted before the treatment to provide less resistance during distalization.

Maxillary first and second molars were intruded significantly with 0.6 mm and 0.5 mm, respectively ($p<0.05$). When the ANS-PNS line was used as the reference line to determine the vertical changes of maxillary molars, because of the significant distal tipping of these teeth after distalization using the pendulum appliance, the crowns repositioned closer to the reference line, and this was interpreted as intrusion, which was previously mentioned by Byloff and Darendeliler (8). The authors also associated the intrusion with the prevention of dentoalveolar vertical growth by the rigid bonded appliance, intrusive force of tongue, and the design of the TMA loops of the appliance. Contrary to these findings, Kırcelli et al. (10) reported insignificant vertical changes in maxillary first molars with bone-anchored pendulum appliance.

The maxillary first and second premolars were used as the anchorage unit with conventional pendulum appliances. Therefore, the reciprocal effects of distalization force result with the mesialization of maxillary premolars (6-8, 15, 16). The previous studies reported a 1.4-2.55 mm mesial movement with 1.29°-4.84° mesial tipping using conventional pendulum appliances (7, 8, 15, 16). During the distalization of maxillary molars, to overcome this side effect and to achieve a spontaneous distal drifting on the maxillary premolars, clinicians supported the pendulum appliance with skeletal anchorage devices. Several of them excluded all the premolars from the anchorage unit (9, 10, 17, 18, 27, 28), whereas others excluded only the second premolars (22, 27, 29). In the present study, only the first premolars were included in the anchorage unit with two occlusal rests. Therefore, a 0.4 mm significant mesialization ($p<0.05$) and a 0.5 mm significant intrusion ($p<0.01$) of maxillary first premolars were observed. The second premolars, not included in the anchorage unit, were observed to be significantly drifted with a 2.2 mm distal movement and 3.4° distal tipping ($p<0.05$) because of the tensile strength of the trans-septal fibers between the maxillary first molars and second premolars.

Proclination of the maxillary incisors is one of the most observed side effect in conventional pendulum appliances studies (7, 8, 15). Also, Kinzinger et al. (22), Gelgor et al. (30), and Oncag et al. (28) reported maxillary incisor proclination with skeletal anchored molar distalization. In the present study, a significant increase in the sagittal position of maxillary incisors was observed; however, the increase in the U1/ANS-PNS angle was found to be insignificant. The sagittal position of incisors was measured between the incisal edge of the most labial incisor and the PNS-vertical line; therefore, the posterior growth on the PNS point could be affecting this distance.

Kırcelli et al. (10) reported a significant increase in the intermolar distance and insignificant molar rotation after maxillary molar distalization with bone-anchored pendulum appliance. In line with these findings, the intermolar distance significantly increased, and insignificant molar rotations in the upper first molars were observed in the present study. The significant increase of intermolar distance demonstrated an expansive force of pendulum springs during distalization. Beside the distalization and expansion forces, the pendulum springs exert two different rotation forces on the maxillary first molars. When the maxillary first molars undergo any rotations before distalization, the rotation force of springs is in the mesiopalatal direction; however, whether the maxillary first molars have a mesiopalatal rotation because of the early loss of deciduous second molars the springs apply a de-rotation force in the disto-palatal direction. In the present study, some of the patients had rotated maxillary first molars at the beginning of distalization and de-rotated using the pendulum springs; therefore, the maxillary first molar rotations remained at an insignificant level.

CONCLUSION

In this study, we aimed to evaluate the dentialveolar and dentofacial effects of a pendulum appliance using two occlusal rests on maxillary first premolars and one mini-screw anchorage in the maxillary molar distalization. The following results were obtained:

- Maxillary first and second molar distalization was achieved with spontaneous second premolar distalization.
- Mesialization of anchorage unit was controlled successfully with the mini-screw support.
- Mandible showed anterior rotation with a significant increase in the SNB angle and a significant decrease in the SN/GoGn angle due to the significant intrusion of maxillary first molars.

Ethics Committee Approval: Ethics committee approval was received for this study from the Gazi University Ethics Committee (23.06.2014/321).

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

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - M.K., A.S.Y.; Design - M.K., A.S.Y.; Supervision - M.K., A.S.Y.; Data Collection and/or Processing - M.K., A.S.Y.; Analysis and/or Interpretation - M.K., A.S.Y.; Writing Manuscript - M.K., A.S.Y.; Critical Reviews - M.K., A.S.Y.

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

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ORIGINAL ARTICLE

The Effect of Different Bleaching Treatments and Thermal-Mechanical Cycling on the Shear Bond Strength of Orthodontic Brackets

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ABSTRACT

Objective: The aim of the present study was to compare the shear bond strength (SBS) of orthodontic brackets bonded to the enamel after at-home and in-office bleaching treatments.

Methods: Sixty bovine incisors were subjected to initial color readings and then classified into three groups: CP (16% carbamide peroxide), HP (35% hydrogen peroxide), and C (control). After treatments, new color readout was obtained, and orthodontic brackets were bonded to the bleached area. Half of the samples of each group (n=10) were subjected to thermal-mechanical cycling (TMC) testing (1,200,000 cycles; 44.2 N; 2 Hz/s), whereas the other half were stored in distilled water at 37 °C for 24 h. Samples were subjected to the SBS test at a speed of 0.5 mm/min. The mean SBS was analyzed (two-way ANOVA, Bonferroni test, $p<0.05$), and the fracture patterns were classified as adhesive, cohesive, and mixed types.

Results: There was no difference ($p>0.05$) in SBS values between the samples subjected to TMC and the cycled samples in any group. Samples subjected to carbamide peroxide presented lower SBS ($p<0.05$) than the non-cycled ones. Enamel adhesive fractures were higher in the bleached groups than in the control group, which presented mixed fractures prevalence, regardless of whether it was subjected to TMC or not.

Conclusion: Thermal-mechanical cycling was not significant for SBS of orthodontic brackets, but tooth bleaching was a factor.

Keywords: Mechanical stress, orthodontic brackets, shear strength, tooth bleaching

INTRODUCTION

Personal appearance care is not a recent concern, and that issue also includes smile care. There is growing demand for tooth bleaching procedures (1, 2) that can be performed in the office, by dental professionals, or self-applied with specific products in multiple and appropriate concentrations for each case (3, 4). The effectiveness of both techniques has been recognized (3, 4). However, some effects have been considered as harmful, such as the decrease in microhardness and elastic modulus of the tooth enamel, the increase in the formation and propagation of microcracks (5), as well as the increase in surface roughness of the tooth surface (4). Studies have demonstrated that solutions of 35% hydrogen peroxide change the structure and composition of the enamel (4, 6).

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Bleaching or whitening products can be used before or after orthodontic treatment (7). For these treatments, the first requirement concerns the bonding of the brackets to the tooth surface. The bonding process should preserve the mechanical stability of the bracket/adhesive interface, which transfers the load generated by the archwires to the tooth (8). Poor bond strength can have adverse consequences on the cost and effectiveness of the orthodontic treatment, as well as patient comfort (9).

There is no consensus in the literature regarding the waiting time between tooth bleaching and performing any bonding procedure, and the periods vary from 24 h to 4 weeks (7, 10, 11). The decrease of the bond strength between the composite/adhesive and the newly cleared enamel may be temporary (10).

Although the bleaching effect on shear bond strength (SBS) has already been extensively studied, most of the previous studies measured the short-term adhesive bond strength and did not extend the study period to comprehend the duration of typical orthodontic treatment (12). The eating, drinking, and breathing routine can induce changes in intraoral temperature (13, 14). Thermal stresses can be pathogenic in two ways. First, mechanical stresses caused by differences in thermal expansion coefficient can directly influence crack propagation through the bonding interface between the tooth and the restorative material. Second, the changing gap dimensions are associated with volume changes that inject pathogenic oral fluids in and out of the gaps (13, 14). Despite the abundance of evidence produced by orthodontic studies, the laboratory configurations and setups used to simulate intraoral conditions are irrelevant to the actual oral environment (15-17). Thermal cycling is an in vivo process often represented in laboratory simulations (13). However, few studies have reported its effects on water sorption and solubility of composite restoratives (14).

The bond strength of the bracket can be affected by several agents (7, 18), such as the action of solvents and other components of the bleaching agents on the degradation of the bracket bond (19). In addition to that, changes in the mineral content of the bleached tooth can increase the porosity and permeability of the enamel, reducing its microhardness (20). The aim of the present study was to compare the SBS of metal orthodontic brackets bonded to the enamel subjected to at-home (16% carbamide peroxide) and in-office (35% hydrogen peroxide) bleaching treatments and thermal-mechanical cycling (TMC) tests. The study tested the null hypothesis that there would be no difference in the SBS, regardless of the type of bleaching treatment to which the enamel was subjected.

METHODS

Ethical approval

Samples used in the present study were obtained from beef packing industries as a donation. All tests were conducted in accordance with the Scientific Requirements and Research Protocols established by the World Medical Association Declaration of Helsinki.

Sample preparation

Sixty sound bovine incisors, without stains and with intact enamel surface, were selected. A circular jig was attached to the labial surface of the teeth to standardize the color readings and to define the area to be bleached (Figure 1). The outer edge of the jig was coated with colorless nail polish (Colorama; São Paulo, SP, Brazil) so that only the inner area would be subjected to any procedure.

The teeth were subjected to initial color readings using an optical reading device (Easyshade®; VITA Zahnfabrik, Bad Säckingen, Germany). It has a digital tip with 19 optical fibers that irradiate the area, and two sensors are capable of reading the color numerically. The color readings were performed in a light chamber (CL6I-45S; INTEKE HS, São Paulo, SP, Brazil) under a D65 artificial daylight source according to the CIE $L^*a^*b^*$ system (21). The system consists of three axes in color space, with a^* and b^* being perpendicular to each other representing the dimension of color tonality (green-red and blue-yellow, respectively) and L^* representing lightness, vertical to the plane a^*b^*. By assigning numerical values to these three coordinates, the CIE $L^*a^*b^*$ system can locate an object in a three-dimensional color space.

Samples were randomly classified into three groups (n=20) according to the type of bleaching treatment to which they were subjected (Table 1).

For bleaching, all the teeth were embedded in colorless and chemically activated acrylic resin (VIPI Flash; VIPI Produtos Odontologicos, Pirassununga, SP, Brazil) in a polyvinyl chloride ring (20 mm high×20 mm inside diameter), with the labial surface of the teeth perpendicular to the horizontal plane, using a parallelometer.

In the CP group, a 16% carbamide peroxide (White & Brite Night; 3M do Brasil Ltda., Sumaré, SP, Brazil) was used in daily applications of 4 h for 14 days at home. In the HP group, a 35% hydrogen peroxide (Whiteness HP; FGM Produtos Odontologicos Ltda., Joinville, SC, Brazil) was used in three 15-minute applications, with a 5-minute interval between them. In the control group (C),

Table 1. Groups studied and clinical protocols used for tooth bleaching treatments

Group	Agent	Treatment
CP	16% carbamide peroxide (White & Brite Night; 3M do Brasil Ltda., Sumaré, SP, Brazil)	Daily bleaching application, 4 h/day for 14 days
HP	35% hydrogen peroxide (Whiteness HP; FGM Produtos Odontologicos Ltda., Joinville, SC, Brazil)	Three bleaching applications lasting 15 min, with 5-minute intervals between them
C	Distilled water (control)	Storage in distilled water for 24 h

samples were stored in distilled water for 24 h (Table 1). After the bleaching treatments, new color readings were performed according to the previously described methodology to verify color change.

Bracket bonding

Sixty metal brackets with a 6 mm^2 base area (Kirium U1R Roth 022; Abzil 3M, São José do Rio Preto, SP, Brazil) were bonded to the bleached enamel surface 24 h after the bleaching procedures. The bleached area was etched with 37% phosphoric acid (Alpha-Etch; Nova DFL, Rio de Janeiro, RJ, Brazil) for 15 s, then washed with water, and dried using air jets. Then, a uniform and thin coat of primer (Transbond™ XT; 3M Unitek, Sumaré, SP, Brazil) was applied. After solvent evaporation, a small amount of adhesive (Transbond™ XT) was used on the base of the bracket, which was immediately positioned on the bleached enamel surface. To correctly adjust the bracket perpendicular to the horizontal plane, its position was checked with an acrylic positioning device (Figure 2).

A Gillmore needle (113.4 g) was used on the bracket for 5 s to standardize the force applied and its duration, so that a uniform adhesive layer would coat the enamel surface.

After a brief 3-second photoactivation (FlashLite 1401; Discus Dental, Culver City, CA, USA; power density ≥1100 mW/cm^2, wavelength range between 460 and 480 nm), the excess adhesive was removed around the base of the brackets without displacing them. Further photoactivation (FlashLite 1401) was performed for 20 s, with 10 s on each interproximal area of the tooth.

Figure 1. Circular template fixed on the vestibular surface of the tooth to standardize position of the spectrophotometer reader and region to be bleached

Samples were randomly separated into two groups (n=10) according to the treatment to which they were subjected: TMC or storage in distilled water for 24 h (control).

Thermal-mechanical cycling

Samples were subjected to 1,200,000 mechanical cycles with a load of 44.2 N at a frequency of 2 Hz/s and a rounded tip 6 mm in diameter as an antagonist (thermal-mechanical wear system-ER-11000 Plus; ERIOS, São Paulo, SP, Brazil) to simulate actual chewing conditions. The frequency used corresponded to 2 chewing cycles/s that simulated 5 years of chewing (2, 22). Thermal cycling was performed in association with mechanical cycling at temperatures of 5 °C, 37 °C, and 55 °C (±2 °C).

After thermal cycling, samples were stored on distilled water at 37 °C for 24 h after which the shear bond test was applied.

Shear bond strength

Samples were subjected to shear test in a mechanical testing machine (DL-2000; EMIC, São José dos Pinhais, PR, Brazil) at a speed of 0.5 mm/min by a chisel parallel to the long axis of the tooth, acting on the enamel/bracket interface. Shear stress was calculated by the following formula: SBS (MPa)=9.81×F (kgf)/A (mm^2), where F corresponds to the maximum bracket debonding force, and A corresponds to the area of the bracket. The SBS values were analyzed by repeated measures two-way ANOVA, Bonferroni post-hoc test ($p<0.05$).

After debonding the brackets, the fracture patterns were qualitatively analyzed under a bench magnifying glass (TL-1106; Toyo, São Paulo, SP, Brazil) at 10× magnification and classified as enamel adhesive (when all the resin remained on the brack-

Figure 2. Bracket positioned perpendicular to the horizontal plane

et), bracket adhesive (when the resin remained on the enamel surface), cohesive (when there was a fracture of the resin), and mixed (when there was a fracture of the resin and damage to the enamel). When the bracket debonding force exceeded the enamel strength, there was substrate fracture, and failure was classified as enamel fracture.

The amount of adhesive left at the enamel was classified by the Adhesive Remnant Index (ARI) as follows (23):

- score 0=no adhesive was left on the tooth
- score 1=less than half of the adhesive was left on the tooth
- score 2=more than half of the adhesive was left on the tooth
- score 3=all of the adhesive was left on the tooth, with a distinct impression of the bracket mesh.

