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TURKISH JOURNAL of ORTHODONTICS

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

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

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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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Figures, graphics, and photographs should be submitted as separate files (in TIFF or JPEG format) through the submission system. The files should not be embedded in a Word document or the main document. When there are figure subunits, the subunits should not be merged to form a single image. Each subunit should be submitted separately through the submission system. Images should not be labeled (a, b, c, etc.) to indicate figure subunits. Thick and thin arrows, arrowheads, stars, asterisks, and similar marks can be used on the images to support figure legends. Like the rest of the submission, the figures too should be blind. Any information within the images that may indicate an individual or institution should be blinded. The minimum resolution of each submitted figure should be 300 DPI. To prevent delays in the evaluation process, all submitted figures should be clear in resolution and large in size (minimum dimensions: 100 × 100 mm). Figure legends should be listed at the end of the main document.

Where necessary, authors should Identify teeth using the full name of the tooth or the FDI annotation.

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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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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.

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ORIGINAL ARTICLE

Combined Use of Retraction and Torque Arch with Mini-Screws: A Cephalometric Study

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ABSTRACT

Objective: Our objective was to investigate and quantify the treatment of micro-implant-aided retraction and torque (R&T) arch on dentofacial structures.

Methods: Twelve patients (mean age 21.2 years) who required orthodontic camouflage treatment were included in the study. Following the canine distalization, mini-screws were placed between maxillary first molars and second premolars, and R&T arch was applied for the retraction of incisors. The vertical retraction arms of the arch were adjusted between the apex of the lateral incisor and the alveolar bone so that the retraction force passed through the center of resistance of four incisors and forced the incisors to bodily retraction. Closed coil-springs applying 150 gr of force were used to retract the incisors. The retraction period lasted for 217±34 days.

Results: SNA and NV-A decreased ($p<0.05$), indicating alveolar bone remodeling around Point A. The reduction in the SNA caused a statistically significant decrease in the ANB ($p<0.01$). SN/1, NA/1, NA-1, and overjet decreased significantly ($p<0.01$), depending on the retrusion of the incisors. The distances from the apex and incisal point of the central incisor to the SV reference plane also decreased significantly ($p<0.01$), revealing a nearly parallel movement of the incisors. Anchorage loss of the molars and decrease in nasolabial angle were not significant ($p>0.05$).

Conclusion: A combined use of R&T arch with mini-screws is an effective method to retract the incisors without anchorage loss. The type of movement is nearly parallel.

Keywords: Mini screw, retraction and torque, arch

INTRODUCTION

An increased procumbency of the upper lip and convex profile are seen due to overjet of upper incisors in patients with Class II Division I malocclusion, or Class I bimaxillary dentoalveolar protrusion. Orthodontic treatment of such patients aims to reduce teeth proclination and to improve the relation between the teeth and lips, and thus provide the patient with a more linear profile (1). The retraction of upper incisors plays an important role in the functions of the stomatognathic system, frontal and profile esthetic views of the face, and the stability of orthodontic therapy. However, the mechanics that would be performed to enhance the anchorage of posterior teeth should be accurately planned prior to the retraction of incisors (2, 3).

Anchorage control plays a key role in both structural and facial esthetics of patients. Maximum anchorage is required when 75% of the extraction cavity has to be covered by anterior teeth. Various techniques have been developed to provide maximum anchorage (4). Traditional methods, such as torque and tip-back bending, intermaxillary elastics, extraoral force, transpalatal arch, or Nance appliance can be used to enhance the ortho-

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dontic anchorage (5, 6). Skeletal anchorage screws are preferred when absolute anchorage is required. The use of mini-screws has become widespread within the last years because they can be placed (safe zone) during any phase of development, the force can be applied immediately, and there is no need for patient co-operation. Easy use for both the patient and physician and low cost are other advantages of mini-screws (7, 8). These screws are temporary anchorage units and have smooth surfaces since they have not been designed for osseointegration. Therefore, they are not available for long-term functional and esthetic use, and they are removed when anchorage is not needed anymore. Today, the most frequently used temporary skeletal anchorage devices include micro-screws, mini-screws, mini-implants, palatal implants, and modified mini-plaques (9).

Bae et al. (10) suggested that micro-implants placed between the second premolar and the first molar could be used with a closed coil spring for the retraction of maxillary incisors. Kawakami et al. (11) placed a mini-screw between the first and second molars and enhanced the anchorage of posterior regions by attaching these implants to the molar bands. Upadhyay et al. (12) performed mass retraction of 6 anterior teeth by applying 150 gr force on micro-screws. Park et al. (13) also performed mass retraction by using micro-screws, and they reported approximately 4-months shorter treatment period with only 0.26 mm anchorage loss.

Retraction and torque (R&T) arch is a retraction wire developed by F. G. Sander and produced in two different compositions for the anterior and posterior segments (14). Two posterior segments are made of stainless steel wire, whereas anterior segment is made of super elastic wire. The anterior segment has been produced in three different diameters so that it could be used in two different bracket systems with .018 and .022 slots. However, the posterior segment has a diameter of .017×.022 only. The anterior segment has a torque of 30° or 45° (Table 1). Palatal root torque is given to the incisor region by attaching the anterior and posterior segments angularly to each other with a piece of crimping. There are vertical, stainless steel retraction arms soldered to the attachment point of anterior and posterior segments. During retraction of incisors, the force is applied to the teeth via closed coil-springs, which are attached to these vertical arms. Literature review revealed that R&T arch wire has not been widely used in the orthodontic practice. Various methods have been used to counteract torque loss in conjunction with retraction of maxillary anterior teeth. One of these is a biomechanic method in which the retraction force vector is optimized, such as R&T arch together with lever arms and mini-screws. The null hypothesis tested was that the use of R&T arch together with lever arms and mini-screws would be more beneficial than sliding mechanics for the treatment of patients requiring maximum anchorage.

Table 1. Production of arch wire (R&T)

	Dimensions		
Technical	**Front segment**	**Torque**	**Lateral Segment**
0.18	0.016x.022	30	0.017x.022
0.18	0.016x.022	45	0.017x.022
0.22	0.017x.025	30	0.017x.022
0.22	0.017x.025	45	0.017x.022

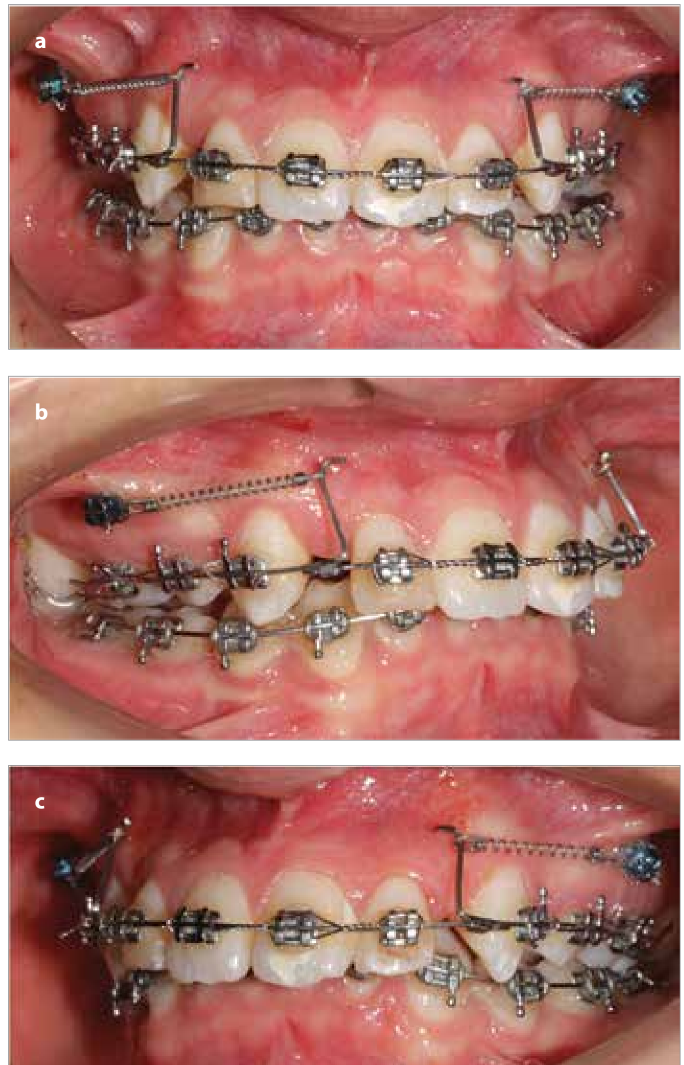

Figure 1. a-c. Clinical setup for retraction and torque arch with mini-screw: intraoral frontal image (a); intraoral left image (b); intraoral right image (c)

METHODS

This study was approved by the ethical committee on research of the Health Sciences University in Ankara, Turkey.

