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

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

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

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Instructions to 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

Tables

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

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

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

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

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

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

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

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

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

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

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

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

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TURKISH JOURNAL of ORTHODONTICS

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Review

Case Report

TURKISH JOURNAL of ORTHODONTICS

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Original Article

Comparison of the Changes Following Two Treatment Approaches: Rapid Maxillary Expansion Versus Alternate Rapid Maxillary Expansion and Constriction

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ABSTRACT

Objective: The aim of the present study was to evaluate the hard and soft tissue changes following rapid maxillary expansion (RME) and alternate rapid maxillary expansion and constriction (Alt-RAMEC) therapies.

Methods: A total of 54 patients who needed maxillary expansion or Alt-RAMEC procedure were recruited and divided into two groups (27 subjects in the RME group and 27 subjects in the Alt-RAMEC group). Expansion screw was activated 0.5 mm/day (2 turns/day) in the RME group. Approximately 11 mm of expansion was achieved. In the Alt-RAMEC group, the screw was activated 1 mm/day (4 turns/day) during a period of 4 weeks. In the first and third weeks, the screw was opened; in the second and fourth weeks, the screw was closed. Cephalometric tracing and analyzing were done with the aid of digital software. Lateral cephalometric radiographs were obtained before (T0) and after (T1) RME and Alt-RAMEC applications.

Results: In the RME group, the maxilla moved forward and downward. Upper incisor retrusion was observed according to the reference planes. In addition, the tip of the nose moved forward, and the upper lip moved downward. In the Alt-RAMEC group, the nasolabial angle became more obtuse, and the stomion superius moved backward and downward.

Conclusion: RME therapy resulted in skeletal and dental changes in the maxilla and related structures, favoring a contribution to solving Class III problems. No remarkable changes were recorded in the Alt-RAMEC group.

Keywords: RME, Alt-RAMEC, Class III

INTRODUCTION

Rapid maxillary expansion (RME) is a traditional method for correcting transverse maxillary deficiency. Although its popularity has changed over time, RME has become a fundamental part of dentofacial orthopedics in modern orthodontics. The maxilla is subjected to heavy forces that can create orthopedic effect, and transverse deficiency problem is solved by separating the maxillary halves. The qualification of the obtained effect varies according to several factors, such as the maturational stage, appliance design, and treatment protocol.

In addition to the treatment of transverse deficiency, RME has been recommended for Class III patients in combination with face mask therapy. The rationale behind this combined treatment is that it disarticulates circummaxillary and intermaxillary sutures, which facilitates maxillary protraction (1, 2). Because the maxilla is loosened from the craniofacial complex, the orthopedic traction of a face mask can be more efficient than that of a face mask therapy alone. Although the amount of advancement varies in different studies, it has been demonstrated that 1.5–3 mm maxillary advancement could be achieved with RME–face mask therapy (3, 4).

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When there is no transverse maxillary deficiency, the degree of expansion is a controversial issue in the literature. Alcan et al. (5) expanded the maxilla for 5 days with a 2 turns/day protocol before protraction. Other authors have also reported that the duration of expansion must be limited to 7–10 days (4, 6, 7). However, Haas (8) advocated that at least 12–15 mm expansion must be achieved for the disarticulation of the circummaxillary and intermaxillary sutures before face mask therapy. It is apparent that if there is no transverse deficiency, 12–15 mm expansion for disarticulation is too much with respect to the correction by the compensation mechanism.

In 2005, Liou (9) introduced a new method called alternate RMEs and constrictions (Alt-RAMEC). In this method, the maxilla is expanded 1 mm/day for the first week and then constricted 1 mm/day for the following week with the aid of a two-hinged expander. This protocol is repeated for 7-9 weeks (9-11). It was advocated that the Alt-RAMEC procedure is a better option than RME. While the maxilla is moved forward approximately 1.5-3 mm with RME–face mask treatment (3,4), Liou and Tsai (9) showed that a 5.8 mm maxillary advancement can be achieved at the level of A point by maxillary protraction combined with Alt-RAMEC. In the study by Isci et al. (12), 2.33 mm of maxillary movement was obtained in the RME group, and 4.13 mm of anterior movement was achieved in the Alt-RAMEC group, with an approximately two-fold movement.

Many researchers have investigated the effects of RME on dentofacial structure, but there are conflicting results with respect to sagittal and vertical changes at the maxilla. Chung and Font stated that maxillary forward and downward movements are induced by expansion. Additionally, the mandible moved downward and backward, and the anterior facial height increased (13). Baratieri et al. (14) studied dental and skeletal changes due to RME in Class II, Division 1 patients and reported immediat maxillary forward movement after therapy. However, in a systematic review, Lagravere et al. (15) investigated the long-term skeletal changes in patients undergoing RME therapy and concluded that RME does not produce significant sagittal and vertical changes at the position of the maxilla. Da Silva Filho et al. (16) researched the short-term results for RME and noted no significant anterior displacement of the maxilla.

Since Alt-RAMEC is a relatively new method, the studies are limited. There are even fewer articles available on the use of Alt-RAMEC in addition to face mask therapy. Yilmaz and Kucukkeles (17) investigated skeletal, soft tissue, and airway changes following Alt-RAMEC protocol. They concluded that a slight forward (0.89±0.93 mm) and downward (0.92±1.62 mm) movement of the maxilla occurred following the Alt-RAMEC procedure. A slight improvement of the overjet was recorded in all Class III subjects.

Researches in this area were generally focused on the total outcomes of combined therapy (Alt-RAMEC or RME–face mask), and the effects of the second part of the combined therapy (Alt-RAMEC or RME) were neglected. The increased effectiveness of combined therapy (Alt-RAMEC or RME–face mask) in comparison with single therapy (face mask) can be attributed to sutural mobilization or the direct skeletal effects of the second part of therapy (Alt-RAMEC or RME). This must be clarified. The aims of the present study were to evaluate and compare the hard and soft tissue changes following RME and Alt-RAMEC.

METHODS

This prospective study was reviewed and approved by the Clinical Research Ethics Committee of the Tokat Gaziosmanpaşa University. A total of 54 patients who needed transverse maxillary expansion or an Alt-RAMEC procedure, according to the treatment plan, were recruited in the study. The patients were divided into two groups: 27 subjects in the RME group and 27 subjects in the Alt-RAMEC group. For both groups, tooth- and tissue-borne rapid maxillary expanders were used (Figure 1).

The RME group consisted of 18 female and 9 male subjects. The mean age of the RME group was 12.5±1.9 years. Expansion screws were activated 0.5 mm/day (2 turns/day). The average expansion at the screw level was 11 mm.

The Alt-RAMEC group consisted of 17 female and 10 male subjects. The mean age of the Alt-RAMEC group was 12.8±1.6 years. Parents were instructed to activate the screw 1 mm/day (4 turns/day). In the first and third weeks, the screw was opened; in the second and fourth weeks, the screw was closed. At the end of the 4-week Alt-RAMEC procedure, the clinician controlled whether or not the screw was at a closed position. Subjects who did not achieve screw activation were excluded from the study.

Lateral cephalometric radiographs were obtained before (T0) and after (T1) RME and Alt-RAMEC applications. After completing the RME and Alt-RAMEC applications, orthodontic treatments were continued in accordance with the predetermined treatment plan. Informed consent was obtained from the parents of the participants.

Cephalometric Analysis

Cephalograms were traced and analyzed with the aid of the Dolphin software (ver. 11.5; Dolphin Imaging and Management Solutions,

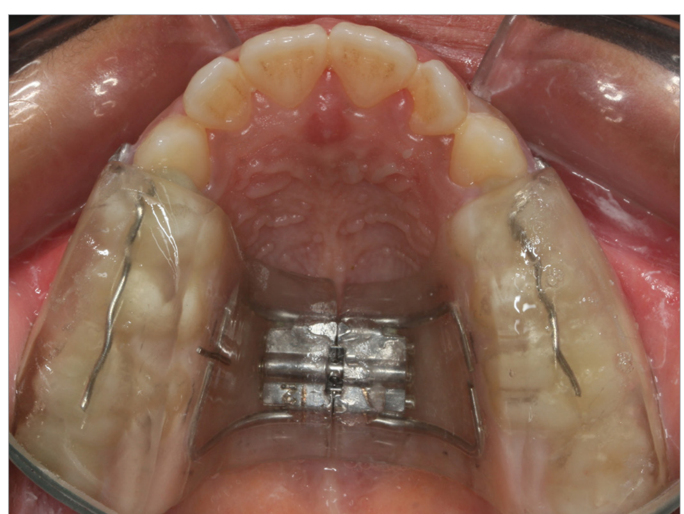

Figure 1. Expansion appliance used in the study

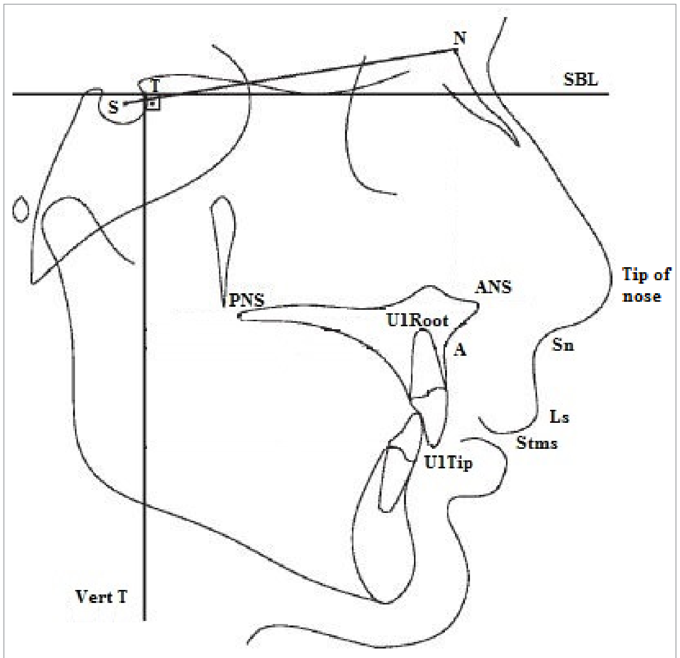

Figure 2. Cephalometric landmarks
Sella (S): Center of the pituitary fossa. Nasion (N): The most anterior point of the frontonasal suture in the median plane. Point A (A): Deepest point on the curve of the maxilla between the anterior nasal spine and supradentale. Anterior nasal spine (ANS): Tip of the anterior nasal spine. Posterior nasal spine (PNS): Tip of the posterior nasal spine. Point T (T): Most superior point of the anterior wall of the sella turcica at the junction of the tuberculum sellae. U1Tip: Tip of the upper central teeth. U1Root: Root of the upper central teeth. Subnasale (Sn): Base of the columella that meets the upper lip. Labrale superior (Ls): Vermillion border of the upper lip in the midsagittal plane. Stomion superius (Stms): Lowest midline point of the upper lip

Chatsworth, CA, USA) by the same operator. Lateral cephalometric radiographs were obtained before (T0) and after (T1) RME and Alt-RAMEC applications. Hard and soft tissue landmarks belonging to the mandible were not used in the present study. The cephalometric landmarks utilized in the present study are shown in Figure 2.

Horizontal and vertical basic reference planes that were utilized for measurements were the following (Figure 2):

1. Stable basicranial line (SBL): horizontal line that passes through the most superior point of the anterior wall of the sella turcica at the junction with the tuberculum sellae (point T), and it is tangent to the lamina cribrosa of the ethmoid. It was stated that these structures are stable in the rest of life after from the age of 4–5 years (18).
2. Vertical T (Vert T): a line passing through point T and perpendicular to SBL.

The other measurements used in the present study were the following:

1. SNA angle: angle constructed by the intersection of the nasion-sella and nasion-point A lines
2. SBL–PP angle: angle constructed by the intersection of the stable basicranial line and the palatal plane
3. U1–PP angle: angle constructed by the intersection of the long axis of the maxillary central incisor and the palatal plane
4. U1–SBL angle: angle constructed by the intersection of the long axis of the maxillary central incisor and the stable basicranial line
5. Nasolabial angle: angle constructed by the intersection of a line passing from the subnasale and tangent to the lower border of the nose with a line from the labrale superius to the subnasale
6. Vert T–ANS: perpendicular distance from the anterior nasal spine (ANS) to the vertical reference line
7. Vert T–PNS: perpendicular distance from the posterior nasal spine (PNS) to the vertical reference line
8. Vert T–A: perpendicular distance from point A to the vertical reference line
9. Vert T–U1Tip: perpendicular distance from the incisal edge of the maxillary central incisor to the vertical reference line
10. Vert T–U1Root: perpendicular distance from the maxillary central incisor root apex to the vertical reference line
11. ANS–SBL: perpendicular distance from the ANS to the stable basicranial line
12. PNS–SBL: perpendicular distance from the PNS to the stable basicranial line
13. A–SBL: perpendicular distance from point A to the stable basicranial line
14. SBL–U1Tip: perpendicular distance from the incisal edge of the maxillary central incisor to the stable basicranial line
15. SBL–U1Root: perpendicular distance from the maxillary central incisor root apex to the stable basicranial line
16. A–Nperp: perpendicular distance from point A to the nasion perpendicular line
17. Vert T–Tip of Nose: perpendicular distance from the tip of the nose to the vertical reference line
18. Vert T–Sn: perpendicular distance from the subnasale to the vertical reference line
19. Vert T–Ls: perpendicular distance from the labrale superior to the vertical reference line
20. Vert T–Stms: perpendicular distance from the stomion superius to the vertical reference line
21. SBL–Tip of Nose: perpendicular distance from the tip of the nose to the stable basicranial line
22. SBL–Sn: perpendicular distance from the subnasale to the stable basicranial line
23. SBL–Ls: perpendicular distance from the labrale superior to the stable basicranial line
24. SBL–Stms: perpendicular distance from the stomion superius to the stable basicranial line.

Statistical Analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences for Windows, version 19.0 (IBM Corp., Armonk, NY, USA). Chi-square test was used to assess gender difference between the groups. At the beginning of the treatments, independent samples t-test was used for comparisons of age and pretreatment cephalometric data among the groups. Independent samples t-test and paired samples t-test were used to evaluate and compare the post-treatment changes among the groups. A p value of <0.05 was considered statistically significant.

RESULTS

There were no differences with respect to gender (RME: 18 female and 9 male and Alt-RAMEC: 17 female and 10 male, p=0.776) or age

Table 1. Comparison of initial cephalometric values between groups

	Groups		
	RME Mean±SD	Alt-RAMEC Mean±SD	p
SNA (°)	79.91±3.42	79.67±3.34	0.792
SBL-PP (°)	1.25±4.76	1.22±3.62	0.980
U1-PP (°)	112.95±8.87	116.23±4.04	0.086
U1-SBL (°)	111.67±9.49	114.98±4.24	0.104
Nasolabial angle (°)	107.62±8.11	108.43±10.09	0.746
Vert T-ANS (mm)	63.34±4.61	62.27±4.97	0.416
Vert T-PNS (mm)	13.29±3.91	14.5±3.61	0.241
Vert T-A (mm)	58.19±4.57	57.49±4.65	0.582
Vert T-U1Tip (mm)	59.65±7.07	60.24±5	0.724
Vert T-U1Root (mm)	51.09±4.9	50.61±4.2	0.706
ANS-SBL (mm)	43.6±4.76	42.84±3.35	0.501
PNS-SBL (mm)	42.51±3.01	41.81±3.78	0.453
A-SBL (mm)	46.84±4.05	46.22±3.4	0.549
SBL-U1Tip (mm)	69.37±4.81	68.37±4.82	0.450
SBL-U1Root (mm)	47.62±4.66	47.69±4.15	0.951
A-Nperp (mm)	-1.09±4.3	-0.66±2.94	0.673
Vert T-Tip of Nose (mm)	85.02±5.4	83.97±5.71	0.490
Vert T-Sn (mm)	72.46±5.27	71.41±4.97	0.457
Vert T-Ls (mm)	73.32±6.27	72.8±5.45	0.744
Vert T-Stms (mm)	66.95±6.41	67.23±5.26	0.861
SBL-Tip of Nose (mm)	39.24±5.97	38.64±5.37	0.699
SBL-Sn (mm)	47.31±5.41	47.5±4.92	0.894
SBL-Ls (mm)	60.96±5.49	61.19±5.34	0.879
SBL-Stms (mm)	66.17±5.55	65.99±5.18	0.902

* Significant at p<0.05.

(RME: 12.55±1.94 years and Alt-RAMEC: 12.88±1.68 years, p=0.505) in the subjects. The groups did not show any differences with respect to pretreatment cephalometric measurements (Table 1).

As a result of treatment in the RME group, changes in measurements of SNA, U1–PP, U1–SBL, Vert T–ANS, Vert T–A, Vert T–U1Root, ANS–SBL, PNS–SBL, A–SBL, SBL–U1Root, Vert T–Tip of Nose, and SBL–Ls were significantly different. SNA, Vert T–ANS, Vert T–A, Vert T–U1Root, ANS–SBL, PNS–SBL, A–SBL, SBL–U1Root, Vert T–Tip of Nose, and SBL–Ls increased significantly, whereas changes in measurements of U1–PP and U1–SBL decreased significantly. The maxilla moved forward and downward without a change in the palatal plane. Significant upper incisor retrusion was found according to both palatal plane and basicranial line. In addition, the tip of the nose moved forward, and the upper lip moved downward (Table 2).

In the Alt-RAMEC group, changes in nasolabial angle, Vert T–Stms, SBL–Ls, and SBL–Stms were statistically significant. Nasolabial angle, SBL–Ls, and SBL–Stms increased significantly, and Vert T–Stms decreased significantly. The nasolabial angle became more obtuse, and the stomion superius moved backward and downward. In addition, the labrale superior moved downward (Table 2).

DISCUSSION

The Alt-RAMEC procedure was first introduced in patients with cleft lip and palate to enhance the Class III therapy by Liou and Tsai (9). Instead of using a Haas/Hyrax expander, they employed a double-hinged expander to achieve a more effective expansion in the anterior region (19). They asserted that this type of expander could provide more forward displacement of the maxilla without the possibility of bone resorption behind the maxillary tuberosity. The original weekly sequence of Alt-RAMEC was 9 weeks, including four pairings of expansion–constriction, followed by a final expansion. However, it has been modified and used differently in many studies. For instance, Canturk and Celikoglu (20) used the protocol along 8 weeks without the final expansion week. Similarly, Isci et al. (12) modified the protocol, and it was 4 weeks in their study. There was no final expansion week in their study, as well. Maino et al. (21) used a 5-week protocol in their study. For instance, Isci et al. (12) and Canturk and Celikoglu (20) used a Haas/Hyrax-type expander in their studies. Maino et al. (21) used a Haas/Hyrax-type expander with mini-screw and tooth anchorage. Similarly, several researchers have selected to apply different weekly sequences without reporting any reason: 9-, 8-, 5-, and 4-weekly sequences have been used (12, 17, 20, 21). There is no clear consensus about which expander and procedure must be utilized.

In the present study, the classical type of expander was used. In patients with cleft palate, mostly, there is dentoalveolar developmental failure in the anterior region due to tooth agenesis or unerupted teeth, so the use of a double-hinged expander or fan-type expander, which can provide further expansion in the anterior segment, is reasonable. However, our study involved subjects who had no cleft lip and palate, so there was no need for extra expansion at the anterior segment. Furthermore, although it has been claimed that a double-hinged expander has an advantage in maxillary protraction compared with Haas/Hyrax-type, no clear evidence has been presented to support this view, except for schematic drawings by their proponents.

A 4-weekly sequence was used without a final expansion week in this study, and screw activation was 1 mm/day (4 turns/day). We preferred to terminate the activation procedure at the initial screw position. Because the Alt-RAMEC procedure has been first introduced as an alternative to the RME procedure and it has been claimed that it does not require unnecessary maxillary expansion in Class III therapy (9). Whereas, if we had added the final expansion week to our procedure, we would have achieved a 7 mm expansion. 7 mm of expansion is almost half of a full screw activation. Since we have thought that such an expansion was contrary to the emergence claim of Alt-RAMEC, we did not include the 5th week (expansion week) in the activation procedure.

In the present study, pure treatment outcomes of RME and of Alt-RAMEC (without any combined therapy) were evaluated and compared. Previous studies have shown that when these treatments are used together with a face mask, the skeletal advancement in the sagittal direction can be greater than that achieved by face mask therapy alone. There are many RME studies in the literature. Several studies have examined RME's contribution to treatments of Class III malocclusion, and two theories have been

Table 2. Changes in RME and Alt-RAMEC groups during treatment

	Groups			Groups	
	RME Mean±SD	Alt-RAMEC Mean±SD		RME Mean±SD	Alt-RAMEC Mean±SD
SNA (°) (T0)	79.91±3.42	79.67±3.34	A-SBL (mm) (T0)	46.84±4.05	46.22±3.4
SNA (°) (T1)	80.58±2.99	80.04±3.43	A-SBL (mm) (T1)	48.05±3.89	46.18±3.4
p	0.003*	0.096	p	0.001*	0.901
SBL-PP (°) (T0)	1.25±4.76	1.22±3.62	SBL-U1Tip (mm) (T0)	69.37±4.81	68.37±4.82
SBL-PP (°) (T1)	1.52±4.04	1.09±3.9	SBL-U1Tip (mm) (T1)	70.76±4.78	66.55±12.7
p	0.406	0.673	p	0.402	0.275
U1-PP (°) (T0)	112.95±8.87	116.23±4.04	SBL-U1Root (mm) (T0)	47.62±4.66	47.69±4.15
U1-PP (°) (T1)	110.63±9.61	115.15±4.66	SBL-U1Root (mm) (T1)	48.75±3.97	47.76±4.17
p	0.001*	0.103	p	0.004*	0.858
U1-SBL (°) (T0)	111.67±9.49	114.98±4.24	A-Nperp (mm) (T0)	-1.09±4.3	-0.66±2.94
U1-SBL (°) (T1)	109.1±10.51	114.06±4.95	A-Nperp (mm) (T1)	-0.71±4.32	-0.34±3.33
p	0.001*	0.213	p	0.206	0.279
Nasolabial angle (°) (T0)	107.62±8.11	108.43±10.09	Vert T-Tip of Nose (mm) (T0)	85.02±5.4	83.97±5.71
Nasolabial angle (°) (T1)	109.23±7.51	111.53±8.95	Vert T-Tip of Nose (mm) (T1)	86.33±6.13	84.75±6.84
p	0.209	0.018*	p	0.019*	0.154
Vert T-ANS (mm) (T0)	63.34±4.61	62.27±4.97	Vert T-Sn (mm) (T0)	72.46±5.27	71.41±4.97
Vert T-ANS (mm) (T1)	64.49±4.94	62.6±5.08	Vert T-Sn (mm) (T1)	73.42±5.9	72.03±6.04
p	0.009*	0.438	P	0.064	0.232
Vert T-PNS (mm) (T0)	13.29±3.91	14.5±3.61	Vert T-Ls (mm) (T0)	73.32±6.27	72.8±5.45
Vert T-PNS (mm) (T1)	13.53±3.82	15.34±6.51	Vert T-Ls (mm) (T1)	73.7±6.66	72.59±6.71
p	0.769	0.315	p	0.501	0.709
Vert T-A (mm) (T0)	58.19±4.57	57.49±4.65	Vert T-Stms (mm) (T0)	66.95±6.41	67.23±5.26
Vert T-A (mm) (T1)	59.14±4.77	57.93±5.06	Vert T-Stms (mm) (T1)	67.82±7.13	65.95±6.45
p	0.022*	0.274	P	0.132	0.028*
Vert T-U1Tip (mm) (T0)	59.65±7.07	60.24±5	SBL-Tip of Nose (mm) (T0)	39.24±5.97	38.64±5.37
Vert T-U1Tip (mm) (T1)	59.9±7.54	60.45±5.66	SBL-Tip of Nose (mm) (T1)	39.57±5.18	38.46±4.62
p	0.634	0.699	P	0.565	0.749
Vert T-U1Root (mm) (T0)	51.09±4.9	50.61±4.2	SBL-Sn (mm) (T0)	47.31±5.41	47.5±4.92
Vert T-U1Root (mm) (T1)	52.44±4.71	51.19±4.92	SBL-Sn (mm) (T1)	47.76±4.56	47.71±4.46
p	0.003*	0.194	P	0.313	0.630
ANS-SBL (mm) (T0)	43.6±4.76	42.84±3.35	SBL-Ls (mm) (T0)	60.96±5.49	61.19±5.34
ANS-SBL (mm) (T1)	44.56±4.36	42.86±3.51	SBL-Ls (mm) (T1)	62.16±4.89	62.67±5.11
p	0.013*	0.960	P	0.039*	0.012*
PNS-SBL (mm) (T0)	42.51±3.01	41.81±3.78	SBL-Stms (mm) (T0)	66.17±5.55	65.99±5.18
PNS-SBL (mm) (T1)	43.26±3.16	41.91±3.16	SBL-Stms (mm) (T1)	67.08±4.73	68.01±4.82
p	0.002*	0.660	p	0.096	<0.001*

*Significant at p<0.05. SD: Standard deviation

presented. In the first theory, without a face mask, it has been claimed that the maxilla slightly moves forward with the aid of RME. However, some studies have shown that the maxilla goes in a backward direction rather than forward as a result of RME. In this regard, this issue is controversial. In the second theory, it was stated that sutural mobilization caused by RME may increase the efficiency of face mask. This is also a matter of debate because sutural mobilization is not irrational, but it is not a measurable phenomenon, except for theoretical models and animal studies.

In contrast, research investigating Alt-RAMEC is relatively limited. Available studies are mostly about the efficacy of combined therapies. We could identify only two studies that focused on the effects of using Alt-RAMEC alone (9, 17). Liou and Tsai (9) examined whether Alt-RAMEC is effective in solving Class III malocclusion. They tested the hypothesis that Alt-RAMEC displaces the maxilla more anteriorly and disarticulates circummaxillary sutures more effectively than RME. However, the participants in their study had unilateral cleft lip and palate, so evaluating the effectiveness of Alt-RAMEC in Class III patients without cleft lip and palate may reveal different results. The anatomies of patients with cleft lip and palate are different from those of normal subjects, so treatment efficiency may differ accordingly. In the other study by Yilmaz and Kucukkeles (17), changes were evaluated following the Alt-RAMEC protocol using cone beam computed tomography. We could not find any other isolated Alt-RAMEC studies.

According to our results, the maxilla moved forward due to RME (SNA, Vert T–A, and Vert T–ANS increased at 0.67°, 0.95 mm, and 1.15 mm, respectively). This is consistent with the previous findings reported by Haas, Davis and Kronman, and Chung and Font, and others (1, 2, 13, 22-26). However, there are also contradictory results in the literature. Da Silva Filho et al. (16) stated that the anterior displacement of the maxilla with significant changes in the SNA angle should not be expected. Similarly, Sarver and Johnston (27) showed that bonded RME causes backward displacement, as opposed to forward movement. We think that many factors, such as appliance design, the subjects' maturation stage, and expansion protocol, could explain these contradictory results. Biederman (25) schematically showed how the maxilla can move in the sagittal direction according to the location of the center of rotation. When the maxilla is expanded and there is no resorption at the site of the bony complex with which it articulates posteriorly, it leads to forward displacement due to the support from the posterior regions. Such a circumstance may have occurred in the present study.

Based on our results, we anticipate that RME can be used alone for mild maxillary retrusion in Class III subjects, as suggested by Haas (2). Studies conducted by Sung and Baik (28), Cha (29), Kapust et al. (30), and Isci et al. (12) showed 1.7 mm, 0.97 mm, 1.97 mm, and 2.33 mm of point A anterior movement, respectively, for subjects aged between 10–14 years, treated with RME and face mask. In our study, using RME alone resulted in a 0.95 mm anterior movement of point A. This effect is almost half the amount of that was obtained by RME and a face mask therapy. RME increased the SNA by 0.67°; it could be speculated that this amount of increase could not solve mild maxillary retrusion. However, it should not be overlooked that the maxilla moved not only forward but also downward (the increases of ANS–SBL, PNS–SBL, and A–SBL were statistically significant with 0.96 mm, 0.75 mm, and 1.21 mm, respectively). Downward movement masks the angular changes in forward movement. Therefore, we think that Vert T–A, rather than SNA, will give more accurate information on the detection of RME's contribution to maxillary advancement.

Another finding is the downward movement of the maxilla (Table 2). This is not surprising when previous publications in the literature are considered. Since Haas' publications in the 1960s, many researchers have observed a downward movement due to RME (1, 2, 13, 16, 26). Maxillary downward movement orients the mandible to a downward and backward direction, which results in a smaller SNB, higher mandibular plane angle, and longer anterior facial height. This outcome, just as forward movement, helps to resolve the sagittal discrepancy in Class III subjects.

In the Alt-RAMEC group, hard and soft tissues did not change to the same extent as they did in the RME group. Changes in nasolabial angle, Vert T–Stms, SBL–Ls, and SBL–Stms, which are all soft tissue parameters, were statistically significant. The nasolabial angle became more obtuse, and the upper lip moved backward and downward. Unfortunately, no adequate preliminary studies exist in the literature to help explain these data. Depending on the premature contacts that occurred after the Alt-RAMEC, the lips may have been incompetent, and these changes may have occurred when the subjects attempted to close their lips. In the RME group, the reason why these changes did not occur (except SBL–Ls) could be that the observed skeletal changes compensated for the soft tissue changes. In response to the backward movement of the upper lip, the maxilla moved forward and compensated the condition.

CONCLUSION

- RME therapy resulted in skeletal and dental changes in the maxilla and related structures, contributing to solve Class III problems. The maxilla moved forward and downward.
- No remarkable changes were recorded in the Alt-RAMEC group.
- In cases of mild maxillary retrusion accompanied by transverse deficiency, RME alone can be advised as a treatment.

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethics Committee of Tokat Gaziosmanpaşa University.

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

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - F.C.; Design - F.C., M.Ç.; Supervision - F.C., M.Ç.; Data Collection and/or Processing - M.Ç.; Analysis and/or Interpretation - F.C., M.Ç.; Writing Manuscript - F.C.; Critical Reviews - F.C.

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

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REFERENCES

1. Haas AJ. The treatment of maxillary deficiency by opening the midpalatal suture. Angle Orthod 1965; 35: 200-17.
2. Haas AJ. Palatal expansion: just the beginning of dentofacial orthopedics. Am J Orthod 1970; 57: 219-55. [CrossRef]
3. Williams MD, Sarver DM, Sadowsky PL, Bradley E. Combined rapid maxillary expansion and protraction facemask in the treatment of Class III malocclusions in growing children: A prospective long-term study. Semin Orthod 1997; 3: 265-74. [CrossRef]
4. Ngan P, Yiu C, Hu A, Hagg U, Wei SH, Gunel E. Cephalometric and occlusal changes following maxillary expansion and protraction. Eur J Orthod 1998; 20: 237-54. [CrossRef]
5. Alcan T, Keles A, Erverdi N. The effects of a modified protraction headgear on maxilla. Am J Orthod Dentofacial Orthop 2000; 117: 27-38. [CrossRef]
6. Baccetti T, McGill JS, Franchi L, McNamara JA Jr, Tollaro I. Skeletal effects of early treatment of Class III malocclusion with maxillary

expansion and face-mask therapy. Am J Orthod Dentofacial Orthop 1998; 113: 333-43. [CrossRef]
7. Turley PK. Orthopedic correction of Class III malocclusion: retention and phase II therapy. J Clin Orthod 1996; 30: 313-24.
8. Haas AJ. The non-surgical treatment of the skeletal Class III. In: Book of Abstract. American Association of Orthodontists. 100th Annual Session; Chicago, Ill, April 29-May 3, 2000; 85.
9. Liou EJ, Tsai WC. A new protocol for maxillary protraction in cleft patients: repetitive weekly protocol of alternate rapid maxillary expansions and constrictions. Cleft Palate Craniofac J 2005; 42: 121-7. [CrossRef]
10. Liou EJ. Effective maxillary orthopedic protraction for growing Class III patients: a clinical application simulates distraction osteogenesis. Prog Orthod 2005; 6: 154-71.
11. Liou EJ. Toothborne orthopedic maxillary protraction in Class III patients. J Clin Orthod 2005; 39: 68-75.
12. Isci D, Turk T, Elekdag Turk S. Activation-deactivation rapid palatal expansion and reverse headgear in Class III cases. Eur J Orthod 2010; 32: 706-15. [CrossRef]
13. Chung CH, Font B. Skeletal and dental changes in the sagittal, vertical, and transverse dimensions after rapid palatal expansion. Am J Orthod Dentofacial Orthop 2004; 126: 569-75. [CrossRef]
14. Baratieri C, Alves M Jr, Bolognese AM, Nojima MC, Nojima LI. Changes in skeletal and dental relationship in Class II Division I malocclusion after rapid maxillary expansion: a prospective study. Dental Press J Orthod 2014; 19: 75-81. [CrossRef]
15. Lagravere MO, Major PW, Flores-Mir C. Long-term skeletal changes with rapid maxillary expansion: a systematic review. Angle Orthod 2005; 75: 1046-52.
16. da Silva Filho OG, Boas MC, Capelozza Filho L. Rapid maxillary expansion in the primary and mixed dentitions: a cephalometric evaluation. Am J Orthod Dentofacial Orthop 1991; 100: 171-9. [CrossRef]
17. Yilmaz BS, Kucukkeles N. Skeletal, soft tissue, and airway changes following the alternate maxillary expansions and constrictions protocol. Angle Orthod 2014; 84: 868-77.
18. Melsen B. The cranial base. Acta Odontol Scand 1974; 32.
19. Huang C, Wang Y, Huang C, Liou E. Maxillary displacement after rapid maxillary expansions: an animal study. J Taiwan Assoc Orthod 2008; 20: 19-31.
20. Canturk BH, Celikoglu M. Comparison of the effects of face mask treatment started simultaneously and after the completion of the alternate rapid maxillary expansion and constriction procedure. Angle Orthod 2015; 85: 284-91. [CrossRef]
21. Maino G, Turci Y, Arreghini A, Paoletto E, Siciliani G, Lombardo L. Skeletal and dentoalveolar effects of hybrid rapid palatal expansion and facemask treatment in growing skeletal Class III patients. Am J Orthod Dentofacial Orthop 2018; 153: 262-8. [CrossRef]
22. Haas AJ. Rapid expansion of the maxillary dental arch and nasal cavity by opening the mid-palate suture. Angle Orthod 1961; 31: 73-90.
23. Wertz RA. Skeletal and dental changes accompanying rapid midpalatal suture opening. Am J Orthod 1970; 58: 41-66. [CrossRef]
24. Sari Z, Uysal T, Usumez S, Basciftci FA. Rapid maxillary expansion. Is it better in the mixed or in the permanent dentition? Angle Orthod 2003; 73: 654-61.
25. Biederman W. Rapid correction of class III malocclusion by midpalatal expansion. Am J Orthod 1973; 63: 47-55. [CrossRef]
26. Davis WM, Kronman JH. Anatomical changes induced by splitting the midpalatal suture. Angle Orthod 1969; 39: 126-32.
27. Sarver DM, Johnston MW. Skeletal changes in vertical and anterior displacement of the maxilla with bonded rapid palatal expansion appliances. Am J Orthod Dentofacial Orthop 1989; 95: 462-6. [CrossRef]
28. Sung SJ, Baik HS. Assessment of skeletal and dental changes by maxillary protraction. Am J Orthod Dentofacial Orthop 1998; 114: 492-502. [CrossRef]
29. Cha KS. Skeletal changes of maxillary protraction in patients exhibiting skeletal Class III malocclusion: a comparison of three skeletal maturation groups. Angle Orthod 2003; 73: 26-35.
30. Kapust AJ, Sinclair PM, Turley PK. Cephalometric effects of face mask/expansion therapy in Class III children: a comparison of three age groups. Am J Orthod Dentofacial Orthop 1998; 113: 204-12. [CrossRef]

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Original Article

Evaluation of the Effect of Fixed Anterior Biteplane Treatment on Temporomandibular Joint in Patients with Deep Bite

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ABSTRACT

Objective: To investigate the effects of fixed anterior biteplane treatment on temporomandibular joint in deep bite patients.

Methods: The sample comprised 17 Class II patients with deep bite and decreased lower anterior facial height. The average patient age was 9.9±0.9 years. Transcranial temporomandibular joint radiographs were obtained from the subjects before (T0) and after fixed anterior biteplane treatment (T1). Anterior joint space, posterior joint space, superior joint space, anteroposterior thickness of the condylar head, vertical height of the articular fossa, and the articular fossa slope were measured on temporomandibular joint radiographs to evaluate the position of the mandibular condyles in the glenoid fossa.

Results: The average treatment duration was 8.5±2.1 months. Slope of the articular fossa, vertical height of the articular fossa, anteroposterior thickness of the condyle, posterior joint space, superior joint space, and anterior joint space showed no statistically significant difference between T0 and T1 ($p>0.05$).

Conclusion: Fixed anterior biteplane appliance treatment did not change the condyle fossa relationship in Class II deep bite patients at the time of appliance removal.

Keywords: Angle Class II, deep bite, temporomandibular joint

INTRODUCTION

The influence of abnormal occlusal characteristics on the temporomandibular joint positions have been a focus of interest in various studies (1-3). Condylar retroposition with a tendency toward smaller posterior joint spaces and larger anterior joint spaces have been reported in patients with various occlusal interferences, such as Class II malocclusion and deep bite (4-7). However, conflicting results have also been reported (8-10). Authors have suggested that these conflicting results may be due to the large age variations in the samples and the differences in the analyzing methods.

Functional appliances are commonly used in the treatment of patients at the age of 8-13 years with Class II malocclusion. Functional appliance treatment has a displacement effect on the condyle in the glenoid fossa and results in growth at the condylar cartilage and joint adaptation (11). Fixed anterior biteplane appliance is a fixed functional appliance that can be used to correct Class II malocclusion and deep bite (12). The treatment outcomes were as follows: increased lower facial height, increased total facial height, downward, and anterior movement of the mandible, labial inclination of the mandibular incisors, and extrusion of the mandibular posterior teeth (12).

Thus far, many studies on the condylar positional changes caused by functional treatment have been performed (11, 13-16). However, to our knowledge, there is no consensus regarding the influence of functional treatment on the temporomandibular joint position in Class II deep bite patients.

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Therefore, this study aimed to analyze the condylar positional changes in patients treated with a fixed anterior biteplane appliance. The null hypothesis was that fixed anterior biteplane treatment does not change the condyle position.

METHODS

The investigation was approved by the Ethics Committee of Medical, Surgical and Drug Research of Hacettepe University (LUT 04/30). Transcranial temporomandibular joint radiographs of 17 patients (mean age: 9.9±0.9 years, Table 1) were included as per the following inclusion criteria: 1) absence of any systemic disease that may adversely affect growth and development and no craniofacial deformity, 2) Class II malocclusion, 3) deep bite ≥4 mm, 4) lower anterior facial height <43°, 5) horizontal growth pattern, and 6) mixed or early permanent dentition. No subjects had undergone orthodontic treatment previously.

All the patients were treated with a fixed anterior biteplane appliance to correct Class II malocclusion and deep bite as shown in Figure 1. Details about the preparation and application of the appliance were explained in an earlier study (12). Hawley appliances for lower and upper dental arches were used for retention after the fixed anterior biteplane treatment in 9 patients. Fixed edgewise treatment was continued after removal of the biteplane in 8 patients to correct dental irregularities, such as rotation and diastema.

In order to assess the temporomandibular joint position changes resulting from treatment, transcranial temporomandibular joint radiographs were taken before (T0) and after fixed anterior biteplane treatment (T1) in each patient. Initial radiography examinations were performed when the patients registered for orthodontic treatment (T0). The final radiograph was taken after achieving Class I molar relationship with decreased over bite (T1). The average treatment time was 8.5±2.1 months (Table 1).

Table 1. Demographic and clinical characteristics of the study population

n	Male subjects	Female subjects	Age (T0) years	Treatment time months
			mean (SD)	mean (SD)
17	8	9	9.9 (0.9)	8.5 (2.1)

SD: standard deviation

Figure 1. Intraoral photograph of the fixed anterior biteplane appliance

Transcranial temporomandibular joint radiographs were obtained under standard conditions using the same millimetric and angular values (coronal, sagittal, and vertical) for radiographs taken at T0 and T1 periods on a periapical radiography device (Planmeca Prostyle Intra, Helsinki, Finland) using the "Denar Accurad 200" head orientation device.

The position of the mandibular condyles in the glenoid fossa; anterior, posterior, and superior joint space widths; anteroposterior thickness of the condylar head; vertical height of the articular fossa; and the slope of the articular fossa were examined on the transcranial joint radiographs according to the method of Cohlmia et al. (8). Points and planes are shown in Figure 2. Measurements are shown in Figure 3.

Statistical Analyses

Statistical calculations were performed with Statistical Package for Social Sciences software, version 11.5 (SPSS Inc.; Chicago, IL, USA). Shapiro-Wilk test was used to test the normality of distribution for continuous variables. The parameters that were normally distributed were analyzed using paired-t test. The statistical significance was established at $p<0.05$.

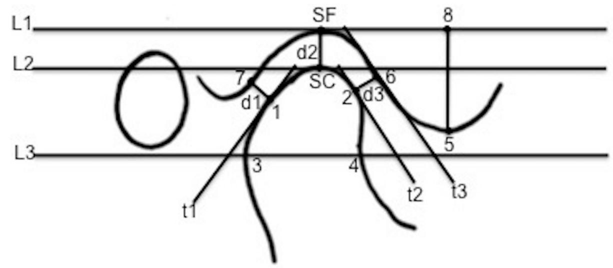

Figure 2. Landmarks and planes: L1, line tangent to the most superior point of the glenoid fossa (SF) and parallel to the superior border of the radiograph; L2, line parallel to L1 to locate the superior aspect of the condyle (SC); L3, line parallel to L2 through the most convex point of the anterior aspect of the condylar head; t1, tangent to the posterior aspect of the condyle from SF; t2, tangent to the anterior aspect of the condyle from SF; t3, line best fit to the anterior slope of the glenoid fossa; d1, line drawn perpendicular to t1 through the posterior condyle point; d2, line drawn perpendicular to L2 through the superior fossa point: d3, line drawn perpendicular to t2 through the anterior condyle point; d4, line drawn perpendicular to L1 through the most inferior point of articular eminence; SF, the most superior point of the glenoid fossa; SC, the superior aspect of the condyle; 1, posterior condyle point; 2, anterior condyle point; 3, the most posterior point of condylar head; 4, anterior head of the condyle; 5, the most inferior point of the articular eminence; 6, point intersected the glenoid fossa perpendicular to t2 from anterior condyle point; 7, point intersected the glenoid fossa perpendicular to t1 from posterior condyle point; 8, intersection of d4 and L1

In order to evaluate the measurement error, the measurements were repeated by the same investigator for all the patients after two weeks. Intraclass coefficient correlation was >0.940.