Table 2. Mean (±standard deviation) values of the color readings

	CP	HP	C
ΔE	7.5±2.7	5.2±1.6	4.4±2.5
ΔL	3.5±1.3	0.6±2.1	-0.9±1.3
Δa	–0.5±0.8	3.2±1.2	-1.4±1.1
Δb	–6.2±3.4	–1.2±3.8	-3.8±2.2

Table 3. Comparison of the mean SBS (MPa) (±standard deviation) for the cycled and non-cycled groups (two-way ANOVA, Bonferroni test, p<0.05)

CP	229.68±86.3^{aA}	189.59±80.4^{aB}
HP	326.94±34.8^{aA}	319.47±139.1^{aA}
C	233.45±69.5^{aA}	313.14±100.7^{aA}

Different letters indicate significant differences (p<0.05)
TMC: thermal-mechanical cycling

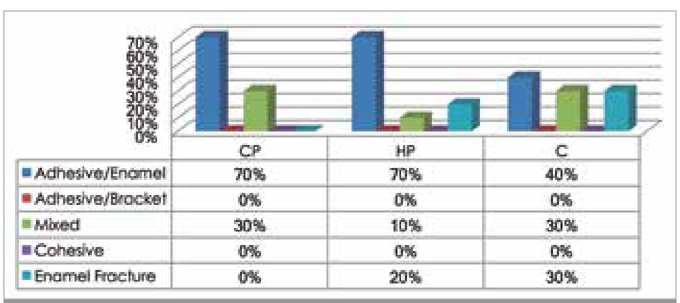

Figure 3. Fracture pattern distribution of samples in group without TMC observed after shear bond strength test

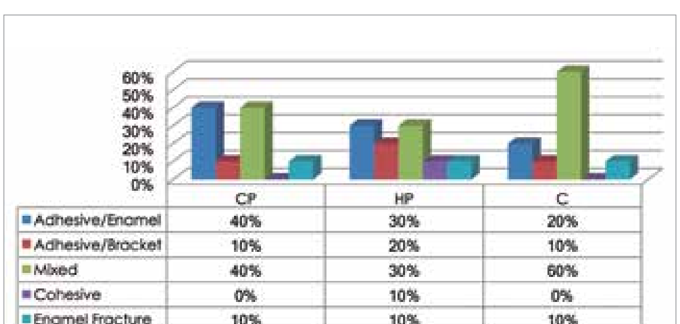

Figure 4. Fracture pattern distribution of samples in group with TMC observed after shear bond strength test

RESULTS

Table 2 shows the color change values (ΔE) of the studied groups (at-home tooth bleaching, in-office tooth bleaching, and control) and the delta values relative to the coordinates analyzed after performing the bleaching treatments.

All treatments produced an enamel color change. The most significant difference was found in the HP group, whereas the least was in the control group.

Table 3 shows the comparison of the mean SBS (two-way ANOVA, Bonferroni test, p<0.05). There was no significant difference (p>0.05) on SBS of the cycled groups, regardless of the type of bleaching tested. When not submitted to TMC, the at-home bleaching had the lowest mean SBS, which was significantly different (p<0.05) from the control and HP groups, which presented no difference (p>0.05) between them.

Before the SBS test, only one sample of the groups that were not submitted to TMC presented bond failure when subjected to the at-home bleaching. The other groups showed no failures. However, failures occurred in all the groups subjected to TMC, with three in the at-home bleaching group, four in the control group, and four in the in-office bleaching group.

Figure 3 and 4 show the fracture patterns observed after the SBS tests. For the non-cycled groups (samples not subjected to TMC), the authors found that enamel adhesive fracture occurred in 70% of the samples for both bleached groups, whereas this type of fracture occurred in 40% of the samples in the control group. There was neither bracket adhesive fracture nor cohesive type. Mixed fracture occurred in 10% of the samples in the HP group,

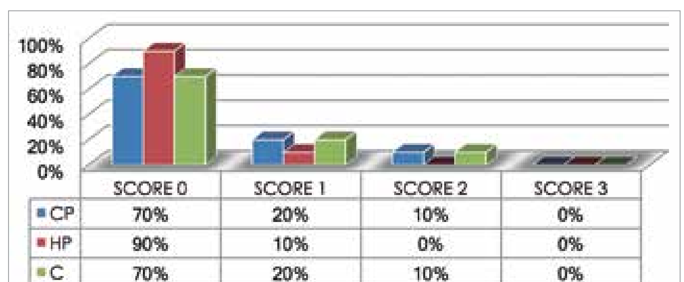

Figure 5. Distribution of Adhesive Remnant Index (ARI) of samples in group without TMC observed after shear bond strength test

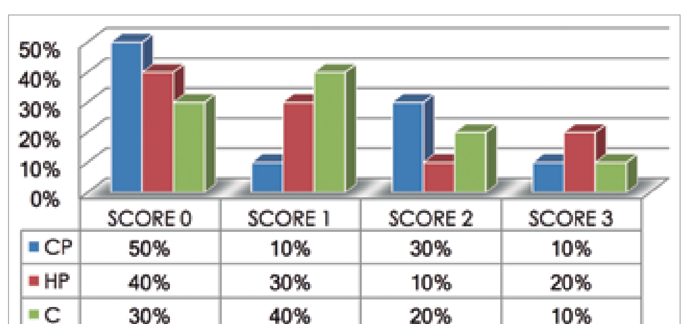

Figure 6. Distribution of Adhesive Remnant Index (ARI) of samples in group with TMC observed after shear bond strength test

whereas this type of fracture occurred in 30% of the samples in the other groups. There was no enamel cohesive fracture in the CP group. However, this type of fracture was observed in 20% of the samples in the HP group and 30% in the control group.

When submitted to TMC, there was balance in the type of fracture that occurred in the groups subjected to bleaching treatments because 30% of enamel adhesive and mixed fractures occurred in the samples submitted to HP and 40% of these same types of fractures after CP, followed by 10% of bracket adhesive fracture and 10% of enamel cohesive fracture.

After in-office bleaching, there were 20% bracket adhesive fracture and 10% cohesive and enamel fractures. The most prevalent fracture in the control group was the mixed type, followed by enamel adhesive fracture; those with the lowest prevalence were the bracket adhesive and cohesive enamel fractures.

Figure 5 and 6 show the distribution of the ARI scores in percentage. For the non-cycled groups, the highest incidence of ARI=0 occurred for both the bleaching treatments performed, being higher for the HP group, indicating that no adhesive was left on the enamel surface.

When subjected to TMC, higher percentages of scores 1, 2, and 3 were observed for all the groups tested. Samples from the control group presented the highest incidence of ARI=1, followed by ARI=0, 2, and 3, respectively. The HP group had a lower percentage of ARI=0 than the CP group when not subjected to TMC. Samples bleached in the office presented, in descending order, the scores 0>1>3>2; the ones bleached at home had the following sequence: 0>2>3=1.

DISCUSSION

The aim of the present study was to evaluate the SBS of orthodontic brackets on the enamel bleached by both at-home and in-office techniques subjected to TMC, starting from the null hypothesis that these factors would not be able to modify the enamel/bracket bonding. The authors observed that when subjected to TMC, the SBS presented no difference (p>0.05), regardless of the type of bleaching treatment performed. However, when not subjected to TMC, the at-home bleaching showed the lowest mean SBS, which was significantly different (p<0.05) from the control and HP groups. Thus, TMC was significant only for the CP group; therefore, the hypothesis of the study was partially accepted.

Studies had shown that the bond strength of composite resins to enamel decreases when tooth bleaching is performed in both at-home and in-office techniques (10, 24). In the present study, there were lower mean SBS for the CP group, corroborating the findings of previous studies (4, 25) that demonstrated that 10% carbamide peroxide is dissociated into 3% hydrogen peroxide and 7% urea, and afterwards, hydrogen peroxide dissociates into oxygen radicals and water. The released oxygen is responsible for bleaching the tooth by breaking down the pigment molecules in the enamel. These oxygen radicals are an inhibitory factor of resin composite polymerization, resulting in a reduction in bond strength right after bleaching (4, 18, 25).

On penetrating into the enamel microstructure and breaking down the pigment molecules, hydrogen peroxide denatures the enamel organic matrix proteins and causes roughness, fissures, and porosity in the tissue (26, 27), leaving it with a granular aspect (24). There may be a decrease in the concentration of calcium ions and enamel microhardness (11). All these factors may result in lower SBS. The concentration of these radicals in the tooth may vary according to the time during which the tooth remains in contact with the bleaching gel, justifying the lower SBS when carbamide peroxide was used in comparison with hydrogen peroxide; the results are similar to those found in a previous study (28).

Hydrogen peroxide was applied three times for 15 min, whereas carbamide peroxide was used for 14 days for 4 h/day. Therefore, the concentration of these radicals in the tooth could vary according to the period during which the enamel remained in contact with the bleaching gel, resulting in a reduction in bond strength that is time-dependent (25).

The action of the bleaching agent on the enamel surface also justifies the prevalence of the fracture patterns (11) and ARI scores. In the present study, the most susceptible area to failure was the enamel-resin interface, as well as ARI=0, indicating factors that demonstrate less bonding ability. These results were prevalent after non-cycled CP bleaching treatment, showing that the bleaching agent reduced the SBS; this corroborated the results of a previous study (28). The point that differentiates our study is that we submitted the samples to TMC, simulating chewing and subjecting the brackets to all the forces involved in this movement.

During the orthodontic treatment period, the materials must conveniently resist tension, traction, torque, and functional loads (16, 29). Mechanical laboratory tests used to evaluate the bonding effectiveness of adhesive systems to the dental structure are usually based on the application of displacement forces on the bonding interface in an attempt to simulate the loads transmitted to the bracket during treatment. Since orthodontic adhesives are routinely subjected to thermal variations in the oral cavity, it is essential to determine whether such temperature variations induce stress on the adhesive interface, influencing bond strength (12, 17).

In the present study, there was no significant difference in the SBS between samples either subjected to TMC or not in any of the groups. TMC was performed to cause fatigue at the bonding interface so that such stress would simulate the intraoral conditions that could be able to decrease the bonding of the tested materials to the enamel. However, the results indicated that the cycles tested were not sufficient to degrade and decrease bond strength; this was a fact also confirmed by the higher prevalence of the enamel adhesive fracture pattern when subjected to TMC. These findings corroborate previous studies that found no significant difference in bond strength after thermal cycling (12, 13, 17).

Despite this, the authors verified that TMC interfered in some way with the ARI scores. Non-cycled samples showed a higher percentage of ARI=0, whereas the groups subjected to TMC presented a higher incidence of an adhesive remnant on the enamel after the SBS test. This demonstrates a decrease in the bracket/adhesive bond strength, although no significant SBS results occurred.

These results may be explained by the significant mismatch of the thermal expansion coefficient between the adhesives, the metal bracket, and the enamel (15). In addition, the cyclical stress may cause any debonded regions at the interfaces to increase progressively in size (15). Thus, temperature alteration and axial load may have decreased the bond strength of thermally cycled specimens relative to those that were not cycled.

Another possible justification is the solubility of the composite. Water absorption that occurs during TMC can cause hygroscopic expansion as well as chemical degradation of materials (14, 15, 30), thereby reducing bond strength. However, as the SBS results showed no significant difference between the cycled and non-cycled samples, these justifications are not conclusive. Further studies are required for a better understanding of this mechanism.

CONCLUSION

Based on the results, the authors concluded that TMC was not a significant factor in SBS of any of the groups tested, regardless of the type of bleaching treatment previously performed. However, the at-home bleaching method significantly reduced the enamel/bracket SBS when non-cycled samples were tested.

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ORIGINAL ARTICLE

Comparing Different Methods to Estimate the Combined Mesiodistal Widths of Maxillary and Mandibular Incisors

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ABSTRACT

Objective: This study aimed to develop regression equations to predict the combined mesiodistal widths of maxillary and mandibular incisors from each other and compare them with other methods.

Methods: One hundred pairs of study models from 100 Iraqi subjects with normal occlusion were used in this study. The individualized mesiodistal widths of maxillary and mandibular incisors were measured using electronic digital calipers. The combined mesiodistal widths of maxillary and mandibular incisors were calculated according to Tonn's and Abhi's formulas and from regression equations to be compared with the actual one.

Results: Both sums of the maxillary and mandibular incisors were significantly correlated. There were significantly high differences between the actual and calculated sum widths, and also between the calculated and predicted ones. On the other hand, a non-significant difference was obtained between the actual and predicted sum widths of maxillary and mandibular incisors.

Conclusion: Tonn's and Abhi's methods are not reliable methods to calculate the sum widths of maxillary and mandibular incisors. New regression equations are developed to predict the sum widths of maxillary and mandibular incisors from each other.

Keywords: Abhi's formula, Tonn's formula, regression

INTRODUCTION

The main purposes of orthodontic treatment are to establish the esthetic harmony, functional efficiency, and structural balance (1, 2), in addition to obtaining straight teeth and stable results. These purposes can be attained by having a good inter-digitation between the maxillary and mandibular teeth with coordinated tooth size materials in the same arch and both arches (3).

The maxillary and mandibular incisors are subjected to many anomalies, such as the difference in size, shape, or number. The most affected tooth is the lateral incisor in both arches. It may be congenitally missed, small in size, and being peg shaped (maxillary) or may be missed (mandibular) (4).

In 1909, Pont established an index to predict the maxillary inter-premolar and inter-molar distances using the combined mesiodistal widths of maxillary incisors (5). This index gave inaccurate prediction in some cases with congenitally missing and abnormally shaped maxillary incisors, especially the laterals (6). To resolve this problem,

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Tonn (7) applied a formula to calculate the mesiodistal widths of the four maxillary incisors using the sum of mandibular incisors widths as follows: Sum of maxillary incisors=(Sum of mandibular incisors*4/3)+0.5.

In 2014, Bansal et al. (3) modified the Tonn's formula to estimate the sum of mandibular incisors widths from the sum of maxillary incisors widths and called it Abhi's formula: Sum of mandibular incisors=(Sum of maxillary incisors-0.5)*0.75. This formula was used to predict the mesiodistal width of impacted or missed lower incisor teeth.

To the best of author knowledge, until now, no study has been published to determine the reliability of the two mentioned methods, so the aim of the present study was to compare the sum mesiodistal widths of the maxillary and mandibular incisors using Tonn's and Abhi's methods with the actual mesiodistal widths and, at the same time, to formulate regression equations to predict the sum mesiodistal widths of the maxillary and mandibular incisors and compare them with the actual and previous methods.

METHODS

Sample

One hundred pairs of study models belonging to 50 male and 50 female subjects were used in this study. All subjects were of Iraqi Arab origin, aged between 17 and 22 years, with full permanent dentition regardless of the third molars. The teeth were in normal occlusion with no caries, fillings, or signs of attrition or abnormal anatomy.

Methods

After signing the consent form, the subjects were examined to fulfill the inclusion criteria. Then, alginate impressions were taken for the maxillary and mandibular teeth using the Hydrogum alginate impression material (Zhermack, Italy) and poured with Type IV dental stone (Navy blue, Zhermack, Italy) according to the manufacturer instructions. The individual mesiodistal width of maxillary and mandibular incisors was measured from the anatomical contact points using electronic digital calipers (Mitutoyo, Japan) with 0.01 mm sensitivity, held parallel to the occlusal plane (1), and the sum of mesiodistal widths of maxillary and mandibular incisors was obtained to be considered as the actual sum of widths, while the calculated widths were obtained using Tonn's and Abhi's methods. The predicted sum widths were obtained using the regression equations.

Statistical analysis

The data were collected and analyzed using the Statistical Package for Social Sciences program version 21 (IBM Corp.; Armonk, NY, USA). The statistical analyses included:

1. Descriptive statistics comprising the Shapiro-Wilk test and the mean and standard deviations
2. Inferential statistics
   a. Intraclass correlation test to test the reliability of the measurements
   b. Independent samples t-test to verify the gender difference for the measurements
   c. Pearson's correlation coefficient (r) to detect the relation between the sum of mesiodistal widths of maxillary and mandibular incisors
   d. Simple regression analysis to establish the regression equations that can be used to predict the sum of mesiodistal widths of maxillary and mandibular incisors from each other
   e. A paired sample t-test to compare the sum of mesiodistal widths of maxillary and mandibular incisors of both genders obtained with different methods

In the statistical evaluation, the following levels of significance were used:

Non-significant	NS	p>0.05
Significant	S	0.05≥p>0.01
Highly significant	HS	p≤0.01

RESULTS

First, testing the normality of data distribution was performed using the Shapiro–Wilk test, and the results indicated normally distributed data. Intraclass correlation indicated good reliability when repeating measurements after 1 week (more than 0.7).