The present study comprised 12 patients with the mean age of 21.2±3.1 years. The inclusion criteria were as follows:

- Eruption of all permanent teeth without congenital absence of any tooth
- Presence of Class II Division I malocclusion and obvious proclination of upper central incisors
- An overbite within the normal ranges
- Regular order of lower incisors or minimal irregularity not exceeding 2-3 mm
- Maximum anchorage cases that require camouflage treatment by eliminating excessive overjet with extraction of maxillary first premolars

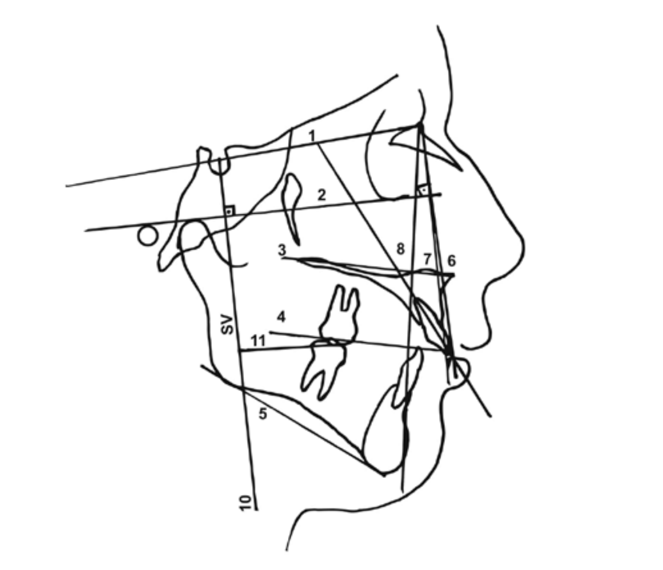

Figure 2. Cephalometric planes used in this study: 1) SN; 2) FH; 3) Palatal plane (PP); 4) Occlucal plane (OP); 5) Mandibular plane (MP); 6) N vertical (NV); 7) NA; 8) NB; 9) 1/NA; 10) Vertical reference plane perpendicular from S to FH (SV); 11) perpendicular distance from mesial cusp tip of maxillary first molar to SV

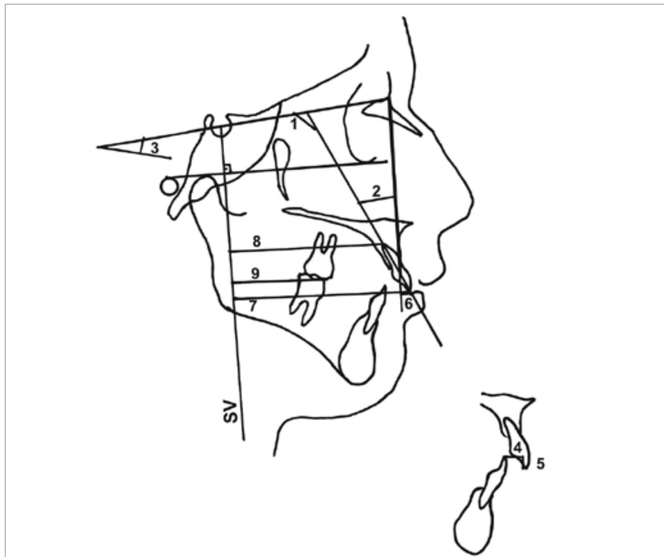

Figure 4. Dental measurements: 1) 1/SN; 2) 1/NA; 3) SN/OP; 4) Overjet; 5) Overbite; 6) 1-NA; 7) Vertical distance between the incisal point of the maxillary central incisor and SV (SV⊥U1i); 8) Vertical distance between the apical point of the maxillary central incisors and SV (SV⊥U1r); 9) Vertical distance between the mesial cusp tip of the maxillary first molar and SV (SV⊥U6t)

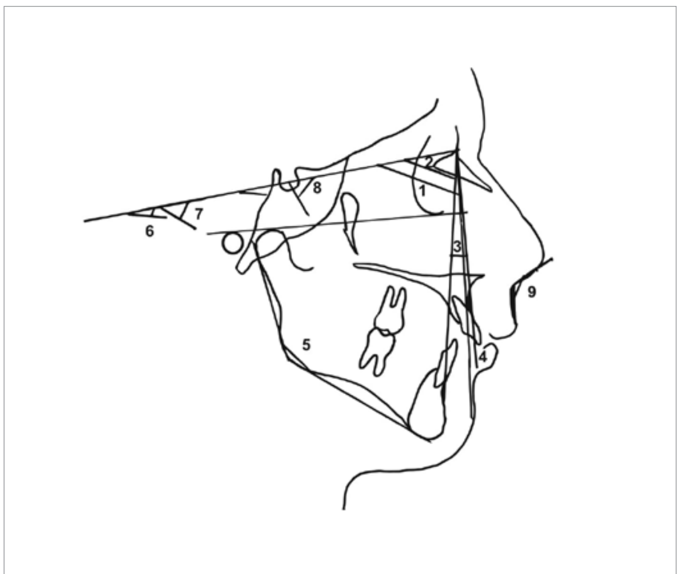

Figure 3. Skeletal and soft tissue measurements: 1) SNA; 2) SNB; 3) ANB; 4) NV-A 5) Gonial angle; 6) SN/PP; 7) SN/MP; 8) Y-axis; 9) Nasolabial angle

- Completed active growth period
- No congenital disease or systemic problem

After the extraction of first premolars, Nance appliance and .018 slot Roth brackets were attached. Following the leveling phase, 0.16×0.16 stainless steel arch wire was applied, and lace-back was performed for canine distalization. Thereafter, a mini-screw (Miniscrews AbsoAnchor, Dentos, Daegu, Korea; diameter, 1.3 mm; length 8 mm) was placed between the first molar and the second premolar and R&T arch with an anterior segment of .016×.022, and a torque value of 45° was applied for the retraction of incisors. Closed coil-springs (Sentalloy, Tomy, Tokyo, Japan) applying 150 gr force were inserted between the miniscrews and the vertical loop of the R&T arch to retract the incisors (Figure 1a–c). The patients were followed up at 3-week intervals, and at the end of the incisor retraction period that lasted for 217±34 days, final settling of the occlusion was provided by intraoral elastics.

Lateral cephalometric radiographs were taken twice in all the patients: T1, before the retraction (after leveling for eliminated initial protrusion of the incisors), and T2, after closure of the extraction spaces. To evaluate the skeletal alterations SNA, SNB, ANB, Nv-A, Go, Y-axis, SN/PP, SN/MP were used. To evaluate the dental alterations SN/Occ, SN/1, NA/1, NA-1, overjet, overbite were measured. The nasolabial angle was used to determine the soft tissue. Despite these conventional analyses, a vertical reference plane (SV) from sella, perpendicular to Frankfort Horizontal plane, was reconstructed, and the vertical distances from the apex and incisal point of the maxillary central incisor were measured to determine the amount of horizontal movement of the maxillary incisor. Skeletal, dental, and soft-tissue measurements are illustrated in Figure 2-4.

Statistical Analysis

Cephalometric measurements were made on cephalograms taken before T1 and after T2 the retraction of incisors to assess dental, skeletal, and soft tissue changes. The measurements of 5 randomly selected patients were repeated to control the personal drawing error level. Nonparametric Wilcoxon signed rank test was used to compare the paired values of measurements. Probability of 0.05 was considered significant.

RESULTS

None of the 36 mini-screws failed before the end of the retraction period. In all the patients, increased overjet was eliminated, and

Table 2. Evaluation of parameters

	T1	T2	p
SV-A	74.6±5.6	66.4±8.3	0.002
SV-C	82.7±5.6	73.6±8.1	0.002
SV-CM	48.2±7.2	48.3±7.2	0.655
Overbite	3.8±1.4	3.8±1.1	0.957
Overjet	6.5±0.5	3.4±0.5	0.001
NA-1	6.4±0.9	4.1±1.1	0.002
NA/1	23.8±3.3	21.7±3.3	0.015
SN/1	103.8±3.4	100.0±2.5	0.002
SN/Occ	17.3±3.7	17.4±3.6	0.552

SV-A: distance from SV (from sella, perpendicular to Frankfort Horizontal Plane) to A; SV-C: distance from SV (from sella, perpemdicular to Frankfort Horizontal Plane) to C; SV-CM: distance from SV (from sella, perpemdicular to Frankfort Horizontal Plane) to CM; NA-1: distance from NA to line joining crown tip and apex of upper incisor; NA/1: angle between NA and line joining crown tip and apex of upper incisor; SN/1: angle between SN and line joining crown tip and apex of upper incisor; SN/Occ: angle between SN and occlucal plane

Table 3. Evaluation of parameters

	T1	T2	p
SNA	80.1±2.1	79.5±2.0	0.052
SNB	74.7±2.7	74.7±2.7	1.000
ANB	5.4±1.1	4.8±1.1	0.011
Nv-A	0.5±3.7	-0.5±3.8	0.048
Go	127.8±3.0	129.3±3.6	0.027
Y-axis	62.6±3.5	64.1±2.7	0.048
SN/PP	9.8±1.5	10.0±1.5	0.405
SN/MP	35.9±5.1	36.5±5.4	0.250
PP/MP	28.1±5.9	28.3±4.8	0.660
Nasiolab	103.5±2.7	102.4±1.9	0.263

SNA: angle between S-N and N-A; SNB: angle between S-N and N-B; ANB: angle between A-N and N-B; Nv-A: distance from NA to A; Go: angle between Ar, Go, and Gn points; Y-axis: agle between SN to SGn; SN/PP: angle between SN and palatal planes; SN/MP: angle between SN and mandibular planes; PP/MP: angle between ANS-PNS- and Go-Gn; Nasiolab: angle between the bottom of the nose (subnasale) and the top of the lip (labrale superiorius)

Class I canine and Class II molar relation were attained at the end of orthodontic treatment that lasted for 217±34 days. In the evaluation of skeletal parameters, it was determined that decreases in SNA and Nv-A were statistically significant ($p<0.05$), indicating alveolar bone remodeling around Point A. The reduction in the SNA caused a statistically significant decrease in ANB ($p<0.001$). Evaluation of dental parameters revealed that SN/1, NA/1, NA-1, and overjet decreased significantly ($p<0.01$), depending on the retrusion of incisors. The distances from the apex and incisal point of the central incisor to SV reference plane also decreased significantly ($p<0.01$), revealing parallel movement of the incisors. The distance between the cusp tip of the first molar and SV reference plane increased, but this increase was not significant, meaning that the anchorage loss was negligible ($p>0.05$). Remodeling around Point A and retrusion of the incisors caused a decrease in nasolabial angle, but this decrease was statistically insignificant ($p>0.05$) (Table 2 and 3).