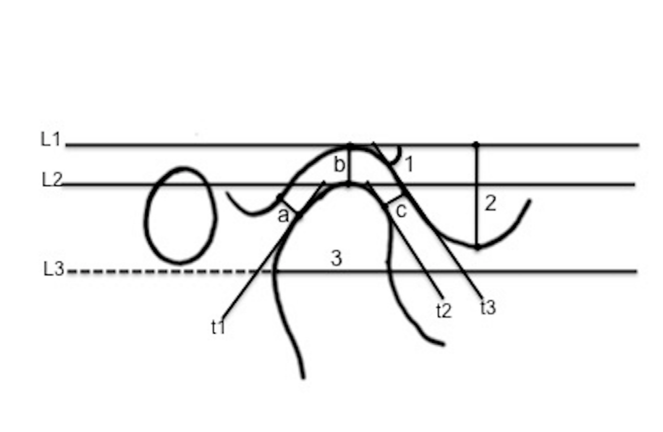

Figure 3. Measurements: 1, Slope of the articular fossa; 2, Vertical height of the articular fossa; 3, Thickness of the condylar head; a, Posterior joint space; b, Superior joint space; c, Anterior joint space

RESULTS

Slope of the articular fossa, vertical height of the articular fossa, thickness of the condylar head, posterior joint space, superior joint space, and anterior joint space showed no significant difference between T0 and T1 ($p>0.05$, Table 2, 3). The slope of the articular fossa and the vertical height of the articular fossa showed a tendency to be more symmetric on the left and right sides from T0 to T1; however, the changes were not statistically significant.

DISCUSSION

Thus far, several studies have been conducted to determine the effects of deep bite and Class II malocclusion on the temporomandibular joint. In some studies, deep bite was associated with posterior condyle displacement, disc luxation, and pain (17-20). In other studies, no effect on condylar displacement was shown (21-24). In this study, transcranial joint radiographs taken before and after fixed anterior biteplane treatment were compared to detect the effect of biteplane on the condyle positions. According to the results, fixed anterior biteplane treatment did not

Table 2. Comparison of the temporomandibular joint position between T0 and T1 on the left side

Left TMJ measurements		Mean	SD	Minimum	Maximum	P
Posterior joint space (mm)	T0	2.5	0.93	1	3.8	0.063
	T1	3.4	1.55	2	7.5	
Superior joint space (mm)	T0	3.4	0.82	2	5	0.449
	T1	3.6	0.93	2	5	
Anterior joint space (mm)	T0	2.7	1.35	1.2	5.5	0.165
	T1	2.1	0.53	1.3	3	
Thickness of condylar head (mm)	T0	11.2	1.72	8.2	14.6	1.000
	T1	11.2	1.23	9.6	14.5	
Slope of articular fossa (°)	T0	43.5	8.17	29.8	53.3	0.137
	T1	47.6	12.63	28	68	
Vertical height of articular fossa (mm)	T0	6.6	2.03	3.5	9.5	0.158
	T1	7.4	2.34	3.2	12	

SD: standard deviation

Table 3. Comparison of the temporomandibular joint position between T0 and T1 on the right side

Right TMJ measurements		Mean	SD	Minimum	Maximum	P
Posterior joint space (mm)	T0	2.6	0.53	1.9	3.7	0.788
	T1	2.6	0.65	2	4	
Superior joint space (mm)	T0	2.9	1.04	1	4.8	0.117
	T1	3.4	0.70	1.5	4.4	
Anterior joint space (mm)	T0	2.2	1.13	1	4.8	0.966
	T1	2.2	1.15	1	4.9	
Thickness of condylar head (mm)	T0	11.3	1.29	9	14	0.378
	T1	11.0	1.82	8.3	14	
Slope of articular fossa (°)	T0	51.0	9.61	39	70	0.455
	T1	48.9	7.68	38	63.8	
Vertical height of articular fossa (mm)	T0	8.3	1.85	5.8	12	0.188
	T1	7.7	1.96	4	10.8	

SD: standard deviation

change the condyle position. The null hypothesis was accepted. This result was in accordance with the reports that showed no significant differences in the condyle position after mandibular positional change with Class II treatment (11, 16, 25). During an average treatment duration of 8.5 months, possible condylar and glenoid fossa remodeling after the mandibular positional change with fixed anterior biteplane might explain the unchanged temporomandibular condyle position.

Anterior joint space on the left side showed greater values than the right side at T0, indicating asymmetric condyle position in Class II deep bite patients. Various studies have reported that this asymmetry should not be considered as a pathology and may be associated with the normal asymmetries of the cranial base (26, 27). After the treatment of fixed anterior biteplane treatment, values of the anterior and posterior joint spaces became closer, and symmetry of the joint spaces was achieved on the left and right sides.

It was stated that the steep slope of the articular fossa may cause greater rotational movement of the disc on the condyle that may increase the risk of disc displacement disorders. Cohlmia et al. (8) showed a steeper articular fossa slope in deep bite patients. After the treatment of deep bite with fixed anterior biteplane, the slope of the articular fossa on the right side tended to decrease and became symmetric with that on the left side.

One of the limitations of the study was the use of two-dimensional radiographs that involve several unwanted factors, such as difficulty in visualizing a three-dimensional structure and superimposition of the surrounding structures. While Computed tomography/Cone-beam computed tomography may be recommended for three-dimensional evaluation of the temporomandibular joint, accounting the ALARA principles, two-dimensional imaging was preferred in order to reduce the effective radiation that the patients received (28). In addition, the clinical validity of two-dimensional tomographic tracing to measure the condylar position is questionable. The difficulty in evaluating small changes in condylar positioning, even with the use of tomography have been discussed previously (29-31).

Another limitation of the study was the lack of a control group; we did not compose a control group due to ethical reasons. However, it is noteworthy that all the patients were in the same cervical vertebral maturation stage in their pre- and post-treatment periods.

CONCLUSION

Considering the limitations of this study, we found no significant changes in the condyle fossa relationship with the use of a fixed anterior biteplane appliance.

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethics Committee of Medical, Surgical and Drug Research of Hacettepe University (LUT 04/30).

Informed Consent: Informed consent was taken from patients at the beginning of the study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - B.A.G., S.C..; Design - B.A.G., S.C.; Data Collection and/or Processing - B.A.G.; Analysis and/or Interpretation - B.A.G., S.C.; Literature Search -B.A.G.; Writing Manuscript - B.A.G.; Critical Review - B.A.G., S.C.

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

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REFERENCES

1. Minagi S, Sato T, Kishi K, Natsuaki N, Akamatsu Y. Comparative study of the temporomandibular joint space in maximum intercuspation and canine edge-to-edge positions in deep bite and non-deep bite subjects. J Oral Rehabil 2000; 27: 517-21. [CrossRef]
2. Selaimen CM, Jeronymo JC, Brilhante DP, Lima EM, Grossi PK, Grossi ML. Occlusal risk factors for temporomandibular disorders. Angle Orthod 2007; 77: 471-7. [CrossRef]
3. Ganugapanta VR, Ponnada SR, Gaddam KP, Perumalla K, Khan I, Mohammed NA. Computed tomographic evaluation of condylar symmetry and condyle-fossa relationship of the temporomandibular joint in subjects with normal occlusion and malocclusion: a comparative study. J Clin Diagn Res 2017; 11: ZC29-ZC33. [CrossRef]
4. Tanne K, Tanaka E, Sakuda M. Association between malocclusion and temporomandibular disorders in orthodontic patients before treatment. J Orofac Pain 1993; 7: 156-62.
5. Sonnesen L, Bakke M, Solow B. Malocclusion traits and symptoms and signs of temporomandibular disorders in children with severe malocclusion. Eur J Orthod 1998; 20: 543-59. [CrossRef]
6. Wood DP, Floreani KJ, Galil KA, Teteruck WR. The effect of incisal bites force on condylar seating. Angle Orthod 1994; 64: 53-61.
7. Pullinger AG, Solberg WK, Hollender L, Petersson A. Relationship of mandibular condylar position to dental occlusion factors in an asymptomatic population. Am J Orthod Dentofacial Orthop 1987; 91: 200-6. [CrossRef]
8. Cohlmia JT, Ghosh J, Sinha PK, Nanda RS, Currier GF. Tomographic assessment of temporomandibular joints in patients with malocclusion. Angle Orthod 1996; 66: 27-35.
9. Katsavrias EG, Halazonetis DJ. Condyle and fossa shape in class I and class III skeletal patterns: a morphometric tomographic study. Am J Orthod Dentofac Orthop 2005; 128: 337-46. [CrossRef]
10. Paknahad M, Shahidi S, Abbaszade H. Correlation between condylar position and different sagittal skeletal facial types. J Orofac Orthop 2016; 77: 350-6. [CrossRef]
11. Cheib Vilefort PL, Farah LO, Gontijo HP, Moro A, Ruellas ACO, Cevidanes LHS et al. Condyle-glenoid fossa relationship after Herbst appliance treatment during two stages of craniofacial skeletal maturation: A retrospective study. Orthod Craniofac Res 2019; 22: 345-53. [CrossRef]
12. Akarsu B, Ciger S. Evaluation of the effects of fixed anterior biteplane treatment on the dental and skeletal structures and masticatory muscles in patients with deep bite. Hacettepe Diş Hekimliği Fakültesi Dergisi 2010; 34: 10-22.
13. LeCornu M, Cevidanes LH, Zhu H, Wu CD, Larson B, Nguyen T. Three-dimensional treatment outcomes in Class II patients treated with the Herbst appliance: a pilot study. Am J Orthod Dentofacial Orthop 2013; 144: 818-30. [CrossRef]
14. Yildirim E, Karacay S, Erkan M. Condylar response to functional therapy with Twin-Block as shown by cone-beam computed tomography. Angle Orthod 2014; 84: 1018-25. [CrossRef]

15. Atresh A, Cevidanes LHS, Yatabe M, Muniz L, Nguyen T, Larson B, et al. Three-dimensional treatment outcomes in Class II patients with different vertical facial patterns treated with the Herbst appliance. Am J Orthod Dentofacial Orthop 2018; 154: 238-48. [CrossRef]
16. Ruf S, Pancherz H. Temporomandibular joint growth adaptation in Herbst treatment: a prospective magnetic resonance imaging and cephalometric roentgenographic study. Eur J Orthod 1998; 20: 375-88. [CrossRef]
17. Williamson EH. Temporomandibular dysfunction in pretreatment adolescence patients. Am J of Orthod 1977; 72: 429-33. [CrossRef]
18. Owen AH 3rd. Orthodontic/orthopedic treatment of craniomandibular pain dysfunction. Part 2: posterior condylar displacement. J Craniomandibular Pract 1984; 2: 333-49. [CrossRef]
19. Thompson JR. Abnormal function of the temporomandibular joints and related musculature. Orthodontic implications. Part I. Angle Orthod 1986; 56: 181-95.
20. Green CS. Orthodontics and temporomandibular disorders. Dent Clin of North Am 1988; 32: 529-38.
21. Egermark Eriksson I, Ingervall B, Carlsson GE. The dependence of mandibular dysfunction in children on functional and morphologic malocclusion. Am J Orthod 1983; 83: 187-94. [CrossRef]
22. Gianelly AA, Petras JC, Boffa J. Condylar position and Class II deep-bite, no-overjet malocclusion. Am J Orthod Dentofacial Orthop 1989; 96: 428-32. [CrossRef]
23. Pullinger AG, Seligman DA. Overbite and overjet characteristics of refined diagnostic groups of temporomandibular disorder patients. Am J Orthod Dentofacial Orthop 1991; 100: 401-15. [CrossRef]
24. Demisch A, Ingervall B, Thüer U. Mandibular displacement in angle class II, division 2 malocclusion. Am J Orthod Dentofacial Orthop 1992; 102: 509-18. [CrossRef]
25. Coskuner HG, Ciger S. Three-dimensional assessment of the temporomandibular joint and mandibular dimensions after early correction of the maxillary arch form in patients with Class II division 1 or division 2 malocclusion. Korean J Orthod 2015; 45: 121-9. [CrossRef]
26. Vig PS., Hewitt AB. Asymetry of the human facial skeleton. Angle Orthod 1975; 45: 125-9.
27. Artun J, Hollender L, Truelove EL. Relationships between orthodontic treatment, condylar position, and internal derangement in the temporomandibular joint. Am J Orthod Dentofacial Orthop 1992; 101: 48-53. [CrossRef]
28. American Dental Association Council on Scientific Affairs. The use of cone-beam computed tomography in dentistry: an advisory statement from the American Dental Association Council on Scientific Affairs. J Am Dent Assoc 2012; 143: 899-902. [CrossRef]
29. Girardot RA. The nature of condylar displacement in patients with TM pain dysfunction. Orthod Rev 1987; 1: 16-23.
30. Lam PH, Sadowsky C, Omerza F. Mandibular asymmetry and condylar position in children with unilateral posterior crossbite. Am J Orthod Dentofacial Orthop 1999; 115: 569e75. [CrossRef]
31. Uzel A, Özyürek Y, Öztunç H. Condyle position in Class II division 1 malocclusion patients: Correlation between MPI records and CBCT images. Journal of World Fed Orthod 2013; 2: e65-e70. [CrossRef]

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Original Article

Evaluating the Efficacy of a Modified Piezo-Puncture Method on the Rate of Tooth Movement in Orthodontic Patients: A Clinical Study

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ABSTRACT

Objective: Owing to the increasing demand from orthodontic patients for a more rapid treatment, many studies have focused on accelerated tooth movement. Currently, one of the prevalent methods to achieve accelerated tooth movement is piezo-puncture. The aim of the present study was to evaluate the effect of a modified piezo-puncture method on tooth movement rate and type during canine retraction.

Methods: A total of 17 patients who required fixed orthodontic treatment with extraction of the maxillary first premolars were included in the study. Following a split-mouth design, upper canines were retracted with Ni–Ti coil spring that applied 150 g of force on each side (piezo-puncture on one side and contralateral side served as the control). Then, the rates of tooth movement, canine angulation and rotation, and anchorage loss were evaluated at T0 (before the intervention), T1 (1 month after the intervention), and T2 (2 months after the intervention). For calculating the canine movement rate, either the distance between the canine and the lateral incisor or the space between the second premolar and the canine was measured. In addition, pain perception was documented by Visual Analog Scale. Data were analyzed using the Kolmogorov–Smirnov normality test, Spearman correlation test, paired sample t-test, and Wilcoxon signed-rank test.

Results: No significant acceleration was observed in canine movement, canine tipping, rotation, or anchorage loss of molar in different times.

Conclusion: Considering the limitations of the study, the application of piezo-puncture employing the protocol used in the present study failed to accelerate tooth movement and to decrease the unfavorable tipping, rotation, and molar anchorage loss.

Keywords: Piezo-puncture, Accelerated tooth movement, Canine retraction

INTRODUCTION

The duration of orthodontic treatment has always been a critical concern for both patients and clinicians; therefore, many solutions have been proposed in recent years to shorten this period (1). Currently, driven by the growing demand of individuals for faster and shorter orthodontic treatments, many studies tend to focus on accelerated tooth movement (2-11). The first efforts to achieve accelerated tooth movement date back to 1890 (1). One of these early methods was alveolar osteotomy in which the bone cortex and medullary bone were completely separated–primarily involved in the reduction of bone mechanical strength–in an attempt to accelerate tooth movement. In 1959, Köle introduced a procedure involving both osteotomy and corticotomy (3). This new approach involved resecting the cortical bone only, resulting in decreased damage and risks compared with osteotomy. During the years that followed, methods to clinically accelerate tooth movement were attributed to

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reduced bone strength (4). However, in 1983, Frost refuted this concept, arguing that the demineralization and remineralization processes of the alveolar bone are the actual causes responsible for tooth movement acceleration. This phenomenon was termed as regional acceleratory phenomenon (RAP) (5).

Although human and animal studies demonstrated the relative efficacy of corticotomy on the rate of tooth movement, some complications and limitations posed by this method prompted the development of corticision and piezocision (6-11). In contrast to corticotomy, these procedures do not require full-thickness flap reflection, but instead, the use of a small vertical incision through the gingiva fulfills the purpose (12, 13). These methods resulted in significantly less trauma and other complications in comparison with the corticotomy method (14).

Some studies have showed that the decortication resulting from piezotome is much more conservative than using a bur and a handpiece. Accordingly, it has been claimed that the vibration of the ultrasonic handpiece could produce a more extensive effect on the osteocytic response (15). Yadav et al. (16) reported no significant increase in tooth movement by applying various low-frequency mechanical vibration, whereas Kalajzic et al. (17) found that tooth movement is significantly inhibited by the application of vibratory forces, and Uribe et al. (18) found that the effect of vibration on accelerating the rate of orthodontic tooth movement is contradictory.

Nevertheless, with the aim of relieving the fear, pain, and discomfort experienced by patients during surgical procedures, a novel method called piezo-puncture was introduced by Kim et al. (19) using an animal model. It is claimed that the piezo-puncture is an optimized less invasive treatment modality, relies on crystallographic, as well as piezoelectric, changes, and involves making several cortical punctures penetrating the gingiva and bone. In this procedure through an ultrasonic tool and sharp tip, without any flap or incision, several punches are created on the gingiva and bone in different locations according to treatment plan and tooth movement direction. Since only one case report is available as clinical study in this subject (20), the aim of this split-mouth clinical trial was to compare the retraction rates of upper canines with sliding mechanics using piezo-puncture method with a control side.

METHODS

Patient Selection

This was a clinical controlled trial. The research protocol was reviewed and approved by the ethical committee of the Mashhad University of Medical Sciences (No: 930554, Date: 2015/02/18). A total of 17 (7 male and 10 female) healthy subjects were included in the study. Inclusion criteria were minimum age of 14 years and maximum age of 30 years (mean age: 18.23±1.35 years); maximum anchorage (group A); Class I/crowding or Class II division 1 malocclusion requiring treatment using bilateral extraction of the first premolars and retraction of the maxillary canines with standard full fixed edgewise appliances; presence of a full complement of dentition from first molar to first molar in both arches and possession of a healthy periodontium despite attachment loss of up to 2 mm—yet without any systemic disease; no history of previous orthodontic treatment; no therapeutic intervention, such as maxillary lateral expansion or growth modification treatment; and requirement of at least 3 mm of canine retraction. Informed consent was obtained from the patients or their legal guardians who agreed to participate in the research.

The orthodontic treatment of patients was scheduled using standard edgewise appliance system with 0.018×0.025-inch slot (Dentaurum, Germany). Transpalatal arches (TPAs) were inserted in all patients. The right and left maxillary first premolars were extracted approximately 3 months before starting canine retraction. Once leveling and aligning were achieved and before canine retraction, the four incisors were connected using a ligature wire, and accurate alginate impressions were obtained from the upper jaw. Thereafter, a set of study casts were poured in dental stone. Then, the periodontist performed piezo-puncture on the distobuccal, mesiobuccal, mesiolingual, and distolingual sides of the canine (parallel to the long axis of the canine root). Then, Ni–Ti coil spring (G&H, USA) was applied exerting 150 g of force by connecting to the hook of canines and molars on a 0.016-inch stainless steel wire for canine retraction. Alginate impression was repeated at the end of the first and second months following spring activation. A code number was allocated to the name of each patient to eliminate possible researcher bias. These code numbers were matched to study casts, and the photographs were obtained from them. A random selection procedure (coin toss) was utilized to consider one side of the participant's upper jaw for piezo-puncture (intervention group) and the other for the control group (no intervention). Further assessment of the photographs, as well as the study casts, was performed 1 month after the completion of the whole project by another researcher who was blind to the intervention group.

Piezo-Puncture Protocol

Initially, the longitudinal axis and the adjacent teeth roots were evaluated using panoramic radiography. Then, local anesthesia (lidocaine 2% with epinephrine 1:100,000) was injected into the target area. A piezo-surgery device (24–26 kHz oscillation; Mectron Piezosurgery®, Italy) with a curved, sharp head (Sharp Insert Tip, OT6) was used to create the cortical tissue punctures.

The punctures were made 3 mm deep into the cortical bone by holding the tip of the device perpendicular to the gingiva and bone for 5 s, while normal saline was being dispersed by the machine for cooling in the process (19). Punctures were made starting from 4–5 mm below the gingival papilla tip. A total of 24 punctures were created in the following order: 8 on the distobuccal side, 8 on the mesiobuccal side (Figure 1. a, b), 4 on the mesiopalatal side, and 4 on the distopalatal side of the canine teeth along the root axis (Figure 1c). Finally, the patients were advised to use 0.2% chlorhexidine mouthwash twice a day for 1 week.

Measuring the Rate of Tooth Movement

The study models were used to measure the amount of canine movement. For this purpose, the following points were identified and marked on the casts: the most distal point on the incisal edge of the lateral incisor, canine cusp tip, distal contact point of the canine, mesial contact point of the maxillary second premo-

Figure 1. a-c. Punches created in buccal side (a, b) and in palatal side (c)

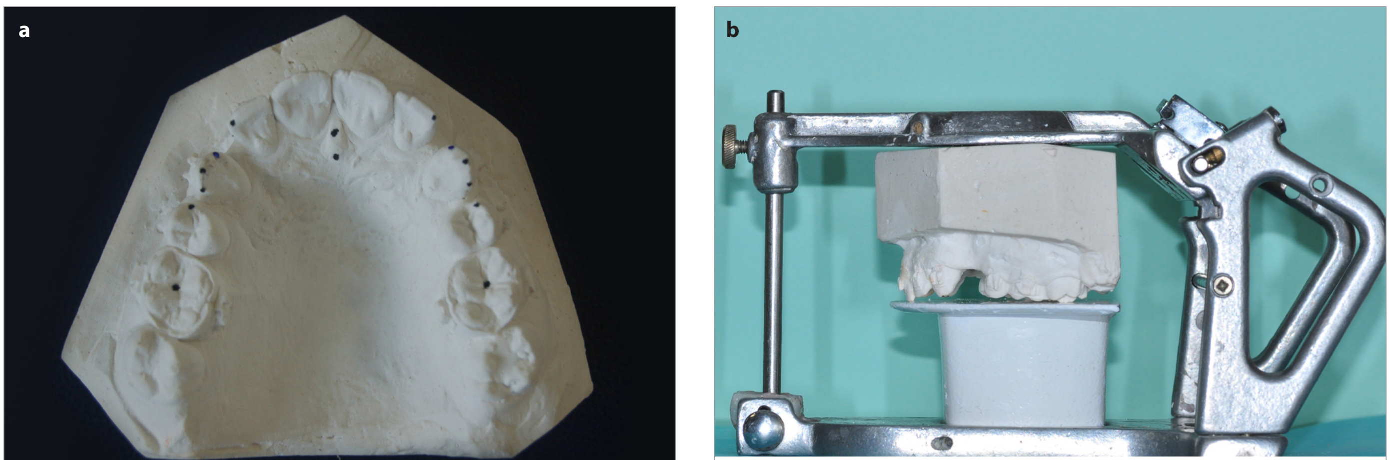

Figure 2. a, b. Identified landmarks on the study model (a), the method of paralleling the occlusal plane with the horizontal plane (b)

lar, central fossa of the maxillary first molar, and the most anterior and posterior points of the incisive papilla (Figure 2a).

Then, the occlusal surface was adjusted using the articulators in the horizontal plane (Figure 2b). The images from all casts were taken with a digital camera positioned at a constant vertical distance from the occlusal surface using the same magnification. Measurements were performed utilizing the Smile Analyzer software (21). Either the distance between the canine cusp tip and the most distal point of the lateral incisor (at incisal level) or the space between the mesial contact point of the second premolar and the distal surface of canine was measured to calculate the tooth movement rate of the canine.

Canine rotation was determined using the angle created between the line connecting the anterior and posterior parts of the incisive papilla (roughly the median palatine suture) and the mesial and distal lines passing through the contact surface of canines during treatment (Figure 3) (22).

A tooth inclination protractor (TIP) device was employed to measure canine tipping during the movement. The metallic wire offered by the TIP device was laid leaning against the labial surface of the canine on the line that passes through the cusp tip and the midpoint of the cervical aspect of the crown. The resultant angle formed between the wires, measured with an angle ruler, was indicative of tooth tipping in the mesiodistal direction (Figure 4) (23).

For the purpose of measuring the amount of molar mesial movement and anchorage loss, an acrylic palatal plug was made on the initial maxillary study model for each patient. Since the acrylic plate of this appliance was almost confined to the rugae area and because this particular site suffered minimal changes in size and shape over time, this appliance could be transferred from the initial cast to the final cast. Acrylic plate included an acrylic part on the palate rugae and the reference wires (0.019×0.025-inch stainless steel) that were embedded in this acrylic part, extending to the tip of the canine cusp and the central fossa of the maxillary first molars. After molar movement, the distance between the central fossa and the wire tip was calculated as the amount of mesial molar displacement (Figure 5) (22).

The amount of pain was evaluated using the Visual Analog Scale. After the completion of surgery and the initiation of retraction, the level of pain and discomfort experienced by the subjects during the first and second months following the piezo-puncture surgery was documented by the patients themselves, rating their pain intensity on a scale of 0–10, where 0 represented no pain and 10 signified severe pain (Figure 6).

Data Analysis and Statistical Analysis

Data collected from all groups were analyzed by the Statistical Package for Social Sciences for Windows software, version 15.0 (SPSS Inc., Chicago, IL, USA).

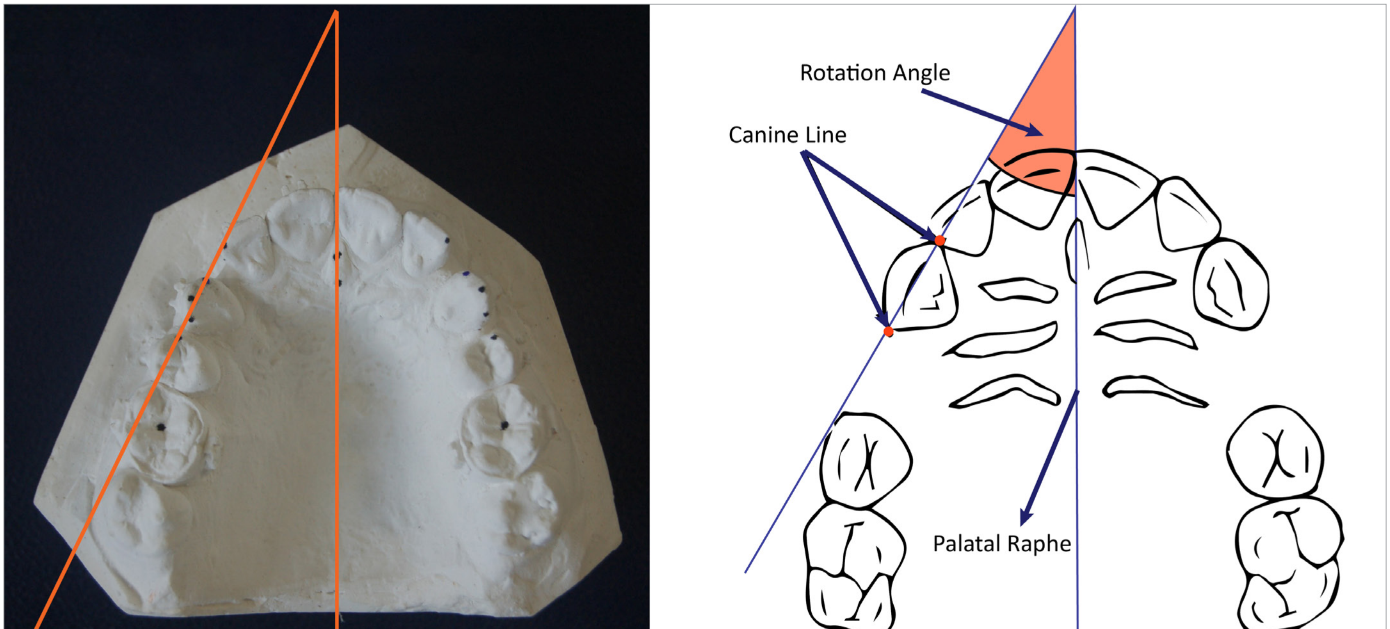

Figure 3. Measurement of canine rotation (22)

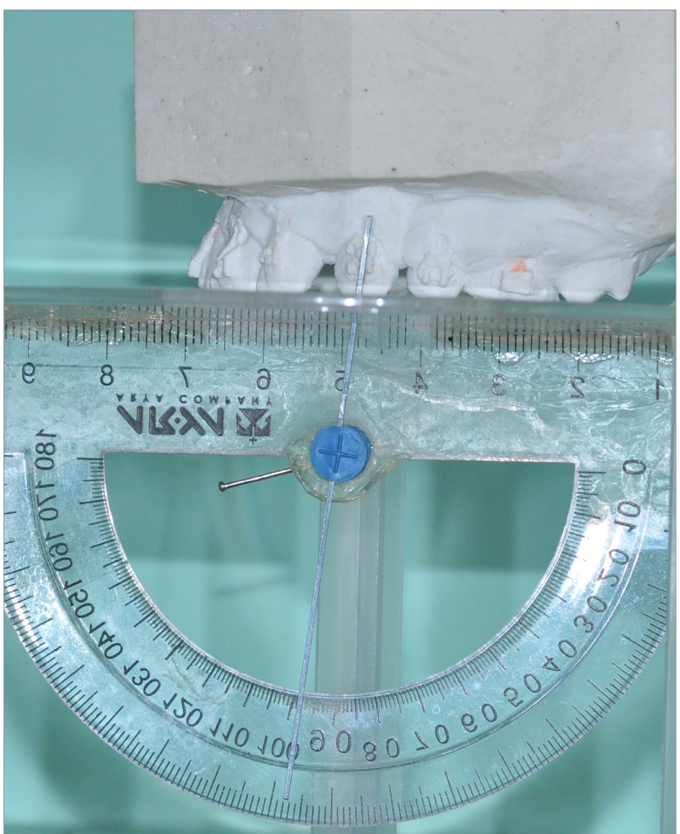

Figure 4. Measurement of canine tipping using TIP

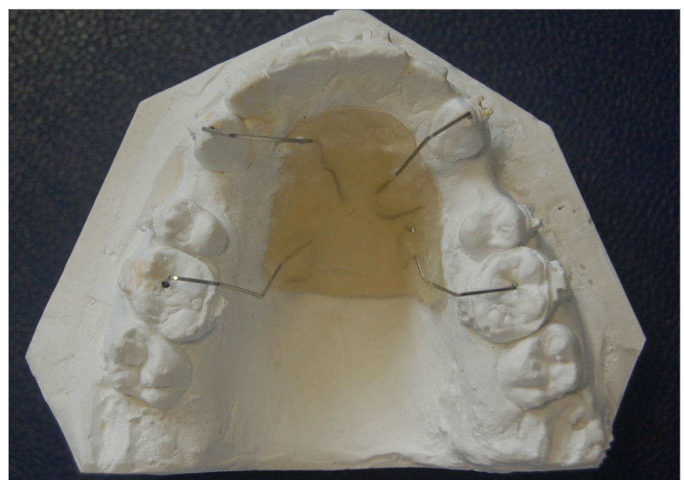

Figure 5. The acrylic plate along with reference wires to measure molar movement rate (anchorage loss)

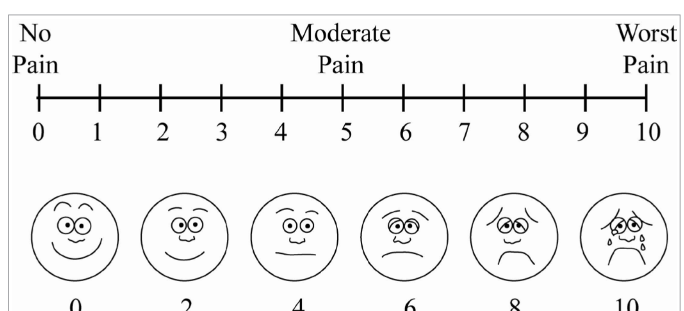

Figure 6. The ruler used for measuring the amount of pain

Evaluations were repeated 15 days after the preliminary measurements to assess intraobserver reliability. The second set of values was compared against the initial values using Spearman correlation test. The results showed a significant correlation ($p<0.05$) between the two sets of measurement values, with the difference being equal to 1 or approximately 1.

Subsequent to the verification of the reliability of measurements, Kolmogorov–Smirnov normality test was conducted to study the data distribution. The results of this test, for most variables, indicated a data distribution level of 5%, which was deemed as normal and acceptable. Then, paired sample t-test was utilized

Table 1. Mean differences, SD, and significance level in the piezo-puncture and control groups

	Time	Group	Mean±SD[a]	p
Distance between the canine and the lateral incisor (mm)	T0–T1[b]	Control	0.74±0.89	0.169
		Piezo-puncture	0.88±1.16	
	T1–T2[c]	Control	0.65±0.83	0.577
		Piezo-puncture	0.60±0.75	
	T0–T2[d]	Control	0.90±1.72	0.297
		Piezo-puncture	1.02±1.91	
Space between the second premolar and the canine (mm)	T0–T1	Control	1.18±1.77	0.458
		Piezo-puncture	1.11±1.92	
	T1–T2	Control	1.17±1.27	0.53
		Piezo-puncture	0.74±1.15	
	T0–T2	Control	1.62±3.05	0.93
		Piezo-puncture	1.49±3.07	
Canine rotation (°)	T0–T1	Control	6.63±3.53	0.29
		Piezo-puncture	8.32±5.94	
	T1–T2	Control	4.24±3.05	0.58
		Piezo-puncture	5.42±2.17	
	T0–T2	Control	6.87±6.58	0.54
		Piezo-puncture	8.40±8.11	
Canine tipping (°)	T0–T1	Control	3.00±0.94	0.055
		Piezo-puncture	1.60±0.64	
	T1–T2	Control	1.75±0.23	0.21
		Piezo-puncture	1.53±0.71	
	T0–T2	Control	2.24±1.17	0.69
		Piezo-puncture	2.02±1.35	
Movement of the first molar (mm)	T0–T1	Control	0.27±0.31	0.309
		Piezo-puncture	0.28±0.22	
	T1–T2	Control	0.15±0.18	0. 200
		Piezo-puncture	0.12±0.15	
	T0–T2	Control	0.32±0.49	0.468
		Piezo-puncture	0.35±0.37	

Significance level at $p<0.05$.
[a]Standard deviation
[b]T0–T1: during the first month of canine retraction
[c]T1–T2: during the second month of canine retraction
[d]T0–T2: total amount of changes during the first and second months

to analyze the variables related to the amount of canine movement, namely, distal movement, rotation, and anchorage loss, as well as pain.

Considering that the normal distribution of data of tipping values was rejected, Wilcoxon signed-rank test was applied to assess this variable.

RESULTS

Since the angular and linear measurements were performed at three different time intervals during the study, the relevant tables were summarized as follows for the ease of reading: T0: initiation of treatment, T1: the end of the first month, T2: the end of the second month, T0–T1: changes during the first month, T1–T2: changes during the second month, and T0–T2: total amount of changes during the first and second months.

Data regarding the distal movement in the piezo-puncture and control groups at three different time intervals are summarized in Table 1. Based on the achieved data, the movement rate of canines belonging to the piezo-puncture group during the first month, the second month, and after 2 months was not significantly different from that of the control group ($p>0.05$).

The total amount of canine rotation in the piezo-puncture and control groups measured at three different time intervals is summarized in Table 1. According to these mean differences, the rotation of canines on both sides at different times was not significantly different ($p>0.05$).

Table 2. Comparison of pain level between the piezo-puncture and control sides

Group	Time	Mean difference±SD[a]	p
Control	T0[b]	0.76±1.05	0.056
Piezo-puncture		1.05±2.09	
Control	T0–T1[c]	0.81±1.14	0.373
Piezo-puncture		0.89±1.07	
Control	T1–T2[d]	0.79±1.07	0.281
Piezo-puncture		0.71±0.9	

Significance level at p<0.05
[a]Standard deviation
[b]After piezo-puncture and connection of spring
[c]During the first month of canine retraction
[d]During the second month of canine retraction

No significant difference was observed in the amount of tipping between the piezo-puncture and on the control sides (Table 1). The tipping values during 2-month of canine retraction were 4.58±2.39° on the control side and 5.29±2.39° on the piezo-puncture side.

Evaluation of the mesial movement of the first molars revealed that there was no significant difference between the experimental (0.37±0.35 mm) and control sides (0.49±0.32 mm) in this aspect (Table 1).

The degree of pain experienced at the early stage of treatment (after surgery) was relatively greater on the piezo-puncture side than on the control side, but the difference was not statistically significant (P>0.05). In addition, during the first and second months, no significant pain level was reported by patients in either experimental or control side, and the difference between two sides was not statistically significant (Table 2).

DISCUSSION

A wide range of surgical intervention methods has been applied on periodontal tissues to accelerate orthodontic tooth movement. The damage caused by such surgical interventions, designed to stimulate the occurrence of the RAP, has been a primary interest factor leading to the development of new surgical techniques that not only accelerate orthodontic tooth movement but also reduce the duration of treatment (24). During the evolutionary process involving techniques, such as osteotomy and corticotomy, followed by corticision, piezocision, and micro-osteoperforation methods in recent years, a more in-depth explanation of the biological and molecular processes has been reported, and researchers are still searching for a more convenient, conservative approach with the hope to further enhance the rate of tooth movement, which can potentially mean the elimination of current problems, reduction of conventional risks, and achievement of comparatively better results (25-28).

One of the latest methods resulting from these attempts is the piezo-puncture method, which involves utilizing a piezoelectric device to create cortical punctures on the attached gingiva around the teeth. It is claimed that this procedure can minimize pain and discomfort in patients-during and after surgery-and increase patient cooperation. On the other hand, since only a few punctures are required, minimal tissue damage is predicted. These pointers regarding the piezo-puncture procedure were presented subsequent to the results of an animal study on beagle dogs. The findings of this study showed rapid tooth movement without any serious damage (19). Following this study, it was deemed necessary to determine the efficacy of the piezo-puncture method in clinical situations. For this reason, the current study employed the piezo-puncture procedure to evaluate the anticipated effect on the movement rate of canines. The study was conducted in the form of a clinical trial following a split-mouth pattern.

Other studies in the literature, which employed more aggressive surgical procedures, such as corticotomy and piezocision, for the purpose of accelerated tooth movement, have reported a faster rate of tooth movement. However, the results of the present study did not indicate any significant increase in the rate of tooth movement. Abbas et al. (29), who used corticotomy and piezocision in their experiment, reported a 1.5- up to 2-fold increase in the rate of canine distal movement. It should be noted that the current study utilized a different method (precisely, a more conservative surgical technique) and therefore, perhaps the reason of the difference between the results of this study with the actual results from other studies employing corticotomy, corticision, piezocision, or micro-osteoperforations due to the proven fact that the rate of the RAP is positively correlated with the severity of the injury (30). However, in relation to studies that have applied piezocision, perhaps the positive impact that these experiments have achieved can be attributed to the depth, length, and number of applied injuries. It is worth mentioning that the method, which was implemented in the course of the present study, involved creating fewer penetrations and perforating a lesser amount of cortical bone than other methods, such as piezocision and corticotomy. The protocol used in the current study applied 16 punctures on the buccal side and 8 punctures on the palatal side. Corticotomy cuts applied in the research performed by Aylikci and Sakin (9) were 10 mm long and 4 mm depth. Thus, compared with other studies, the total depth of punch penetration applied to the cortical bone in the present study was decreased (approximately 3 mm), which was similar to the results achieved in the study by Kim et al. (19). Several other studies have reported a larger total of puncture depth (up to 4-5 mm) (10, 12, 29).

The available literature on piezo-puncture method is relatively scant. Therefore, no clinical trial on human population had been conducted to assess the effectiveness of this method. The only source of information available is an animal study by Kim et al. (19) in 2013, which was performed on dogs to evaluate the effectiveness of this particular method on the rate of tooth movement and bone remodeling. Among the possible causes to explain the difference between the results of these two studies, we could point out the different bone structures that humans and dogs possess. In addition, the measurement model applied in the study by Kim et al. (19) was in accordance with the dental and jaw situation of dogs, which is completely different from that of a human study. Anatomical limits of a dog's mouth make it completely impossible to install TPAs or springs to ensure generalizability. Moreover, the number of samples examined in that animal study (6 experimental samples and 4 controls) was lower than the present human study (17 samples).

According to the achieved results, although pain perception at the early stages following piezo-puncture was higher on the experimental side than on the control side, the difference was not statistically significant. The pain induced by piezo-puncture might have been clinically negligible. Of course, it should be mentioned that the study followed a split-mouth design, and differentiation between the pain from surgery and that originating from the control sides is difficult, and perhaps, somewhat confusing for the patient.

With respect to the cost/benefit ratio of the piezo-puncture method, it should be mentioned that it is a relatively safe method, inducing the least amount of pain and discomfort for the patient compared with more aggressive surgeries, such as corticotomy. However, the piezo-puncture device should be available in the dental clinic. Although this study did not show significant benefits in favor of the applied method, modifying the protocol of piezo-puncture including the number of punctures or repeating the punctures after a period or measuring the tooth movement in shorter intervals may suggest the clinical efficiency of the piezo-puncture method.

Basically, the intention to cut the soft tissue using the piezo tips will result in crushing or bruising of the tissue rather than cutting. It should be pointed out that in our study, the soft tissue was penetrated by the sharp tips of the piezo blade. The OT6 piezo tip with its saw-shaped design allows the operator to penetrate through the thin soft tissue of the gingiva or oral mucosa with a gentle squeezing of the soft tissue between the points of the tip and bone. Using this technique may cause less soft tissue opening with no need of suturing, although if the soft tissue is thick, the punches may join together, necessitating suturing. We believe that the whole concept of piezo-puncture for tooth movement acceleration is still far from being a standard and universally accepted technique, and therefore a standard and effective piezo-puncture method is yet to be developed.