Table 1. Descriptive statistics and gender difference of the mesiodistal width of individualized and combined maxillary and mandibular four incisors

Teeth		Males		Females		Gender Difference		
		Mean	SD	Mean	SD	Mean Difference	t-Test	p
Maxillary	RL	6.779	0.530	6.636	0.464	0.143	1.431	0.156 (NS)
	RC	8.899	0.535	8.489	0.438	0.409	4.187	0.000 (HS)
	LC	8.898	0.523	8.533	0.459	0.365	3.705	0.000 (HS)
	LL	6.770	0.561	6.645	0.461	0.125	1.218	0.226 (NS)
	Sum	31.345	1.739	30.304	1.548	1.042	3.164	0.002 (HS)
Mandibular	RL	6.014	0.448	5.678	0.319	0.336	4.318	0.000 (HS)
	RC	5.369	0.329	5.167	0.304	0.203	3.196	0.002 (HS)
	LC	5.332	0.373	5.197	0.319	0.136	1.956	0.053 (NS)
	LL	5.987	0.360	5.720	0.318	0.267	3.938	0.000 (HS)
	Sum	22.703	1.332	21.761	1.079	0.942	3.886	0.000 (HS)

RL: Right lateral; RC: Right central; LC: Left central; LL: Left lateral

Table 1 revealed the descriptive statistics and gender difference of the mesiodistal width of individualized and combined maxillary and mandibular four incisors. Generally, the mean values of the measured parameters were significantly higher in males than females except for the maxillary right and left laterals and mandibular left central incisor where there was non-significant gender difference.

The relation between the combined widths of maxillary and mandibular incisors was presented in Table 2 for both genders.

Table 2. The relation between the sum width of maxillary and mandibular incisors

Gender	r	p
Males	0.867	0.000 (HS)
Females	0.731	0.000 (HS)

Table 3. Regression equations for both genders

Gender	Maxilla	Mandible
Males	Y=5.631+1.133 X1	Y2=1.877+0.664 X2
Females	Y1=7.486+1.049 X1	Y2=6.325+0.509 X2

Y1: Sum of maxillary incisors widths; X1: Sum of mandibular incisors widths; Y2: Sum of mandibular incisors widths; X2: Sum of maxillary incisors widths

There was a strong direct significantly high correlation between them.

Regression equations to predict the sum of mesiodistal widths of the maxillary and mandibular incisors from each other are presented in Table 3, also for both genders.

In Tables 4 and 5, the actual sum of widths of maxillary and mandibular incisors was compared with that obtained from Tonn and Abhi and with that predicted by regression equations in both genders. There were significantly high method differences between both the actual and the predicted methods with that of Tonn's and Abhi's methods, while a non-significant method difference was detected between the actual and predicted one.

DISCUSSION

One of the most reliable methods of estimating the width of unerupted teeth is the developing of regression equation utilizing other teeth. Many studies had been conducted in Iraq to estimate the width of unerupted canine and premolars using this method and other methods (8-17).

Pont (5) tried to predict the maxillary inter-premolar and inter-molar distances using the combined mesiodistal widths of

Table 4. Descriptive statistics and methods' comparison in the male group

Teeth		Descriptive Statistics			Comparison		
	Methods	N	Mean	SD	Mean Difference	t-Test	p
Maxillary	Actual	50	31.345	1.739	0.574	4.490	0.000 (HS)
	Tonn	50	30.771	1.776			
Mandibular	Actual	50	22.703	1.332	-0.432	-4.500	0.000 (HS)
	Abhi	50	23.135	1.304			
Maxillary	Actual	50	31.345	1.739	-0.009	-0.069	0.946 (NS)
	Regression	50	31.354	1.510			
Mandibular	Actual	50	22.703	1.332	0.013	0.137	0.892 (NS)
	Regression	50	22.690	1.155			
Maxillary	Tonn	50	30.771	1.776	-0.583	-15.515	0.000 (HS)
	Regression	50	31.354	1.510			
Mandibular	Abhi	50	23.135	1.304	0.445	21.062	0.000 (HS)
	Regression	50	22.690	1.155			

Table 5. Descriptive statistics and methods' comparison in the female group

Teeth		Descriptive Statistics			Comparison		
	Methods	N	Mean	SD	Mean Difference	t-Test	p
Maxillary	Actual	50	30.304	1.548	0.789	5.071	0.000 (HS)
	Tonn	50	29.515	1.438			
Mandibular	Actual	50	21.761	1.079	-0.593	-5.082	0.000 (HS)
	Abhi	50	22.354	1.161			
Maxillary	Actual	50	30.304	1.548	-0.009	-0.064	0.949 (NS)
	Regression	50	30.313	1.130			
Mandibular	Actual	50	21.761	1.079	0.012	0.113	0.910 (NS)
	Regression	50	21.749	0.788			
Maxillary	Tonn	50	29.515	1.438	-0.798	-18.357	0.000 (HS)
	Regression	50	30.313	1.130			
Mandibular	Abhi	50	22.354	1.161	0.605	11.451	0.000 (HS)
	Regression	50	21.749	0.788			

maxillary incisors, but the problems associated with the presence and absence of lateral incisors made his index inaccurate. To solve this problem, Tonn (7) developed a formula to calculate the mesiodistal width of the four maxillary incisors using the sum of mandibular incisors width. Bansal et al. (3) benefited from this idea and calculated the mesiodistal widths of the four mandibular incisors using the sum of maxillary incisors width. Till now, there was no evidence about the accuracy of these methods, and to the best of the authors' knowledge, no study had been performed to ensure their accuracy. Hence this study was conducted.

The sample included Iraqi Arab subjects with full permanent dentition and class I occlusal relation. The individualized mesiodistal width of maxillary and mandibular anterior teeth was measured and collected for both genders. Reviewing Table 1 revealed that there was a significantly high difference between the genders for most of the measurements except the width of maxillary laterals and mandibular left central incisor. This difference is in the agreement with previous findings indicating significantly wider teeth in males (18, 19). The common finding that the tooth crown sizes in males exceeded, on average, those in females results from a greater thickness of dentin in male teeth. The difference is elucidated by the indorsing effect of the Y chromosome on dentin growth, probably through cell proliferation (20, 21).

The second step was finding the relationship between the sum of maxillary and mandibular anterior teeth widths using Pearson's correlation coefficient test. The results in Table 2 indicated that there was a direct strong significantly high correlation between the parameters in both genders. Vardimon and Lambertz (22) reported that if the value of the correlation coefficient test is greater than 0.70, the prediction procedures will be more reliable. These results paved the road for the next step, which was developing regression equations to estimate the combined widths of maxillary and mandibular incisors from each other for both genders, as described in Table 3.

The equation was calculated as $Y=a+b X$, where Y is the combined mesiodistal crowns widths of mandibular or maxillary permanent anterior teeth, X is the combined mesiodistal crowns widths of maxillary or mandibular anterior teeth based on which to predict, a is constant, and b is the regression coefficient. Now the actual sum widths (measured from study casts), calculated sum widths (calculated from Tonn's and Abhi's methods) in addition to the estimated sum widths (gained from applying the regression equations) were compared in both genders (Tables 4 and 5). The results revealed that there was a significantly high difference between the actual width and the calculated width. On the other hand, there was a non-significant difference between the actual and the predicted widths, while a significantly high difference was observed between the calculated and predicted widths. These results confirmed that the sum mesiodistal widths calculated from Tonn's and Abhi's methods were not reliable, and hence one cannot rely on these methods to calculate the sum widths of maxillary and mandibular anterior teeth.

Further studies are needed to develop regression equations in different countries as the mesiodistal widths of teeth are not the same in all people.

CONCLUSION

The present study is the first to determine the accuracy of the previous methods since no research has been performed to examine these methods statistically. Tonn's and Abhi's methods were not reliable in calculating sum mesiodistal widths of maxillary and mandibular incisors.

New regression equations to predict the sum widths of maxillary and mandibular anterior teeth were developed for both genders, and they proved statistically that their results were not different from the actual sum widths.

Ethics Committee Approval: Ethics committee approval was received for this study from the scientific committee in the Department of Orthodontics, University of Baghdad School of Dentistry, Iraq.

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

Peer-review: Externally peer-reviewed.

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ORIGINAL ARTICLE

Evaluation of Orthodontic Patients at State and Foundation Universities According to the ICON Index

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ABSTRACT

Objective: In Turkey, orthodontic treatments of individuals aged <18 years are covered by the Social Security Institution (SSI) according to the Index of Complexity, Outcome, and Need (ICON) index at contracted healthcare providers. The aim of this study was to determine treatment needs and difficulties of patients applying to orthodontic clinics in state and foundation universities in Istanbul according to the ICON and to evaluate the extent of treatment coverage by the SSI.

Methods: Pre-treatment study casts of 831 patients were evaluated in terms of treatment needs and difficulties according to the ICON. This sample was distributed as 677 patients who applied to a State University's Orthodontic Department and 154 who applied to a Foundation University's Orthodontic Department.

Results: At the state university, 27.9% of the 437 patients had a score of <43 and were thus, described as "no treatment needed." At the foundation university, 35% of the 154 patients had a score <43 and were thus, described as "no treatment needed." When the ICON scores of the two universities were compared, no statistically significant difference was found between treatment needs distributions.

Conclusion: The number of patients who applied for treatment for the same period was three times higher in the state university than in the foundation university, whereas the rates of treatment needs were found to be similar between both state and foundation universities. At both universities, nearly one-third of patients were evaluated as "no treatment needed." The ICON index was found to be a reliable index in terms of reproducibility.

Keywords: ICON, orthodontic treatment difficulty, orthodontic treatment need

INTRODUCTION

Nowadays, increased aesthetic expectations have increased the demand for orthodontic treatments (1). Therefore, several indices have been developed that, together, assess the treatment needs, difficulties, or both (2,3,4,5,6).

In 2000, the Index of Complexity, Outcome, and Need (ICON) was developed by Daniels and Richmond by consulting opinions of 97 orthodontists in nine different countries, and its applications have been wide-ranging. The index is evaluated over five sections, namely the aesthetic component, upper arch crowding/spacing, crossbite, overbite/open bite, and right and left buccal antero-posterior relationships. The aesthetic component is evaluated on a scale comprising 10 photographs from the Index of Orthodontic Treatment Need (IOTN) (Figure 1). Scores obtained from each section are multiplied by their own weight coefficients to obtain the total score (table 1) (2).

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Over the past years in our country, orthodontic treatment has been offered free of charge at contracted healthcare providers to all those aged <18 years by the Social Security Institution (SSI) (7). However, the number of individuals in need of orthodontic treatment is increasing day by day, leading to the necessity of a better management of health resources and their more effective use based on the treatment need.

Our Ministry of Health has reported to file number 23642684/010/2013.5363.34716 that the ICON will be used to determine the need for orthodontic treatment. In accordance with this decision, a report by the patient health board has determined that anybody aged <18 years and with a score of ≥43 on the ICON will be able to access treatment and have their fee repaid by the SSI, whereas those with a score <43 will be treated for a fee for "aesthetic purposes," except in the case of some criteria (8).

The aim of this study was to determine treatment needs and difficulties of patients applying to orthodontic clinics in state and foundation universities in Istanbul according to the ICON and to evaluate the extent of treatment coverage by the SSI.

METHODS

In this study, pre-treatment study casts and panoramic radiographs of 831 patients who applied to universities between 2013 and 2014 were evaluated. This sample was distributed as follows: 677 patients (392 women and 285 men) who applied to a State University's Orthodontic Department (first clinic) and 154 patients (94 women and 60 men) who applied to a Foundation University's Orthodontic Department (second clinic). The exclusion criteria were as follows: patients whose orthodontic models and panoramic X-rays were unclear and who previously underwent orthodontic treatment. A written informed consent form allowing the use of treatment records was obtained from all patients (or the patients' parents) at the beginning of treatment. Ethics committee approval was obtained from the Istanbul University Faculty of Dentistry's Clinical Research Ethics Committee with the file number 2016/25.

Pre-treatment study casts were evaluated according to the ICON. Panoramic radiographs were used to detect missing teeth. They were rated by the same researcher at both universities, with the orthodontic models viewed from the frontal plane while in occlusal contact. Obtained scores were multiplied by their own weight coefficients, and the total score was determined. Those with a total score of ≥43 were considered as "treatment is indicated" and those with a score <43 were considered as "no treatment needed." Orthodontic treatment complexity was evaluated as "easy" if the score was <29, as "mild" if it was between 29 and 50, as "moderate" if it was between 51 and 63, as "difficult" if it was between 64 and 77, and as "very difficult" if it was >77 (2).

Statistical Analysis

To evaluate the repeatability of the ICON index, 160 models from the first clinic and 35 from the second clinic were randomly selected from the total of 831 models, and second measurements were taken by the same investigator 1 month later. The Number Cruncher Statistical System (NCSS) 2007 (version 1) Statistical Software (Utah, USA) package program was used for statistical analysis. Descriptive statistical methods (mean, standard deviation) were used in the evaluation of data as well as an independent t-test for comparison of binary groups and chi-square test for comparison of qualitative data. Results were evaluated at a significance level of $p<0.05$. The intraclass correlation coefficient (ICC) was calculated to analyze the level of coherence of researchers regarding their ICON index scoring measures.

RESULTS

The mean age distribution of patients evaluated at the first clinic was 16 years and 5 months; 27.9% (189 patients) out of the 437 patients had a score of <43 and were thus, described as "no treatment needed," whereas 72.1% (488 patients) had a score of ≥43 and were thus, described as "treatment needed." In terms of treatment difficulty, 7.97% of the scored patients were evaluated as "easy" and 16.2% were evaluated as "very difficult" (table 2).

The mean age distribution of patients evaluated at the second clinic was 17 years and 1 month; 35% (54 patients) of the 154 patients had a score of <43 and were thus, described as "no

Table 1. ICON scoring protocol

	Score						
Component	**0**	**1**	**2**	**3**	**4**	**5**	**Weight**
1.Aesthetic assessment	Score 1-10						7
2. Upper arch Crowding	<2 mm	2.1-5 mm	5.1-9 mm	9.1-13 mm	13.1-17 mm	>17 mm or Impacted teeth	5
Spacing	<2 mm	2.1-5 mm	5.1-9 mm	>9 mm			5
3. Crossbite	No crossbite	Crossbite present					5
4. Anterior Openbite	Edge to edge	<1 mm	1.1-2 mm	2.1-4 mm	>4 mm		4
Overbite	<1/3 lower incisor coverage	1/3-2/3 coverage	2/3 up to completely covered	Completely covered			4
5. Buccal Segment Antero-posterior	Cusp to embrasure only. Class I, II, III	Any cusp relation up to but not including cusp to cusp	Cusp to cusp				3

treatment needed," whereas 65% (100 patients) had a score of ≥43 and were thus, described as "treatment needed." In terms of treatment difficulty, 12.98% of the scored patients were evaluated as "easy" and 20.12% were evaluated as "very difficult" (table 3). The female average was significantly higher in the second clinic than in the first clinic (p=0.016). When the ICON scores of the two universities were compared, no statistically significant differences were found between treatment needs distributions (p=0.096). The average score of "treatment needed" (score, >43) group was significantly lower in the second clinic than in the first clinic (p=0.011). The complexity grades "easy" (0-28) and "very difficult" (77-100) scores were significantly higher in the second clinic than in the first clinic (p=0.032), whereas grade "mild" (29-50) score was significantly lower in the second clinic (p=0.031). The complexity grade "very difficult" (77-100) score average was significantly lower in the second clinic than in the first clinic (p=0.011) (table 4).

