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Turkish Orthodontic Society

TURKISH JOURNAL of ORTHODONTICS

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Aims and Scopes

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

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

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

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REVIEW ARTICLE	5000	250	50	6	10 or total of 20 images
CASE REPORT	1000	200	15	No tables	10 or total of 20 images
LETTER TO THE EDITOR	500	No abstract	5	No tables	No media

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

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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].

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TURKISH JOURNAL of ORTHODONTICS

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TURKISH JOURNAL of ORTHODONTICS

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Original Article

Comparison of the Force Released by Intermaxillary Elastics Used for Different Time Periods

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ABSTRACT

Objective: The objective of the present study was to compare the strength degradation of the force of intermaxillary elastic used for different periods.

Methods: The sample included intermaxillary elastics used for 20 adult patients with bilateral Class II or III malocclusion in orthodontic treatment with fixed appliances, with a mean age of 27.25 years. Latex orthodontic elastics with 3/16 inch of diameter were used, with an average stretching of three times its diameter. The elastics were used in the same patient bilaterally for different periods, with each pair of elastics used for 1, 12, 24, and 48h. Thus, the sample consisted of 200 elastics, with 40 being used in each period (one pair used by each patient) and 40 new elastics without use tested as control. Elastics were tested using a universal testing machine, stretched with a velocity of 30 mm/min, and the force was evaluated in stretches of 15, 20, 25, and 30 mm. The degradation force was compared in the four different times of use and control by one-way ANOVA (analysis of variance) and Tukey tests.

Results: There were significant differences among the groups in all evaluated stretches (15, 20, 25, and 30 mm). The control elastics presented higher average forces numerically and statistically significant for all tested times, except for the elastic used for 1h. The elastics used for 1, 12, and 24h had similar forces among them, with a significant difference to the elastics used for 48h.

Conclusion: It is recommended to change the intermaxillary elastics after 24 h of use.

Keywords: Elastomers, materials testing, dental materials

INTRODUCTION

The orthodontic literature reports the introduction of intermaxillary elastics after 1893 (1). This accessory was used to aid dental intercuspation to generate light and continuous forces in canine retraction, space closure, rotational correction, and anteroposterior correction of the malocclusions (2).

According to the material of manufacture, there are two types of orthodontic elastics: rubber or synthetic. Rubber or latex elastics are obtained from vegetable extraction (3). The synthetic, elastomeric, or plastic elastics are obtained by means of chemical transformations of coal, petroleum, and some vegetable alcohols (3, 4). Latex orthodontic elastics are widely used in orthodontics due to their low cost and great practicality (3).

The main characteristic of the elastics and determining their effectiveness is the elasticity, which is a property that is defined by the ability to return to the original dimensions, after suffering a substantial deformation (5). Elasticity is determined by the geometric pattern and by the type of existing molecular traction (5).

Most of the orthodontic devices used to exert forces and consequently to move teeth do not present a constant force (6). Over time, the magnitude of force initially employed is reduced and, with this, the tooth movement may decrease or cease. Elastic materials exhibit this characteristic, which is called the degradation of force (5, 7-9).

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Little is known about the strength degradation properties of the elastics after the use in vivo in orthodontic mechanics with intermaxillary elastics since few studies have been performed after the use in patients (10).

Therefore, it was decided to evaluate the elastics under dynamic conditions in vivo for verification of the degradation of force over a period of time due to the conflicting results in the literature regarding the elastic exchange time and because the methodology of most of the articles did not evaluate the behavior of the elastics after the use in patients. The aim of the present study was to evaluate the strength degradation of intermaxillary elastics used by patients in different periods to establish the clinical parameters regarding the frequency of exchange that should be used in orthodontic treatment.

METHODS

The present study was approved by the Research Ethics Committee of UNINGÁ University Center, Maringá, Brazil. Written informed consent was obtained from the patients who participated in this study.

The sample included intermaxillary elastics used by adult patients with the following criteria:

- aged >16 years,
- presence of permanent teeth to erupted first molars,
- without dental anomalies of number and shape,
- Class II or III bilateral malocclusion in orthodontic treatment with fixed appliances and requiring the use of Class II or III intermaxillary elastics.

Thus, the elastics were used by 20 patients. The mean age of the patients was 27.25 (d.p.=9.53, minimum 16 and maximum 42) years. The study was composed of 2 male and 18 female patients. Of the 20 patients, 17 had Class II malocclusion, and 3 had Class III malocclusion, both bilaterally, using Class II and III intermaxillary elastics, respectively. Cases of subdivision were excluded from the study. The sample consisted of intermaxillary elastics used by these patients, coming from the dental clinic of one of the authors in the city of Maringá, Brazil.

Latex orthodontic elastics were classified as strength generators of medium intensity (130 g) according to the manufacturer (Dental Morelli Ltda, Morelli-Sorocaba, SP, Brazil) with a diameter of 3/16 inch (ref 60.01.311, lot 1930589).

The elastics were selected in pairs in plastic packaging and used by the same patient bilaterally for different periods, 1, 12, 24, and 48 h and an average stretch of three times their diameter. The distance of the application point of the elastics varied from each patient (from the canine to the first molar). However, since each patient used the elastics in each time evaluated (1, 12, 24, and 48h), the distance between points was not important because it did not influence the results.

However, the forces were not individually measured with the mentioned stretching, ranging from 150 to 200 g. Replacement reserves have been provided in case of loss. The patients used the elastics in their normal day-to-day routine, removing them to feed and brush their teeth.

After use, they were kept in a closed and thermal recipient to minimize the effects of storage. They were then tested for no >2 weeks after the use by patients.

In this way, the sample consisted of 200 elastics, 40 of which were used in each of the four periods (one pair for each patient), totaling 160 plus 40 new as the control group.

All tests were performed at the Experimental Dentistry Laboratory of the UNINGÁ University Center, Maringá, Brazil.

The force released by the elastics used at different times was tested using a universal testing machine, EMIC model DL500 (INSTRON), Claws GR001, coupled to a 50 kgf load chart and adaptation for distension of a C hook.

The elastics were individually taken to the hook of the machine with the aid of a bonding plier for brackets and stretched at a speed of 30 mm/min, and the force was evaluated in the stretches of 15, 20, 25, and 30 mm (Figure 1).

The results observed after the traction of the elastics were recorded in gram force (gf) by the computer program Tesc version 3.04 (EMIC, São José dos Pinhais, Brazil). The duration of the trial of each specimen was approximately 1 min.

Statistical Analysis

The Kolmogorov-Smirnov test was used to verify data with normal distribution.

The strength of degradation of the elastics was compared in the four different times of use and control, without use, by the one-way ANOVA and Tukey tests. The tests were performed using Statistica software (Statistica for Windows, version 7; StatSoft, Tulsa, OK, USA). A p value <0.05 was considered significant.

RESULTS

There was a significant difference among the times (groups) in all stretches evaluated (15, 20, 25, and 30 mm) (Table 1).

The control elastics presented higher mean strengths numerically and with a statistically significant difference for all the times tested, except for the elastics used for only 1h.

The elastics used for 1, 12, and 24h had similar forces between them, with a significant difference for the elastics used for 48h.

DISCUSSION

Several mechanical studies were performed with the purpose of analyzing the properties of the intermaxillary elastics objecting

Figure 1. a, b. Stretch of the elastic for the test from 0 to 30mm

Table 1. Results of the elastic degradation force among the different times used and the control (one-way ANOVA and Tukey tests) (n=40)

Degradation force (gf)	1h Mean (SD)	12h Mean (SD)	24h Mean (SD)	48h Mean (SD)	Control Mean (SD)	p
15 mm	155.45 (13.23) AC	152.99 (9.80) A	149.37 (13.27) A	142.63 (13.55) B	162.22 (6.79) C	0.000*
20 mm	185.80 (15.46) AC	183.90 (11.53) A	178.84 (15.71) A	170.95 (15.77) B	194.17 (8.19) C	0.000*
25 mm	216.75 (18.21) AC	213.68 (13.95) A	208.63 (18.35) A	199.09 (18.28) B	226.17 (9.83) C	0.000*
30 mm	248.86 (20.99) AC	247.11 (14.99) A	239.82 (20.91) A	228.89 (21.03) B	259.38 (11.53) C	0.000*

*Statistically significant at p<0.05
Different letters in the same row indicate the presence of a statistically significant difference.
SD: standard deviation; gf: gram force; mm: millimeters

to find a behavior closer to the one occurring in the oral environment and its effects after its stretching at a certain distance and its analysis of the released force (6, 8, 11-16).

The present study was conducted on patients who needed the use of Class II and III elastics to conduct an analysis of the behavior of the elastics according to the reality and the time of use by the same patient and their stretching. The present results must be extrapolated with care, because it is a study, although clinical, transversal, and presents some limitations, as discussed below.

The versatility and practicality of the use of intermaxillary elastics become its main characteristic, with the 3/16 inch elastic the most used because of the distance of the stretch between the molar to the canine (6, 17). The professional must know the characteristics of elastics, their effects, advantages, and disadvantages to make an adequate planning and application (3, 18).

Intermaxillary elastics may help to correct Class II and III malocclusions and midline corrections. They can also be used for the extrusion of teeth, correction of crossbites, and intercuspation for finishing of orthodontic treatment, among others (3, 18). Therefore, the sample consisted of patients using Class II and III elastics.

The methods of analysis of the present study attempted to simulate the use of intermaxillary elastics in a real environment, being used by patients in their normal daily routine, removed in meals, and during teeth brushing. The tests were performed in a dynamic environment, and elastic tests and their strength degradation were performed in different periods in the same patient. Other studies have tested the conditions of the orthodontic elastics in a static and dry environment or using cyclic tests for elastics, either latex or non-latex (6, 8, 19, 20).

The choice of patients aged >16 years was justified due to the concern with the fidelity of the sample of elastics and the responsibility of the patient to use them correctly, and adults tend to be more responsible and also to have all the teeth up to the first molar. The selection also included patients who had a history of good conduct and frequency in the clinic, as an attempt to obtain a reliable sample (5). The difference in sex distribution did not influence the results since compliance was not evaluated in the study. Consecutive patients who agreed to participate in the study were included in the study, and it appears that women are more likely to participate in the research. Some compliance and attention were necessary to use the elastics exactly as we ask for, and women appeared to be more cooperative.

As the test was performed in the same patient at all periods and the distance was the same, there were no factors that influenced the sample. According to Vilella (2), the force produced by the elastic is directly related to the distance between the hooks and the size of three times its distance (18, 21). A rigid standardization of the force applied and the distance of the points of support of the elastics was not necessary since it was the same for both time groups. For example, if a patient used the elastics stretched in 15 mm, with a force of 170 g, the same patient used elastics for the groups of 1, 12, 24, and 48h; the other patient with the elastics stretched in 18 mm with a force of 200 g also used elastics for all the groups evaluated. This way, this lack of rigid standardization did not influence the results.

The patient itself controlled the time that each elastic was used (1, 12, 24, or 48h). We intended to perform the study to represent the actual clinical situation of the use of intermaxillary elastics, and it represents the patient removing the elastics to feed and oral hygiene. This way, the time of use of 48h, for example, was not really the 48h literally, but 48h of use of elastics after their installation, considering the removal for meals and oral hygiene, reproducing the actual clinical situation.

In relation to the stretching studied, there was a decrease in strength in relation to the increase of stretches 15, 20, 25, and 30 mm throughout the sample including in the control group, corroborating with other studies (6, 9, 19, 20, 22-29). With the increase of the time of 0 (control group), 1, 12, 24, and 48h observed that the 3/16 inch elastic has greater significant force degradation after the 24h (10, 20, 26, 29, 30). Some authors obtained the same result, but others verified a loss of strength after 72h (6). According to Loriato et al. (3) with respect to the degradation of force, with the passage of time, the intensity of the force initially employed decreases.

However, Liu et al. (17) suggested that after the interval of 1 day, the decrease in the values of the forces stabilizes, assuming non-significant variation characteristics. For these authors, the stretch variable, due to the opening and closing of the mouth, does not imply cumulative influence on the material.

Authors, such as Bishara and Andreasen (13), Kanchana and Godfrey (14), and Wang (9), comment on the loss of strength after 24h consistent with our results. Beattie and Monaghan (30), Kumar et al. (26), and Fernandes et al. (19) found similar results of force loss with 1/4 inch elastics after 24 h. According to Oliveira et al. (20), there was also a larger drop of force after 24h.

Researches, such as by Liu et al. (17) and Bishara and Andreasen (13) comment on the choice and distance of elastic stretching between 20 and 50 mm. In other works, they were standardized to 30 mm, three times their size as Kersey et al. (31) but there is no standardization for this.

Wang (9) performed in vivo and in vitro research comparing the strength degradation of the elastics at time intervals of 24 and 48h showing similar results of force decrease in the range of 24-48h. Thus, this research suggests replacing 3/16 inch elastics every 24h along with several authors.

The control elastics presented the highest mean forces, similar to the elastics used for 1 h. This is a common point among all of the following authors (6, 9, 12, 14, 18, 19, 22-29, 31) that the degradation of force occurs over time, and that the force of the intensity initially employed decreases.

The elastics used for 1, 12, and 24h had similar forces between them, with a significant difference for the elastics used for 48h, which presented greater degradation in the means of forces. This result is similar to others (20, 26, 29, 30) who state that elastic forces decrease significantly after the first 24h of use, rendering the use for a longer period ineffective. Moris et al. (6) stated that the use for 3 days is recommended, but their study was reproduced in a simulated dynamic laboratory environment and in artificial saliva, which are not the actual conditions to which the elastics are exposed, so this will not be its expected performance when used in Class II or III malocclusion corrections.

CONCLUSION

Control and 1h use elastics showed the highest mean forces. The elastics used for 1, 12, and 24h had similar forces between them, with a significant difference for the elastics used for 48h, which showed the smallest means of forces. Therefore, it is recommended to replace the intermaxillary elastics every 24h.

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethics Committee of UNINGÁ University Center, Maringá, Brazil.

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

Peer-review: Externally peer-reviewed.

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Original Article

Comparison of the Angulation of the Unerupted Mandibular Second Premolar in Turkish Population with Tooth Agenesis

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ABSTRACT

Objective: This study aimed to evaluate the unerupted mandibular second premolar (MnP2) angulation in individuals with different tooth agenesis in Turkish population.

Methods: We retrospectively reviewed panoramic radiographs of patients treated at Akdeniz University. According to the agenesis, the subjects were categorized into three groups: 22 patients with unilateral MnP2 agenesis (Group 1), 22 patients with bilateral mandibular incisor agenesis (MnI, Group 2), and 22 patients with no agenesis excluding third molars (Group 3). The angle between the first mandibular molar and unerupted MnP2 (γ angle) and the angle between the mandibular basis and unerupted MnP2 (Θ angle) were measured on both the right and left sides in Groups 2 and 3 using the method determined by Shalish et al.

Results: Groups 1 and 2 were compared with the control group with respect to (γ) and (Θ). No significant difference was found between Groups 2 and 3 on both the right and left sides ($p>0.05$). The comparison between Groups 1 and 3 revealed significant differences in the γ and Θ angle only on the left side ($p>0.05$).

Conclusion: Posterior rotation of the mandibular condyle during the growth-development period may be one of the factors responsible for the difference in the Θ angle between the MnI agenesis and control groups. A difference in the total number of teeth on the dental arch may be a reason for the differences in the γ angle between the MnI agenesis and control groups.

Keywords: Tooth agenesis, unerupted second premolar, hypodontia

INTRODUCTION

Dental agenesis is one of the most common cases of dental anomalies in humans (1). The relationship between dental agenesis and other dental anomalies that may lead to malocclusion has been a topic of research, especially for orthodontists. Delayed tooth development/eruption is included in these dental anomalies (2).

Mandibular second premolar (MnP2) agenesis occurs most frequently in European population (3), whereas mandibular incisor agenesis (MnI) is more common in Asian population (4, 5).

The incidence of malocclusion in MnP2 agenesis is evaluated in terms of orthodontics (6). To assess the relationship between malocclusion and MnP2 agenesis, the presence of various dental anomalies and the distal angulation of the unerupted MnP2 in the contralateral area have been investigated. Panoramic radiographs have been used to determine distal angulation, and usually, consistent results have been obtained (6-8).

Various studies have shown that distal angulation of the MnP2 is greater in patients with agenesis than in patients who have no MnP2 agenesis (6, 7). It has been reported that genetic factors may explain differentiation of

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MnP2 distal inclinations in those with mandibular incisive agenesis and unilateral MnP2 agenesis (9).

When distal inclinations were examined throughout the formation stages of the unerupted MnP2 tooth, it was observed that the angle between the mandibular basis and the tooth increased with the progress of the development (10).

In the literature, a limited number of studies examine the change in the angulation of unerupted MnP2 in cases with agenesis (9). In the studies, the change of the angulation of unerupted MnP2 due to lack of teeth was investigated, but the change of these angles according to different age groups was not investigated without age factor.

This study aimed to:

- Evaluate the unerupted mandibular second premolar (MnP2) angulation in individuals with different tooth agenesis in Turkish population.
- Compare with past studies involving patients with unilateral MnP2 and bilateral mandibular incisive agenesis.
- Evaluate the angle of eruption according to age.

METHODS

Ethical approval of this retrospective clinical study was obtained from the local ethics committee of Antalya Training and Research Hospital. The panoramic radiographs of patients (7210 patients) treated at the School of Dentistry of Akdeniz University between March 2014 and January 2017 were retrospectively reviewed. Written consent was obtained from all patients who applied to our clinic for treatment purposes, indicating that their radiographs or materials can be used in scientific articles. Among the panoramic radiographs examined, it was aimed to form groups of patients with unilateral MnP2 agenesis (Group 1), patients with bilateral MnI agenesis (Group 2), and patients with no agenesis excluding third molars (Group 3). For the sample size, the archive was scanned to determine how many patients were in accordance with our criteria. Then power analysis was done, confirming that our sample size (n=22) was sufficient. Radiographs taken during periods when the unerupted MnP2 teeth were between the D-G phases, according to the Koch Classification (11), were included in the study. If there was more than one radiograph that matched the criteria, the most recent one was selected. Patients who met the inclusion criteria were selected from the patients who were examined. The exclusion criteria for the study were the presence of any systemic disease or syndrome that causes agenesis, the presence of orthodontic treatment history, and the absence of a panoramic radiograph suitable for measurement.

Table 1. Comparison of the chronological ages and gender distributions between the groups

Parameter	Group 1 Mean±SD	Group 2 Mean±SD	Group 3 Mean±SD	p
Gender (*n*)				
Female	14	13	14	0.742 * (NS)
Male	8	9	8	
Age (year)	9.51±0.93	9.62±0.67	9.40±0.48	0.563 ** (NS)

p: * Pearson Chi-square test. ** Student's t-test. SD: standard deviation
p>0.05: NS: non-significant

The mean age of the patients was 9.51±0.69 years (range 7.9-12.1 years). According to the agenesis, the subjects were categorized into three groups: 22 patients with unilateral MnP2 agenesis (8 males, 14 females, mean age 9.51±0.93 years), 22 with bilateral MnI agenesis (9 males, 13 females, mean age 9.62±0.67 years), and 22 no agenesis excluding third molars (8 males, 14 females, mean age 9.40±0.48 years). Patient characteristics are presented in Table 1.

Angular measurements were made on panoramic radiographs of the patients. The angle between the first mandibular molar and unerupted MnP2 (ɣ angle; Figure 1) and the angle between the mandibular basis and unerupted MnP2 (Ɵ angle; Figure 1) were measured on both the right and left sides in Groups 2 and 3 using the method determined by Shalish et al. (8) and Baccetti et al. (12). In patients with unilateral MnP2 agenesis, only the Ɵ angle was measured in the contralateral area, which included the MnP2. Comparison of the angulation of the MnP2 between the unilateral MnP2 agenesis group with the control group and bilateral MnI agenesis group with the control group is shown in Table 2.

The same researcher repeated all tracings and measurements to determine the reliability of the measurements. The repro-

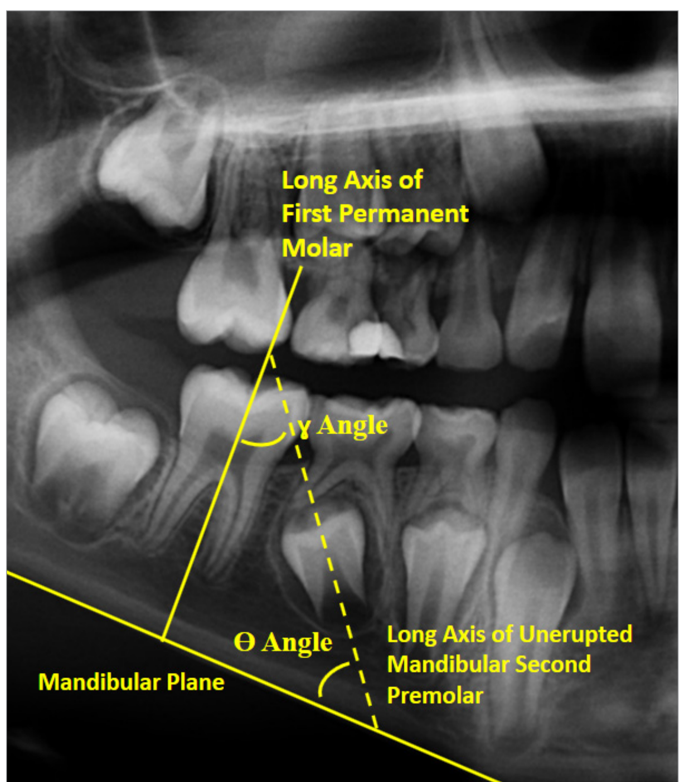

Figure 1. Measurement of angulation of unerupted MnP2 in panoramic radiograph [Distal angle (Ɵ) and Premolar-molar angle (ɣ)]

Table 2. Statistical comparison between unilateral MnP2 and bilateral MnI agenesis groups with control group

	Right Side				Left Side			
	(Θ) Angle Mean±SD	**p**	**(ɣ) Angle Mean±SD**	**p**	**(Θ) Angle Mean±SD**	**p**	**(ɣ) Angle Mean±SD**	**p**
Unilateral Agenesis Group (Group I)	77.15±8.58	0.319	16.60±9.89	0.123	75.78±17.3	0.01	17.65±18.38	0.01
Control Group (Group III)	76.76±9.56		14.54±6.49		78.85±8.11		12.81±6.45	
	(Θ) Angle Mean±SD	p	(ɣ) Angle Mean±SD	p	(Θ) Angle Mean±SD	p	(ɣ) Angle Mean±SD	p
Bilateral Agenesis Group (Group II)	70.57±16.64	0.889	20.05±12.96	0.419	65.11±15.82	0.456	27.58±17.81	0.254
Control Group (Group III)	76.76±9.56		14.54±6.49		78.85±8.11		12.81±6.45	

p: Student's t-test. SD: standard deviation
p: p<0.05: * (Level of Significance), p>0.05: NS: non-significant

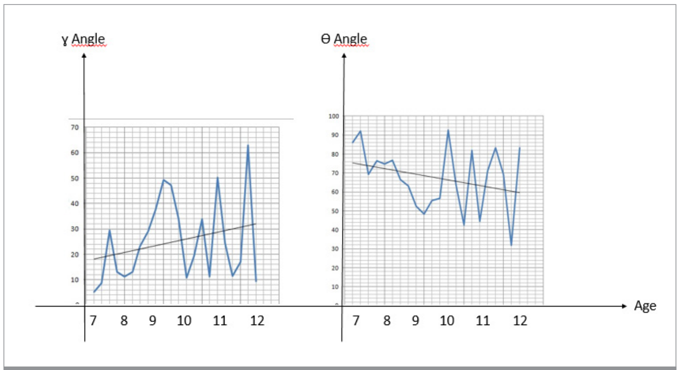

Figure 2. Distribution of (Θ) - (ɣ) angles according to age and trend line in bilateral MnI agenesis group

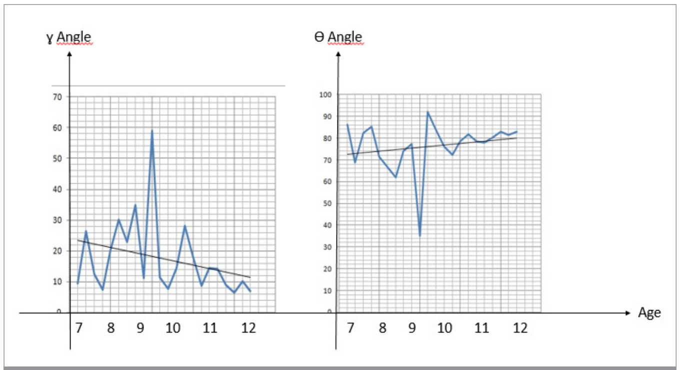

Figure 3. Distribution of (Θ) - (ɣ) angles according to age and trend line in unilateral MnP2 agenesis group

ducibility coefficients of all measurements were quite high. Parametric tests were performed for data analysis because Shapiro-Wilks test showed normal distribution. Gender distribution was tested by Pearson Chi-square test. The chronological ages and statistical comparison between the groups were achieved using Student's t-test. All statistical analyses were performed using the Statistical Package for Social Sciences software package program for Windows 98, version 10.0 (SPSS Inc, Chicago, IL, USA). The significance level was set at p<0.05 for all statistical tests.

RESULTS

No significant differences between the groups were found in terms of the gender distribution and chronological age (p>0.05; Table 1). Groups 1 and 2 were compared with the control group (Group 3) with respect to (ɣ) and (Θ), and no significant difference was found between Groups 2 and 3 in on both the right and left sides (p>0.05). In the comparison between Groups 1 and 3, there were significant differences in the ɣ and Θ angle only on the left side (p<0.05). The ɣ angle in Group 1 was significantly larger than in Group 3, while the Θ angle was significantly smaller in Group 1 than in Group 3 (Table 2).