The authors recommend future studies without split-mouth design to prevent the spreading of the RAP in the entire jaw. In addition, the study period should be considered more than 2 months. Studies with repeated piezo-punctures at regular intervals are recommended to investigate the therapeutic benefits of piezo-puncture procedure in orthodontic tooth movement. Further studies with larger sample size are highly recommended. One of the limitations of the study was using traditional measuring methods rather than digitized or 3D measuring methods. Furthermore, only two time-points were used to measure the amount of space closure per month; RAP is a time-limited process, and therefore the acceleration period might have been missed in this study.

CONCLUSION

Considering the limitations of this in vivo study and according to the protocol used, it appears that piezo-puncture did not have a significant impact on the canine retraction rate, canine angulation, amount of rotation, and discomfort levels during the first month or at the two examination intervals following surgery compared with the control side.

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethics Committee of the Mashhad University of Medical Sciences (No: 930554, Date: 2015/02/18).

Informed Consent: Informed consent was obtained from the patients or their legal guardians who agreed to participate in the research.

Peer-review: Externally peer-reviewed.

Author Contributions: Supervision - O.M., R.M.; Design - O.M.; Resources - O.M., R.M.; Materials - O.M., R.M.; Data Collection and/or Processing - A.M.; Analysis and/or Interpretation - O.M. A.M.; Literature Search - O.M., A.M., D.M.; Writing Manuscript - O.M., D.M.; Critical Review - O.M., D.M.

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

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REFERENCES

1. Charavet C, Lambert F, Lecloux G, Le Gall M. Accelerated orthodontic treatment using corticotomies: what are the minimally invasive alternatives? Orthod Fr 2019; 90: 5-12. [CrossRef]
2. Davidovitch Z. Tooth movement. Crit Rev Oral Biol Med 1991; 2: 411-50. [CrossRef]
3. Kole H. Surgical operations on the alveolar ridge to correct occlusal abnormalities. Oral Surg Oral Med Oral Pathol 1959; 12: 515-29. [CrossRef]
4. Anholm JM, Crites DA, Hoff R, Rathbun WE. Corticotomy-facilitated orthodontics. Cda J 1986; 14: 7-11.
5. Frost HM. The regional acceleratory phenomenon: a review. Henry Ford Hosp Med J 1983; 31: 3-9.
6. Iino S, Sakoda S, Ito G, Nishimori T, Ikeda T, Miyawaki S. Acceleration of orthodontic tooth movement by alveolar corticotomy in the dog. Am J Orthod Dentofacial Orthop 2007; 131: 448.e1-8. [CrossRef]
7. Nimeri G, Kau CH, Abou-Kheir NS, Corona R. Acceleration of tooth movement during orthodontic treatment--a frontier in orthodontics. Prog Orthod 2013; 14: 42. doi: 10.1186/2196-1042-14-42. [CrossRef]
8. Kim SJ, Park YG, Kang SG. Effects of Corticision on paradental remodeling in orthodontic tooth movement. Angle Orthod 2009; 79: 284-91. [CrossRef]
9. Aylikci O, Sakin C. Piezocision-assisted canine distalization. J Orthod Res 2013; 1: 70. DOI: 10.4103/2321-3825.116288. [CrossRef]
10. Brugnami F, Caiazzo A, Dibart S. Lingual orthodontics: accelerated realignment of the "social six" with piezocision. Compend Contin Educ Dent 2013; 34: 608-10.
11. Mittal S, Sharma R, Singla A. Piezocision assisted orthodontics: a new approach to accelerated orthodontic tooth movement. J Innov Dent 2011; 1: 1-4.
12. Dibart S, Keser EI. Piezocision™. Minimally invasive periodontally accelerated orthodontic tooth movement procedure. Orthodontically Driven Corticotomy: Tissue Engineering to Enhance Orthodontic and Multidisciplinary Treatment NJ (USA): editors: Brugnami F, Alfonso C. Wiley-Blackwell 2014: 119. [CrossRef]
13. Dibart S, Sebaoun JD, Surmenian J. Piezocision: a minimally invasive, periodontally accelerated orthodontic tooth movement procedure. Compend Contin Educ Dent 2009; 30: 342-4, 6, 8-50.

14. Cassetta M, Giansanti M. Accelerating orthodontic tooth movement: A new, minimally-invasive corticotomy technique using a 3D-printed surgical template. Med Oral Patol Oral Cir Bucal 2016; 21: 483-7. [CrossRef]
15. Dibart S, Yee C, Surmenian J, Sebaoun JD, Baloul S, Goguet-Surmenian E, et al. Tissue response during Piezocision-assisted tooth movement: a histological study in rats. Eur J Orthod. 2014; 36: 457-64. [CrossRef]
16. Yadav S, Dobie T, Assefnia A, Gupta H, Kalajzic Z, Nanda R. Effect of low-frequency mechanical vibration on orthodontic tooth movement. Am J Orthod Dentofacial Orthop 2015; 148: 440-9. [CrossRef]
17. Kalajzic Z, Peluso EB, Utreja A, Dyment N, Nihara J, Xu M, et al. Effect of cyclical forces on the periodontal ligament and alveolar bone remodeling during orthodontic tooth movement. Angle Orthod 2014; 84: 297-303. [CrossRef]
18. Uribe F, Dutra E, Chandhoke T. Effect of cyclical forces on orthodontic tooth movement, from animals to humans. Orthod Craniofac Res 2017; 20(Suppl 1): 68-71. [CrossRef]
19. Kim YS, Kim SJ, Yoon HJ, Lee PJ, Moon W, Park YG. Effect of piezo-puncture on tooth movement and bone remodeling in dogs. Am J Orthod Dentofacial Orthop 2013; 144: 23-31. [CrossRef]
20. Omidkhoda M, Radvar M, Azizi M, Hasanzadeh N. Piezo-puncture-assisted canine distalization in orthodontic patients: two case reports. J Dent (Shiraz) 2018; 19: 74-82.
21. Rashed R, Heravi F, Raziee L. Smile Analyzer: a software package for analyzing the characteristics of the speech and smile. J Dent Mater Tech 2012; 1: 1-5.
22. Mezomo M, de Lima ES, de Menezes LM, Weissheimer A, Allgayer S. Maxillary canine retraction with self-ligating and conventional brackets. Angle Orthod 2011; 81: 292-7. [CrossRef]
23. Shpack N, Davidovitch M, Sarne O, Panayi N, Vardimon AD. Duration and anchorage management of canine retraction with bodily versus tipping mechanics. Angle Orthod. 2008; 78: 95-100. [CrossRef]
24. Verna C. Regional Acceleratory Phenomenon. Front Oral Biol 2016; 18: 28-35. [CrossRef]
25. Buschang PH, Campbell PM, Ruso S, editors. Accelerating tooth movement with corticotomies: is it possible and desirable? Seminars in Orthodontics 2012: Elsevier. [CrossRef]
26. Alikhani M, Alansari S, Sangsuwon C, Alikhani M, Chou MY, Alyami B, et al. Micro-osteoperforations: Minimally invasive accelerated tooth movement. Semin Orthod 2015; 21: 162-9. [CrossRef]
27. Alikhani M, Raptis M, Zoldan B, Sangsuwon C, Lee YB, Alyami B, et al. Effect of micro-osteoperforations on the rate of tooth movement. Am J of Orthod Dentofacial Orthop 2013; 144: 639-48. [CrossRef]
28. Tsai CY, Yang TK, Hsieh HY, Yang LY. Comparison of the effects of micro-osteoperforation and corticision on the rate of orthodontic tooth movement in rats. Angle Orthod 2016; 86: 558-64. [CrossRef]
29. Abbas NH, Sabet NE, Hassan IT. Evaluation of corticotomy-facilitated orthodontics and piezocision in rapid canine retraction. Am J Orthod Dentofacial Orthop 2016; 149: 473-80. [CrossRef]
30. McBride MD, Campbell PM, Opperman LA, Dechow PC, Buschang PH. How does the amount of surgical insult affect bone around moving teeth? Am J Orthod Dentofacial Orthop. 2014; 145 (Suppl 4): S92-9. [CrossRef]

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Original Article

Evaluation of Root Resorption, Tooth Inclination and Changes in Supporting Bone in Class II Malocclusion Patients Treated with Forsus Appliance

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ABSTRACT

Objective: The aim of our study was to evaluate apical root resorption and changes in tooth inclinations, marginal bone height, and labio-lingual bone thickness at the mid-root and apical level in mandibular anterior teeth during the Forsus treatment using cone beam computed tomography (CBCT).

Methods: CBCT scans of 16 subjects (8 males and 8 females) with Class II malocclusion (age group: 13–29 years) taken before and 6 months after the Forsus treatment were evaluated for apical root resorption, tooth inclination, marginal bone height, and thickness of bone at the mid-root and apical level in mandibular anterior teeth.

Results: There was statistically significant root resorption of central incisors (0.39 mm) and canines (0.66 mm); a decrease in the angle of inclination for all teeth; an increase in the marginal bone measurement in labial (1.31 mm) and decrease in lingual (0.93 mm) aspect at the canine region; and an increase in bone width by 0.87 mm and 0.75 mm in central and lateral incisor regions, respectively, at the mid-root level lingually. At the apex level in the canine region, bone width increased by 1.4 mm labially, while it decreased by 2.18 mm lingually; it increased significantly for incisors in the lingual region.

Conclusion: The Forsus appliance therapy causes clinically insignificant root resorption and bone changes, and clinically significant proclination of mandibular anterior teeth. The findings of the present study aid clinicians in proper case selection and reinforce the prevention of incisor proclination while using the Forsus therapy to achieve better treatment results and stability.

Keywords: Forsus, root resorption, tooth inclination, bone

INTRODUCTION

One of the keys to a successful orthodontic treatment is a detailed evaluation of treatment outcomes. Orthodontically induced inflammatory root resorption (OIIRR) is a side effect of biological tissue response to tooth movement (1). Forsus fatigue resistance device (FRD) is a fixed functional appliance that provides effective correction of Class II malocclusion by combining skeletal and dentoalveolar effects (2). While attempting to camouflage a skeletal problem with moderate Class II malocclusion, there will be tipping of lower incisors, which might be detrimental to root length and bring about changes in the alveolar bone thickness around incisors (3).

There is literature available on root resorption following orthodontic therapy. However, most of studies use intraoral radiography, which misestimates the extent of resorption due to magnification errors (1, 3-5). The OIIRR affects every aspect of tooth in three dimensions, hence two-dimensional images mask the true extent of resorption. Cone beam computed tomography (CBCT) is a three-dimensional diagnostic modality capable of imaging complex craniofacial structures with a lower radiation dose compared to computed tomography (CT). The diagnostic value of CBCT in the diagnosis of OIIRR lies in its ability to obtain distortion-free reproducible images of roots with high sensitivity and specificity (3). It has the capability to collimate the primary beam to the area of interest, thus reducing the unnecessary patient exposure.

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A systematic review and meta-analysis on randomized and non-randomized studies with three-dimensional images in linear and volumetric OIIRR during and after orthodontic treatment suggests that <1 mm of resorption is seen in an average tooth with CBCT (6). However, there were considerable differences in the amount of measured resorption seen according to tooth category, jaw, incorporation of extraction in treatment plan, and duration.

Another systematic review on Class II malocclusion states that the camouflage treatment mechanics subjects the teeth to large apical displacement, which may lead to mild-to-moderate root resorption (5). There is only one CBCT study on the assessment of resorption in Class II malocclusion treatment with a fixed functional appliance, to the best of our knowledge (7). Based on the results of this study, there was an evidence of statistically significant OIIRR affecting the tooth upon which the Herbst appliance was anchored (upper and lower first molars). In Forsus appliance therapy, the push rod is anchored anteriorly on a stainless steel archwire, just distal to the canine bracket. This has a more direct mesializing force on the lower anterior segment. There are studies for the assessment of apical root resorption and tooth inclination changes after orthodontic treatment in general (8-11). But, to the best of our knowledge, there are no studies that precisely measure the effects of Forsus appliance therapy concentrating on the lower anterior dento-alveolar segment. The aim of the present study was to evaluate the variations in root length, teeth inclination, and bone in the mandibular anterior teeth with regard to accuracy provided by the CBCT scanning technique.

METHODS

The Institutional Ethics Committee approved the study, and it was registered with Clinical Trials Registry-India (CTRI/2017/09/009865). Sample size determination revealed that for the two-tailed test on two groups, with an effect size of 0.75 for the root length, an alpha level of 0.05, and a power of 0.8, a minimum of 16 subjects in each group was required (G-Power software v. 3.1.9.2) (3, 12-14). The means used to get the effect size of 0.75 were 20.37 mm of root length before orthodontic treatment and 19.62 mm of root length after orthodontic treatment with the standard deviations of 1.06 and 0.96, respectively (13-14).

The methology is presented in the PICO format.

Population/Patient (P): Seventeen subjects were recruited for the study from the Department of Orthodontics and Dentofacial Orthopeadics, KLE Society's Institute of Dental Sciences, Bangalore, India. All of them belonged to south Indian population. The patients who fulfilled the following criteria were enrolled in the study: 1) Class II malocclusion; 2) with ANB ranging between 4 and 8°, and an overjet >4 mm; 3) decreased or optimal vertical facial height (FMA ranging from 17 to 34°); 4) lower incisors upright on the basal bone (IMPA ranging from 89 to 100°); 4) post-pubertal patients with cervical vertebral maturation index 6; 5) minimal crowding in the mandibular arch (<2 mm) and good periodontal status as assessed by panoramic radiograph; 6) the presence of fully erupted permanent teeth, including second molars with the exception of third molars; 7) none of the lower anteriors were malformed, carious, fractured, or attrited; and 8) non-syndromic patients. All patients and parents were informed about the orthodontic treatment procedures throughout the study, and signed informed consent was obtained. Table 1 shows the baseline data of the patients included in the study. The study group comprised of 17 post-pubertal patients (9 males, 8 females) in the age group 13-29 years.

Intervention (I): The treatment protocol was standardized using the MBT preadjusted appliance (3M Unitek Orthodontic Products, Monrovia, Calif) with 0.022-inch slots. After leveling and aligning of both the arches, 0.021X0.025-inch stainless steel archwires were placed. The transpalatal arch in the maxilla, second molar-to-second molar laceback and cinch-back of 0.021X0.025-inch stainless steel archwires enabled anchorage reinforcement. This archwire was left in both arches for a period of 4 weeks before placement of the Forsus appliance. Forsus FRD (3M Unitek Corp, Monrovia, CA, USA), that comes either in a three-piece (L-pin module) or two-piece (EZ2 module) system, was placed for a period of 6 months (mean, 6.23 months).

The patients were scanned in upright position using the CARESTREAM 9300 3D machine with a field of view of 5x5 cm (12), 90 kVp tube voltage, 6.3 mA tube current, and 9-micron isometric voxel to obtain the CBCT images of the mandibular anteriors region before (T0) and 6 months after the Forsus placement (T1).

Comparison (C): One patient dropped out of the study, as he did not report back for the treatment in the stipulated time frame of the study. A total of 32 scans 16 each of pre- and post-Forsus were analyzed to compare treatment effects on the lower anterior region. The untreated control group was not included as it is unethical to expose patient to radiation without proper indications.

Table 1. Baseline data of study subjects before the Forsus therapy

					95% CI	
	Mean	Standard Deviation	Minimum	Maximum	Lower	Upper
SNA	82.53	4.92	71.5	90.0	79.91	85.16
SNB	77.91	3.52	71.0	85.0	76.03	79.78
ANB	4.81	1.55	2.5	8.0	3.99	5.64
FMA	26.09	4.54	17.0	34.0	23.68	28.52
IMPA	98.59	6.15	89.0	111.0	95.32	101.87

Workstation: The CBCT data were exported in the DICOM format, and multiplanar reconstruction in axial, sagittal, and coronal reconstructions were done using the CS 3D Imaging Software v 3.5.7 on a workstation with Microsoft XP Professional SP-2 software (15). All measurements were made on the same system by the same observer.

Figure 1. Measurement of root length by means of axial guided navigation (AGN) method. Measured from root apex to intersection between CEJ and long axis of tooth.

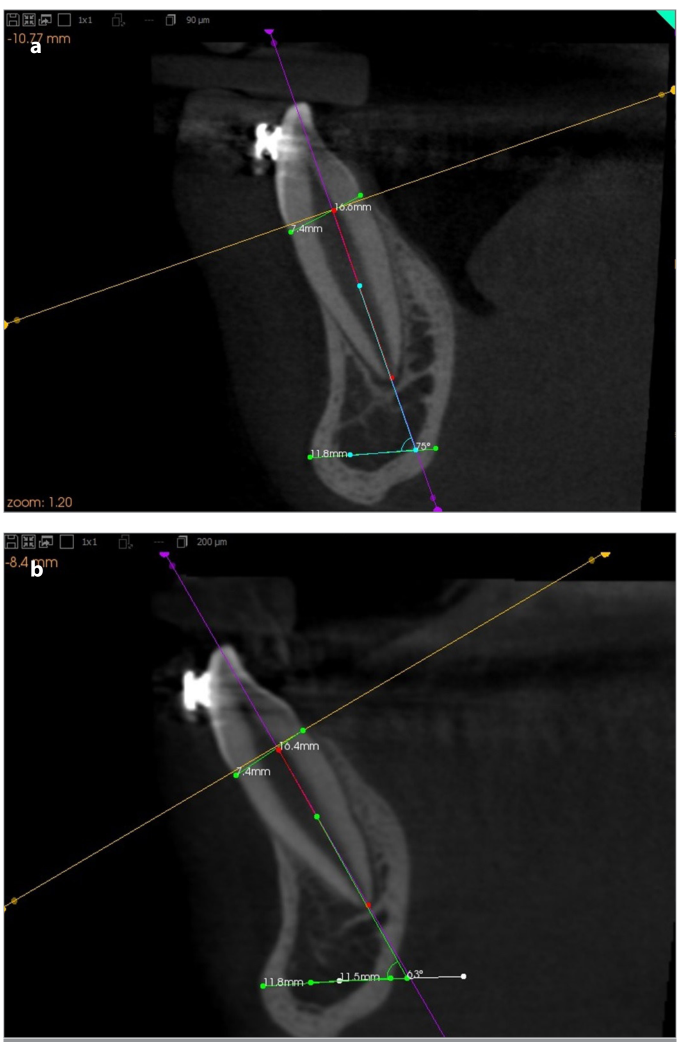

Figure 2. a, b. Tooth inclination is measured as an angle formed between the long axis of tooth and symphyseal base line at a) T0, b) T1. The base line length remains constant.

The following parameters were evaluated using these images:

1. Apical Root Resorption: All the mandibular anterior teeth were evaluated for root resorption. The axial guided navigation method was used (Figure 1). It makes use of the axial cursor movement three-dimensionally with axial and coronal multiplanar reconstruction (9, 11).

To make all the measurements of the apical resorption from standardized location for each tooth and to eliminate any bias due to the attrition of anteriors during the course of treatment, the cementoenamel junction (CEJ) width and crown height were measured before Forsus therapy (at T0) in the sagittal plane. These measurements were kept constant on the post-Forsus image (at T1) for standardization. The root length was measured along the long axis from CEJ to the root apex. The reduction in the values in post-Forsus therapy (i.e., at T1) showed the amount of apical root resorption.

2. Tooth Inclination: Tooth inclination was measured as an angle formed between the long axis of a tooth and the horizontal symphyseal baseline (11). The symphyseal baseline was drawn by a line passing along the most convex surface on the outer and inner margins in the symphyseal region in the sagittal plane (Figure 2a) (16). Any difference in the measured angle between pre- and post-Forsus therapy showed changes in the tooth inclination (Figure 2b).

3. Bone Variations:

a) Marginal bone height: This is a direct distance measured in the sagittal section from the CEJ to the coronal most aspect of labial and lingual marginal crestal bone (Figure 3) (9).

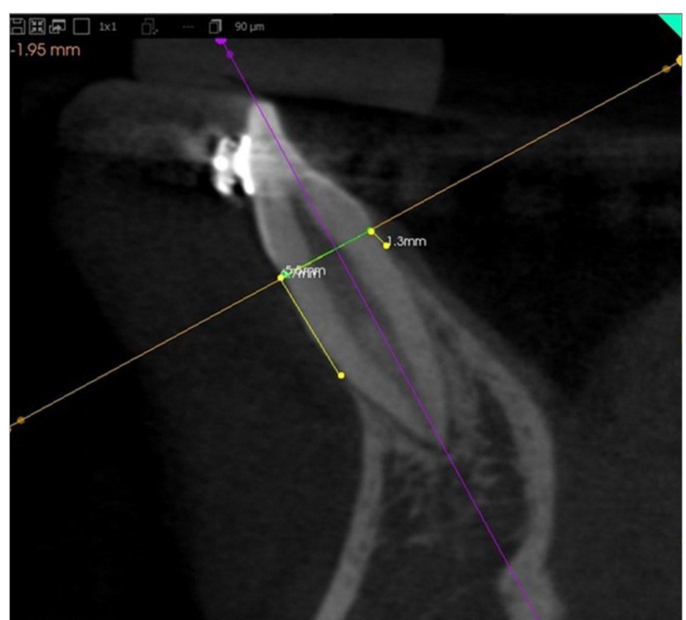

Figure 3. Marginal bone height (MBH) is measured from CEJ to coronal most portion of marginal bone crest on labial and lingual sides.

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b) Bone thickness-"Simulated T0 tooth position": In post-treatment CBCT images (at T1), it was observed that the tooth moved counterclockwise due to proclination during the time frame of the study (Figure 2. a, b). The proclination changed the tooth long-axis orientation and gave a false-increased value of bone thickness labially, especially in the apex region at T1 (as the axial cursor marking is dependent on the long axis of the tooth). To reorient the cursor at T0 position of tooth long axis, a clockwise compensatory line was drawn in T1 image (Figure 4) at the CEJ long-axis intersection (at an angle equal to "the change in inclination of the tooth" from T0 to T1). This will be the new "simulated T0 tooth position" on T1 image. This was done for accurate measurement of bone thickness at the mid-root and apical root level at T1 CBCT images.

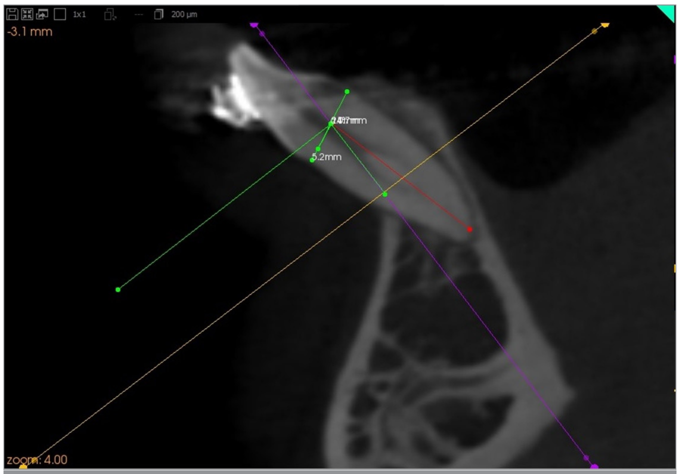

Figure 4. On T1 image, a compensatory line is drawn at CEJ-long axis intersection (at an angle equal to the change inclination of the tooth: refer Fig 2) in clockwise direction to simulate T0 position of tooth long axis.

A) At the mid-root level: First the mid-root was marked in sagittal view at half of the total root length, as seen in Figure 5a (3). The bone thickness at this level was measured in the corresponding axial plane as a distance between the tooth circumferences to the external cortical border both labially and lingually (Figure 5b). To evaluate bone thickness at the mid-root level in T1, the above-mentioned "simulated tooth T0 position" was drawn on T1 image (Figure 4) and the mid-root level was kept constant (as that of T0) for standardization. Then, bone thickness was measured in the corresponding axial view.

B) At the apical level: First, in the sagittal view (Figure 6a), the root apical level was marked at 2 mm short of root length, to eliminate any bias of root length loss during fixed functional therapy (3, 17). The bone thickness at this level was measured in the corresponding axial plane as a distance between the tooth circumferences to the external cortical border, both labially and lingually (Figure 6b). To evaluate bone thickness at the apical root level in T1, above-mentioned "simulated T0 tooth position" was drawn on T1 image (Figure 4), and the apical root level was kept constant (as that of T0) for standardization. Then, bone thickness was measured in the corresponding axial view.

The Forsus was activated to the same amount bilaterally. Hence, a single value obtained by the average of the right and left side for each tooth was considered in every patient, and the same was generated for the final statistical analysis.

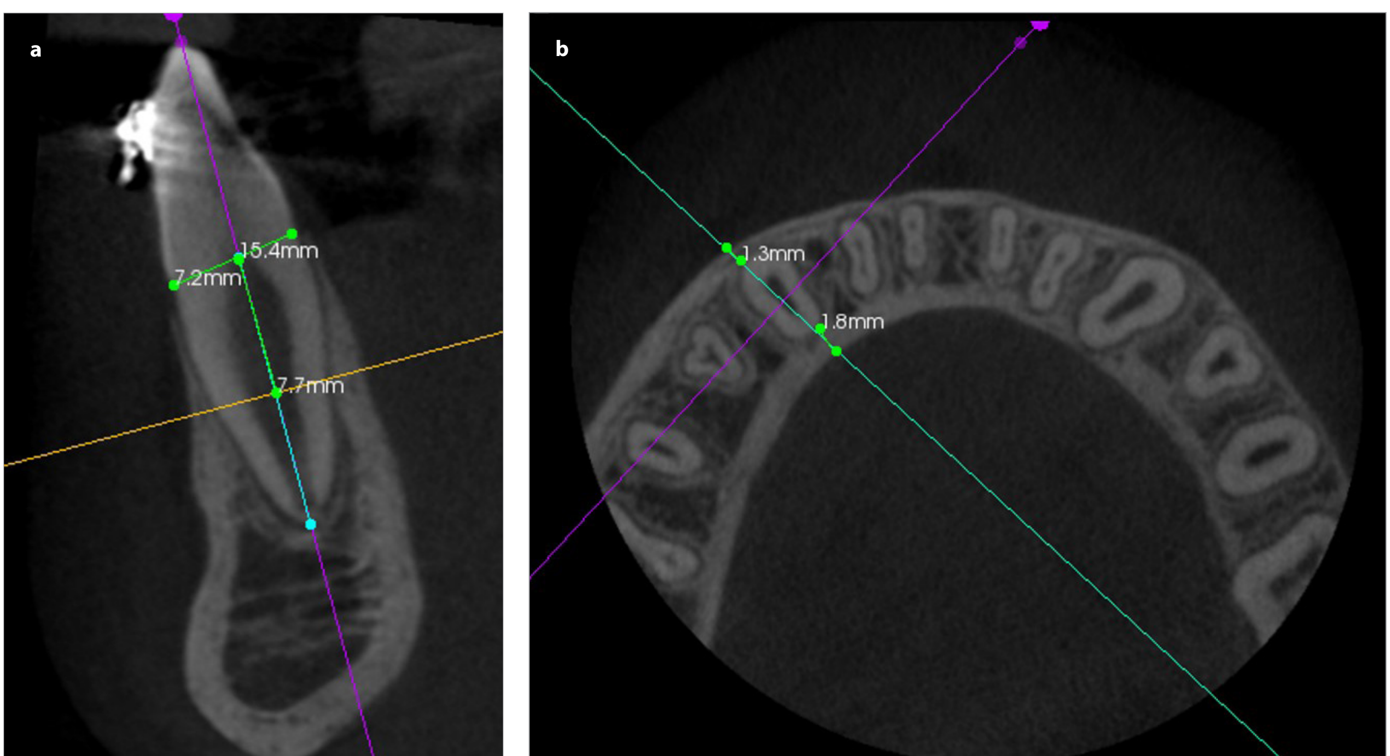

Figure 5. a, b. Measurement of bone at mid root level: a) In sagittal view, the mid-root level is marked at half of the total root length, b) Corresponding axial view used to measure bone thickness.

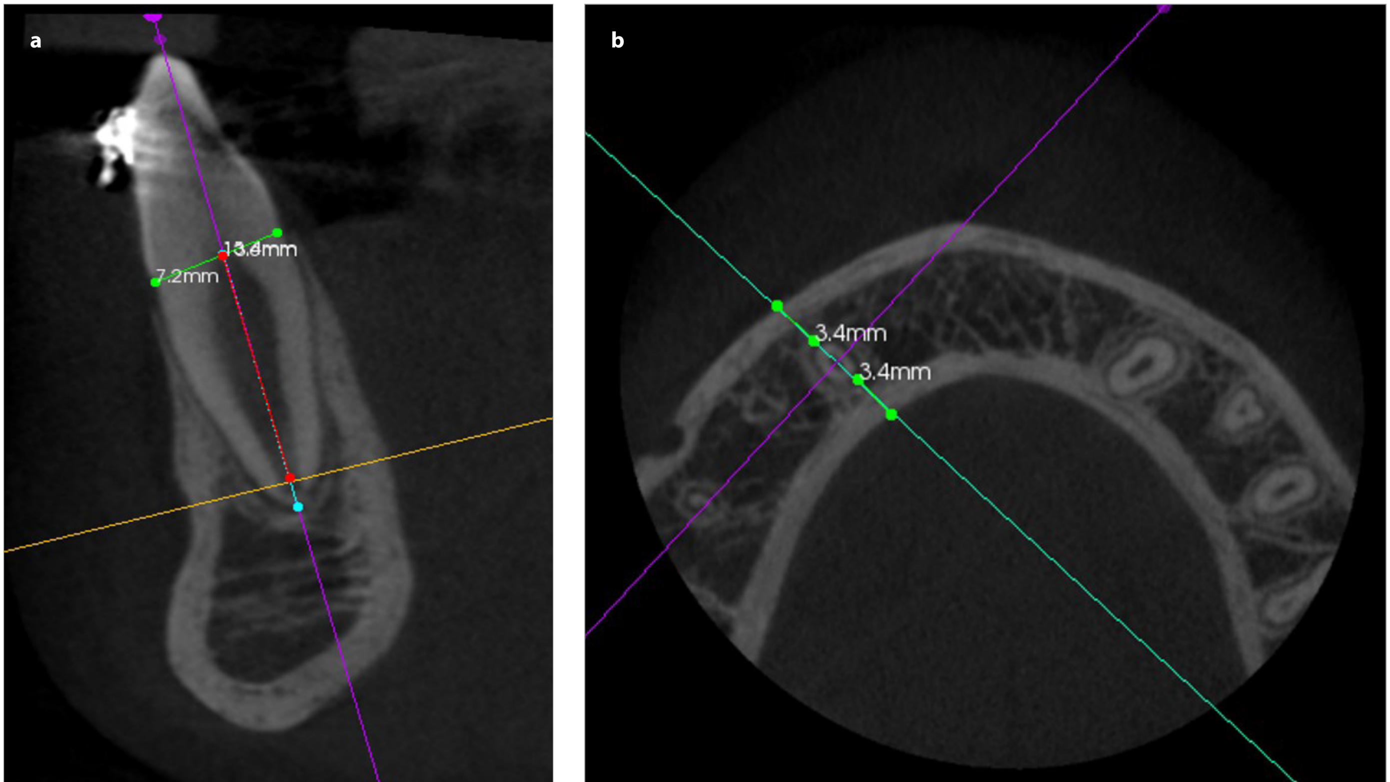

Figure 6. a, b. Measurement of bone at apical level: a) In sagittal view, the 2 mm short of root length is marked, b) Corresponding axial view used to measure bone thickness.

Statistical Analysis

Measurements were reevaluated randomly after a 2-week interval by the same-blinded examiner. Intraclass correlation coefficient (ICC) was used to evaluate the error of the method. ICC showed good-to-excellent reliability (ICC, 0.81–1.00), indicating high reproducibility of the method used for the study (Table 2). The Wilcoxon signed-rank test was used to compare parameters at T0 and T1. Spearman's correlation coefficient was used to analyze correlation between different parameters. The level of significance was set at $p<0.05$. Statistical Package for Social Sciences for Windows Version 22.0 (IBM Corp.; Armonk, NY, USA) was used to perform statistical analyses.

RESULTS

Outcome (O): The root length of central incisors and canines showed a statistically significant reduction by 0.039 mm and 0.66 mm, respectively, at T1 (Table 3). The angle of inclination was reduced for all teeth (central incisor, 6.47°; lateral incisor; 7.88°; canine, 8.69°).

A statistically significant increase by 1.31 mm and decrease by 0.93 mm in the marginal bone height measurement was seen in the canine region at both the labial and lingual aspect, respectively. A statistically significant decrease by 0.8 mm was also observed at the lingual aspect of central incisors (Table 4).

At the mid-root level of the lingual aspect, a statistically significant increase of bone width by 0.87 mm and 0.75 mm was found in the central and lateral incisor region, respectively (Table 4). Also, at the apical level in the lingual aspect, there was a statistically significant increase of bone width by 0.48 mm and 0.41 mm for the central incisor and the lateral incisor, respectively.

The bone width at apex in relation to canine showed a statistically significant increase by 1.40 mm on the labial aspect, whereas there was a decrease by 2.18 mm on the lingual aspect (Table 4).

However, there was a statistically insignificant weak correlation between the angle of inclination and other parameters (Table 5).

DISCUSSION

The incidence of OIIRR differs between various studies due to different techniques used to quantify it (4,5,8,17,18). A systematic review suggests that majority of incisors experienced mild to moderate OIIRR in treated Class II division 1 malocclusions (5). Samandara et al. (6) observed the greatest amount of OIIRR in central incisors (0.82 mm). Another study on root resorption that used panoramic radiographs showed 67.3% of moderate and 42.9% of severe root resorption of incisors (4).

Although the canine tooth has a good crown-to-root ratio and is capable of tolerating high occlusal forces, we found the highest (0.66 mm with $p=0.001$) root resorption of canines (Table 3), (19). One of the reasons for this observation could be because they are closer to the site where the rod of the Forsus FRD appliance is engaged on the lower arch, hence subjected directly to the push force compared to incisors. This is in accordance with a study on the Herbst appliance, where it was concluded that it delivers unphysiologic forces to immediate anchor teeth, thereby expos-

Table 2. Intra-examiner reliability assessment of parameters at pre- and post-Forsus therapy using intra-class correlation (ICC) statistic

	T0				T1			
		95% Conf. Interval				95% Conf. Interval		
Parameters	ICC	Lower	Upper	Reliability	ICC	Lower	Upper	Reliability
RL_CI	0.97	0.87	0.99	Excellent	0.99	0.98	1.00	Excellent
RL_LI	0.96	0.86	0.99	Excellent	0.95	0.91	0.98	Excellent
RL_CN	0.98	0.94	0.99	Excellent	0.99	0.98	0.99	Excellent
AI_CI	0.98	0.94	0.99	Excellent	0.95	0.86	0.99	Excellent
AI_LI	0.85	0.78	0.99	Good	0.98	0.95	1.00	Excellent
AI_CN	0.81	0.70	0.98	Good	0.84	0.33	0.97	Good
MBHL_CI	0.99	0.94	1.00	Excellent	0.97	0.94	0.99	Excellent
MBHL_LI	0.98	0.93	0.99	Excellent	0.98	0.96	0.99	Excellent
MBHL_CN	1.00	0.99	1.00	Excellent	0.98	0.97	1.00	Excellent
MBHLI_CI	0.96	0.86	0.99	Excellent	1.00	0.98	1.00	Excellent
MBHLI_LI	0.99	0.98	1.00	Excellent	0.97	0.95	0.99	Excellent
MBHLI_CN	0.95	0.91	0.98	Excellent	0.99	0.97	1.00	Excellent
MRBL_CI	0.91	0.81	0.98	Excellent	0.86	0.66	0.93	Good
MRBL_LI	0.90	0.64	0.94	Good	0.88	0.68	0.97	Good
MRBL_CN	0.86	0.52	0.96	Good	0.85	0.65	0.93	Good
MRBLI_CI	0.80	0.47	0.92	Good	0.88	0.57	0.99	Good
MRBLI_LI	0.93	0.90	0.96	Excellent	0.89	0.70	0.97	Good
MRBLI_CN	0.88	0.69	0.97	Good	0.94	0.84	0.98	Excellent
ABL_CI	0.89	0.70	0.97	Good	0.88	0.47	0.94	Good
ABL_LI	0.89	0.85	0.92	Good	0.94	0.84	0.98	Excellent
ABL_CN	0.98	0.97	1.00	Excellent	0.90	0.68	0.97	Good
ABLI_CI	0.93	0.90	0.96	Excellent	0.88	0.56	0.95	Good
ABLI_LI	0.83	0.55	0.95	Good	0.96	0.92	0.99	Excellent
ABLI_CN	0.92	0.88	0.96	Excellent	0.97	0.95	1.00	Excellent

ICC: intraclass correlation coefficient; CI: central incisor; CN: canine; LI: lateral incisor; RL: root length; AI: angle of inclination; MBHL: marginal bone height labial; MBHLI: marginal bone height lingual; MRBL: mid-root bone width labial; MRBLI: mid-root bone width lingual; ABL: apex bone width labial; ABLI: apex bone width lingual

Table 3. Comparison of mean, median, minimum and maximum values of root length (in mm) and angle of inclination (in °) for lower anterior teeth between pre- and post-Forsus phase by the Wilcoxon signed-rank test

		T0				T1				T1 – T0						
														95% Conf. Interval		
Variable	Tooth	Mean	Median	Min	Max	Mean	Median	Min	Max	Mean	Median	Min	Max	Lower	Upper	p-value
RL	CI	11.15	11.7	8.9	12.85	10.76	10.45	8.5	14.15	-0.39	-1.25	-0.4	- 1.3	-.11	-.68	0.01*
	LI	11.61	11.95	9.3	13.9	11.61	11.60	8.8	13.4	0.00	-0.35	-0.5	-0.5	1.30	-1.30	1.00
	CN	13.94	14.2	11.15	16.8	13.28	13.55	10.1	14.75	-0.66	-0.65	-1.05	- 2.05	-.53	-.79	0.001**
AI	CI	69.16	63.5	53	96.5	62.69	62.55	40.5	86.5	-6.47	-0.95	-12.5	-10	-3.79	-9.15	0.001**
	LI	71.00	72.2	53.5	99.5	63.13	65.5	42.5	87.5	-7.87	-6.7	-11	-12	-5.02	-10.7	0.001**
	CN	72.69	67.7	58.5	96	64.00	64.5	49.5	87	-8.69	-3.2	-9	-9	-6.25	-11.13	0.001**

RL: root length; AI: angle of inclination; CI: central incisor; CN: canine; LI: lateral incisor
*Statistically significant, **Highly significant

ing them to a higher risk of root resorption (20). However, in our study, we have not included the evaluation of teeth in posterior segment. Molars also being the anchor teeth would have shown significant resorption.

Narendran et al. (21) reported a prospective CBCT study on the effects of Class II malocclusion treatment with the Powerscope and Forsus FRD appliance. According to the results of this study, both the appliances lead to a statistically significant amount of linear and volumetric root resorption in all maxillary first molars and mandibular anteriors (p=0.001). The mandibular anteriors showed lesser extent of root resorption in subjects treated with a Forsus appliance than those treated with Powerscope, because the latter is secured to the archwire, and hence, stronger hori-

Table 4. Comparison of the mean median, minimum, and maximum values of marginal bone height, mid-root bone width, and apex bone width in labial and lingual regions (in mm) for lower anterior teeth between pre- and post-Forsus phase by the Wilcoxon signed-rank test

			T0				T1				T1 – T0						
															95% Conf. Interval		
Variable		Tooth	Mean	Median	Min	Max	Mean	Median	Min	Max	Mean	Median	Min	Max	LOWER	UPPER	p-value
MBH	CI	Labial	6.94	7.22	4.95	8.95	6.94	7.22	0	9.35	0.00	0	-4.95	0.4	.90	-.90	1.00
		Lingual	2.58	2.45	0.55	7.5	1.78	1.72	0.25	3.25	- 0.80	-0.73	-0.3	-4.25	.50	-1.80	0.01*
	LI	Labial	6.48	6.95	4.3	8.8	7.12	7.35	0.75	10.3	0.64	0.4	-3.55	1.5	1.63	-.355	0.14
		Lingual	2.28	2.15	0	7.4	1.93	1.65	0	7.55	- 0.35	-0.5	0	0.15	.70	-1.39	0.26
	CN	Labial	4.50	5.35	1.0	7.9	5.80	6.1	1.6	8.15	1.30	0.75	0.6	0.25	2.11	.51	0.006*
		Lingual	2.40	1.6	1	6.5	1.47	0.87	0.4	4.9	- 0.93	-0.73	-0.6	-1.6	.12	-1.99	0.01*
MRB	CI	Labial	0.02	0	0	0.3	0.01	0	0	0.1	- 0.01	0	0	-0.2	.03	-.06	0.66
		Lingual	1.20	1.7	0.1	2.95	2.07	2.10	0.1	4.0	0.87	0.4	0	1.05	1.17	.57	0.001**
	LI	Labial	0.15	0	0	1.1	0.14	0	0	0.75	- 0.01	0	0	-0.35	.09	-.11	0.94
		Lingual	0.98	0.82	0.2	2.0	1.73	1.62	0.65	3.65	0.75	0.80	0.45	1.65	1.04	.45	0.001**
	CN	Labial	0.67	0.32	0	3.8	0.77	0.37	0	3.45	0.10	0.05	0	-0.35	.77	-.56	0.21
		Lingual	1.57	1.57	0.15	3.25	1.65	1.5	0.2	3.45	0.08	-0.07	0.05	3.30	.28	-.12	0.86
AB	CI	Labial	0.97	0.92	0	2.15	1.29	1.32	0	3.8	0.32	0.4	0	1.65	.74	-.10	0.15
		Lingual	2.41	2.15	0	5.85	2.89	2.70	0.3	6.8	0.48	0.55	0.3	0.95	1.12	-.14	0.02*
	LI	Labial	2.00	1.47	0.45	4.05	2.28	1.97	0	6.7	0.28	0.5	-0.45	2.65	.65	-.10	0.19
		Lingual	1.63	1.47	0.45	4.05	2.04	1.62	0.6	5.8	0.41	0.5	0.15	1.75	.71	.12	0.008*
	CN	Labial	3.11	2.17	0.1	3.15	4.51	4.40	0.3	7.8	1.40	2.23	0.2	4.65	1.86	.95	0.001**
		Lingual	3.64	2.17	0.1	3.15	1.46	1.32	0	4.15	- 2.18	-0.85	-0.1	-1.0	.43	-4.80	0.002*

MBH: marginal bone height; MRB: mid-root bone width; AB: apex bone width; CI: central incisor; CN: canine; LI: lateral incisor
*Statistically significant, **Highly significant

Table 5. Spearman's correlation statistics to assess the relationship between the angle of inclination and other study parameters for different teeth

Angle of Inclination	Root Resorption		MBH Labial		MBH Lingual		MRB Labial		MRB Lingual		AB Labial		AB Lingual	
	Rho	P-Value	Rho	P-value	Rho	P-Value	Rho	P-Value	Rho	P-Value	Rho	P-value	Rho	p-Value
CI	0.27	0.31	-0.04	0.89	-0.05	0.85	-0.44	0.09	0.46	0.08	-0.36	0.18	0.05	0.86
LI	-0.25	0.35	0.04	0.89	0.22	0.41	0.29	0.27	-0.33	0.21	0.45	0.08	0.18	0.50
CN	0.17	0.53	-0.15	0.58	-0.03	0.93	-0.20	0.46	0.26	0.33	-0.09	0.74	0.31	0.24

CI: central incisor; CN: canine; LI: lateral incisor; MBH: marginal bone height; MRB: mid-root bone width; AB: apical bone width
The correlation coefficients are denoted by Rho.
Correlation coefficient range
0.0: No Correlation
0.01–0.40: Weak correlation
0.41–0.70: Moderate correlation
0.71–1.00: Strong correlation

zontal force vectors cause more resorption. The Forsus appliance is placed on 19X25 stainless steel lower arch wires with added 10° of labial root torque to minimize proclination (21). However, in our study, we make use of 21X25 stainless steel archwires to ensure a rigid anchorage unit before the engagement of Forsus appliance so as to minimize deleterious effects on anchor teeth.