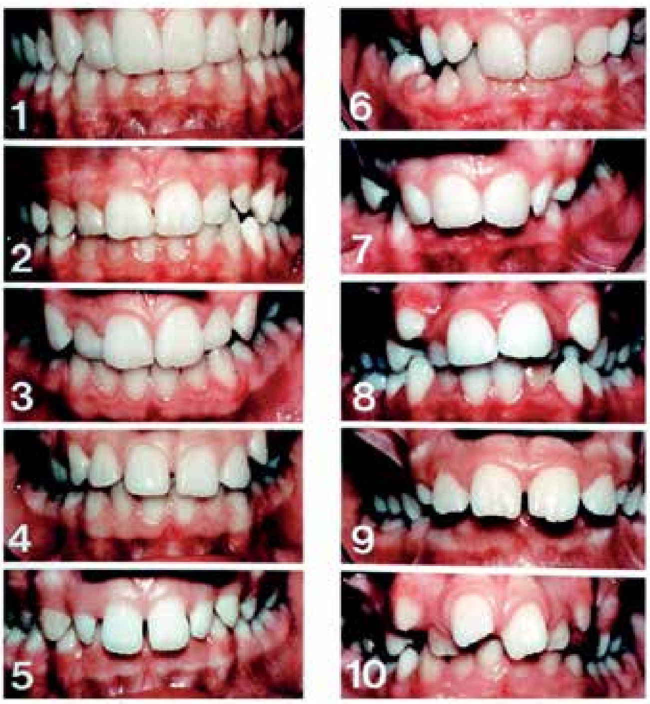

Figure 1. Aesthetic Component (AC) of the IOTN (2). 1-10. 10 photographs display dental attractiveness: (1) The most attractive and (10) the least attractive

When the level of compliance between the first and second measurement results of both universities was evaluated, a positive correlation with all values and between the total values was observed, with a statistically significant level of 98.8% (p<0.01) (table 5).

DISCUSSION

In this study, orthodontic models of patients that applied for treatment at state and foundation universities were scored by the same investigator according to the ICON index. The level of compliance with the first and second measurements (ICC: 0.988) was high, indicating that the ICON index is highly reproducible. The ICON index has been applied by the same researcher or by different researchers to obtain compatible results (9-12).

In this study, 72.1% of patients at the first clinic and 65% of those at the second clinic were scored as ≥43 and were thus, evaluated as "treatment needed" according to the ICON. Onyeaso and Be Gole (10) have reported treatment needs according to the ICON in 86% of 100 patients, Kamak et al. (13) in 58% of 154 patients, Utomi and Onyeaso (14) in 38% of 150 patients, and Lopez et al. (15) in 37% of 162 patients. Rates observed when evaluating treatment needs vary according to factors such as race, number of patients, and age distribution. The number of patients evaluated in our study was considerably higher than that in other studies in the literature. Furthermore, patients in our study comprised those who had applied for orthodontic treatment, instead of randomly selected members of the normal population. The higher ICON scores of our study can be attributed to this.

In terms of treatment difficulties, results showed that in the first clinic, 7.97% of patients were evaluated as "easy," 37.2% were

Table 2. ICON scores, age, and sex distributions of patients at the state university

			Number	Percentage (%)	Mean Deviation±SD
Sex		Female	392	58	
		Male	285	42	
		Total	677		
Age		Female	392		16.74±3.77
		Male	285		16.36±4.01
		Total	677		16.58±3.99
ICON Scoring	Treatment need: Yes	≥43	488	72.1	65.42±16.70
	Treatment need: No	<43	189	27.9	32.44±7.73
	Complexity Grade	Easy (0-28)	54	7.97	22.44±5.08
		Mild (29-50)	252	37.2	40.98±5.96
		Moderate (51-63)	124	18.3	56.62±3.74
		Difficult (64-77)	137	20.2	70.38±3.60
		Very difficult (77-100)	110	16.2	89.04±11.14

Table 3. ICON scores, age, and sex distributions of the patients at the foundation university

			Number	Percentage (%)	Mean Deviation±SD
Sex		Female	94	61	
		Male	60	39	
		Total	154		
Age		Female	94		17.81±4.21
		Male	60		16.02±5.02
		Total	154		17.16±5.88
ICON Scoring	Treatment need: Yes	≥43	100	65	67.20±14.88
	Treatment need: No	<43	54	35	29.22±9.54
	Complexity Grade	Easy (0-28)	20	12.98	19.10±7.28
		Mild (29-50)	54	35.06	39.03±6.13
		Moderate (51-63)	15	9.74	55.53±3.44
		Difficult (64-77)	34	22.07	69.35±3.88
		Very difficult (77-100)	31	20.12	83.67±5.92

Table 4. ICON scores, age, and sex distributions of patients between the two universities

			Number	Percentage (%)	Mean Deviation±SD
Age		Female	16.74±3.77	17.81±4.21	0.016
		Male	16.36±4.01	16.02±5.02	0.569
		Total	16.58±3.99	17.16±5.88	0.141
Sex		Female	392 57.90%	94 61.04	0.534
		Male	285 42.10%	60 38.96	
ICON Scoring	Treatment need	≥43 Yes	488 72.08%	100 64.94	0.096
		<43 No	189 27.92%	54 35.06	
	Treatment need (Mean Deviation)	≥43 Yes	65.42±16.70	67.20±14.88	0.323
		<43 No	32.44±7.73	29.22±9.54	0.011
	Complexity Grade	Easy (0-28)	54 7.98%	20 12.99	0.032
		Mild (29-50)	252 37.22%	54 35.06	
		Moderate (51-63)	124 18.32%	15 9.74	
		Difficult (64-77)	137 20.24%	34 22.08	
		Very difficult (77-100)	110 16.25%	31 20.13	
	Complexity Grade (Mean Deviation)	Easy (0-28)	22.44±5.08	19.10±7.28	0.029
		Mild (29-50)	40.98±5.96	39.03±6.13	0.031
		Moderate (51-63)	56.62±3.74	55.53±3.44	0.284
		Difficult (64-77)	70.38±3.60	69.35±3.88	0.143
		Very difficult (77-100)	89.04±11.14	83.67±5.92	0.011

Table 5. Level of coherence between the researcher's ICON scores

	Intraclass correlation coefficient (ICC)	95% CI		p
Aesthetic component	0.984	0.979	0.988	0.000**
Upper arch crowding/spacing	0.992	0.989	0.994	0.000**
Crossbite	0.986	0.981	0.990	0.000**
Overbite/openbite	0.971	0.961	0.979	0.000**
Right buccal antero-posterior	0.951	0.934	0.964	0.000**
Left buccal antero-posterior	0.912	0.881	0.935	0.000**
Total	0.988	0.983	0.991	0.000**

ICC: Intraclass correlation coefficient 95% CI: 95% confidence interval ** p<0.01

evaluated as "mild," 18.3% were evaluated as "moderate," 20.2% were evaluated as "difficult," and 16.2% were evaluated as "very difficult." In the second clinic, 12.98% of patients were evaluated as "easy," 35.06% were evaluated as "mild," 9.74% were evaluated as "moderate," 22.07% were evaluated as "difficult," and 20.12% were evaluated as "very difficult." Richmond et al. (16) have reported that 36% of 100 patients they examined were evaluated as "very difficult," whereas Kamak et al. (17) have reported that 56.4% of 500 patients they examined were evaluated as "difficult" or "very difficult" and Onyeaso (18) has reported the same for 10% of 274 patients examined.

In our country, treatment fees for patients aged <18 years applying for orthodontic treatment are covered by the government if they score ≥43 on the ICON index. With this rule of force since 2013, its aim is to increase treatment quality by providing orthodontic treatment to patients who need treatment and whose treatment difficulty is high. In our study, an average of one-third of patients who applied to both universities scored <43 and was thus, ineligible for treatment. This practice ensures that the health budget is rationally used by directing resources to patients of most need of treatment, instead of to purely aesthetic patients.

The limitation of our study was the difference between the number of patients at the two clinics. In our study, patients referred to both state and foundation universities during the same period were examined. Therefore, the number of patients at these two clinics was variable because of the high concentration of patients at the state university.

CONCLUSION

In our study, the distribution of orthodontic treatment services funded by the SSI for individuals with treatment needs according to the ICON index was examined at both state and foundation universities. The number of patients who applied for treatment during the same period was three times higher in the state university than in the foundation university, whereas the rates of treatment needs of patients were similar in both universities. At both universities, nearly one-third of patients were evaluated as "no treatment needed." The ICON index was found to be a reliable index in terms of reproducibility.

Ethics Committee Approval: Ethics committee approval was received for this study from the Istanbul University School of Dentistry's Clinical Research Ethics Committee (2016/25).

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ORIGINAL ARTICLE

The Accuracy of Information about Orthodontics Available on the Internet

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ABSTRACT

Objective: The aim of the present study was to evaluate the content of the informative websites related to orthodontic terms in Turkish and in English.

Methods: Five different orthodontic terms ("orthodontic appliances (ortodontik aygıtlar)," "orthodontic braces (ortodontik braketler)," "orthodontic elastics (ortodontik elastikler)," "orthognathic surgery (ortognatik cerrahi)," and "orthodontic treatment (ortodontik tedavi)") both in Turkish and in English were searched using Google. There were 25 websites evaluated for each term. A total of 137 different websites were evaluated with three measurement tools: DISCERN (questionnaire, University of Oxford, 1999) (quality of information), LIDA (v1.2 Minervation, 2007) (accessibility, usability, and reliability), and AChecker (v0.1 ATutor, 2011) (accessibility).

Results: The mean overall score of the quality of information was "good" for terms in Turkish and in English. The LIDA score was classified as "moderate" for terms in Turkish and in English. More accessibility errors were found on the Turkish websites than on the English counterparts. Most of the statistical evaluations between Turkish and English terms were insignificant. However, intragroup evaluation of the terms mostly showed significant differences.

Conclusion: Accessibility, usability, and reliability; quality of information; and scores of access errors showed variations among Turkish and English sites. The collaboration of website designers and clinicians to increase the quality level of the websites is recommended.

Keywords: Internet, orthodontics, health information systems, medical informatics

INTRODUCTION

The Internet comes from the words "interconnected networks" or "international networks," meaning "networks connected to each other." This interconnectedness has given users the ability to do daily tasks quickly, making life easier and saving much time.

Health-related information is among the most frequently accessed information on the Internet. Today, approximately three-quarters of the population in developed countries use the Internet to receive information about health issues (1).

The Internet is also being used increasingly by patients to access dental information. Therefore, the number of dentistry-related websites on the Internet is increasing every day. However, the lack of any control over the Internet and the ease by which information is published and spread created the need for safe and reliable sites that provide health information. Promotional websites about dentistry or orthodontics often contain advertising information that pushes the limits of what treatments offer. Therefore, a number of ethical principles have been

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identified by national and international organizations to ensure that health websites are accurate and do not in any way mislead users with the information they provide (2). Even though the ethical rules are being determined, the audit system is weak.

Some validated tools, which evaluate the content of the websites from different perspectives, have been developed as a result of the preponderant access of the public to online health-related information. The DISCERN questionnaire, which was developed in 1999 (University of Oxford, UK), has been originally framed to analyze the quality of written information (3). The DISCERN was the first standardized and validated tool to evaluate the quality of the healthcare information spread through the web. The tool includes 16 questions. The first part evaluates the reliability of the written information, the second part assesses the presentation of alternative treatment options, and the final part analyzes the general quality rating question. All answers are scored from 1 to 5, and the total available maximum score is 80 versus the minimum score of 16. Som and Gunawardana (4) categorized the DISCERN scores as excellent (63-75), good (51-62), fair (39-50), poor (27-38), and very poor (15-26).

The LIDA (v1.2 Minervation, 2007) instrument is designed to evaluate the accessibility, usability, and reliability features of health websites (5). Accessibility indicates the compliance with the World Wide Web Consortium (W3C) accessibility guidelines. Usability is the ease of use of a website for an end-user, without requiring any specialized training. On the other hand, reliability refers to whether the information provided by the website is evidence-based, accurate, objective, or current. It is also expected to provide information on other treatment options and links to access additional sources on the websites. Deficiently designed websites create barriers to aggregate online information. Therefore, increasing the accessibility of the websites increases the ability of consumers to access information more efficiently. The accessibility score of the evaluated website is automatically generated by the tool. The usability score evaluates four main parameters: clarity, consistency, functionality, and engageability. The reliability score of the websites is defined by currency, conflicts of interest, and content production method. The questions are scored on a scale resulting in a total possible LIDA score of 144, with the maximum scores for accessibility (63), usability (54), and reliability (27). The LIDA scores are classified as high if the score is ≥90%, moderate if the score is between 50% and 90%, and low if the score is <50% according to Livas et al. (6).

As previously mentioned, web accessibility refers to targeting to inhibit obstacles that prevent interaction with or access to websites by people with disabilities. All users have equal access to information if websites are correctly designed. In addition to the LIDA instrument, there are a variety of instruments to detect access errors. AChecker (v0.1 ATutor, 2011) is a tool developed in 2009 by the Inclusive Design Research Centre of the University of Toronto. The tool provides evaluation options using the website's URL, HTML source, or HTML file. The user can choose among the guidelines to evaluate it against, such as HTML Validator, BITV, Section 508, Stanca Act, Web Content Accessibility Guidelines (WCAG) 1.0, or WCAG 2.0. The WCAG 2.0 comprises a list of recommendations for making content accessible to a wider range of people with visual, cognitive, motor, auditive, or speech disabilities. The tool automatically generates a general and a detailed report of the accessibility problems based on the selected guidelines (7). The detailed report identifies three kinds of access problems:

1. Known problems: These accessibility hurdles are precisely defined. It is necessary to design the page from the beginning to be able to correct it.
2. Likely problems: These are probable barriers requiring a human being to decide.
3. Potential problems: These are problems that cannot be detected by the AChecker and require human judgment. It might be necessary to modify the webpage or just confirm that the problem is not present.

The aim of the present study was to evaluate the websites in English and in Turkish, providing orthodontic information in different perspectives. Three measurement tools have been used: DISCERN to evaluate the quality of information; LIDA to interpret accessibility, usability, and reliability; and AChecker to detect access errors.

All of these three tools were accessible via the Internet and were proven to be reliable, up-to-date, easy to use, and cost free.

METHODS

Internet access was established from Bezmialem Vakif University's wireless connection. A list of possible popular keywords, which might be used by lay people to obtain information regarding orthodontics, was made in Turkish. After reviewing the list and excluding words that are too specific, five keywords were determined with the consensus of the two authors: "orthodontic appliances (ortodontik aygıtlar)," "orthodontic braces (ortodontik braketler)," "orthodontic elastics (ortodontik elastikler)," "orthognathic surgery (ortognatik cerrahi)," and "orthodontic treatment (ortodontik tedavi)." A literal translation was made for English terms.

Google (www.google.com) was used to display websites related to orthodontic terms from January to March 2017. Fifty (25 in Turkish and 25 in English) websites were evaluated for each term using three tools (DISCERN, LIDA, and AChecker). A total of 137 (72 in Turkish and 65 in English) different websites were included in the study. One operator scored all the websites.

The search was limited to the English and Turkish languages only. The results that were not related to the searched term or those that linked to other websites were excluded as well as advertisements and sponsored links. News, photos, videos, magazines, discussion or forum groups, and duplicate sites were also eliminated.

Statistical analysis was performed using the Statistical Package for the Social Sciences for Windows 22.0 (IBM Corp.; Armonk, NY, USA). The Mann-Whitney U test was used for comparison of two non-normally distributed groups. The Friedman test was applied for intragroup comparisons. The Wilcoxon rank test was utilized to determine the difference between the intragroup recurrent measurements. The results were evaluated at a 90% confidence interval. $p<0.05$ was considered as statistically significant.

No approval from the ethics committee was required in the present study since it involved the analysis of freely available online information.

RESULTS

The mean overall score of the information quality was classified as "good" (Turkish terms: 53.7±2.07 and English terms: 52.1±1.49), and the mean overall score of the LIDA tool was "moderate" (Turkish terms: 78.9±2.09 and English terms: 82.3±5.83). Accessibility errors detected with the AChecker in orthodontics-related Turkish websites (21.2±9.44) were higher than those English websites (18.4±1.66) (Table 1).

The highest scores among the Turkish terms were reported for "orthodontic treatment" in terms of information quality. "Orthognathic surgery" had the higher scores related to LIDA, whereas the lowest access errors were encountered with "orthodontic appliances" (Table 1).