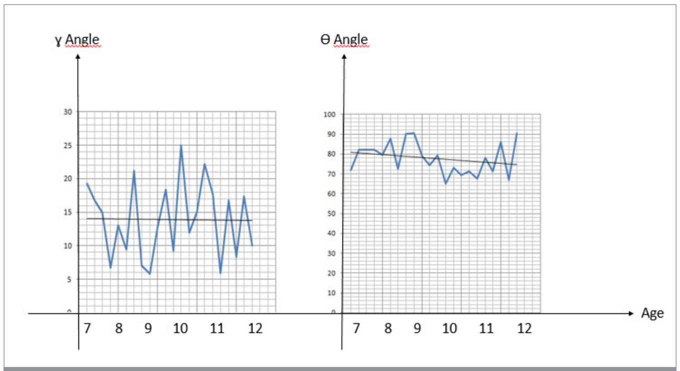

Figure 4. Distribution of (Θ) - (ɣ) angles according to age and trend line in control group

When the patients were aligned according to age in each groups, the trend line of the ɣ angle on the graphs decreased, whereas the trend line of the Θ angle increased in Group 2 (Figure 2). The trend line of the Θ angle showed a decrease when the linear trend line of the ɣ angle increased in the contralateral area in Group 1 (Figure 3). On the control group graphs, there was a decrease in the trend line for both the ɣ and Θ angles (Figure 4).

DISCUSSION

This study aimed to evaluate the incidence of MnP2 distal angulation and angle of eruption in individuals in the Turkish population. In addition, with different aspects, the reliability of MnP2 distal angulation has been tested according to change with age. The MnP2 distal angulation in patients with unilateral MnP2 hypodontia was found to be higher than in patients without agenesis. The ϴ angle trend line increased in the patients with MnI agenesis, whereas the ϴ angle trend line decreased in the control group with age. These results indicate that many factors may effect change in both the ɣ and ϴ angles with age, such as genetic factors, dental abnormalities, and the growth-development process.

In studies of hypodontia conducted in European, American, and Australian societies, MnP2 agenesis was found to be the most common type of hypodontia (3, 13, 14), while mandibular incisive hypodontia was found to be the most common in Asian population (4, 5). It has also been reported that the prevalence of hypodontia in North America is lower than in Europe and Australia (3). Studies conducted in Turkish society have also observed a similar prevalence of hypodontia in European population (15, 16). If the genetic factors are considered to affect the type of hypodontia seen in societies, it can be said that Turkish society is similar to European societies rather than Asian societies in terms of hypodontic characteristics.

In our study, the unerupted MnP2 distal angulation in patients with unilateral MnP2 hypodontia was found to be higher than in patients without agenesis as in both European and Japanese studies (7, 9). Navarro et al. (7) stated that MnP2 distal angulation is associated with genetic features of dental abnormalities. Kure et al. (9) in a study comparing MnP2 distal angulation between a MnI agenesis group and unilateral MnP2 agenesis group stated that different genetic factors affect type of agenesis. This situation may suggest that genetic factors do not predominantly affect the physical and quantitative characteristics of the hypodontia that has occurred, while they do affect the type of hypodontic prevalence that will occur. Aside from genetic factors, local factors such as mesial inclination of the permanent first molars due to early loss of a primary second molar or anklyloses primary molars below the occlusal level may also be responsible for the angular measurements between the long axis of the molar and the premolar. Otherwise, vertical growth pattern may have an important influence on the mesial angulation of the molars and premolars.

In association with the unerupted MnP2, increasing of ϴ angle value has been shown in recent studies during the progressive phases of the formation (10). It can be said that the change in ϴ angle starts with by rotation toward the vertical of the unerupted MnP2 tooth during progression of the formation and the posterior rotation of the mandibular condyle and angulus with the effect of growth and development (17). It should be expected that the vertical rotation of the MnP2 increases the ϴ angle, while the posterior rotation of the mandibular condyle decreases. In the same process, a decrease in the ɣ angle due to acquired vertical direction of the MnP2 tooth with progression of the formation process should be expected. The graphs obtained from age-matched patients within their own groups can provide insight regarding the differences in the angles during the formation stages, as well as the differences in the ɣ and ϴ angles in different agenesis groups and in the control group.

In their study, Wasserstein et al. (10) showed that the ϴ angle increased as the formation stages progressed. Navarro et al. (7) showed similar results in both the control group and unilateral MnP2 agenesis group depending on the developmental stage. Kure et al. (9) found that the ϴ angle of the control group was significantly higher than the ϴ angle of the unilateral MnP2 agenesis group and numerically a little higher than the ϴ angle of the MnI agenesis group. In our study, the ϴ angle trend line increased in the patients with MnI agenesis (Figure 2), whereas the ϴ angle trend line decreased in the control group (Figure 4). This situation is related to using different measurement techniques or to the measurement errors between the two studies. Also, it can be said that distal angulation measurements obtained with panoramic radiography may not always present clinically accuracy results. In addition, in our study, it was thought that MnP2 in the control group may have a more vertical direction, and the effect of posterior rotation of the mandibular condyle during growth-development on the ϴ angle may be higher. Thus, a decrease in the ϴ angle in the control group was reached in this study. The reason the rotation in the condyle had more of an effect on the ϴ angle than change of the MnP2 in the vertical direction in our study can be explained by the genetic factors because the studies were conducted in different societies. Similarly, in our study, the trend line of the ϴ angle decreased in the control group, although it increased in patients with MnI agenesis. The reason for this may be that the posterior rotation of the condyle is greater in the control group than in the MnI agenesis group, which may be related to the genetic factors. In other words, it can be said that the change of the ϴ angle according to the developmental stage can be determined by degree of dominance of the condylar rotation and MnP2 vertical direction.

Furthermore, Navarro et al. (7) found that the ɣ angle decreases according to developmental stage and explained that these findings are related to genetic factors. In our study, the tendency of the ɣ angle to decrease in the control group was very unclear, whereas the trend line of the ɣ angle showed a high tendency to decrease in patients with MnI agenesis. In addition, it was found that the values of the inclination graphic according to age in both groups were very close. This may be due to errors/differences in measurement and genetic factors, the same way the presence of more space on the dental arch for teeth due to hypodontia in patients with MnI agenesis may result in this finding, compared to patients without agenesis. In addition, the difference in the graph slopes due to the eruption path of the MnP2 teeth may be more rotational in the MnI agenesis group, and more linear in the non-agenesis control group patients.

In the group of patients with unilateral MnP2 agenesis, when the trend line of ɣ angle increases with age, the decrease in the trend line of ϴ angle shows that it does not meet the expectation in terms of changes in the angle values (Figure 3). This finding supports past studies (7-9) that showed the value of the ɣ angle of MnP2 in the contralateral area in unilateral MnP2 agenesis was significantly higher than in the control group, and the ϴ angle was significantly lower than in the control group. In other words, this finding can be interpreted as the possibility of malocclusion in patients with unilateral MnP2 agenesis being higher, which may be caused by genetic factors.

Because using panoramic radiography in our study may have caused erroneous values due to limitations in 2D imaging, few studies using 3D imaging techniques would be helpful to obtain more reliable results. In other words, distal angulation measurements obtained with panoramic radiography might not always present clinically accuracy results. New studies should be undertaken to support the past studies and our study using techniques involving more reliable measurements to achieve more reliable results, including a larger patient population.

CONCLUSION

- In unilateral MnP2 agenesis, the ɣ angle of the MnP2 in the contralateral was higher than in the control group, and the ϴ angle was lower than in the control group.

- The results obtained in the group with unilateral premolar agenesis support the literature in terms of age-related changes in angle of eruption.

- Posterior rotation of the mandibular condyle during the growth-development period may be one of the factors responsible for the difference in the ϴ angle between the MnI agenesis and control groups. The difference in the total number of teeth on the dental arch may be a reason for the reason for the differences in the ɣ angle between the MnI agenesis and control groups. Also, local factors such as mesial inclination of the permanent first molars due to early loss of a primary second molar or anklylosis of the primary molars below the occlusal level may also be responsible for the angular measurements between the long axis of the molar and premolar.

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethics Committee of Antalya Training and Research Hospital.

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

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Original Article

Assessment of the Relationship Between Facial and Dental Midlines with Anatomical Landmarks of the Face and Oral Cavity

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ABSTRACT

Objective: The purpose of the present study was to determine the facial anatomical landmarks, in order of accuracy, closest to the midline of the face, as well as oral cavity midline, and to specify which intraoral anatomical landmarks are closer to the dental midline.

Methods: Three commonly used anatomical landmarks including nasion, nose, and philtrum tips were marked clinically in 108 subjects. A frontal full-face digital image was used for midline analysis in accordance with the esthetic frame. Deviations from the facial and oral midlines were measured for the three clinical landmarks. Dental midline was considered as the fourth landmark. Alginate impressions were taken, and casts were analyzed under standardized conditions. The labial frenum and incisive papilla were marked. Cast images were taken and analyzed.

Results: Data showed difference between the mean ratios of the selected anatomical landmarks and the facial and oral midlines ($p \leq 0/05$). The anatomical landmark hierarchies, in proximity to the facial midline, are commissural midlines, nasion, philtrum tip, nose tip, and dental midline, respectively. The anatomical landmark hierarchies, in proximity to the commissural midline, include dental midline, philtrum tip, nose tip, and nasion. The labial frenum was less deviated from the dental midline than the incisive papilla.

Conclusion: With respect to shortcomings, the results showed that all of the anatomical landmarks were deviated from the facial and oral midlines. The order of proximity of the anatomical landmarks to the facial midline was as follows: commissural midline, nasion, philtrum, and dental midline.

Keywords: Facial midline, dental midline, commissural midline, oral midlines

INTRODUCTION

Symmetry in face is known as one of the fundamental indicators of beauty (1, 2). It is defined as "correspondence in size, shape, and relative position of parts on opposite sides of a dividing line or median plane or about a center or axis (3)," but clinically, it means "existence of balance and coordination" (4). One of the components of facial symmetry is coordination of the dental and facial midlines that is an essential part of prosthetic rehabilitations and orthodontic treatments (5, 6).

During a smile, symmetrical teeth display plays an important role in creating a beautiful smile (4). However, in a pleasant smile, almost maxillary teeth are displayed, and coordination of the maxillary central incisors midline with the facial midline is more important than mandibular incisors. Nevertheless, coordination of the upper and lower arch dental midlines is necessary to achieve beauty and a proper occlusion, and in addition, it can increase

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the duration and complexity in orthodontic treatment cases (4). Anatomical landmarks including interpupillary distance, nasion, tip of the nose, philtrum, and center of the chin have been used to assess facial symmetry. One of the methods of midline determination is to determine the center of lip commissures and then drawing a perpendicular line, which is stated to be of higher accuracy (7). In some cases, such as asymmetric development, trauma, and facial neoplastic lesions where landmarks are changed, other landmarks should be used. In these cases, some intraoral landmarks, such as incisive papilla, labial frenum, and median palatal suture, are also suggested by researchers (8). The incisive papilla had the highest degree of compatibility with the midline of the face in a previous study (9). Previous studies are mainly based on the extent of the acceptable range of discrepancy between dental midline with facial midline that is approximately 2–3 mm, and they did not have a definite reference to the midline (1, 10, 11). In two separate studies (12, 13) in the same results, 70% of the dental midline compatibility with the facial midline has been reported. The major problem of studies in this area is the shortage of sufficient scientific evidence regarding the relationship between facial midlines and anatomical landmarks in the mouth. Therefore, the purpose of the present study was to investigate the relationship between facial and dental midlines and anatomical landmarks of the face and mouth.

METHODS

A total of 108 students from a local university participated in the present study. The study included 54 male and 54 female subjects. The age of the students was between 20 and 25 years. Inclusion criteria were the following: (1) no anterior tooth extraction, (2) no orthodontic treatment, (3) no restorative or prosthetic treatment, (4) no cosmetic surgery on the jaws or rhinoplasty, (5), no crowding or spacing in the upper and lower dental arches, and (6), no obvious asymmetry or defect on the face and dental arch. Using a marker (Faber Castell Grip 1583 Marker, Germany), three points were drawn on the nasion, in the middle of the philtrum, and the tip of the nose with an approximate diameter of half a millimeter. A digital camera (Canon EOS 1300D, EF 100 mm MACRO Lens, Taiwan) with spot flash was set at the 12 o'clock position. The camera diaphragm was set in automatic mode at 4.5, and the camera was mounted on a tripod (CT-2491 Carbon Fiber Tripod, USA), switched into the automatic mode, and then placed at a standard distance of 1.5 m from the subject. The room light conditions were similar for each photo. The photos were taken from the subjects in a seated position while they were wearing a social smile. The position of the head is adjusted in natural head position (NHP). The lens height of the camera on the tripod was adjusted the same as the height of the subject's eyes when they were sitting straight on the chair. The subjects were asked to look directly toward the camera, and the subjects' heads were positioned vertically and horizontally in a standard manner (Figure 1).

Care was taken to ensure that the subject does not rotate his head especially around the vertical axis, since this rotation around the vertical axis causes the midline to move against the direction of the axis of rotation. Four pictures were taken from each subject, and among these, the following photos were set aside: (1) having head rotation, (2) asymmetric eyes, (3) clinical marker sign was incorrect or unreadable, and (4) low-quality and low-resolution photos; the best photos were then selected. The images were transferred to Photoshop CS6 software for processing.

It is almost impossible for the midline of the face to define in both dynamic movements and esthetic. A rectangle known as the esthetic frame was used to define the face midline. This area is defined as a zone where esthetic items, such as the midline and the occlusal plane inclination, and smile parameters are readily recognizable. The upper border runs from the outer contour of one eye and extends toward the outer contour of the other eye. This line helps in detecting the rotation of the head around the sagittal axis. External borders were drawn from the outer corner of the eyes so that they are perpendicular to the horizontal line and are exactly parallel to each other. The lower border is drawn parallel to the upper border on the lower rim of the lower lip. These four lines complete the "esthetic frame." Two defaults were considered for drawing the esthetic frame. First, the midline of the esthetic frame was considered equivalent to the midline of the face. Second, soft tissues outside this area, such as the cheeks, buccal soft tissue, and frontal tissue, have a small effect on midline perception. Buccinator muscle hypertrophy, weight, and size of the forehead are factors that can influence midline perception. Dental midline is defined as the vertical line that runs from the tip of the embrasure between two central incisors of the maxilla to the relevant contact area, which is the midline parallel to the midline of the esthetic frame. Oral commissure midline is defined as the midline between the corners of the subject's lips during smiling. The relative facial midline (RFV) and the relative commissural midline (RCV) serve as tools for evaluating the relationship between anatomical landmarks and defined midlines. Three vertical lines were drawn along each of the anatomical points that were clinically determined. The fourth line was drawn along the dental midline of the subjects. The RFV is defined as an indicator of the proximity of a landmark to the facial midline. It is measured from the external border of the frame to the facial midline as shown by the letter F. The measured distance from the outer boundary of the frame to the nasion is shown as the n variable. Then, the RFV is obtained by dividing n by F. Similarly, the RFVs were obtained for the next landmarks including nose tip (t), point in the middle of the philtrum

Figure 1. The standard position for imaging

(p), and dental midline (d) (d/F, p/F, and t/F), and the numbers were recorded. To investigate the relationship between anatomical landmarks and commissural midline, a point was determined at the center of each commissure, and a line was drawn between these two points. A point in the middle of the intercommissure line was assumed, and from that point, a line parallel to the midline of the esthetic frame was drawn and considered as the commissural midline. The RCV as an indicator of the proximity of an anatomical landmark to the commissural midline (center of the mouth) is considered as point C. In fact, the distance from point C to each of the commissures was considered as a variable. The measured distances from nasion, philtrum, tip of the nose, and dental midline to the commissures were considered as variables (nx), (px), (tx), and (dx), respectively. Then, RCVs were obtained by dividing these points into C, and data were recorded (nx/C, tx/C, px/C, and dx/C). The measured distances from the external border of the esthetic frame to the central point between the commissures were defined as a variable called Cx.

This is a standard denominator for all the anatomical landmarks in the esthetic frame, and there is no need to match the image with the subject's face (Figure 2, 3).

RFV1 and RCV1: Nasion relationship with the midline of the face and the commissural midline.

RFV2 and RCV2: Nose tip relationship with the midline of the face and the commissural midline.

RFV3 and RCV3: Relationship of the tip of the philtrum with the midline of the face and the commissural midline.

RFV4 and RCV4: Dental midline relationship with the midline of the face and the commissural midline.

RFV5: Relationship of the commissural and facial midlines.

Therefore, by considering the symmetry in all of the five aforementioned subjects, it can be deduced that the RFVs and the RCVs are equal to each other and to 1. The right or left border of the esthetic frame to commissure is selected based on the direction of anatomical landmarks classification. Therefore, the shorter distance from the outer border of the esthetic frame is always selected. Hence, the RFV and the RCV are never >1. For each subject, an alginate impression was taken and immediately poured with

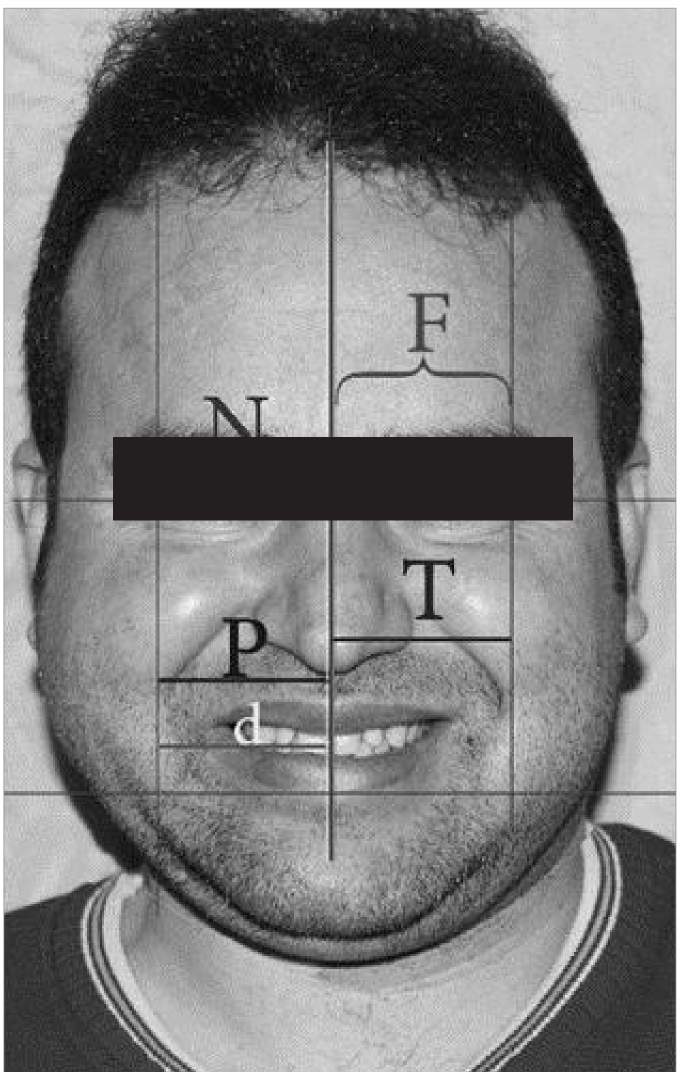

Figure 2. Determining the indices for calculating RFV

Figure 3. Determining the indices for calculating RCV and RFV5

type 3 plaster (premiumplusuk™, UK). When the bases are placed on a flat horizontal surface, the casts were placed on the smooth surface of the occlusal edge to standardize the casts in accordance with an occlusal plane parallel to the horizontal plane. Then, by a ruler, several points around the casts were marked with a pencil (Mars® Lumograph® black 100B) at a 30 mm height. The points were connected by one line, and the casts were orthodontically trimmed according to the line drawn (Figure 4).

Anatomical landmarks including the anterior point of the incisive papilla (IPa), posterior point of the incisive papilla (IPb), anterior point of the labial frenum (LFa), and posterior point of the labial frenum (LFb) were drawn on the casts. The casts were placed on a flat black slab inside a cardboard box that places the camera at a height of 200 mm. The digital camera was adjusted in such a way that the axis of the lens was in the vertical and downward directions relative to the occlusal plane. Digital data were processed with Photoshop CS6 software. The IPa, IPb, LFa, and LFb points were digitally connected with one line, and the line extends on both sides. The contact area of the two central teeth is a line drawn in the same way that in fact is the dental midline. The distance of each of the two lines drawn from the labial frenum and incisive papilla to the dental midline was measured, and the results were recorded.

Figure 4. The standard situation of cast imaging

Ethics committee approval was received for this study from the Ethics Committee of Ardabil University of Medical Sciences. Written informed consent was obtained from the patients who participated in this study.

Statistical Analysis

Data were analyzed by one-sample t-test and t-test for the independent groups using Statistical Package for Social Sciences version 24.0 (IBM Corp.; Armonk, NY, USA). The level of statistical significance was considered as 0.05.

RESULTS

All variables in the present study had normal distribution using kurtosis test. For each variant, the results of one-sample t-test are shown in Table 1–3. The analysis showed that the difference between the mean ratio of each anatomical landmark and the midline of the face was statistically significant $p<0.001$. There was a significant difference (Table 4) between the mean ratios of the dental midline, commissural midline, and philtrum with the facial midline in males and females $p<0.05$. Moreover, the results showed that there is a statistically significant difference (Table 5) between the mean ratios of the nose tip with the commissural midlines in males and females $p<0.001$. The results of independent-samples t-test for the male and female groups are shown in Table 4–6.

DISCUSSION

Since the human face is not primarily symmetrical, there are no single rules for midline diagnosis, but noncoincident midlines are readily detectible by the patients (12). Lay people tend to be less sensitive to midline changes than dentists, but as problems

Table 1. Comparison between mean ratios of RFV 1-5 with criterion number

Variant	mean	Stand Criterion	Dev Number	df	t	p
RFV1 (Nasion)	0/96	0/03	1	107	-14/02	0.001*
RFV2 (Tip of the nose)	0/96	0/03	1	107	-12/99	0.001*
RFV3 (Philtrum)	0/96	0/03	1	107	-14/07	0.001*
RFV4 (Dental midline)	0/95	0/03	1	107	-13/95	0.001*
RFV5 (Midline of commissures)	0/97	0/02	1	107	-12/73	0.001*

*One Sample t- test; p≤0/05

Table 2. Comparison between mean ratios of RCV1-4 with criterion number

Variant	mean	Stan Dev	Criterion Number	df	t	p
RCV1 (Nasion)	0/94	0/05	1	107	-13/36	0.001*
RCV2 (Tip of the nose)	0/95	0/05	1	107	-11/72	0.001*
RCV3 (Philtrum)	0/95	0/03	1	107	-16/78	0.001*
RCV4 (Dental Midline)	0/97	0/03	1	107	-11/51	0.001*

*One Sample t- test; p≤0/05

Table 3. Comparison between mean ratios of IP and FL with criterion number

Variant	mean	Stan Dev	Criterion Number	df	t	p
IP	0/80	0/65	0	107	12/78	0.001*
FL	0/53	0/50	0	107	11/06	0.001*

*One Sample t- test; p≤0/05

Table 4. Comparison between mean ratios of facial and intraoral anatomic landmarks with facial midlines in males and females

Variant	mean	Stan Dev	Criterion Number	df	t	p
RFV1 (Nasion)	male	54	0/97	0/03	0/81	0.423*
	female	54	0/96	0/03		
RFV2 (Tip Of The Nose)	male	54	0/96	0/03	1/65	0.1*
	female	54	0/95	0/04		
RFV3 (Philtrum)	male	54	0/95	0/03	2/32-	0.02*
	female	54	0/97	0/02		
RFV4 (Dental Midline)	male	54	0/97	0/03	3/04	0.003*
	female	54	0/95	0/04		
RFV5 (Midline Of Commissures)	male	54	0/97	0/02	1/65	0.101*
	female	54	0/96	0/03		

Independent-Samples t-test; p≤0/05

Table 5. Comparison between mean ratios of facial and intraoral anatomic landmarks with commissural midlines in males and females

Variant	mean	Stan Dev	Criterion Number	df	t	p
RCV1 (Nasion)	male	54	0/94	0/04	-0/794	0.429*
	female	54	0/94	0/05		
RCV2 (Tip of the nose)	male	54	0/93	0/05	-0/363	0.001*
	female	54	0/96	0/04		
RCV3 (Philtrum)	male	54	0/95	0/03	-0/067	0.947*
	female	54	0/95	0/02		
RCV4 (Dental midline)	male	54	0/96	0/03	-0/121	0.904*
	female	54	0/96	0/04		

Independent-Samples t-test; p≤0/05

Table 6. Comparison between mean intraoral anatomical landmarks and dental midlines in males and females

Variant	mean	Stan Dev	Criterion Number	df	t	p
IP	male	54	0/58	0/54	1/030	0.305*
	female	54	0/48	0/45		
FL	male	54	0/86	0/66	0/971	0.334*
	female	54	0/74	0/64		

Independent-Samples t-test; p≤0/05

aggravate, they tend to be more sensitive than dentists (11, 14). Moreover, lay people are able to discern the discrepancy of axial dental midline angulation as low as 3.5°, and this is aggravated by having chin or nose deviation in the opposite direction and vice versa (15). However, further investigations are still needed to determine whether it is more pleasant to have a slight dental midline deviation in the same direction in subjects bearing chin and nose deviation; if it is yes, then how much?