In our study, canines showed maximum proclination compared to other teeth. Orthodontic camouflage of a Class II malocclusion with fixed functional appliance therapy often leads to proclination of the mandibular incisors (6-18). Our findings are in accordance with other studies, which show significant proclination post-Forsus ranging from 5.0° to 6.2° (2, 22). In a cephalometric study, Hansen et al. (23) reported 10.8° of proclination and anterior movement of the incisal edge by 3.2 mm with the Herbst appliance. In the present study, CBCT scans enabled us to evaluate the inclination change of individual anterior teeth, which is impossible with two-dimensional images.

The post-pubertal subjects in our study belonged to a wide-range age group, ranging from 13 to 29 years, which included both non-growing and younger patients with a residual growth potential. This would not have affected our study results, as the correction achieved in growing patients with post-pubertal maturation status is same as that in adults, that is, by mandibular dentoalveolar proclination (24). However, the growing patients may have unstable occlusion after the orthodontic treatment, unlike adults whose results would be retained better due to stable interdigitation, which prevents unfavorable occlusal changes post-debonding (25).

The substantial amount of proclination of anteriors is a concern in all age-group patients. The clinician must be cautions considering the initial inclination of lower anteriors before treatment initiation. We recommend the use of pre-torqued 0.021x0.028-inch stainless steel archwire in lower arch (which provides 6° lingual crown torque in the anterior segment)/use of –6° torque on mandibular anterior brackets or use of miniscrews to minimize the proclination post-therapy (2).

The marginal bone height and thickness of bone encapsulating the tooth are important factors to be considered to evaluate the response of tooth to the FRD force (26). In the present study, the marginal bone height measurement increased labially and decreased lingually at T1 for all the anteriors, indicating labial resorption and lingual deposition, respectively (Table 4). These findings indicate that the mandibular incisors proclination is associated with vertical bone loss (26, 27). However, statistically significant findings for marginal bone height were seen only with respect to canines (both labially and lingually) and in lingual aspect for central incisors, which is related to the proclination of teeth at T1, although they are clinically insignificant.

The thickness of bone where the tooth is embedded affects its response to force and visa-versa. We found a varied response to force by different tooth groups. If initially T0, the tooth was closer to the labial cortical bone, and labial marginal bone height was less; the bone thickness at the mid-root and apical level reduced in the labial aspect at T1 time frame. Also, the tooth translated labially at T1 due to least bony resistance but did not change the inclination much. On the other hand, if the tooth had a good cortical bone thickness labially and marginal bone height and at T0; experienced tipping (that is, inclination change causing proclination) along the bony fulcrum (located at the labial marginal bone height). So at T1, translation moved the tooth as a whole labially, and compensatory bone deposition occurred on the lingual aspect, increasing the lingual bone thickness, as observed in the incisors region (Table 4). However, tipping moved the coronal portion of the root labially, while pushing the root apex lingually, thereby increasing the bone thickness labially and decreasing it lingually, especially at the level of canine apex (Table 4), (27).

Considering the above explanation, it is now clearer that the lingual bone thickness both at the mid-root and apical regions for incisors increased significantly, showing that T0 incisors might not have had a good labial cortical bone thickness, which would have caused their bodily movement in the labial direction along with some proclination at T1, which is detrimental to periodontal support. In addition, a statistically significant decrease in the bone thickness on the lingual aspect at the apical region of canines shows that due to a good labial cortical bone thickness at T0, they have tipped more than incisors (by 8.69°, Table 3). These detailed findings highlight the importance of the labial cortical thickness as a crucial parameter to be considered for case selection prior to Forsus placement.

The standardization technique used in our study was predictable, stable and reconstructable anytime during our study. We could effectively achieve the individualized values for every tooth studied. The consideration was given to the proclination of teeth post-Forsus. To measure the bone thickness at the same level, "simulated T0 tooth position" was constructed, which was not done in the previous study (3). We have measured the root resorption from CEJ to root apex to prevent bias of any loss of the incisal edge in the study time frame (9).

The changes in bone are not inflammatory in nature as the bone height distal and mesial to tooth was within physiologic limits (28). It is has been documented that there is always some lag in the bone remodeling in response to tooth movement (29, 30). The alveolar bone has a bending capacity, and the orthodontic mechanotherapy induces alveolar bone distortion, which alters electric environment and initiates highly synchronized changes in the bone (29, 30). In this process, the alveolar bone retains its structural characteristic size through coordinated apposition and resorption. Hence, future CBCT studies on long-term changes induced by the Forsus appliance are recommended with a control group to evaluate the appositional bony repair and remodeling post-Forsus.

There was some weak positive correlation between the angle of inclination and root resorption of central incisors (Rho value, 0.27) and canines (Rho value, 0.17). Also, there was a weak correlation between the angle of inclination and bone changes, which was statistically insignificant (Table 5). This could have been because many factors such as periodontal environment, gingival type, and others influence alveolar bone changes (26). In a CT study by Garlock et al. (27), a similar weak positive correlation between the facial bone height and change in the apex position owing to the proclination of teeth was found.

An additional observation in the present study was surface root resorption, which led to a decrease in root thickness when viewed in the axial plane, especially in the apical region (31). This kind of resorption was more profound when the root surface was in close approximation to cortical bone at T0. The micro-CT scans enable volumetric evaluation of resorption craters, which can be a future scope of study (32).

Despite the excellent clinical relevance of the present study, we could not standardize the size of the Forsus FRD appliance as it varied according to the severity of patient's malocclusion. Although we took into consideration pubertal maturation, the age range of patients was wide, and the sample size was small (although it was minimal required to achieve clinically relevant results). The study also lacks a control group, but in that case, patients with skeletal Class II malocclusion would have to be left untreated, which would cause an ethical dilemma. The small focal of view reduced the availability of routinely used stable cranial anatomical structures needed for standardization.

We recommend a future randomized clinical trial using CBCT scans on Class II malocclusion patients with a narrower age group treated with the Forsus appliance with a larger sample size to evaluate long-term changes induced by the appliance. This will also provide additional information on appositional bony repair and remodeling in the lower anterior region post-Forsus.

CONCLUSION

- Forsus FRD appliance therapy showed statistically significant but clinically insignificant apical root resorption of mandibular canines.
- After Forsus FRD appliance therapy, statistically and clinically significant proclination of mandibular anterior teeth was observed.
- After Forsus FRD appliance therapy, clinically insignificant changes in the marginal bone height were observed.
- The teeth with good labial bone thickness are a pre-requisite for Forsus FRD therapy to prevent future bone and periodontal problems and to maintain a good long-term stability.

Ethics Committee Approval: Ethics committee approval was received for the study from the Ethics committee of KLE institute of Dental Sciences, Bangalore, India (IEC No.: KIDS/IEC/11-2016).

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

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REFERENCES

1. Gegler A, Fontanella V. In vitro evaluation of a method for obtaining periapical radiographs for diagnosis of external apical root resorption. Eur J Orthod 2008; 30: 315-9. [CrossRef]
2. Cacciatore G, Alvetro L, Defraia E, Ghislanzoni LTH, Franchi L. Active-treatment effects of the Forsus fatigue resistant device during comprehensive Class II correction in growing patients. Korean J Orthod 2014; 44: 136-42. [CrossRef]
3. Schwartz JP, Raveli TB, Schwartz-Filho HO, Raveli DB. Changes in alveolar bone support induced by the Herbst appliance: a tomographic evaluation. Dental Press J Orthod 2016; 21: 95-101. [CrossRef]
4. Tieu L, Normando D, Toogood R, Flores-Mir C. External apical root resorption generated by Forsus simultaneously with brackets vs. Xbow followed by brackets to correct Class II malocclusions. J World Fed Orthod 2015; 4: 120-3. [CrossRef]
5. Tieu LD, Saltaji H, Normando D, Flores-Mir C. Radiologically determine orthodontically induced external apical root resorption in incisors after non-surgical orthodontic treatment of class II division 1 malocclusion: a systematic review. Prog Orthod 2014; 15: 48. doi: 10.1186/s40510-014-0048-7. [CrossRef]
6. Samandara A, Papageorgious SN, Ioannidou- Marathiotou I, Kavvadia Tsatala S, Papadopoulos MA. Evaluation of orthodontically induced external root resorption following orthodontic treatment using cone beam computed tomography (CBCT): a systematic review and meta- analysis. Eur J Orthod 2019; 41: 67-79. [CrossRef]
7. Schwartz JP, Raveli TB, Almeida KC, Schwartz-Filho HO, Raveli DB. Cone beam computed tomography study of apical root resorption induced by Herbst appliance. J Appl Oral Sci 2015; 23: 479-85. [CrossRef]
8. Dudic A, Giannopoulou C, Leuzinger M, Kiliaridis S. Detection of apical root resorption after orthodontic treatment by using panoramic radiography and cone-beam computed tomography of super-high resolution. Am J Orthod Dentofacial Orthop. 2009; 135:434-437. [CrossRef]
9. Lund H, Grondahl K, Grondahl HG. Cone Beam Computed Tomography for Assessment of Root Length and Marginal Bone Level during Orthodontic Treatment. Angle Orthod 2010; 80: 466-73. [CrossRef]
10. Castro IO, Alencar AH, Valladares-Neto J, Estrela C. Apical root resorption due to orthodontic treatment detected by cone beam computed tomography. Angle Orthod 2013; 83: 196-203. [CrossRef]
11. Gerszewski C, Topolski F, Correr GM, Gomes RAP, Morais ND, Moro A. Dentoalveolar evaluation of lower incisors by CBCT after treatment with Herbst appliance. Braz Dent J 2018; 29: 562-8. [CrossRef]
12. Suresh KP, Chandrashekara S. Sample size estimation and power analysis for clinical research studies. J Hum Reprod Sci 2012; 5: 6-14.
13. Ni M, Lei Y, Chen WJ, Wu GR. Cone beam computed tomography study on the apical root resorption after orthodontic treatment in root-filled teeth. Stomatologie 2016; 36: 233-6.
14. Deng Y, Sun Y, Xu T. Evaluation of root resorption after comprehensive orthodontic treatment using cone beam computed tomography (CBCT): a meta-analysis. BMC Oral Health 2018; 18: 2-14. [CrossRef]
15. Lund H, Gröndahl K, Hansen K, Gröndahl HG. Apical root resorption during orthodontic treatment A proscpective study using cone beam CT. Angle Orthod 2012; 82: 480-7. [CrossRef]
16. Nguyen T, Cevidanes L, Franchi L, Ruellas A, Jackson T. Three-dimensional mandibular regional superimposition in growing patients. Am J Orthod Dentofacial Orthop 2018; 153: 747-54. [CrossRef]
17. Nakada T, Motoyoshi M, Horinuki E, Shimizu N. Cone-beam computed tomography evaluation of the association of cortical plate proximity and apical root resorption after orthodontic treatment. J Oral Sci 2016; 58: 231-6. [CrossRef]
18. Brezniak N, Wasserstein A. Root resorption after orthodontic treatment: Part 2. Literature review. Am J Orthod Dentofacial Orthop 1993; 103: 138-46. [CrossRef]
19. Pasricha N, Sidana V, Bhasin S, Makkar M. Canine protected occlusion. Indian J Oral Sci 2012; 3:13-8. [CrossRef]
20. Kinzinger GS, Savvaidis S, Gross U, Gülden N, Ludwig B, Lisson J. Effects of Class II treatment with a banded herbst appliance on root lengths in the posterior dentition. Am J Orthod Dentofacial Orthop 2011; 139: 465-9. [CrossRef]
21. Narendran N, Batra P, Sonar S, Singla A. Effects of Class II treatment with hybrid fixed functional appliances on root length and root volume- a prospective study using CBCT. Int J Sci Res 2019; 8: 28-31.
22. Giuntini V, Vangelisti A, Masucci C, Defraia E, McNamara JA Jr, Franchi L. Treatment effects produced by the Twin-block appliance vs the Forsus Fatigue Resistant Device in growing Class II patients. Angle Orthod 2015; 85: 784-9. [CrossRef]

23. Hansen K, Koutsonas TG, Pancherz H. Long-term effects of Herbst treatment on the mandibular incisor segment: A cephalometric and biometric investigation. Am J Orthod Dentofac Orthop 1997; 112: 92-103. [CrossRef]
24. Mahamad IK, Neela PK, Mascarenhas R, Husain A. A comparison of Twin block and a Forsus (FRD) functional appliance-a cephalometric study. Int J Orthod Milwaukee 2012; 23: 49-58.
25. Ruf S, Pancherz H. Herbst/ multibracket appliance treatment of Class II Division 1 malocclusions in early and late adulthood: a prospective cephalometric study of consecutively treated subjects. Eur J Orthod 2006; 28: 352-60. [CrossRef]
26. Gracco A, Luca L, Bongiorno MC, Siciliani G. Computed tomography evaluation of mandibular incisor bony support in untreated patients. Am J Orthod Dentofacial Orthop 2010; 138: 179-87. [CrossRef]
27. Garlock DT, Buschang PH, Araujo EA, Behrents RG, Kim KB. Evaluation of marginal alveolar bone in the anterior mandible with pretreatment and posttreatment computed tomography in non-extraction patients. Am J Orthod Dentofacial Orthop 2016; 149: 192-201. [CrossRef]
28. Wehrbein H, Bauer W, Diedrich P. Mandibular incisors, alveolar bone, and symphysis after orthodontic treatment. A retrospective study. Am J Orthod Dentofacial Orthop 1996; 110: 239-46. [CrossRef]
29. De Angelis V. Observations on the response of alveolar bone to orthodontic force. Am J Orthod 1970; 58: 284-94. [CrossRef]
30. Yodthong N, Charoemratrote C, Leethanakul C. Factors related to alveolar bone thickness during upper incisor retraction. Angle Orthod 2013; 83: 394-401. [CrossRef]
31. Brezniak N, Wasserstein A. Orthodontically induced inflammatory root resorption. Part I: The basic science aspects. Angle Orthod 2002; 72: 175-9.
32. Dudic A, Giannopoulou C, Meda P, Montet X, Kiliaridis S. Orthodontically induced cervical root resorption in humans is associated with the amount of tooth movement. Eur J Orthod 2017; 39: 534-40. [CrossRef]

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Original Article

Attention-Deficit Hyperactivity Disorder Symptoms in A Group of Children Receiving Orthodontic Treatment in Turkey

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ABSTRACT

Objective: Children with attention-deficit hyperactivity disorder (ADHD) are known to have several oral health problems, particularly traumatic dental injuries, decayed or filled teeth, and poor oral hygiene. The objective of the present study was to determine the ADHD symptoms in a group of patients with malocclusion and receiving orthodontic treatment.

Methods: A total of 88 subjects with a diagnosis of malocclusion between aged 8 and 17 years were included in the study. Socio-demographic characteristics, breastfeeding history, oral habits, and dental trauma history of the subjects were acquired by a detailed questionnaire. Subjects and their parents completed questionnaires addressing ADHD, other psychiatric problems, and dental health impact on the quality of life. During the orthodontic examination, the Index of Complexity, Outcome, and Need was applied to confirm the diagnosis of malocclusion.

Results: Parent-reported psychiatric complaint occurred in almost half of the patients (n=38, 43.2%); the most frequent psychiatric complaints were inattention (n=22, 25%), opposition (n=13, 14.8%), and hyperactivity (n=11, 12.5%). The estimated ADHD prevalence according to parent measure was 15.9% (n=14). Self-report measures revealed that 18.4% (n=16) had behavioral symptoms. The most affected quality of life domain was psychological discomfort.

Conclusion: The findings indicate that ADHD prevalence in children with malocclusion is high. The orthodontists should have a keen eye on behavioral problems.

Keywords: Attention-deficit hyperactivity disorder, malocclusion, behavior, orthodontics

INTRODUCTION

Attention-deficit hyperactivity disorder (ADHD) is a neurodevelopmental disorder characterized by persistent inattention, impulsivity, and hyperactivity. It begins in childhood and interferes with significant functional and developmental impairment (1). It is considered as one of the most common chronic health conditions in school-aged children, with a worldwide prevalence of 5.3% (2). Despite being consistently diagnosed in childhood, it contributes to lifelong impairment in the quality of life, as cognitive and behavioral symptoms mostly persist into adulthood. ADHD etiology is considered multifactorial and heterogeneous, with an important contribution from genetic factors. It is a highly heritable disorder in the range of 60%–90%. Along with genetic risk factors, there are many environmental factors associated with ADHD symptoms, such as prenatal exposure to nicotine and alcohol, premature birth, and low birth weight, as well as low socioeconomic status (1, 3). Some studies demonstrate an association between ADHD and insufficient breastfeeding, whereas some dispute (4, 5).

Dental problems in children with ADHD have been widely investigated. Children with ADHD have more frequent dental visits than those without ADHD. Some studies have found higher Decayed Missed Filled Tooth (DMFT)

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scores, whereas some have found no significant differences (6-9). However, a recent meta-analysis revealed that children with ADHD had significantly more decayed surfaces in permanent teeth, higher plaque scores, and higher dental trauma risk (10).

It has been shown that children with ADHD have worse oral hygiene status and tooth pain and bruxism is more frequent (6, 7, 11, 12). Non-nutritive sucking habits, such as nail biting, lip biting, bottle-feeding, and pacifier use, were observed more frequently in children with ADHD than in those without ADHD (4, 11). The research consistently demonstrates that there is a significant link between traumatic dental injuries (TDIs) and ADHD (10, 13). In some studies, this difference was not evident (12, 14). However, this controversy may be explained by the fact that the ADHD groups of these studies were recruited from psychiatry departments as already having an ADHD diagnosis at the time of the study. All of the children in the ADHD group were under pharmacological treatment for ADHD in Chau et al. (10) study and under behavioral therapy or pharmacotherapy in Altun et al. (14) study. It is well-established that the appropriate treatment of ADHD may result in diminished symptoms and fewer injuries (3).

In a review analyzing the oral–pharyngeal conditions relating to ADHD, it was suggested that there might be a link between ADHD and malocclusion, which are both well-established risk factors for TDIs (15). Additionally, breastfeeding duration and non-nutritive oral habits are associated with both ADHD and malocclusion (16, 17). It has been shown that children with ADHD have a narrower dental arch and higher prevalence of posterior cross-bite than those without ADHD (18). A recent study comparing dental and skeletal age between children with ADHD regarding methylphenidate use found that methylphenidate did not cause a delay (19).

Behavioral management and treatment compliance of children with ADHD have been shown to be challenging, and there is an increasing data in the research area about these difficulties and probable solutions to this problem, though we still do not know the ADHD prevalence in children with malocclusion (9, 11, 20, 21). Thus, the aim of the present study was to identify the ADHD symptoms and prevalence in children with malocclusion receiving orthodontic treatment and to investigate the probable association between ADHD and malocclusion.

METHODS

Subjects

This was a cross-sectional, descriptive design study conducted from April 2015 to August 2015. The study was approved by the local ethics committee (approval no.: 09.2015.112, 70737436-050.06.04). The authors informed all of the subjects about the details of the procedure. Written informed consent was obtained from one parent of each patient, and children's verbal consent was taken.

A convenience sampling method was used; a total of 100 consequent subjects who were newly referred to the orthodontics clinic for malocclusion and had an Index of Complexity, Outcome, and Need (ICON) score >43 during the diagnostic orthodontic examination were enrolled in the study. The ICON cut-off score was established because it is the cut-off value to decide the treatment need for malocclusion in Turkey (22). The age range of the participants was determined to be between 8 and 17 years according to the formal education period in Turkey and developing the ability of understanding the questionnaires. Children with an intellectual disability, a positive history of cleft lip/palate, or a seizure disorder were excluded from the study. Of the 100 subjects presented to the orthodontics clinic during the study period, 12 were included due to the lack of consent for the study. The participation percentage was 88%. Only the new referrals were included not to rely on retrospective data about malocclusion.

Data Collection

A qualified orthodontist examined all subjects. During the dental examination, orthodontists determined malocclusion classes according to Angle criteria, oral hygiene status, and TDI history. Oral hygiene was determined as bad, moderate, and good. The presence and the number of TDIs were noted. The authors collected socio-demographic information using a form designed for the study. The first author, a trained child and adolescent psychiatrist, conducted the scales during an interview format rather than a questionnaire format. The in-person interview has been found to provide more reliable data (23).

Measures

The authors filled out the socio-demographic form during an interview with the parents. It included the subjects' age, gender, and perceived socioeconomic status. This form also determined the subjects' breastfeeding history and current or previous psychiatric complaints. The parents completed the Swanson, Nolan, and Pelham (SNAP)-IV Rating Scale, the Strengths and Difficulties Questionnaire (SDQ), and the Oral Habits Questionnaire; the children completed the SDQ and the Oral Health Impact Profile (OHIP)-14.

The SNAP-IV Rating Scale, derived from the Diagnostic and Statistical Manual of Mental Disorders-IV criteria for ADHD, is a Likert questionnaire consisting of 18 items. Parents rate each item from 0 to 3 according to symptom frequency. The original version of the SNAP-IV has been used in clinical trials (The MTA Cooperative Group, 1999) and in community surveys to identify children with probable ADHD in other countries (24). The Turkish version has also been used in large-scale community studies to identify ADHD prevalence (25-27). The ADHD prevalences found in the studies using the SNAP-IV were similar with studies using structured diagnostic interviews (27). The parent form has profound psychometric features with coefficient alpha values of 0.94 for total score, 0.90 for inattention score, and 0.79 for hyperactivity score. The Turkish version of the questionnaire has been shown to be valid and reliable; and a per item score >1.2 is a positive determinant for ADHD clinical threshold (25).

The SDQ is a brief behavioral screening questionnaire that determines children's and adolescents' symptoms and positive attributes. It consists of 25 questions that belong to five subscales: emotional symptoms, conduct problems, hyperactivity/inattention, peer relationship problems, and prosocial behavior. All items can be scored from 0 to 2, and the sum of the first four scales generates a total difficulties score. The cut-off scores for the subscales were determined by the developers. The SDQ has an impact supplement that was not used in the present study. Five minutes is required to complete the form, and it has solid psychometric properties and can be used as a reliable guide for child psychiatric cases in population studies. The cross informant correlations were found to be higher than other relevant scales (28). There are child/adolescent, parent, and teacher versions. The validity and reliability study of the Turkish translation of the SDQ has been previously conducted (psychometric properties of the Turkish version of the SDQ). SDQ was found to be efficient to measure psychopathology in a nationwide study, which compared the SDQ with a structured diagnostic interview (24). Cronbach's alpha values those that estimate the internal consistency of the parent and child versions were 0.84 and 0.73, respectively. In the present study, the parent and child versions were used.

OHIP-14 is a self-rated questionnaire that measures the perceived impact of oral health on the quality of life using 14 questions pertaining to seven subscales: functional limitation; physical pain; psychological discomfort; physical, psychological, and social dimensions of disability; and handicap dimension. Higher scores represent higher severity of the problem and lower quality of life. Each item is answered from 0 to 5 according to the frequency of the problem. The Turkish adaptation of the OHIP-14 has been conducted and found to be valid and reliable (29).

The Oral Habits Questionnaire developed for an earlier study (4) consists of items pertaining to the breastfeeding period; bottle-feeding experiences; non-nutritive sucking habits, such as thumb sucking or pacifier use; and parafunctional oral habits, such as nail biting and mouth breathing.

Statistical Analysis

Statistical Package for the Social Sciences software version 21.0 (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. Statistical analysis was conducted to compare the groups according to gender and ADHD diagnosis. Categorical variables were expressed as frequency and percentage, and continuous variables were expressed as mean and standard deviation for the evaluation of the descriptive data. Independent sample t-test, Mann–Whitney U test, Spearman test, and Pearson correlation test were used according to the nature of the data. A probability level of $p \leq 0.05$ was regarded as statistically significant.

Data from 12 subjects who did not complete the questionnaires were excluded in the analyses.

RESULTS

The analyses were conducted on 88 subjects; the study group consisted of 47 (53.4%) female and 41 (46.6%) male individuals. The average age of the study group was 12.9±2.5 years. Perceived socioeconomic status was low in 18 (20.5%) subjects, medium in 58 (65.9%) subjects, and high in 12 (13.6%) subjects. Of the 88 subjects, 25% (n=22) had Class I malocclusion, 47.7% (n=42) had Class II malocclusion, and 27.3% (n=24) had Class III malocclusion according to Angle's classification. Thirty-five (39.8%) subjects had good oral hygiene, 36 (40.9%) subjects had moderate oral hygiene, and 17 (19.3%) subjects had bad oral hygiene. A positive TDI history was seen in 14 (16.1%) subjects; 2 subjects had more than one TDI.

Psychiatric complaint, as identified with the clinical intake form, occurred in 43.2% (n=38) of the subjects; 23.8% (n=21) subjects had more than one complaint. The most frequent complaints were inattention (n=22, 25%), oppositional behavior (n=13, 14.8%), and hyperactivity (n=11, 12.5%). Nine (10.2%) subjects had a prior psychiatric diagnosis, and 12 (13.6%) subjects had a prior psychiatric referral.

The mean SNAP-IV scores of the subjects are presented in Table 1. Fourteen (15.9%) subjects had a SNAP-IV per item score >1.2, which is the clinical threshold for ADHD. The distribution of probable ADHD, as identified with the SNAP-IV, according to gender was 7 (14.9%) girls and 7 (17.1%) boys.

According to the self-rated version of the SDQ, 18.4% (n=16) of the subjects scored higher than the cut-off value (abnormal) for total difficulty score. The percentages of subjects identified as abnormal in the hyperactivity/attention problems, conduct problems, emotional problems, and peer relationship problems subscales were 17.2% (n=15), 17.2% (n=15), 13.6% (n=12), and 23% (n=20), respectively. For the prosocial behavior subscale, 9.2% (n=8) of the subjects scored lower than the cut-off value.

According to the parent version of the SDQ, 25.3% (n=21) of the subjects were identified as abnormal in the total difficulty score. The percentages of the subjects identified as abnormal for the hyperactivity/inattention problems, conduct problems, emotional problems, and peer relationship problems subscales were 14.5% (n=12), 20.5% (n=17), 31.3% (n=26), and 53% (n=43), respectively. For the prosocial behavior subscale, 9.6% (n=8) of the subjects scored abnormal according to the parent reports.

Total scores from the OHIP-14 ranged from 0 to 36 with a mean of 8.62±6.92. Subscale mean scores were 0.68±0.99 for functional limitation, 1.61±1.86 for physical pain, 2.30±1.79 for psychological discomfort, 0.78±1.20 for physical disability, 1.52±1.57 for psychological disability, 1.14±1.60 for social disability, and 0.56±1.15 for handicap. The association between OHIP scores and ADHD is presented in Table 2.

Table 1. Parent SNAP-IV per item scores of the subjects (n=88)

	Girls (n=47) Mean±SD	Boys (n=41) Mean±SD	p
Inattention	0.67±0.49	0.62±0.47	0.370
Hyperactivity	0.76±0.54	0.85±0.64	0.528
Total	0.72±0.46	0.73±0.46	0.698

SNAP-IV: Swanson, Nolan, and Pelham-IV Rating Scale

Table 2. The relationship between OHIP scores and ADHD

	ADHD (n=14) r	Non-ADHD (n=71) r	p
OHIP-functional limitation	53.50	40.93	0.044*
OHIP-physical pain	37.86	44.01	0.373
OHIP-psychological discomfort	40.82	43.43	0.713
OHIP-physical disability	49.00	41.82	0.258
OHIP-psychological disability	39.75	43.64	0.574
OHIP-social disability	47.43	42.13	0.424
OHIP-handicap	44.71	42.66	0.726
OHIP total	46.04	42.40	0.614

*p<0.05, Mann–Whitney U test

Table 3. Correlation between ADHD and dental trauma among genders

		TDI presence		No. of TDIs	
		Girl	Boy	Girl	Boy
SNAP-IV					
Parent	r	0.192	0.011	0.204	0.011
	p	0.205	0.949	0.179	0.949
SDQ					
Parent	r	0.512	–0.016	0.516	–0.016
	p	0.001**	0.927	0.001**	0.927
Self-rated	r	0.355	0.015	0.378	0.015
	p	0.014*	0.927	0.009*	0.927

r: Correlation coefficient.
*p<0.05.
**p<0.01.

Of the 88 subjects, 92% (n=81) were breastfed; mean breastfeeding duration was 12.09±8.91 months. Bottle-feeding ratio was 70.5% (n=62); mean bottle-feeding duration was 14.41±13.38 months. Pacifier use history was present in 50% (n=44) of the subjects; mean pacifier use duration was 12.52±9.14 months. As identified with the Oral Habits Questionnaire, 12.5% (n=11) of the subjects had thumb sucking, 34.1% (n=30) had nail biting, 23.9% (n=21) had lip biting, 19.3% (n=17) had pencil biting, 25% (n=22) had bruxism, and 54.5% (n=48) had mouth breathing in the past or present that lasted >6 months. There was a relationship between probable ADHD, as identified with the SNAP-IV, and thumb sucking (p=0.013), nail biting (p=0.014), and pencil biting (p=0.001) habits, as identified with the Oral Habits Questionnaire. Durations of breastfeeding, bottle-feeding, and pacifier use were not significantly related with probable ADHD, as identified with the SNAP-IV (p=0.454, p=0.775, and p=0.408, respectively). According to the SDQ parent and self-report scores, dental trauma history frequency was positively correlated with ADHD symptom scores in girls but not in boys. That correlation was not evident in parent SNAP-IV (Table 3).

DISCUSSION

In our study, we recruited subjects according to treatment need using an ICON cut-off score of 43. The mean age of the subjects was 12.9±2.5 years, and the female-to-male ratio was 1:14; these numbers are consistent with data from epidemiological studies of malocclusion. In one of those studies, the age range of peak orthodontic treatment need was 13–14 years, and in the other, the age range of orthodontic patients receiving clinical care was 13.4±2.3 years (30). Therefore, we assume that our subjects represent the population characteristics of patients with malocclusion.

Among the 88 subjects, 43.2% (n=38) had at least one psychiatric complaint, as identified with the clinical intake form, and only 13.6% (n=12) had a previous psychiatry referral. The ratio of subjects who had a prior psychiatric referral in the group who had psychiatric complaints was 26.3%. The referral rate of children with at least one psychiatric complaint is one-fourth, which represents the service gap in mental health service and liaison between dentistry and psychiatry.

The prevalence of children who were ever breastfed was 92% in our study group. Compared with the national estimated rate of breastfeeding of 96%, this is a relatively low rate (Turkish Statistical Institute, Turkish Health Survey, 2012). Bottle-feeding prevalence in our study group was 70.5%, which was substantially higher than the national prevalence of 41% (Turkish Statistical Institute, Turkish Health Survey, 2012).

A positive TDI history was present in 16.1% (n=14) of the subjects. In the literature, there is no consistent prevalence for TDI, but according to the World Health Organization report, TDI prevalence in industrialized countries is 4%–33% (31). We found an association between ADHD, as identified with the SNAP-IV, and TDI, which is in agreement with recent studies of the relationship between ADHD and TDI (10, 12, 13, 32). The association of TDI and ADHD was significant in girls but not in boys; there are no data showing female gender as a risk factor for TDI in ADHD. However, there is a study regarding female gender as a greater risk factor for unintentional injuries in children with ADHD (33).

On the OHIP-14, the psychological discomfort subscale had the highest score, indicating that the psychological impairment had the most severe impact on life quality. Supporting our finding, another study also found emotional well-being and social well-being to be the lowest domains in the oral health quality of life assessment (34). In a study investigating patient expectations from orthodontic treatment, general health, oral functionality, aesthetic appearance, and social functionality were the prominent items (35). It is understood that mental health is a matter of clinical importance in patients with malocclusion, and clinicians should maintain vigilance for psychological–psychiatric symptoms. As understood from the above list of psychiatric complaints, ADHD symptoms appear to constitute a substantial part of the symptom spectrum.

High rates of peer problems reflected on the SDQ may be explained by the social problems mentioned herein and the findings that patients with malocclusion are more frequently the victims of bullying (34, 35). Peer relationship problem rate in parent SDQs was 53%, which shows that those problems were well observed by the caregivers. ADHD prevalences were 17.2% and

14.3% in self-rated and parent forms, respectively. Epidemiological studies from our country and worldwide show that the ADHD prevalence ranges from 5% to 8% (2, 25, 36).

Many studies have investigated ADHD in dental diseases but not malocclusion. To our knowledge, this is the first study investigating ADHD symptoms and prevalence in children with malocclusion. The worldwide prevalence of ADHD among children is estimated to be 5.29% (2). In our sample, the ADHD prevalence, as identified with the SNAP-IV-Parent Scale, in patients with malocclusion was 15.9%. An epidemiological study with a very similar population recruiting 3110 children and their parents used the same instrument and obtained the ADHD prevalence as 9.6%. This finding reveals that ADHD prevalence is high in children with malocclusion. This finding is consistent with the findings of a previous study comparing the dental health status of psychiatric patients and healthy controls. In the present study, it was found that along with higher DMFT scores and increased prevalences of caries and TDI, orthodontic treatment need was also more frequent in patients with ADHD than in healthy controls and other psychiatric disorders (29).

The high prevalences of probable ADHD, as identified with the SNAP-IV and SDQ scores, found in the present study support the hypothesis that there could be an association between malocclusion and ADHD. Moreover, significant associations between several variables provide further support for the model proposed in 2013 (15). The association between malocclusion and ADHD should be investigated through a developmental perspective as both systems are developed from ectodermal tissues during embryogenesis.

Management of children with ADHD during orthodontic treatment, organization of visit frequency and duration, and further compliance at home has been known to be challenging, and there have been studies addressing techniques to solve these problems (11, 20, 21). Dentists should be able to recognize the early signs of ADHD and emotional and social problems to provide therapeutic and preventive mental health services. Mental health professionals should also be aware of the significance and importance of the link described in the present study.

Our study has limitations. The findings of the present study should be interpreted in light of some limitations. The first is the small sample size of the study that limits the power of the data. The second concern is the broad age range of the subjects as the presentation of ADHD may differ according to age and a broad age range might cause heterogeneity of symptoms. Since the study was limited to a clinical sample from a single center, it was not possible to generalize these findings for the population. Another limitation is that the results regarding ADHD symptoms came from self-report measures and not diagnostic interviews. However, all of the measures were valid and reliable in Turkish, and the SNAP-IV has been used in several large population studies to determine ADHD symptoms, and the SDQ has been equivalent to diagnostic interviews (24-27). Additionally, the scales were administered as in-person interviews by the first author who is a trained child psychiatrist. Another limitation regarding data collection is that the breastfeeding duration was collected through maternal recall, which may raise concerns about the accuracy of the data. However, the long-term maternal recall of breastfeeding duration was found to be quite accurate (37). Further population-based studies with large sample sizes and a narrow age need to be conducted to validate our findings.

CONCLUSION

Within the limitations of the present study, we conclude that ADHD symptoms may be seen to be high in children receiving orthodontic treatment and orthodontists should have a keen eye on psychiatric symptoms, especially ADHD symptoms.

Ethics Committee Approval: Ethics committee approval was received for this study from the Clinical Researches Ethics Committee of Marmara University (approval no.: 09.2015.112, 70737436-050.06.04).

Informed Consent: Written informed consent was obtained from one parent of each patient, and children's verbal consent was taken.

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REFERENCES

1. American Psychiatric Association (2013) Diagnostic and Statistical Manual of Mental Disorders (DSM-5®). American Psychiatric Pub, 2013. [CrossRef]
2. Polanczyk G, de Lima MS, Horta BL, Biederman J, Rohde LA. The worldwide prevalence of ADHD: a systematic review and metaregression analysis. Am J Psychiatry 2007; 164: 942-8. [CrossRef]
3. Thapar A, Cooper M. Attention deficit hyperactivity disorder. Lancet 2015; 387: 1240-50. [CrossRef]
4. Sabuncuoglu O, Orengul C, Bikmazer A, Kaynar SY. Breastfeeding and parafunctional oral habits in children with and without attention-deficit/hyperactivity disorder. Breastfeed Med 2014; 9: 244-50. [CrossRef]
5. Tseng PT, Yen CF, Chen YW, Stubbs B, Carvalho AF, Whiteley P, et al. Maternal breastfeeding and attention-deficit/hyperactivity disorder in children: a meta-analysis. Eur Child Adolesc Psychiatry 2019; 28: 19-30. [CrossRef]
6. Blomqvist M, Ahadi S, Fernell E, Ek U, Dahllof G. Dental caries in adolescents with attention deficit hyperactivity disorder: a population-based follow-up study. Eur J Oral Sci 2011; 119: 381-5. [CrossRef]
7. Bimstein E, Wilson J, Guelmann M, Primosch R. Oral characteristics of children with attention-deficit hyperactivity disorder. Spec Care Dentist 2008; 28: 107-10. [CrossRef]
8. Hidas A, Noy AF, Birman N, Shapira J, Matot I, Steinberg D, et al. Oral health status, salivary flow rate and salivary quality in children, adolescents and young adults with ADHD. Arch Oral Biol 2011; 56: 1137-41. [CrossRef]
9. Aminabadi NA, Najafpour E, Erfanparast L, Jamali Z, Pournaghi-Azar F, Tamjid-Shabestari S, et al. Oral health status, dental anxiety, and

behavior-management problems in children with oppositional defiant disorder. Eur J Oral Sci 2016; 124: 45-51. [CrossRef]

10. Chau YC, Peng SM, McGrath CP, Yiu CK. Oral Health of Children with attention deficit hyperactivity disorder: systematic review and meta-analysis. J Atten Disord 2017; doi: 10.1177/1087054717743331. [CrossRef]
11. Atmetlla G, Burgos V, Carrillo A, Chaskel R. Behavior and orofacial characteristics of children with attention-deficit hyperactivity disorder during a dental visit. J Clin Pediatr Dent 2006; 30: 183-90. [CrossRef]
12. Chau YC, Lai KY, McGrath CP, Yiu CK. Oral health of children with attention deficit hyperactivity disorder. Eur J Oral Sci 2017; 125: 49-54. [CrossRef]
13. Sabuncuoglu O. Traumatic dental injuries and attention-deficit/hyperactivity disorder: is there a link? Dent Traumatol 2007; 23: 137-42. [CrossRef]
14. Altun C, Guven G, Akgun OM, Acikel C. Dental injuries and attention-deficit/hyperactivity disorder in children. Spec Care Dentist 2012; 32: 184-9. [CrossRef]
15. Sabuncuoglu O. Understanding the relationships between breastfeeding, malocclusion, ADHD, sleep-disordered breathing and traumatic dental injuries. Med Hypotheses 2013; 80: 315-20. [CrossRef]
16. Mimouni-Bloch A, Kachevanskaya A, Mimouni FB, Shuper A, Raveh E, Linder N. Breastfeeding may protect from developing attention-deficit/hyperactivity disorder. Breastfeed Med 2013; 8: 363-7. [CrossRef]
17. Palmer B. The influence of breastfeeding on the development of the oral cavity: a commentary. J Hum Lact 1998; 14: 93-8. [CrossRef]
18. Andersson H, Sonnesen L. Sleepiness, occlusion, dental arch and palatal dimensions in children attention deficit hyperactivity disorder (ADHD). Eur Arch Paediatr Dent 2018; 19: 91-7. [CrossRef]
19. Tehranchi A, Younessian F, Fadaei V, Arabgol F, Shirvani A. The effect of methylphenidate on cervical vertebral maturation and dental age in patients with attention deficit hyperactivity disorder. J Dent (Shiraz) 2018; 19: 197-205.
20. Blomqvist M, Augustsson M, Bertlin C, Holmberg K, Fernell E, Dahllof G, et al. How do children with attention deficit hyperactivity disorder interact in a clinical dental examination? A video analysis. Eur J Oral Sci 2005; 113: 203-9. [CrossRef]
21. Fakhruddin KS, ElBatawi H, El-Damanhoury HM. Behavioral management using sequenced treatment paradigm and audiovisual distraction during dental treatment in children with attention deficit/hyperactivity disorder. Eur J Dent 2018; 12: 262-8. [CrossRef]
22. Ogutlu NY, Almahdi E, Sayar G, Kilicoglu H. Evaluation of orthodontic patients at state and foundation universities according to the ICON index. Turk J Orthod 2018; 31: 122-6. [CrossRef]
23. Bergmann MM, Jacobs EJ, Hoffmann K, Boeing H. Agreement of self-reported medical history: comparison of an in-person interview with a self-administered questionnaire. Eur J Epidemiol 2004; 19: 411-6. [CrossRef]
24. Bussing R, Fernandez M, Harwood M, Wei H, Garvan CW, Eyberg SM, et al. Parent and teacher SNAP-IV ratings of attention deficit hyperactivity disorder symptoms: psychometric properties and normative ratings from a school district sample. Assessment 2008; 15: 317-28. [CrossRef]
25. Guler AS, Scahill L, Jeon S, Taskin B, Dedeoglu C, Unal S, et al. Use of multiple informants to identify children at high risk for ADHD in turkish school-age children. J Atten Disord 2017; 21: 764-75. [CrossRef]
26. Gokce S, Yazgan Y, Ayaz AB, Kayan E, Yusufoglu C, Carkaxhiu Bulut G, et al. Association Between Age of Beginning Primary School and Attention Deficit Hyperactivity Disorder. J Dev Behav Pediatr 2017; 38: 12-9. [CrossRef]
27. Ercan ES, Polanczyk G, Akyol Ardic U, Yuce D, Karacetin G, Tufan AE, et al. The prevalence of childhood psychopathology in Turkey: a cross-sectional multicenter nationwide study (EPICPAT-T). Nord J Psychiatry 2019; 73: 132-40. [CrossRef]
28. Goodman R. Psychometric properties of the strengths and difficulties questionnaire. J Am Acad Child Adolesc Psychiatry 2001; 40: 1337-45. [CrossRef]
29. Basol ME, Karaagaçlioglu L, Yilmaz B. Developing a Turkish Oral Health Impact Profile-OHIP-14-TR. Turkiye Klinikleri J Dental Sci 2014; 20: 85-92.
30. Nur RB, Ilhan D, Fisekcioglu E, Oktay I, Arun T. Total and interregional differences of the need for orthodontic treatment in Turkey: Epidemiologic surveillance analysis. Turk J Orthod 2014; 27: 1-8. [CrossRef]
31. Petersen PE. Challenges to improvement of oral health in the 21st century-the approach of the WHO Global Oral Health Programme. Int Dent J 2004; 54: 329-43. [CrossRef]
32. Sabuncuoglu O, Irmak MY. The attention-deficit/hyperactivity disorder model for traumatic dental injuries: a critical review and update of the last 10 years. Dent Traumatol 2017; 33: 71-6. [CrossRef]
33. Guo NW, Lin CL, Lin CW, Huang MT, Chang WL, Lu TH, et al. Fracture risk and correlating factors of a pediatric population with attention deficit hyperactivity disorder: a nationwide matched study. J Pediatr Orthop B 2016; 25: 369-74. [CrossRef]
34. O'Brien C, Benson P, Marshman Z. Evaluation of a quality of life measure for children with malocclusion. J Orthod 2007; 34: 185-93. [CrossRef]
35. Taylor KR, Kiyak A, Huang GJ, Greenlee GM, Jolley CJ, King GJ. Effects of malocclusion and its treatment on the quality of life of adolescents. Am J Orthod Dentofacial Orthop 2009; 136: 382-92. [CrossRef]
36. Erol N, Simsek Z, Oner O, Munir K. Epidemiology of attention problems among Turkish children and adolescents: a national study. J Atten Disord 2008; 11: 538-45. [CrossRef]
37. Natland ST, Andersen LF, Nilsen TI, Forsmo S, Jacobsen GW. Maternal recall of breastfeeding duration twenty years after delivery. BMC Med Res Methodol 2012; 12: 179. [CrossRef]

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Original Article

In Vitro Evaluation of Direct and Indirect Effects of Sonic and Ultrasonic Instrumentations on the Shear Bond Strength of Orthodontic Brackets

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ABSTRACT

Objective: Sonic and ultrasonic instrumentations generate vibrations that may influence debonding characteristics. The objective of this in vitro study was to assess the direct and indirect effects of sonic and ultrasonic periodontal instrumentations on the shear bond strength (SBS) and the adhesive remnant index (ARI) scores of metallic orthodontic brackets.