The highest scores among the English terms were reported for "orthodontic braces" in terms of information quality. The highest

Table 1. Mean scores related to terms in Turkish and in English

Terms in Turkish	**"Ortodontik aygıtlar"**	**"Ortodontik braketler"**	**"Ortognatik cerrahi"**	**"Ortodontik elastikler"**	**"Ortodontik tedavi"**
DISCERN	53.6+6.33	53.8+6.60	51.8+5.52	52.3+4.15	57.1+4.80
LIDA	78.1+5.88	78+7.73	81.8+7.17	76.5+8.94	80.3+10.83
AChecker	9+2.81	16.2+6.06	26.8+3.45	33.5+4.71	20.4+6.68
Terms in English	**Orthodontic appliances**	**Orthodontic braces**	**Orthognathic surgery**	**Orthodontic elastics**	**Orthodontic treatment**
DISCERN	53.2+3.82	53.7+6.16	52.5+8.14	50.9+5.15	50.2+7.74
LIDA	78.6+9.42	76+7.52	88+6.38	78.4+6.86	88.6+10.91
AChecker	46.1+4.98	26+6.19	29+7.36	20.6+2.27	24.7+3.64

Table 2. Comparison of the DISCERN, LIDA and AChecker scores between the groups

DISCERN		**Orthodontic appliances**	**Orthodontic treatment**	**Orthodontic elastics**	**Orthodontic braces**	**Orthognathic surgery**
Terms in Turkish (n=25)	Median	37	38	49	44	56
	Minimum	19	24	43	25	40
	Maximum	64	60	58	63	76
Terms in English (n=25)	Median	37	44	49	49	53
	Minimum	27	30	43	30	41
	Maximum	52	55	62	72	72
	p	0.977	0.171	0.969	0.007*	0.741
LIDA						
Terms in Turkish (n=25)	Median	103	107	93	107	102
	Minimum	65	61	77	60	75
	Maximum	127	134	132	131	134
Terms in English (n=25)	Median	104	100	109	96	96
	Minimum	77	76	54	50	72
	Maximum	125	135	137	129	133
	p	0.854	0.655	0.503	0.454	0.426
AChecker						
Terms in Turkish (n=25)	Median	14	22	22	14	16
	Minimum	3	1	1	0	2
	Maximum	89	56	56	43	59
Terms in English (n=25)	Median	9	22	22	21	10
	Minimum	0	0	0	2	0
	Maximum	98	125	125	55	59
	p	0.072	0.93	0.655	0.091	0.641

Mann-Whitney U test, p<0,05 was considered as statistically significant scores were recorded for "orthognathic treatment" for the evaluation using the LIDA tool, whereas the lowest access errors were encountered with "orthodontic elastics."

A comparison of the Turkish and English websites revealed that statistically significant differences were present for "orthodontic braces" in terms of information quality (DISCERN, p=0.007) (Table 2), but no statistically significant differences were found for the LIDA and AChecker tools (Table 2). In-group evaluations for Turkish terms showed statistically significant differences in terms of information quality (p=0.000) and access errors (known problems, p=0.046 and likely problems, p=0.000) (Table 3). A statistically significant difference was determined in terms of information quality (p=0.000), information reliability (p=0.015), and access errors (likely problems, p=0.001) for English terms (Table 3).

DISCUSSION

The Internet is an established portal of information. The number of websites providing healthcare information on the Internet has dramatically risen in the past years. Nowadays, there are no standards required for health information on the Internet (8). Taking advantage of this, some websites that appear to be educational are promotional in nature, whereas others may be inefficient, incomplete, not easy to understand, or may contain conflicting information (9, 10).

Although there are many engines that allow you to search the Internet, we listed the results derived from a single search engine (Google). Previous authors who evaluated online health-related information preferred using single or multiple search engines. We used Google for our search because it provides a larger number of results for keywords compared with other search engines.

Table 3. Intragroup comparison of DISCERN, AChecker and LIDA scores

		Information Quality (DISCERN)	Access Errors (AChecker)		LIDA		
			Known problems	Likely problems	Accessibility	Usability	Reliability
Terms in Turkish (n=25)	p	0.000**	0.046*	0.000**	0.814	0.531	0.715
Terms in English (n=25)	p	0.000**	0.177	0.001**	0.425	0.271	0.015*

Friedman test, p<0,05 was considered as statistically significant

Table 4. Former studies using the LIDA and/or DISCERN instruments

Author(s)	Release year	Search engine	Number of the evaluated websites	Measurement tools and scores	Searched terms
Berland and Elliott (19)	2001	10 search engines in English and 4 in Spanish	25 websites from each search engine	Fry Readability Graph. Method (86% high school level) and key words for information quality	Depression, obesity, breast cancer and childhood asthma (in English and in Spanish)
Patel and Cobourne (11)	2011	Google and Yahoo	50	LIDA (93)	Orthodontic extractions (in English)
Aldairy et al. (8)	2012	Google, Yahoo, and Ask.com	25	DISCERN (21-64)	Orthognathic surgery Jaw surgery (in English)
Som and Gunawardana (4)	2012	Google	10	DISCERN (56.1)	Chemotherapy information (in English)
Livas et al. (6).	2013	Google, Bing, Yahoo, Ask.com, and AOL	25	LIDA (16,9%–86,2%)	Orthodontic pain and braces pain (in English)
Patel and Cobourne (5)	2015	Google	100	LIDA (110) DISCERN (48)	Orthodontic braces (in English)
Shital Kiran et al. (19)	2015	Google	36	DISCERN (16-55)	Thumb sucking habit (in English)
Doğramacı and Rossi-Fedele (20)	2016	Google, Yahoo, Ask.com, Web Wombat, and Bing	200	LIDA (72%) DISCERN (47%)	Orthodontic retainers (in English)
McMorrow and Millet (17)	2016	Google, Yahoo and Bing	13	DISCERN (3,9/5) LIDA (115)	Adult orthodontics and adult braces (in English)
Canıgür Bavbek et al. (21)	2017	Google	25	DISCERN (28/75)	Orthognathic surgery (in Turkish)
Present study	2017	Google	137	LIDA (78,9/82,3) AChecker (21,8/18,4) DISCERN (53,7/52,1)	Orthodontic appliances, orthodontic braces, orthodontic elastics, orthognathic surgery and orthodontic treatment (in Turkish and in English)

Moreover, it is the most popular search engine (10). Nevertheless, more than one search engine can be used in future studies.

A total of 137 websites in two languages (72 in Turkish and 65 in English) were evaluated in the present study. Based on the statement by Aldairy et al. (8) that patients would not visit more than the first 20 results in a regular search, 25 websites are chosen to be assessed for each term. A total of 50 webpages were evaluated for each term in both languages. Exclusion criteria included those web-based studies with similar aims (11). Previous studies that have focused on orthodontic terms have yielded 21 to 49 websites fitting the criteria for evaluation (12, 13).

One of the assessment tools used in the present study was DISCERN, which has been demonstrated as an effective tool to evaluate the information quality (14). The results of our study indicated that few websites showed high standards in information quality. Although DISCERN has been previously criticized for not analyzing insignificant detail when compared with other tools, the tool was proven to have good internal consistency (15). The mean total DISCERN score for the terms in both languages can be classified as "good," with 52.9/80 (66.1%). The total DISCERN scores for Turkish and English websites were 53.7 and 52.1, respectively (Table 1). None of the websites was scored as excellent. These results indicate that when building practice websites, the designers can focus on the excellent level for the quality of information, and they can aim to ameliorate the information quality of the new websites.

The mean total LIDA score for all of the websites included in the study was 80.6/144 (55.9%), which could be classified as "moderate." The total LIDA scores for Turkish and English websites were 78.9 and 82.3, respectively (Table 1). Other studies that evaluated websites providing information about orthognathic surgery, orthodontic pain, and oral hygiene instructions with fixed appliances using LIDA reported a similarly moderate level of the mean score (13, 16). In our study, the highest score of the LIDA tool was found for accessibility, and the lowest was found for reliability, similar to other studies (17).

The use of the Internet by lay people will hold a preponderant importance in the near future. Considering our results, even though the Internet is a powerful tool for people requiring orthodontic information, there are many issues that should be ameliorated in many perspectives. Table 4 shows some previous studies in the fields of dentistry and medicine evaluating online informative pages using the DISCERN and LIDA tools.

In many countries, there are steps taken to ensure that differently abled citizens have the same rights as others. With the recognition and growth of the W3C, special laws regarding the use of the Internet for people with disabilities have been established. For example, in 2004, the government of Italy approved a new legislation designed to provide differently abled citizens access to online services.

There are a variety of tools to evaluate accessibility. However, most of them are used to evaluate images and screenshots (e.g., Cynthia Says and Accessibility Valet). Some of these tools require payment, whereas the tool used in the present study, AChecker, is free of charge and allows limitless use. Moreover, AChecker is easy to use and subjectively reports the accessibility errors in three domains (known, likely, and potential problems) since it automatically generates the reports. Even though there are studies evaluating general health websites accessibility, there is no previous study about the access errors of websites providing information about orthodontic terms. Therefore, our results regarding this tool are unique and cannot be compared.

Similar to previous studies, the results of the present study provide the "snapshot" of the websites at one point in time. Websites are constantly being updated, and their content can change over time, suggesting the dynamic feature of the Internet. This is the reason why we can find different results if the same search is conducted at a future date. Although there is a consensus from previous studies that improvements in online orthodontic information are required, no specific guidance on how to address these improvements has been documented (6, 8, 11). On the other hand, the American Medical Association has established guidelines that websites should follow (18). A similar international guideline could be developed regarding online dental or orthodontic online sources. Orthodontic societies should collaborate to create reliable online sources about commonly searched orthodontic topics. The Internet resources should be developed with reference to the validated tools (LIDA and DISCERN) and in conjunction with informatics experts.

Only one operator made all the evaluations in the present study. Even though the tool's intra-operator reliability has been demonstrated to be good, we could include more examiners to provide a more objective evaluation.

Most similar studies evaluated terms in only one language (generally in English) (8, 17, 19-21). Only one study was performed with terms in two languages (English and Spanish) to evaluate terms such as depression, obesity, breast cancer, and childhood asthma (22). To our knowledge, this is the first bilinguistics study in the field of dentistry and, more specifically, in orthodontics to evaluate orthodontic information on the Internet. Furthermore, other terms in other languages can be incorporated into a future study to perform an international overview.

Based on these results, we suggest that websites can be checked for usability, quality of information, and access errors with suitable measurement tools before being made available to the public. Official organizations having no financial benefit can consider establishing norms for the websites providing health-related information, and an audit system supported by the government can be established. An alternative could be to create state-supported informative websites and question-and-answer forums. Public spots could direct patients to those perfectly designed, up-to-date websites to produce high-quality online services. Moreover, the awareness of accessibility issues among web developers and clinicians should be increased since problems could be easily solved if they are recognized.

CONCLUSION

Accessibility, usability, and reliability (LIDA), quality of information (DISCERN), and access errors' scores showed variations among Turkish and English sites. The scores of English websites in information quality for "orthodontic braces" are significantly higher than those of Turkish websites. The average score for the information quality of the English and Turkish terms was reported as "good," and the average LIDA score was found to be "moderate."

People searching for information about orthodontics on the Internet should be aware that the information they find may not be appropriate or reliable. The collaboration of website designers and clinicians to increase the quality level of the websites is recommended.

Ethics Committee Approval: No approval from the ethics committee was required in the present study since it involved the analysis of freely available online information.

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ORIGINAL ARTICLE

Comparison of the Accuracy of Manual and Digital Cephalometric Prediction Methods in Orthognathic Surgical Planning: A Pilot Study

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ABSTRACT

Objective: To compare and evaluate the reliability of manual and digital cephalometric prediction methods in orthognathic surgical planning

Methods: Ten adults (5 females and 5 males) with skeletal class III malocclusion were included. The mean patient age was 21.97 years. Pre- to postoperative changes were evaluated using paired t-test. Manual surgical predictions made by tracing on acetate paper and digital predictions made using computer software were compared with actual postoperative values using intraclass correlation coefficient and root mean square.

Results: Statistically significant changes were observed in SNA, SNB, ANB, U1i-FH, and Nperp-A following bimaxillary orthognathic surgery ($p<0.001$). Postoperative changes in Co-A and Nperp-Pg were statistically significant ($p<0.05$). Comparison of manual and digital surgical predictions with actual postoperative values revealed that overbite and overjet showed the lowest agreements. Manual predictions were less accurate for points that were difficult to distinguish (Co and U6). Skeletal predictions were more accurate than dental predictions.

Conclusion: Parameters with low reproducibility (Co and U6) decrease the reliability of predictions. Dental predictions were inaccurate in both methods due to the effects of intermaxillary elastics, but both methods yielded similar predictions for skeletal parameters. The impact of applying strong elastics for postoperative intermaxillary fixation should be considered when making surgical predictions.

Keywords: Skeletal class III malocclusion, orthognathic surgery, surgical predictions

INTRODUCTION

Lateral cephalometric radiographic examination and analysis are a routine and important part of orthognathic surgeries. These procedures enable physicians to predict changes in the soft tissue and skeletal structure as a result of surgery and also help the patient to be informed about the planned surgery. Conventionally, orthognathic surgery is manually planned using acetate tracing paper. Today, however, these tracings can be performed digitally using computer software.

In the literature, Cohen (1) first described the degree of mandibular retraction required in mandibular surgeries to achieve satisfactory facial esthetic results. He marked reference points on patients' preoperative lateral cephalometric radiographs and used a compass to estimate postoperative changes. In another method developed by McNeill et al. (2), preoperative plaster models were created and an articulator was used to bring the maxilla and mandible into the ideal position. Henderson (3) developed a different method in which patients'

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lateral cephalometric radiographs were superimposed on profile images in an attempt to predict the outcomes of osteotomy. The surgical procedure was performed virtually by applying LeFort 1 osteotomy incision lines on these superimposed images. Worms et al. (4) established a guide for use in orthognathic surgery planning, which specified the movement ratios between the soft and hard tissues. They used reference points, such as the incisor position on the jaw base and the hard tissue pogonion. Hohl et al. (5) made vertical and horizontal measurements using the nasion–pogonion line as a reference. Fish and Epker (6) developed another method of predicting postoperative changes in the skeletal and soft tissue structures following orthognathic surgery. They used the Ricketts' cephalometric analysis as well as growth estimation and objective parameters of visual treatment defined by Bench et al. to predict changes following mandibular advancement and combined maxillary and mandibular osteotomies (7). The Frankfort horizontal line and a vertical line drawn from the nasion were used as reference s to determine the optimal facial depth. In their study, the authors concluded that the repositioning of the posterior maxilla resulted in the autorotation of the mandible. In the mid-1980s, Wolford et al. (8) conducted a systematic review and developed an estimation table of hard and soft tissue changes after surgeries using different osteotomy techniques. Altuğ et al. (9) reported that favorable changes in the facial profile following bimaxillary orthognathic surgery were largely due to the posterior movement of the mandible and accompanying changes in the lower lip position.

Bhatia and Sowray (10) developed the first computer software for use in orthognathic surgical planning. This software could analyze reference points marked on patients' lateral cephalometric radiographs and import profile photographs to create animations of the possible postoperative changes. Moreover, programs with similar features were developed by Harradine and Burnie (11) and Walters and Walters (12). Currently, several computer programs are available to assist orthognathic surgical planning. One of these is Quick Ceph (Quick Ceph Systems, San Diego, California, USA), which was the first commercially available software developed for surgical planning. In this program, patient records are imported into the system, and surgeries can be simulated according to predefined normative values. In a similar program called Dolphin, various changes can be imposed on lateral cephalometric radiographs and profile images to facilitate a more accurate marking of reference points. In a 2009 study, Kaipatur et al. (13) showed that although surgical plans created using computer software may be clinically acceptable, they may yield misleading results, especially in the prediction of soft tissue movements involving the lower lip region. In a similar study conducted in 2007, Pektaş et al (14) found that computer software provided satisfactory results in the prediction of soft

Table 1. Preoperative mean age of patients with skeletal Class III malocclusion, presented as mean with standard error (SE), minimum (min), and maximum (max) values

N	Chronological Age (years)			
	Mean	SE	Min	Max
10	21.97	2.01	18.58	25.00

tissue changes after surgery. The authors reported that digital predictions were the most accurate toward the tip of the nose and least accurate in the lower lip area. They also noted that digital predictions were more accurate in the sagittal plane than in the vertical plane.