Even people from different cultures have different sensitivities to midline discrepancies (16, 17). The investigation of the relationship between the facial and dental communication lines using the esthetic frame represents the deviation from the ideal symmetry and thus helps to improve the treatment plan (7). Midline problems are not related to age and sex (11). Facial midlines were defined by using the esthetic frame named by Bidra (7). The esthetic frame was designed to analyze the problems caused by the lack of an attractive smile. In the present study, the NHP was used and controlled by a trained researcher because it is valid and reliable, and it is absolutely necessary to avoid turning the head of the subjects around the vertical axis (18, 19). Nevertheless, human error in detecting this rotation should not be completely ruled out. The smile's image was selected while none of the cases have a highly asymmetrical smile or a smile that does not show the maxillary central incisors. The study was designed to be completely clinically applicable. Thus, the markings of each anatomical landmark were done clinically (and not on a digital image), and the connecting lines were drawn along these markings. Despite the high precision, inherent human errors in marking anatomical landmarks cannot be ignored. Among the clinical landmarks, it was difficult to mark the nasion soft tissue and nasal tip for nasal anatomy reasons. Therefore, caution must be taken when using the results of these landmarks, and more studies should be conducted. There was a significant difference between the mean ratios of the selected anatomical landmark and facial midline in the evaluation of the facial midline and anatomical landmarks. Commissural midline was considered as an anatomical landmark when analyzing the hierarchical arrangement for midline that had the first rank in matching with the facial midline. Similar findings have also been found in studies conducted by Moshkelgosha et al. (20), Bidra et al. (7), and Kurian et al. (21), which may be due to the use of the concept of the esthetic frames in aforementioned studies. Nasion has a good position during the mid-fifth, but its relationship with the midline of the face and the commissural midline has not been studied much. However, in the present study, nasion is in the second rank in order of proximity to the facial midline, but due to the difficulty in clinical marking and its distances from the dental midline, it may compromise the results, so it cannot be a good clinical indicator for analyzing each of the midlines. In many previous studies, the philtrum or vermilion border was used to provide facial form, and due to its results and its position, it could be a reliable landmark for midline analysis (1, 9, 10, 12, 22). In the present study, philtrum was ranked third in order of proximity to the midline. The dental midline was also considered as a landmark when analyzing the hierarchy order, and its relationship to the facial midline was evaluated. However, the vertical angle of the dental midline was not considered in the analysis. Dental midline was ranked last in order of proximity to the facial midline. In addition, in the present study, there was a significant difference between the mean of the philtrum and dental midline indices in males and females, which requires further studies to confirm the results. The second part of the study examines the proximity and hierarchy order of anatomical indices to the commissural midline (center of the mouth). Dental midline at the highest level and then philtrum, nasal tip, and nasion were closest to the commissural midline, respectively. In the present study, philtrum was ranked second in the hierarchy order, indicating that the philtrum is a more reliable indicator for the determination of the oral midline. In the present study, a significant difference was found between male and female subjects in relation to the commissural midline only in the nasal tip index, but in other indices, there was no significant difference in the need for further studies to confirm the results.

The third part of the study evaluated the relationship between the anatomical landmarks of the incisive papilla and labial frenum with the dental midline and found that there was a significant difference between the mean deviation of these two anatomical landmarks and the dental midline. The labial frenum with a mean deviation of 0.53 mm in comparison with the incisive papilla with an average deviation of 0.80 mm was closer to the dental midline. McVay et al. (18) reported that the mean deviation of the labial frenum from the midline is 0.93 mm, but the labial frenum is less deviated from the midline than the incisive papilla (18). The average deviation cannot be compared with other previous studies that measured measurements manually from the casts owing to the method used in the present study and the magnification in the preparation of digital images, and more studies need to be conducted. According to some researcher's belief, in determining the position of the frenum, a very precise dental cast is required (5, 15). In the present study, it was attempted to observe the position of the frenum and then take the dental impression precisely, and the cast pouring was carefully done to prevent the frenum from bubbling or fracturing. During the capturing of digital images, it was also very important to record the marked lines on the frenum at the maximum resolution and the smallest magnification. In addition, inherent human errors cannot be ignored. Despite all of the above, the results of the present study and other studies were conducted with regard to the lack of significant superiority of the incisive papilla, and if it was possible to record the labial frenum accurately, it could be described as a more appropriate landmark. However, the labial frenum, which is more often referred to as a reliable key indicator for determining the position of the maxillary central incisors, is used.

CONCLUSION

In the present study, the following conclusions were achieved:

- The hierarchy of the facial anatomical landmarks closest to the midline of the face was as follows: commissural midline, nasion, philtrum, and dental midline.
- With consideration of the commissural midline, the hierarchy of the facial anatomical landmarks closest to it was as follows: dental midline, philtrum, nasal tip, and nasion.
- If an impression record is taken accurately, the labial frenum could be described as a more appropriate landmark and is more often referred to as a reliable key indicator for determining the position of the maxillary central incisors.

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethics Committee of Ardabil University of Medical Sciences.

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

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Original Article

The Effects of Using Plaque-Disclosing Tablets on the Removal of Plaque and Gingival Status of Orthodontic Patients

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ABSTRACT

Objective: The aim of this study was to investigate the effects of using plaque-disclosing tablets (PDTs) on the plaque and gingival index scores of patients wearing fixed orthodontic appliances.

Methods: In group A (n=16), the subjects were motivated by conventional oral hygiene instructions, including verbal information about tooth brushing. The patients in group B (n=17) were motivated using PDTs used in the dentists' office to show the locations of biofilms in addition to the instructions given to group A. Both the chairside demonstration performed in group B and the at-home use of disclosing tablets were undertaken by those in group C (n=15). The periodontal parameters were recorded before applying the fixed appliance (T0) and after the first (T1) and third (T2) months.

Results: The plaque index (PI) scores of group C were significantly lower ($p<0.05$), when compared to groups A and B, after the first (T1) and third months (T2); however, no significant differences ($p>0.05$) were found between groups A and B. The gingival status of group C did not change significantly ($p>0.05$) over the three months and was statistically lower when compared to groups A and B.

Conclusion: The use of PDTs at home may enhance the plaque removal efficiency and gingival health stability, by facilitating self-examination.

Keywords: Plaque-disclosing tablets, oral hygiene, orthodontics

INTRODUCTION

Dental plaque is a predisposing factor for hyperplastic gingivitis, white spots, periodontal breakdown, and carious lesions (1, 2). Fixed orthodontic appliances cause greater plaque accumulation due to the creation of plaque-retentive sites, especially in the areas between the brackets and around the gingival margins (3). Therefore, the removal and control of dental plaque is very important for oral health maintenance in orthodontic patients. Poor oral hygiene can lead to unsatisfactory outcomes, such as white spot lesions and premature termination of the treatment, as reported in 5%-10% of orthodontic patients (4, 5).

Clinicians should motivate orthodontic patients to acquire satisfactory, steady oral hygiene at each appointment, and several oral hygiene motivational techniques have been evaluated and compared in numerous studies. These methods can be classified into verbal (6, 7), written (8), and supplemental visual techniques, such as showing illustrations and videos (9), the application of phase-contrast microscopy (10), or dyeing teeth with disclosing agents (6, 10-12).

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Disclosing agents, including dye (erythrosine, fluorescein, and iodine), are available in solution, swab, and tablet forms, and these agents allow clinicians to show the localization of the biofilm on the patient's teeth. Specifically, plaque-disclosing tablets (PDTs) can be used after brushing to allow a self-examination of the brushing quality. In the literature, the effects of using disclosing agents as motivational factors in orthodontic patients at the clinic have been investigated in numerous studies (6,10-12). However, no studies were found comparing the effects of using PDTs at the clinic and at home on the plaque index (PI) and gingival index (GI).

The aim of the present study was to compare the effects of using PDTs at the clinic and at home on the PI and GI scores during a fixed orthodontic treatment.

METHODS

This study was conducted at the Department of Orthodontics (Gaziantep University School of Dentistry, Turkey, from February 2015 to October 2015) and approved by the Ethics Committee of Gaziantep University (No.: 44). The patients and their parents were given information about the study design, and they signed informed consent forms at the beginning of the study. Forty-eight patients were selected according to the following inclusion criteria: requirement of a non-extraction fixed orthodontic treatment, 12–18 years of age, crowding under 5 mm in the incisors, presence of at least 20 natural permanent teeth and a completely healthy periodontal tissue, and the absence of dental caries. The exclusion criteria were the presence of systemic or chronic diseases, physical or mental disorders, previous orthodontic treatment, dental fluorosis, use of antibiotics during the previous six months, and smoking. According to the calculations performed using GPOWER 3.1, the minimum sample size, which would guarantee a power equal to 0.80, was 42 for the total of three groups.

Study Design

This study was conducted as a double-blind randomized clinical trial. A computer program was used to randomly distribute each patient to one of the three groups. Random sequencing was managed by a statistician. The baseline balance was tested after randomization among the treatment groups. Concealed allocation was performed using opaque, sealed envelopes that contained each group's patient listing; these were provided by another researcher before the initial bonding session. During the study, the examiner, data collector, and random sequence statistician were all blinded in terms of patient groupings.

Conventional 0.022 slot stainless steel brackets (MBT system; Opal, Utah, USA) were applied only to the maxillary arch to compare the differences between the arches with and without brackets. The examinations were conducted by the same researcher for three months. The mandibular arch was bonded after the study ended (three months).

Motivational Interviewing Protocol

The researcher informed the patients and their parents about the study. All of the groups received conventional oral hygiene instructions, including verbal information about tooth brushing (modified Bass technique) and daily dietary suggestions. The cleaning of the bracket walls and teeth using a toothbrush and interdental brush was demonstrated on a model and in the patient's mouth. The oral health biofilm risks and the importance of eliminating dental plaque were emphasized, and the oral hygiene instructions were repeated by the same blinded examiner at each appointment.

Each of the patients used the same toothbrush and toothpaste during the study, and each was instructed to brush their teeth at least three times a day for 3 minutes. The brushing techniques of the patients were checked at each appointment, and stainless steel ligatures were used to ligate the orthodontic arch wires.

The patients were then randomly distributed to one of the following three intervention groups:

Group A: Conventional motivational techniques were used in group A (control group), including oral hygiene instructions, a model demonstration, and self-application by the patient (T0).

Group B: The patients were motivated by a chairside technique in addition to the techniques used for group A. PDTs (GUM Red Cote Disclosing Tablets; Sunstar, Chicago, IL, USA) were used twice during the chairside appointments. The first PDT showed the quantity and location of the biofilm and the second one showed the brushing efficiency. The patient chewed each tablet for two minutes and then rinsed with water.

Group C: The PDTs were provided for at-home use in addition to the chairside motivations given to group B. The patients were instructed to use the tablets at home, once a day, after dinner. They were instructed to chew the tablets before and after brushing. A compliance chart was provided to each patient to assess the use of PDTs. The patients and their parents signed this chart after each time they used the tablets. Patients with a compliance rate lower than 90% were excluded.

Periodontal Evaluation

A calibrated examiner, blinded to the group allocations, measured the periodontal parameters at each time point. He was trained by a periodontist to calculate the Loe and Silness GI and the Silness and Loe PI, and was allowed to perform two PI measurements on 20 dentistry student volunteers before the study. The measurements were taken before the appointment and they were forbidden to brush until the measurement time.

The second and third molars were not included in the PI and GI measurements. The PI and GI scores of the maxillary and mandibular arches were calculated separately, and the maxillary arch was separated into anterior and posterior sections. The average scores of the anterior (canine to canine) and posterior teeth were detected separately, whereas those of the mandibular teeth were calculated without separating the anterior from the posterior.

The periodontal parameters were recorded before applying the fixed appliance (T0), after both the first (T1) and third (T2) months.

Statistical Analyses

The statistical analyses were performed using Statistical Package for Social Sciences for Windows, version 20.0 (IBM Corp., Armonk, NY, USA). The Shapiro-Wilk test was used to assess the normal distribution of the continuous variables, the Kruskall-Wallis H test was used to assess the discontinuous (non-parametric) data, and the

Mann-Whitney U test was used to assess the non-normally distributed variables. A post-hoc multiple comparison test was also used. When examining the differences between two dependent, normally distributed variables, the Wilcoxon signed rank test was used. A P value of <0.05 was considered to indicate statistical significance. A two-proportion *z*-test was used to compare the drop-out rates; additionally, a Bonferroni test was performed, and any α value lower than 0.143 was considered to indicate statistical significance.

RESULTS

Fifty-four patients were initially included in the study; however, six patients (in group A, n=2; in group B, n=1; and in group C, n=3) were lost after the three-month follow-up, at stages T1 and T2 (Figure 1). Four of six patients were lost (in group A, n=2; in group B, n=1; and in group C, n=2) because of inconsistent appointment attendance. Additionally, one patient from group C was excluded on account of a lack of cooperation in using PDTs. No significant differences were found among the three groups in terms of drop-out rates (α>0.143). Patients were excluded from the study if measurements were not performed within the week of the appointment, or if the compliance was under 90% according to the compliance chart provided for group C. The final sample included 48 patients who had completed all of the study measurements (Table 1).

PI and GI scores between the groups

PI Scores

No significant differences were observed in the PI scores at the baseline (T0) between the three groups (Table 2). At T1 and T2, no differences were found between groups A and B (p>0.05) in the maxillary anterior and posterior PI scores. However, group C exhibited lower PI scores than groups A and B at T1 and T2 (p<0.05) in the maxillary anterior and posterior PI scores.

In the mandible, no differences were found between the groups at T0 and T1 (p>0.05). Group C had significantly lower scores than groups A and B (p<0.05) at T2, but no statistically significant differences were observed between groups A and B (p>0.05) at T2.

GI Scores

For the anterior and posterior maxillary teeth, group C exhibited statistically lower scores than groups A and B at T1 and T2 (p<0.05) (Table 2). In addition, group B showed lower GI scores for the maxillary teeth than group A at T1 and T2 (p<0.05). For the mandibular GI scores, statistically lower scores were observed in group C when compared to groups A and B at T1 and T2 (p<0.05). Group B also had significantly lower scores than group A at T1 and T2 (p<0.05).

Table 1. Baseline age, gender characteristics, and periodontal scores of groups

	Group A	Group B	Group C	p
Age (years) (mean±SD)	15.4±2.9	15.7±2.6	16.1±2.8	0.503
Gender (n) (F/M)	8 / 8	9 / 8	8 / 7	0.773
Maxillary anterior PI	0.85±0.45	0.75±0.37	0.70±0.38	0.891
Maxillary posterior PI	1.01±0.43	0.87±0.43	0.94±0.32	0.791
Mandibular PI	0.87±0.38	0.78±0.39	0.76±0.36	0.696
Maxillary GI	1.33±0.18	1.20±0.32	1.10±0.18	0.082
Mandibular GI	1.16±0.20	1.17±0.15	1.11±0.17	0.279

SD: standard deviation; F: female; M: male; PI-plaque index; GI-gingival index

Table 2. Intergroup comparison of the mean plaque and gingival scores

		Group A Mean±sd	Group B Mean±sd	Group C Mean±sd	p
Maxillary anterior PI	T0	0.85±0.45	0.75±0.37	0.70±0.38	0.891
	T1	0.95±0.56 [c]	0.81±0.31 [c]	0.59±0.24 [ab]	0.041
	T2	1.09±0.64 [c]	0.90±0.50 [c]	0.29±0.24 [ab]	0.001*
Maxillary posterior PI	T0	1.01±0.43	0.87±0.43	0.94±0.32	0.791
	T1	1.04±0.50 [c]	0.92±0.33 [c]	0.65±0.20 [ab]	0.015*
	T2	1.17±0.40 [c]	1.04±0.73 c	0.51±0.35 [ab]	0.001*
Mandibular PI	T0	0.87±0.38	0.78±0.39	0.76±0.36	0.696
	T1	0.82±0,34	0.69±0.36	0.54±0.27	0.072
	T2	0.76±0.29 [c]	0.84±0.61 [c]	0.38±0.28 [ab]	0.003*
Maxillary GI	T0	1.33±0.18	1.20±0.32	1.10±0.18	0.082
	T1	1.34±0.19 [bc]	1.20±0.36 [ac]	1.10±0.17 [ab]	0.011*
	T2	1.34±0.19 [bc]	1.21±0.38 [ac]	1.10±0.17 [ab]	0.013*
Mandibular GI	T0	1.16±0.20	1.17±0.15	1.11±0,17	0.279
	T1	1.29±0.24 [bc]	1.16±0.24 [ac]	1.10±0.21 [ab]	0.016 *
	T2	1.37±0.23 [bc]	1.23±0.50 [ac]	1.10±0.17 [ab]	0.023*

[a]Significantly different from group A, [b]significantly different from group B, and [c]significantly different from group C. PI-Plaque Index, GI-Gingival Index, *P ≤ 0.05.

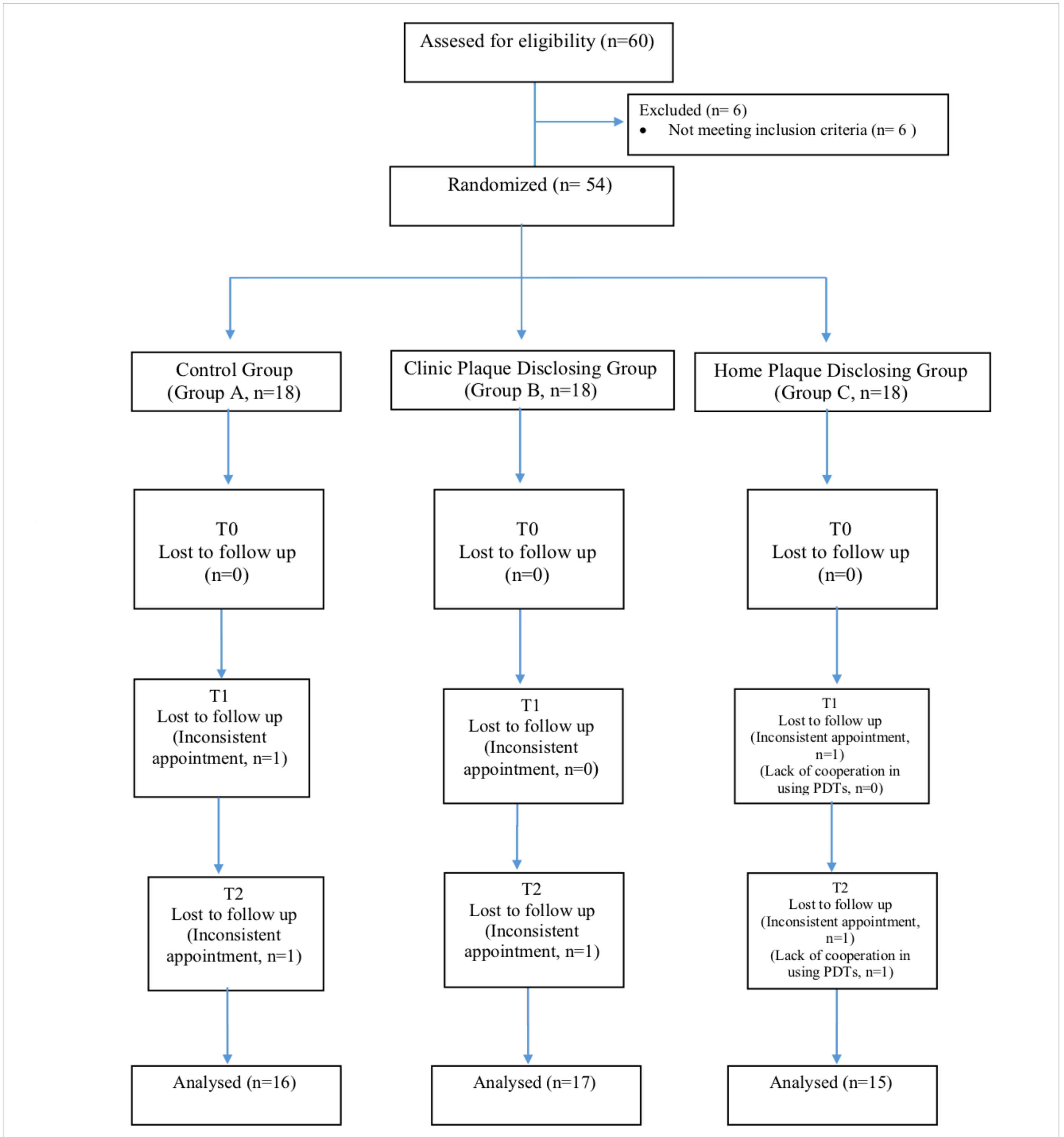

Figure 1. Study flow chart

PI and GI Scores Among the Groups

PI Scores

According to the PI scores, there were no significant differences between the time points (T0-T1, T0-T2, and T1-T2) in group A (p>0.05) and group B (p>0.05) (Table 3). However, the PI scores were significantly decreased in group C (p<0.05). The decreases were observed in the anterior maxillary teeth (T0-T2 and T1-T2), posterior maxillary teeth (T0-T1 and T0-T2), and mandibular teeth (T0-T1 and T0-T2).

GI Scores

The GI scores were statistically increased for the mandibular teeth between T0 and T2 in group A (p<0.05); however, the other groups did not show significant differences between the time points (p>0.05) (Table 3).

PI Scores Between Bonded and Non-Bonded Jaws and Between Anterior and Posterior Maxillary Teeth

No significant differences were found between the bonded and non-bonded jaws (p>0.05) in any of the groups (Table 4). In addition,

Table 3. Comparison of the plaque and gingival scores among the groups

		Group A	Group B	Group C
		p	p	p
Maxillary anterior PI	T0 vs T1	0.414	0.695	0.102
	T0 vs T2	0.065	0.311	0.001*
	T1 vs T2	0.293	0.334	0.003*
Maxillary posterior PI	T0 vs T1	0.826	0.776	0.008*
	T0 vs T2	0.182	0.345	0.004*
	T1 vs T2	0.201	0.798	0.099
Mandibular PI	T0 vs T1	0.691	0.256	0.048*
	T0 vs T2	0.532	0.615	0.006*
	T1 vs T2	0.730	0.394	0.061
Maxillary GI	T0 vs T1	0.173	0.394	0.916
	T0 vs T2	0.173	0.594	0.916
	T1 vs T2	0.173	0.594	0.916
Mandibular GI	T0 vs T1	0.136	0.900	0.969
	T0 vs T2	0.036*	0.345	0.969
	T1 vs T2	0.173	0.594	0.916

PI-Plaque Index, GI-Gingival Index, *p ≤ 0.05.
PI-Plaque Index, GI-Gingival Index.

Table 4. Comparison of the plaque and gingival scores between maxillary anterior and posterior and between maxillary and mandibular arches

	Group A (p)			Group B (p)			Group C (p)		
	T0	T1	T2	T0	T1	T2	T0	T1	T2
Maxillary anterior PI vs. posterior PI	0.213	0.074	0.395	0.381	0.723	0.361	0.074	0.493	0.061
Maxillary PI vs. mandibular PI	0.384	0.678	1.000	0.520	0.756	0.852	0.173	0.184	0.309
Maxillary GI vs. mandibular GI	0.074	0.254	0.756	0.785	0.395	0.818	0.528	0.587	1.000

there were no significant differences in the PI scores between the anterior and posterior maxillary teeth in any of the groups (p>0.05).

GI Scores Between Bonded and Non-Bonded Jaws and Between Anterior and Posterior Maxillary Teeth

There were no significant differences in the GI scores between the jaws in any of the groups (p>0.05) (Table 4). In addition, there were no significant differences in the GI scores between the anterior and posterior maxillary teeth (p>0.05).

DISCUSSION

The influences of the use of PDTs at the clinic and at home on the PI and GI scores were compared in this study. Patients aged 12–18 years old were included in this research because adolescents are commonly referred for orthodontic treatment, and studies have shown that their PI and GI scores are higher than in adults (12, 13). In addition, the continued maintenance of good oral hygiene during orthodontic treatment in adolescents is a very big problem in the field of orthodontics (14). Six patients were lost after the three-month follow-up. Patients were excluded because of inconsistency in keeping appointments, and one patient in group C was excluded because of a lack of cooperation in using PDTs. No significant differences were found among the groups in terms of drop-out rates (α>0.143).

The mandibular arches were not bonded in the present study to investigate the differences between bonded and non-bonded arches in the PI and GI scores. After three months, we applied braces to the mandibular arch to prevent prolonging the patient's total treatment period. Additionally, previous research has indicated that plaque retention shows peak values three months after applying fixed appliances (12). According to the social psychology literature, 66 days are required to turn a behavior into an automatic habit, which means that routine brushing for three months is adequate to gain good brushing habits (15). Therefore, the present study lasted for three months. The Silness and Loe PI scores show the quantity of the dental plaque on the gingival margin of the teeth (16).

In the literature, plaque indicator solutions, including erythrosine, have been used generally to show the quantity and location of the biofilm (6, 10, 11, 17, 18). However, PDTs were chosen for the present study because of their ease of application chairside and at home. Stainless steel ligature wires were used for the ligation because they create less plaque retention than elastic ligatures (19).