Methods: Metallic brackets were bonded to 75 extracted mandibular central incisors that were embedded in acrylic resin. Instrumentations around the bracket base performed with ultrasonic (UltrasonicB group, n=15) and sonic (SonicB group, n=15) scalers were used to evaluate the direct effects on the SBS of brackets. Lingual surface instrumentations with ultrasonic (UltrasonicL group, n=15) and sonic (SonicL group, n=15) scalers were performed to assess the indirect effects. The control group (n=15) did not have any treatment. Instrumentations were performed for 30 s with 0° scaler tip angulations with settings recommended by manufacturers. The SBS of the brackets tested with a universal testing machine and ARI scores were recorded. Data were analyzed by Kruskal–Wallis and Mann–Whitney U tests.

Results: The mean SBS of the control group was significantly higher than that of the UltrasonicB and SonicB groups (p=0.008). The UltrasonicL and SonicL group instrumentations also decreased the SBS, although the difference was statistically insignificant. UltrasonicB instrumentations caused significantly higher frequency of ARI scores than the control group.

Conclusion: The decrease of the SBS of metallic brackets indicates the influence of ultrasonic and sonic instrumentations on the breakage behavior at the bracket–resin interface. Instrumentations around the bracket base should be conducted with caution to decrease the bond failure risk of metallic brackets.

Keywords: Ultrasonics, orthodontic brackets, periodontics, dental bonding, dental prophylaxis

INTRODUCTION

Orthodontic treatment with fixed appliances increases the plaque retention areas and impairs the appropriate oral hygiene measures by patients. Changes in oral microbiota can be detected that might be associated with the observed white spot lesions, carie, and periodontal problems (1-5). In addition to increased plaque accumulation, patients often exhibit gingival enlargements, bleeding, and calculus formation during the orthodontic treatment (6). Although the importance of oral hygiene measures was emphasized to all patients before and during the orthodontic treatment, the necessity of professional oral hygiene procedures, including plaque removal and scaling that were accomplished by manual and power-driven instrumentations, is observed frequently for patients with fixed appliances.

Power-driven instruments, which have been proven to have less treatment time and reduce the subgingival biofilm to the same extent compared with manual instrumentation, vary in their clinical efficiency and mechanism

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of action (7-9). In sonic scalers, air-turbine-generated vibrations range between 2 and 6 kHz/3000 and 8000 cycles/s, and scaler tip oscillates almost circularly (10-12). In piezoelectric ultrasonic instruments, a quartz crystal that was inserted into the hand-piece is provided with high-frequency alternating current causing dimensional changes of crystal generating the vibrations. The scaler tip vibration is linear, and the vibration frequency ranges between 25 and 42 kHz/25,000 and 50,000 cycles/s (10-12). In addition to physical action of oscillating tip, cavitational effect and acoustic microstreaming may influence the removal of deposits from the root surface (13, 14). The direct effect of oscillating scaler forms on surface contact with the tip and the influence of vibrations transmitted through the tooth defines the indirect effect of power-driven instrumentations. During ultrasonic scaling procedures, transmission of acoustic energy through the tooth has been demonstrated (15).

During the professional oral hygiene procedures of patients with orthodontic brackets, sonic and ultrasonic instrumentations were performed around the bracket base and at the lingual (reciprocal tooth surface) surface if necessary. The generated instrumentation vibrations could have influenced the brackets on the tooth as high-frequency vibrations of sonic and ultrasonic instruments are also known to facilitate the removal of posts, crowns, and bridge restorations and debonding of orthodontic brackets (16-19). While performing professional oral hygiene procedures, the instrumentation around the bracket base presents a *direct effect* as the scaler tip mostly works in contact with brackets and the vibrations directly influence the bracket base area. On the other hand, instrumentation at the lingual (reciprocal) surfaces *indirectly affects* the tooth–bracket interface as the vibrations were transmitted through the tooth without any scaler tip contact to the bracket base. However, the effect of instrumentation on the shear bond strength (SBS) of brackets has not been investigated until the study conducted by Bonetti et al. (20) that revealed that prolonged ultrasonic instrumentation around the bracket base has been shown to reduce the SBS of metallic orthodontic brackets.

Considering the differences of vibration frequencies and tip actions, sonic and piezoelectric ultrasonic instrumentations were suggested to vary by means of direct and indirect effects on the SBS of metallic orthodontic brackets. The tested null hypothesis was that direct and indirect applications of sonic and ultrasonic instrumentations do not decrease the SBS values of orthodontic brackets. Therefore, the aim of the present study was to evaluate the direct and indirect effects of sonic and piezoelectric ultrasonic instrumentations on the SBS and failure type of metallic orthodontic brackets.

METHODS

The study was approved by the Institutional Review Board and Ethics Committee of Başkent University (project no. D-KA14/15) and supported by the Başkent University Research Fund.

The sample size was calculated by using G*Power 3.1.9.2 (21). Given an α level of 0.05 (difference between two independent means) with a power of 80%, a minimum number of 14 specimens were required for each group.

A total of 75 mandibular central incisors, which were extracted for periodontal reasons, without any presence of caries, restorations, decalcifications, microcracks, and enamel fractures were collected. After extraction, all teeth were debrided, washed, and stored in distilled water.

Each tooth was individually embedded in autopolymerizing acrylic resin (Meliodent; Heraeus Kulzer, Hanau, Germany) blocks using the cemento-enamel junction as the lower limit. During the embedding procedure, all teeth were centered, and crowns were oriented as perpendicular to the bonding labial surface and parallel to the force to be applied for the SBS test. All resin blocks were code-numbered for identification.

Buccal surface prophylaxis was performed with pumice slurry using rubber cups. All teeth were washed with water spray and dried with air spray for 15 s. The bonding procedures were performed by one operator. The brackets (Ormco Mini 2000; Ormco Corporation, Glendora, CA, USA) were bonded according to the manufacturer's instructions, with 30 s of etching with 37% phosphoric acid gel (Pulpdent Corporation, Watertown, MA, USA), followed by washing for at least 15 s and drying with water–air spray until a characteristic frosty white etched area was observed on the enamel. A thin uniform layer of bonding agent (Transbond™ XT Lightcure adhesive primer; 3M™ Unitek, Monrovia, CA, USA) was applied. The brackets were bonded with light cure adhesive paste (Transbond™ XT) and were adjusted to ensure that the SBS test force to be applied would be perpendicular to the bracket base. Brackets were pressed lightly in their final position, the excess adhesive was removed with a sharp scaler, and the adhesive was cured with a LED light curing unit (Ortholux™, 3M™ Unitek, Monrovia, CA, USA) for 20 s (5 s on each of the mesial, distal, gingival, and incisal margins).

The specimens were randomly divided into five groups: UltrasonicB group, ultrasonic instrumentation of specimens around the bracket base; UltrasonicL group, ultrasonic instrumentation of specimens on the lingual surface; SonicB group, sonic instrumentation of specimens around the bracket base; SonicL group, sonic instrumentation of specimens on the lingual surface; and control group, specimens without any instrumentation. In the UltrasonicB and SonicB groups, the scaler tip was applied in contact with the bracket base. These groups represented the direct effect, and the UltrasonicL and SonicL groups represented the indirect effect as the instrumentations were performed on the reciprocal-lingual surface to evaluate the effects of vibrations transmitted through the tooth.

Ultrasonic instrumentation was performed using a piezoelectric ultrasonic scaler (Suprasson® P5 Newtron SATELEC; ACTEON, Merignac, France). The scaler tip (Universal tip, #1, SATELEC; ACTEON) was used with a 0° scaler tip angulation. A sonic scaler (SONICflex 2000N; KaVo Dental GmbH, Biberach, Germany) was used for sonic instrumentation procedures. The scaler insert (SONICflex scaler tip no. 6; KaVo Dental GmbH) was used with a

Table 1. Descriptive data of shear bond strength (MPa) analysis of the test and control groups

Group	n	Mean±SD	Minimum	Maximum	Median
UltrasonicL	15	10.52±4.48	4.70	18.50	9.86
UltrasonicB	15	7.93±3.10*	0.00	14.20	7.79
SonicL	15	9.36±2.36	6.37	13.07	8.18
SonicB	15	8.16±2.26†	5.52	13.34	7.33
Control	15	12.19±4.16*, †	6.69	18.20	9.63

*p=0.002, †p=0.004 (same characters on the same column indicate statistical significance).
SD: standard deviation; UltrasonicL: ultrasonic instrumentation of specimens on the lingual surface; UltrasonicB: ultrasonic instrumentation of specimens around the bracket base; SonicL: sonic instrumentation of specimens on the lingual surface; SonicB: sonic instrumentation of specimens around the bracket base; Control: control specimens without any instrumentation

0° scaler tip angulation. A new scaler tip was used in each study group. The manufacturer's recommended power settings were applied (settings of 14–15 for ultrasonic instrumentation and medium for sonic instrumentation). All instrumentation procedures were conducted by one experienced operator. A pilot study to maintain reproducible and the least possible load application was performed by the operator, with a reproducibility of 92% based on intraclass correlation coefficient index.

A pilot study of professional oral hygiene procedures was performed with sonic or ultrasonic instrumentation to estimate the time required for applications for patients with fixed orthodontic appliances. Periodontal procedures at the buccal or lingual sites were completed within 30 s/tooth for both sonic and ultrasonic instrumentations. Depending on the results of the pilot study, the instrumentation period was determined as 30 s for each of the specimens in the test groups. In the UltrasonicB and SonicB groups, instrumentation was performed for 10 s on each mesial, distal, and incisal side of the bracket base. The gingival bracket side instrumentation was excluded in the present study as the selected scaler tip angulation restricted the appropriate access to the area. The tip angulation was ensured by positioning the ultrasonic/sonic scaler tip parallel to the bonding surface and perpendicular to the bracket base for buccal instrumentation in the UltrasonicB and SonicB groups.

In the UltrasonicL and SonicL groups, instrumentation was performed on the lingual surfaces of each specimen excluding the incisal 1/3 part of the crown. With maintaining scaler tip parallel to the long axis of the crown in an apico-coronal direction, the 0° angulation of the scaler tip in contact to tooth surfaces was achieved, and instrumentation on the lingual surfaces was performed continuously for 30 s in an apico-coronal direction.

All samples were stored for 24h in distilled water before SBS testing. The test was performed using a standard knife-edge chisel in a universal testing machine (3343, Instron Corporation, Norwood, MA, USA) with a crosshead speed of 0.5 mm/min. The specimens were positioned to ensure the long axis of the incisors, and the bracket base was parallel to the direction of the applied force. An occlusogingival load was applied to the bracket at the incisal groove, producing a shear force at the bracket–tooth interface. The breaking loads required for debonding were recorded in Newtons (N) and converted into stress values in megapascals (MPa) that were calculated by dividing the failure load (N) by the surface area of the bracket base (7.386 mm^2).

After the SBS testing, the teeth and bracket surfaces were examined using a stereomicroscope (Leica MS5; Leica Microsystems, Singapore) at ×16 magnification to determine the type of failure. The adhesive remnant index (ARI) scoring system was used to assess the amount of adhesive left on the enamel surface of each specimen (22). The ARI scores were as follows: 0, no adhesive remained on the tooth; 1, less than half of the adhesive remained on the tooth; 2, more than half of the adhesive remained on the tooth; and 3, all of the adhesive remained on the tooth with a distinct impression of the bracket base.

Statistical Analysis

All statistical analyses were performed by using Statistical Package for Social Sciences version 20.0 for Windows (IBM Corp.; Armonk, NY, USA). Shapiro–Wilk test was used for the distribution of data. Data were not normally distributed. Levene test was used for the evaluation of homogeneity of variances. Kruskal–Wallis test was used to determine whether the differences in the SBS and ARI scores among the groups were statistically significant or not. Mann–Whitney U test was used for comparisons of all groups, and Bonferroni correction ($p<0.01$) was applied for controlling Type I error.

RESULTS

One specimen in the UltrasonicB group failed during the instrumentation, and it was accepted as a presentation of clinical instrumentation procedure, and the SBS value of this specimen was accepted as 0 MPa (20).

The SBS values and standard deviations for all groups are shown in Table 1. The SBS values of the lingual instrumentation groups were higher than those of the buccal instrumentation groups, although a statistical significance was not observed. Comparisons of instrumentation methods have shown that the SBS values of sonic instrumentation were lower than those of the UltrasonicL group and higher than those of the UltrasonicB group without any statistical significance. The SBS values of the UltrasonicB and SonicB groups were significantly lower than the highest SBS values of the control group ($p<0.01$, $p=0.002$ and $p<0.01$, $p=0.004$, respectively).

Kruskal–Wallis analysis revealed the presence of significant differences among the groups for ARI scores. The ARI scores of buccal instrumentations were higher than those of lingual instrumentations, although the difference was not statistically sig-

Table 2. Descriptive data and frequencies of the adhesive remnant scores (ARI) of the test and control groups

	n	ARI=0 (%)	ARI=1 (%)	ARI=2 (%)	ARI=3 (%)	Mean±SD
UltrasonicL	15	0 (0.0)	0 (0.0)	12 (80)	3 (20)	2.20±0.41
UltrasonicB	15	0 (0.0)	0 (0.0)	4 (26.7)	11 (73.3)	2.73±0.46*
SonicL	15	0 (0.0)	1 (6.7)	8 (53.3)	6 (40)	2.33±0.62
SonicB	15	0 (0.0)	1 (6.7)	5 (33.3)	9 (60)	2.53±0.64
Control	15	0 (0.0)	1 (6.7)	11 (73.3)	3 (20)	2.13±0.52*

*p=0.009 (same characters on the same column indicate statistical significance)
SD: standard deviation; UltrasonicL: ultrasonic instrumentation of specimens on the lingual surface; UltrasonicB: ultrasonic instrumentation of specimens around the bracket base; SonicL: sonic instrumentation of specimens on the lingual surface; SonicB: sonic instrumentation of specimens around the bracket base; Control: control specimens without any instrumentation

nificant. Intergroup comparisons showed that the ARI scores of the UltrasonicB group were significantly higher than those of the control group (p=0.009) (Table 2). The ARI scores of the UltrasonicB group were also higher than those of the SonicB group, but statistical significance was not revealed (p>0.01).

DISCUSSION

To the best of our knowledge, this is the first study investigating the direct and indirect effects of sonic and ultrasonic instrumentations on metallic orthodontic brackets' SBS and failure mode. Sonic and ultrasonic instruments are usually used for periodontal therapy of patients with fixed orthodontic appliances, disregarding their possible direct and indirect effects.

The type of scaler tip oscillations and the operating frequencies are different for sonic and piezoelectric ultrasonic instruments. Considering the characteristics of instruments, the effects of vibrations conducted on the tooth and tooth–resin–bracket interface could also be expected to be different, with similar clinical treatment outcomes. Instrumentations of the UltrasonicB and SonicB groups around the bracket base had been performed to determine the direct effects of vibrations, whereas instrumentations of the UltrasonicL and SonicL groups, that aimed to simulate periodontal therapy on the lingual surfaces, had been performed to define the indirect effects of vibrations on the SBS of orthodontic brackets.

The sonic scaler tip oscillates almost circularly performing a localized hammering effect on the tooth surface; on the other hand, the piezoelectric ultrasonic scaler tip has a linear vibration pattern. Depending on the oscillation patterns and vibration frequency ranges, piezoelectric ultrasonic instrumentations around the orthodontic bracket base were expected to be more "detrimental" on bond failure. Bonetti et al. (20) reported that prolonged piezoelectric ultrasonic instrumentation around the bracket base has been shown to decrease the SBS values significantly, indicating a higher risk of bracket bond failure. In agreement with the former study, the study results revealed that sonic and piezoelectric ultrasonic instrumentations around metallic orthodontic brackets have affected the SBS significantly compared with control specimens. Therefore, the null hypothesis that direct and indirect applications of sonic and ultrasonic instrumentations do not decrease the SBS values of orthodontic brackets was rejected. The decrease in the mean SBS of the UltrasonicB group specimens was more pronounced than that of the SonicB group specimens, which might be attributed to effects of higher frequencies of piezoelectric scaler than sonic scalers. The reduction of the SBS supports the direct effect of sonic and piezoelectric ultrasonic instrumentations on the tooth–bracket interface. The mean SBS of the control group specimens was higher than that of the UltrasonicL and SonicL group specimens, although the difference was statistically insignificant.

As vibration formed during instrumentation with ultrasonic scaler is higher than sonic scalers, the mean SBS values of the UltrasonicL group, which had the highest mean value among the test groups, were unexpected. This result in the UltrasonicL group could be attributed to specimen-based characteristics that may affect the vibrations transmitted through the tooth structure, although a single type of tooth was used to determine the influence of instrumentations. For each of the instrumentation type, buccal applications have more efficiency on the SBS of metallic brackets than lingual instrumentation. The findings demonstrate that vibrations produced by sonic and piezoelectric ultrasonic instrumentations appear to have a limited indirect effect on the SBS of metallic brackets. The instrumentation of both buccal and lingual surfaces with sonic and ultrasonic scalers had not been performed. However, an increase of detrimental effects of both instrumentation types might be expected, as application on both buccal and lingual sides might generate a synergistic effect on the tooth–bracket interface. Further studies to evaluate the consecutive instrumentation of both buccal and lingual surfaces should be conducted to clarify this issue.

The scaler tip angulation has considerable effects on root substance removal and defect depth. The defect depth of piezoelectric ultrasonic instrumentation was found to be the highest at 45° angulations (23). The root damage was not severe with 0° tip angulation, and the tip angulation <15° or the scaler tip aligned parallel to the root surface during instrumentation was recommended to prevent severe root damage (12, 24, 25). Ultrasonic instrumentation around the bracket base with 0° and 45° tip angulations did not reveal significant differences by means of the effect on the SBS (20). Therefore, 0° tip angulation was selected for instrumentation in all test groups to decrease the possible damage. However, this scaler tip angulation prevented the appropriate access and instrumentation at the gingival side of the bracket base, which might have an effect on the bond strength, if it had been performed.

The time required for professional hygiene procedures depends on various factors, such as clinical case characteristics, experience of the dental professionals, and instrumentation-based considerations. The average times for a single session supra- and subgingival debridement of adult patients with periodontitis were determined as 4 min/tooth and 3.3 min/tooth for sonic and ultrasonic instrumentations, respectively (26). The mean time needed for ultrasonic instrumentation was 0.4 min/tooth for patients in maintenance periodontal therapy (27). In a study assessing the influence of ultrasonic instrumentation around metallic orthodontic brackets, instrumentation was performed for 60 s, which was reported to be overrated to simulate extreme conditions and to highlight the most detrimental effects (20). Instrumentation time was determined as 30 s in this in vitro study. The decreased levels of the SBS of brackets in test specimens compared with control specimens have shown that instrumentation time was long enough to affect the bracket bond failure. Considering that in clinical procedures power-driven instrumentation around the bracket base is generally shorter than 30 s, the given results represent the effects of prolonged instrumentation, although it was less than the mean application time reported in former studies.

The present study should be evaluated by considering other factors that might have an influence on the results. The mandibular central incisors used to test the SBS had been shown to have different bond failure probabilities at a particular stress compared with premolar teeth, which have been used frequently for SBS evaluating studies (28). In the UltrasonicB, SonicB, and SonicL groups, stress strength values were reduced with power-driven instrumentation, which may increase the probability of failure rates calculated (28). The failure rate probability of 1st premolars and central incisors was higher than that of 2nd mandibular premolars; therefore, conducting a study with different tooth types may reveal different results. The mandibular incisors also have the smallest bracket base area, and prolonged instrumentation around the bracket base might have decreased the stress strength more easily.

The absorption depth of vibrations by different tooth types or the influence of transmission of vibrations through the tooth has not been studied. Regarding the differences in tooth dimensions, tooth volumes, and structural characteristics, such as mineralization, thickness, and density of the enamel and dentin, the transmission and absorption of vibrations could be expected to be various if different tooth types have been tested. Another issue to be considered is the tooth-supporting structures, such as periodontal ligament and alveolar bone, that absorb or limit the effects transferred through the tooth. During the orthodontic treatment, bone remodeling and changes in periodontal ligament occur, which would have at least partly an impact on the absorption of vibrations by tooth or vibrations transferred through the tooth (29-30). Although a limited influence of vibrations transmitted through the tooth was detected, the dimensional and structural characteristics of the selected teeth might have affected the results in the present study. The lack of periodontal ligament simulation and testing of resin-embedded specimens in this study might also have an effect on results.

Evaluation of ARI scores revealed that piezoelectric instrumentation around the bracket base significantly affects the debonding characteristics on the tooth–resin–bracket system compared with control specimens. The vibrations formed during the instrumentation of the UltrasonicB groups in contact to the bracket appear to influence the breakage behavior at the bracket–resin interface. The remaining intergroup comparisons of ARI scores revealed non-significant differences. Bond failure type of all groups had a mean index >2, indicating that the failure was mostly confined to the bracket–resin interface and decreased risk of enamel damage after debonding could be expected.

The results indicate that sonic and ultrasonic periodontal instrumentations around the orthodontic metallic bracket base reduce the SBS of metallic orthodontic brackets that may increase bracket failure risk. Considering the displeasing outcomes of bracket failure on orthodontic treatment progression, such as prolonged treatment time, sonic and ultrasonic instrumentations around the bracket base should be conducted with caution. Further studies investigating the sonic and ultrasonic periodontal instrumentations should be interpreted to clarify the direct and indirect effects on the SBS of orthodontic metallic brackets and to reveal the influence of instrumentation- and specimen-based factors on the bond strength of orthodontic brackets.

CONCLUSION

The simulation of sonic and piezoelectric ultrasonic instrumentations reduced the bond strength of metallic orthodontic brackets tested in this in vitro study. Instrumentation around the bracket base was detected to have more dramatic effects on the SBS than instrumentation performed on the lingual surface. Sonic instrumentation applied around the bracket base demonstrated higher SBS than ultrasonic instrumentation. Given the results that sonic and ultrasonic periodontal instrumentations around the orthodontic metallic bracket base reduce the SBS of brackets, instrumentations particularly around the bracket base should be conducted with caution.

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethics Committee of Başkent University (Project no: D-KA14/15).

Informed Consent: N/A.

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REFERENCES

1. Freitas AO, Marquezan M, Nojima Mda C, Alviano DS, Maia LC. The influence of orthodontic fixed appliances on the oral microbiota: a systematic review. Dental Press J Orthod 2014; 19: 46-55. [CrossRef]
2. Chapman JA, Roberts WE, Eckert GJ, Kula KS, González-Cabezas C. Risk factors for incidence and severity of white spot lesions during treatment with fixed orthodontic appliances. Am J Orthod Dentofacial Orthop 2010; 138: 188-94. [CrossRef]
3. Richter AE, Arruda AO, Peters MC, Sohn W. Incidence of caries lesions among patients treated with comprehensive orthodontics. Am J Orthod Dentofacial Orthop 2011; 139: 657-664. [CrossRef]
4. Bollen AM, Cunha Cruz J, Bakko DW, Huang GJ, Hujoel PP. The effects of orthodontic therapy on periodontal health: A systematic review of controlled evidence. J Am Dent Assoc 2008; 139: 413-22. [CrossRef]
5. Atack NE, Sandy JR, Addy M. Periodontal and microbiological changes associated with the placement of orthodontic appliances. A review. J Periodontol 1996; 67: 78-85. [CrossRef]
6. Türkkahraman H, Sayin MO, Bozkurt FY, Yetkin Z, Kaya S, Onal S. Archwire ligation techniques, microbial colonization, and periodontal status in orthodontically treated patients. Angle Orthod 2005; 75: 231-6.
7. Tunkel J, Heinecke A, Flemmig TF. A systematic review of efficacy of machine-driven and manual subgingival debridement in the treatment of chronic periodontitis. J Clin Periodontol 2002: 29; 72-81. [CrossRef]
8. Petersilka GJ, Ehmke B, Flemmig TF. Antimicrobial effects of mechanical debridement. Periodontol 2000 2002; 28: 56-71. [CrossRef]
9. Baehni P, Thilo B, Chapuis B, Pernet D. Effects of ultrasonic and sonic scalers on dental plaque microflora in vitro and in vivo. J Clin Periodontol 1992; 19: 455-9. [CrossRef]
10. Menne A, Griesinger H, Jepsen S, Albers H, Jepsen K. Vibration characteristics of oscillating scalers. J Dent Res 1994; 73: 434.
11. Lea SC, Landini G, Walmsley AD. Displacement amplitude of ultrasonic scaler inserts. J Clin Periodontol 2003; 30: 505-10. [CrossRef]
12. Arabaci T, Ciçek Y, Canakçi CF. Sonic and ultrasonic scalers in periodontal treatment: a review. Int J Dent Hyg 2007; 5: 2-12. [CrossRef]
13. Laird WRE, Walmsley AD. Ultrasound in dentistry. Part 1-biophysical interactions. J Dent 1991; 19: 14-7. [CrossRef]
14. Khambay BS, Walmsley AD. Acoustic microstreaming detection and measurement around ultrasonic scalers. J Periodontol 1999; 70: 626-31. [CrossRef]
15. Walmsley AD, Laird WR, Williams AR. Intra-vascular thrombosis associated with dental ultrasound. J Oral Pathol 1987; 16: 256-9. [CrossRef]
16. Olin PS. Effect of prolonged ultrasonic instrumentation on the retention of cemented cast crowns. J Prosthet Dent 1990; 64: 563-5. [CrossRef]
17. Marchan SM, White D, Smith W, Dhuru V. The influence of sonic and ultrasonic vibration on the shear bond strength of a selected resin luting cement. Eur J Prosthodont Restor Dent 2015; 23: 29-32.
18. Bishara SE, Trulove TS. Comparisons of different debonding techniques for ceramic brackets: an in vitro study. Part II. Findings and clinical implications. Am J Orthod Dentofacial Orthop 1990; 98: 263-73. [CrossRef]
19. Krell KV, Courey JM, Bishara SE. Orthodontic bracket removal using conventional and ultrasonic debonding techniques, enamel loss, and time requirements. Am J Orthod Dentofacial Orthop 1993; 103: 258-66. [CrossRef]
20. Alessandri Bonetti G, Incerti Parenti S, Ippolito DR, Gatto MR, Luigi C. Effects of ultrasonic instrumentation with different scaler-tip angulations on the shear bond strength and bond failure mode of metallic orthodontic brackets. Korean J Orthod 2014; 44: 44-9. [CrossRef]
21. Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods 2007; 39: 175-91. [CrossRef]
22. Artun J, Bergland S. Clinical trials with crystal growth conditioning as an alternative to acid-etch pretreatment. Am J Orthod Dentofacial Orthop 1984; 85: 333-40. [CrossRef]
23. Flemmig TF, Petersilka GJ, Mehl A, Hickel R, Klaiber B. The effect of working parameters on root substance removal using a piezoelectric ultrasonic scaler in vitro. J Clin Periodontol 1998; 25: 158-63. [CrossRef]
24. Petersilka GJ, Draenert M, Mehl A, Hickel R, Flemmig TF. Safety and efficiency of novel sonic scaler tips in vitro. J Clin Periodontol 2003; 30: 551-5. [CrossRef]
25. Flemmig TF, Petersilka GJ, Mehl A, Hickel R, Klaiber B. Working parameters of a magnetostrictive ultrasonic scaler influencing root substance removal in vitro. J Periodontol 1998; 69: 547-53. [CrossRef]
26. Loos B, Kiger R, Egelberg J. An evaluation of basic periodontal therapy using sonic and ultrasonic scalers. J Clin Periodontol 1987; 14: 29-33. [CrossRef]
27. Badersten A, Nilveus R., Egelberg J. Effect of nonsurgical periodontal therapy. I. Moderately advanced periodontitis. J Clin Periodontol 1981; 8: 57-72. [CrossRef]
28. Hobson RS, McCabe JF, Hogg SD. Bond strength to surface enamel for different tooth types. Dent Mater 2001; 17: 184-9. [CrossRef]
29. King GJ, Keeling SD, Wronski TJ. Histomorphometric study of alveolar bone turnover in orthodontic tooth movement. Bone 1991; 12: 401-9. [CrossRef]
30. Davidovitch Z. Tooth movement. Crit Rev Oral Biol Med 1991; 2: 411-50. [CrossRef]

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Original Article

Evaluation of Enamel Roughness *in Vitro* After Orthodontic Bracket Debonding Using Different Methods of Residual Adhesive Removal

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ABSTRACT

Objective: The aim of the present study was to compare different techniques for resin remnant removal (RRR) after orthodontic bracket debonding and to evaluate alterations on the dental enamel caused by these methods. The null hypothesis tested was that there is no difference between RRR techniques in relationship the changes caused on the dental enamel.

Methods: A total of 75 bovine mandibular permanent incisors were used in the study. Brackets were bonded and debonded in each tooth in two experimental regions. Five RRR techniques were used in the experimental groups (n=15): Group 1-diamond bur (6-bladed), Group 2-diamond bur (12-bladed), Group 3-diamond bur (30-bladed), Group 4-aluminum oxide sandblasting (AOS), and Group 5-Er:YAG laser. Enamel surface was evaluated using profilometry, and surface roughness analysis was performed at three time intervals: before bracket bonding, after RRR techniques, and after final polishing. Qualitative analyses of the enamel surfaces were performed using scanning electron microscopy.

Results: Multiblade burs showed the best results, and the 30-bladed bur created a less irregular enamel surface. AOS caused greater enamel wear, and Er:YAG laser caused more surface irregularity.

Conclusion: The null hypothesis was rejected. The multiblade burs were the least harmful than the other techniques. Enamel surface roughness after using the 30-blade bur was similar to the original enamel. These results indicate that the type of bur tested (30-bladed) can be indicated to remove resin remnants after bracket debonding.

Keywords: Orthodontic debonding, enamel, orthodontic brackets

INTRODUCTION

Orthodontic brackets are fixated to the enamel for the purpose of providing support to perform orthodontic mechanics. Over the past few years, composites have been used to bond brackets to the enamel. In most cases, bonding is obtained through mechanical retention of both the bonding agent and composite to the micropores created by acid etching on the enamel surface and by the interlocking of the composite in the bracket base mesh (1, 2).

Once treatment has been completed, the orthodontic appliance must be removed. After bracket debonding, regardless of the method used, the ideal situation is that all composite used for fixation remains adhered to the enamel, thus protecting the surface against possible fractures (3, 4). When the brackets are removed, the resin remnants on the enamel must also be removed.

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Mechanical removal for the remaining composite, after debonding orthodontic brackets, has been shown to be detrimental to the enamel surface (5-8). Studies have assessed composite resin remnant removal (RRR) from the enamel, after bracket debonding, using various methods, including pliers, low- and high-speed drill with burs, manual scrapers, ultrasound, aluminum oxide sandblasting (AOS), and lasers (5-19).

During the bonding and debonding processes using the appropriate technique, it is estimated that 5–20 µm of the enamel is lost (20-22). Koprowski et al. (23) assessed the quality of the enamel after the treatment and clean-up procedure of debonding brackets through the use of computed tomography. The results showed that the enamel thickness after the orthodontic treatment had decreased by approximately 125 µm. Ulusoy (24) expressed that the search for the ideal method, which returns the enamel surface as closely as possible to its original state, is still ongoing. After removing the remnants of bonding material, it is a consensus that prophylaxis must be performed using a low-speed motor with a rubber cup, pumice stone paste, and water to polish the enamel (25).

The aim of the present study was to evaluate and compare, using profilometry and surface roughness, the following: 1) different techniques for removing resin remnants after orthodontic bracket debonding and 2) possible alterations on the enamel caused by these methods. The null hypothesis tested was that there is no difference between RRR techniques and polishing and there is no interaction among them.

METHODS

The approval letter of the ethics committee was not included because, in accordance with the provisions of Art. 3 Item III and Art. 10 of Law 11,794 of 10/08/2008, experimental protocols that do not involve the use of live animals should not be analyzed.

Sample size was based on the study by Ahrari, considering an effect size of 0.25, power of 0.80, and alpha of 0.05 for six groups with a correlation of 0.10. Sample size was calculated using the G*Power program for repeated measurements.

A total of 75 bovine mandibular permanent incisors were stored for 1 week in 0.1% thymol for disinfection. The criteria for selection of teeth were intact crowns and absence of demineralization, cracks, fractures, or stains. The roots were sectioned (2 mm below the cement–enamel junction) using a water-cooled double-faced diamond disk (KG Sorensen, 7015, Brazil) mounted on a sectioning machine (Miniton; Struers A/S, Denmark). The buccal face of each crown was fixed onto a glass plate using utility wax. They were then embedded in self-curing acrylic resin using a plastic cylinder (20 mm diameter× 2 cm high) as a mold. Specimens were polished (240-, 600-, and 1200-grit silicon carbide papers) in a polishing machine (Struers, Copenhagen, Denmark) to expose an area of at least 15 mm long in the cervical–incisal direction. The surface received final polishing (damp felt and 0.3- and 0.5-µm aluminum particle) to obtain an enamel without scratches. Buccal faces were randomly divided into three regions, one control and two experimental, and covered with a yellow adhesive polyethylene tape "mask" measuring 70 mm × 200 mm. Teeth were stored in distilled water at 37°C.

Prophylaxis was performed for 10 s using fluoride-free pumice and water slurry on a rubber cup, followed by washing and drying at the same time. Rubber cups were replaced after five uses. In the two experimental groups, the enamel surfaces were etched (37% phosphoric acid gel, 15 s and washed and dried, 15 s) and coated with a layer of adhesive primer (Transbond XT; 3M Unitek, Monrovia, CA, USA), and 150 standard edgewise metal brackets for lower incisors (base area of 9.78 mm^2; Morelli, Sorocaba, SP, Brazil) were bonded with Transbond XT composite resin (3M Unitek). The adhesive was cured for 40 s on the mesial, distal, incisal, and cervical faces (10 s/each face) at 1 mm from the bracket base using a halogen light-curing unit XL 1500 (3M ESPE, St. Paul, MN, USA) with a light intensity of 400 mW/cm^2, verified after five activations with a Demetron curing radiometer (Danbury, NH, USA) (Figure 1). Test specimens were stored in distilled water (37°C for 24 h), and then all brackets were debonded (JTLF) with curved How pliers no. 110 (3M Unitek).

Five groups (n=15) were formed according to the RRR technique (Table 1). In each test specimen, three regions were established using a table of random numbers in: 1) control area, 2) enamel after RRR, without final polishing, and 3) enamel after RRR, with final polishing. The polishing was performed for 10 s using fluoride-free pumice and water slurry on a rubber cup, followed by washing and drying for the same amount of time.

Figure 1. Radiometer to measure light intensity

Table 1. Experimental groups

Group (n=15)	Resin remnant removal techniques	Manufacturer
30B	30-bladed bur	Beavers Dental
12B	12-bladed bur	Beavers Dental
6B	6-bladed bur	TP Orthodontics
AOS	Aluminum oxide sandblasting 50 μm	VH Equipments
Laser	Er:YAG laser	Fotona Medical Lasers

All groups were evaluated without and with final prophylaxis

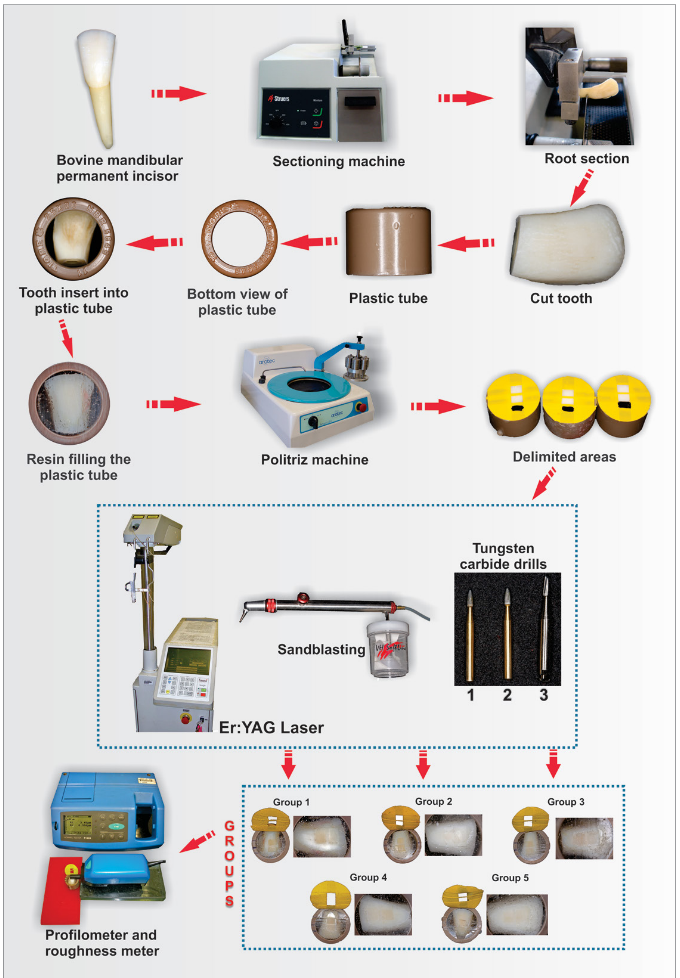

Figure 2. Flowchart of the study steps

The RRR from the enamel after bracket debonding was performed by three techniques: multibladed burs, AOS, and Er:YAG laser. For the multibladed burs, 6-bladed (TP Orthodontics, La Porte, IN, USA) and 12-bladed and 30-bladed (jet carbide burs; Beavers Dental, Morrisburg, ON, Canada) were applied with paintbrush movement, at low speed, on the resin remnants. Each multiblade bur was replaced after five uses.

For AOS, the Microjato Gold Line appliance was used (VH Equipments Medical/Dental and Accessories Ltda., Araraquara, SP, Brazil), with a 50-μm aluminum oxide particle stream, a standardized distance of 10 mm from the tooth surface, at a 45° angle for 15 s.

The Er:YAG laser Twin Light (Fotona Medical Lasers, Ljubljana, Slovenia) was used with 200–450 ms pulse duration, 2.94 μm wavelength, 500 mJ maximum pulse energy, and 2–15 Hz pulse repetition rate. This delivery system has two articulated arms with a sapphire window in non-contact mode and an air–water spray cooling system. Irradiation on the enamel was aided by a guide beam directing laser emission on the area to be irradiated. To avoid overheating during irradiation, the air–water spray was activated, and the water flow was regulated at 1.5 mL/min. Irradiation was performed using parallel horizontal movements from top to bottom in non-contact mode. It was focused perpendicular to the tooth surface, at a distance of 12 mm with 260 mJ pulse energy and 47 J/cm^2 energy density, 3 Hz pulse repetition rate, and 30 s irradiation time. Enamel surfaces were irradiated using an automatic custom-designed device (MPC ElQuip, São Carlos, SP, Brazil) that was affixed to the laser handpiece in such a manner that the laser beam was delivered perpendicular to the specimen surface at a constant distance from the target site.

After the RRR procedures, enamel surfaces were re-examined. The five groups were evaluated at three time points: 1) after prophylaxis prior to bracket bonding (control), 2) after RRR before final polishing, and 3) after RRR after final polishing.

Profilometry and roughness analyses were performed using Hommel Tester T1000 (Hommelwerke GmbH, Schwenningen, Germany) equipment. For roughness, the parameters were established at L_t (assessment length): 1.5 mm and L_c (cut-off): 0.25 mm. In the profilometry measurement, the needle of the device was positioned in the region considered to be the control and then from this point for all regions of the specimens. Three random readings were obtained on each evaluated surface. The baseline was obtained using the arithmetic mean of these three readings.