Patients who have completed growth and development and have severe skeletal defects are managed using orthognathic surgical protocols incorporating both orthodontics and surgery. The success of these treatments is highly dependent on the pre- and postoperative orthodontic interventions used as well as presurgical planning. Changes in the skeletal and soft tissue structures after surgery can be predicted using conventional cephalometric tracings or computer software. Previous studies evaluating class III bimaxillary orthognathic surgical predictions have compared computer-generated predictions with surgical outcomes. However, no studies have compared conventional prediction using acetate tracing paper over lateral cephalometric radiographs, digital prediction using computer software, and actual postoperative results. Therefore, our objective in the present study was to determine which of these two prediction methods is more reliable by comparing them with each other and with postoperative outcomes.

METHODS

Ten patients (5 females and 5 males) with skeletal class III malocclusion were included in the study. All patients underwent presurgical orthodontic decompensation in the Orthodontics Department of the Ankara University School of Dentistry, followed by bimaxillary orthognathic surgery prepared and planned by the same surgical team in the Oral and Maxillofacial Surgery Department. The mean patient age is given in Table 1.

Patients Meeting the Following Criteria were Included in the Study

- Completed growth and development and skeletal class III malocclusion (ANB<0);
- Absence of any craniofacial syndrome;
- Skeletal class III malocclusion corrected through maxillary advancement (LeFort 1 osteotomy) and mandibular set-back (sagittal split osteotomy);
- Orthognathic surgery planned and performed by the same team;
- Absence of any additional treatment.

Patients Meeting Any of the Following Criteria were Excluded from the Study

- Incomplete growth and development, currently developing;
- Open or deep skeletal bites and severe hyperdivergent growth pattern;
- Any condition involving the craniofacial region;
- Inadequate or inaccessible radiographic records.

Cephalometric Evaluation

The study was conducted using pre- and postoperative lateral cephalometric radiographs, which were analyzed using the Steiner and McNamara normative values. All orthodontic radiographic records were collected using the same x-ray machine (Sirona Orthophos XG5, Sirona Dental Company, Long Island City, NY, USA). Postoperative lateral cephalometric radiographs were obtained 6 months after the surgery. Conventional surgical predictions (manual tracings on acetate paper) and computer-generated predictions (Dolphin Imaging 11.8, Dolphin Imaging & Management Solutions, Chatsworth, CA, USA) based on the same preoperative lateral cephalometric radiographs and the same surgical manipulations were compared with the actual postoperative values. The conventional method comprised manual tracing of the preoperative lateral cephalometric radiographs on acetate paper with a light box. Once the anatomical structures were traced, desired surgical movements were performed on the maxilla and mandible by cutting and repositioning the skeletal segments. The soft tissue structures were manipulated depending on the hard tissue changes, as described in literature (13).

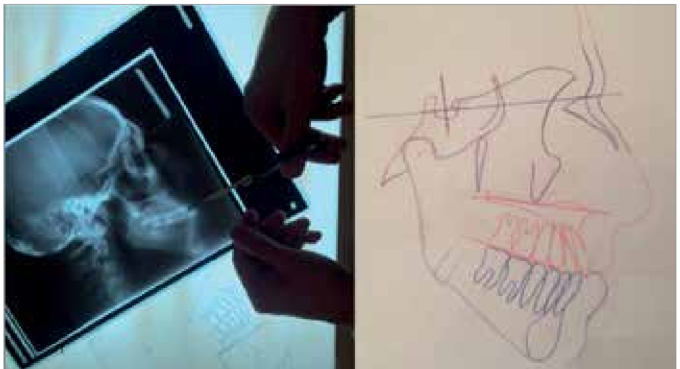

Figure 1. Manual prediction method

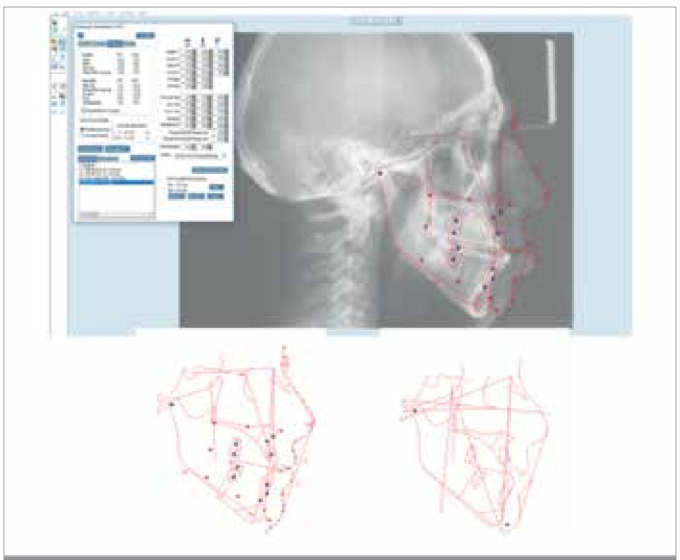

Figure 2. Digital prediction method

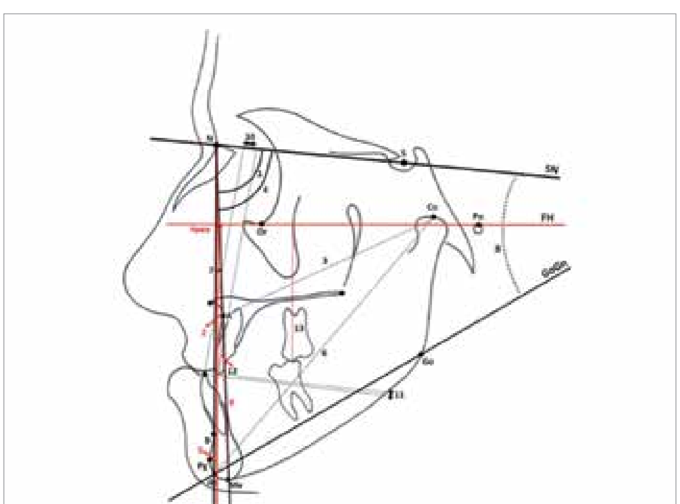

Figure 3. Reference points and planes used in lateral cephalometric radiographs

Cephalometric Points and Measurements

Reference points and planes used in lateral cephalometric radiographs (Figure 3).

Craniofacial Cephalometric Measurements

- SELLA-NASION PLANE (SN): The plane between the sella and nasion points
- FRANKFURT HORIZONTAL PLANE (FH): The plane passing through the porion and orbita points

Reference Points Used in Lateral Cephalometric Radiographs

The cephalometric landmarks used in our study are shown in Figure 1 and are as follows:

- S: Sella
- N: Nasion
- ANS: Anterior nasal spine
- PNS: Posterior nasal spine
- Point A: Subspinale
- U1i: Incisal edge of maxillary first incisor
- U6t: Tip of the mesiobuccal cusp of the maxillary first molar
- B Point: Supramentale
- Pg: Pogonion
- Gn: Gnathion
- Me: Menton
- Go: Gonion
- Co: Condylion
- Po: Porion
- Or: Orbita

Maxillary Measurements

- SNA: The angle between the SN and nasion-point A planes
- Nperp-A: Perpendicular distance between point A and nasion
- Co-A: Distance between condylion and point A
- U1i-FH: Distance between the Frankfurt Horizontal Plane and incisal edge of the maxillary first incisor
- U6t-FH: Distance between the FH plane and the tip of the mesiobuccal cusp of the maxillary first molar

Mandibular Measurements

- SNB: The angle between the SN and nasion-point B planes
- Nperp-Pg: Perpendicular distance between pogonion and nasion
- Co-Gn: Distance between condylion and gnathion

Maxillomandibular Measurements

- ANB: The angle between the nasion-point A and nasion-point B planes.

Table 2. Preoperative (pre-op) to postoperative (post-op) changes in skeletal class III anomalies treated by bimaxillary orthognathic surgery were evaluated using paired t-test (SE: Standard error, Sig.: Level of significance *p<0.05, **p<0.01, ***p<0.001)

Measurements	Pre-op		Post-op		Difference		
	Mean	±SE	Mean	± SE	Mean	± SE	Sig.
Maxillary Measurements							
1. SNA (°)	79.05	0.99	83.22	0.85	4.17	0.85	***
2. Nperp-A (mm)	-0.18	0.99	4.17	1.0	4.35	0.76	***
3. Co-A (mm)	80.60	1.1	85.59	1.4	4.99	1.73	*
Mandibular Measurements							
4. SNB (°)	83.24	1.2	80.92	1.2	-2.32	0.46	***
5. Nperp-Pg (mm)	6.39	2.0	3.02	1.7	-3.37	1.06	*
6. Co-Gn (mm)	119.70	1.3	117.43	2.3	-2.27	1.68	
Maxillomandibular Measurements							
7. ANB (°)	-4.23	0.96	2.33	0.70	6.56	0.99	***
8. SN/GoGn (°)	36.27	2.1	34.68	1.9	-1.59	1.08	
9. N-Me (mm)	126.40	2.8	123.50	2.9	-2.90	0.67	
Dental Measurements							
10. Overjet (mm)	-7.40	0.85	2.40	0.21	9.80	0.80	***
11. Overbite (mm)	1.60	0.16	1.50	0.15	-0.10	0.22	
12. U1i-FH (mm)	55.45	1.5	51.80	2.0	-3.65	0.80	***
13. U6t-FH (mm)	50.30	1.1	49.15	1.6	-1.15	1.10	

Table 3. Comparison of conventional surgical predictions based on lateral cephalometric radiographs with actual postoperative results using intraclass correlation coefficient (ICC) and root mean square

Parameter	Standard Deviation	ICC
SNA (°)	0.714	0.9613
Nperp-A (mm)	1.017	0.9492
Co-A (mm)	4.508	0.6278
SNB (°)	1.409	0.9209
Nperp-Pg (mm)	2.439	0.8968
Co-Gn (mm)	4.094	0.8460
ANB (°)	1.388	0.7879
SN/GoGn (°)	2.205	0.9212
N-Me (mm)	1.466	0.9829
Overjet (mm)	0.716	0.6920
Overbite (mm)	0.612	0.5000
U1i-FH (mm)	1.984	0.9306
U6t-FH (mm)	2.695	0.7893

Table 4. Comparison of digital surgical predictions based on lateral cephalometric radiographs with actual postoperative results using intraclass correlation coefficient (ICC) and root mean square

Parameter	Standard Deviation	ICC
SNA (°)	1.581	0.8626
Nperp-A (mm)	1.308	0.9121
Co-A (mm)	1.525	0.9312
SNB (°)	1.392	0.9187
Nperp-Pg (mm)	2.282	0.9136
Co-Gn (mm)	2.795	0.9194
ANB (°)	1.598	0.6450
SN/GoGn (°)	2.368	0.9088
N-Me (mm)	2.127	0.9676
Overjet (mm)	0.680	0.3944
Overbite (mm)	0.316	0.7500
U1i-FH (mm)	2.550	0.9178
U6t-FH (mm)	2.188	0.8957

- GoGnSN: The angle between the gonion-gnathion and SN planes.
- N-Me: The distance between the nasion and menton.

Dental Measurements

- Overjet
- Overbite

Statistical Analysis

Paired t-test was used to analyze the mean pre- and postoperative values of the treatment group and to evaluate changes that occurred as a result of surgery. Variation between manual predictions and actual postoperative values as well as that between digital predictions and actual postoperative values was assessed using the intraclass correlation coefficient (ICC) (reproducibility) and square root of the mean square (root mean square).

RESULTS

The patient's cephalometric values before and after the orthognathic surgery and the differences between these measurements are presented in Table 2.

Following bimaxillary orthognathic surgery, significant increases were observed in the maxillary parameters SNA (4.17°, p<0.001), Nperp-A (4.35 mm, p<0.001), and Co-A (4.99 mm, p<0.05).

Significant decreases were noted in the mandibular parameters SNB (2.32°, p<0.001) and Nperp-Pg (3.37 mm, p<0.05).

Of the maxillomandibular measurements, there was a significant increase of 6.56° in ANB (p<0.001).

Dental measurements showed a statistically significant increase of 9.80 mm in overjet and significant decrease of 3.65 mm in U1i-FH (p<0.001).

When conventional surgical predictions were compared with actual postoperative values using ICC and root mean square, overbite measurement was the most unpredictable parameter (0.5000). Following overbite, manual predictions of Co-A, overjet, ANB, and U6t-HF were less accurate (0.6278, 0.6920, 0.7879, and 0.7893, respectively; Table 3).

Comparison of digital predictions with actual postoperative values revealed that overjet was the most unpredictable parameter (0.3944). Moreover, digital predictions of ANB and overbite were less accurate (0.6450 and 0.7500, respectively).

Comparisons of manual and digital orthognathic surgical predictions with actual postoperative results are presented in Tables 3 and 4, respectively.

DISCUSSION

Severe skeletal defects are managed using orthognathic surgical protocols incorporating both orthodontics and surgery. Pre- and postoperative orthodontic interventions and surgical planning based on preoperative lateral cephalometric radiographs are important factors for the success of these treatments. Changes in the skeletal and soft tissue structures after surgery can be predicted using conventional cephalometric tracings or computer software. Several previous studies evaluating class III bimaxillary orthognathic surgical predictions have compared computer-generated predictions with surgical outcomes (15-17). However, no studies have compared conventional prediction using acetate tracing paper over lateral cephalometric radiographs, digital prediction using computer software, and actual postoperative results. Therefore, we aimed to compare these two commonly used prediction methods (manual and digital) with each other and with postoperative values.

Ten patients (5 females and 5 females) with similar skeletal class III malocclusion characteristics and who had completed growth and development were included. Ensuring that all orthodontic treatments and orthognathic surgical preparations, planning, and procedures are performed by the same team is important for the reliability of the study.

In the present study, the same researcher made conventional surgical predictions based on preoperative lateral cephalometric radiographs (manual tracings on acetate paper), obtained computer-generated predictions (Dolphin Imaging 11.8, Dolphin Imaging & Management Solutions, Chatsworth, CA, USA), and measured actual postoperative values.

In both manual and digital predictions, the mean impaction, advancement, and set-back were 2.4, 4.9, and 4.45 mm. Predicted impaction and advancement values were similar to actual postoperative values (N-Me: -2.90 mm and Nperp-A: 4.35 mm), while actual set-back values were different (Nperp-Pg: -3.37 mm).

Manual predictions of Co-A, Co-Gn, and U6t-FH were less accurate compared with digital predictions. This may be attributed to the ability to adjust the contrast values of cephalometric images in computer software, thus allowing a clear visualization of points, which may be difficult to distinguish otherwise.

Overjet and overbite predictions showed poor agreement with postoperative values in both methods. Postoperative radiographs of the study subjects were obtained after a period of intermaxillary fixation. Therefore, strong elastics used in the anterior region during this phase may have affected the measurements. Moreover, unpredictable dental movement may occur because of the low anchorage value of the incisors.

Limitations

Being a pilot study, there are certain limitations in this research. First, the sample size is small (5 females and 5 males), but a more detailed study with 30 subjects is ongoing. Second, this study did not include the assessment and comparison of soft tissue changes after orthognathic surgery. Soft tissue parameters were intentionally excluded while designing the pilot study as the complete healing of soft tissues following orthognathic surgeries requires a long time. As mentioned before, a more detailed study is ongoing to specifically address these limitations. Nevertheless, this pilot study provides valuable initial data regarding the accuracy of manual and digital cephalometric prediction methods.

CONCLUSION

Cephalometric points and their associated parameters (Co and U6) with low reproducibility reduce the reliability of prediction.