In this study, the PI scores of groups A and B did not change significantly during the observation period. The conventional oral hygiene instructions and chairside motivational techniques, including PDTs, did not make differences in the plaque accumulation. These findings are in accordance with those of Acharya et al. (10), who showed that the PI scores did not change significantly over three months in orthodontic patients undergoing conventional plaque control techniques (i.e., the plaque was disclosed with 2% mercurochrome). Contrary to our results, Marini et al. (18) demonstrated that patients who received conventional repeated oral hygiene motivation and chairside motivational techniques, including a plaque indicator solution and manual toothbrush, showed significant decreases in their PI scores after three months. Peng et al. (12) reported that the PI scores of their control group (routine oral hygiene instructions only) and biofilm-disclosing group (biofilm-disclosing tablets) increased significantly after three months when compared with the baseline. These differences may have been related to the different demographic characteristics of patients, measuring methods, and motivational techniques. However, in the present study, the use of the PDTs at home in group C caused significant decreases in the PI scores over three months. Therefore, the use of PDTs at home may help reduce plaque accumulation.

The PDTs were used to show the localization of plaque and brushing quality at the clinic in group B. However, there were no significant differences in the PI scores between groups A and B. This could have been related to patient stress at the clinic, and providing education only once per month may have been inadequate. Previous studies using plaque-disclosing agents as chairside motivational techniques have reported different results. For example, Boyd (6) showed that using a disclosing solution for motivation was more effective than plaque control instructions only in the overall removal of plaque. However, Peng et al. (12) and Acharya et al. (10) indicated that the use of disclosing agents was not effective as a motivational technique in plaque control when compared with the control group.

In the present study, the self-application of PDTs at home in group C seemed to be more effective in decreasing the PI scores. This may have been related to the oral hygiene self-education at home, and the daily repetition of the procedure. Seeing the plaque-retentive areas regularly may have made the patients more aware of these areas and may have enhanced their visual memory and brushing ability. Research has indicated that the repetition of oral hygiene helps improve plaque elimination (18, 20).

The GI scores indicate the gingivitis status (16), and there were no significant differences between the time points in groups B and C. This may have been related to the PI scores, which did not change significantly in groups A and B or decrease significantly in group C. These findings are similar to those of Acharya et al. (10) but contrary to those of Peng et al. (12) who reported that the control group and plaque-disclosing group showed significant increases in their GI scores after three months. However, the mandibular teeth in group A showed significant increases after three months when compared to the baseline. These results may have been related to the focus on the bonded upper arch and extra due diligence when brushing, while neglecting the lower arch. Clinically, these results implied that PDTs could positively affect gingival health during the treatment period on the non-bonded arch in groups B and C by raising awareness of brushing activity.

Group C exhibited statistically lower scores than the other two groups at T1 and T2 in the GI scores of the maxillary and mandibular arches. This shows the efficiency of self-examination of the use of PDTs on the gingival health (15, 21, 22). In addition, group B showed lower GI scores than group A at T1 and T2 ($p<0.05$) in the maxillary and mandibular arches. These findings are contrary to those of previous studies (10, 12) showing no differences between the control group and chairside motivation group. The significantly lower GI scores in group B, when compared to group A, may have been related to the extra brushing activity of the study subjects in group B. The repeated PI and GI scoring may have been a motivational factor (23). In the literature, this is described as the Hawthorne effect, meaning that when the patients were awake they were being examined and evaluated, and this awareness could influence their behavior (24, 25). Feil et al. (25) investigated the influences of the Hawthorne effect on oral hygiene compliance in orthodontic patients. They indicated that there was significant improvement in the oral hygiene compliance of the experimental group, when compared to the control group, and significant quantitative differences between the two groups at the 3-month and 6-month evaluations.

No significant differences were found between the maxillary anterior and posterior areas in any of the groups or times. These unexpected results may relate to similar conditions in the anterior and posterior areas, such as the presence of fixed appliances and the same brushing activity in the same mouth. The mandibular arch was not separated into anterior and posterior sections because evaluation of fixed orthodontic appliances on periodontal health was the primary aim of this study. The mandibular arch was bonded after the study ended.

Previous studies have shown that fixed orthodontic appliances promote the accumulation and enlargement of microbial dental plaque (19, 22). However, there were no significant differences between the bonded maxillary and non-bonded mandibular arches in any of our groups. These results may have been related to the instructions insisting on careful brushing near the gingival third of the teeth. The Silness and Loe PI technique may also have led to this lack of difference because of the inclusion of only the gingival third and not the retentive areas of the brackets. These results imply that patients who are motivated regularly at the clinic may not demonstrate significant difference in the gingival status between bonded maxillary and non-bonded mandibular arches.

Orthodontists use PDTs to help educate their patients about plaque-retentive areas and to ease brushing after orthodontic bonding (26). However, one of the principal aims in orthodontics is the maintenance of continuous good oral hygiene to decrease undesirable treatment outcomes. Therefore, clinicians may advise patients undergoing fixed orthodontic treatment to use PDTs at home regularly during the first few months of treatment to determine the biofilm-retentive areas and increase the quality of brushing.

The Silness and Loe PI system (16) was used to measure the plaque quantity in this study. Similar to previous studies (10, 27-29) conducted on orthodontic patients, the bonded maxillary and non-bonded mandibular arches were compared using this system. Further investigations should be performed with specific systems for quantifying the plaque scores showing the retentive areas of orthodontic patients (27).

Individual handedness was not considered and evaluated, which is another limitation of the study. Tezel et al. (30) indicated that right-handed individuals cleaned their left jaws better than their right jaws, and left-handed people were more successful with the right jaw than the left jaw. In the present study, quadrants were not evaluated between times and groups, as they were included in the study by Tezel et al. (30). In the same study, they found that left-handed subjects were more successful in providing oral hygiene than right-handed subjects. Future studies should be performed considering subjects' handedness.

One of the biggest limitations of this study is its short, three-month observation period, which cannot suffice in undertaking a PDT efficiency assessment (on account of the Hawthorne effect). Abdulraheem and Bondemark (24) indicate that to minimize the risk inherent in the Hawthorne effect, studies should be designed with observation periods longer than six months. This study's relatively small sample size is another limitation; further studies should be designed so as to feature a larger sample size.

CONCLUSION

The self-application of disclosing tablets at home during treatment in addition to repeated oral hygiene motivation may be effective in improving oral hygiene and motivating the patient. However, the application of disclosing tablets at the clinic may not be as effective as a good oral hygiene aid.

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethics Committee of Gaziantep University (No.: 44).

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

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Original Article

Efficiency and Accuracy of Three-Dimensional Models Versus Dental Casts: A Clinical Study

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ABSTRACT

Objective: The aim of this study was to compare the accuracy of digital and plaster model methods and the time required for analysis.

Methods: A total of 30 subjects (20 females, 10 males; mean age, 14.36±6.30 years), who required plaster models for the construction of either a fixed or a removable orthodontic appliance, were randomly selected. As part of the diagnostic records, digital impressions with a three-dimensional (3D) intra-oral scanner (TriosColor-P13 Shape) were taken from all subjects. Conventional impressions for the orthodontic appliances were taken with alginate (Orthoprint, Zhermack, Italy), and the plaster models were obtained (Scheu-Dental, GmbH.D-58642, Iserlohn, Germany). Two groups were formed. In the conventional measurement group, manual measurements were taken on the plaster models, while in the digital measurement group, the 3Shape OrthoAnalyzer 2013 software was used to make the measurements on the 3D models. In both groups, the total time required to perform the Bolton analysis and space analysis was recorded, and the results were compared.

Results: There was no statistically significant difference found between the two groups in terms of the measurement values. The total time to perform all the analyses was determined to be shorter with digital models compared to conventional plaster models ($p<0.001$).

Conclusion: The Bolton analysis and space analysis measurements carried out on 3D models did not show any statistically significant difference compared to plaster models. The time taken to perform the analyses was shorter using digital models than for conventional plaster models.

Keywords: Dental models, imaging, three-dimensional, orthodontics, software

INTRODUCTION

Successful orthodontic treatment is based on a comprehensive diagnosis and treatment planning. One of the diagnostic and treatment planning tools used to determine the degree of obliquity and the incompatibility between the arch shape and tooth dimensions are orthodontic models (1). They are also used for three-dimensional (3D) documentation of the dental arches in pre-treatment, progress, and post-treatment records (2).

In comparison to other methods of documenting treatment records, plaster models require a significant amount of effort to be produced and a storage space because of their size and weight (3). Despite these disadvantages and the risk of models being lost or damaged, plaster models continue to be the gold standard and preferred method in clinical and scientific applications (4, 5).

One of the most recent innovations in the field of orthodontics is the introduction of intra-oral scanners, which scan the teeth and surrounding tissues, as an alternative to plaster models (6). Digital models have several advantages, such as the low storage requirement and rapidly obtained data that can be easily sent to the dentist,

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laboratory, or the patient (7, 8). Digital models also allow patient-specific virtual "set-up" and advanced treatment planning in both removable and fixed orthodontic appliances (7, 8).

Comparisons of digital models and plaster models have been made with respect to diagnostic accuracy and measurement sensitivity (9, 10). The space analysis and Bolton analysis are the most commonly used analyses for orthodontic diagnosis and treatment planning in the majority of studies that have compared the digital models and plaster models. The space analysis is traditionally made according to the difference between the mesiodistal dimensions of the teeth in the arch from the mesial of the left molar tooth to the mesial of the right molar tooth and the length of the line forming the parabola of these teeth (11). The Bolton analysis was first used in 1958 with the establishment of two ratios using the total of the mesiodistal widths of the maxillary and mandibular teeth of patients with ideal occlusion (12). Bolton analysis provides clinicians with information about the incompatibility of the tooth size and the amount of deviation from the ideal ratio of the arch dimension (13). Although systematic reviews in the literature could not find any clinically relevant significance of both of these analyses (14, 15), there were statistically significant differences in the Bolton analysis in some studies (6). Furthermore, due to the continuous updating of digital modeling methods, examining the importance of reliability, and especially the assessment of time duration, is still ongoing.

Therefore, the purpose of the present study was to compare digital and plaster models with respect to the accuracy and time taken for space and Bolton analyses. The three hypotheses considered were that there was no significant difference between the two methods with respect to space analysis, that there is a statistical difference between the two methods in the proportional comparison in the Bolton analysis, and that there is no difference between the two methods in terms of analysis duration.

METHODS

The study included 30 patients (20 females, 10 males; mean age, 14.36±6.30 years) who presented at the Orthodontics Department of Bulent Ecevit University School of Dentistry to seek orthodontic treatment. The study approval was granted by the Clinical Research Ethics Committee of Bulent Ecevit University.

In addition to the digital impressions taken as routine diagnostic records, a prerequisite for inclusion in the study was the patient requiring either a removable or a fixed orthodontic appliance treatment, for which a plaster model was constructed. For patients who met this prerequisite, the following criteria were examined:

- No previous orthodontic treatment
- The presence of all the permanent teeth from the first right molar to the first left molar
- No absence of any region in the plaster model and digital model

In a total of 30 patients who met the study inclusion criteria, digital impressions were taken using a 3D intra-oral scanner (Trios-Color-P13 Shape). In addition to the digital impressions taken as routine, impressions were taken with alginate (Orthoprint, Zhermack, Italy) for the fixed or removable orthodontic appliance construction. These impressions were immediately used to obtain plaster models (Scheu-Dental, GmbH.D-58642, Iserlohn, Germany). The study materials comprised 60 models, as 30 plaster models (conventional measurement group) and 30 digital models (digital measurement group) from 30 patients.

The space analysis and Bolton analysis of the obtained digital and plaster models were conducted by the same researcher (HY). To increase the reliability of the measurements, they were repeated five times, and the arithmetic average value was used in the evaluation.

The measurements of the upper and lower arch length in the plaster models were taken with the aid of a brass wire. The mesiodistal width of incisors, canines, premolars, and first molars was measured between the anatomic medial and distal contact points, parallel to the occlusal plane. The anterior and overall Bolton ratios were calculated by dividing the total of the widths of the maxillary teeth by the total of the widths of the mandibular teeth (12). The conventional measurement group model analysis was made with a compass (Münchner Design, 042-751-00, Dentaurum). Measurements were made with a specificity of 0.1 mm because of the needle width of the compass used. The measurement values were recorded to 1% (0.01) of a millimeter.

In the digital measurement group, the upper and lower arch of each patient was digitized using a Trios 3Shape 3D scanner. The accuracy of this scanner has been listed as 15 microns by the manufacturer. However, previous studies have shown this value to be 25–45 microns (16, 17). Measurements of the intra-oral models obtained with the Trios 3Shape device were made with the OrthoAnalyzer 2013 software program, which is an integral part of the system. For maximum specificity, the magnification as far as the program allowed or a greater proximity to the desired area of the model was used. The time taken to perform the digital and manual measurements was recorded for each sample. In the analyses of both models, distance was measured in millimeters (mm) and time in seconds (sec).

Statistical Analysis

Statistical analyses were performed using the Statistical Package for Social Sciences version 25.0 software (IBM Corp.; Armonk, NY, USA). The data conformity to normal distribution was assessed using the Shapiro–Wilk test. To analyze the difference between measurement values, the t-test was used for data with normal distribution and the Mann–Whitney U-test for data that did not show normal distribution. A value of $p<0.05$ was accepted as statistically significant.

RESULTS

The descriptive statistics of the measurements taken from upper and lower arches in the conventional measurement and digital measurement groups are shown in Table 1.

Table 1. Descriptive statistics of the measurements made with the conventional and digital methods

Manual measurements	**N**	**Minimum**	**Maximum**	**Mean**	**SD**
Space analysis of upper arch (mm)	30	-19.36	11.46	-4.63	6.23
Space analysis of lower arch (mm)	30	-11.53	7.36	-2.57	3.76
Bolton ratio of anterior	30	70.11	110.43	79.16	6.61
Bolton ratio of overall	30	85.27	103.30	91.83	3.81
Analysis times (secs)	30	450.00	1245.00	894.33	160.14
Digital measurements					
Space analysis of upper arch (mm)	30	-17.26	9.25	-4.38	5.45
Space analysis of lower arch (mm)	30	-15.28	9.94	3.09	4.50
Bolton ratio of anterior	30	73.00	110.00	78.77	6.39
Bolton ratio of overall	30	81.00	116.00	91.60	5.43
Analysis times (secs)	30	437.00	990.00	597.73	141.31

N, number of samples; mm, millimeter; secs, seconds; SD, standard deviation

Table 2. Comparison between the groups in respect of the space analysis of the two methods

	Conventional (N=30)		**Digital (N=30)**			
Variables	**Mean Rank**	**Sum of Ranks**	**Mean Rank**	**Sum of Ranks**	**Z**	**p**
Space analysis of Upper arch	30.70	921.00	30.30	909.00	.089	.929
Space analysis of Lower arch	31.90	957.00	29.10	873.00	.621	.535

Table 3. Comparison between the groups in respect of the two methods of Bolton analysis

	Conventional (N=30)		**Digital (N=30)**			
Variables	**Mean Rank**	**Sum of Ranks**	**Mean Rank**	**Sum of Ranks**	**Z**	**p**
Bolton ratio of anterior	32.73	982.00	28.27	848.00	-.992	.321
Bolton ratio of overall	31.53	946.00	29.47	884.00	-.459	.646

Table 4. Comparison of the Time Taken for the Analyses in Both Methods

	Conventional (N=30)			**Digital (N=30)**					
Variables	**Mean**	**SD**	**Std. Error Mean**	**Mean**	**SD**	**Std. Error Mean**	**df**	**F**	**P**
Analyses times	908.33	136.586	24.937	577.00	95.811	17.493	51.976	4.834	.000*

SD, standard deviation

Before the comparison of two independent groups, a normality analysis was applied. According to the result of the Shapiro–Wilk test, the distribution of the space analysis and Bolton measurements in the conventional and digital models was not normal, but normal distribution was determined in the time measurements. Therefore, the non-parametric Mann–Whitney U-test was used for comparisons of the space analysis and Bolton analysis measurements in the conventional and digital methods, and the parametric t-test was used in the time comparisons.

In the conventional measurement group, the mean space was found to be 4.63 mm in the upper arch and 2.57 mm in the lower arch, while in the digital measurement group, these values were 4.38 mm and 3.09 mm, respectively. No statistically significant difference was found in both groups and measurements (p>0.05) (Table 2).

The Bolton overall ratio was mean 91.83 in the conventional measurement group and 91.60 in the digital measurement group. The Bolton anterior ratio was mean 79.16 in the manual measurement and mean 78.76 in the digital measurement. The differences between the digital and manual methods in both the Bolton anterior ratio and the Bolton overall ratio were not found to be statistically significant (p>0.05) (Table 3).

The descriptive statistics of the required time to complete the measurements in conventional and digital measurement groups are shown in Table 4. The total time spent for the space analysis and the Bolton analyses that were necessary for orthodontic diagnosis was 894.33 secs for the conventional measurement group and 597.73 secs for the digital measurement group. The digital measurements were completed 296.6 secs sooner than the conventional measurements, and this difference was determined to be statistically significant (p<0.001).

DISCUSSION

Because of the similarities of the obtained results, the hypothesis that there is no significant difference between the two methods with respect to space analysis was accepted. The hypothesis that there is a statistical difference between the two methods in the proportional comparison in the Bolton analysis was rejected, as both the anterior and overall Bolton ratios did not show any statistical difference in the comparison of the two methods. The hypothesis that there is no difference between the two methods in terms of the analysis duration was rejected, as the analysis duration was shorter in digital models compared to conventional models.

In the current study, the inclusion criteria from previous studies were taken as reference (6, 18, 19). In addition to these criteria, we included plaster and digital models only from subjects who required either the removable or fixed orthodontic appliances treatment.

Several previous studies have compared the accuracy and reliability of plaster models and digital models. However, the majority of those studies obtained the digital model from the plaster model (3, 6, 10, 18, 20-26), and only a few studies have used a direct intra-oral scan (19, 27). Alcan et al. (28) reported that even if the plaster model was obtained within 1 hour of the alginate measurement taken from the patient, a deviation in the amount of 1.285% from the main model occurs to be able to register the dental arches with maximum accuracy reduce and to clearly reveal the difference between the two methods, digital models were obtained by direct intra-oral scanning of dental arches.

Since the introduction of 3D digital modeling, its use has been increasing in the field of dentistry. However, only few studies that compared the conventional method with the digital modeling method have used 3D scanning and an analysis software program interface from the same manufacturer (10, 20, 23-25). Several studies have used a different model analysis software not provided by the scanner manufacturer (3, 6, 18, 19, 21, 26, 27). In the current study, the use of the 3Shape scanning system with integral OrthoAnalyzer software allowed an analysis of digital models obtained with a continuous 3D scan system. Furthermore, there was no loss of data or time during the calibration and orientation of 3D images.

The operator reliability is important when taking measurements on digital or plaster models. There can be data loss or deviation because of the learning curve for taking digital and plaster model measurements (29). To reduce these variations to minimum, the measurements of each model were taken five times by a single operator, and the arithmetic average of these measurements was used in the evaluations.

Several studies in the literature have evaluated plaster and digital models with respect to validity and reliability. Despite a statistical difference in some of these studies (21), no clinically significant difference has been determined (18, 22). In studies that have found a statistical difference between the two methods, the greatest difference was reported to be 1.48 mm (30). Profitt et al. (1) reported that a difference of <1.50 mm in the model analysis was not clinically significant. The results of the current study support the findings of previous studies as no statistically or clinically significant difference was determined between the two methods with respect to space analysis.

Some previous studies that have compared the Bolton anterior and overall ratios in digital and plaster models have found a statistically significant difference. There are more studies that have reported a statistically significant difference in the Bolton analysis than in the space analysis. However, the mean difference in these studies of 0.05–1.2 mm was not reported as clinically significant (6, 20, 21, 23, 30). The data obtained in the current study were similar, with no statistically or clinically significant difference determined in the Bolton analysis.

Due to a large number of analyses in orthodontic practice, the duration of the analysis can play an important role in the selection of digital or conventional methods. In the current study, which used the 3Shape scanning system with the integral, simple interface of OrthoAnalyzer software, the total duration of the space and Bolton analyses was 894.33 seconds. Using the conventional method, this value was 597.73 secs, and the difference was found to be statistically significant. According to these results, the duration of the analyses made using the digital method was 4.94 mins shorter compared to the conventional method. In a study by Reuschl et al. (25) using the OrthoAnalyzer program, the mean duration of analysis for each model was 2 min shorter than the conventional method, and these results were found to be statistically significant. In another study, the digital analysis was found to be 1 min shorter than the conventional method (30). In contrast, in a study by Grunheid et al. (19), using a different analysis program, no time difference was found between the two methods. However, in that study, the analysis software program was not compatible with the intra-oral scanning device. In studies related to duration, it is necessary for digital analysis methods to be used at least as much as conventional methods, because mastery of the analysis program and the ease of use of the program interface could change the results.

One of the limitations of the study was that the comparison of the two methods in terms of the duration of analysis did not take into account the total chairside time, which is an important factor for clinicians. Another limitation was that the operator experience and ability were not equal in both measurement methods. In addition, the speed of the digital modeling software program may vary, depending on the version and different hardware specifications. Digital modeling methods and analysis programs are constantly updated and accelerated. Because of this fact, further studies should be carried out taking into account the deficiencies of our study.

CONCLUSION

The digital analysis method is as reliable as the conventional model analysis method, and it seems to be more time effective. Although some difficulties may be experienced in the manipulation of the digital model analysis software, this method can be sufficient in diagnosing and treatment planning. The major advantages of the digital model software include quick reassessment of the measurements and an easy access to data required for analysis. Therefore, more importance should be given to digital modeling methods and software for clinicians to be able to use them easily.

Ethics Committee Approval: Ethics committee approval was received for this study from the Clinical Research Ethics Committee of Bülent Ecevit University.

Informed Consent: Informed consent was obtained from the family or legal representatives of the patients included in the study.

Peer-review: Externally peer-reviewed.

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Original Article

Evaluation of the Efficacy of Different Cleaning Methods for Orthodontic Thermoplastic Retainers in terms of Bacterial Colonization

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ABSTRACT

Objective: This study investigated the antimicrobial efficacy of three different cleaning methods on *Streptococcus mutans* (SM) and *Lactobacillus* (LB) bacteria colonization *in vivo*. The three different cleaning methods were applied by volunteers on clear vacuum formed retainers (VFRs).

Methods: In this prospective, cross-over study, a total of 21 volunteers were included. All VFRs used by the volunteers were cleaned using three different cleaning methods in a sequence. These methods were peroxide-based cleanser tablets (PBCTs) plus brushing, control (only brushing), and vinegar plus brushing, respectively. The obtained salivary, VFR material, and periodontal data were statistically compared by factorial design repeated measures analysis of variance.

Results: The SM and LB bacteria counts on VFRs after using both PBCTs and vinegar were statistically similar (p>0.05), but bacteria counts were statistically lower than the control method (p<0.01). There were no statistically significant differences between the SM and LB bacteria counts in saliva samples taken before and after the application of the cleaning methods (p>0.05). Similarly, there were no significant differences between periodontal data obtained from plaque and bleeding indices at all study times. The periodontal pocket depth gradually decreased in the successively performed cleaning applications (p<0.05).

Conclusion: The application of PBCTs and vinegar to VFRs at sequential time intervals resulted in similar bacteria counts. The higher LB counts and similarly higher SM counts on the VFR samples indicate that mechanical cleaning only (control method) is not adequate to obtain hygiene. Salivary flora was not correlated with bacteria counts of VFRs.

Keywords: Bacterial colonization, *Streptococcus mutans, Lactobacillus,* thermoplastic retainers, retention

INTRODUCTION

Various retainers are used to maintain successful outcomes after an active orthodontic treatment. Vacuum formed retainers (VFRs) are frequently used due to their perfect esthetic features, small dimensions, ease of use and manufacture, and low cost (1, 2). However, these devices have disadvantages such as loosening over time, discoloration, fracture and crack formation, and limitation of the washing and buffering effects of saliva on teeth (2, 3). In addition, the presence of a thermoplastic retainer in the mouth affects the oral flora in favor of the cariogenic bacteria *Streptococcus mutans* (SM) and *Lactobacillus* (LB) (2). Therefore, when the pathologies related with microbial dental plaque are considered, the cleaning and hygiene of the VFRs are of great significance when it comes to oral and systemic health.

There are numerous mechanical and chemical cleaning methods used to remove the microorganisms accumulated on removable devices (4, 5). As the mechanical methods do not provide a sufficient antimicrobial effect on their own, they are recommended to be used together with chemical cleaning methods (5). Chemical products

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include household and commercially manufactured products (6, 7). Alkaline peroxide is a commercial disinfectant that provides mechanical cleaning by oxygen emission. In addition, alkaline peroxide-based tablets are having an antimicrobial effect similar to (8) or higher than (9) sodium hypochlorite, but causing less physical damage than sodium hypochlorite (9).

Among household products, white vinegar, shows antimicrobial and anti-tartar properties with its acidic features (10, 11). In addition, white vinegar is used in the cleaning of prosthodontic devices in dentistry due to its advantages, as being cheap and natural (11-13). There are many studies investigating the effects of fixed orthodontic treatment on oral microflora and periodontal health (14). However, there are a limited number of studies investigating the effects of cleaning methods on the devices used in the retaining treatment on oral flora and periodontal health after the active treatment is finished (15-17).

Table 1. Age and gender distribution of the individuals

		Age (year)		
Gender	**N**	**X± SD**	**min**	**max**
Female	16	16.63±3.14	13	25
Male	5	18.20±2.59	15	22
Total	21	17.42±2.87	13	25

N, number; X, mean; SD, standard deviation; min, minimum; max, maximum

This study comparatively assessed the effects of three different cleaning methods (peroxide-based cleanser tablets (PBCT) plus brushing, only brushing (control), vinegar plus brushing) under *in vivo* conditions for periodontal health parameter and SM and LB colony numbers, on the VFRs, and in saliva samples. In addition, the correlation between SM and LB counts in saliva and both VFRs was assessed. The null hypothesis was that there were no differences in the SM and LB colony numbers on the VFRs and in the saliva during the sequential application of PBCT plus brushing, only brushing (control), and vinegar plus brushing, in the same individuals.