Two teeth from each group were randomly selected for analysis using scanning electron microscopy (SEM) by the EVO 50® appliance (Carl Zeiss SMT, Gottingen, Germany) operated at 20.00 kV.

Figure 2 represents the flowchart of the methodology used in the present study.

Statistical Analysis

All analyses were performed using the SAS 9.4 (PROCMIXED) statistical program using an alpha of 0.05. A generalized linear mixed model was used in the analysis for repeated measures. It took into consideration the dependence of data within each tooth specimen. Interaction between type of treatment and polishing was tested. Tukey-Kramer post-test was used for comparison of the adjusted means for each treatment and polishing condition.

RESULTS

Profilometry Analysis

The analysis of variance for mixed models for profilometry showed a statistically significant difference between the RRR techniques (<0.0001) and the final polishing type (0.0049). More-

Table 2. Profilometry means and difference (µm) for polishing among each removal technique of resin remnants

	Polishing			
Groups	Yes	No	Dif (95% CI)*	p**
Blade-30	7.96	5.20	2.75 (–4.51 to 10.36)	0.9675
Blade-12	11.39	8.62	2.77 (–4.50 to 10.05)	0.9666
Blade-6	11.66	12.10	–0.43 (–7.71 to 6.84)	0.9999
AOS	29.61	32.05	–2.44 (–9.71 to 4.83)	0.9855
Laser	24.67	12.86	11.80 (4.53 to 19.08)	<0.0001

*95% confidence interval
**p-value for the comparison between means (Tukey-Kramer post-test, α=0.05)

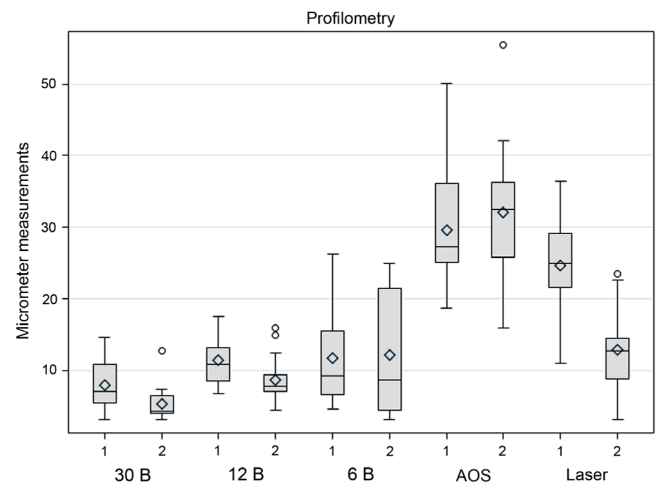

Figure 3. Box-plot showing distribution for profilometry for the different residual removal resin techniques with (number 2) and without polishing (number 1). Diamonds represent means only for reference

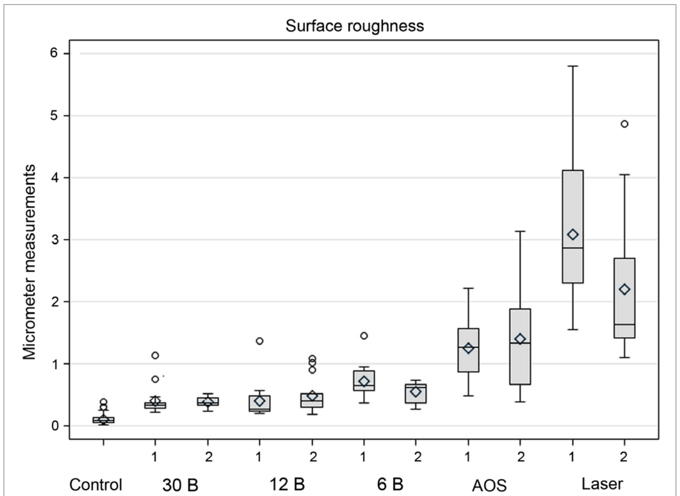

Figure 4. Box-plot showing distribution for surface roughness for the different residual removal resin techniques with (number 2) and without polishing (number 1). Diamonds represent means only for reference

over, there was an interaction between the techniques and polishing (0.0002). This interaction means that polishing interfered with the performance of the techniques, but this interaction only occurred for laser therapy (Table 2). Profilometry means for laser technique was lower (p<0.0001) for no polishing (12.86 µm) and then the one observed for polishing (24,67 µm).

Comparison between profilometry means of the RRR techniques can be better illustrated through box-plots in Figure 3 (no. 1-without polishing and no. 2-with polishing) and in Table 3 in which adjusted mean differences and 95% confidence intervals are described with indication of those differences that were statistically significant (p<0.05). Table 3 shows a matrix with differences between RRR techniques among polishing in the upper part of the matrix and among non-polishing in the lower part.

There was no observed difference among bladed burs, with or without polishing. Independent of polishing, all bladed burs were statistically different from AOS. The laser was statistically different from all bladed burs in the absence of polishing, and it was not different from 6- to 12-bladed burs when polishing was performed. No difference between the laser and AOS could be observed in the absence of polishing; the two techniques were different when polishing was performed.

Surface Roughness Analysis

Analysis of variance showed that both techniques (<0.001) and polishing (0.0446) interfered in the final roughness, with significant interaction between technique and polishing (0.0006). The mean comparison revealed that the interaction was due to the differences in polishing only for laser treatment. Polishing did not affect any other treatment.

Box-plots depicting roughness distribution and polishing status are shown in Figure 4 (no. 1-without polishing and no. 2-with polishing). There was no statistical difference between the multiblade burs, regardless of whether final polishing was performed or not (Table 4). All other comparisons between AOS and laser and blades were statistically significant, except for difference between AOS and blade-6 among the samples without polishing (Table 5).

SEM Evaluation

SEM micrographs obtained from each method of RRR (Figure 5-9) showed that after polishing, the surface on which the AOS was used showed fewer irregularities (Figure 8). The 6-, 12-, and 30-bladed tungsten carbide burs showed surface irregularities even when final polishing was performed (Figure 5-7).

SEM micrographs obtained using AOS and laser showed that both techniques caused very irregular enamel surfaces (Figure 8, 9).

DISCUSSION

With the emergence of new materials and techniques in dentistry, research has been conducted to evaluate the possibility of their use in the dental clinic. Thus, orthodontics has been searching for new technologies to RRR adhered to the enamel after debonding procedures. Among the most used techniques, multiblade burs are the most common (11, 26, 27). Various bur shapes and different blade types are available for clinical use.

Table 3. Surface roughness means difference and 95% confidence interval between techniques among polished and non-polished

		Polishing				
		Blade-30	Blade-12	Blade-6	AOS	Laser
No polishing	Blade-30	1	3.4 (−3.85 to 10.69)	6.90 (−0.37 to 14.17)	−26.84* (−34.12 to −19.57)	7.65* (14.93 to 0.38)
	Blade-12	3.4 (−3.84 to 10.70)	1	3.48 (−3.79 to 10.76)	−23.43* (−30.70 to −16.15)	−4.24 (11.51 to −3.03)
	Blade-6	3.70 (3.57 to 10.98)	0.27 (−7.00 to 7.55)	1	−19.95* (−27.22 to −12.67)	0.76 (−6.5 to 18.04)
	AOS	21.65* (14.37 to 28.92)	18.22* (10.94 to 25.49)	17.9* (10.87 to 25.2)	1	19.19* (11.91 to 26.46)
	Laser	16.71* (9.43 to 23.98)	13.28* (6.00 to 20.55)	13.0* (5.73 to 20.28)	4.94 (−2.33 to 12.22)	1

*Statistically different means (p<0.05) for multiple comparison t

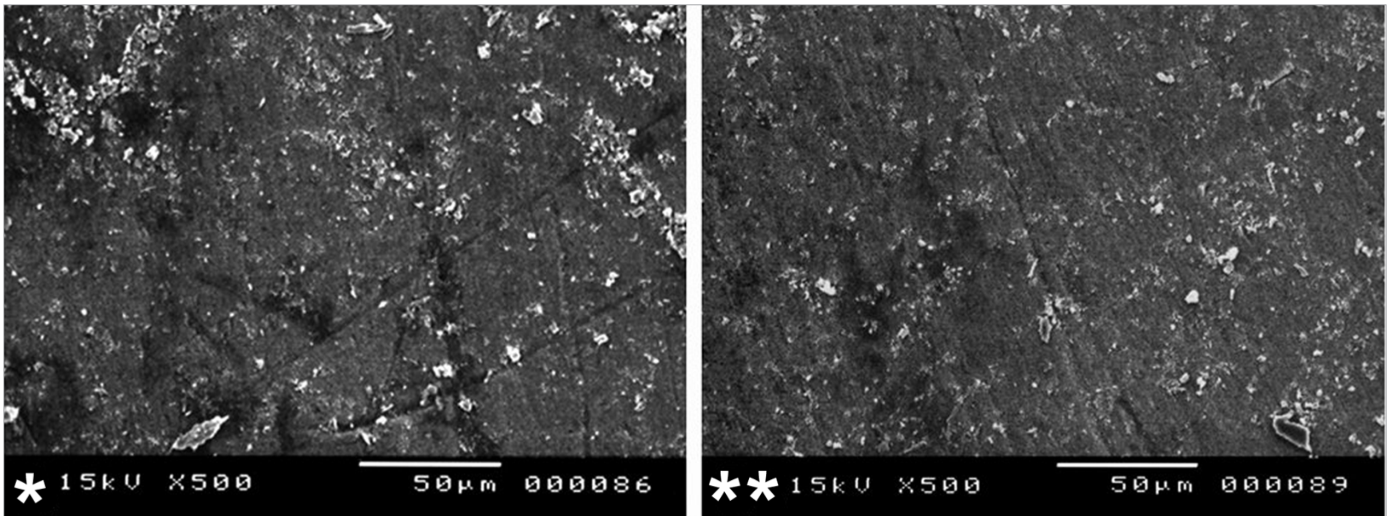

Figure 5. SEM micrograph of enamel surface whose resin remnant was removed by 30-blade tungsten carbide bur: *without polishing and **with polishing (500X magnification)

Table 4. Profilometry means and difference (μm) for polishing among each removal technique of resin remnants

	Polishing			
Groups	Yes	No	Dif (95% CI)*	p**
Control	0.11		0.01 (0.01 to 0.21)	
Blade-30	0.41	0.38	0.02 (−0.58 to 0.62)	0.9999
Blade-12	0.40	0.49	−0.08 (−0.68 to 0.51)	0.9999
Blade-6	0.72	0.55	0.17 (−0.43 to 0.76)	0.9978
AOS	1.24	1.40	0.15 (−0.75 to 0.44)	0.9990
Laser	3.09	2.21	0.88 (0.28 to 1.48)	0.0002

**95% confidence interval.
**p-value for the comparison between means (Tukey–Kramer post-test, α=0.05).

Thus, 6-, 12-, and 30-bladed burs were evaluated. Moreover, AOS with 50-μm particles and Er:YAG laser were used to remove the resin remnant after bracket debonding. All techniques were evaluated with and without final polishing. Therefore, this investigation aimed to identify which technique proposed here causes the least amount of alteration in the enamel surface during the RRR procedures. Thus, samples were evaluated and compared using profilometry, whose analysis was obtained in depth, and roughness, whose analysis was superficial.

The average values obtained in the profilometry analysis, considering whether or not final polishing, showed that only the laser technique presented a statistically significant difference. The higher level of depth recorded with the AOS and laser techniques represented a higher loss of enamel. Although polishing was not significant between multiblade burs and AOS, polishing tended to decrease the value found in the profilometry when using different techniques, with the exception of treatments with 6-bladed burs and AOS, which showed higher numeric values after final polishing.

The AOS is dispersed, and therefore, a wide surface region is reached. It is different from the laser, in which the beam is emitted unidirectionally. A size of 50-μm particle may have influenced dispersion and thus influenced the results and the greater depth found in the profilometer values when using the technique. Duration of AOS for RRR, although not observed in the present study, was measured by SEM during the time intervals of 5, 15, 30, 45, and 60 s and did not cause differences on the enamel surface, as shown by Sargison et al. (15). In contrast, Mhatre et al. (16) compared the RRR with carbide burs and AOS and found a significant difference between them. These authors found lower values in the profilometry, without a show of application time interval and particle size. Thus, larger oxide particles possibly caused higher and more irregular patterns on surface wear. Irregularities caused by AOS were also found on surfaces of extracted human teeth (15). In the present study, polishing possibly regulated surfaces with fragment fractures formed by AOS.

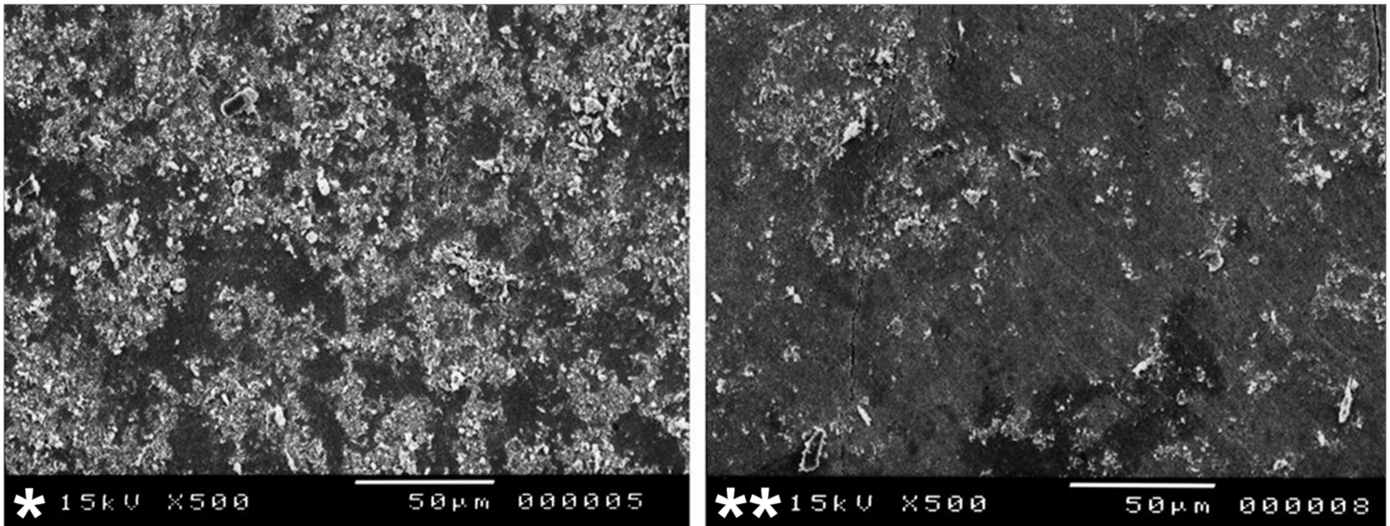

Figure 6. SEM micrograph of enamel surface whose resin remnant was removed by 12-blade tungsten carbide bur: *without polishing and **with polishing (500X magnification)

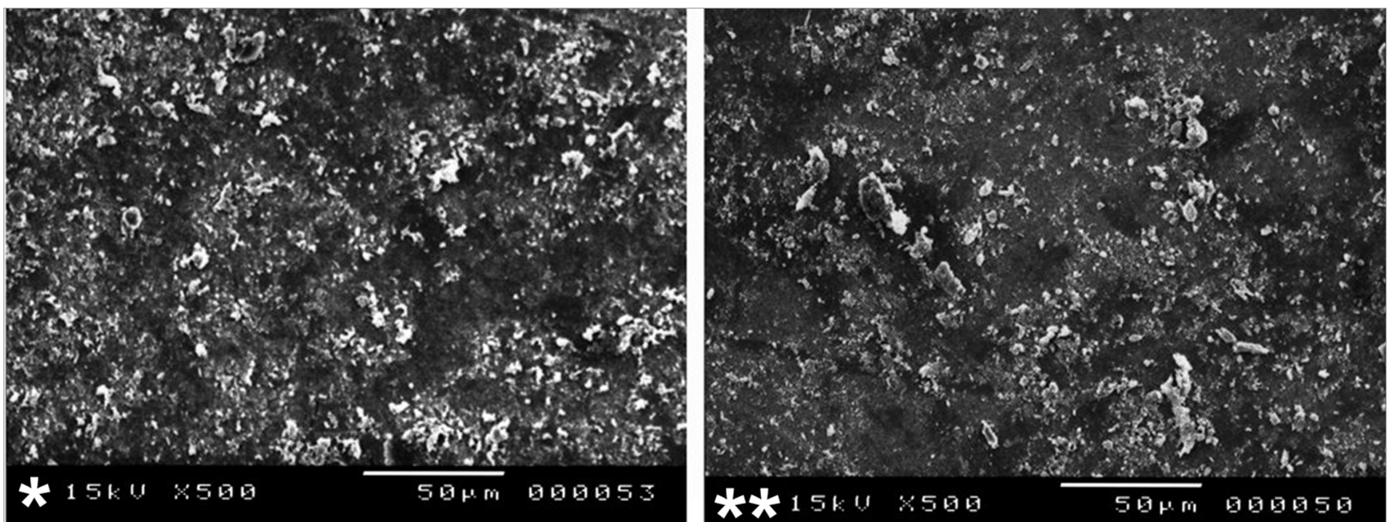

Figure 7. SEM micrograph of enamel surface whose resin remnant was removed by 6-blade tungsten carbide bur: *without polishing and **with polishing (500X magnification)

Table 5. Surface roughness means difference and 95% confidence interval between techniques among polished and non-polished

		Polishing				
		Blade-30	**Blade-12**	**Blade-6**	**AOS**	**Laser**
No polishing	Blade-30	1	0.10 (–0.49 to 0.70)	0.16 (–0.43 to 0.76)	1.00* (0.41 to 1.61)	1.82* (1.22 to 2.42)
	Blade-12	0.01 (–0.59 to 0.59)	1	–0.06 (–0.65 to 0.53)	0.90* (0.31 to 1.50)	1.72* (1.12 to 2.31)
	Blade-6	–0.31 (–0.91 to 0.28)	–0.31 (–0.91 to 0.28)	1	0.84* (0.25 to 1.44)	1.66* (1.16 to 2.25)
	AOS	–0.84* (–1.45 to –0.24)	–0.84* (–1.45 to –0.24)	–0.52 (–1.2 to 0.07)	1	0.81* (0.21 to 1.41)
	Laser	–2.68* (–3.28 to –2.08)	–2.68* (–3.28 to –2.08)	–2.37* (–2.96 to –1.77)	–1.80* (–2.44 to –1.24)	1

*Statistically different means ($p<0.05$) for multiple comparison t

When comparing RRR techniques, no significant difference was found among multibladed burs, regardless of whether final polishing was performed. Among multiblade burs, 6-bladed burs showed more unsatisfactory performance. It can be verified from the dispersion of results obtained with the 6-bladed bur when compared with 12- and 30-bladed burs and the quality of the enamel surface showed by SEM. Ulusoy (24) observed that 12- and 30-fluted tungsten carbide burs at high speed with water coolant are fast and efficient in residual resin removal, but the resultant enamel surface with enamel scars needs to be finished by other polishing techniques. Although this investigation showed lower surface alterations, scratches on the surface were found when a 30-bladed bur was used, even when final polishing was performed.

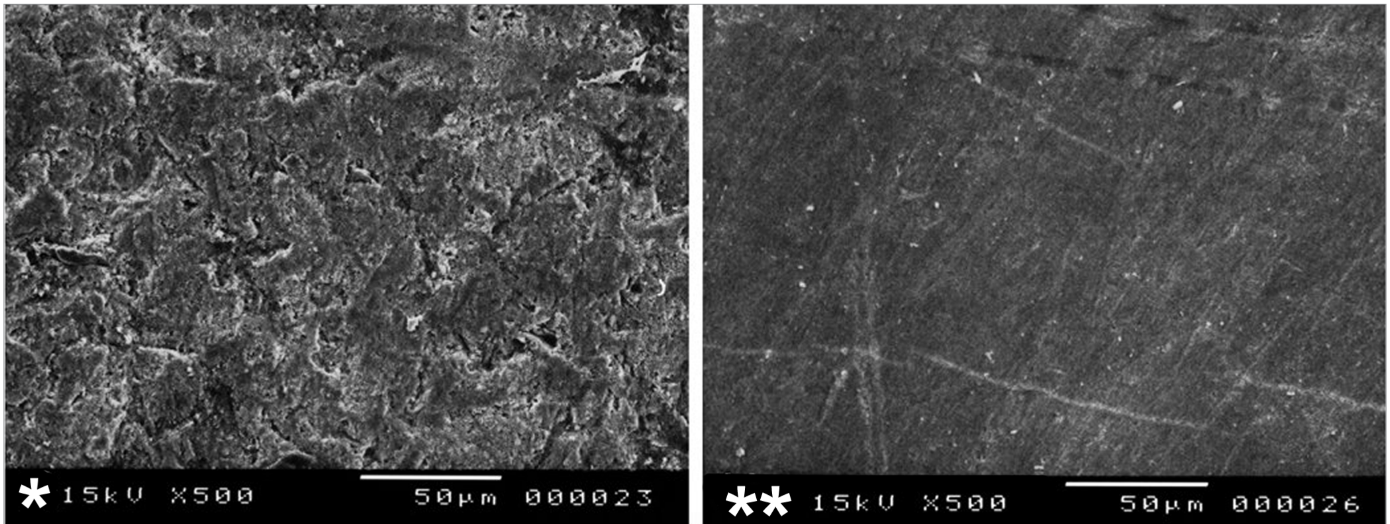

Figure 8. SEM micrograph of enamel surface whose resin remnant was removed by AOS: *without polishing and **with polishing (500X magnification)

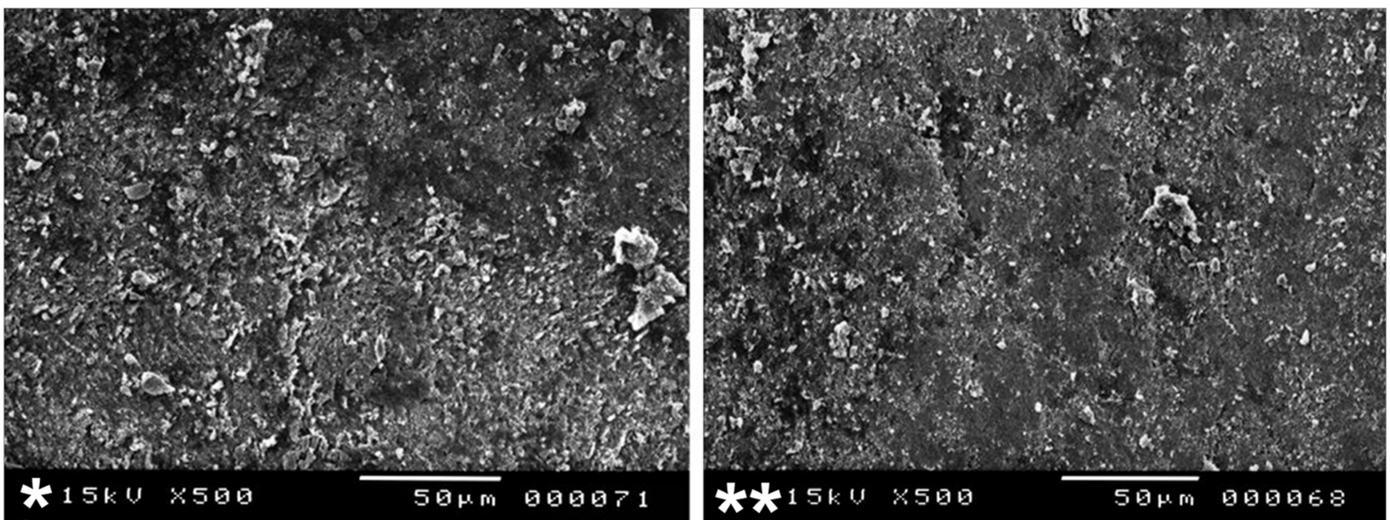

Figure 9. SEM micrograph of enamel surface whose resin remnant was removed by Er:YAG laser: *without polishing and **with polishing (500X magnification)

Considering AOS and laser, the test specimens on which AOS was used showed the least favorable results among the performed techniques, as greater wear depth in micrometers was found in the profilometry. However, considering the condition in which the final polishing was not performed, AOS was similar to laser because the depths recorded in both techniques were similar. This likely occurred because of the laser beam being directed, in contrast to the jet, which was applied in a dispersed manner. The intensity used in the irradiation and concentration of this beam in a smaller area than that obtained with sandblasting (jet dispersion and particle thickness) is possibly responsible for a smaller depth of surface changes than observed with the laser technique. Both sandblasting and laser were statistically different from the three multiblade tips, corroborating the study by Almeida et al. (17).

However, provided that the final polishing was performed, results for laser were similar to those of 6- and 12-bladed burs, but statistically different from abrasion and 30-bladed burs. Final polishing was important for all techniques, although the laser technique caused a decrease in the surface depth in micrometers, probably because of fractures or irregularities left during its application, leading to a smaller dispersion of the results obtained with polishing. This result is in agreement with Howell and Weekes, who affirmed that polishing performed after RRR might cause loss of the enamel. This loss is proportional to the time spent on the procedure (25).

In the present study, significant surface alterations were caused by the laser, as shown by the depths recorded by the profilometer and SEM, according to Ahrari et al. (8) and Kwon et al. (19).

When analyzing the surface roughness data, the mean values obtained by all of the techniques were higher than that recorded for the control region, corroborating the study by Kim et al. (22), who compared the RRR with low-speed tungsten bur and AOS.

In the present study, both multiblade burs and AOS did not show significant differences.

No statistically significant difference was observed between multiblade burs for the different techniques used for removing resin remnants under conditions in which the final polishing was or was not performed.

Comparing all multiblade burs with the other techniques, only the 6-bladed bur without polishing was statistically different from the control and similar to AOS. The other results of AOS and laser were statistically significant, thus showing more damage to the enamel surface. Comparing the condition in which the final polishing was performed, the 6-, 12-, and 30-bladed burs were equal to each other and the control among all the techniques used. AOS and laser were statistically different from the control and all multiblade burs.

Among all the investigated techniques, the 30-bladed bur showed fewer surface alterations. This information is in disagreement with the study by Degrazia et al. (28). Despite improving surface quality, final polishing does not remove deep scratches, as previously reported (5). It is important to point out that it made no difference whether or not polishing was performed when using different multiblade burs.

Comparing the results from profilometry and surface roughness, it was observed that the 6-bladed bur showed higher dispersion of results, both with and without final polishing, although the 6-bladed bur did not show a significant difference from the results of the other two multiblade burs. Regarding surface roughness, 6-, 12-, and 30-bladed burs showed a more regular surface, with no statistical difference among them, although the results of the 30-bladed bur left the surface more similar to the control region.

The literature has shown that multiblade burs cause the least amount of harm to the enamel and are the most indicated for RRR, which was also found in the present study (11, 12, 14, 23, 28).

Regarding AOS, although the profilometry analysis showed a higher depth and dispersion of results, the surface roughness analysis showed a less rough surface than that of the laser. The laser showed a lower depth in the profilometry analysis than in the AOS. However, surface quality observed in the roughness evaluation was comparatively less favorable when using laser than that found for AOS.

In extrapolating from the clinical orthodontics, among all the used techniques, AOS is the one that caused more enamel wear, whereas Er:YAG laser caused more irregularities, which favored the accumulation of biofilm.

All of the used techniques caused superficial irregularities and enamel loss, which could not be quantified. Thus, enamel thickness was not quantified in the evaluated surfaces. This evaluation could have shown how much of the enamel was lost, in addition to comparing the experimental areas with the control areas. Only two randomly selected teeth from each group were evaluated by SEM. The results would be more consistent if all the teeth had been subjected to electron microscopy. An *in situ* study will likely bring greater applicability to the clinical practice. It was, in fact, a limitation of the present study.

CONCLUSION

- The null hypothesis was rejected.
- Multiblade burs promoted fewer irregularities in the enamel, as they were less harmful than the other techniques, regardless of whether the final polishing was performed or not.
- AOS caused greater wear on the enamel surface, whereas the Er:YAG laser caused the largest irregularities on the enamel surface.

Ethics Committee Approval: Ethics Committee on Animal Use – CEUA/FORP is responsible "for complying with and enforcing, within the scope of its attributions, the provisions of national legislation and other applicable rules to the use of live animals for teaching and research at FORP/USP" (emphasis added), in accordance with the provisions of Art. 3 – Item III and Art. 10 of Law 11,794, of 10/08/2008, not analyzing, therefore, experimental protocols that do not involve the use of live animals.

Informed Consent: N/A.

Peer-review: Externally peer-reviewed.

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REFERENCES

1. Buonocore M. A simple method of increasing the adhesion of acrylic filing materials to enamel surfaces. J Dent Res 1955; 34: 849-53. [CrossRef]
2. Newman GV. Bonding plastic orthodontic attachments. J Pract Orthod 1969; 3: 231-8.
3. Zachrisson BU, Arthun J. Enamel surface appearance after various debonding techniques. Am J Orthod 1979; 75: 121-7. [CrossRef]
4. Artun J, Bergland S. Clinical trials with crystal growth conditioning as an alternative to acid-etch enamel pretreatment. Am J Orthod 1984; 85: 333-40. [CrossRef]
5. Eliades T, Gioka C, Eliades G, Makou M. Enamel surface roughness following debonding using two resin grinding methods. Eur J Orthod 2004; 26: 333-8. [CrossRef]
6. Pont HB, Özcan M, Bagis B, Ren Y. Loss of surface enamel after bracket debonding: an in-vivo and ex-vivo evaluation. Am J Orthod Dentofacial Orthop 2010; 138: 387-9. [CrossRef]
7. Ryf S, Flury S, Palaniappan S, Lussi A, Van Meerbeek B, Zimmerli B. Enamel loss and adhesive remnants following bracket removal and various clean-up procedures in vitro. Eur J Orthod 2012; 34: 25-32. [CrossRef]

8. Ahrari F, Akbari M, Akbari J, Dabiri G. Enamel surface roughness after debonding of orthodontic brackets and various clean-up techniques. J Dent 2013; 10: 82-93.
9. Salehi P, Pakshir H, Naseri N, Baherimoghaddam T. The effects of composite resin types and debonding pliers on the amount of adhesive remnants and enamel damages: a stereomicroscopic evaluation. J Dent Res Dent Clin Dent Prospects 2013; 7: 199-205.
10. Webb BJ, Koch J, Hagan JL, Ballard RW, Armbruster PC. Enamel surface roughness of preferred debonding and polishing protocols. J Orthod 2016; 43: 39-46. [CrossRef]
11. Mohebi S, Shafiee HA, Ameli N. Evaluation of enamel surface roughness after orthodontic bracket debonding with atomic force microscopy. Am J Orthod Dentofacial Orthop 2017; 151: 521-7. [CrossRef]
12. Ferreira FG, Nouer DF, Silva NP, Garbui IU, Correr-Sobrinho L, Nouer PR. Qualitative and quantitative evaluation of human dental enamel after bracket debonding: a non-contact three-dimensional optical profilometry analysis. Clin Oral Investig 2014; 18: 1853-64. [CrossRef]
13. Vidor MM, Felix RP, Marchioro EM, Hahn L. Enamel surface evaluation after bracket debonding and different resin removal methods. Dental Press J Orthod 2015; 20: 61-7. [CrossRef]
14. Cardoso LA, Valdrighi HC, Vedovello Filho M, Correr AB. Effect of adhesive remnant removal on enamel topography after bracket debonding. Dental Press J Orthod 2014; 19: 105-12. [CrossRef]
15. Sargison AE, McCabe JF, Millett DT. A laboratory investigation to compare enamel preparation by sandblasting or acid etching prior to bracket bonding. Br J Orthod 1999; 26: 141-6. [CrossRef]
16. Mhatre AC, Tandur AP, Reddy SS, Karunakara BC, Baswaraj H. Enamel surface evaluation after removal of orthodontic composite remnants by intraoral sandblasting technique and carbide bur technique: a three-dimensional surface profilometry and scanning electron microscopic study. J Int Oral Health 2015; 7: 34-9.
17. Almeida HC, Vedovello Filho M, Vedovello SA, Young AA, Ramirez-Yañez GO. ER:YAG laser for composite removal after bracket debonding: a qualitative SEM analysis. Int J Orthod Milwaukee 2009; 20: 9-13.
18. Macri RT, de Lima FA, Bachmann L, Galo R, Romano FL, Borsatto MC, et al. CO2 laser as auxiliary in the debonding of ceramic brackets. Lasers Med Sci 2015; 30: 1835-41. [CrossRef]
19. Kwon YH, Kwon OW, Kim HI, Kim KH. Nd:YAG laser ablation of enamel for orthodontic use: tensile bond strength and surface modification. Dent Mater J 2003; 22: 397-403. [CrossRef]
20. Pus MD, Way DC. Enamel loss due to orthodontic bonding with filled and unfilled resins using various clean-up techniques. Am J Orthod 1980; 77: 269-83. [CrossRef]
21. Thompson RE, Way DC. Enamel loss due to prophylaxis and multiple bonding/debonding of orthodontic attachments. Am J Orthod 1981; 79: 282-95. [CrossRef]
22. Kim SS, Park WK, Son WS, Ahn HS, Ro JH, Kim YD. Enamel surface evaluation after removal of orthodontic composite remnants by intraoral sandblasting: a 3-dimensional surface profilometry study. Am J Orthod Dentofacial Orthop 2007; 132: 71-6. [CrossRef]
23. Koprowski R, Machoy M, Woźniak K, Wróbel Z. Automatic method of analysis of OCT images in the assessment of the tooth enamel surface after orthodontic treatment with fixed braces. Biomed Eng Online 2014; 13: 48. doi: 10.1186/1475-925X-13-48. [CrossRef]
24. Ulusoy C. Comparison of finishing and polishing systems for residual resin removal after debonding. J Appl Oral Sci 2009; 17: 209-15. [CrossRef]
25. Howell S, Weekes WT. An electron microscopic evaluation of the enamel surface subsequent to various debonding procedures. Aust Dent J 1990; 35: 245-52. [CrossRef]
26. Janiszewska-Olszowska J, Szatkiewicz T, Tomkowski R, Tandecka K, Grocholewicz K. Effect of orthodontic debonding and adhesive removal on the enamel - current knowledge and future perspectives - a systematic review. Med Sci Monit 2014; 20: 1991-2001. [CrossRef]
27. Sfondrini MF, Scribante A, Fraticelli D, Roncallo S, Gandini P. Epidemiological survey of different clinical techniques of orthodontic bracket debonding and enamel polishing. J Orthod Sci 2015; 4: 123-7. [CrossRef]
28. Degrazia FW, Genari B, Ferrazzo VA, Santos-Pinto AD, Grehs RA. Enamel Roughness Changes after Removal of Orthodontic Adhesive. Dent J (Basel) 2018; 6: pii: E39. doi: 10.3390/dj6030039. [CrossRef]

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Original Article

Effect of Fluoride Releasing Bonding Materials on 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 three different fluoride-releasing bonding agents with a conventional adhesive system.

Methods: Eighty-four extracted human premolar teeth were separated into four groups and embedded in acrylic molds consisting of 21 teeth in each group. Brackets were bonded with Transbond XT in group 1, Clearfil SE Protect Bond in group 2, LED Proseal in group 3, and Opalseal in group 4. After bracket bonding, the teeth were thermocycled 1000 times. SBS test was performed, and Adhesive Remnant Index (ARI) scores of the groups were assessed.

Results: One-way analysis of variance test was used to compare the significant differences between the groups. Chi-square and Fisher's exact tests were used to evaluate ARI scores. The Opalseal group showed the highest bond strength, but there was no statistically significant difference between the groups in SBS values ($p=0.067$). The results of ARI scores were statistically significant.

Conclusions: All bonding materials used in the study showed clinically sufficient bond strengths.

Keywords: ARI, bonding, fluoride, orthodontic brackets, shear bond strength

INTRODUCTION

It is difficult to maintain oral hygiene when the fixed orthodontic appliances are placed on the teeth. Residual adhesive and rough surfaces of brackets, arch wires, or ligatures may increase bacterial colonization, and tooth demineralization may occur (1). During fixed orthodontic treatment, demineralization is one of the major problems, especially in patients with poor oral hygiene (2-4). The first step of demineralization is white spot lesions (WSLs), and these lesions could be seen clinically exactly 4 weeks after the beginning of orthodontic treatment (5). The frequencies of WSL were reported to be between 2% and 96% in orthodontic patients and 25% in non-orthodontic patients (2-6).

It has been reported that the use of fluoride during orthodontic treatment reduces demineralization (4-6). The uses of fluoride-containing toothpastes, mouthwashes, and gels require patient cooperation, but applications of fluoride-releasing glass ionomer cements, fluoride-added composites, fluoride-releasing bonding agents, fluoroelastomeric ligatures, or fluoride lacquers need no cooperation. The use of fluoride-containing bonding agents during orthodontic treatment is a non-patient-dependent protective action.

In orthodontic direct bonding, acid etchant is used to remove prismatic and interprismatic enamels, and after that a primer (bonding agent) is applied to the enamel to form resin tags. Orthodontic adhesive can penetrate the enamel surface by the aid of a bonding agent (7, 8).

Conventional or fluoride-releasing bonding agents can be used in orthodontic bonding. Fluoride-releasing bonding supplies fluoride ions by the aid of the aqueous oral environment, and these ions penetrate the enam-

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el prisms. Fluoride ions transform the hydroxyapatite crystals to fluorohydroxyapatite, and the structure of the enamel becomes more resistant to acid attacks and caries. Therefore, this strong fluorohydroxyapatite barrier may have different effects on the bond strength of orthodontic brackets (9).

The effect of bonding agents on bracket bond strength was previously reported in several studies (10, 11). Various brands of bonding agents are present in the market, and bond strength of these agents is critical for orthodontists. Therefore, the aim of the present study was to compare the shear bond strength (SBS) of three different fluoride-releasing bonding agents with a conventional bonding agent. The null hypothesis of the present study was that the fluoride-releasing bonding materials do not have any effect on the SBS of orthodontic brackets.

METHODS

Sample size estimation was performed prior to the study using the G*Power 3.0.10 software with a 95% confidence interval (CI) and α of 0.05 to detect a significant difference of 1 MPa in SBS value, and it was determined that to have a power of 80%, there should be 19 teeth in each group (12). According to sample size estimation, 84 human first premolar teeth were used in the present study, meaning that 21 teeth were included in each group. Inclusion criteria were as follows: teeth were not extracted for periodontal purpose and teeth with no caries, no filling or restoration, no crack on the surface of the enamel, and no malformation on the vestibule surface. The study was approved by the Research Ethics Committee of İstanbul Medipol University. (protocol no. 10840098-604.01.01-E.5731, 21/04/2016).

Figure 1. Plastic cylindrical molds

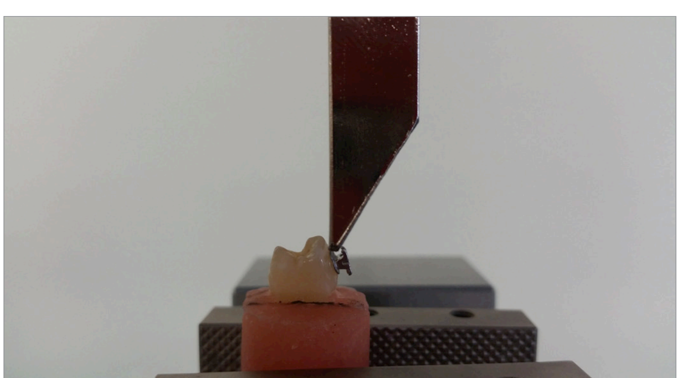
Figure 2. Testing apparatus

The enamel surfaces were assessed before the experiment by using a stereomicroscope (SZX10; Olympus, Japan) at 10× magnification, and the teeth that did not meet the criteria were excluded from the study. The teeth were washed to remove organic debris and were kept in a 0.1% thymol solution to prevent degradation of the enamel structure and bacterial colonization.

Preparation of Acrylic Molds

The teeth were removed from the thymol solution, washed, and dried, and grooves were opened using a diamond bur on the root surface to provide retention before embedding to acrylic blocks. The teeth were embedded in acrylic blocks vertically to the ground, and the long axis of the teeth up to 1 mm apical of the cement–enamel junction was exposed (Figure 1). Plastic cylindrical molds with a 25 mm inner diameter and 30 mm height were used to prepare acrylic blocks. The vestibule surfaces of the teeth were brushed with a micromotor for 15 s using a soft brush and a fluoride-free pumice, washed for 15 s, and then dried. The teeth were treated with 37% phosphoric acid, each bonding material was applied in accordance with the manufacturer's instruction, and then all of the brackets were bonded with Transbond XT adhesive (3M Unitek, Monrovia, CA, USA). Light curing of the adhesive was performed for 20 s using 3M Espe Elipar S10 (3M ESPE, Seefeld, Germany). Brackets were bonded with Transbond XT (3M Unitek) in group 1, with Clearfil SE Protect Bond (Kuraray Medical Inc., Tokyo, Japan) in group 2, with LED Proseal (Reliance Orthodontics, IL, USA) in group 3, and with Opalseal (Opal Orthodontic; Ultradent, South Jordan, UT, USA) in group 4. After bonding of the brackets, all groups were kept in distilled water at room temperature for 24 hours and then subjected to thermocycling with a thermal cycler (SD Mechatronik Thermocycler THE-1100; Feldkirchen-Westerham, Germany). The samples were immersed in water baths at temperatures between 5 °C and 55 °C for 1000 times. The samples were set to have a waiting time of 30 s and a transfer time of 5 s in each bath.

SBS Test

SBS tests were performed by a Universal Test Machine (Shimadzu Autograph AGS-X, Japan) at a crosshead speed of 1 mm/min loading on bracket–tooth interface by using a 0.5 mm thickness blade (60° cut end face, Shimadzu toothed pushrod B, Japan) (Figure 2). The specimens were placed as their long axis was vertical to the ground and fixed in the mesiodistal direction by using two screw plates to avoid their rotational movement. The force at debonding of the bracket was recorded in Newton (N); thereafter, the results were converted to megapascals (MPa) by dividing the force value (N) into the bracket base area (mm^2). The bracket surface area was 11.98 mm^2 according to the manufacturer's instruction. The buccal surfaces of the teeth were assessed using a camera of a stereomicroscope (SZX10; Olympus) at 20× magnification. Residual adhesive on the teeth surface was classified using the Adhesive Remnant Index (ARI) (13). The ARI scores were as follows: 0: no adhesive residue on the tooth, 1: <50% of

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adhesive remains on the tooth, 2: >50% of adhesive remains on the tooth, and 3: all the adhesive remains on the tooth (Figure 3).