Cephalometric points that are difficult to distinguish using the manual method can be visualized through digital images by adjusting contrast settings.

Dental predictions were inaccurate in both methods due to the effects of intermaxillary elastics.

Both methods yielded similar predictions for skeletal parameters. Skeletal predictions were more accurate than dental predictions.

The effect of applying strong elastics for postoperative intermaxillary fixation should be considered in manual or digital predictions.

Mechanisms that enhance anchorage, such as skeletal anchorage units, can be used to reduce unwanted dental movement caused by strong elastics.

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethical Committee of Ankara University School of Dentistry (24.04.2017).

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

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - C.A., A.T.A.; Design - C.A., A.T.A.; Supervision - A.T.A., T.U.T.M; Data Collection and/or Processing - E.M.A., E.B.; Analysis and/or Interpretation - A.T.A., T.U.T.M.; Writing Manuscript - C.A., A.T.A.

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REVIEW

Reverse Engineering in Orthodontics

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ABSTRACT

Three-dimensional (3D) imaging has advanced greatly and is used extensively in orthodontics. It is worth outlining and reviewing the developments of reverse engineering (RE) as its applications are growing more widespread and diverse. Data from an existing object are used to create a digital model. A traditional RE process is usually performed in these stages: (1) obtaining data, (2) restructuring the surfaces, and (3) creating a useful model. They are classified as (1) laser projection based and (2) fringe projection based. This digital technology has been used in creating 3D model scanning, 3D digital model superimposition, diagnostic setup, volumetric assessment of tooth wear, soft tissue facial analysis, incorporation of digital model to 3D facial image, lip position and smile reproducibility, analysis of tooth position after orthodontic treatment, and anthropometric measurements. This system has proven itself to have a varied probability of applications and researches in the field of orthodontics. Similar to every single system, even RE has its own benefits and shortcomings. The complexity of the process and high cost are the major disadvantages reported so far. Rapid advancement of this technology possibly will rapidly inverse the negative results that emerged previously. As a future work, innovative use of RE technology is necessary to make this system triumph in the field of orthodontics.

Keywords: Digital technology, reverse engineering, three-dimensional imaging, orthodontics

INTRODUCTION

It is worth outlining and reviewing the developments of reverse engineering (RE) as its applications are growing more widespread and diverse. The term "reverse engineering" can be interpreted as copying from an original. Data from an existing object are used to create a digital model. RE shows promise in emerging applications in the field of orthodontics (1).

Reverse engineering systems were classified as (1) laser projection based and (2) fringe projection based. Intraoral scanning systems made appearance in the last decade but are scarcely used in practice (2). To be efficaciously executed in our global commercialized society, a high degree of automation will be required in these areas (1). Three-dimensional (3D) imaging grew significantly in the past few years and established abundant uses in the field of orthodontics. Diagnostic imaging is used to obtain the anatomical data that are processed by a computer and then presented on a two-dimensional screen. Depth perception causes the image to appear in 3D (3).

The quality of service, in terms of improvement of patient's satisfaction, is an increasingly important objective especially imperative in orthodontics. Digital design tools can significantly influence to enhance these procedures. However, computer-aided design/computer-aided manufacturing (CAD/CAM), RE, and rapid prototyping (RP) systems were conceived and developed for industrial applications; they should be evaluated, studied, and customized with a view to use in medicine (4). Table 1 lists several advantages and disadvantages of RE.

Orthodontics is a field that has evolved significantly within the past. 3D technology has remodeled this field, leading to a more practical and patient-friendly treatment results. Today, orthodontic clinics are loaded with

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high technical school, progressive instrumentation designed to boost the patient expertise by delivering quicker and additional economical treatment, whereas this technology has advantages to all patients, it is largely effective for complicated cases.

This technology is not inevitable, but it improves a valuable insight at the time of diagnosis and treatment planning and enhances the standard of treatment effects. Historically, fitting an orthodontic appliance on a patient was not a precise science. Similar to shoes, braces were designed based on standard average. This technology allows us to tailor the appliances that match specifically to the patient's teeth. Every patient's jaw is formed and sized otherwise. Therefore, brackets and wires are formed and sized to match every patient. This makes the patient more comfortable since the treatment is more predictable as changes are not required throughout the course that brings the results quicker and attain a smile personalized to the form of one's face and jaws.

The information obtained within the past in sort of two dimensions had few drawbacks. Teeth are physical objects and have six degrees of freedom; move in x, y, and z directions; and also have roll, pitch, and yaw. It is humanly impossible to address all six degrees at a time. Different softwares are designed to report these components each and every time. RE allows duplicating the complete patient morphology and at the same time manufacturing the appliances and templates that might increase exactness and decrease technique sensitivity and chair side time in addition to providing high accuracy to the treatment.

Table 1. Advantages and disadvantages of reverse engineering process

Advantages	Disadvantages
Rapid fabrication	Difficult to acquire meaningful details, such as curve and edges
Minimal time	Complexity of process
Minimal radiation exposure	CAD modeling skills necessary
Easy handling	High cost
Better visualization	Difficult to evaluate accuracy and usability
Reuse of design	
Repeated verification	

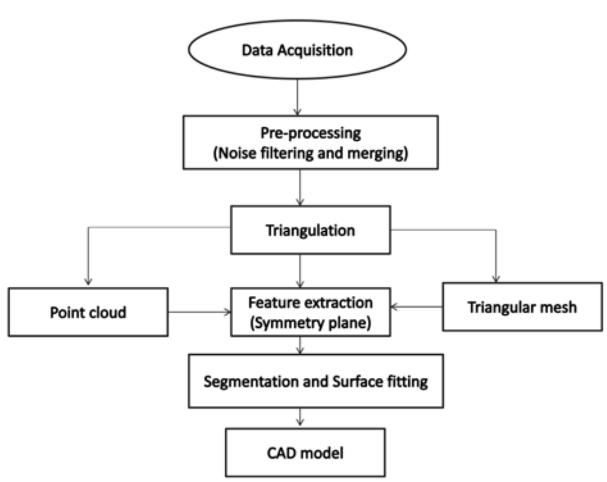

Figure 1. a, b. Flow of reverse engineering process

There are several studies that have used 3D imaging methodologies in the past; however, they have not analyzed knowledge with this technology. It might be unwise to mention that the study or its results would be different if they had used this technology as each study is exclusive in its own sense; however, for sure, innovative use of this technology can undoubtedly improve the future of orthodontia.

History
The history of RE dates back to World War II and Cold War. It was primarily employed by the military to duplicate rival's weapons, devices, and technology. In the past few years, advances within the field of computers have hugely taken an enormous leap to develop this technology. RE had gained prime importance in automotive production and aviation business to accommodate the speedy rate of reinvention of contemporary instruments and machinery.

The engineering originality of the organic structure of the human body has placed RE in an exceedingly distinctive place within the bioscience and medical device industries significantly in implementing artificial elements into the organic structure. The overview of the literature was based on the applications of RE in automobile industry, automotive industry, medical life sciences, and software industries. RE is employed in many medical fields, including manufacture of individual surgical templates; fabrication of individual surgical implants and prostheses, such as artificial knees, hip and spine implants; fabrication of hearing aids; made-to-order surgical tools; medical coaching models; and medical devices. It has vast applications within the field of dentistry as well. Manufacturing customized dental abutments and dental implants, surgical templates, computer-aided dental prostheses, customized bridges and crowns, digital dental models, and customized removable appliances (5). Various applications of RE in orthodontics include the following:

- 3D model scanning,
- 3D model superimposition,
- digital diagnostic setup,
- volumetric valuation of tooth wear,
- 3D soft tissue facial analysis,
- lip position and smile reproducibility,
- anthropometric measurements.

Process of RE
The procedural steps involve data acquisition, preprocessing (noise filtering and merging), triangulation, feature extraction, and segmentation and surface fitting (Figure 1). The whole method of RE should to be computer aided (6).

Data Acquisition
This part is meant to collect the information regarding the geometric facet of the physical half through scanning. There are several different approaches by which product surface data can be acquired. They can be classified into two broad categories: contact and non-contact methods. Contact scanners are those that con-

tain a contact probe that moves on the silhouette of the physical half. A common example of such a scanner is the coordinate measuring machine, whereas non-contact scanners are ones that do not have a contact probe instead they use lasers, optics, and charge-coupled device sensors to capture the information.

Preprocessing

Data are obtained as a result of scanning and are then processed so as to eliminate noise and to scale back the quantity of points. This part of the process additionally offers us the advantage to merge multiple scan data sets. A number of commercial softwares are available for point processing.

Triangulation and Feature Extraction

Triangulation is a process of formation or division of point data into triangles. Feature extraction is the next step during this process that is outlined because of the method of shaping a collection of options, or image characteristics, which can most expeditiously represent the knowledge that is necessary for analysis and classification.

Table 2. Description of superimposition points

Superimposition points	Description
Point 1	Left lateral canthus
Point 2	Left medial canthus
Point 3	Soft tissue nasion
Point 4	Right medial canthus
Point 5	Right lateral canthus

Segmentation, Surface Fitting, and Solid Modeling

Segmentation is the most crucial step in RE. This section of the process involves rending a triangular mesh into submeshes to which an appropriate single surface can be fitted. This seriously affects the standard of the ensuing CAD model. New RE modules or separate software packages are commonly required for point processing.

Application of RE in Orthodontics

3D model analysis

The accuracy and authenticity of digital study models are evaluated by linear, surface, and volumetric parameters, surface scanning devices that are used to record the surface detail of such models, and its genuineness is renowned from the literature. 3D orthodontic study model superimposition system for evaluating tooth movements was concluded to be consistent and dependable (7) after comparison of cephalometric superimposition with 3D digital model superposition. INUS dental scanning solution was used for 3D scanning of dental casts, and surface-to-surface matching was used to perform the superimposition. Keating et al. (8) assessed the precision of surface details of plaster study

Table 3. Different RE applications in orthodontics are compared on their mode of modeling software and RE software

Author	Application	Scanning technique	Reverse engineering software
Cha (7)	Superimposition of tooth movement	INUS dental scanning solution	Rapidform 2002; INUS Technology Inc., Seoul, South Korea
Choi et al. (13)	Maxillary expansion and protraction	3D optical scanner; Orapix; Orapix Co., Seoul, South Korea	Rapidform 2002; INUS Technology Inc., Seoul, South Korea
Duran (14)	Molar distalization	Dental scanner; Activity 850; Smart Optics, Bochum, Germany	Rapidform; INUS Technology Inc., Seoul, South Korea
Kihara (16)	Digital models	3D surface scanner; RexcanDS; Solutionix, Seoul, South Korea	Rapidform 2006; INUS Technology Inc., Seoul, South Korea
Park (20)	Tooth wear	Laser surface scanning system; KOD300, accuracy 50 mm, Orapix Co., Ltd., Seoul, South Korea	Rapidform XOR3; INUS Technology Inc., Seoul, South Korea
Yook (28)	Volume changes of lip at bonding and debonding	Rexcan III 3D scanner; Solutionix Corp., Seoul, South Korea	Rapidform XOR/REDESIGN 3; INUS Technology Inc., Seoul, South Korea
Dindaroglu (29)	Lip position	3dMD Flex; 3dMD, Atlanta, GA, USA	Geomagic Control 3D Systems, Rock Hill, SC, USA
Dindaroglu (30)	Smile reproducibility	3dMD; Flex System; 3dMD, Atlanta, GA, USA	Geomagic Control, 3D Systems Inc., Cary, NC, USA
Deli (31)	Soft tissue	Five high-definition digital single-lens reflex cameras with flash; Canon 40D, 10 Mpx	PhotoModeler™ Scanner version 6; Eos Systems Inc., Vancouver, BC, Canada
Kau et al. (32)	Growth changes	Minolta Vivid VI900 3D; Osaka, Japan	Rapidform™ 2004; INUS Technology Inc., Seoul, South Korea—RF4
Djordjevic et al. (33)	Facial asymmetry	Two Minolta Vivid 900 laser scanners; Konica Minolta, Tokyo, Japan	Rapidform 2006; INUS Technology Inc., Seoul, South Korea
Elnagar et al. (34)	Maxillary protraction	Facial Insight 3D Scanner; Motion View Software, Chattanooga, TN, USA	Geomagic Control 14; Geomagic, Research Triangle Park, NC, USA
Ivanov et al. (35)	Soft tissue changes after RME	Roland LPX-250 laser scanner; Roland DG, Hamamatsu, Japan	Roland DG, Hamamatsu, Japan
Yu et al. (36)	Nasoalveolar molding	Vivid 910; Konica Minolta Holdings, Inc., Tokyo, Japan	Rapidform 2006; INUS Technology Inc., Seoul, South Korea

models recorded using a 3D optical laser scanning device. It was concluded that capturing the surface details using Minolta Vivid 900 is consistent and is aimed at capturing the details of plaster models with high accuracy. Data obtained from such reliable scans are subjected to RE software for further analysis.

i) 3D digital model superimposition

Assessments of treatment results are possible only by the superimposition of before and after lateral cephalograms. They are currently the most extensively used means for evaluating various tooth movements despite its inherent errors. Its major drawbacks are difficulties in the identification of inherent landmarks, high costs, tracing errors, frequent radiation exposure, technique sensitivity, and head position variation between serial radiographs (9, 10).

Progress technically during this technology permits superimposition of the maxillary dental arch with the help of a 3D digital model scanning software. This technique was established for the superposition of digital orthodontic models, and it allowed detailed amounts of movements in all the dimensions (11). 3D digital orthodontic model superposition techniques were declared to be clinically as dependable as cephalometric superimposition for evaluating orthodontic tooth movement (7), and it was verified that the superposition of the dental arch digitally was repeatable (12).

ii) 3D model analysis after rapid palatal expander (RME) and protraction headgear

Choi et al. (13) assessed the validity of the digital models three dimensionally in patients who received treatment with rapid maxillary expansion and protraction headgear. Maxillary dental casts were scanned using a non-contact 3D optical scanner. Rapidform 2002, a reverse modeling software, was used to perform reconstruction and superimposition. 3D models were superimposed using the palate to measure various tooth movements. They concluded that this 3D model superimposition method was reliable as cephalometric superimposition for assessing anteroposterior movements. Cases managed with orthopedic appliances, such as maxillary protraction headgear and rapid maxillary expansion, can also be assessed in a similar manner.

iii) 3D model analysis after miniscrew-supported molar distalization

Duran et al. (14) evaluated the dentoalveolar effects of miniscrew-supported molar distalization by 3D RE method. The dental casts were scanned by an optical dental scanner (Activity 850; Smart Optics, Bochum, Germany). The scans were converted into digital data, and data were imported into the RE software (Rapidform). The authors of these studies concluded that the method is clinically reliable, and with this method, the movement of each tooth over the arch can be analyzed in all three planes of space, and measurements can be performed frequently since digital models do not involve radiation.

iv) Digital diagnostic setup

Virtual surgical splint was fabricated in virtual articulator (15); it consumed less time than to perform the mock surgery of dental casts for the fabrication of the surgical splint.

Visualization of tooth roots was also possible in digital models by registering exact crown prototypes to cone beam computed tomography (CBCT) scans (16). The process for visualizing tooth roots in a digital model was created by a non-contact 3D surface scanner of each patient's dentition.

v) Integration of 3D digital cast and 3D facial photo

3D setup greatly helps an orthodontist in various stages of diagnosis along with determining several treatment possibilities; it assists in monitoring the changes after treatment and records the predicted and final treatment outcomes (17).

Rangel et al. (18) presented practicality of the integration of a digital dental cast into a 3D facial picture. A digital dental model was matched to place on a 3D photograph of the patient in the precise anatomical location. These images can improve the preciseness of diagnosis and treatment planning along with providing a scope for future investigation about non-cephalometric analysis or superimpositions.

vi) 3D assessment of volumetric tooth wear

Loss of occlusal surface by attritional wear disturbs the vertical dimensions of dentition and may cause tooth interferences; it was also reported that the increased activity of the masticatory system executed increased stress on the underlying structures (19).