DISCUSSION

Angle Class II Division 1 malocclusion is the most frequent form of malocclusion according to the epidemiological surveys (15). One of the treatment approaches to reduce the increased overjet in adult patients is camouflage treatment that consists of the extraction of maxillary first premolars to allow retraction of the anterior segment maintaining the disto-basal jaw relationship (16). Patients who required camouflage treatment were included in our study, and increased overjet was corrected with a combined use of R&T arch wire with mini-screw.

Ricketts et al. (17) defined that canines and four incisors exist on different planes in the space and defended that they should be retracted independently from each other because of this difference. Therefore, in our study, canine distalization was done prior to the retraction of incisors. An R&T arch with 45° palatal torque was preferred in our study. This torque prevents tipping of incisors and forces the teeth to parallel movement. To provide maximum anchorage, mini-screws were placed between the first molar and second premolar, and retraction force was applied on the incisors by using open coil-springs fixed on these screws. Samuels et al. (18) reported that 150 gr and 200 gr closed coil-springs produce more consistent space closure than an elastic module, and the researchers found no significant difference regarding the rates of space closure caused by 150 gr and 200 gr springs. In our study, open coil-spring applying 150 gr force was used.

When the distance from the apex of molars and mesial cusp tip to the SV reference plane was measured, no anchorage loss was observed in the posterior teeth. On the other hand, Dinçer et al. (19) found an anchorage loss with tipping movement of molar teeth during the retraction of upper incisors with both PG spring and open-coil spring systems, despite the use of transpalatal arch in the open-coil spring group. Upadhyay et al. (12) compared micro-screws and conventional anchorage methods during the retraction period of incisors and observed no anchorage loss in the molar region during the retraction with mini-screws. Park et al. (13) and Yao et al. (1) compared mini-screws and conventional methods during the retraction period of incisors and reported superiority of mini-screws over the conventional methods with regard to anchorage loss.

In our study, a statistically significant reduction was observed in SN/1, NA/1, and NA-1 parameters at the end of retraction period of 217±34 days. The height of the right and left vertical arms of the R&T arch was arranged to be in the middle of the root of lateral incisor so that the force passed through the center of resistance of maxillary four incisors. Thus, incisors were forced to bodily movement, which is more difficult and takes more time as compared to tipping movement. Evaluating the distance from the apex and incisive margin of central incisor to SV reference plane, it was detected that the apex and incisive margin moved 8.2 mm and 9.1 mm respectively in the posterior direction, and the movement was nearly parallel. On the other hand, Demir et al. (20), who evaluated the effects of camouflage treatment in patients with Class II Division I malocclusion, reported lingual tipping of upper incisors rather than bodily retraction, depending on the lack of third-order control. Sarıkaya et al. (21) found that maxillary incisors moved 4.5 mm in the lingual direction at the coronal level, 3 mm at the cervical level, and 1.5 mm at the apical level. The type of movement in that study was not pure translation, but rather a controlled tipping. Upadhyay et al. (12) as well used mini-screws as an anchorage during the retraction of incisors and detected that maxillary anterior incisors were retracted primarily by controlled tipping and partly by translation.

The nasolabial angle is made up of both the soft tissue (pronasale) and the cartilagious (columella) partions of the nose, which continues to grow forward, as well the soft tissue of the upper lip. In some studies, there were significant changes in the nasolabial angle resulting from tooth extraction (22, 23). However, this study concurs with the study of Janson et al. (24). Almeida et al. (25) displayed a statistically insignificant nasaolabial angle change. The nasolabial angle did not respond uniformly to the retraction of the upper incisors in this study. This was probably due to the use of different reference planes or difference in soft tissue thickness. This indicates a high number of variables, including differences in soft tissue thickness and tension between individuals. This was probably due to the use of different reference planes or difference in soft tissue thickness.

In our study, retraction of the incisors caused a remodeling around the Point A. The SNA angle decreased at the end of the retraction period revealing that the A-point was located further posterior relative to the anterior cranial base after treatment. This decrease also caused a reduction in the ANB angle. These results concur with the study of Bravo (26) in which patients who had 4 premolar extractions were compared with those who never had a premolar extraction. The results of this study showed that the A-point was retruded by the retrusion of the maxillary incisors. Similar to our study, Vardimon et al. (27) stated that the movement of the root in the posterior direction caused a remodeling at the labial cortical bone.

In the present study, no statistically significant change was observed regarding palatal, occlusal, and mandibular plane angles. Staggers (28), who compared the treatment with and without a first premolar extraction, found statistically insignificant increase in the mandibular plane angle in both groups. Although the retraction of maxillary incisors and remodeling at Point A caused an increase in the nasolabial angle, this increase was not statistically significant in our study. This result is compatible with the results of Conley et al. (29) and Weyrich et al. (30). In the present study, overbite did not change significantly. Although the incisive margin was remarkably retracted, a significant vertical change was not observed. Whereas the results concerning overbite are consistent with the results of the PG retraction group, they are inconsistent in terms of the type of upper-incisor movement in the sagittal plane.

CONCLUSION

The null hypothesis was accepted. The findings of our study are as follows:

1. A combined use of R&T arch wire with mini-screws is an effective method to retract the incisors without the anchorage loss.
2. When the vertical retraction arms of the R&T arch are adjusted between the apex of the lateral incisor and the deepest point of the alveolar bone, the retraction force passes through the center of resistance of four incisors and provides bodily retraction.
3. There are a few limitations to the present study as there is no control group and no different study methods. Further studies using different retraction methods with a control group are needed.

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

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

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - M.A.; Design - Ş.K.; Literature Search - M.D.; Writing Manuscript - M.A.; Other - F.A.S.

Conflict of Interest: No conflict of interest was declared by the authors.

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ORIGINAL ARTICLE

Dentofacial Effects of Fixed Functional Appliances with or without Mini Screw Anchorage in the Treatment of Class II Division I Malocclusion: A Finite Element Analysis

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ABSTRACT

Objective: This study aimed to examine the biomechanical effects of the fixed functional appliances reinforced with miniscrews by finite elements analysis over the cranial and facial bones, temporomandibular joint, and maxillary-mandibular teeth, which are used for the treatment of Class II division 1 malocclusions characterized as mandibular retrognathia.

Methods: Three-dimensional (3-D) models of the cranial, mandibular, and maxillary bones were purchased from a company that produces 3-D models of the bones. Simulations of Forsus, screwed Forsus, Twin-Force and screwed Twin-Force appliances were conducted on the 3 D models. The miniscrew was placed in the inter-radicular area between the upper canine and first upper premolar teeth.

Results: It was observed in the models that the first upper molar tooth was the most affected. The compressive stress was observed in the anterior area of the mandibular condyle neck in the Forsus appliances; however, it was observed in the posterior area of the mandibular condyle neck in Twin-Force appliances.

Conclusion: It was observed that molar distalization and expansion decreases in the functional appliances with the support of miniscrew. The highest tension rates were determined in the areas of condylar and articular discs.

Keywords: Functional treatment, miniscrew, finite element analysis

INTRODUCTION

In the treatment of Class II division 1 malocclusions characterized by mandibular inadequacy, functional and fixed appliances are used that allow forward positioning of the mandibular to stimulate mandibular growth. In contrast to the removable functional appliances, fixed functional appliances provide advantages, such as not requiring patient cooperation, and they can be used along with brackets (1).

Fixed functional appliances are available in rigid, flexible, and semi-rigid models. The Forsus Fatigue Resistance Device (FRD; 3M Unitek Corp, Monrovia, Calif) and Twin-Force Bite Corrector (TFBC; Ortho Organizers Inc., Carlsbad, Calif) are semi-rigid fixed functional appliances and were developed to avoid the ruptures that can occur with flexible fixed functional appliances. Furthermore, rigid fixed functional appliances restrict mouth opening, which has been resolved with the use of semi-rigid fixed functional appliances. Therefore, the FRD and TFBC semi-rigid fixed functional appliances were used in our study. Previous studies using these appliances have reported distal and intrusive movement of the maxillary molars, mesial movement of the mandibular molars, retrusive movement of the maxillary incisors, labial tipping of the mandibular incisors, and skeletal effect with certain amounts (2-10).

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Undesired dental effects also occur along with the desired skeletal effects with the usage of functional appliances. The use of miniscrews has increased in orthodontic practice to control these dental movements (11). Conversely, the functional appliance is not used by placing the miniscrews in the maxillary.

Hypothetically, with the use of FRD and TFBC in patients with normal maxillary and retrusive mandibular, it is possible to decrease the maxillary effect and increase the mandibular effect by increasing the maxillary dental anchorage using a miniscrew. The purpose of our study was to comparatively examine the effects of the FRD and TFBC therapy reinforced with miniscrews and conventional FRD and TFBC therapy over the dentofacial structures using finite elements analysis.

METHODS

This study was approved by the noninvasive clinical research ethics committee of Cumhuriyet University.

Class II division 1 malocclusion characterized by normal maxillary and retrognatic mandibular and the 7-mm overjet have been modeled.