Two samples from each group were examined at 40× and 250× magnification by using a scanning electron microscope (Zeiss EVO LS 10; Carl Zeiss, Oberkochen, Germany) (Figure 4-7).

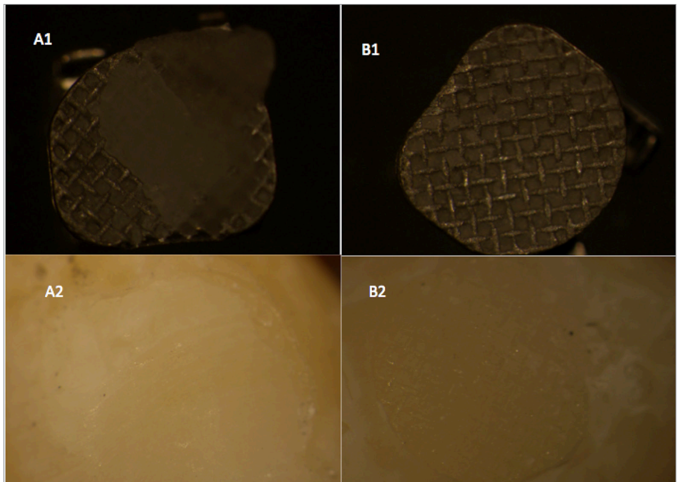

Figure 3. a, b. ARI views of the sample brackets and teeth.

(A1) ARI 1 score bracket view. (A2) ARI 1 score tooth view. (B1) ARI 2 score bracket view. (B2) ARI 2 score tooth view

Statistical Analysis

Data were evaluated by Statistical Package for Social Sciences version 22.0 (IBM Corp.; Armonk, NY, USA). Shapiro–Wilk test was used to evaluate the normality of the data. One-way analysis of variance (ANOVA) test was used to compare group differences. Tukey HSD (Honestly Significant Difference) test was used for post-hoc comparisons. Chi-square and Fisher's exact tests were used to evaluate qualitative data. A p value <0.05 was considered as significant.

RESULTS

SBS Test Results

The results of SBS tests are given in Table 1. There was no statistically significant difference in SBS between the groups (p=0.067). The Opalseal group showed the highest bond strength (12.56±2.32). The lowest bond strength was measured in the Proseal group (10.66±2.06).

ARI Scores

The results of ARI scores are given in Table 2. There was a statistically significant difference between the groups with respect to ARI scores (p=0.016 and p<0.05). There were no ARI scores of 0 and 3.

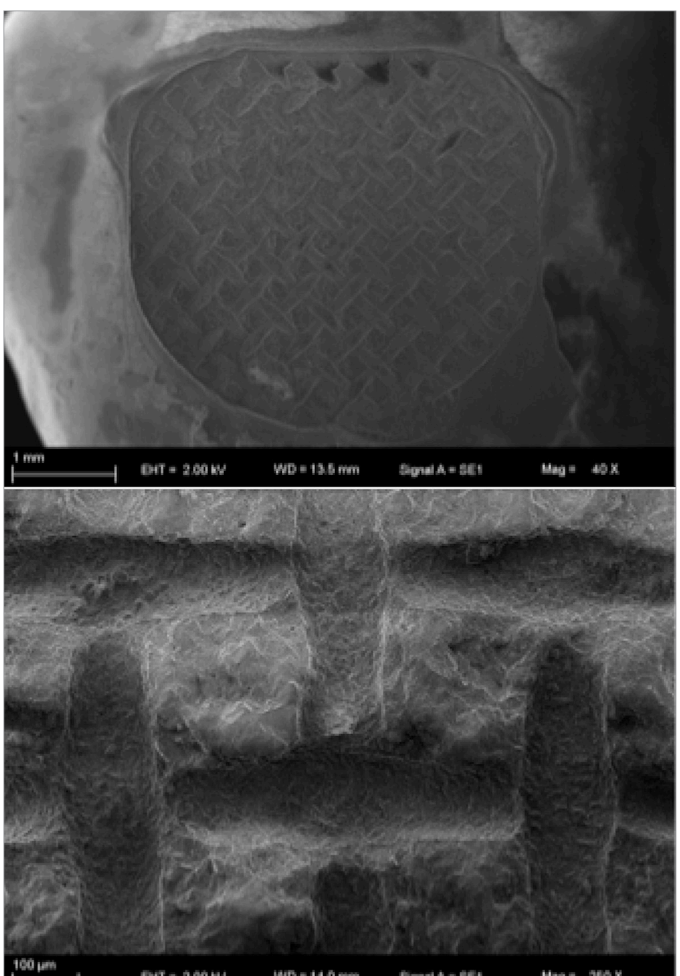

Figure 4. SEM view of the Transbond XT sample

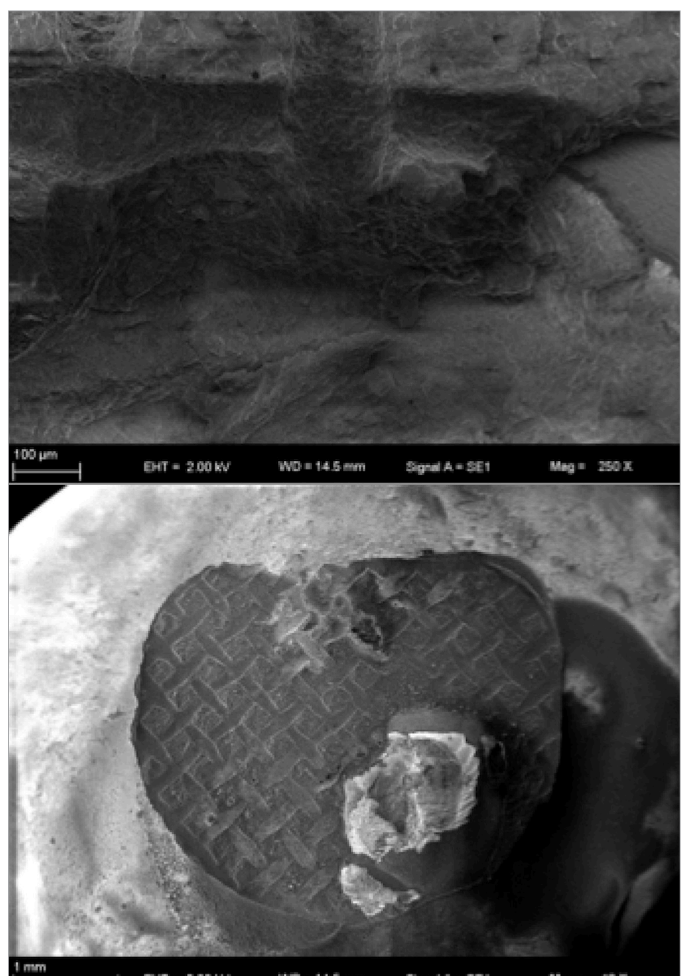

Figure 5. SEM view of the Clearfil sample

DISCUSSION

Fluoride-containing materials are widely used to prevent WSLs in orthodontic practice. It is possible to measure the bond strength of brackets in in vivo and in vitro conditions. Murray and Hobson reported that there is a difference in force values between these two conditions in their study (14). The mean bond strength values of brackets were found to be 9.78 MPa in vitro and 14.34 MPa in vivo. Researchers have usually preferred to perform in vitro bond strength tests instead of in vivo ones because of the difficulty of intraoral measurements of bond strength (10-12). Therefore, bond strength values were measured in vitro in the present study.

The incisor, premolar, and molar teeth can be used in SBS tests (10-12, 15). Human premolar teeth were used in the present

Table 1. Shear bond strength values of the compared groups stratified by one-way ANOVA test and Tukey HSD test results

	One-way ANOVA	Tukey HSD				
	Shear bond strength (MPa) Mean±SD		Mean difference	95% CI (min)	95% CI (max)	p
Transbond XT	11.55±3.06	Transbond XT–Clearfil	0.800	−2.875	1.275	0.743 (NS)
Clearfil	10.75±2.70	Transbond XT–Opalseal	1.010	−1.065	3.085	0.580 (NS)
Opalseal	12.56±2.32	Transbond XT–Proseal	0.890	−2.965	1.185	0.675 (NS)
Proseal	10.66±2.06	Clearfil–Opalseal	1.810	−0.265	3.885	0.109 (NS)
p	0.067 (NS)	Clearfil–Proseal	0.090	−2.165	1.985	0.999 (NS)
		Opalseal–Proseal	1.900	−3.975	0.175	0.084 (NS)

*p<0.05.
NS, non-significant.

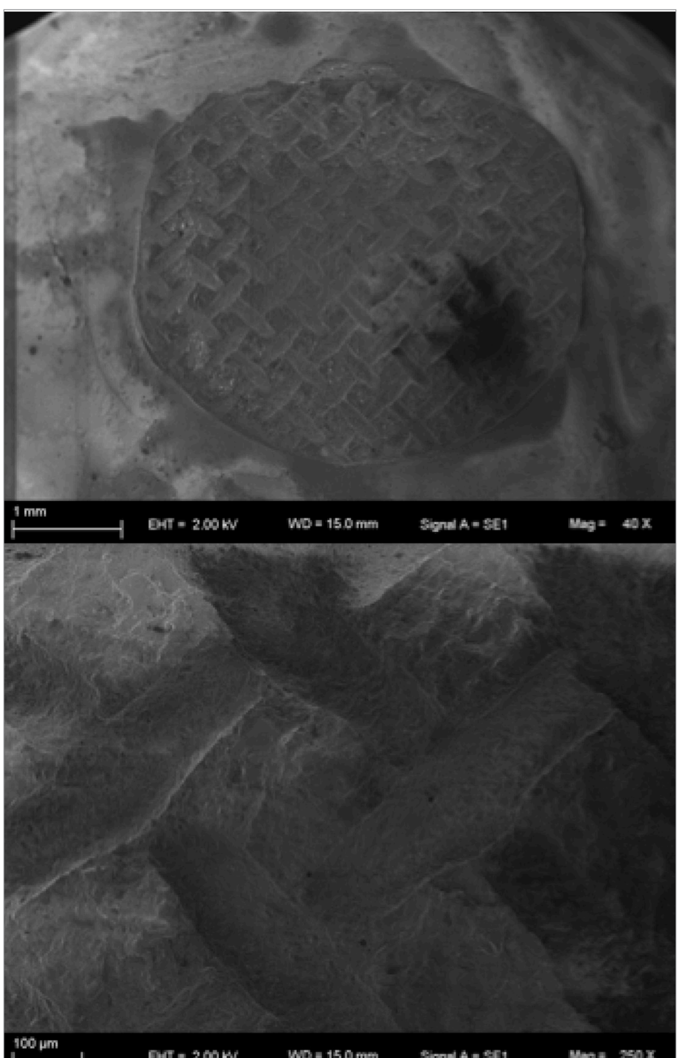

Figure 6. SEM view of the Opalseal sample

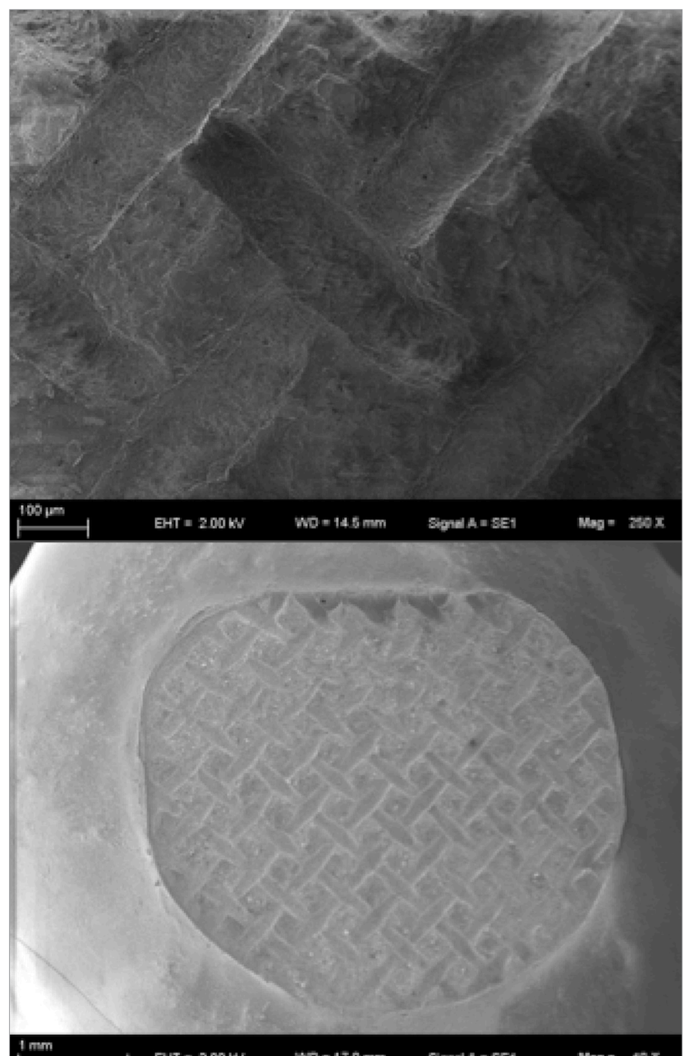

Figure 7. SEM view of the Proseal sample

Table 2. Comparison of ARI scores between the groups based on Fisher's exact and chi-square tests

	ARI scores n (%)			
	0	1	2	3
Transbond XT	0 (0)	5 (23.8)	16 (76.2)	0 (0)
Clearfil	0 (0)	0 (0)	21 (100)	0 (0)
Opalseal	0 (0)	0 (0)	21 (100)	0 (0)
Proseal	0 (0)	4 (19)	17 (81)	0 (0)

*p<0.05.

study because they can be easily obtained by orthodontic extractions.

Dental materials are subjected to thermal, mechanical, and chemical stresses in the mouth. Applying thermal cycle or water retention process to the dental materials allows to simulate oral conditions. Application of thermal cycling was previously reported to make a decrease in SBS values (16-18). The thermal cycling was usually conducted between 5 °C and 55 °C in different numbers of cycle, such as 500, 1000, 2000, 10,000, and 20,000. Bishara et al. (19) demonstrated that there is a significant reduction in bond strength of a cyanoacrylate-containing adhesive up to 80% after 500 cycles of thermal cycling. However, Hasegawa et al. (20) suggested that the effect of 500 rounds of thermal cycling will not be sufficient to change the bond strength. In light of this knowledge, 1000 rounds of thermal cycle between the temperatures of 5 °C and 55 °C were applied to the specimens in the present study.

Different brands of universal testing machines were previously used for SBS tests (10-12). The angle and the speed of the blade can change the reliability of SBS tests. As the angle of the applied force changes, the SBS is also affected. Klocke and Kahl-Nieke (21) reported that as the blade angle changes from +15° to −45°, the connection force values decrease from 22.9 MPa to 6.65 MPa. In our study, the parallelism of the blade to the long axis of the bracket was checked before each force application. Bishara et al. (22) stated that if the blade speed decreases from 5 to 0.5 mm/min, the bond strength increases from 7 to 12.2 MPa. The test reliability of in vitro studies decreases as the blade speed increases; therefore, we used a blade with a crosshead speed of 1 mm/min (10-12, 23).

Reynolds (2) stated that the bond strength values of the brackets should be in the range of 5.9–7.8 MPa or above in clinical and 4.9 MPa in laboratory conditions. Enamel fracture strength was known as 14 MPa, and it was reported that an increase in the risk of enamel fracture can be seen over the value of 10 MPa. The desired mean values of SBS were criticized in previous studies, but no consensus was present in the literature (25-27). All groups in our study provided sufficient SBS values.

Artun and Bergland (13) defined the ARI score to assess the adhesive remnants, which is still widely used today, and in our study, the original ARI score was performed (12, 23, 28, 29). The failure type is not only related with the applied debonding force but also related with the type of the adhesive and the bracket base design (29). In our study, although statistically significant differences were observed in ARI scores between the groups, the results were generally concentrated in ARI 2 score. Although bonding materials were different, the use of the same bracket and adhesive might have an effect on the similarity of ARI scores. The ARI 2 score shows that debonding occurred at the bracket–adhesive interface. Bishara et al. (30) advocated the failure that occurred in the bracket–adhesive interface and stated that this type of debonding can reduce enamel fractures.

The results of our study were compared with other similar studies in the literature. However, the lack of standardization in many factors, such as the type of teeth, storage conditions, preferred acid type, type of the adhesive, bracket type, light curing device, and light curing time, whether thermal cycle is applied or not, and the crosshead speed of the test device prevented us to perform the precise comparison. Korbmacher et al. (23) compared the SBS values of a conventional bonding agent (Transbond XT) with fluoride-releasing self-etching primer (Clearfil Protect Bond, CPB) and found that SBS results and ARI scores of their study were consistent with our study. Arhun et al. (31) evaluated the SBS values of Adper Prompt L-Pop (3M ESPE, St. Paul, MN, USA) self-etch adhesive, CPB, and Transbond plus self-etching primer (3M Unitek) in their study and found a significant difference between the groups. CPB showed the highest SBS value of 13.85±4.32 MPa. Although the etching process was not performed before application, the SBS values of CPB was higher than that of our study. Application of thermal cycle might have decreased the bond strength in this study. Tuncer et al. (10) assessed the SBS values of Transbond Self-etching Primer (3M Unitek) and Ortho-Coat, CPB, and CPB+Ortho-Coat. The mean SBS value of the CPB group was 13.48±1.78 MPa, which was higher than that of our study, and this result can be attributed to the absence of thermal cycle in their study. No significant difference was observed in ARI scores between the groups, and the majority of the failures were in the enamel–adhesive interface in contrast to our study. Minick et al. (28) used Aegis Ortho (Bosworth Co., IL, USA), CPB, iBond, Clearfil S3 Bond (Kuraray, USA), and Transbond XT (3M Unitek) combined with metal brackets and bovine teeth in their study. Transbond XT showed 10.05±0.84 MPa, and CPB showed a 7.5±0.79 MPa bond strength exactly after bonding. The specimens that were tested after 24 h showed 10.11±1.02 MPa and 6.09±0.56 MPa SBS values, respectively. Lower SBS values of samples may be related to the use of bovine teeth in that study. On the other hand, CPB showed clinically sufficient bond strength values, and the ARI scores were similar to our study. Raji et al. (32) assessed the SBS values of Transbond XT and CPB, and they could not find a significant difference between the groups. The SBS values and ARI scores of their study were consistent with our study. Soake et al. (33) evaluated the SBS values of Clearfil SE, CPB, Prompt L-Pop, and Reliance self-etching primer and found that the mean SBS value of CBP is 11.94±2.74 MPa, which was similar to our study.

Bishara et al. (34) investigated the effects of Proseal on the bond strength of orthodontic brackets comparing with conventional bonding agent, and no significant difference was found between the groups. Furthermore, the mean SBS value of the Proseal group was found to be 4.8±2.3 MPa. Although the SBS value of Proseal was clinically sufficient, it was quite low compared with the SBS value in this study. This difference may have been related to the application of SBS tests exactly 30 min after bonding of the brackets and use of molar teeth in that study. Paschos et al. (35) assessed conventional and self-etch adhesive systems whether they affect the bond strength. As a result, they found that the use of Proseal had no negative effect on the bond strength. The bond strength of Proseal after 500 cycles of thermal cycling showed a very close result (10.8±2.9 MPa) to our findings. Similar to our study, the ARI scores were concentrated in 2 scores. Varlik and Ulusoy (36) reported that Proseal does not have a significant effect on the SBS values of any group in their study. The Proseal–metal bracket combination group presented a mean value of 6.65±1.01 MPa, which was lower than that of our results. This difference may have originated from the use of different types of bracket and adhesive.

Hofmann et al. (37) combined three different kinds of fluoride-releasing bonding materials and a conventional bonding agent (Transbond XT) with four different kinds of orthodontic brackets. Similar to our study, they stated that all bonding materials presented adequate SBS values for clinical application. Furthermore, Transbond XT showed the highest SBS values among the other fluoride-releasing agents.

Kirschneck 2019 et al. (38) used Proseal in their prospective split-mouth study, and they stated that the use of enamel sealant before bracket bonding may increase the probability of bond failure especially in the lower jaw. They concluded that it is more suitable to use fluoride-releasing materials adjacent to the brackets after bracket bonding.

The nature of the present study was a limitation, and in vivo studies would provide more precise knowledge about this issue.

The study would be more valuable if the calcium and fluoride mass of the enamel could be measured with energy dispersive X-ray microanalysis.

CONCLUSION

- There was no statistically significant difference between mean SBS values of the Transbond XT, Clearfil SE Bond, Opalseal, and LED Proseal groups. The null hypothesis was accepted.
- The highest SBS values were measured in the Opalseal group, followed by the Transbond XT, Clearfil SE Protect Bond, and Proseal groups, respectively.
- The bond strength of all groups were above the desired SBS value of 6-8 MPa.

Ethics Committee Approval: Ethics committee approval was received for this study from the Research Ethics Committee of İstanbul Medipol University (protocol no. 10840098-604.01.01-E.5731, 21/04/2016).

Informed Consent: N/A.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - G.S.; Design - GS.; Supervision - G.S.; Resources - D.Y.; Materials - D.Y.; G.S.; Data Collection and/or Processing - G.S., D.Y.; Analysis and/or Interpretation - G.S.; Literature Search - D.Y.; Writing Manuscript - G.S.; Critical Review - G.S.

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

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REFERENCES

1. Buonocore MG. A simple method of increasing the adhesion of acrylic filling materials to enamel surfaces. J Dent Res 1955; 34: 849-53. [CrossRef]
2. Sudjalim TR, Woods MG, Manton DJ. Prevention of white spot lesions in orthodontic practice: a contemporary review. Aust Dent J 2006; 51: 284-90. [CrossRef]
3. Gorelick L, Geiger AM, Gwinnett AJ. Incidence of white spot formation after bonding and banding. Am J Orthod 1982; 81: 93-8. [CrossRef]
4 Mizrahi E. Enamel demineralization following orthodontic treatment. Am J Orthod 1982; 82: 62-7. [CrossRef]
5. Geiger AM, Gorelick L, Gwinnett AJ, Griswold PG. The effect of a fluoride program on white spot formation during orthodontic treatment. Am J Orthod Dentofacial Orthop 1988; 93: 29-37. [CrossRef]
6. Lundström F, Krasse B. Streptococcus mutans and lactobacilli frequency in orthodontic patients; the effect of chlorhexidine treatments. Eur J Orthod 1987; 9: 109-16. [CrossRef]
7 Bishara SE, VonWald L, Laffoon JF, Warren JJ. Effect of a self etch primer/adhesive on the shear bond strength of orthodontic brackets. Am J Orthod Dentofacial Orthop 2001; 119: 621-4. [CrossRef]
8. Fjeld M, Øgaard B. Scanning electron microscopic evaluation of enamel surfaces exposed to 3orthodontic bonding systems. Am J Orthod Dentofacial Orthop 2006; 130: 575-81. [CrossRef]
9. Cossellu G, Lanteri V, Butera A, Laffi N, Merlini A, Farronato G. Timing considerations on the shear bond strength of orthodontic brackets after topical flüoride varnish applications. J Orthod Sci 2017; 6: 11-5. [CrossRef]
10. Tuncer C, Tuncer BB, Ulusoy C. Effect of fluoride-releasing light-cured resin on shear bond strength of orthodontic brackets. Am J Orthod Dentofacial Orthop 2009; 135: 14.e1-6; discussion 14-5. [CrossRef]
11. Korbmacher HM, Huck L, Kahl-Nieke B. Fluoride-releasing adhesive and antimicrobial self-etching primer effects on shear bond strength of orthodontic brackets. Angle Orthod 2006; 76: 845-50.
12. Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods 2007; 39: 175-91. [CrossRef]
13. Artun J, Bergland S. Clinical trials with crystal growth conditioning as an alternative to acid-etch enamel pretreatment. Am J Orthod 1984; 85: 333-40. [CrossRef]
14. Murray SD, Hobson RS. Comparison of in vivo and in vitro shear bond strength. Am J Orthod Dentofacial Orthop 2003; 123: 2-9. [CrossRef]
15. Baysal A, Yasa A, Sogut O, Ozturk MA, Uysal T. Effects of different orthodontic primers on enamel demineralization around orthodontic brackets. J Orofac Orthop 2015; 76: 421-30. [CrossRef]
16. Elekdag-Turk S, Turk T, Isci D, Ozkalayci N. Thermocycling effects on shear bond strength of a self-etching primer. Angle Orthod 2008; 78: 351-6. [CrossRef]
17. Sokucu O, Siso SH, Ozturk F, Nalcaci R. Shear Bond Strength of Orthodontic Brackets Cured with Different Light Sources under Thermocycling. Eur J Dent 2010; 4: 257-62. [CrossRef]

18. Al Jabbari YS, Al Taweel SM, Al Rifaiy M, Alqahtani MQ, Koutsoukis T, Zinelis S. Effects of surface treatment and artificial aging on the shear bond strength. Angle Orthod 2014; 84: 649-55. [CrossRef]
19. Bishara SE, Ajlouni R, Laffoon JF. Effect of thermocycling on the shear bond strength of a cyanoacrylate orthodontic adhesive. Am J Orthod Dentofacial Orthop 2003; 123: 21-4. [CrossRef]
20. Hasegawa T, Retief DH, Russell CM, Denys FR. Shear bond strength and quantitative microleakage of a multipurpose dental adhesive system resin bonded to dentin. J Prosthet Dent 1995; 73: 432-8. [CrossRef]
21. Klocke A, Kahl-Nieke B. Effect of debonding force direction on orthodontic shear bond strength. Am J Orthod Dentofacial Orthop 2006; 129: 261-5. [CrossRef]
22. Bishara SE, Soliman M, Laffoon J, Warren JJ. Effect of changing a test parameter on the shear bond strength of orthodontic brackets. Angle Orthod 2005; 75: 832-5.
23. Korbmacher H, Huck L, Adam T, Kahl-Nieke B. Evaluation of an antimicrobial and fluoride-releasing self-etching primer on the shear bond strength of orthodontic brackets. Eur J Orthod 2006; 28: 457-61. [CrossRef]
24. Reynolds IR. A review of direct orthodontic bonding. Br J Orthod 1975; 2: 171-8. [CrossRef]
25. Henkin FS, Macêdo ÉO, Santos KD, Schwarzbach M, Samuel SM, Mundstock KS. In vitro analysis of shear bond strength and adhesive remnant index of different metal brackets. Dental Press J Orthod 2016; 21: 67-73. [CrossRef]
26. Oz AA, Oz AZ, Arici S. In-vitro bond strengths and clinical failure rates of metal brackets bonded with different light-emitting diode units and curing times. Am J Orthod Dentofacial Orthop 2016; 149: 212-6. [CrossRef]
27. Finnema KJ, Ozcan M, Post WJ, Ren Y, Dijkstra PU. In-vitro orthodontic bond strength testing: a systematic review and meta-analysis. Am J Orthod Dentofacial Orthop 2010; 137: 615-22. [CrossRef]
28. Minick GT, Oesterle LJ, Newman SM, Shellhart WC. Bracket bond strengths of new adhesive systems. Am J Orthod Dentofacial Orthop 2009; 135: 771-6. [CrossRef]
29. O'Brien KD, Watts DC, Read MJ. Residual debris and bond strength-is there a relationship? Am J Orthod Dentofacial Orthop 1988; 94: 222-30. [CrossRef]
30. Bishara SE, Oonsombat C, Ajlouni R, Laffoon JF. Comparison of the shear bond strength of 2 self-etch primer/adhesive systems. Am J Orthod Dentofacial Orthop 2004; 125: 348-50. [CrossRef]
31. Arhun N, Arman A, Sesen C, Karabulut E, Korkmaz Y, Gokalp S. Shear bond strength of orthodontic brackets with 3 self-etch adhesives. Am J Orthod Dentofacial Orthop 2006; 129: 547-50. [CrossRef]
32. Raji S, Ghorbanipour R, Majdzade F. Effect of clearfil protect bond and transbond plus self-etch primer on shear bond strength of orthodontic brackets. Dent Res J (Isfahan) 2011; 8: 94-9.
33. Sorake A, Rai R, Hegde G, Suneja R, Kumar N,Skaria J. Comparison of shear bond strength of new self-etching primer with conventional self-etching primers: An in-vitro study. J Int Oral Health 2015; 7: 17-21.
34. Bishara SE, Oonsombat C, Soliman MM, Warren J. Effects of using a new protective sealant on the bond strength of orthodontic brackets. Angle Orthod 2005; 75: 243-6.
35. Paschos E, Okuka S, Ilie N, Huth KC, Hickel R, Rudzki-Janson I. Investigation of shear-peel bond strength of orthodontic brackets on enamel after using Pro Seal. J Orofac Orthop 2006; 67: 196-206. [CrossRef]
36. Varlik SK, Ulusoy C. Effect of light-cured filled bonding bonding of metal and ceramic brackets with a resin-modified glass ionomer cement. Am J Orthod Dentofacial Orthop 2009; 135: 194-8. [CrossRef]
37. Hofmann E, Elsner L Hirschfelder U, Ebert T, Hanke S. Effects of enamel sealing on shear bond strength and the adhesive remnant index: Study of three three fluoride-releasing adhesives in combination with metal and ceramic bracket. J Orofac Orthop. 2017; 78: 1-10. [CrossRef]
38. Kirschenck C, Rohn C, Proff P, Reicheneder C. Influence of enamel sealing with a light-cured filled sealant before bracket bonding on the bond failure rate during fixed orthodontic therapy. J Orofac Orthop 2019; 80: 136-43. [CrossRef]

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Review

Changes in Upper Airway Dimensions Following Orthodontic Treatment of Skeletal Class II Malocclusion with Twin Block Appliance: A Systematic Review

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ABSTRACT

Objective: This systematic review intends to evaluate the dimensional changes in upper airway dimensions (UAD) of the respiratory tract subsequent to orthodontic treatment of skeletal Class II malocclusion with Twin Block Appliance (TBA).

Methods: The quality of reporting systematic reviews and meta-analyses was decided by the PRISMA standards with PROSPERO registration number CRD42017060317. The systematic search included EMBASE, MEDLINE, Psych INFO, Scopus, CINAHL, and other reference journals and review articles. The article search was performed from March 2017 until November 2017. Cochrane's risk of bias in non-randomized studies – of interventions (ROBINS-I) was used to grade the methodological quality of the included studies.

Results: The screening procedure identified 302 studies, among which seven studies satisfied the inclusion criteria for eligibility. The UAD at the pretreatment time varied from 7.2 mm to 41.9 mm with a mean of 14.16 mm. The post-treatment change in UAD ranged from 8.2 mm to 43.7 mm with a mean of 15.6 mm.

Conclusion: There was a significant increase in UAD following the TBA treatment in the patient group as compared to the control group.

Keywords: Systematic review, twin block appliance, upper airway, Class II malocclusion

INTRODUCTION

Class II malocclusion is one of the most commonly encountered problems in orthodontic practice and is associated with functional, esthetic, and psychological problems of varying intensities. A change in the upper airway volume due to narrowing of the airway dimensions is a commonly encountered problem in developing Class II malocclusion with a retrognathic mandible (1). The retarded mandible causes the backward displacement of the tongue and hyoid bone, which in turn leads to a reduction in the upper airway volume. Constriction of the upper airway is one of the causative factors for the development of obstructive sleep apnea (OSA) syndrome (2). A majority of patients with OSA present with skeletal Class II malocclusion with a deficient mandible. Studies have shown that the nasopharyngeal area and depth were significantly higher among individuals with normal occlusion as compared to subjects with Class II malocclusion and the oropharyngeal airway volume was directly correlated with the length of the mandible (1, 2).

Many treatment modalities have been developed to treat Class II malocclusion with a retrognathic mandible. Functional appliances like mandibular advancement devices, activator headgear treatment, Twin block appliances, and fixed appliances like Forsus-fixed functional appliance and fixed appliance with activator headgear were used with or without surgical correction (3-7). Studies have shown that if the skeletal Class II malocclusion

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is diagnosed at an early age, the best treatment option is the use of functional appliances, which allows the forward growth of the mandible and prevents upper airway collapse during sleep (7, 8). However, the functional appliance treatment requires patient cooperation in order to be effective, which is often a major problem. The Twin Block appliance (TBA) is one of the preferred removable functional appliances used in correcting retrognathic mandible in Class II malocclusion (7, 9-16). A majority of the studies showed the use of TBA increases pharyngeal airway dimensions through the forward movement of the mandible and hyoid bone (7, 9-14); few studies showed negative results (15, 17). Thus, the effect of TBA on upper airway dimensions (UAD) remains uncertain. Previously, two systematic reviews have been conducted to assess the changes in airway dimensions following functional appliance treatment of Class II malocclusion (18, 19). The evaluation of the dimensional changes in upper airway subsequent to orthodontic treatment of skeletal Class II malocclusion with TBA was the principal objective of this systematic review.

METHODS

The systematic review is constructed in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) standards of quality for the planning, conducting, and reporting of systematic reviews and meta-analyses (20). The review did not necessitate the approval from the Institutional Review Board and is registered under PROSPERO (CRD42017060317).

Questions

The study focused on the quantitative effects of the TBA on UAD changes in Class II malocclusion. The PICO format was used to define the research questions of the present systematic review, which is as follows:

P (Population/Patients): The human subjects with skeletal Class II malocclusion treated with TBA.

I (Intervention): TBA in skeletal Class II malocclusion.

C (comparison): Subjects not received or receiving any treatment with another appliance.

O (Outcome): Changes in UADs (in mm).

Study Eligibility

Only previously published studies in the English language that investigated the changes in UAD following TBA treatment of Class II malocclusion were included in the study. The editorial letter, case report, in vitro studies, not investigating the changes in UAD subsequent to Class II malocclusion treatment with TBA, studies with syndromes, and cleft lip or palate studies were excluded from the research

Study Identification

The database search performed included Medline (PubMed, OVID Medline, and Ebsco), Cochrane library (Cochrane review, Trails), Web of Knowledge (Social science, conference abstract), Embase (European studies, pharmacological literature, conference abstract), CINAHL (Nursing and allied health), PsycInfo (Psychology and psychiatry), SCOPUS (Conference abstracts, scientific web pages), and ERIC (Education) for specific search strategy with focused key terms (Class II malocclusion, skeletal, occlusion, upper airway, pharyngeal airway, nasopharyngeal airway, oropharyngeal airway, volume, dimensions, changes, evaluation, Twin block appliance, Clarks twin block, TB).

The gray literature search was performed using the following databases: Google Scholar, National Library of Medicine, Social science research for thesis (EthOS, DART-Europe), Open Grey, Institutional repositories (OpenDOAR, Bielefeld Base, Lenus, RIAN, e-publications@RCSI). In addition, four key orthodontic journals (Angle Orthodontics, American Journal of Orthodontics and Dentofacial Orthopedics, Journal of Clinical Orthodontics, and European Journal of Orthodontics) were searched from their table of contents for relevant articles. The article search was performed from March 2017 until November 2017.

Study Selection

All the titles and abstracts were screened independently and duplicated to be included in the study. An intra-class correlation coefficient of 0.86 was achieved in inter-rater agreement for study inclusion. Any conflicts among the reviewers were addressed by discussion to arrive at a consensus.

Risk of Bias Assessment

Cochrane's tool of the risk of bias in ROBINS-I was used to assess the risk of bias (21). The domains used to assess the risk of bias are summarized in Table 2. The included studies were further graded for each domain as low risk, moderate risk, serious risk, and critical risk of bias using standardized criteria. The studies were comparable to a well-performed clinical randomized trial and the domain in question was considered as having a low risk of bias. The studies which could not be compared to well-performed randomized trials but were sound for a non-randomized trial within the domain were considered as having a moderate risk of bias. The studies containing some important problems were categorized under serious risk of bias. The studies which were too problematic to provide any useful evidence on the effect of the intervention or which give no information on the basis of the judgment were categorized under critical risk of bias.

Data Extraction and Data Synthesis

The data was extracted independently by two reviewers for the included studies using a data extraction sheet and any discrepancies were resolved by arriving at a consensus through discussion. The data extracted from each included study was: first author, publication year, study type, study quality, sample size, inclusion criteria, treatment type, UAD changes (before, after, and long-term treatment), statistical analysis used, and the authors' conclusion.

RESULTS

Trail Flow

Our search strategy yielded 293 articles and an additional 9 articles were identified from the review of references and journal

Table 1. Descriptive data of included studies

Author/year	Study design	Malocclusion criteria	Intervention type	Statistical analysis	Study conclusion
Verma /2012	R	Class II division 1 G1, G2, G3, ANB >4° (SN +3 mm)	TBA	Paired t-test and One-way ANOVA	Significant increase in PAD
Vinoth /2013	R	Skeletal Class II with RM (SNB < 80), ANB > 4°, CVM- stage 2 or 3	S - TBA	Paired t-test	Significant increase in PAD
Jena /2013	P	Class II, division 1 malocclusion with RM, FMA -20° to 25°	S – TBA C –MPA	Paired t-test and One way ANOVA	TBA more effective in increasing PAD compared to MPA
Zhang / 2013	P	Skeletal Class II with RM, ANB > 3°, SNB < 80°, incisor over jet > 3mm	TBA	Paired t-test	Significant increase in PAD
Ghodke/2014	P	Skeletal Class II with RM, SNB ≤ 76°, FMA - 20° to 28°	S – TBA C – Minor ortho treatment	Paired t-test	Significant increase in PAD following TBA
Ali /2015	R	Skeletal Class II malocclusion with RM, SNB < 78°, ANB > 4°	S – TBA followed by fixed mechanotherapy C – no treatment	Mann-Whitney U test	Significant increase in PAD following TBA, remained stable for 2.5 years
Chand / 2017	P	Skeletal Class II with RM	TBA	Paired t-test	Significant increase in PAD

P: prospective study; R: retrospective study; S: study group; C: control group, G: growing subjects; RM: retrognathic mandible; CVM: cervical vertebral maturity; FMA: frankfort mandibular plane angle; TBA: twin block appliance; MPA: mandibular protraction appliance; PAD: pharyngeal airway dimensions; PAV: pharyngeal airway volume; ANOVA: analysis of variance; S: strong; M: moderate; W: weak; G1: group 1; hypo-divergent (SN-MP: <31°); G2: group 2, normodivergent (SN-MP: 31°–34°); G3: group 3, hyper-divergent (SN-MP: >34°)

Table 2. Risk of bias assessment of included studies using Cochrane's risk of bias in non-randomized studies of interventions (ROBINS-I)

	Author						
ROBINS –I criteria	Verma	Vinoth	Jena	Zhang	Ghodke	Ali	Chand
BC	L	L	L	L	L	L	L
BSP	L	L	L	L	M	L	M
BCI	S	L	L	L	L	M	L
BDI	M	M	L	M	M	M	M
BMD	M	M	L	L	L	L	L
BMO	L	L	L	L	M	M	L
BSR	L	L	L	L	L	L	L
Overall bias	M	M	L	L	M	M	M

BC: bias due to confounding; BSP: bias in selection of participants into the study; BCI: bias in classification of interventions; BDI: bias due to deviations from intended interventions; BMD: bias due to missing data; BMO: bias in measurement of the outcomes; BSR: bias in selection of the reported result; L: low risk of bias; M: moderate risk of bias; S: serious risk of bias; C: critical risk of bias; NI: no information

indices. Among these, 7 articles were identified as suitable for inclusion in the present systematic review (Figure 1).

Study Characteristics and Study Quality

The data were available from the year 2012 to 2017. Out of the 7 studies included in the review, 4 were prospective studies (2 without controls and 2 without control). Three studies were retrospective studies (2 without controls and 1 with control) (Table 1). Five studies were graded as a moderate risk of bias and 2 studies were graded as low risk of bias (Table 2). The number of study participants ranged from 14 to 74 (total n=274), with a mean of 39.14. In all of the included studies, lateral cephalogram was used to analyze the upper airway changes. Mean active treatment duration ranged from 4 months to 14.5 months (Table 3).

Changes in Upper Airway Dimension (UAD)

The UAD at the pretreatment time varied from 7.2 mm to 41.9 mm with a mean of 14.16 mm. The post-treatment change in UAD ranged from 8.2 mm to 43.7 mm with a mean of 15.6 mm. All of the included studies showed a significant increase in UAD following the TBA treatment as compared to the control group (Table 4).