Park et al. (20) suggested appraisal of tooth wear that emerges in the course of orthodontic management by using the digital superimposition method. They concluded that recording the teeth in 3D models remains valuable and can be intended for the assessment of tooth wear in orthodontic patients.

3D Soft Tissue Facial Analysis

Appraisal of facial morphology is vital in the field of orthodontics right from the diagnosis to the effective treatment planning (21). Medical CT or CBCT has replaced the traditionally used lateral radiographs earlier used for facial analysis (9).

i) Soft tissue superimposition

Advances in technology led to the development of many procedures, including laser scanners (22), stereophotogrammetry (23), and structured light systems (24), which are used to obtain the digital images of the dentition and craniofacial structures. Simplicity and rapidity in usage has made the laser scanner system, which is also known as optical surface scanner, the most extensively used system, and therefore it has various possibilities of scientific uses and researches (22,25,26). Its principle application is to monitor growth and treatment-related changes in all the different planes of space (26). Superimposition is possible by the registration of analogous regions on two different overlapped images (27,28). Moss et al. (27) combined five anatomical landmarks as shown in Table 2 together with five fabricated points on the forehead. The forehead was suggested to be a stable area for superimposing 3D images of the face (12).

ii) Volumetric changes in the lip after placement and removal of fixed appliance

Yook et al. (28) evaluated volumetric change in the lips after placement or removal of labial fixed orthodontic appliances using a 3D surface scanning system. 3D facial scanning was performed before placement, immediately after placement of the labial orthodontic appliances, before removal, immediately after removal, and 3 to 6 months after removal of the appliances. They established that the upper and lower lips are immediately protruded after bonding and retruded after debonding them.

iii) Lip position and smile reproducibility

Dindaroglu et al. (29) evaluated the reproducibility of the lip position at rest in three dimensions using the RE software and stereophotogrammetric images. The outcome of the study suggests that the rest position can be replicated both on the same day and between the sessions in a small range.

Dindaroglu et al. (30) used the 3D stereophotogrammetry and RE technology to assess social smile reproducibility. Social smile images of White adolescents were obtained. Sixteen social smiles were recorded on each individual at 3-minute breaks. They stated that there exists individual variability in duplication of social smile, and that this discrepancy was not noticeable under routine clinical observation.

iv) Anthropometric measurements

Deli et al. (31) conducted a study with the objective to describe a procedure that is perfect, accurate, repeatable, quick, and beneficial for soft tissue analysis of anthropometric characteristics. A new clinical procedure was used to perform this investigation. It involved four separate stages: setting up of a portable equipment on which field analysis could be achieved, scanning of dissimilar expressions, preparation of the subject and spatial positioning, and treatment and processing of data. They established that this innovative protocol for the attainment of anthropometric measurements is quick, repeatable, reliable, and precise.

v) Soft tissue growth changes

As children behave differently from adults in front of laser scanning devices, a study (32) was performed prospectively to define the changes that occur when attaining a set of laser scans from children and adults and to determine if children could be appropriate subjects for the study of facial morphology employing a laser scanning technique. Laser scans were performed, and the obtained information was transferred to reverse modeling software for analysis. It was concluded from this study that children are reliable candidates for laser-based studies of facial morphology, and the laser scanning system employed in this study has great potential in the capture and study of facial morphology.

vii) Facial asymmetry

Quantification of facial symmetry in healthy adolescents and exploration if there is any gender variations were administrated with the assistance of the RE process. The surface matching between the first face and its likeness was measured for the full face, upper, middle, and lower facial thirds. Additionally, three angular and 14 linear parameters were measured. The faces of 15-year-old male adolescents were less symmetric than those of female adolescents, however the distinction within the quantity of symmetry. The upper, middle, and lower thirds of the face did not differ in the amount of 3D symmetry. Angular and linear parameters of facial symmetry did not show any gender distinction (33).

vii) Maxillary protraction

3D facial soft tissue changes in growing patients with maxillary jaw deficiency associated with maxillary jaw protraction were performed using an innovative approach consisting of 3D stereophotogrammetry and sophisticated RE software (34). Facial images were scanned and imported to RE process package for additional analysis. The 3D analysis of the soft tissue changes showed vital favorable changes including advancement of the soft tissues of the upper lip; significant changes were observed in the middle face. Additionally, redirection of soft tissue growth was evident within the lower lip and mandible areas.

viii) Soft tissue changes after RME

Visualization and evaluation of transverse palatal soft tissue changes were performed following maxillary expansion treatment in 33 Caucasian children with posterior crossbite. They were treated with tooth-borne Haas-type expander. Colored palatal maps were generated that clearly showed the change in width of palatal soft tissues following RME. This method allowed to measure and present correlation between intermolar widths measured on the plaster models, to width changes on soft tissue palatal surface. The expansion appliance in children resolved the crossbite and led to palatal widening that was clearly visualized by creating mathematical morphometric models (35).

ix) Nasoalveolar molding (NAM) for cleft lip and palate

A novel technique of presurgical NAM was developed based on a computer-aided RE and RP technique in infants with unilateral cleft lip and palate. The upper denture casts were recorded using a 3D laser scanner, and a digital model was constructed that was analyzed to simulate the NAM procedure with RE software. The appliances were fabricated based on the RP technique. With this innovative approach, the treatment design and appliance fabrication was simplified (36).

Different RE applications in orthodontics are compared on their mode of modeling software and RE software used as illustrated in Table 3.

CONCLUSION

Quick advancement of CAD/CAM technology and persistent progress in 3D imaging systems facilitate a clinician not only to diagnose but also to view the effects of treatment from several perspectives. RE projects require amalgamation of the finest approaches and technologies from different alternatives available, making it a daunting task. An increasing number of scanner service bureaus offers RE services, making it effortlessly reachable. Experts point their opinion that RE is destined to persist as a market niche. This advanced methodology is readily accessible, and efforts should be made by each and every practitioner to avail the most out of it.

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CASE REPORT

Orthodontic Extrusion with Circumferential Supracrestal Fiberotomy: A Report of Two Cases

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ABSTRACT

Surgical extrusion, surgical crown lengthening, and orthodontic extrusion (OE) with circumferential supracrestal fiberotomy (CSF) are reported as effective methods in cases when clinical crowns are destroyed. The aim of these case reports was to evaluate the results of OE+CSF in a canine and a mandibular second molar tooth. Case 1: A 24-year-old male patient was referred with a fracture of the maxillary canine at the subgingival level. After the examinations, OE+CSF was planned. Following leveling-aligning, a mini-screw was placed into the root canal of the canine, and 50 g of extrusive force was applied from the mini-screw to a stainless steel (SS) wire. Case 2: A 67-year-old female patient was referred with a mandibular second molar destroyed at the gingival level. OE+CSF was planned. An extrusive force (50 g) was applied from the segmental SS wire to the hook inserted into the root canal. CSF and root planning (RP) were performed weekly in both patients. Overall, 5 mm of extrusion was achieved for the upper canine after 6 weeks of active extrusion in Case 1. In Case 2, 5 mm of extrusion was achieved after 3 weeks of active extrusion. OE+CSF is an effective and rapid method for the extrusion of teeth with insufficient clinical crown.

Keywords: Circumferential supracrestal fiberotomy, orthodontic extrusion

INTRODUCTION

The main concern in restorative dentistry is to reestablish the function, form, and esthetics of teeth. Post-core treated teeth require at least 2 mm of ferrule design for fracture resistance (1). However, tooth preparation usually extends under the gingival level to achieve a ferrule design, which compromises the biological width (2). The treatment options considering the biological width are surgical extrusion (SE) (3), surgical crown lengthening (SCL) (4), and orthodontic extrusion (OE) (5-7).

Heithersay (5) and Ingber (6) were the first authors who proposed OE. In slow extrusion, with light forces (30 g), tensions of the periodontal fibers are delivered to the bone, and coronal migration of periodontium occurs (6). In rapid extrusion, a force greater than 50 g is required, and supracrestal circumferential fiberotomy (CSF) is performed to move the tooth, leaving its alveolar bone behind (8). The resection of stretched fibers will prevent the gingival margin and bone to follow the tooth movement (8-10). However, after CSF, the remaining fibers on the root surface would reconstruct gingival fiber apparatus in some parts of the root (11). To prevent reattachment, Kozlovsky et al. (10) suggested root planning (RP) with CSF. Carvalho et al. (12) compared OE with/without CSF+RP and reported that CSF+RP is an effective method to prevent the coronal tissue migration.

The first case was presented at the Turkish Orthodontic Society Annual Session, 2015, Eskişehir, Turkey; the second case was presented at the Turkish Orthodontic Society Annual Session, 2016, Antalya, Turkey.

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Mostly, forced eruption is applied to anterior teeth because of esthetic reasons and having one-root. There are no available data in the literature reporting the results of OE+CSF in molar teeth. This article presents the treatment results of a canine and a second molar tooth treated with OE with CSF+RP. The criteria of rapid extrusion in these cases were the presence of single/fused roots, an adequate root length, healthy periodontal tissues, and to achieve the extrusion without any changes at the gingival level.

CASE PRESENTATIONS

Case 1

A 24-year-old patient was referred with a fractured upper right canine at the subgingival level (Figure 1). Radiographic examination revealed that the root length was 17.5 mm initially without any dilacerations. A periodontal examination showed an adequate biological width without any sign of a periodontal disease. Because the patient had a missing upper lateral incisor, instead of extraction, an extrusion of the canine was decided, and an informed consent was obtained. Following the leveling-aligning, a 16x22 SS wire was inserted on the upper arch, and a mini-screw placed into the root canal of the canine was used to apply extrusive forces by an elastic thread (50 g) (Figure 2, 3). CSF+RP was performed weekly for 6 weeks. The crown-to-root ratio was 2:5 after the 5 mm of extrusion on the maxillary canine as it was planned at the beginning, and then the tooth was stabilized for 8 weeks. The mandibular right canine was leveled, and OE without CSF was performed; therefore, the gingival margin followed the tooth movement (Figure 4).

Case 2

A 67-year-old patient was referred with a lower left second molar damaged at the gingival level. Radiographic examination revealed that the molar had a fused root with 12 mm of root length. A periodontal examination showed an adequate biological width without any signs of a periodontal disease. Because the patient did not complain about the anterior crowding and having multiple missing teeth, OE with CSF+RP was planned for this tooth with

Figure 1. Initial photographs and radiograph in Case 1

Figure 2. Treatment mechanics in Case 1

Figure 3. Intermediate photographs in Case 1

segmental technique, and informed consent was obtained. A temporary metal crown was fabricated with a bracket soldered for the lower second premolar (Figure 5). Following the leveling-aligning, a 16x22 SS wire was inserted. A hook was bent from the 16x22 SS wire and cemented into the root canal of the lower second molar. Then, 50 g of force was applied by an elastic thread from the hook to the SS wire. CSF+RP was performed weekly for 3 weeks (Figure 6, 7). The crown-to-root ratio was 1:1 after 5 mm of extrusion; later, the tooth was stabilized for 8 weeks (Figure 8).

DISCUSSION

The main goal of restoration is to reestablish the function, form, and esthetic of a tooth. Placing the margin of restoration on a sound tooth structure is crucial for long-term stability and periodontal health (1, 2).

Orthodontic extrusion is an effective method for crown lengthening (5, 6). With light extrusive forces, periodontium follows the tooth movement, which is desirable when there is an uneven gingival margin between the adjacent teeth (6). To avoid periodontium move with the tension of fibers, it was suggested to apply greater forces together with CSF (8-10). Kozlovsky et al. (10) suggested RP together with CSF to prevent reattachment of fibers. A randomized clinical trial comparing OE with/without CSF+RP reported that fiberotomy prevents coronal tissue migration (12). In presented cases, it was not possible to place the margins of restorations on a sound tooth structure without affecting

Figure 4. Final photographs and radiograph in Case 1

Figure 5. Initial photographs and radiograph in Case 2

Figure 6. Treatment mechanics in Case 2

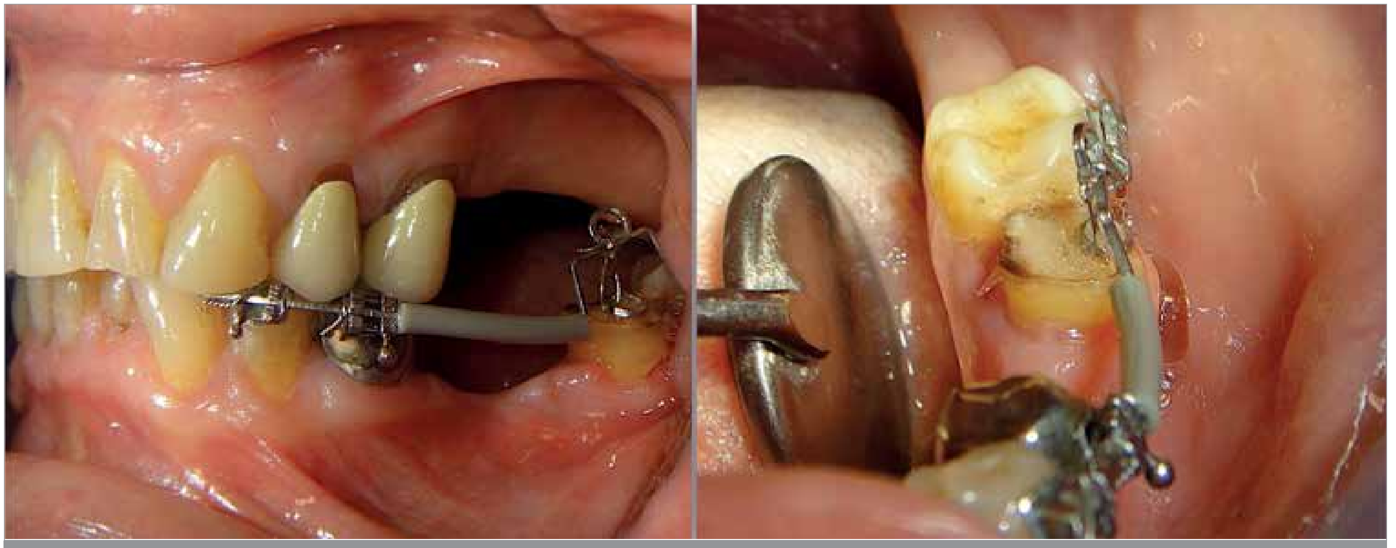

Figure 7. Intermediate photographs in Case 2

Figure 8. Final photographs and radiograph in Case 2

the biological width. It was decided to perform OE with CSF+RP, and 50 g of extrusive force was applied for rapid extrusion (8).

Fiberotomy can be performed either at 7- to 10-day intervals or every 2 weeks (9, 10). In our study, CSF+RP was performed weekly. OE was finished in 6 weeks in the first case and in 3 weeks in the second case. Especially in adult cases, a rapid dental correction is very important for both cooperation and functional stability (13). Although the same extrusive force was applied in both cases, the same amount of extrusion was achieved in different times because some factors such as the age of the patients, form of the teeth, and root surface area affect treatment outcomes.

Crown-to-root ratio is an important factor for prognosis. Ideally, it should be 1:2 or minimum 1:1 in extreme cases (14). While extruding a tooth, it is mandatory to take the crown-to-root ratio into consideration. In our study, both cases presented an adequate crown-to-root ratio.

Besides several advantages of OE with CSF+RP, it should be conducted carefully to avoid causing root resorption, ankylosis, or mobility (15). Furthermore, CSF should not be performed in ectopically erupted teeth and in teeth associated with periodontal defects.

CONCLUSION

There are several treatment options for teeth damaged at the gingival or subgingival levels. Deciding on a treatment protocol depends on several factors, such as esthetic needs, the crown-to-root ratio, bony support, and clinician's preference/skill. Among all treatment options, OE with CSF+RP is a successful approach with stable results, which prevents periodontium to follow the tooth movement and eliminate corrective surgical procedures.

Informed Consent: Written informed consent was obtained from the patients

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