The three-dimensional (3-D) models of the cranial, mandibular, and maxillary bones were purchased from a company (21^{st} Century Solutions Ltd.; Suite 31, Don House, 30-38 Main Street, Gibraltar) that produces the 3-D models of these bones. The models were scanned using a 3-D optic surface scanner by the company, and all data were transferred to the computer (Figure 1). The Sobotta Anatomy Atlas was used and all teeth, periodontal ligaments, sutures (frontomaxillaris, zygomaticomaxillaris, pterigopalatina, zygomaticotemporalis, nasofrontalis, and zygomaticofrontalis), joint discs, and ligaments were modeled using the NX Advanced v10 (Siemens PLM Software, 5800 Granite Parkway, Suite 600, Plano, TX, ABD) software. The tetrahedral model was constructed using the NX Nastran (Siemens PLM Software, 5800 Granite Parkway, Suite 600, Plano, TX, ABD) software, thereby forming the finite elements model of the complete craniofacial structures.

Teeth, cortical bones, and trabecular bones were accepted as homogenous and linear elastic. The 1-mm cortical bone that covers the surface areas of the jaw bones where the teeth were, and beneath this layer was modeled as the trabecular bone. Furthermore, the areas without teeth were modeled as cortical bone (12). Brackets were modeled as the fixed ties and a 0.017×0.025″ stainless steel wire was used as the arc wire.

The Sabotta Anatomy Atlas was used for modeling of the sticking points of joint ligaments to the bone surfaces. The role of discal ligaments is to prevent divergence of the disc and condyle head; hence, discal ligaments were modeled through fixing the distance between some nodes on the disc and condyle head. In case of temporomandibular and capsular ligaments, they were modeled as arc elements by using the sticking points as the base. The auxiliary ligaments that have no effect on the movements of the mandibular were excluded from modeling. The arc rating of these modeled ligaments was adjusted as 272.4 N/m (13).

The appliances were modeled by measuring horizontal and vertical components of the FRD and TFBC using digital calipers (Figure 2, 3). Miniscrews were placed in the interradicular area, between the upper canine and first upper premolar teeth and their positions were 3 mm apically away from the cemento-enamel junction (14). The miniscrews were tied to both the upper lateral and upper first molar teeth in the screwed models. In the simulation of Forsus and screwed Forsus appliances, a two-sided pushing force of 200 gf was applied between the distal of the lower canine tooth and first upper molar tooth. In the simulation of Twin-Force and screwed Twin-Force appliances, a two-sided pushing force of 200 gf was applied to the arc wire between the first upper molar and second upper premolar teeth and to the arc wire between the lower canine tooth and the first lower premolar tooth.

Panigrahi et al. (15) modeled the entire skull and used a total 13590 elements and 18582 nodal points. In our study, the numbers of elements and nodal points were increased compared with previous studies, and the model of the skull was formed using 389,851 elements and 636,198 nodes.

Because our study did not include multiple patient groups, statistical analysis was not performed.

The elastic characteristics of the material were taken from previous studies (Table 1) (16-27). Mega-Pascal unit (MPa) was used to evaluate stress findings. The color scale at the left side of the figure indicates the stress ratings for each figure.

RESULTS

The areas with the minimum principal stresses, which get low negative ratings in the mandibular, were observed in the anterior area of the mandibular condyle neck in the FRD and screwed-FRD models. They were observed however in the posterior area of the mandibular condyle neck in the TFBC and screwed-TFBC models. The dominant type of stress in these areas was found to be compressive. The areas with the maximum principal stresses, which get high positive ratings, were observed in the posterior area of the mandibular condyle neck in the FRD and screwed-FRD models. They were observed however in the anterior area of the mandibular condyle neck in the TFBC and screwed-TFBC models.

Table 1. The physical properties of the materials

	Young's modulus (MPa)	Poisson's ratio
Cortical Bone	13700	0.3
Trabecular Bone	7900	0.3
Teeth	20290	0.3
PDL	7	0.49
Cartilage	0.79	0.49
Articular Disc-Anterior	10	0.4
Articular Disc-İntermediate	10.73	0.4
Articular Disc-Posterior	9	0.4
Sutures	7	0.49
Orthodontic wire	200000	0.3
Miniscrew	105000	0.33
Connective Tissue	0.49	0.49
Ligament	0.49	0.49

In the simulation of the FRD appliance, the compressive stress (-0.767 MPa) occurred in the anterior area of the condylar neck and the tensile stress (0.871 MPa) occurred in the posterior area. Similarly, in the simulation of the screwed-FRD appliance, the compressive stress (-0.787 MPa) occurred in the anterior of condylar neck, and the tensile stress (0.962 MPa) occurred in the posterior area. However, in the simulation of the TFBC appliance compared with the FRD appliance, the tensile stress (8.77 MPa) occurred in the anterior of condylar neck, and the compressive stress (-6.611 MPa) occurred in the posterior area. In the simulation of the screwed-TFBC appliance, the tensile stress (9.07 MPa) occurred in the anterior of the condylar neck, and the compressive stress (-7.577 MPa) occurred in the posterior area.

The areas with the minimum principal stresses, which get low negative ratings in the articular disc, were observed in the anterior area of the surface of the articular disc facing the condyle in the FRD and screwed-FRD models. They were observed however in the posterior area of the disc facing the condyle in TFBC and screwed-TFBC models. The dominant type of stress in these areas is compressive. The areas with the maximum principal stresses, which get high positive ratings, were observed in the posterior area of the disc facing the condyle in the FRD and screwed-FRD models. They were observed however in the anterior area of the disc facing the condyle in the TFBC and screwed-TFBC models. The dominant type of stress in these areas is tensile.

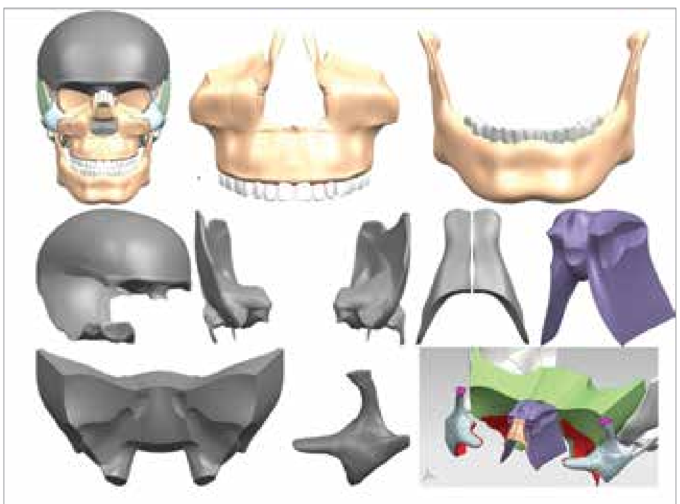

Figure 1. 3-D model of the craniofacial complex (head, maxilla, mandibular, cranium, os temporale, os nasale, os ethmoidale, os sphenoidale, os zygomaticum, sutures)

Figure 2. Model of the FRD and miniscrewed FRD

FRD: fatigue resistance device

Figure 3. Model of the TFBC and miniscrewed TFBC

TFBC: twin-force bite corrector

In the simulations of the FRD and screwed-FRD models, the compressive stress (FRD: -0.190 MPa, screwed-FRD: -0.114 MPa) occurred in the anterior area of the disc facing the condyle, and the tensile stress (FRD: 0.247 MPa, screwed-FRD: 0.135 MPa) occurred in the posterior area. However, in the simulations of the TFBC and screwed-TFBC appliances, compared with the FRD appliance, the tensile stress (TFBC: 1.256 MPa, screwed-TFBC: 1.230 MPa) occurred in the anterior area of the disc facing the condyle, and the compressive stress (TFBC: -1.184 MPa, screwed-TFBC: -1.239 MPa) occurred in the posterior area.

In all the models, the areas with the minimum principal stresses, which get low negative ratings in the maxilla, were observed in the buccal area of the socket of the first upper molar. The dominant type of stress in these areas is compressive. The areas in the FRD, screwed-FRD, TFBC, and screwed-TFBC models with the maximum principal stresses, which get high positive ratings, were observed in the palatinal area of the first upper molar.

It was observed in all the models that the intensities of minimum and maximum principal stresses in the neck areas of the first upper molar were increased. In the screwed models, particularly in the screwed-FRD model, the minimum and maximum principal stresses in the upper lateral teeth were significantly high (Figure 4, 5).

DISCUSSION

In a study by Gupta et al. (27), the highest post mandibular protraction stress was observed in the posterior area and posterio-superior areas of the condyle, and the stress was determined in this area to be tensile. Compressive stress occurred in the anterio-superior areas of the condyle and a resorptive area developed in this region. Similarly, Zhou et al. (25) examined the cartilage structures of the condyle using 3-D finite element analysis (FEM) after the mandibular protraction. After simulation of the mandibular protraction, they reported that tensile stresses occurred in the posterior areas of cartilage surfaces of the condyle. In our study, similar to these two studies, we observed the highest tensile stress in the posterior area of the condyle and the highest compressive stress in the anterior area of the condyle for the FRD and screwed-FRD appliances. We reached different conclusions in the models of TFBC and screwed-TFBC and we this difference is attributed to the appliance's more vertical components and consequently, to the application of more vertical force.