This study was a prospective study with a cross-over design, approved by the ethics committee of the Republic of Turkey, Ministry of Health, Pharmaceuticals and Medical Devices Agency (21.04.2017.-71146310-511.06-E.89281). Written informed consent was obtained from all volunteers. The study was performed in the Department of Orthodontics, School of Dentistry, and in the Department of Microbiology, School of Medicine, Süleyman Demirel University, Isparta, Turkey, between May 2017 and December 2017. The inclusion criteria were the following: (1) undergoing the final stage of nonextraction orthodontic treatment with fixed appliances (the orthodontic attachments have not been removed yet), (2) having no active cavities, (3) being systemically healthy, (4) being a nonsmoker, (5) not having a carbohydrate-rich diet, (6) not undergoing dental fluoride treatment in the past 4 weeks, (7) not using a mouthwash containing anti-

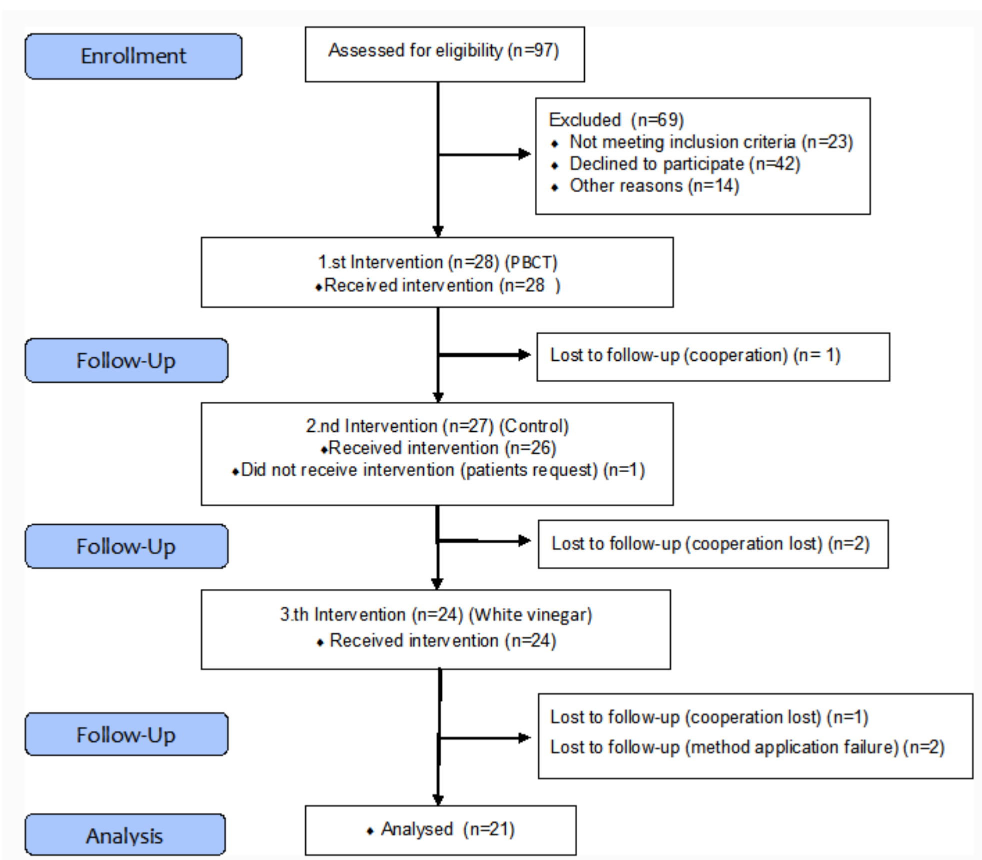

Figure 1. Flow diagram

Figure 2. Saliva samples at T0 were collected without VFRs, and at T1, they were collected while VFRs were in the mouth. Unstimulated saliva was obtained by sitting the patient upright, tilting the head forward, and draining the saliva to a sterile container for 10 minutes. The saliva was stored in a sterile container

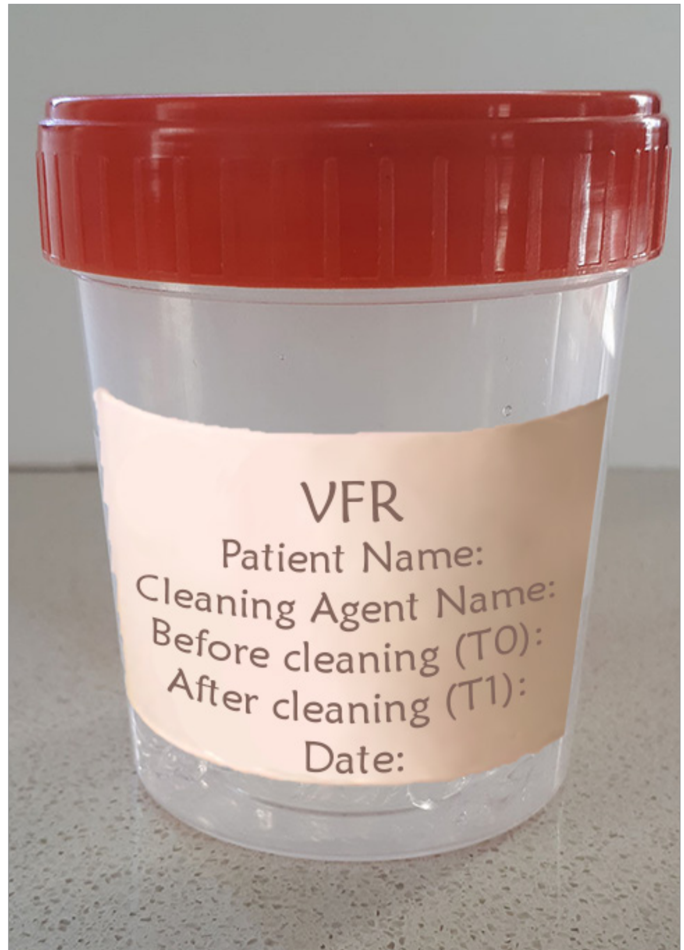

Figure 3. Storing the upper VFR in a sterile container with PBS. The name, surname, the period of experiment, cleaning agent name, and date were written

biotics or steroids in the past 2 weeks, (8) not being pregnant or lactating. In this study, a preliminary calculation was performed to obtain the sample size by using the G*Power software version 3.0.10 (Franz Faul Universität, Kiel, Germany). To achieve the 80% power, 20 patients were required to participate. Among the 95 individuals who satisfied the criteria of the study, 26 participated voluntarily in the study, but the data of 21 individuals were assessed (Table 1, Figure 1).

After all the orthodontic attachments were removed, dental scaling and polishing were performed, oral hygiene motivation was done, and the modified Bass technique was explained to the volunteers. Fixed lingual retainers were applied, and three pairs of upper-lower VFRs (DispoDent Sert Gece Plağı, Yağmur Dental, İstanbul, Turkey) were fabricated for each of them. In this study, VFRs were cleaned with three different cleaning methods: PBCT and brush, water and brush (without any cleaning solution-control), and vinegar and brush, respectively. Each cleaning method was applied to the new VFRs in a 4-week period, in succession and at sequential time intervals by each volunteer. But before the application of every new pair of VFRs and cleaning methods, one washout period (without using VFRs for 2 weeks) was applied. After the washout period, lower and upper VFRs were provided to the volunteers, and they were recommended to use them all day long, except for meals for 4 weeks. As the first cleaning method, the individuals were asked to use PBCT (Corega Tabs; GlaxoSmithKline, Brentford, Middlesex, United Kingdom) to their first VFR pairs, as explained in the prospectus. For each cleaning, a tablet was put into enough mild water to cover the upper and the lower VFR pair, and the VFRs were kept in this solution for 5 minutes. Then, the devices were brushed with a soft brush and rinsed with running water. After a 2-week washout period, the second cleaning method was applied. All surfaces of the second pairs of VFRs were brushed using only mild water and a soft brush, and then rinsed with running water (control method). After the third washout period, the third cleaning method was applied. 5% white vinegar (Ferfresh, Fersan, Izmir, Turkey) was put into a vessel to cover the third pairs of VFRs, and the devices were kept in this solution for 5 minutes. Later, all surfaces of the VFRs were brushed using a soft brush and rinsed with running water. For all cleaning agents, the applied procedures were repeated every day before bedtime. After the end of each cleaning method period (4 weeks), individuals cleaned their VFRs before bedtime, 1 day prior to each appointment, and arrived in the morning without having breakfast and brushing. At this appointment, the first unstimulated saliva samples were collected (Figure 2). Unstimulated saliva was collected by seating the

1. Step
- Medical history
- Removing fixed orthodontic tretment attachments
- Scaling and polishing
- Application of fixed lingual retainers on upper and lower anterior teeth.
- Oral care training (Colgate Triple Action®, Colgate-Palmolive Ltd., China) and the toothbrush (Zigzag Plus Medium 2+1 Colgate toothbrush, Colgate-Palmolive Ltd., Vietnam) provided by the researchers, and perform their oral care at least three times a day, using the modified Bass method).

2. Step (2 week)
- Washout period

3. Step (4 weeks) (PBCT and brush method T0)
- Saliva sample collectionn (in the morning hours with their teeth brushed before bedtime the previous night and skipping their breakfast; 2-3 ml unstimulated saliva samples)
- Periodontal examination (the plaque index, pocket depth measurement, and bleeding index parameters)
- Providing VFRs (custom-made 1 mm thick vacuum-shaped VFRs (DispoDent Hard Night Plate [polyethylene terephthalate glycol], Yagmur Dental, Istanbul, Turkey) on both upper and lower arches and explaining continuous usage for 4 weeks
- Training for PBCT and brush method
- Transfer to laboratory for microbiological analysis (only saliva samples) (The saliva samples collected from the individuals were gathered in sterile empty flasks and transferred to the microbiology laboratory within one hour for culture)

4. Step (PBCT and brush method T1)
- Saliva sample collection (Unstimulated saliva samples were collected while the VFRs were in participants' mouths).
- Periodontal examination
- Transfer to laboratory stage for microbiological analysis (saliva and upper VFR samples)(The VFRs, which had been cleaned with the determined cleaning methods during the preceding four weeks, were removed from the mouth using sterile gloves, cut into three pieces at the distal of the canines using sterile scissors, and transferred to a sterile vessel containing phosphate-buffered saline solution (20 ml PBS).

5. Step (2 week)
- Washout period

6. Step (4 weeks) (Control, water and brush method T0)
- Saliva sample collection
- Periodontal examination
- Providing new VFRs on both upper and lower arches and explaining continuous usage for 4 weeks
- Training for Control, water and brush method
- Transfer to laboratory for microbiological analysis (only saliva samples)

7. Step (Control, water and brush method T1)
- Saliva sample collection
- Periodontal examination
- Transfer to laboratory stage for microbiological analysis (saliva and upper VFR samples)

8. Step (2 week)
- Washout period

9. Step (4 weeks) (white vinegar and brush method T0)
- Saliva sample collection
- Periodontal examination
- Providing new VFRs on both upper and lower arches and explaining continuous usage for 4 weeks
- Training for white vinegar and brush method
- Transfer to laboratory for microbiological analysis (only saliva samples)

10. Step (white vinegar and brush method T1)
- Saliva sample collection
- Periodontal examination
- Transfer to laboratory stage for microbiological analysis (saliva and upper VFR samples)

Figure 4. Clinical steps during the study period

Figure 5. Homogenization of the saliva sample in a vortex mixer and taking 1 ml of saliva sample

Figure 6. Dilution of the saliva sample

subject in an upright position at rest, tilting the head forward, and draining the saliva to a sterile container for 10 min. Then the upper and lower VFRs were removed, and upper VFR was divided into three pieces by using a sterile scissors. These were put into a sterile container with phosphate-buffered saline solution (PBS) (Figure 3). At each time, saliva samples from individuals were collected into a sterile empty container. Samples of the thermoplastic retainers were placed into a sterile container, containing PBS. Later, the plaque index, pocket depth measurement, and bleeding index (18) were obtained by one operator (FAA) as periodontal parameters. The study steps are presented in Figure 4.

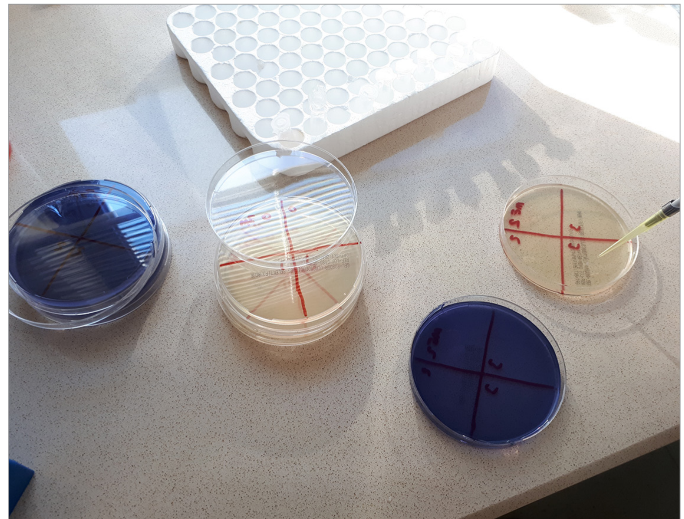

Figure 7. The Mitis Salivarius Bacitracin agar and Rogosa agar plates were divided into four equal parts with the acetate pen, and each dilution was numbered from 0 to 10. 10-µl diluted saliva specimens were cultivated to the plates numbered by dividing, according to the dilution degree. The same dilution was cultivated twice

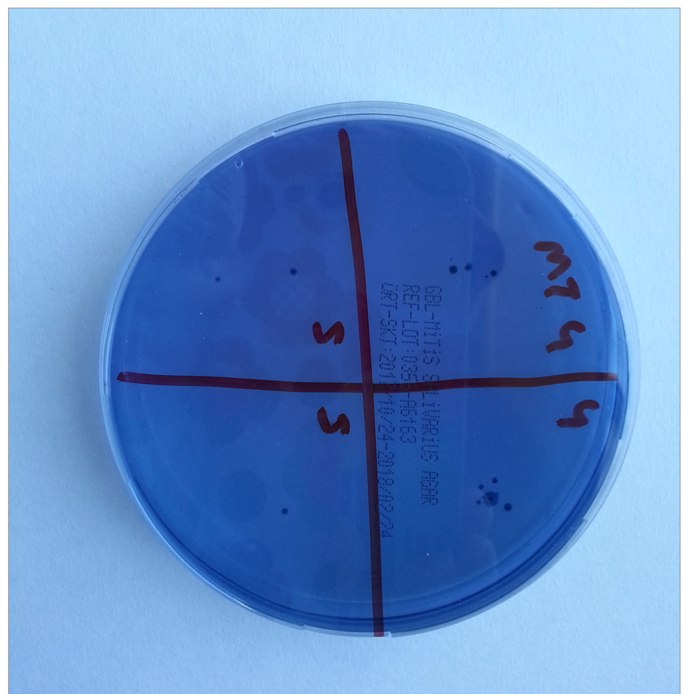

Figure 8. The plates were sorted according to their degree of dilution, and the colony counts were based on plaques where the colonies were fully counted with the naked eye

Microbiological Analyses of Saliva and VFR Samples

The saliva samples that were transferred to sterilized containers were homogenized in a vortex mixer (Figure 5) (VELP Scientifica, Fisher ZX3 Vortex Mixer, Italy), and tenfold serial dilutions of 10^{-1} to 10^{-10} were prepared in a sterile 0.9% NaCl isotonic

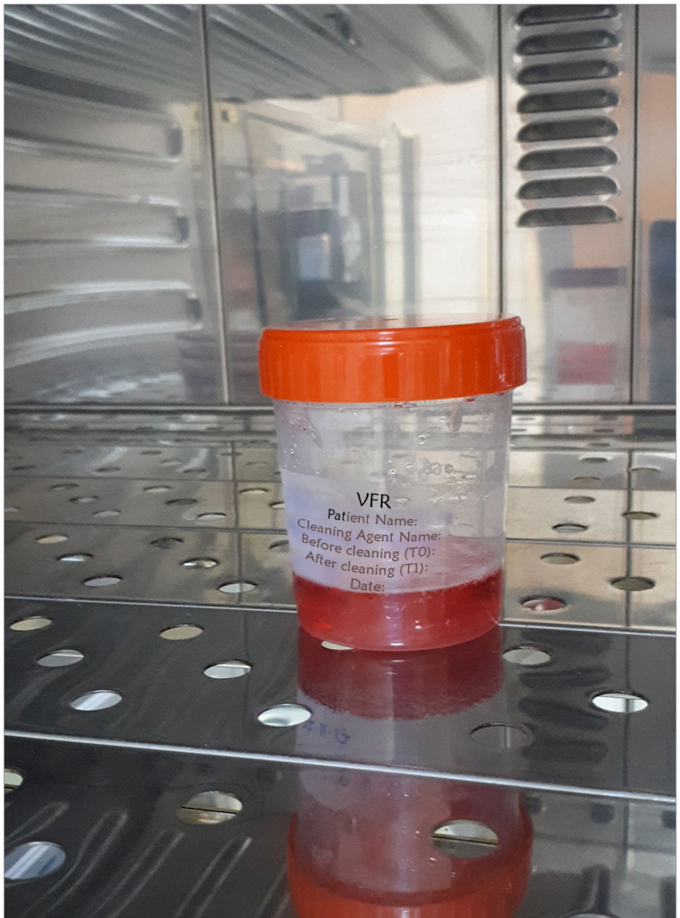

Figure 9. VFR samples were kept in closed containers, filled with 20 ml 0.25% Trypsin-EDTA in a 35ºC±2ºC incubator for 45 min

Figure 10. Homogenization of the VFR sample and Trypsin-EDTA in a vortex mixer and taking 1 ml of Trypsin-EDTA solution

solution, by means of taking 1 ml of saliva (Figure 6). Following the tenfold serial dilution, 10 µl saliva aliquots were plated in duplicate onto the mitis salivarius agar to obtain SM cultures, and the *Rogosa lactobacillus* selective agar for LB cultures (GBL, Istanbul, Turkey) (Figure 7). Samples were incubated in an anaerobic atmosphere (AnaeroPack-Anaero, Mitsubishi Gas Chemical Co. Inc., Japan) at 35ºC±2ºC for 48 h. The total number of colony-forming units (CFU) on each plate was counted after incubation (Figure 8).

The VFR samples were brought to the laboratory in a sterilized tube containing PBS, which was removed from the tube with a sterile syringe without touching the VFR samples, and 20 ml of 0.25% trypsin-EDTA solution was added to each tube. These VFRs were kept in this solution at 37ºC for 45 min (Figure 9). Then, all specimens were homogenized in a vortex mixer (Figure 10). Following the homogenization, 1 ml of 0.25% trypsin-EDTA solution, including the VFR sample, was taken for the microbiological cultivation procedure. Next, microbiological cultivation was performed, as in the case of saliva samples.

SM and LB Colony Counts in Saliva and VFR Specimens

SM and LB colony counts were determined based on the dilution ratios of the plates on which the colonies were counted with the naked eye (Figure 8, 11). Each dilution was subjected to duplicate inoculation of the plates. Therefore, the number of colonies on the plates of countable dilution was determined by taking the arithmetic average of the two cultures. The SM and LB colony counts belonging to saliva and VFR samples per individual were expressed as CFU in 1 ml (CFU/ml) of each sample. To determine the SM and LB colony numbers in a given 1 ml sample, the number of colonies determined on the plate was multiplied by the plate dilution factor and then divided by the volume transferred from the dilution tube to the culture plate.

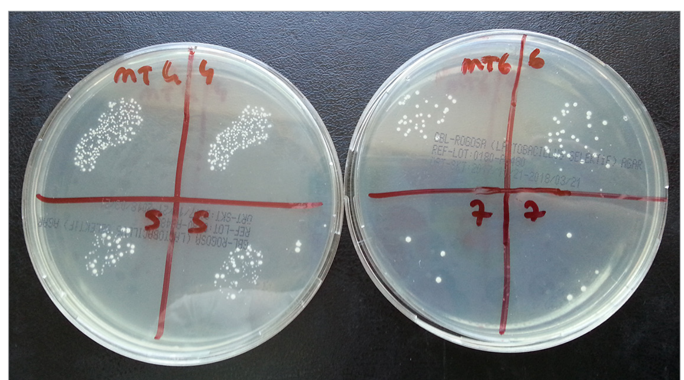

Figure 11. The plates were sorted according to their degree of dilution, and the colony counts were based on plaques where the colonies were fully counted with the naked eye

CFU/mL = (colony count × dilution factor)/volume transferred from the dilution tube to the culture plate (ml)

Dilution factor = 1/dilution ratio (19)

The data originally measured in CFU were transformed to $\log_{10}$ for statistical analysis and reported as log CFU.

In this study, saliva samples and periodontal parameters were obtained after each washout period before the application of each cleaning solution (T0), 4 weeks after the application of each cleaning solution (T1). Upper VFR samples were obtained 4 weeks after the application of each cleaning solution (T1). Microbiological counts including SM and LB colony numbers were determined in saliva and on upper VFR samples.

Statistical Analysis

The obtained data were assessed by using Statistical Package for Social Sciences version 23.0 (IBM Corp., Armonk, NY, USA). To compare the duration of VFRs' wear, the one-way analysis of variance (ANOVA) test was used. In this study, periodontal parameters and saliva were evaluated by factorial design repeated measures ANOVA. The cleaning method factor had three levels; PBCT, control, and vinegar. In addition, the time factor had two levels: T0 and T1. The data obtained in terms of SM and LB colony numbers in saliva and on VFRs were analyzed by factorial design repeated measures ANOVA after log transformation. In the analyses, the cleaning method factor has three levels, as PBCT, control, and vinegar. The repeated measurements were conducted at the levels of the method factor. The Bonferroni multiple comparison tests were used in determining the differences between the factor levels at the end of the analysis of variance. Reverse-angle (arcsine) transformation was applied to the percentage results of the bleeding index, and analyzed by the factorial design repeated measures ANOVA. Arcsine transformation stabilizes variance and normalizes proportional data. The use of arcsine transformation, also known as inverse transformation or angular transformation, is useful in analysis of proportion data that tends to be skewed when the distribution is not normal. As the normal distribution was obtained for the plaque index data of the individuals, parametric tests were applied. The Pearson correlation test was used to determine the relation between the number of bacteria in the saliva and VFR samples. The significance level was assessed as 0.05.

RESULTS

The duration of the VFR wear by the patients during each cleaning method did not show any significant differences ($p>0.05$) (Table 2).

According to the factorial design repeated measures ANOVA, no interaction was found between cleaning methods and the time factor, and no differences were found in the cleaning method factor and in the time factor regarding the SM and LB bacteria counts ($p>0.05$) (Table 3). Similarly, no interaction was found between cleaning methods and the time factor, and no differences were found in the cleaning method factor and in the time factor ($p>0.05$) (Table 3). However, the differences in the cleaning methods for gingival pocket depth data were statistically significant ($p<0.05$) (Table 3). Both the SM bacteria counts on the VFR samples and the LB bacteria counts on the VFR samples were statistically significant with different cleaning methods (T1) ($p<0.001$). At T1, both SM and LB bacteria counts obtained for PBCT and vinegar cleaning methods were similar, and lower than the control method ($p<0.05$) (Table 4).

The correlation between the SM and LB bacteria counts in saliva samples at T1, and SM and LB bacteria counts on VFR samples at T1, was not statistically significant ($p>0.05$) (Table 5). A high correlation was found between the SM bacteria counts and LB bacteria counts on the VFRs at T1, for each cleaning method used in the study (Table 6).