DISCUSSION

The use of functional appliances in the treatment of developing Class II malocclusion with retrognathic mandible can bring the mandible forward, prevent the posterior relocation of the tongue, and improve pharyngeal airway passage (8). The present systematic review was conducted to evaluate the dimensional

Table 3. Summary of sample size, malocclusion type, extraction, retainers used, and treatment duration

Author	Sample size (male, female)/ mean age in years	Reliability measurement	Measurement technique	Upper Airway measurement	Mean active treatment duration
Verma	40 (18, 22)/11.4	12 radiographs at 15 day interval	Cephalometric	Posterior outline of soft palate to PPW	NA
Vinoth	25 (12, 13)/11-13 y	NA	Cephalometric	AA to PNS	14.5 m
Jena	S – 21 (11, 10)/11.3 C – 16 (9, 7)/12.8	NA	Cephalometric	NA	S – 9.3 m, C -6.1 m
Zhang	46 (31, 15)/9.7	10 randomly selected radiographs	Cephalometric	PNS to Gonion plane	10.8 m
Ghodke	S – 20 (11, 9)/ 10.9 C – 18 (9, 9)/ 10.9	10% randomly selected radiographs at 15 day interval	Cephalometric	NA	S – 8.2 m C – 7.3 m
Ali	S – 42 (21, 21)/10.4 C – 32 (16, 16)/10.1	30 radiographs at 1 month interval, ANB > 4mm	Cephalometric	Perpendicular line dropped on S-Ba from PNS.	S - 8.1 m followed-fixed therapy, 28.3 m C – 3 m
Chand	14/12-14 y	14 radiographs at 15 days interval	Cephalometric	PNS to the posterior wall of the pharynx	4-5 m

S: study group; C: control group; m: months; y: years, CBCT: cone-beam computed tomography scans; AB: anterior boundary; PB: posterior boundary; SB: superior boundary; IB: inferior boundary; S: sella; PNS: posterior nasal spine; SPW: superior pharyngeal wall; SP: soft palate plane; EB: epiglottis plane; PNS: posterior nasal spine; AA: anterior arch of atlas; PPW: posterior pharyngeal wall; PTM: pterygomaxillary points; NA: not available

Table 4. Summary of results of included studies (Upper airway dimensions (UAD): before, after, and long-term follow-up)

Author		T1 UAD mm mean (SD)	T2 UAD mm mean (SD)	T3 UAD mm mean (SD)	T2-T1 mm (SD)	T3-T1 mm (SD)
Verma	G1	12.4 (2.4)	13.6 (2.3)	NA	1.3 (2.3)*	NA
	G2	12.1 (3.5)	13.2 (3.0)	NA	1.3 (1.3)*	NA
	G3	10.5 (1.4)	12.0 (1.8)	NA	1.4 (0.9)*	NA
Jena	S	7.2 (2.04)	9.4 (2.7)*	NA	NA	NA
	C	7.7 (3.6)	8.6 (3.7)	NA	NA	NA
Zhang		8.7 (1.8)	12.4 (2.3)**	NA	NA	NA
Ghodke	S	9.1 (2.03)	10.7 (2.4)**	NA	NA	NA
	C	7.8 (2.1)	8.7 (1.8)	NA	NA	NA
Ali	S	32.9 (4.5)	33.8 (4.2)*	35.5 (4.6)	0.69	2.6 (1.5) *
	C	41.9 (4.5)	43.7 (4.4)	NA	NA	1.8 (1.9)
Chand		7.6 (0.7)	8.2 (0.8)*	NA	0.6 (0.5)	NA
Vinoth		12.02	13.1*	NA	1.08	NA

* - P <0.05, ** P <0.001, G1: Group 1, hypo-divergent (SN-MP: <31°), G2: Group 2, normodivergent (SN-MP: 31°–34°), G3: group 3, hyper-divergent (SN-MP: >34°), S: study group, C: control group

changes in upper airway following orthodontic treatment of skeletal Class II malocclusion with TBA.

Inclusion Criteria: In the present study, individuals with Class II skeletal malocclusion were included because the degree of displacement of hyoid bone (superiorly and posteriorly) was greater in Class II malocclusion as compared to Class I. TBA is most commonly used in these malocclusions to increase the UAD by causing functional mandibular displacement (10-13). The present systematic review is done in accordance with PRISMA standards (20) because they are associated with better reporting of included study quality with a better assessment of bias within and across the studies included in the present review.

Changes in Upper Airway Dimension: All the included studies showed a significant increase in UAD following the TBA treatment as compared to the controls. The expansion of the maxillary arch, along with the forward growth of mandible leads to forward relocation of the tongue, thereby increasing the posterior tongue space (7, 10-13, 15, 16). The study by Verma et al. (13) showed a significant increase in UAD among individuals with skeletal Class II malocclusion following treatment with TBA. However, there were no significant changes in the lower pharynx. This may be attributed to the fact that TBA causes mandibular advancement and forward positioning of the tongue, which in turn relieves the pressure on the soft palate, thus leading to an increase in upper oropharyngeal dimension and improved airway permeability. The growth of oropharyngeal muscles caused by forward move-

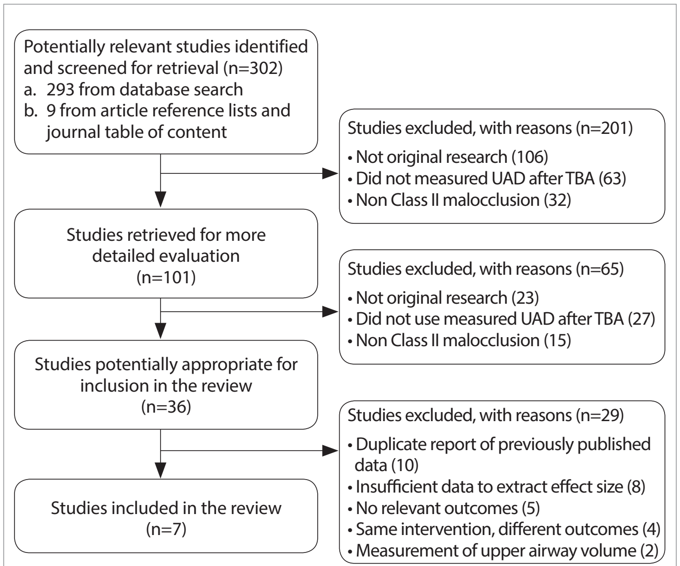

Figure 1. Flow diagram showing the subject selection of the systematic review

ment of the mandible increases UAD. Studies (1-4) have shown a positive correlation between upper airway space and the length of the mandible. Retrognathic mandible results in the reduction in UAD by causing the tongue to be positioned posteriorly. TBAs are constructed in a protrusive bite that effectively modifies the occlusal inclined plane, which causes forward growth of the mandible and in turn increases UAD (9, 14).

Method of measurement of airway dimensions: All the studies which measured the UAD used the two-dimensional lateral cephalograms (7, 10-13, 15, 16). The main limitation with lateral cephalogram is that it cannot reveal changes in the transverse dimension but the alternative of CBCT imaging is associated with high radiation dose (9, 14, 22, 23). As the area measurements of the pharyngeal airway correlate more closely with linear measurements than that of the three-dimensional measurements, the conventional lateral cephalogram still remains a reliable diagnostic tool for monitoring the pharyngeal dimensions when utilizing area measurements.

This systematic review presented with a limitation; a meta-analysis could not be performed because there was heterogeneity across the studies. Heterogeneity results from differences in race and variations in growth patterns, which act as confounders and controls in case of ethical limitations. The construction of forest plots or funnel plots was not appropriate for the included studies. A simple descriptive and stratified comparison was able to be reported due to the disparate nature of the studies.

CONCLUSION

From the results of the explicitly selected studies included in this systematic review, it can be concluded that the use of Twin Block appliance for the correction of Class II skeletal malocclusion resulted in significantly greater improvement in increasing the UAD from 7.2 mm to 41.9 mm with a mean of 14.16 mm at pretreatment time to 8.2 mm to 43.7 mm with a mean of 15.6 mm at post-treatment time as compared to the controls.

Peer-review: Externally peer-reviewed.

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REFERENCES

1. Indriksone I, Jakobsone G. The upper airway dimensions in different sagittal craniofacial patterns: a systematic review. Stomatologija 2014;16:109-17.
2. Katyal V, Pamula Y, Martin AJ, Daynes CN, Kennedy JD, Sampson WJ. Craniofacial and upper airway morphology in pediatric sleep-disordered breathing: Systematic review and meta-analysis. Am J Orthod Dentofacial Orthop 2013;143:20-30. [CrossRef]
3. Buck LM, Dalci O, Darendeliler MA, Papageorgiou SN, Papadopoulou AK. Volumetric upper airway changes after rapid maxillary expansion: a systematic review and meta-analysis. Eur J Orthod 2017; 39: 463-73. [CrossRef]
4. Mattos CT, Vilani GN, Sant'Anna EF, Ruellas AC, Maia LC. Effects of orthognathic surgery on oropharyngeal airway: a meta-analysis. Int J Oral Maxillofac Surg 2011; 40: 1347-56. [CrossRef]
5. Hanggi MP, Teuscher UM, Roos M, Peltomaki TA. Long-term changes in pharyngeal airway dimensions following activator-headgear and fixed appliance treatment. Eur J Orthod 2008; 30: 598-605. [CrossRef]
6. Temani P, Jain P, Rathee P, Temani R. Volumetric changes in pharyngeal airway in Class II division 1 patients treated with Forsus fixed functional appliance: A three- dimensional cone beam computed tomography study. Contemp Clin Dent 2016; 7: 31-5. [CrossRef]
7. Ghodke S, Utreja AK, Singh SP, Jena AK. Effects of twin-block appliance on the anatomy of pharyngeal airway passage (PAP) in class II malocclusion subjects. Prog Orthod 2014; 15: 68. doi: 10.1186/s40510-014-0068-3. [CrossRef]
8. Xiang M, Hu B, Liu Y, Sun J, Song J. Changes in airway dimensions following functional appliances in growing patients with skeletal class II malocclusion: A systematic review and meta-analysis. Int J Pediatr Otorhinolaryngol 2017 ;97: 170-80. [CrossRef]
9. Li L, Liu H, Cheng H, Han Y, Wang C, Chen Y, et al. CBCT evaluation of the upper airway morphological changes in growing patients of class II division 1 malocclusion with mandibular retrusion using twin block appliance: a comparative research. PLoS One 2014; 9: doi: 10.1371/journal.pone.0094378. eCollection 2014. [CrossRef]
10. Jena AK, Singh SP, Utreja AK. Effectiveness of twin-block and Mandibular Protraction Appliance-IV in the improvement of pharyngeal airway passage dimensions in Class II malocclusion subjects with a retrognathic mandible. Angle Orthod 2013; 83: 728-34. [CrossRef]
11. Ali B, Shaikh A, Fida M. Effect of Clark's twin-block appliance (CTB) and non-extraction fixed mechano-therapy on the pharyngeal dimensions of growing children. Dental Press J Orthod 2015; 20: 82-8. [CrossRef]
12. Vinoth SK, Thomas AV, Nethravathy R. Cephalomteric changes in airway dimensions with twin block therapy in growing Class II patients. J Pharm Bioallied Sci 2013; 5(Suppl 1): S25-9. [CrossRef]

13. Verma G, Tandon P, Nagar A, Singh GP, Singh A. Cephalometric evaluation of hyoid bone position and pharyngeal spaces following treatment with Twin block appliance. J Orthod Sci 2012; 1: 77-82. [CrossRef]
14. Elfeky Hy, Fayed MMS. Three-dimensional effects of twin block therapy on pharyngeal airway parameters in Class II malocclusion patients. J World Federation of Orthod 2015; 4: 114-9. [CrossRef]
15. Chand K, Jacob S, Charles A. Assesment of changes in the sagittal pharyngeal airway dimensions post twin block therapy using polar planimeter. J Res in Dent Sci 2017; 3: 51-7.
16. Zhang C, He H, Ngan P. Effects of twin block appliance on obstructive sleep apnea in children: a preliminary study. Sleep Breath 2013; 17: 1309-14. [CrossRef]
17. O'Brien K, Wright J, Conboy F, Sanjie Y, Mandall N, Chadwick S, et al. Effectiveness of early orthodontic treatment with the Twin-block appliance: A multicenter, randomized, controlled trial. Part 1: Dental and skeletal effects. Am J Orthod Dentofacial Orthop 2003; 124: 234-43. [CrossRef]
18. Kannan A, Sathyanarayana HP, Padmanabhan S. Effect of functional appliances on the airway dimensions in patients with skeletal class II malocclusion: A systematic review. J Orthod Sci 2017; 6: 54-64. [CrossRef]
19. Xiang M, Hu B, Liu Y, Sun J, Song J. Changes in airway dimensions following functional appliances in growing patients with skeletal class II malocclusion: A systematic review and meta-analysis. Int J Pediatr Otorhinolaryngol 2017; 97: 170-80. [CrossRef]
20. Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. J Clin Epidemiol 2009; 62: 1006-12. [CrossRef]
21. Sterne JA, Hernan MA, Reeves BC, Savovic J, Berkman ND, Viswanathan M, et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. BMJ 2016; 355: doi: 10.1136/bmj.i4919. [CrossRef]
22. Aboudara C, Nielsen I, Huang JC, Maki K, Miller AJ, Hatcher D. Comparison of airway space with conventional lateral headfilms and 3-dimensional reconstruction from cone-beam computed tomography. Am J Orthod Dentofacial Orthop 2009; 135: 468-79. [CrossRef]
23. Aboudara CA, Hatcher D, Nielsen IL, Miller A. A three-dimensional evaluation of the upper airway in adolescents. Orthod Craniofac Res 2003;6 (Suppl 1): 173-5. [CrossRef]

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Case Report

Class III Malocclusion Treated by Combined Orthodontic and Orthognathic Approach Along with Growth Prediction: A Case Report

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ABSTRACT

To devise a comprehensive treatment strategy for patients with Class III malocclusion, it is critical to address etiology in the process of differential diagnosis. Growth prediction has always been a part of the deduction science. It is important not only in treatment planning and treatment provision, but it is equally important in the evaluation of prognosis during retention and after retention. The visual treatment objective by Ricketts is a complete analysis and the first of its kind defining every aspect of malocclusion and also assessing where the etiology lies. Here, we present one such case of skeletal Class III in which the growth prediction has played a vital role in the comprehensive treatment planning and treatment outcome.

Keywords: Growth prediction, orthognathic surgery, skeletal discrepancy

INTRODUCTION

The incidence of Class III malocclusion comprises a meager amount of the average orthodontic practice, but these are among the most demanding and at the same time rewarding cases to treat effectively and comprehensively. In the bygone days, Class III malocclusions were believed to be solely due to the prognathic mandible (1). Present knowledge of etiology has revealed that it can occur due to maxillary retrognathism, mandibular prognathism, or a combination of both. Another possible etiology can be due to a centric relation-centric occlusion shift leading to a mesial shift of the lower arch in the truancy of a true maxillomandibular skeletal discrepancy (pseudo-Class III). Therefore, the treatment strategy must be devised considering a myriad of factors such as the growth status, age, the severity of the skeletal dysplasia, severity of dental malocclusion, and patient compliance. According to a systemic review and meta-analysis conducted by Daniel et al. (2), the average prevalence of Class III malocclusion in combined sample of all races is 7.04% with a range from 0 to 26.67%. Populations from Southeast Asian countries showed the highest Angle's Class III malocclusion prevalence rate of 15.80% (3-7). The European studies had an average prevalence rate of 4.88%, and Indian populations had the lowest prevalence rate of 1.19 % (6-8).

To devise a comprehensive treatment strategy for Class III patients, it is critical to address etiology in the process of differential diagnosis. Growth prediction has always been a part of the deduction science. Baumrind has rightly said that the ability to predict assists the orthodontist psychologically in the treatment-planning process by removing the so-called art and adding a little more of science (9). The amount and direction of facial growth have long been regarded as the key factor in determining the success or failure of orthodontic treatment. The ability to predict craniofacial growth will accurately improve the reliability of treatment planning (10, 11). It is not possible to know where to position the

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teeth unless it is known where the bony bases will be during and at the end of treatment. Growth prediction is important not only in treatment planning and treatment provision, but it is equally important in the evaluation of prognosis during retention and post retention (12, 13). Evaluation of the visual treatment objective (VTO) by Ricketts is a complete analysis and, to the best of our knowledge, the first of its kind defining every aspect of malocclusion and resolving the etiology where it actually lies. Using this method, the behavior of the mandible was predicted in 52 of the 55 patients with a 96% accuracy rate (14). Ideally, it is desirable to come up with a ratio that can directly predict soft tissue changes form hard tissue movement, but due to significant variation in the soft tissue profile between individuals, it will not be possible to accurately measure such changes. Furthermore, it is important to predict soft tissue changes that can occur with maxillary advancement surgery. Misdiagnosis of soft tissue responses with maxillary advancement surgery can result in an undesirable esthetic outcome (15).

Figure 1. Pretreatment photographs

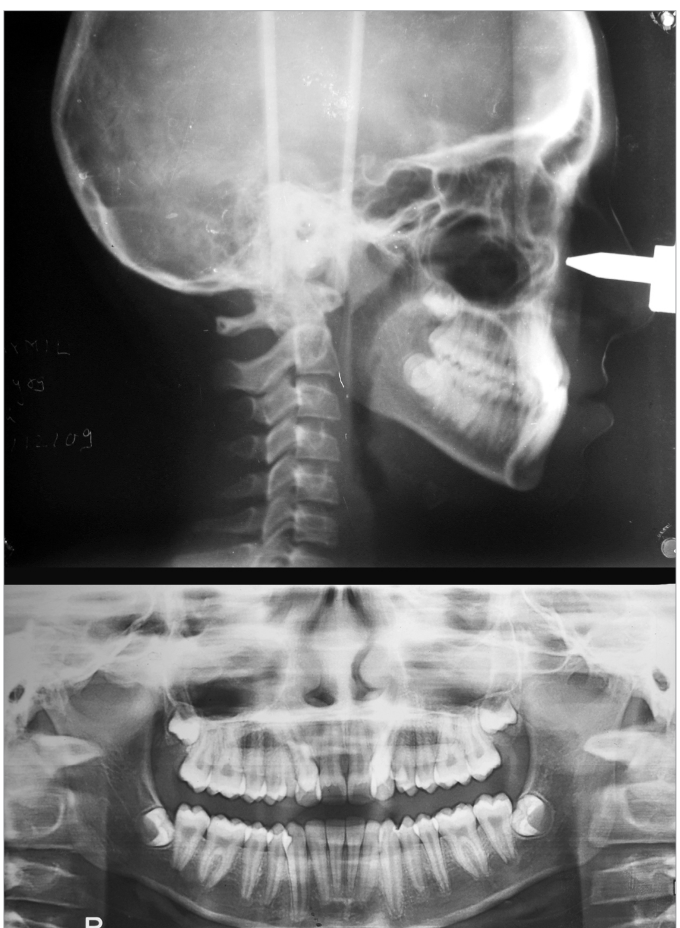

Figure 2. Pretreatment radiographs

Here, we are presenting one such case of skeletal Class III in which growth prediction has played a vital role in the comprehensive treatment planning and treatment outcome.

Etiology and Diagnosis

A 14-year-old male patient came to the Department of Orthodontics and Dentofacial Orthopedics with the chief complaint of irregularly placed upper front teeth. On extraoral examination, the patient had a mesoprosopic facial type with competent lips and nonconsonant smile arc. The patient had a straight soft tissue profile. Intraoral examination showed (super) Class I molar relation bilaterally. The upper central incisors were in crossbite and the lateral incisors were palatally blocked out (Figure 1). The model analysis revealed 13 mm crowding in the upper arch, and the lower midline had shifted toward the right side by 2 mm. the overbite was 6 mm, the reverse overjet was 2.5 mm, and the curve of Spee was 2.5mm. Furthermore, there were retroclined lower incisors. All these features suggested a typical case of Class III malocclusion in growing age. A cephalometric analysis revealed that patient was having skeletal Class III malocclusion (ANB=-3°, Wits appraisal=-4 mm) with horizontal growth pattern (FMPA=22°, GoGn to SN=27°) and proclined upper and retroclined lower incisors (upper incisor to NA=30°, lower incisor to NB=17°, IMPA=86°). Grummon's cephalometric analysis disclosed the underlying skeletal mandibular asymmetry (Ag-Me: right 44 mm and left 53 mm, Me-MSR linear: 6 mm) (Figure 2). Based on clinical and cephalometric findings, our diagnosis was Angle's (Super) Class I molar relation superimposed over skeletal Class III base relation due to retrognathic maxilla and orthognathic mandible with horizontal growth pattern, crossbite in relation to upper central incisors, and palatally displaced lateral incisors, over retained maxillary deciduous canines, straight soft tissue profile, and nonconsonant smile arc, as well as skeletal mandibular asymmetry supported by Grummon's analysis (Figure 1, 2) (Table 1, 2).

After meticulous calculations and reaching the diagnosis, the next critical step was devising a comprehensive treatment plan. At this conjecture, there were a few possible treatment alternatives, but the use of Rickett's growth prediction helped us to choose the most appropriate treatment plan.

Treatment Alternatives

Nonextraction, nonsurgical treatment with rapid palatal expansion and facemask followed by extraction of upper first premolars and fixed orthodontic treatment.

Since the cephalometric data of this patient indicated a retrognathic maxilla, a facemask would have been an option to correct maxillary sagittal retrognathism. But the ideal time for facemask therapy is 8–9 years of age, and this patient was 14 years old, and that was one of the reasons for not considering this approach.

Extraction of upper first premolars, decompensation and surgical maxillary advancement, and asymmetric mandibular setback, which would be the treatment that would address all the problems in this case.

In our surgical treatment objective (STO), the patient's soft tissue profile was not looking pleasant with only maxillary advancement, and furthermore, the patient had asymmetric mandibular growth.

Table 1. Lateral cephalometric analysis

Parameters (mm)	Normal	Pre-Treatment	Pre-Surgical	Post-Surgical	Post-Debonded
SNA	82	78	79	81	81
SNB	80	81	84	80	80
ANB	2	-3	-5	1	1
Upper Incisor to NA Angular	22	30	28	26	27
Upper Incisor to NA Linear	4	4	5	6	6
Lower Incisor to NB Angular	25	17	22	18	21
Lower Incisor to NB Linear	4	4	6	5	5
Interincisal Angle	131	138	134	135	132
GoGn to SN	32	27	28	29	29
Na-Apg	(-8 to 10)	-7	-11	2	0
Npg- Fh	82-95	89	91	87	88
Fmpa	25	22	23	24	24
Impa	90	86	88	86	86
Wits Appraisal	(-1 to 0)	(-4)	(-9)	(-1)	(-1)
N-Perpendicular to Point A	0 to 1	(- 4)	(-4)	(-1)	(-1)
N-Perpendicular to Point Pg	1 to 3.5	(-2)	(+2)	(-3)	(-3)
Nasolabial Angle	102 ± 8	118	116	100	101

Table 2. Grummon's posterioanterior cephalometric analysis

	Linear Measurements (In Millimeters)			
	Right		Left	
	Pre-Surgical	Post-Surgical	Pre- Surgical	Post-Surgical
1 Co- Ag	69	71	66	70
2 Ag- Me	44	50	53	49
3 Co- Me	104	109	106	108
4 Ag-Msr	48	45	42	42
5 J Point- Msr	34	34	32	32
6 Co-Msr	55	58	52	52
	Other Measurement			
1 Angle Co-Ag-Me	125	123	125	125
	Pre- Surgical		Post- Surgical	
1 Angle Me-Cg-Msr	3°		0°	
2 Me-Msr Linear	6 mm		0 mm	
	Frontal Vertical Proportion Analysis			
	Pre-Surgical	Pre-Surgical	Post-Surgical	Post-Surgical
1 Upper Facial Ratio Cg-Ans : Cg-Me	50:120	0.42	52:122	0.43
2 Lower Facial Ratio Ans-Me : Cg-Me	67:120	0.56	67:122	0.55
3 Maxillary Ratio Ans-A1 : Ans- Me	29:67	0.43	30:70	0.43
4 Total Maxillary Ratio Ans-A1: Cg-Me	29:120	0.24	30:122	0.25
5 Mandibular Ratio B1-Me : Ans- Me	37:67	0.55	37:69	0.54
6 Total Mandibular Ratio B1- Me : Cg- Me	37:120	0.31	37:122	0.30
7 Maxillomandibular Ratio Ans- A1 : B1- Me	29:37	0.78	30:37	0.81

Hence, mandibular setback surgery was also required to correct prognathism as well as skeletal asymmetry. Since the patient had a skeletal problem, orthognathic surgery was the only viable option for correction of the sagittal discrepancy. The ideal time for surgical correction is after growth completion which is mostly after 18 years of age. However, to plan accurate surgical treatment in this patient at this age, we needed substantial evidence of the growth potential of the jaw bases. Hence, we forecasted the 4-year mandibular growth using Rickett's VTO. As displayed in Figure 3, with the VTO for this patient, we predicted that the mandible would continue to grow forward significantly leaving the maxilla behind and worsen the profile in the next 4 years. By this image, we forecasted that the soft tissue profile would turn into Class III from straight and that the patient would require surgical correction once the growth is ceased. The literature also supports the accuracy and reliability of Ricketts VTO to be almost 96%.

Wait-and-Watch Approach

One option was to keep patient on routine observation, and once the growth is ceased, go for surgical correction. However, the patient was presented with complex dentoalveolar as well as underlying skeletal malocclusion. If we had waited for growth to cease, perhaps till the age of 18 years, then it would have taken another 2 years for dental decompensation before we could send him for orthognathic surgery. At this age when he enters college for an education, peer pressure and appearance are of prime importance. Thus, parents and patient had rejected this approach.

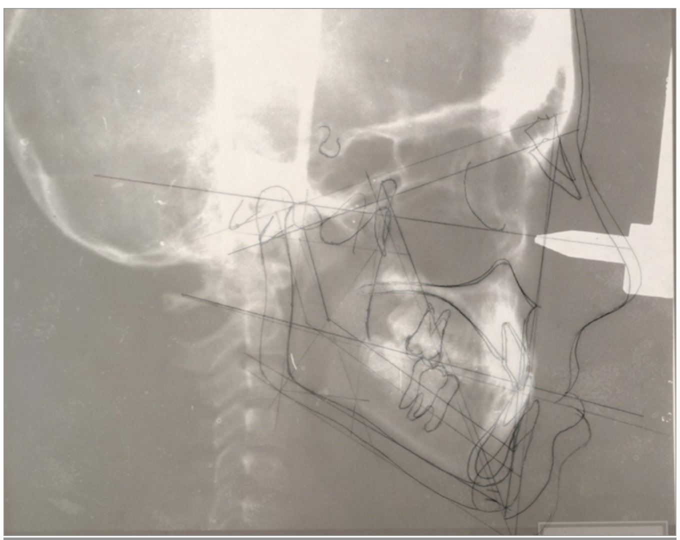

Figure 3. Rickets VTO (visual treatment objective) showing expected growth of mandible over 4 year period

Figure 4. Presurgical photographs

Distraction Osteogenesis

Another option to think about was the distraction osteogenesis. However, based on the envelope of discrepancy, this treatment option would be suitable for more severe skeletal problems that may not be corrected with orthognathic surgery.

TREATMENT PROGRESSION

After keeping in mind all possible outcomes, we chose the second option, which was the extraction of upper first premolars and dentoalveolar decompensation followed by maxillary advancement and mandibular asymmetric setback. Treatment was conducted in three phases.

Presurgical Orthodontics

Treatment was begun at the age of 14 years and 8 months. Standard 0.022" inch MBT preadjusted straight wire appliance (3M Unitech) was used throughout the course of treatment. Following the extraction of upper premolars and deciduous canines, space was utilized to correct the angulation of upper anteriors and get lateral incisors and canines in proper alignment. Wire progression and space closure were done from the initial 0.014" NiTi till 0.021"x0.025" stainless steel wire with appropriate anchorage preparation (Nance appliance). Simultaneously, lower arch alignment and leveling were done, and the arch was prepared till passive 0.021"x0.025" stainless steel wire. At the end of decompensation, molar relation was end-on to Class I on the right side and Class III on the left side, canines were in Class III bilateral with 6 mm of reverse overjet, and midline was shifted toward right side by 2 mm (Figure 4). Surgical decompensation was achieved in almost 2 years and 7 months. All third molars were removed 6 months before the surgery, giving enough time for sockets to get mineralized (Figure 5).

Orthognathic Surgery

Combination of certain dental specialties may offer services with certain advantages for patients, as well as practitioners (16). Face bow transfer and articulation of anatomic models was done on the HANAU articulator (Figure 6), and two surgical wafers (first one for maxillary positioning and second one for mandibular positioning) were fabricated as per the mock surgery that was carried out on models (Figure 7). In the mock surgery on the HANAU articulator, the mounted casts were separated using a handsaw and repositioned with the help of modeling wax, leaving the 4 mm advancement of the maxillary cast and asymmetric setback of the mandibular cast (5 mm on right and 3 mm on the left side). At the age of 18 years, almost after 4 years of the beginning of the orthodontic treatment, Lefort I surgical procedure was carried out as decided, and the maxilla was repositioned 4 mm an-

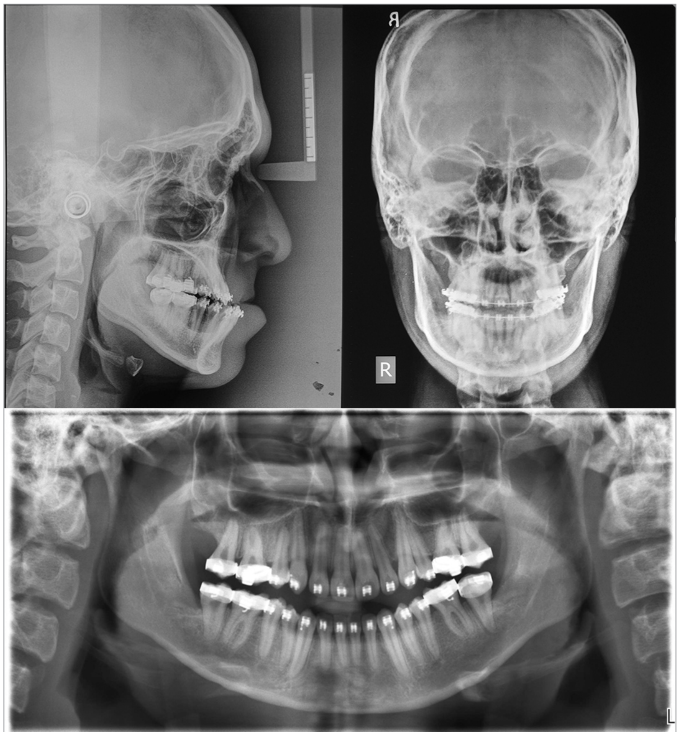
Figure 5. Presurgical radiographs


Figure 6. Face bow transfer


Figure 7. Surgical splint in placed along with intermaxillary fixation


Figure 8. Extraoral photographs captured after 3 days of surgery


Figure 9. Post-surgical photographs

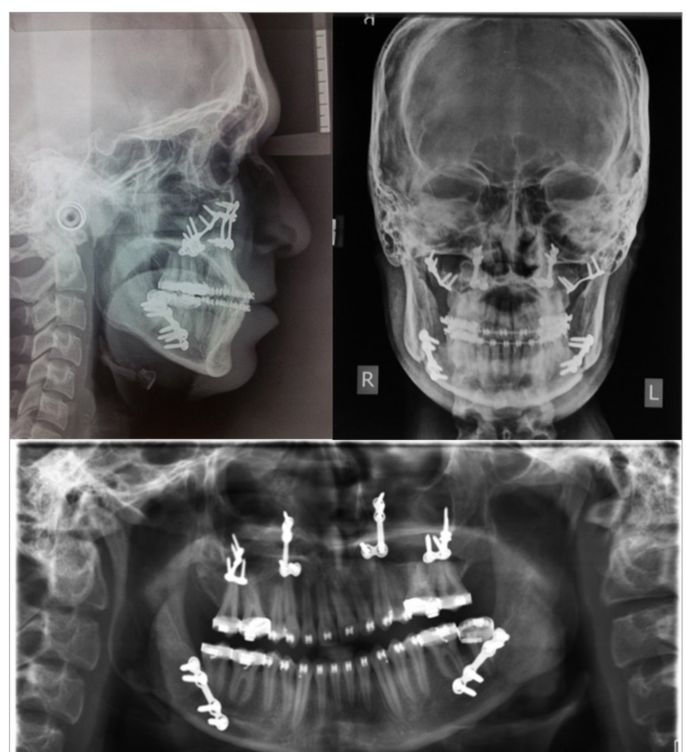
Figure 10. Post-surgical radiographs

teriorly. At the same time, bilateral sagittal split osteotomy was performed, and the mandible was asymmetrically set back by 5 mm on the right side and 3 mm on the left side (Figure 8-10). The amount of maxillary advancement and mandibular setback was calibrated based on presurgical occlusion, profile, and STO. Initially, in the STO, only maxillary advancement was simulated. However, with only single-jaw surgery, the profile did not appear very favorable. Thus, we followed the presurgical occlusion on casts, and it was noticed that the correction of 9 mm on the right side and 7 mm on the left side was required to achieve full cusp Class II molars and Class I canines bilaterally with coincident midlines. Then, we simulated various combination in STO and finally concluded that the 4 mm maxillary advancement and asymmetrical mandibular (5 mm on right and 3 mm on the left side) setback were the most favorable surgical corrections.

Figure 11. Post-debonded photographs

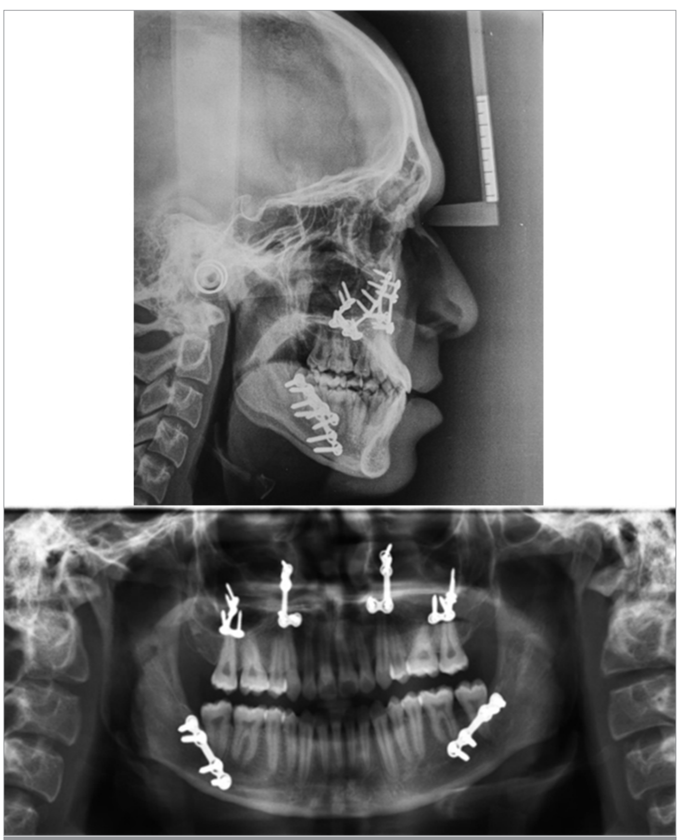

Figure 12. Post-debonded radiographs

Postsurgical Orthodontics

Postsurgical orthodontics was initiated after a period of 4 weeks. Archwires were sequentially changed from 0.017″X 0.025″ NiTi to 0.019″ X 0.025″ stainless steel. Finishing and settling of the final occlusion were carried out by short settling elastics. Mild Class 3 elastics were used in this phase.

The total duration of treatment was 4 years and 6 months. At the time of debonding, the patient was having Class II molar and Class I canine relationship bilaterally, and upper and lower midlines were coinciding. Also, the soft tissue profile was mildly convex and overjet, and the overbite was 2 mm with a consonant smile arch (Figure 11, 12). Cephalometric superimposition was carried out on the SN plane, maxillary plane (ANS–PNS), and mandibular symphysis. This reflects the maxillomandibular movement in the sagittal plane as per our surgical planning (Figure 13).

DISCUSSION

Whether to wait till growth is over or to plan an orthognathic surgery right away has always been part of an active debate in

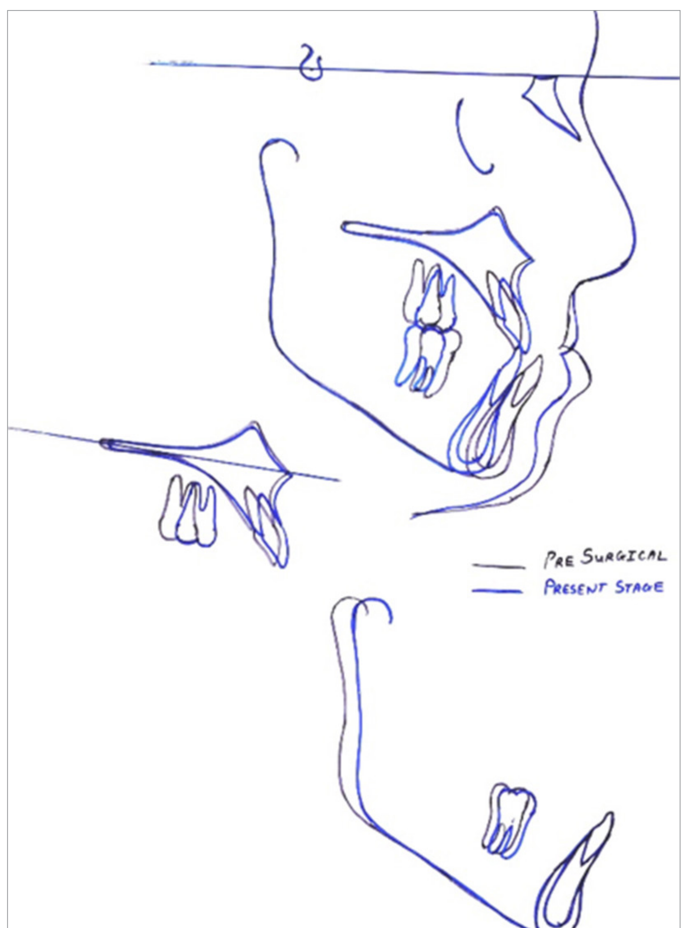

Figure 13. Superimposition

orthodontics. Choosing a nonsurgical compromised treatment or delaying orthognathic surgery until growth is complete could be damaging to the patient's self-image. Delaying treatment until adulthood can exacerbate problems related to pain, speech, airway, anatomy, occlusion, aesthetics, temporomandibular joint function, masticatory function, and psychosocial factors (17). To overcome these issues, orthodontists started to incline toward an early surgical treatment in the growing phase. However, the determination of the growth rate or vector can be challenging. In the past, few authors have attempted to predict the facial growth using various methods such as manual or computerized; and two-dimensional cephalometric or three-dimensional cone-beam computed tomography (CBCTs). Out of these methods, Rickett's VTO has been reported to be one of the most precise techniques. In a study that included Turkish children, Kocadereli and Telli (18) reported statistically significantly higher correlations between predicted and actual measurements of various parameters. In another independent study on Turkish adolescents, Enacar (19) concluded that there was a high correlation between the predicted and actual measurements, and mandibular parameters were accurately predicted. In both of these studies, the authors used Rickett's long-range growth prediction as a tool. Furthermore, by presenting this case, we tried to elucidate that even after so many years following its introduction, Rickett's growth prediction is still working as an efficient diagnostic tool.

CONCLUSION

The treatment of dentofacial deformities of young patients is complex, especially when transverse and sagittal discrepancies exist, and it requires orthodontic treatment combined with orthognathic surgery to achieve stable, functional, and aesthetic results (20, 21). Prediction must be performed before finalizing the treatment plan for growing patients. For this particular case, orthognathic surgery has not have been considered at a young age since the profile was not severely concave. However, by Rickett's method, it was predicted how the mandible would grow and how the patient would look in 4 years. Rickett's prediction played a paramount role in deciding our final treatment plan. Thus, one should always put an emphasis the prediction method when treating growing children.

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

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - V.G., M.F, P.D.; Design - V.G., M.F, P.D.; Supervision - M.F.; Data Collection and/or Processing - V.G., H.P., J.H.; Analysis and/or Interpretation - V.G., H.P., J.H.; Writing Manuscript - V.G., J.H.; Critical Reviews - M.F.

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REFERENCES

1. Kapadia RM, Shah AP, Diyora SD, Rathva VJ. Non-surgical treatment of skeletal Class III malocclusion. BMJ Case Rep 2014: bcr2013202326. [CrossRef]
2. Hardy D, Cubas Y, Orellana M. Prevalence of angle class III malocclusion: A systematic review and meta-analysis. O J Epi 2012; 2: 75-82. [CrossRef]
3. Lew KK, Foong WC, Loh E. Malocclusion prevalence in an ethnic Chinese population. Aus Dent J 1993; 38: 442-9. [CrossRef]
4. Tang EL. Occlusal features of Chinese adults in Hong Kong. Aus Orthod J 1994; 13: 159-63.
5. Tang EL. The prevalence of malocclusion amongst Hong Kong male dental students. Bri J Orthod 1994; 21: 57-63. [CrossRef]
6. Woon KC, Thong YL, AbdulKadir R. Permanent dentition occlusion in Chinese, Indian and Malay groups in Malaysia. Aus Orthod J 1989; 11: 45-8.
7. Soh J, Sandham A, Chan YH. Occlusal status in Asian male adults: Prevalence and ethnic varia- tion. Angle Orthod 2005; 75: 814-20.
8. Gauba K, Ashima G, Tewari A, Utreja A. Prevalence of malocclusion and abnormal oral habits in North Indian rural children. J Ind Soc Ped and Prev Dent 1998; 16: 26-30.
9. Baumrind S. Prediction in the planning and conduct of orthodontic treatment. In: Melson B, ed. Current controversies in orthodontics. Chicago: Quintessance 1991; 25-43.
10. Burstone CJ. Process of maturation and growth prediction. Am J Orthod 1963;49:907-19. [CrossRef]
11. Ricketts RM. Planning treatment on the basis of the facial pattern and an estimate of its growth. Angle Orthod 1957; 27: 14-37.
12. Mitchell DL, Jordan JF, Ricketts RM. Arcial growth with metallic implants in mandibular growth prediction. Am J Orthod 1975; 68: 655-9. [CrossRef]
13. Tweed CH. Treatment planning and therapy in the mixed dentition. Am J Orthod 1963; 49: 881-906. [CrossRef]
14. Ricketts RM. Facial and denture changes during orthodontic treatment as analysed from the temporomandibular joint. Am J Orthod 1955; 41: 163-79. [CrossRef]
15. Nagori H, Fattahi T. Maxillary Advancement Surgery and Nasolabial Soft Tissue Changes. IOSR J Dent and Med Sci 2017: 3: 23-9. [CrossRef]
16. Jones MB, Nagori H, Litschel K, Swigler W, Farill-Guzman J. Parental Preference for Dual-Trained Orthodontist. J Orthod Endod 2017; 3: 2. doi: 10.21767/2469-2980.100042. [CrossRef]
17. Wolford LM, Karras SC, Mehra P. Considerations for orthognathic surgery during growth, part 1: mandibular deformities. Am J Orthod Dentofacial Orthop 2001; 119: 95-101. [CrossRef]
18. Kocadereli I, Telli AE. Evaluation of Ricketts' long-range growth prediction in Turkish children. Am J Orthod Dentofacial Orthop 1999; 115: 515-20. [CrossRef]
19. Enacar A. Ricketts'in "mandibulanın arkial büyümesi" kuramının ve uzun süreli tah- min yönteminin ülkemiz bireylerinde deerlendirilmesi (longitudinal arastırma). Büyüme Gelisim ve Ortodonti, Tübitak Yayın Daıtım Daire Baskanligi, Ankara, 1991.
20. Guloy R, Nagori H, Gandhi V. Orthodontic and Surgical Correction of Class-III Malocclusion with Excellence Facial Aesthetic Results- Case Report. IOSR J Dent Med Sci 2017; 16: 82-91.
21. Gandhi V, Malek F. Orthognathic Surgery and Facial Changes - A Review. J Orthod Endod 2018; 4: 1. doi: 10.21767/2469-2980.100050. [CrossRef]