In all the models, the minimum principal stress (FRD: -2.025 MPa, screwed-FRD: -1.627 MPa, TFBC: -1.525 MPa, and screwed-TFBC: -1.074 MPa) in the buccal neck of the first upper molar is more active; hence, the compressive stress is observed in the buccal of the first upper molar teeth. In these models, the maximum principal stress (FRD: 1.749 MPa, screwed-FRD: 1.370 MPa, TFBC: 0.686 MPa, and screwed-TFBC: 0.481 MPa) in the palatinal neck of the first upper molar is more active and hence the tensile stress is observed in the palatinals of the first upper molar teeth. It is

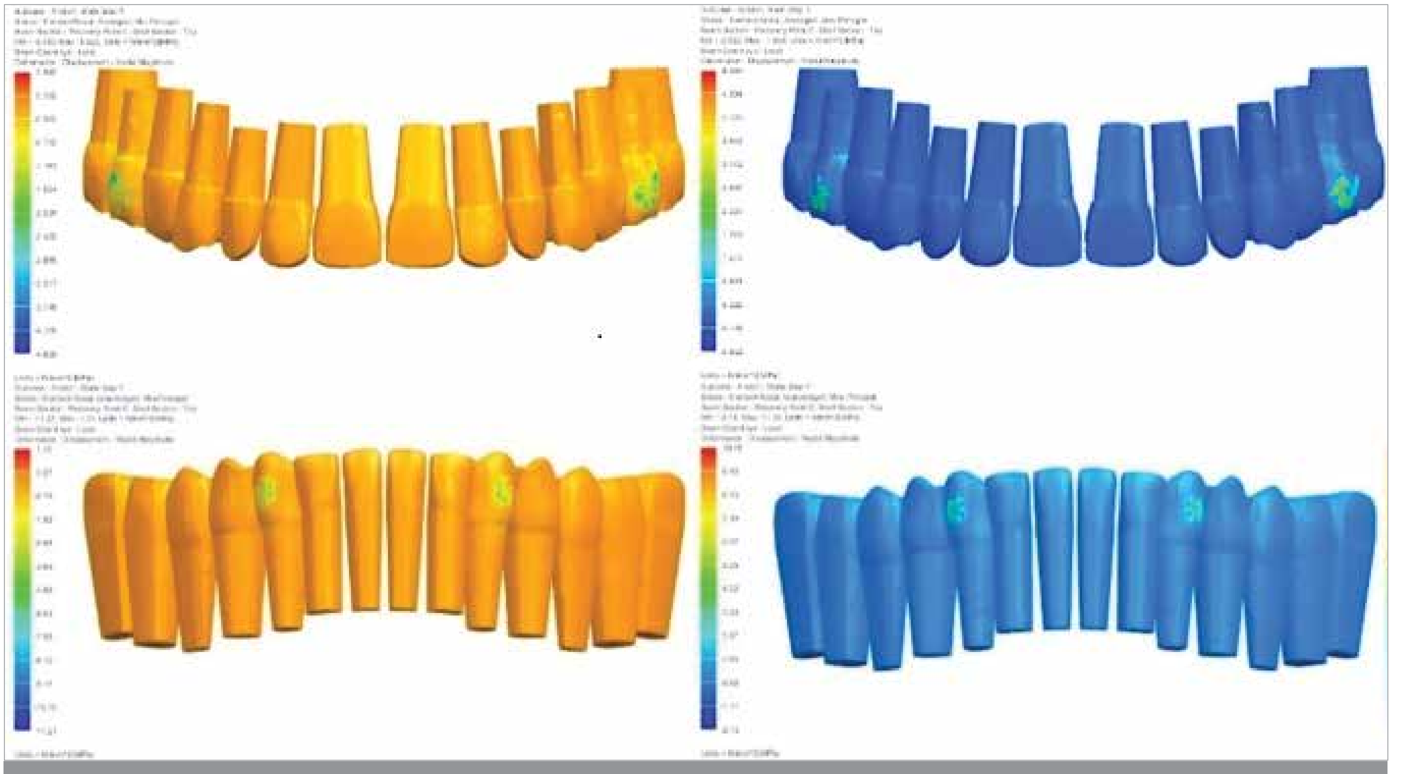

Figure 4. The minimum principal and maximum principal stress ratings of maxillary and mandibular teeth in the model of the FRD appliance (in order of from left to right)

FRD: fatigue resistance device

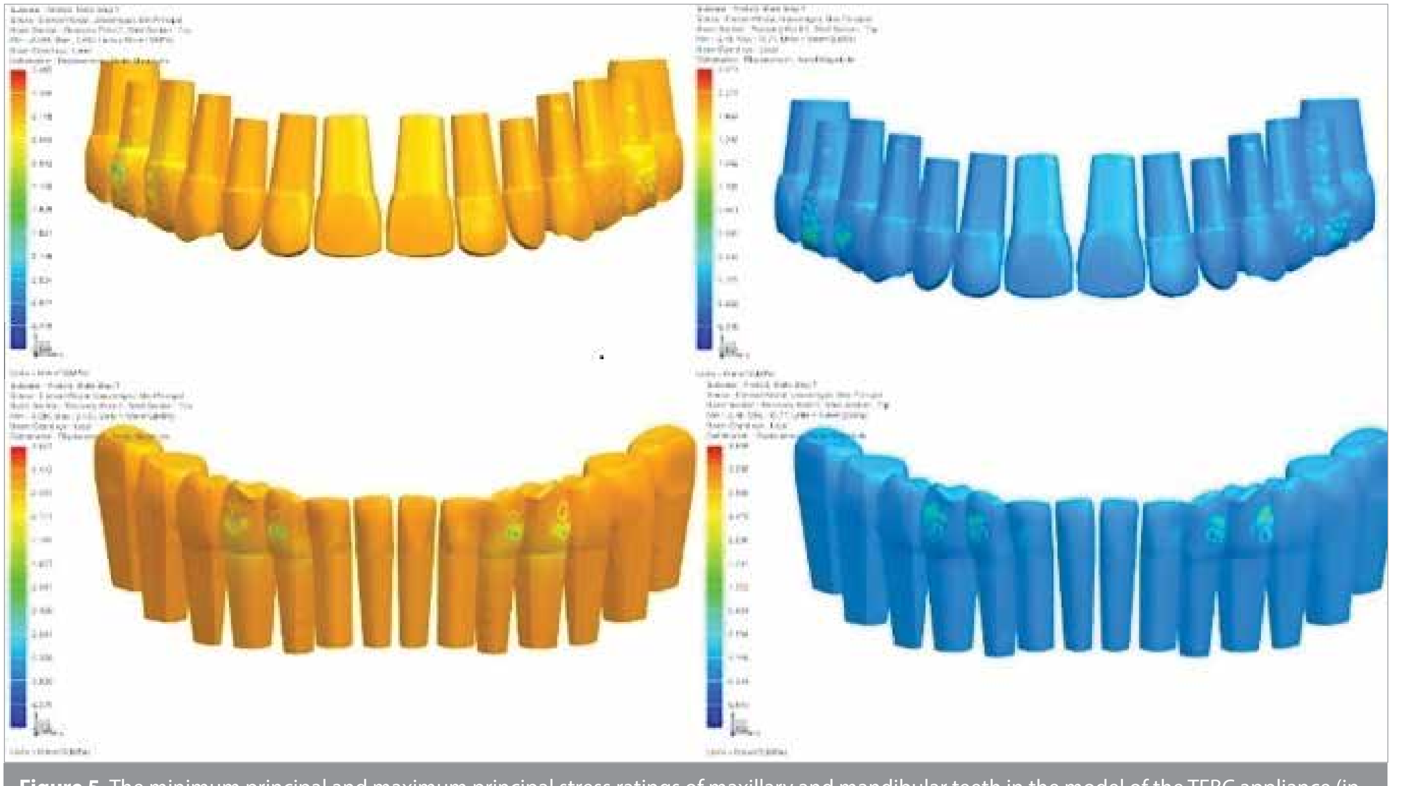

Figure 5. The minimum principal and maximum principal stress ratings of maxillary and mandibular teeth in the model of the TFBC appliance (in order of from left to right)

TFBC: twin-force bite corrector

suggested that these stresses occur in the neck area of the first upper molar due to the expansive force applied to the tooth by appliances. According to the principal stress ratings, the FRD appliance has more expansive effect than the TFBC appliance. Furthermore, the FRD appliance has a more expansive effect than the screwed-FRD appliance, and the TFBC appliance has more expansive effect than the screwed-TFBC appliance. According to these results, it is suggested that the support of miniscrews decreases the undesired expansive effect that occurs on the first upper molar tooth.

In all the models, the minimum principal stress (FRD: -1.594 MPa, screwed-FRD: -1.043 MPa, TFBC: -0.852MPa, screwed-TFBC: -0.570 MPa) in the distal neck of the first upper molar is more active and hence the compressive stress is observed in the distal of the first upper molar teeth. We believe that these stresses on the first upper molar tooth occur due to the distalization force applied by the appliances on the tooth. According to the principal stress ratings, the FRD appliance has more effect than the TFBC appliance, which causes molar distalization. We believe that the reason for this outcome is that the FRD appliance applies a primarily horizontal and direct force on the first upper molar tooth and the TFBC appliance applies a primarily vertical force on the arc wire. Furthermore, the FRD appliance causes greater distalization than the screwed-FRD appliance, and TFBC appliance has more effect to cause distalization than the screwed-TFBC appliance. According to these results, it is suggested that the support of miniscrews decreases the undesired distalization that occurs on the first upper molar tooth.

In all models, the minimum principal stress (FRD: -0.79 MPa, screwed-FRD: -0.90 MPa, TFBC: -1.162 MPa, and screwed-TFBC: -1.487 MPa) is more effective in the buccal neck of the lower canine and hence the compressive stress is observed in the buccal neck of the canine teeth. This compressive stress occurs in the lower canine teeth because of the force resulting in the protrusion of the lower incisors. According to the data, maximum protrusion of lower incisors is observed in the screwed-TFBC model, minimum protrusion of the lower incisors are observed in the FRD model, and the TFBC appliance causes more protrusion of the lower incisors than the FRD appliance. This result is considered to occur because the molar distalization is less with the TFBC appliance. Unscrewed appliances cause less protrusion of the lower incisors than the screwed appliances. This result is considered to have occurred because the anchorage rating has increased in the maxillary teeth due to the miniscrews.