Table 2. Duration of the VFR wear during each cleaning method

	Duration of VFR Wear (Hour)			
	N	x̄	SD	p
PBCT cleaning method	21	460.57	108.63	0.154
Control method	21	430.905	132.71	
Vinegar cleaning method	21	436.143	125.02	

x̄, mean; SD, standard deviation; N, number of volunteers; P, significance according to one-way ANOVA

Table 3. Descriptive statistics and the statistical evaluation of SM and LB counts in the saliva, total plaque index, periodontal pocket depth, and bleeding index according to applied cleaning methods

	PBCT				Control				Vinegar				P-Value		
	T0		T1		T0		T1		T0		T1				
	x̄	SD	x̄	SD	x̄	SD	x̄	SD	x̄	SD	x̄	SD	CMAT	CMA	T
Saliva SM Count	7.81	0.51	7.57	0.35	7.97	1.10	7.65	0.45	7.67	0.50	7.65	0.46	0.316	0.672	0.079
Saliva LB Count	7.70	0.49	7.49	0.33	7.88	1.19	7.52	0.45	7.50	0.49	7.50	0.45	0.605	0.605	0.054
Total Plaque Index	0.82	0.25	0.82	0.24	0.80	0.24	0.81	0.22	0.73	0.26	0.78	0.19	0.734	0.416	0.566
Periodontal Pocket Depth	2.06	0.33	2.06[a]	0.23	1.87	0.28	2.00[a,b]	0.25	1.89	0.31	1.89[b]	0.48	0.461	0.032	0.336
Bleeding Index	27.60	16.21	30.14	13.13	28.68	14.18	34.14	15.13	26.03	13.53	28.54	16.96	0.615	0.382	0.171

PBCT, peroxide-based cleanser tablets and brush method; Control, water and brush method; Vinegar, vinegar and brush method; T0, pre-application of cleaning method; T1, post-application of cleaning method; SM, *Streptococcus mutans*; LB, *Lactocbacillus*; x̄, mean; SD, standard deviation; CMAT, interaction between cleaning method application and time; CMA, cleaning method application factor; T, time factor; P, significance according to factorial design repeated measures ANOVA; superscript letters indicate the differences between the cleaning methods according to the Bonferroni multiple comparisons

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Table 4. Descriptive statistics and the statistical evaluation of SM and LB counts on upper VFRs according to applied cleaning methods at T

	PBCT		Control		Vinegar		P	
	x̄	SD	x̄	SD	x̄	SD	CMAT	CMA
VFR SM count	5.20[b]	0.63	5.99[a]	0.87	5.43[b]	0.82	0.455	0.000
VFR LB count	5.13[b]	0.74	5.90[a]	0.94	5.28[b]	0.86	0.149	0.000

VFR, vacuum formed retainer; PBCT, peroxide-based cleanser tablets and brush method; Control, water and brush method; Vinegar, vinegar and brush method, T1, post-application of cleaning method; SM, Streptococcus mutans; LB, Lactocbacillus; x̄, mean; SD, standard deviation; CMAT, interaction between cleaning method application and time factor; CMA, cleaning method application factor; T, time factor; P, significance according to factorial design repeated measures ANOVA, superscript letters indicate the differences between the cleaning methods according to the Bonferroni multiple comparisons

Table 5. Assessment of the correlation between the bacteria count in the saliva samples at T1 and the bacteria count on the VFR samples at T1

		PBCT VFR		Control VFR		Vinegar VFR	
		SM	LB	SM	LB	SM	LB
PBCT Saliva	SM	r=−0.111	r=−0.118				
	LB	r=−0.181	r=−0.151				
Control Saliva	SM			r=0.276	r=0.230		
	LB			r=0.329	r=0.311		
Vinegar Saliva	SM					r=0.125	r=0.259
	LB					r=0.053	r=0.192

PBCT, peroxide-based cleanser tablets and brush method; Control, water and brush method; Vinegar, vinegar and brush method; VFR, vacuum formed retainer; T1, post-application of cleaning method; SM, *Streptococcus mutans*; LB, *Lactocbacillus*; the data related to the SM and LM counts on the VFR samples were exposed to logarithmic transformation; r, Pearson's correlation coefficient; 0.7≤r high correlation; 0.3<r<0.7 moderate correlation; 0.3≥low correlation

Table 6. Assessment of the correlation between the SM and LB bacteria counts on the VFR samples at T1

		LB Count on VFR T1		
Bacteria Counts		PBCT	Control	Vinegar
SM count on VFR T1	PBCT	r=0.910**		
	Control		r=0.988**	
	Vinegar			r=0.921**

PBCT, peroxide-based cleanser tablets and brush method; Control, water and brush method; Vinegar, vinegar and brush method; VFR, vacuum formed retainer; T1, post-application of cleaning method; SM, *Streptococcus mutans*; LB, *Lactobacillus*; the data related to the SM and LM counts on the VFR samples were exposed to logarithmic transformation; r, Pearson's correlation coefficient; 0.7≤r high correlation; 0.3<r<0.7 moderate correlation; 0.3≥low correlation; **; p<0.01

DISCUSSION

There are various appliances for maintaining the achieved ideal dental and skeletal outcomes, as a result of an active orthodontic treatment. VFR, one of the widely utilized removable appliances used in retention, is routinely applied in orthodontic clinics since it is easy to prepare, cheap, and esthetically preferred (1).

In previous studies, the accumulation of microorganisms such as SM, *Streptococcus sobrinus*, LB, *Staphylococcus epidermidis* and *Staphylococcus aureus, Enterobacteriaceae,* and *Candida* on removable orthodontic devices was investigated (20-22). Among these, the most cariogenic microorganisms are SM and LB. Therefore, the effect of the three different cleaning methods on the SM and LB bacteria counts were evaluated in our study. Periodontal parameters were also assessed, because the SM and LB counts may be affected by the oral hygiene status of the individuals and the presence of oral devices.

The duration of the VFR wear during the application of each cleaning method in our study was similar. It has been reported that the number of the microorganisms increased when the duration of the removable device usage increased (23). The similarity in the duration of removable device usage ensured that the conditions in the application of the cleaning methods were similar and that the effect of cleaning agents could be comparable (22).

Although, the periodonto-pathogenic bacteria counts after the orthodontic treatment were frequently investigated (17, 24-26), a limited number of studies were about the bacteria counts in the saliva (15, 16). Kim et al. (17) and Sallum et al. (24) stated that there was a significant decrease in some periodonto-pathogens and the total number of bacteria after the removal of orthodontic appliances. On the other hand, Jung et al. (16) reported that, while the total number of bacteria significantly decreased in the saliva samples taken 5 weeks after the removal, the numbers of SM and *Streptococcus sobrinus* increased due to the usage of removable retainers. In our study, the saliva samples had been collected 2, 6, 8, 12, 14, and 18 weeks after the removal of fixed orthodontic attachments, and no statistically significant differences were found in the SM or LB bacteria counts in the saliva before or after the application of cleaning methods. Similar bacteria counts in the saliva during our study period may be a result of the performed dental scaling and polishing application. In addition, the oral hygiene motivation of volunteers could have been increased by the given oral hygiene training after ending their fixed treatment. The participants who were aware that they were monitored during the study might have exhibited increased motivation (the Hawthorne effect). Furthermore, during the 2-week washout period, the oral flora might have got over the effects of the fixed treatment and attained their normal composition.

The similar plaque index scores assessed at all study periods for all three cleaning methods show that the oral hygiene status for all individuals was similar during the whole study. Similar to our findings, Kim et al. (17) obtained similar plaque index scores for the 1st, 5th, and 13th weeks after the removal of orthodontic attachments. In contrast, Yáñez-Vico et al. (27) found lower plaque index scores 15 days after the removal session than in the control group who had never received the orthodontic treatment. These conflicting results could be caused by the patients who improve their oral hygiene before the appointments.

In this study, the difference between the pocket depth data for cleaning methods was statistically significant ($p<0.05$). The cleaning methods applied were PBCT, control, and vinegar, and the periodontal pocket depths were found to decrease following this order, with a statistically significant difference between them ($p<0.05$). Although a decrease in the pocket depth with time seems to be related with the change of the cleaning agent, the real reason might be the decrease of gingival hyperplasia caused by the orthodontic treatment. The removal of fixed treatment devices enables oral hygiene to be performed more easily. The studies reported that the increased pocket depth did not change significantly 4 weeks after the removal sessions (28) and that it either decreases (29, 30) or recovers (30) in 2 years.

The bleeding on probing index scores was similar at all study times for the three cleaning methods. In the literature, it was reported that the bleeding indices decreased after the removal session (28). These conflicts might have resulted from the increased oral hygiene motivation of volunteers during our study and the performed washout period before the experiment.

When the SM bacteria counts on the VFR samples are considered, it is observed that after the application of different cleaning methods, the difference between the SM bacteria counts on the VFR samples were statistically significant ($p<0.001$). While the SM bacteria count on the VFR samples cleaned with PBCT and vinegar was statistically similar ($p>0.05$), the SM bacteria count on the VFR samples cleaned with the control method was statistically higher than in other methods ($p<0.05$). When VFR samples were cleaned with different cleaning methods, the difference between the LB counts was statistically significant ($p<0.001$). The LB count on the VFR samples cleaned with PBCT and vinegar is statistically similar, while the LB counts on the VFR samples cleaned with the control method are statistically higher than other methods ($p<0.05$). The higher SM counts and similarly higher LB counts on the VFR with the control method might indicate that only mechanical cleaning (control method) is not adequate to obtain hygiene. This result is compatible with literature (5). On the other hand, contradictorily to our PSB cleaning agent and vinegar result, it was stated that vinegar has a less expressed antimicrobial effect than the PSB cleaning agents (7). Contrary to that finding, there are also studies reporting that vinegar is more effective (11, 13). These contradictory results could be caused by the fact that different kinds of microorganisms were investigated or that different chemical agent brands were compared. Different application procedures and research designs used in the studies could be the other reasons for this conflict.

Although it has been reported in the literature that the disinfection of the removable appliance decreases the number of microorganisms in the saliva (31), we did not determine any correlations between the number of bacteria on the VFR sample and saliva samples. The reasons for these contradictory results might include comparing different cleaning solutions and investigating different VFR materials.

A high correlation was found between the SM counts and LB counts separately for the PBCT, control, and vinegar cleaning methods (PBCT, $r=0.910$; control, $r=0.988$; vinegar, $r=0.921$). This is because the VFR was fabricated with vacuum and had many indentations, and these surfaces form accumulation areas for microorganisms. In addition, the increase in the roughness of the VFR material from intraoral use increases dental plaque accumulation. The increase of SM on a surface decreases the pH of the environment. The decrease in the oral environment's pH causes an increase in the number of LB. The coexistence of these bacteria in the oral environment causes the number of the bacteria to increase. However, to the best of our knowledge, there are no studies in the literature investigating the correlation between the number of the SM and LB bacteria accumulating on the removable orthodontic devices.

Investigating a limited number of cleaning agents and bacterial species was the limitation of this study. In future studies, other commercial and natural cleaning agents can be compared with regard to their microbiological effects. In addition, surface property changes of biomaterials with the use of these cleaning agents can be investigated in a long term.

CONCLUSION

Both the SM and LB counts were similar on the VFRs cleaned with PBCT and vinegar, but bacteria counts were statistically lower than in the control method. The higher LB counts and similarly higher SM counts on the VFR samples indicate that mechanical cleaning only (control method) is not adequate to obtain hygiene. The SM and LB bacteria counts in the saliva samples at the T0 and T1 were similar, independently from the cleaning method used. A statistically significant decrease was recorded for the pocket depth scores during the study.

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethics Committee of the Republic of Turkey, Ministry of Health, Pharmaceuticals and Medical Devices Agency (21.04.2017.-71146310-511.06-E.89281).

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

Peer-review: Externally peer-reviewed.

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E.S.Ç.; Data Collection and/or Processing - F.A.A., N.E.Ş, E.S.Ç.; Analysis and/or Interpretation - F.A.A., N.E.Ş, E.S.Ç.; Literature Search - F.A.A., N.E.Ş, E.S.Ç.; Writing Manuscript - F.A.A., N.E.Ş, E.S.Ç.; Critical Review - F.A.A., N.E.Ş, E.S.Ç.

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Original Article

Comparative Assessment of Clinical and Predicted Treatment Outcomes of Clear Aligner Treatment: An in Vivo Study

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ABSTRACT

Objective: The objective of this clinical study was to assess the predicted software models and clinical models and to compare the stage models of both the groups so as to evaluate the efficacy of tooth movement with clear aligner.

Methods: The sample size included 10 cases with mild anterior crowding treated with aligner therapy. The predicted software models were superimposed on the clinical stereolithography (STL) models at various stages by using the MeshLab software. The predicted software models showing orthodontic tooth movement were compared with the actual movement achieved clinically.

Results: The results of the present study have shown that when a comparison was made on the basis of irregularity scores in both the groups, it was seen that the irregularity score was higher at 2.55 at T4, 1.65 at T6, and 1.0 at T8 in the clinical STL group at each stage, whereas it was 2.0 at T4, 0.90 at T6, and 0.25 at T8 in the software model group. In addition, in comparing the mean accuracy of these three stages, the analysis of data showed that the mean accuracy is 62.5% at T4, 68.8% at T6, and 78.1% at T8.

Conclusion: The predicted software models do not accurately reflect the patient's tooth position. There is an overestimation by predicted software as compared with actual clinically achieved tooth position. There is a need of overcorrection to be built in the treatment planning stage itself and execution of the anticipated end result.

Keywords: Clear aligners, clinical outcome, predicted outcome, comparison, accuracy

INTRODUCTION

Movement of teeth without the use of bands, brackets, or wires was described as early as 1945 by Dr H.D. Kesling (1). He reported the use of a flexible tooth positioning appliance. Later, Nahoum et al. (2) wrote about various types of overlay appliances, such as invisible retainers.

Minor tooth movements have also been achieved with a technique developed by Raintree Essix (New Orleans, LA, USA). This technique used clear aligners formed on plaster models of the teeth. This type of appliance was effective in correcting mild discrepancies in the alignment of the teeth (3-5). However, movements are limited to 2–3 mm, (4) and beyond this range, another impression and a new appliance were advocated.

Currently, in this modern world of orthodontics, various new techniques have been developed to make the treatment more comfortable and aesthetic for the patient. The patient has a plethora of options to choose from based on different factors, such as cost, treatment time, aesthetics, and comfort, and so on. Owing to these factors, increasing numbers of adult patients have sought orthodontic treatment, and the demand for aesthetic appliances has increased in recent years (6).

With further advancement in orthodontic technology, Align Technology introduced Invisalign™ in 1998, a series of removable polyurethane aligners, as an aesthetic alternative to fixed labial appliances. Usually scanned

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images are converted to physical models by using different stereolithography (STL) techniques to fabricate a series of aligners that sequentially reposition the teeth (7, 8). Stereolithographic models are constructed at every stage (9). Each aligner is programmed to move a tooth or a small group of teeth 0.25-0.33 mm every 14 days (10).

Since there can be many variables that could affect tooth movement, (6) these variables can be biological factors, such as periodontal ligament, age and sex of the patient, root length, bone levels, bone density, and medications, and certain systemic conditions can have inhibitory, synergistic, or additive effects on orthodontic tooth movement (OTM) (11). Variability among patients can affect OTM. Hence, it is necessary to evaluate the difference between the predicted and actual teeth movement achieved. Consistently performing these analyses during treatments will provide a useful database that could be used to study treatment progress and variables affecting tooth movement over time.

There is a lack of literature that determines the deviation of the clinical outcome of clear aligners with their predicted outcome. No in vivo study has compared the predicted and stage clinical treatment outcome. In addition, no study has been conducted at different stages of aligner therapy to measure the disparity in predicted and achieved outcome. In the fast growing aligner market, it is essential to know the efficacy of the appliance being used. Hence, there is a need to evaluate and compare the clinical and predicted treatment outcome of clear aligners.

The aim of the present study was to compare the clinical treatment outcome and the predicted treatment outcome of clear aligner.

The objectives of the present study were as follows:

1. To evaluate the predicted treatment outcome of clear aligners,
2. To evaluate the clinical treatment outcome,
3. To compare the predicted and clinical treatment outcome.

Methodology

- Source of the patients: Patients visiting the department who were indicated for comprehensive orthodontic treatment.
- Study subjects: 10 orthodontic patients with mild to moderate crowding in the lower incisors were scheduled for regular evaluation using Little's Irregularity Index (12).

Sample Size Calculation

The sample size was calculated using the nMaster 2.0 software. The power of the study was 80% with 95% confidence interval (CI).

Inclusion Criteria

- Adult patients.
- Healthy, compliant, and motivated patients who can visit the department regularly.
- Mild to moderate lower anterior crowding according to Little's Irregularity Index.
- Non-extraction treatment plan in the lower arch.
- The tray should not be altered with scissors or thermopliers for treatment.

Exclusion Criteria

- Severe crowding.
- Large restorations in the lower anterior teeth.
- Prosthetic replacements in the lower anterior teeth.
- Gross gingival/periodontal problems in the lower anterior teeth.
- Recent extraction and tooth trauma.

Study Design

Steps in the study protocol were

↓

Ten patients with lower anterior crowding were selected.

↓

All patients were treated with clear aligners.

↓

The average time for the treatment was 6 months–1 year.

↓

The predicted outcome simulated by computer-aided software was evaluated in STL format at different stages 4, 6, and 8.

↓

The clinical outcome using clear aligners was converted and evaluated in STL format at different stages.

↓

The predicted and clinical treatment models were superimposed.

On the basis of Little's Irregularity Index, a sample size of 10 patients including males and females with mild to moderate crowding was selected.

Impressions were taken repeatedly with polyvinyl siloxane at different stages and sent to the laboratory for 3D scan of dentition to make a virtual model of the cast. After completing the initial series of aligners, polyvinyl siloxane impressions were taken at various stages starting from stages T4, T6, and T8; and mailed to the aligner company whose aligners were used (13, 14).

T0 is zero aligner, T4 is the stage after aligner no. 4, T6 is the stage after aligner no. 6, and T8 is the stage after aligner no. 8. The stage impressions were scanned using the extra oral dental scanner Maestro 3D MDS400 (Figure 1) and converted to an STL format. A clinical STL file was created for each set of models for maxillary and mandibular arch separately. The company, whose aligners were used, shared the files in STL format for software models as well.

The MeshLab software (Figure 2) with the support of the 3D-coform project program was used in the study to superimpose the stage clinical STL files and the software STL files. The MeshLab software is software for processing 3D scans, which consist of a fully automated voxel-based registration method. In each of the comparisons, the STL superimpositions used the reference points. To maintain uniformity, the same operator performed the point based gluing. The clinical STL and software STL files were superimposed with the points of a first mesh (clinical STL) onto the corresponding points of a second mesh (software STL), within the same reference space with an accuracy of 8 μm. T

Figure 1. Maestro 3D MDS400

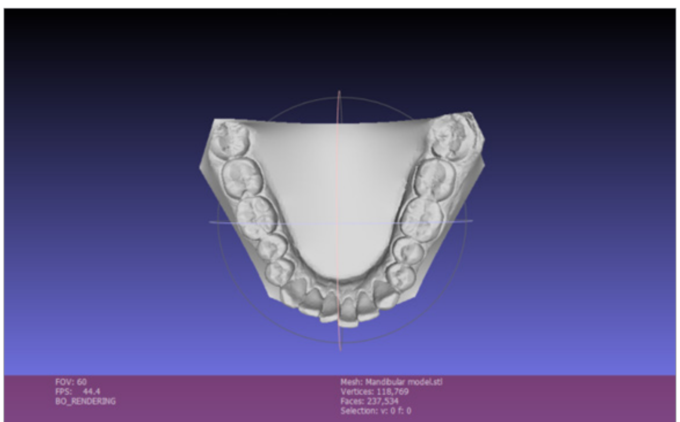

Figure 2. MeshLab software

The software also includes a measuring tool, allowing for linear measurements between points to measure the irregularity scores on both the clinical STL models and software STL models and compare the achieved teeth position at different stages, namely, T4, T6, and T8. With the aid of a measuring tool, it measured the resolution of crowding, rotation, and alignment of each anterior tooth (Figure 3). The difference between the scores of the clinical model and the software model is calculated for total score and/or discrepancy.

The clinical and software STL models of zero aligner at T0 stage, aligner at T4 stage, aligner at T6 stage, and aligner at T8 stage were taken, and superimpositions were done (Figure 4-7). Once two models are superimposed, the software will perform an efficacy analysis report that will show quantitative measurements for predicted and achieved movements. The percentage of accurate tooth movement will be determined by the following equation:

Percentage of accuracy=100%–[(|predicted–achieved|/|predicted|)×100%].

Figure 3. Measuring tool software in MeshLab

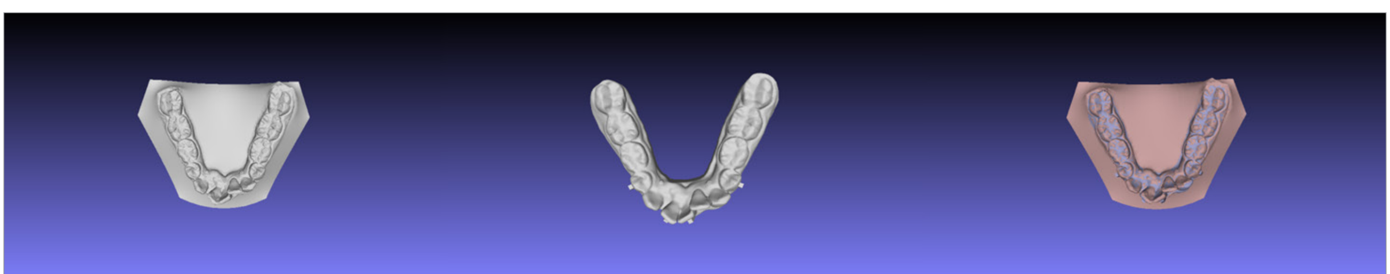

Figure 4. Clinical models, software models, and their superimposition at T0

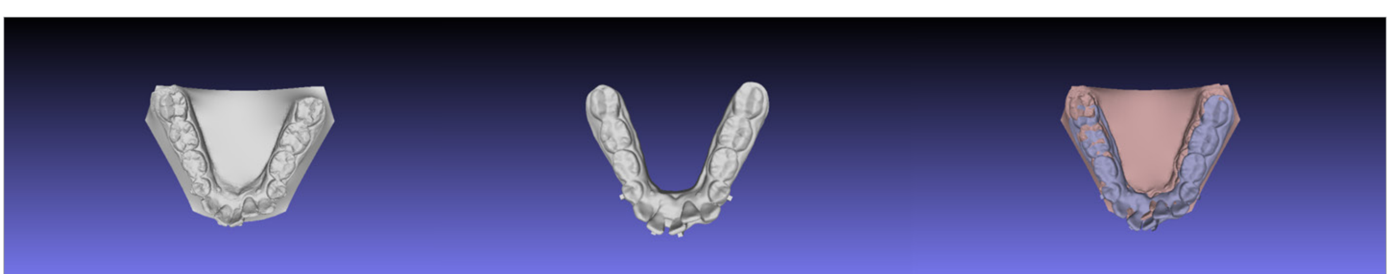

Figure 5. Clinical models, software models, and their superimposition at T4

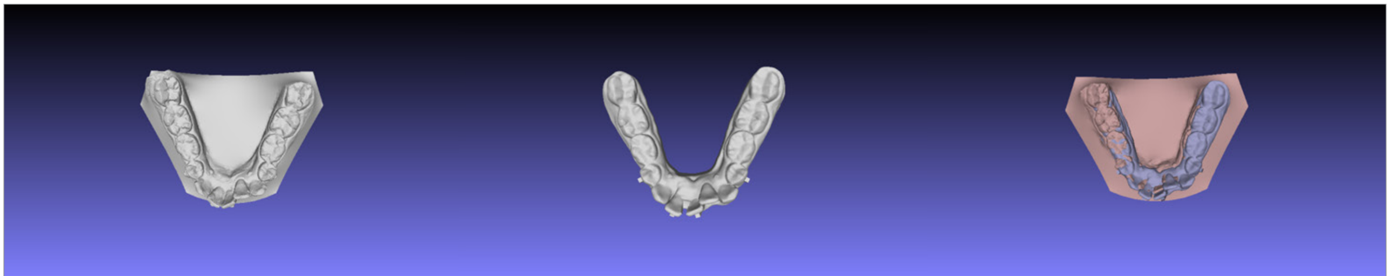

Figure 6. Clinical models, software models, and their superimposition at T6

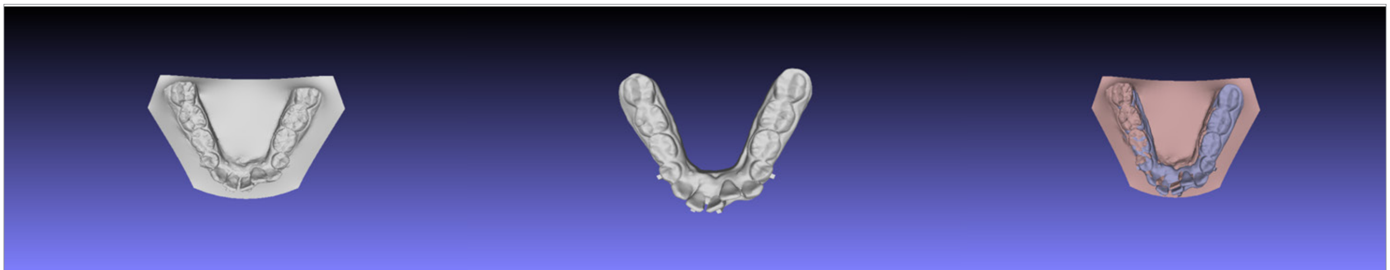

Figure 7. Clinical models, software models, and their superimposition at T8

Statistical Analysis

Data were entered into Microsoft Excel spreadsheet and were checked for any discrepancies. Summarized data were presented using tables. The software used for statistical analysis was Statistical Package for Social Sciences version 21.0 (IBM Corp.; Armonk, NY, USA) and Epi-info version 3.0. Shapiro–Wilk test was used to check which all variables were following normal distribution. Paired or dependent t-test was used for comparison of two mean values obtained from the same group or a pair of values obtained from the same sample when the data follow normal distribution. A p-value <0.05 was accepted as significant with 95% CI.

RESULTS

This study was conducted to assess the difference between the stage clinical outcome and the predicted outcome of clear aligners and also percentage of accuracy. In the present study, the mean change from T0 to T4, T0 to T6, and T0 to T8 was compared from clinical models and software models, and it was seen that the mean change was more in the software models at each stage, respectively. The mean accuracy of the clear aligners was approximately 78% at T8.

The mean change from T0 to T4 was compared between the clinical and software models using the Paired t-test. The mean change from T0 to T4 was significantly more in the software model with 1.25 than in the clinical model with 0.70 (Figure 8) (Table 1).

The mean change from T0 to T6 was compared between the STL and software models using the Paired t-test. The mean change from T0 to T6 was significantly more in the software model with 2.35 than in the clinical model with 1.60 (Figure 9) (Table 2).

The mean change from T0 to T8 was compared between the STL and software models using the Paired t-test. The mean change from T0 to T8 was significantly more in the software model with 3.00 than in the clinical model with 2.25 (Figure 10) (Table 3).