In a clinical study, Aslan et al. (28) compared the FRD and screwed-FRD appliances. They placed miniscrews between the lower canine and the first lower premolar teeth and secured the miniscrew into the lower canine tooth. The first upper molar distalization of 1.45 mm was observed with the FRD appliance; however, the first upper molar distalization of approximately 2.11 mm was observed in the screwed-FRD appliance. In this study, the anchorage of the mandibular dental arc increased and the molar distalization observed in the screwed-FRD appliance was more than the FRD appliance. Although the mandibulary anchorage was observed to be increased in the study by Aslan et al., the maxillary anchorage was increased in our study and in the screwed models; the upper molar distalization is increased in the study by Aslan et al. (28), whereas protrusion of the lower incisors was increased in our study. The result of this study was consistent with our findings.

It is determined that screwed Forsus and screwed Twin-Force appliances can be used to prevent unwanted molar distalization and expansion of the upper molars, but precautions should be taken for lower incisor protrusions. Our study showed that miniscrews can be inserted into the mandible to prevent lower incisors protrusion.

CONCLUSION

- The FRD appliance has more expansive effect on the upper molar area than the TFBC appliance. Furthermore, unscrewed models have more expansive effect than the screwed models. Based on these conclusions, the undesired expansive effect on the first upper molar tooth can be decreased through miniscrew support.
- High stress ratings were observed in the condyle neck.
- In the fixed functional appliances, the miniscrew support can decrease the maxillary dental effect and increase the mandibular effect.

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

Informed Consent: N/A.

Peer-review: Externally peer-reviewed.

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Conflict of Interest: No conflict of interest was declared by the authors.

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ORIGINAL ARTICLE

Assessment of Gingival Biotype and Keratinized Gingival Width of Maxillary Anterior Region in Individuals with Different Types of Malocclusion

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ABSTRACT

Objective: The aim of the present study is to evaluate the relationship of gingival thickness and width of keratinized gingiva with different malocclusion groups and amount of crowding.

Methods: A total of 181 periodontally healthy subjects were enrolled in the present study. The study participants were divided into three malocclusion groups: Angle Class I, Angle Class II, and Angle Class III. Each group was divided into subgroups according to the amount of dental crowding, namely mild, moderate, and severe. The width of keratinized gingiva was calculated as the distance between mucogingival junction and free gingival margin, whereas gingival thickness was determined by a transgingival probing technique.

Results: Tooth numbers 13 and 23 were observed to have thin gingival biotype. The width of keratinized gingiva for tooth numbers 13 and 23 was narrower in the severe crowding group than in the moderate and mild crowding groups. The relationship of gingival thickness and width of keratinized gingiva with Angle classification was not found to be significant.

Conclusion: Although it is thought that there is a relationship between gingival thickness, width of keratinized gingiva, and Angle classification with regard to malaligned teeth, this cross-sectional evaluation of 181 patients failed to show a significant relationship.

Keywords: Malocclusion, crowding, gingival biotype, transgingival probing

INTRODUCTION

Some researchers consider the position of the upper incisors as a fundamental parameter during orthodontic diagnosis and treatment planning (1). Since the upper incisors support the upper lip and affect the vertical lip thickness, the correct position of these teeth is very important esthetically (2). Vertical positioning of the upper incisors is sufficient to permit the exposure of the incisal edge 4-5 mm beneath the upper lip. Horizontally, several clinical and cephalometric parameters, such as nasal projection, upper lip support, and thickness and angulation of the upper lip, should be taken into consideration for positioning the upper incisors (2, 3).

Anteroposterior tooth movements, for positioning the upper incisor, made in the anatomical limits of the alveolar bone by controlled orthodontic forces do not cause any pathological problems (4). However, dehiscence and fenestrations are observed as a result of tooth movements exceeding the anatomical limits of the alveolar bone. Such tooth movements enhance susceptibility to gingival recession particularly in individuals with thin gingival biotype due to the gingiva losing its alveolar bone support (4, 5).

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'Gingival biotype' is a term used to define buccolingual thickness of the gingiva (6). Gingival thickness, which is determined by the shape and size of the dental root and contour of the alveolar bone, is classified into two types: thin and thick (6, 7). The thin biotype is identified as gingival thickness <1 mm, whereas the thick biotype is identified as gingival thickness ≥1 mm (8).

The width of keratinized gingiva is one of the other factors that need to be evaluated in order not to encounter any periodontal problems during orthodontic treatment (9, 10). The width of keratinized gingiva, which has been recommended to be at least 2 mm to maintain periodontal health, could be increased by mucogingival surgical procedures such as free gingival grafts, coronal advancement flaps, subepithelial connective tissue grafts, acellular dermal grafts, and enamel matrix proteins in cases with narrow keratinized gingiva (4, 10).

The present study aims to investigate the relationship of gingival thickness, which is considered to be a significant risk factor for periodontal problems that may be observed in the maxillary anterior region due to orthodontic tooth movements, and width of keratinized gingiva with different malocclusion groups and amount of crowding. The hypothesis was that different malocclusion groups may have a relationship with gingival thickness and keratinized gingival width of the maxillary anterior region.

METHODS

A total of 181 subjects aged 11-28 years, who presented to Yüzüncü Yıl University Faculty of Dentistry, Department of Orthodontics, were enrolled in the study. A total of 118 of the patients in the study group were females (mean age: 17.27±3.96 years) and 63 were males (mean age: 15.82±2.56 years). The study was commenced after obtaining approval from the Yüzüncü Yıl University School of Medicine, Research Ethics Committee (B.30.2.YYU.0.01.00.00/141).

The study group consisted of periodontally healthy subjects, who have not undergone orthodontic treatment before, have completed permanent dentition, and had no congenital anomaly, dental structural disorder, loss of attachment, or a pocket deeper than 4 mm. In addition, informed consent was obtained from all patients.

The participants were divided into three groups: Angle Class I, Angle Class II, and Angle Class III according to dental malocclusion. The mesiobuccal cusp of the maxillary first molar was noted to be occluded with the mesiobuccal groove of the mandibular first molar in Angle Class I malocclusion. Further, the mandibular first molar was distally positioned in Angle Class II malocclusion and mesially positioned in Angle Class III malocclusion relative to the upper first molar (11).

Each Angle classification group was divided into subgroups according to the amount of dental crowding in the maxillary anterior region as mild (0-3 mm), moderate (4-6 mm), and severe (>6 mm) (12). It was determined that there were 71 (39.2%), 80 (44.2%), and 30 (16.6%) patients in the Angle Class I, Class II, and Class III malocclusion groups, respectively. In addition, there were 57 (31.5%), 40 (22.1%), and 84 (46.4%) patients in the mild, moderate, and severe crowding groups, respectively (Table 1).

Figure 1. Transgingival probing with an endodontic file

Figure 2. Measurement points

Plaque index (PI; Silness and Löe, 1964), gingival index (GI; Löe and Silness, 1963), and probing depth (PD) measurements of the periodontal pocket were performed from the mesial and distal surfaces and vestibular and palatinal midpoints of the maxillary anterior teeth. In addition, keratinized gingival widths of the maxillary anterior teeth were determined by the distance between free gingival margin and mucogingival junction. All these measurements were achieved using a periodontal probe (PQW7; Williams, Hu Friedy, Chicago, USA).

For transgingival probing, if necessary, Xylocaine spray (Vemcain 10% Lidocaine) was applied over the examination area to relieve pain. Gingival thickness of each tooth was me asured by piercing the soft tissue perpendicular to the long axis of the tooth using a 10 mm endodontic file with a rubber stopper until the alveolar bone is reached (Figure 1). While in this position, the rubber stopper of the endodontic file was fixed on the soft tissue. After removal, gingival thickness was measured using a digital compass (Mitutoyo Corp., Kanagawa, Japan) with 0.01 mm sensitivity. Gingival thickness of each tooth was measured at the apical from free gingival margin and coronal from mucogingival junction (Figure 2). After the measurements were repeated twice in these regions, gingival thickness of each tooth was determined by the arithmetic mean of these four measurements. If the gingival thickness was <1 mm, the gingiva was classified as thin biotype; if it was >1 mm, the gingiva was classified as thick biotype (8). The distributions of thin and thick gingival biotypes according to gender, Angle classification, and amount of crowding were evaluated in the present study.

All measurements were performed by the same researcher (YK). The intra-examiner repeatability of the researcher was analyzed at 20 patients and found to be high (Pearson correlation coefficient: 0.895, $p<0.001$).

Statistical Analysis

Power analysis was performed, and sample size was determined according to 80% power value. Descriptive statistics for the considered parameters were presented as mean, standard deviation, and maximum and minimum values. The normality test of data was evaluated using the Kolmogorov–Smirnov test, and the homogeneity was evaluated using the Levene test. After these tests, the distribution of data was observed to be normal, and the variances were homogeneous. Then, factorial variance analysis was performed to determine whether there was a difference according to Angle classification and amount of crowding. Following variance analysis, Duncan's multiple range test was performed to determine the crowding groups and different classes of Angle classification. The relationship of gingival biotype with Angle classification, amount of crowding, and gender was determined using chi-square test. Probability values <5% were considered as significant. Statistical analysis of data was completed using SPSS for Windows version 22.0 (IBM Corp.; Armonk, NY, USA) package software.

RESULTS

No statistically significant difference was found between genders in terms of number and mean age of patient. In addition, there

Table 1. Distribution and percentage of patients

		Amount of crowding		
		Mild	Moderate	Severe
Angle Class I	Count	22	17	32
	% within Angle classification	31%	23.9%	45.1%
	% within crowding amount	38.6%	42.5%	38.1%
	% of total	12.2%	9.4%	17.7%
Angle Class II	Count	24	14	42
	% within Angle classification	30%	17.5%	52.5%
	% within crowding amount	42.1%	35%	50%
	% of total	13.3%	7.7%	23.2%
Angle Class III	Count	11	9	10
	% within Angle classification	36.7%	30%	33.3%
	% within crowding amount	19.3%	22.5%	11.9%
	% of total	6.1%	5.0%	5.5%

p<0.05

Table 2. Distribution of plaque index, gingival index, and probing depth measurements according to Angle classification and crowding amount

		Mild crowding	Moderate crowding			
Mean±SD	Mean±SD	Mean±SD	Mean±SD	Severe crowding	Total	p*
Plaque index	Angle Class I	1.20±0.34	1.08±0.11	1.14±0.20	1.14±0.24	0.334
	Angle Class II	1.18±0.23	1.06±0.12	1.13±0.12	1.11±0.16	
	Angle Class III	1.17±0.12	1.12±0.28	1.15±0.29	1.17±0.26	
	Total	1.18±0.26	1.08±0.18	1.14±0.19	1.13±0.21	
Gingival index	Angle Class I	0.38±0.48	0.41±0.50	0.40±0.47	0.39±0.48	0.634
	Angle Class II	0.39±0.51	0.39±0.67	0.38±0.42	0.38±0.49	
	Angle Class III	0.37±0.29	0.38±0.09	0.40±0.47	0.38±0.35	
	Total	0.38±0.46	0.39±0.53	0.39±0.44	0.35±0.47	
Probing depth	Angle Class I	1.89±0.53	1.60±0.63	1.77±0.55	1.75±0.56	0.086
	Angle Class II	1.86±0.40	1.78±0.68	1.87±0.35	1.82±0.44	
	Angle Class III	1.89±0.35	1.87±0.16	1.96±0.35	1.91±0.30	
	Total	1.87±0.45	1.75±0.58	1.84±0.44	1.79±0.48	

SD: standard deviation
*Two-way (factorial) ANOVA (interaction is not statistically significant)

Table 3. Distribution and percentage of gingival biotype according to Angle classification, amount of crowding, and gender

		Gingival biotype		
		Thick	Thin	p
Angle Class I	Count	50	21	0.895
	% of total	27.6%	11.6%	
Angle Class II	Count	57	23	0.895
	% of total	31.5%	12.7%	
Angle Class III	Count	20	10	0.895
	% of total	11%	5.5%	
Mild crowding	Count	39	18	0.794
	% of total	21.5%	9.9%	
Moderate crowding	Count	27	13	0.794
	% of total	14.9%	7.2%	
Severe crowding	Count	61	23	0.794
	% of total	33.7%	12.7%	
Females	Count	78	40	0.102
	% of total	66.1%	33.9%	
Males	Count	49	14	0.102
	% of total	77.8%	22.2%	
Total	Count	127	54	
	% of total	70.2%	29.8%	

p<0.05

was no statistically significant difference in terms of number of patients between Angle classification and amount of crowding groups (Table 1).

PI, GI, and PD measurements of patients and distribution of these parameters according to Angle classification and amount of crowding are shown in Table 2. No statistically significant difference was found between the groups.

Distribution of the patients with thin and thick gingival biotypes according to Angle classification, amount of crowding, and gender is shown in Table 3. The prevalence of thin gingival biotype was 29.8%. Although thin biotype was more common in the Angle Class II malocclusion group, severe crowding group, and females, the difference was not statistically significant (p<0.05).

The keratinized gingival width and gingival thickness of the maxillary anterior teeth according to Angle classification and amount of crowding are shown in Tables 4 and 5, respectively. The width of keratinized gingiva of tooth numbers 13 and 23 was determined to be narrower in the severe crowding group than in the mild and moderate crowding groups. The relationship between the width of keratinized gingiva and Angle classification was not found to be statistically significant.

Table 4. WKG of maxillary anterior teeth according to Angle classification and amount of crowding

		Mild crowding	Moderate crowding	Severe crowding	Total
	Angle classification	Mean±SD	Mean±SD	Mean±SD	Mean±SD
WKG of tooth number 11	Angle Class I	5.20±1.71	5.22±1.47	4.70±1.88	4.98±1.74
	Angle Class II	4.94±1.41	5.43±1.83	4.74±1.18	4.92±1.39
	Angle Class III	4.18±0.98	5.00±2.24	4.90±1.37	4.67±1.56
	Total	4.89±1.49	5.24±1.75	4.75±1.49	4.90±1.56
WKG of tooth number 12	Angle Class I	7.41±2.56	7.06±1.48	7.28±2.02	7.27±2.08
	Angle Class II	7.23±1.96	7.79±1.85	6.93±1.95	7.17±1.94
	Angle Class III	5.91±2.34	6.56±3.09	6.80±2.20	6.40±2.49
	Total	7.04±2.31	7.21±2.07	7.05±1.99	7.08±2.10
WKG of tooth number 13	Angle Class I	5.05±1.81	3.72±1.62	3.28±2.45	3.94±2.21
	Angle Class II	5.06±2.13	4.54±1.93	3.44±2.00	4.13±2.14
	Angle Class III	3.14±1.47	3.72±2.93	2.70±1.48	3.17±1.99
	Total	4.68A±2.02	4.01AB±2.07	3.29B±2.12	3.89±2.15
WKG of tooth number 21	Angle Class I	4.89±1.68	4.84±1.06	4.70±1.47	4.79±1.44
	Angle Class II	4.83±1.58	5.07±1.64	4.56±1.29	4.73±1.44
	Angle Class III	4.23±1.25	5.06±2.40	4.70±1.40	4.63±1.69
	Total	4.74±1.56	4.97±1.61	4.63±1.36	4.74±1.48
WKG of tooth number 22	Angle Class I	7.14±2.10	6.22±1.82	6.56±1.90	6.66±1.95
	Angle Class II	6.90±1.78	7.71±1.94	6.51±2.01	6.84±1.96
	Angle Class III	6.00±2.14	6.17±2.83	7.10±2.28	6.42±2.38
	Total	6.82±1.99	6.74±2.19	6.60±1.99	6.70±2.02
WKG of tooth number 23	Angle Class I	5.25±2.78	4.25±1.85	3.50±2.21	4.22±2.43
	Angle Class II	5.00±2.38	4.21±2.15	3.38±1.87	4.02±2.18
	Angle Class III	3.82±2.04	4.17±2.21	2.80±1.34	3.58±1.92
	Total	4.87A±2.50	4.22A±1.99	3.36B±1.95	4.03±2.24

WKG: width of keratinized gingiva; SD: standard deviation
Two-way (factorial) ANOVA (interaction was not statistically significant)
A and B: Statistically significant difference between amount of crowding (p<0.05)
a, b, c: Statistically significant difference between Angle classification (p<0.05)

Table 5. GT of maxillary anterior teeth according to Angle classification and amount of crowding

		Mild crowding	Moderate crowding	Severe crowding	Total
	Angle classification	**Mean±SD**	**Mean±SD**	**Mean±SD**	**Mean±SD**
GT of tooth number 11	Angle Class I	1.16±0.27	1.22±0.24	1.21±0.24	1.20±0.25
	Angle Class II	1.28±0.30	1.30±0.43	1.22±0.27	1.25±0.31
	Angle Class III	1.12±0.17	1.11±0.20	1.48±0.22	1.24±0.26
	Total	1.20±0.27	1.22±0.32	1.25±0.26	1.23±0.34
GT of tooth number 12	Angle Class I	1.00±0.37	1.13±0.40	1.39±0.53	1.21±0.49
	Angle Class II	1.01±0.28	1.19±0.47	1.38±0.49	1.23±0.46
	Angle Class III	1.11±0.36	1.21±0.39	1.60±0.53	1.30±0.47
	Total	1.02B±0.33	1.17B±0.42	1.41A±0.51	1.24±0.55
GT of tooth number 13	Angle Class I	0.94±0.23	0.88±0.26	0.83±0.26	0.88±0.26
	Angle Class II	0.96±0.22	0.99±0.17	0.83±0.29	0.89±0.26
	Angle Class III	0.86±0.28	0.78±0.33	0.94±0.25	0.86±0.29
	Total	0.93±0.25	0.90±0.26	0.84±0.28	0.88±0.30
GT of tooth number 21	Angle Class I	1.27±0.40	1.19±0.27	1.21±0.26	1.22±0.32
	Angle Class II	1.35±0.35	1.18±0.27	1.24±0.28	1.27±0.31
	Angle Class III	1.17±0.27	1.13±0.43	1.43±0.27	1.25±0.33
	Total	1.27±0.36	1.17±0.31	1.26±0.28	1.25±0.32
GT of tooth number 22	Angle Class I	1.10±0.45	1.11±0.50	1.33±0.46	1.20±0.47
	Angle Class II	1.14±0.40	1.27±0.47	1.45±0.64	1.33±0.56
	Angle Class III	1.15±0.48	1.16±0.49	1.60±0.55	1.30±0.54
	Total	1.13B±0.43	1.18B±0.49	1.25A±0.23	1.23±0.53
GT of tooth number 23	Angle Class I	0.92±0.33	0.89±0.26	0.81±0.26	0.86ab±0.28
	Angle Class II	0.98±0.32	1.01±0.33	0.88±0.32	0.93a±0.32
	Angle Class III	0.83±0.21	0.77±0.24	0.81±0.33	0.81b±0.25
	Total	0.93±0.31	0.90±0.30	0.84±0.29	0.88±0.30

GT: gingival thickness; SD: standard deviation.
Two-way (factorial) ANOVA (interaction is not statistically significant)
A and B: Statistically significant difference between amount of crowding ($p<0.05$)
a and b: Statistically significant difference between Angle classification ($p<0.05$)

When the gingival thickness of the maxillary anterior teeth was evaluated, only tooth numbers 13 and 23 were observed to have thin biotype, and that gingival thickness of tooth number 23 was higher in the Angle Class II group than in the Angle Class I and Angle Class III groups. However, not only the difference between Angle Class I and Angle Class II groups but also the difference between Angle Class I and Angle Class III groups was not found to be statistically significant. Gingival thickness of tooth numbers 12 and 22 with thick biotype was higher in the severe crowding group than in the mild and moderate crowding groups.