Table 1. Mean change from T0-T4 between both the groups

Change from T0 to T4	Mean	Std. Deviation	Mean Difference	t-test value	p
Clinical STL model	0.70	0.26	-0.55	-3.498	0.007
Software model	1.25				

Table 2. Mean change from T0-T6 between both the groups

Change from T0 to T6	Mean	Std. Deviation	Mean Difference	t-test value	p
Clinical STL model	1.60	0.32	-0.75	-6.708	0.000
Software model	2.35	0.41			

Table 3. Mean change from T0-T8 between both the groups

Change from T0 to T8	Mean	Std. Deviation	Mean Difference	t-test value	p
Clinical STL model	2.25	0.35	-0.75	-4.392	0.002*
Software model	3.00	0.82			

Table 4. Mean accuracy at different stages

Accuracy	Mean	Std. Deviation
T4	62.50%	29.20%
T6	68.83%	13.05%
T8	78.12%	13.84%

In addition, the evaluation of the mean accuracy of clear aligners in clinical models at T4 was found to be 62.5 and 68.83 at T6 and 78.12 at T8 (Figure 11) (Table 4).

Moreover, the comparative evaluation of the irregularity score of the clinical and software models has been depicted at T0 stage with 3.25 and 3.25, at T4 stage with 2.55 and 2.00, at T6 stage

Table 5. Comparison of irregularity score between both the groups at different stages

	Clinical STL model		Software models	
	Mean	SD	Mean	SD
T0	3.25	1.16	3.25	1.16
T4	2.55	1.26	2.00	1.11
T6	1.65	1.16	0.90	0.99
T8	1.00	0.91	0.25	0.42

SD: standard deviation

with 1.60 and 0.90, and at T8 stage with 1.00 and 0.25, respectively (Fig. 12) (Table 5).

DISCUSSION

Although clear aligner treatment (CAT) has been cited as a safe, aesthetic, and comfortable orthodontic procedure for adult patients, only a few investigations (6) have focused on the predictability of OTM. In 2005, Lagravère and Flores-Mir (15) published a systematic review in which only two studies met their inclusion criteria related to Invisalign™ therapy efficacy (16, 17). It was stated that no strong conclusions could be made regarding the treatment effects of this kind of orthodontic treatment. Thus, clinicians who plan to use the CAT on their patients have to rely on their clinical experience, the opinions of experts, and limited published evidence. The present study aimed to assess the effect of these variables on the clinical outcome along with the biological restraints in the patients and compared it with the software models that had no constraints to OTM. In addition, it also enunciates that these variables could alter the predictability of the aligner treatment.

The purpose of the present study was to compare a proprietary software model with the actual clinical outcome to determine whether overall occlusion and crowding at various stages of aligners, such as aligner nos. 4, 6, and 8, are comparable. The present study endeavored to establish the relative validity of predicted proprietary software models by determining whether the 3D treatment outcome of aligner therapy can be accurately predicted.

The results of the present study show that the mean change from T0 to T4, T0 to T6, and T0 to T8 comparing both the groups was significantly more in the software models than in the clinical models.

The result provided an inference that the clinical models showed resolution of crowding when it is assessed individually at different stages. However, when it is compared with the software models at different stages, the mean change is lesser in the clinical models than in the software models, thereby suggesting that resolution of crowding is better in the software models and it overestimates the correction of crowding and misalignment.

The comparison was made for the mean accuracy of the clear aligners at different stages of aligners. The analysis of data showed the mean accuracy that concluded from the data that the maximum accuracy matched for both the groups at the T8 stage, though the accuracy of this match was lesser in the initial stages of treatment; the accuracy between the predicted and clinical outcomes improves as the treatment progressed.

Moreover, a study was conducted using the Invisalign™ with their proprietary system. Kravitz et al. (10) conducted a prospective clinical study in 2009 to evaluate the efficacy of tooth movement with Invisalign™. The amount of tooth movement predicted by ClinCheck (Align Technology) was compared with the amount achieved after Invisalign™ treatment. Tooth movement was evaluated on Tooth-Measure, Invisalign's proprietary virtual model superimposition software. It concluded that the mean accuracy of tooth movement with Invisalign was 41% (18, 19).

In addition, Buschang[7] conducted a prospective study that compared the patients' models taken immediately after treatment, ClinCheck™ models overestimated alignment, buccolingual inclinations, occlusal contacts, and relations.

For aligner treatments to be valid and effective, the predicted and actual outcomes should be comparable. Digital computerization allows the visualization of the treatment plan at not only beginning and end but also step by step, and aligner by aligner throughout the treatment that purportedly reflects the treatment outcomes and hence the anticipated end result can be visualized. However, there is no study that correlates and compares the predicted software models and the clinical outcome at varied stages along with the variables in the patient's mouth into consideration, as they can alter the clinical outcome end results.

The present study was one of a kind where the comparison was made at different stages to assess the efficacy and the accuracy of the aligners and to correlate it with the predicted outcomes. In addition, the comparison showed that the accuracy of the appliance is approximately 78%, which is more than reported by other authors in their study. In addition, it should be taken into consideration that there must be some variables or biological restraints that affected the mean accuracy of the treatment, as it has affected the clinical treatment outcome at every stage.

In addition, a study by Drake et al. (20) stated that bodily movement is not achievable by the CAT; the aligners can easily tip the tooth crown but cannot tip the root because of the inadequate root control movement with the aligner system. Although the tooth movement programmed by the software is bodily movement, tipping of the teeth occurs. Therefore, the end result will vary from the programmed or predicted result.

Another study was conducted by Clements et al. (21) using Align Technology to compare two different materials of the aligner (soft and hard). The hard material group showed the best results in Peer Assessment Rating score reduction. The stiffness of the material is an important factor in achieving the desired result as it has better tooth control.

These variables along with wear of the aligners by the patient for requisite hour are an important factor in achieving the predicted end result that should be taken into consideration. Clearly, successful aligner treatment is not limited to aligners alone; there are different adjuncts and auxiliaries that should be used to explore the horizons of aligner in treating patients with difficult or different malocclusion. These variables diminish the clinical outcome of the aligners as to which it was predicted and reduce the mean accuracy of the CAT. And so as to overcome this variability and hindrance in the accuracy and predictability to achieve as it was desired. Certain limitations are associated with the present study.[1] Mild to moderate crowding cases were included, excluding the posterior segment that was taken as a reference for superimposition (2). Restraints, such as the thickness of material that can alter the tooth movement, were not taken into account (3). No adjuncts or auxiliaries were used (4). Overcorrection was not incorporated in the software (5). Torque expression was not accounted for.

Emphasis should be given to the need of overcorrection to be built in the software, effective attachment designs so as to make aligners more reliable with respect to treating difficult malocclusions and to achieve the desired result. The present study was performed using the XYZ aligner system with the same proprietary software so as to maintain uniformity on all patients and results. However, more studies should be conducted on similar pattern involving more number of patients, and also further studies need to be performed to evaluate the expression of the torque with the aligner system and also the material qualities.

CONCLUSION

The present study was conducted to evaluate the clinical outcome and the predicted outcome and to compare the results of both outcomes. Data were evaluated, and statistical analysis was done to find the results. The present study concluded the following:

- The mean change from T0 to T4, T0 to T6, and T0 to T8 was significantly more in the software models than in the clinical models.
- The software models overestimated the alignment and the resolution of crowding in comparison with the actual clinical models. Software models do not accurately reflect the patient's final occlusion immediately at the end of active treatment.
- The mean accuracy is 62% at T4, 68% at T6, and 78% at T8, concluding that it is an efficient appliance for correcting mild to moderate crowding. In addition, there are variables or biological restrains that alter the accuracy of the CAT.
- Hence, there is a need of overcorrection to be built in the treatment planning stage itself and execution of the anticipated end result so as to achieve the desired correction as seen in software models.

Ethics Committee Approval: Ethics committee approval was received for this study from the Institutional Ethics Committee of Sudha Rustagi College of Dental Sciences and Research.

Informed Consent: Informed consent was obtained from the patients included in the study.

Peer-review: Externally peer-reviewed.

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Review

Pain and/or Discomfort During Debracketing: A Review

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ABSTRACT

The topic of bracket removal and enamel integrity has been extensively investigated. Nevertheless, bracket removal, as far as pain and/or discomfort are concerned, is poorly delineated in the orthodontic literature, i.e., the scarcity of reports in this area is conspicuous. In fact, only six studies were retrieved upon a PubMed search. These clinical studies performed with metal brackets are presented in a chronological order in the present review. Pain and/or discomfort during bracket removal are urgently in need of additional studies. The orthodontists have to be well-informed and updated to convey all the aspects of this procedure to the patient.

Keywords: Pain, discomfort, debracketing, orthodontics

"Whatever words we utter should be chosen with care for people will hear them and be influenced by them for good or ill."
Buddha

INTRODUCTION

The International Association for the Study of Pain described pain as "an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage. "The final phrase of this definition, i.e., "or described in terms of such damage," was intended to acknowledge the complaints of individuals experiencing pain without evidence of tissue stress or damage, despite a thorough investigation (1). The definition of pain as presented in 1979 is still considered valid today (2).

The multifaceted and biopsychosocial phenomenon of pain is a subjective, complex response, which demonstrates large individual variation (3, 4). It has been emphasized that the perception of pain may be linked to a large number of factors, such as age, individual pain threshold, gender, cultural differences, present emotional state and stress, previous pain experiences, and genetic, as well as epigenetic mechanisms (3-5).

In orthodontics, the terms "pain" and "discomfort" are frequently used to describe an unpleasant feeling or experience. These two terms are often used interchangeably in orthodontics; yet, they do by no means imply the same intensity or magnitude (6). For example, the use of burs and discs, as well as rubber cups, with pumice for adhesive remnant removal, subsequent to debracketing of healthy teeth, might cause some discomfort; however, not pain. The lack of a clear-cut distinction between these two terms does create ambiguity.

Furthermore, the term "debonding" needs to be defined. Debonding is the removal of orthodontic brackets (debracketing) and the residual adhesive from the enamel at the completion of active orthodontic treatment (7).

A considerable amount of studies whether orthodontic patients experience pain and/or discomfort during treatment have been published (3, 4, 6 , 8-12). Nevertheless, little has been reported regarding pain and/or discomfort

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in relation to bracket removal, i.e., debracketing (4). A PubMed database search revealed only six clinical studies on this topic. These studies were all performed with labial metal brackets (13-18). The scarcity of studies in this area is conspicuous (Table 1). These studies are presented chronologically (13-18).

In 1992, the first study regarding this topic was conducted (13). This pilot study was composed of 15 (10 female and 5 male) patients and assessed the discomfort threshold immediately before bracket removal. The discomfort threshold was described as the point just before the feeling of pain during force application. These forces, such as intrusive, mesial, distal, lingual, buccal, extrusive, and torque (a shear-torsion force), were applied to the bracket or to the enamel surface after archwire removal. The shear-torsion force was applied with a forked lever arm, 87.6 mm in length, grasping the mesial and distal sides of the metal bracket. A force meter able to record the forces ranging from 100 to 1000 g was used. No attempt was made to remove the metal brackets during this testing.

The previous study concluded that the discomfort threshold is significantly influenced by the direction of force application and the mobility of the tooth (13). Teeth with increased mobility demonstrated increased sensitivity. Intrusive forces were the best tolerated type (mean average 934 g) of force application, whereas extrusive forces were the least tolerated (mean average 827 g). Teeth were most sensitive to the application of shear-torsion force. Nevertheless, a mean average value in g could not be obtained for this type of force application, since the force gauge could not record forces <100 g. Thus, the previous study cautioned that this type of force, applied with a long lever arm, should be avoided during bracket removal (13).

Gender and tooth type differences also had an effect on the discomfort threshold, but to a lesser degree (13). Data regarding the age of the participants were not given.

This study's clinical implications were highlighted, namely the clinician should apply finger pressure or ask the patient to firmly bite into a piece of cotton roll to provide an intrusive, stabilizing force during bracket removal (13). The better stabilized the teeth, the better they are able to withstand the debracketing forces. Discomfort during bracket removal can be minimized in this manner (13).

In 2010, a split-mouth study assessed the level of discomfort and pain during debracketing (14). A total of 37 (25 female and 12 male) patients composed this study. The age of the patients ranged from 12 years and 9 months to 44 years and 2 months. Two instruments, the lift-off debracketing instrument (LODI; 3M Unitek, Monrovia, CA, USA) and a ligature cutter plier, were used. With the LODI method, a piston grip plier was positioned over the bracket, and a pulling force was applied on the bond through a pull-wire placed under the bracket tie-wing, thereby pulling the bracket directly away from the tooth surface. With the ligature cutter plier method, the pliers grabbed the bracket wings and applied gentle pressure mesially and distally. All metal brackets were removed by the same professional. The archwire was removed prior to debracketing.

Discomfort was determined by asking the patients to assess, on a scale of 0–4, the level of sensitivity at the time each bracket was removed. The scale is rated as follows: 0, total absence of pain; 1, mild discomfort with no pain; 2, mild pain; 3, considerable pain, yet tolerable, pain; and 4, intolerable pain.

No pain and mild discomfort were the most frequently reported scores for both methods. Yet, 12.8% of the patients reported pain (score ≥2) with the LODI, whereas 24.3% of the patients reported pain (score ≥2) with the ligature cutting plier. Therefore, the LODI is the preferred method.

The amount of composite remaining on the tooth surface after debracketing was determined with a minor modification of the original Adhesive Remnant Index (ARI) (19). Interestingly, the ARI was the same for both debracketing methods. These researchers underlined that the ideal bracket removal should be free of pain, as well as free of harm to the enamel (14).

The author of this review believes that a comment regarding the wide age range at the time of bracket removal, from 12 years and 9 months to 44 years and 2 months, of this study is appropriate (14). A systematic review and meta-analysis concluded that there is insufficient evidence regarding age and pain perception (20). Interestingly, another systematic review and meta-analysis (21) published within the same year as the study by El Tumi et al. (20) stated that aging reduces pain sensitivity, i.e., the pain threshold increases with age. In light of these

Table 1. Summary of the publications (PubMed) on pain and discomfort during debracketing

Authors	Year	Country	Bracket type	No. of patients	Age range (year/month)	Archwire at debracketing	Pain assessment
Williams and Bishara (13)	1992	USA	Metal	15 (10 females and 5 males)	Not given	Ex situ	Discomfort threshold (the point just before feeling pain during force application)
Normando et al. (14)	2010	Brazil	Metal	37 (25 females and 12 males)	12/9–44/2	Ex situ	Pain and discomfort evaluation with a scale from 0 to 4
Mangnall et al. (15)	2013	UK	Metal	90 (51 females and 39 males)	12/0–18/0	In situ	VAS
Pithon et al. (16)	2015	Brazil	Metal	70 (70 females)	14/3–45/11	Ex situ	VAS
Bavbek et al. (17)	2016	Turkey	Metal	63 (32 females and 31 males)	13/0–21/0	In situ	VAS
Kılınç and Sayar (18)	2019	Turkey	Metal	120 (84 females and 36 males)	12/0–18/0	In situ	NRS

findings, even though not consistent, a narrower age range for future studies on pain perception during debracketing might be prudent (20, 21).

Furthermore, the author of this review believes that some facts about the LODI will be beneficial for the reader, since this instrument is not routinely used by orthodontic clinicians (Figure 1). The instructions for use state that the even contact of this instrument's plastic rests with the enamel surface stabilizes the tooth (22). It is also indicated that for hypersensitive or mobile teeth, the application of an intrusive force with a finger on the incisal edge/occlusal surface reduces discomfort during debracketing. The pull-wire of this instrument is engaged under one gingival or occlusal bracket wing with full-size brackets, whereas the pull-wire is engaged under two gingival or occlusal bracket wings with miniature brackets for debracketing. Finally, it is pointed out that this instrument is only appropriate for the removal of metal brackets.

Normando et al. (14) did not give any information whether such an intrusive force was applied.

In 2013, a randomized controlled trial evaluated the patients' expectations of pain prior to fixed appliance removal and whether biting into a 3-millimeter thick, U-shaped, soft acrylic bite wafer minimizes pain during this procedure (15). A total of 90 (51 female and 39 male) patients with pre-coated metal brackets composed this study. The age of the patients ranged from 12 to 18 years. The patients were randomly allocated to the control group or to the wafer group. The bite wafers were manufactured "in-house." The control group had their teeth out of occlusion during bracket removal.

The archwire was left in situ during bracket removal for both groups. Bracket removal was performed by one investigator. A bracket removal plier (BRP) with right-angled beaks for easy access was used. The beaks of this plier were placed under the occlusal and gingival bracket tie-wings applying a peeling force for bracket removal. A visual analog scale (VAS) was used for pain assessment (23).

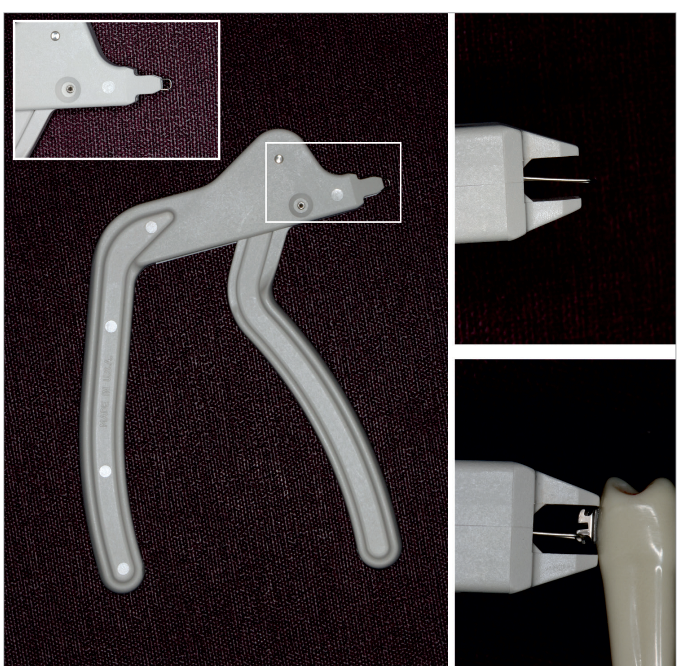

Figure 1. The lift-off debracketing instrument

Overall, the results of this study implied that the use of bite wafers, applying an intrusive and stabilizing force, renders bracket removal more comfortable (15). In this manner, any shear/peel and rotational forces applied to the periodontal ligament during debracketing are counteracted. Nevertheless, the debracketing of the lower anterior teeth (central incisor, lateral incisor, and canine teeth) was reported as most painful for both groups. The authors explained this outcome by the greater debracketing force per unit surface area of the roots of the lower anterior teeth (15).

These authors recommend that reiterating the steps of bracket removal to alleviate any potential anxiety prior to this procedure is important, since the pain expected was found to be significantly greater than the actual pain experienced (15).

The author of this review would like to add that an effective communication in health care is of utmost importance. Clear communication, such as thoughtfully walking a patient through a procedure that is being performed or one that will be conducted in the future, will render patients less anxious and more optimistic. Health care is a shared endeavor, and communication is its sine qua non (24, 25).

In 2015, a clinical investigation was published with the aim to compare the level of discomfort during the removal of metal brackets with different hand instruments (16). This split-mouth study was composed of 70 female patients. The age of the patients ranged from 14 years and 3 months to 45 years and 11 months. Only canine and premolar teeth were evaluated for standardization. The discomfort of the procedure was evaluated by the VAS at the completion of debracketing.

Four different methods, i.e., hand instruments, were used. The first method was performed with the LODI. The second method was performed with a straight cutter (SC) plier, i.e., a ligature cutter plier. The SC was used to apply pressure to the mesial and distal sides of the bracket base, i.e., the blades of the SC were placed at the adhesive interface. The third method was performed with a How plier (HP), i.e., pressing the mesial and distal wings of the bracket. The fourth method was performed with a BRP. The blades of the BRP were placed below the mesial and distal wings of the bracket for pressure application. The archwire was removed prior to debonding. The brackets were removed by one clinician.

The authors concluded that the use of the LODI caused lower levels of pain or discomfort, whereas the SC method presented the highest discomfort. The HP and the BRP methods showed similar mean discomfort values, which were located between the discomfort levels of the SC and LODI. The result reported for the LODI is in agreement with the result reported by Normando et al. (14).

Following debracketing, the adhesive remaining on the enamel was evaluated using a portable digital microscope (Vehs, Hong Kong, China). The ARI scores for the SC were noticeably less than those of the other debracketing methods (19). This indicates a higher risk for enamel injury with the SC than the other debracketing methods. Pithon et al. (16) point out that the ideal method for debracketing should cause no harm to the enamel surface, as well as no pain to the patient. This point has also been emphasized by Normando et al. (14).

Pithon et al. (16) only enrolled female patients for standardization. The wide age range of these participants is apparent.

The author of this review believes that some remarks about gender and pain perception will be useful. A meta-analysis performed by Riley et al. (26) stated that there is a general consensus of a gender difference in response to pain. Nevertheless, Riley et al. (26) underlined the ambiguity of these findings. Thus, it might be plausible to believe that gender differences in pain behavior may reflect the influence of cultural patterns, as well as cultural variations, in the verbalization of pain experience rather than differences in physiology (6).

In 2016, a clinical study aimed to evaluate the level of pain during debracketing, as well as the assessment of three pain control methods (17). A total of 63 (32 female and 31 male) patients composed this study. The age of the patients ranged from 13 to 21 years. Three groups were formed according to the pain control method. These groups were the finger pressure (FP) group, elastomeric wafer (EW) group, and stress relief (SR) group. The FP and EW groups were set up to evaluate the effect of intrusive forces on debracketing.

In the FP group, pressure was applied from the occlusal surface in a gingival direction with a thumb. A cotton pad was interposed between the thumb and the occlusal surface to eliminate the occlusal morphological differences. In the EW group, an elastomeric wafer fabricated from a heavy-body silicone impression material and 5–6 mm thick was used. Patients were instructed to bite firmly into this wafer during debracketing. In the SR group, the patients were instructed not to occlude, i.e., open mouth position. For SR, the patients were told that bracket removal would not cause harm or serious pain.

Debracketing was performed by the same orthodontist with the same hand instrument (Direct Bond Metal Bracket Remover, 001-346E; American Orthodontics, Sheboygan, WI, USA) for all groups. The dual chisel tips of these pliers were wedged between the bracket base and the tooth, i.e., the adhesive interface. The pliers were applied occlusal-gingivally. The archwire was left in situ during debracketing. The patients were asked to record their VAS scores after each metal bracket was removed (23).

Furthermore, this study employed the Pain Catastrophizing Scale (PCS) to assess the relationship of the participants' personal traits and the actual pain experience during bracket removal (27). The tendency to catastrophize influences pain perception by heightening the emotional responses to pain, i.e., the individual experiences pain as more intense (28). The PCS was completed 1 week after the debonding procedure during routine retainer control.

As expected, pain catastrophizers reported higher pain levels (higher VAS scores) during bracket removal. Higher VAS scores were also obtained for female patients. For all groups, higher VAS scores were obtained for the anterior regions (central and lateral incisors) in the upper, as well as the lower, jaw. Interestingly, neither FP nor EW was superior to SR in reducing the perceived pain during debracketing.

These authors stated that the finishing archwires were present for at least 2 months (17). This is the only study presenting some information on finishing archwire duration. Unfortunately, these authors did not discuss this point (17). Might this period have caused a decrease in tooth mobility? Teeth with increased mobility demonstrate increased sensitivity and vice versa (13).

In 2019, a study evaluating the patients' pain levels using four different approaches for bracket removal was published (18). A total of 120 (84 female and 36 male) orthodontic patients composed this study. The age of the patients ranged from 12 to 18 years. These patients were enrolled into four equal groups. In Group 1, debracketing was performed with an open mouth position. In Group 2, a single dose of pain reliever (acetaminophen 500 mg tablet) was given 1 h before debracketing, which was performed with an open mouth position. In Group 3, each patient was asked to bite into a soft bite wax (Ormco, Glendora, CA, USA) during debracketing. In Group 4, the patient was asked to bite into a soft acrylic bite wafer (3M Unitek). Debracketing was performed with the same hand instrument, the Weingart plier, in all groups. The plier beaks squeezed the mesial and distal tie-wings for debracketing. Debracketing was performed by the same clinician. The archwire was in situ during the debracketing procedure. After bracket removal, the Numerical Rating Scale (NRS) was used for the assessment of pain perception (29).

The null hypothesis of this study was that the patients' pain perception of the four groups would not present a statistically significant difference (18). Interestingly, this null hypothesis was accepted.

The author of this review would like to make some final comments before proceeding to a succinct conclusion. Personally, the word "pain" (Latin: poena, a fine, a penalty) should never be mentioned prior to the debonding procedure (30). The bright side of the completion of active orthodontic treatment should be reinforced, i.e., spotlighted. Nonthreatening words, such as "discomfort," should be used for this unique and long-awaited procedure. The patients' responses are profoundly colored and molded by their expectations (24, 25, 31).

The scales used in the aforementioned studies all employ the word "pain." The use of the word "pain" by the orthodontist may inadvertently evoke the phenomenon of pain (13-18). Orthodontists might have to devise a "Debracketing Discomfort Scale" due to the sui generis nature of this procedure.

CONCLUSION

- An assessment of the published literature demonstrates a very poor documentation of the level of discomfort experienced during bracket removal. Thus, further investigation in this area is obligatory.
- Ceramic bracket removal with debracketing instruments specifically designed for their bracket brand should be investigated (32).

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Review

Orthodontic Treatment with Clear Aligners and The Scientific Reality Behind Their Marketing: A Literature Review

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ABSTRACT

As the demand for esthetic treatments is increasing, more people are seeking alternatives to fixed orthodontic appliances. Clear aligners are an esthetic and comfortable option for orthodontic treatment and have gained immense popularity over the last decade. This review will highlight the increasing popularity of clear aligners by describing some aligner systems frequently used today. The scope, limitations, effectiveness, efficacy, and stability of treatment results achieved with this method will be discussed. Further, this paper will assess the possible side effects caused by clear aligner treatment.

Keywords: Orthodontics, orthodontic treatment, aesthetics, clear aligners

INTRODUCTION

The increase in the number of adult orthodontic patients has prompted an upsurge in the demand for esthetic and comfortable alternatives to conventional fixed appliances (1-4). Clear aligners that satisfy this demand are also prone to rapid technological improvements in aligner materials and production techniques (1). Developments in clear aligner technologies have increased the number and complexity of cases treated with this method (5). Clear aligners provide an esthetic and comfortable treatment experience, facilitate oral hygiene, cause less pain as compared to fixed orthodontic appliances, reduce the number and duration of appointments, and require less emergency visits (6-8). However, the expense in production, dependency on patient cooperation, and the inability to treat certain malocclusions limit the usage of clear aligners (1, 3, 5, 9-12). An electronic search in the English language was conducted in December 2017 in the following electronic databases: Google Scholar, Web of Science, and PubMed. We checked the bibliographies of included papers and relevant review articles. Only prospective and retrospective human studies were included while animal studies, editorials, and case reports were excluded.

Clinical and Research Consequences

According to production methods, clear aligner systems can be broadly grouped into two categories; aligners made from thermoplastic materials via manual set up and systems using CAD-CAM technologies to design and produce aligners (13). It is impossible to describe each system in this review; therefore, the most widely used systems will be discussed.

Aligners Produced by Manual Set up

The manual approach is a labor-intensive process, requiring manual repositioning of the teeth, wax setting, and production of vacuum-formed retainers. This approach allows the fabrication of aligners easily in laboratory conditions in a cost-effective manner. It also facilitates the follow-up process of the treatment and allows the orthodontist to make the necessary treatment changes at an earlier stage.

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Full arch impressions are taken using polyvinyl siloxane material and a working cast is obtained. On the working casts, teeth that are planned to be moved in each aligner are determined and removed from the cast using a 0.25-mm handsaw. The separated target teeth are then moved to the desired position and are fixed using the block-out wax. If needed, the interproximal reduction is performed at this stage. After this realignment, plastic sheets are molded on the setup model using a pressure molding machine or vacuum machine. Following the final trimming procedures, a 3-piece set of aligners are delivered to the patient (19).

Aligners are produced in various thickness levels (0.020-inch, 0.025-inch, or 0.030-inch). The use of gradually thickening aligners provides more control on tooth movement and reduces the pain caused by orthodontic forces. With one set of impressions, two or three aligners of various thickness levels are produced, and the patient is instructed to use each aligner for 10 to 15 days. The aligners are fabricated from a new working cast and obtained from a new impression taken at each visit, which allows the clinician to modify the treatment plan throughout the course of treatment, and to be able to follow the progression of tooth movement (14, 15). Clear Aligner system CA (Scheu Dental, Germany) is an example of aligner systems requiring a manual setup. In this system, a computer program, Aligner Aid (AAP, IV- Tech, South Korea) is used to accurately measure the tooth movement obtained. It is possible to measure the tooth movement by naked eye visualization, but this program is recommended when more than one tooth is to be moved. Before the initial setup is made, a photo of the working cast is taken using a digital camera, and this photo is superimposed over the photo of the setup model. The program measures the distance and angle of the teeth that are to be moved and recommends that the total teeth movement obtained in one set of aligners be limited to 5 mm (14, 15).

Aligners Produced by CAD-CAM Technologies

The incorporation of digital technology has revolutionized the practice and appliances used in orthodontics. As in other fields of dentistry, CAD-CAM systems have become involved in orthodontics and aligner treatment.

Invisalign® being the best-known aligner system has become a generic name for other high-quality systems using CAD-CAM technology This system is known to be the most sophisticated and most commonly used clear aligner technology currently available (1). In 1999, the Invisalign® system was introduced to the orthodontic market to treat mild malocclusions only; however, the development of different attachments and auxiliaries now enables Invisalign® system to perform major tooth movements and treat more complex cases such as those requiring premolar extraction (16-18). Aligners in Invisalign® system are designed and produced using CAD-CAM technology (13). The combination of computerized virtual treatment planning, and stereolithographic prototyping technology for manufacturing gives Invisalign® a leading role in aligner therapy (4, 5, 19, 20).Today, Align Technology continues to be a leader in the market, and Invisalign has become a household name for aligners produced by computers since more than 4 million people are treated by this system. Meanwhile, literature research in 2015 revealed approximately 27 different clear aligner systems on offer, a number that continues to increase rapidly (21-26).Companies like Orthero, ECligner, EON Aligner, and Clear Correct are examples of other aligner systems created using computer technology

Biomechanics of Aligner Treatment

Understanding the mechanics of tooth movement using aligners could lead to the more appropriate selection of patients and more accurate treatment sequencing, leading to better results (10).

Tooth movement mechanism with clear aligners can be explained from two different perspectives: the displacement driven system and the force driven system (10, 21). The displacement driven system mainly controls simple movements such as tipping or minor rotations. Aligners are formed according to the position of the tooth in the next staged location and the tooth continues to move until it lines up with the aligner. This system is known to be less effective in controlling tooth movement and is insufficient in producing root movements. The force driven system, however, requires biomechanical principles to facilitate tooth movement. Aligners are designed to apply desired forces on the tooth. The shape of aligners to produce such forces is not necessarily the same as the shape of the tooth. The movement required for each individual tooth, mechanical principles to accomplish this movement, and the aligner shape are determined via Clincheck® (Align Technology, Santa Clara, CA, USA) software. The aligner shape is altered via pressure points or power ridges in order to apply the desired forces (4, 10, 21). Pressure points lead to more difficult uprighting and intrusion movements, whereas power ridges control axial root movements and torque (1, 27) (Figure 1, 2).

Despite the alterations in the shape of the aligner, movements such as root paralleling, extrusion, and rotation were still difficult to obtain using aligners until Align Tech. (Align Technology, Santa Clara, CA, USA) introduced smart force attachments for the Invisalign® system. These attachments are small composite bulges designed to produce a force system favorable for the designed movement. Their position and shape are determined via Clincheck® software according to the movement to be obtained. Extrusion attachment, rotation attachment, and root control attachments are currently used. Extrusion of a single tooth is moderately difficult using clear aligners when compared to fixed-appliance systems, however, some auxiliaries such as buttons and elastics can be used to facilitate this movement. Also, the extrusion of a group of teeth (i.e., maxillary incisors) can be performed using aligners (Figure 3).

The use of temporary anchorage devices in combination with clear aligners further widened the range of treatments possible with aligners (27, 28).

Scope and Limitations of Treatment with Clear Aligners

Although the number and complexity of cases treated with clear aligners continue to increase, it is impossible to treat all kinds of malocclusions with this system. Clear aligners are convenient in mild to moderate crowding or diastema, posterior expansion, intrusion of one or two teeth, lower incisor extraction cases, and distal tipping of molars. Movements like extrusion, correction of severe rotations, molar uprighting, and closure of extraction spaces are known to be more challenging to accomplish with aligners. Even so, incisor extrusion, molar transition, and closure of extraction spaces are possible with the use of attachments in the Invisalign® system (4, 9, 18, 23).

Efficacy and Efficiency of Clear Aligners

As the demand and interest toward the clear aligner system continue to grow, questions regarding the efficacy of the system remain (20, 29). To date, published data include little clinical research on the effectiveness and efficacy of clear aligners (1, 30). Previous literature primarily includes case reports or descriptions of the product, making it difficult to objectively characterize the efficacy of clear aligner systems (29, 30).

Clinical Effectiveness of Clear Aligners

In 2005, Djeu et al. (31) conducted the first retrospective cohort study on the effectiveness of clear aligners, which compared the treatment results of Invisalign® patients with the results of conventional fixed braces using the American Board of Orthodontics grading system. They reported that both systems are equally effective in space closure, marginal ridge alignment and, root paralleling; however, the Invisalign® system is deficient in the correction of anteroposterior discrepancies, providing occlusal contacts, and posterior torque.

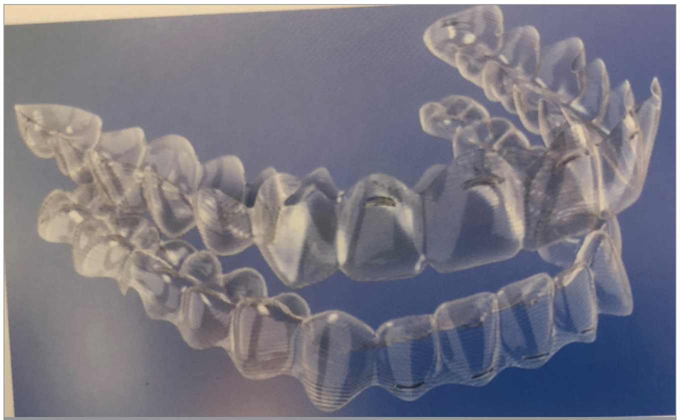

Figure 1. Power ridges

Parallel to the previous study, Kassas et al. (32) reported that the clear aligner system is effective in leveling and aligning arches in mild and moderate cases and in correcting buccolingual inclinations effectively, however, it is not sufficient for providing ideal occlusal contacts. The deterioration in occlusal contacts is caused by the thickness of aligners, which interferes with the settling of the occlusal plane. Kravitz et al. (20) evaluated the accuracy of tooth movement obtained by the Invisalign® system and reported that only 41% of the predicted tooth movement was achieved. The most effective movement was lingual constriction (47.1%), the least accurate was extrusion (29.6%), and only 33% of predicted rotation correction was achieved.

The lower canine is the most difficult tooth to control. Weihong et al. (33) evaluated the effectiveness of the Invisalign system on mild to moderate cases treated with premolar extractions and compared the treatment results obtained with fixed appliances. Their results revealed that both systems can be used in the treatment of extraction cases, and that root angulation attained with clear aligners are adequate when proper attachments are to be used. However, it should be kept in mind that treating extraction cases requires experience and extensive knowledge of the system (34, 35). The majority of the literature focuses on the effects obtained via the Invisalign system. Yıldırım et al. (36) investigated the efficacy of tooth movements obtained with clear aligner appliances. In their study, retrusion was found to be the most accurately obtained tooth movement followed by a rotation, fan-type expansion, and protrusion respectively. Retrusion of mandibular central incisors is considered to be the most accurate single-tooth movement, whereas the rotation of mandibular canine is the least accurate movement. Due to the lack of scientific data and poor methodologies of the available studies, results should be interpreted with caution. Further research is required in this field (19, 35).

Time Efficiency of Clear Aligners

Time efficiency is an important outcome to consider for private practice orthodontists because spending less time with one patient in the clinic and completing the treatment earlier both pleases the current patient and allows the orthodontist to treat more patients (37). Bushang et al. (38) investigated the difference between conventional fixed appliances and Invisalign® aligners in terms of total treatment time and chair time in non-extraction patients. Total treatment time was found to be 67% lesser in the In-

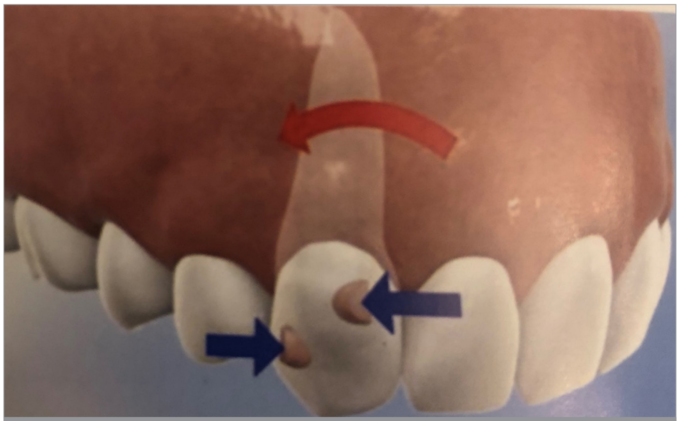

Figure 2. Root control attachment

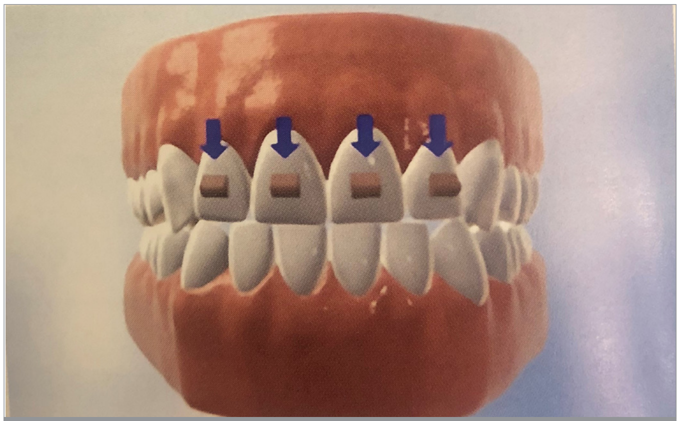

Figure 3. Extrusion of anterior teeth using aligners

visalign® group. The short duration of treatment with aligners was asserted with the absence of the finishing and detailing phase, which can take up to 6 months with fixed appliances. On the contrary, in extraction cases, Invisalign® treatment duration is 44% longer as compared to fixed-appliance treatment (33). Patients with good compliance are required to visit the orthodontist in 10–12 week intervals in aligner therapy, whereas 4–6 week intervals are inevitable when treating with fixed appliances. Therefore, more appointments are required in fixed appliances therapies (38). Also, the chair time is found to be significantly shorter in clear aligners group, allowing the clinician to treat more patients (38, 39).

Effects of Clear Aligners on Periodontal Status and Oral Health

As the number of adults treated with clear aligners increased, the periodontal effects of this treatment were found to be negative in the literature (40-42). Use of clear aligners facilitates oral hygiene, thus improving the periodontal status and causing a decrease in plaque levels, gingival inflammation, bleeding upon probing, and pocket depth (2, 40). Fixed appliances and wires made plaque control difficult and had adverse effects on periodontal tissues, making orthodontic treatment a predisposing factor for periodontal diseases (43). However, according to the study of Han et al. (40), with careful oral hygiene education and repeated plaque control, patients treated with fixed appliances and clear aligners showed similar gingival and plaque index. Clear aligners not only promote better oral hygiene, and better periodontal health but also reduce the plaque accumulation and the development of white spot lesions. According to the study of Azeem et al. (44), orthodontic treatment with clear aligners showed a low incidence of newly developed WSL's.

Post Orthodontic Treatment Stability of Clear Aligners

As in all types of orthodontic treatment, stability is one of the most important issues to discuss regarding clear aligners. One study investigated the post-retention stability outcomes of cases treated with clear aligners and fixed orthodontic appliances using the American Board of Orthodontics objective grading system (30). Retention protocol included only the use of removable thermoplastic Essix retainers and no fixed retainers were applied. Three years following the retention phase, relapse was seen in both groups in terms of total alignment, however, maxillary anterior leveling seemed to be stable in the fixed appliances group but relapsed in the Invisalign group (30). This data can only provide a preliminary insight for post-retention outcomes of clear aligners and the results cannot be generalized since only removable retention appliances were used and the researchers relied heavily on patient cooperation. Since clear aligner therapy is a relatively novel treatment method, retention studies regarding aligners are limited in the literature and further investigation is required on this subject (16, 30).

Root Resorption and Clear Aligners

Root resorption is one of the chief problems of orthodontic treatment and it is known that fixed orthodontic appliances can give rise to root resorption, generating excessive pressure at the apical level and causing external apical root resorption (45-48). However, few studies have assessed root resorption caused by thermoplastic aligners. A systematic review conducted in 2017 that could include only three studies concluded that aligners could also cause root resorption at the end of orthodontic treatment; however, the incidence and severity are lower as compared to fixed appliances (49). Another study stated that the incidence of root resorption caused by aligners is similar to the resorption caused by light orthodontic forces (50). According to the study by Gay et al. (49), 41.81% of teeth showed signs of apical root resorption after clear aligner treatment, with upper and lower incisors being the most affected teeth. This situation is explained by the root structure and the great extent of movement shown by the incisors.

CONCLUSION

- Clear aligners provide an esthetic and comfortable option to conventional fixed mechanics.
- Obtaining periodontal health is easier in patients treated with clear aligners and less white spot lesions develop during the treatment.
- Clear aligners can be used in mild to moderate crowding cases but caution must be exercised in complex cases.
- Root resorption is still a risk associated with orthodontic treatment in aligner therapy, such as in fixed appliances.
- Long term stability studies are required in this field.

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Case Report

Modified Haas Expander for the Treatment of Anterior Openbite and Posterior Crossbite Associated with Thumb Sucking-A Case Report: 3-Years Follow-Up

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ABSTRACT

Thumb sucking is an abnormal habit that occurs in childhood and can cause several malocclusions if it persists for a long time. Malocclusions caused by oral habits require proper treatment timing to maintain a normal growth and should be treated at an early age. This case report shows the management of thumb sucking and early correction of anterior open bite and posterior crossbite by a modified Haas expander. Three-year follow-up results showed the effectiveness of this special designed appliance.

Keywords: Thumb sucking, Modified Haas expander, anterior openbite, posterior crossbite, tongue crib

INTRODUCTION

Abnormal oral habits are repetitive actions that may lead to disturbance in physical growth depending on their frequency, duration, and intensity (1). Thumb or finger-sucking is one of the most common oral habits practiced by children, occurring in approximately 17% of them (2, 3). Malocclusion prevalence studies have established that prolonged thumb sucking may cause specific abnormal effects on occlusion, surrounding bone development and orofacial musculature function (4, 5).

Traisman (6) reported a highly significant difference in the number of malocclusions, with 9.7% in thumb-suckers compared with 6.7% in non-thumb-suckers. Thumb sucking for extended periods can lead to various types of malocclusion including anterior open bite, posterior crossbite, increased overjet, crowding, and increased probability of developing a Class II malocclusion (7).

The main cause of posterior crossbite in thumb-suckers is alteration of the functional equilibrium between the tongue and orofacial musculature (8). This imbalance leads to the narrowing of the maxillary arch that results with a posterior crossbite.

Intense habits can deform the alveolus and dentition during the primary dentition years (9). Finger pressure can impede the eruption of the permanent incisors and cause anterior open bite. Most of the changes resolve spontaneously as soon as the habit stops before the eruption of the permanent incisor.

Here, we report a case of a thumb-sucker patient with anterior open bite and posterior crossbite in the early mixed dentition stage.

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CASE PRESENTATION

Diagnosis

An 8-year- and 4-month-old male patient accompanied by his parents was referred to the Department of Orthodontics with a chief complaint of prolonged thumb sucking (Figure 1). The patient was in the early mixed dentition stage. No pathological background information was reported according to his medical history.

Unilateral posterior crossbite, 3.5 mm anterior open bite, slight midline deviation to the left, and a constructed maxillary arch were revealed on complete clinical examination. He presented a Class I molar relationship on the right side and Class II on the left side (Figure 2).

His anamnestic information revealed that his sucking habit lasted all night long; however, he stopped the habit when someone reminded him during daytime.

His skeletal and alveolar structures appeared to be normal in panoramic radiographs. Cephalometric analysis showed that

Figure 1. Thumb sucking position

Figure 2. Pretreatment (T_0) extraoral and intraoral photographs

Figure 3. Cephalometric radiographs

Table 1. Cephalometric measurements

Parameter	Norm	Pretreatment T_0	Posttreatment T_1	3-year follow-up T_2
SNA (°)	80±2	92.1	91.7	90.8
SNB (°)	78±2	86.0	84.8	86.5
ANB (°)	2±2	6.0	6.9	4.3
Wits (mm)	0±1	2.1	0.9	−0.7
SN-GoGn (°)	32±6	26.0	28.3	24.0
FMA (°)	25	18.5	17.7	15.8
U1-PP (°)	112±6	117.6	115.3	114.0
IMPA (°)	90±3	106.5	97.2	93.2
U1-NA (mm)	4.0	−1	0.8	3.3
L1-NB (mm)	4.0	7.5	5.6	4.6
UL-E (mm)	−4	0	−0.1	−2.2
LL-E (mm)	−2	1.4	1.6	−0.9

both the maxilla and the mandible were protrusive relative to SN, whereas the ANB angle was 6° (Figure 3 and Table 1). Although the patient had an anterior open bite, he a skeletally low angle. The lower incisors were proclined due to the altered type of thumb sucking pressure on them.

Treatment goals

The main goals of treatment were breaking the habit, correcting posterior crossbite, providing the necessary environment for permanent teeth eruption, and obtaining normal overbite.

Written informed consent was obtained from the parents of the patient.

Treatment plan and progress

A special appliance was designed by modifying the Haas expander for preventing thumb sucking and expanding the maxilla at the same time (Figure 4). This expander was anchored to the deciduous second molars and canines. A tongue crib, which was used to help break the habit, was attached to the anterior arms of the expander behind the anterior teeth. The crib was covered with acrylic making it smoother and was split into two so as not to prevent the expansion. The patient's mother was instructed to activate the screw two turns per day in the first 10 days and then once a day. Expansion was performed until transverse overcorrection was obtained on the deciduous molars. After completion of the active expansion phase, the expander was kept in the mouth for 6 months for retention of the expansion and ensuring that the habit has truly stopped.

Figure 4. Modified Haas expander with tongue crib

Treatment Results

Posterior crossbite was corrected successfully, including the permanent molars, even though no direct forces were applied on them. When the proper transverse dimension was achieved in the maxilla, the mandible returned to its normal position, resulting in spontaneous correction of the midline and a Class II molar relationship on the left side (Figure 5).

Thumb sucking was reduced significantly in the first weeks with the appliance and was prevented completely at the end of the first month. The delayed permanent anterior teeth eruption was normalized when finger pressure was eliminated.

The appliance was removed at the end of 6 months and was recalled for follow-up visits at 3-month intervals for 3 years (Figure 6).

The overall treatment resulted in a slight posterior rotation of the mandible. The ANB angle showed a slight increase after expansion, whereas the SNA angle remained unchanged. During the follow-up period, mandibular growth was mainly in an anterior direction, resulting in an increase in SNB angle and a decrease in ANB angle (Table 1). Proclined lower incisors were found to tip lingually at the end of the treatment and continued with increasing age (Figure 7).

Figure 5. Posttreatment (T_1) extraoral and intraoral photographs

DISCUSSION

The period between age 3 and 6 years is the transitional period for addressing potential oral habits (10). Abnormal oral habits, such as thumb sucking, should be decreased significantly by the end of this period. If the habit is not eliminated before the permanent incisors erupt, it leads to considerable malocclusions, especially for those who continue the habit for a duration of ≥6 h/day (11).

Our patient was in the early mixed dentition stage and had already anterior open bite because of thumb sucking. Many studies have reported that if the habit is stopped during the mixed dentition years, some of the adverse dental changes will begin to reverse naturally (10, 12). At the end of 6 months of treatment, anterior open bite was corrected spontaneously due to increased growth of the alveolar processes and eruption of the permanent incisors.

In contrast to anterior open bite, posterior crossbite is not a self-correcting malocclusion and should be treated early to avoid the negative long-term effects on growth and development of the teeth and jaws (13). Our patient had unilateral posterior crossbite in the left side that was corrected with a modified Haas expander.

Routine orthodontic treatment protocols require more than one appliance to break the habit and correct the malocclusion. Orthodontic approaches with more than one appliance increase treatment time and costs. The present design used in this case was effective in the correction of anterior open bite and posterior crossbite at the same time. On the other hand, as compared with conventional rapid palatal expansion appliances, the expander was anchored on deciduous teeth to prevent any damage or negative effects to permanent teeth.

CONCLUSION

The long-term stability of crossbite and open bite correction associated with thumb sucking in the mixed dentition was favorable. The unique design of the appliance provided an opportunity to resolve three major problems with one appliance and can be preferred as a convenient alternative to conventional habit breakers.

Figure 6. Three-year follow-up (T_2) extraoral and intraoral photographs

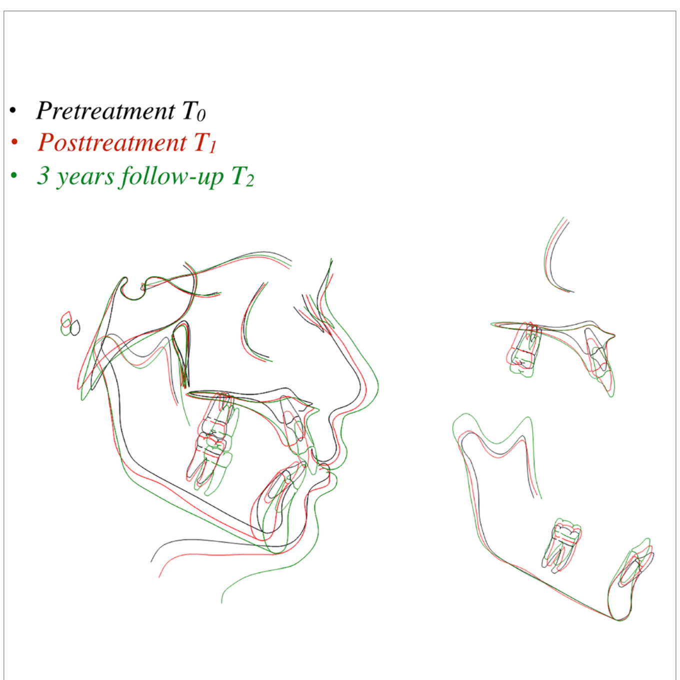

Figure 7. Cephalometric superimposition

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

Peer-review: Externally peer-reviewed.

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