DISCUSSION

Careful evaluation of the periodontal tissues of the subjects is of critical importance in order not to be faced with pathological conditions such as gingival recession in cases undergoing protrusion of the incisors. While determining the amount of protrusion in such cases, biological factors such as biotype and quality of periodontal tissues in the relevant region should also be taken into account together with the width of keratinized gingiva (4, 13, 14). Wenström et al. (15) and Yared et al. (5) noted that the gingival biotype is more important than these other parameters, which should be evaluated during treatment planning. At this point, the present study aims to evaluate the relationship of the width of keratinized gingiva and gingival thickness of the maxillary anterior teeth that are prone to periodontal problems, with different malocclusion groups and amount of crowding.

The literature review demonstrated that visual assessment, ultrasonic devices, cone beam computed tomography, periodontal probe, and transgingival probing techniques have been used in determining gingival thickness (6, 12, 16-22). It has been observed that visual assessment, which is a simple method, is not reliable as clinical experience is an important issue and thin biotype cannot always be identified correctly (12, 17). Furthermore, small changes cannot be detected correctly by the measurements performed by ultrasonographic devices, which yield more reliable and repeatable assessments (18, 19). It is observed that cone beam computed tomography provides the closest results to reality, but is not preferred owing to the potential side effects of radiation in routine clinical practice (20).

Today, periodontal probing and transgingival probing are generally preferred in determining gingival biotype. Kan et al. (12) in their study in which they compared the reliability of visual assessment, periodontal probing, and transgingival probing techniques in determining gingival thickness of the maxillary anterior teeth determined similar and reliable outcomes with periodontal probing and transgingival probing techniques. However, Alkan et al. (23) compared the transgingival probing and periodontal probing in 2184 maxillary and mandibular anterior teeth and concluded that although similar results were obtained with both techniques for the teeth with thick biotype and teeth with gingival thickness <0.8 mm, the coherence was lower between two techniques for the teeth with gingival thickness of 0.8-1 mm. Further, Greenberg et al. (21) compared transgingival probing and surgical flap procedure in measuring gingival thickness and concluded that there was no significant difference between these two techniques, but transgingival probing technique was less traumatic. In the present study, we preferred transgingival probing technique, which allows assessment of gingival thickness from two points in millimeters.

Some studies, which investigated the relationship of gingival biotype with different malocclusion groups and amount of anterior crowding, took the central teeth as the reference in determining gingival biotype of the subject (6, 24). However, Wennström (8) and Hirschfeld (25) reported that gingival thickness may change depending on the position of the teeth in the dental arch. For this reason, the present study evaluated the relationship of gingival thickness of each maxillary anterior tooth with different malocclusion groups and amount of crowding.

Gingival thickness is reportedly influenced by the changes in the location of the teeth during the eruption period, and that it decreases with increasing age as the connective tissue becomes denser, cell count decreases, epithelium becomes thinner, and keratinization increases (22, 26). Ramesh et al. (27), in their study in which they investigated the relationship between gingival thickness and age, allocated the subjects aged between 14 and 29 years to the young-age group and the subjects aged between 30 and 59 years to the advanced-age group. For this reason, the present study group consisted of subjects aged <29 years who had all permanent teeth erupted for gingival thickness to be less influenced by age-related changes.

Studies evaluating the relationship of gingival biotype with gender reported that gingival thickness is lower in females than in males (6, 22, 27). In the present study, it was also observed that thin gingival biotype was more common in 11.7% of females than males, with the difference being not statistically significant.

In the literature, there are different opinions on keratinized gingival width that would maintain periodontal health during orthodontic treatment. Lang and Löe (10) and Yared et al. (5) reported that keratinized gingival width <2 mm would be insufficient to maintain periodontal health, whereas Coatoam et al. (28) noted that keratinized gingival width <2 mm would be sufficient in the subjects with good oral hygiene. Wennström et al. (15) reported that whether the attached gingiva is sufficient cannot be determined by measuring only the width of keratinized gingiva, but that the gingival thickness should be measured as well. In the present study, keratinized gingival width of the maxillary anterior teeth was found between 3.29±2.12 mm and 7.21±2.07 mm. With regard to the relationship with different malocclusion groups and amount of crowding, it was determined that only the keratinized gingival widths of tooth numbers 13 and 23 were smaller in the severe crowding group than in the mild and moderate crowding groups. The relationship with Angle classification was not found to be statistically significant.

When the gingival thickness of the maxillary anterior teeth was evaluated, it was found that gingival thickness of the canine teeth was lower than that of the central and lateral teeth, which is consistent with the results of the studies conducted by Younes et al. (29) and Müller et al. (30) Since permanent canine tooth germs, which are localized in the same direction with the roots of deciduous canine teeth, show vestibular eruption when there is no adequate space in the dental arch, it is known that these teeth have less alveolar bone, narrow keratinized gingiva, and lower gingival thickness (8, 25, 31, 32).

The literature contains a limited number of studies evaluating the relationship of gingival biotype with the amount of crowding. Among these studies, Zawawi and Al-Zahrani (24) reported that there was no significant relationship between the amount of crowding and gingival thickness in the maxillary anterior region. Kaya et al. (33) observed that when the crowding increases in the mandibular anterior jaw, the gingival thicknesses of the mandibular incisors increased, whereas the gingival thicknesses of the canines decreased. In the present study, it was also observed that gingival thicknesses of tooth numbers 12 and 22 were greater in the severe crowding group than in the mild and moderate crowding groups. This was attributed to the greater amount of alveolar bone, wider keratinized gingiva, and increased gingival thickness due to the eruption of permanent lateral tooth germs, which are localized in the lingual aspect of the lateral deciduous teeth roots, without correcting their positions in the event of crowding (8, 31, 32).

Zawawi et al. (6) investigated the relationship between gingival biotype and Angle classification and reported no statistically significant relationship between them. In the present study, it was observed that gingival biotype of the individuals was determined only from the maxillary central teeth by periodontal probing. Further, Kaya et al. (33) investigated the gingival thickness of the mandibular anterior teeth, determined by transgingival probing, with different malocclusion groups. It was concluded that the mandibular anterior teeth have thin gingival biotype, and there was no association between Angle classification and mean gingival thickness of the mandibular anterior region. Since the gingival thicknesses of the upper and lower jaws may vary, the relationship between gingival thicknesses of the maxillary anterior teeth, determined by transgingival probing, with different malocclusion groups was evaluated in the present study. No statistically significant relationship was found between Angle classification and gingival thickness excluding tooth number 23. Gingival thickness of tooth number 23 was found to be higher in the Angle Class II group than in the Angle Class I and Angle Class III groups. However, neither the difference between Angle Class I and Angle Class II groups nor the difference between Angle Class I and Angle Class III groups was found to be statistically significant. Even so, teeth movement in this region should be done within the anatomical limits of the alveolar bone with controlled orthodontic forces. When incisor protrusion is planned, it is necessary to increase the gingival thickness with mucogingival surgical methods (13).

CONCLUSION

- No relationship was determined between Angle classification and gingival thickness and keratinized gingival width.
- The width of keratinized gingiva of the maxillary anterior teeth was determined to be wider than 2 mm, which was considered necessary for the maintenance of periodontal health.
- The width of keratinized gingiva of the maxillary canine teeth was determined to be smaller in the severe crowding group than in the mild and moderate crowding groups.
- The maxillary canine teeth were observed to have thin gingival biotype in all groups.
- Gingival thickness of the maxillary lateral incisors was determined to be higher in the severe crowding group than in the mild and moderate crowding groups.
- Gingival thickness and keratinized gingival width are observed to have been influenced by the position of the teeth in the dental arch.

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethics Committee of Yüzüncü Yıl University School of Medicine.

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

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REVIEW

Microbial Colonization on Elastomeric Ligatures during Orthodontic Therapeutics: An Overview

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ABSTRACT

The current review focuses on the studies conducted on the colonization of microorganisms on orthodontic ligatures during orthodontic treatment. The fixed orthodontic appliances have long been associated with an increase in plaque accumulation, bacterial colonization, and resultant enamel decalcification. Voluminous research has been carried out on the microbial colonization of even newer orthodontic materials such as elastomeric ligatures with an evidence of variably increased microbial counts during orthodontic treatment. However, conclusive material-based data for minimal microbial colonization to establish acceptance criteria for the use of elastomeric ligatures are hardly available. Thus, there is a need for further studies with dual emphasis on exploring microbial associations based on surface chemistries of different elastomers and their requisite modifications for hampering microbial biofilms to evolve efficacious oral health friendly orthodontic ligatures.

Keywords: Orthodontic ligatures, microbial colonization, biofilm, elastomers

INTRODUCTION

Orthodontic treatment is becoming increasingly popular among adults. It has evolved rapidly over the years with significant advent of newer orthodontic materials. Despite the tremendous advancements in orthodontics, the creation of a favorable substratum for bacterial adherence to orthodontic materials during orthodontic therapy remains an unresolved challenge to the scientific fraternity. The fixed orthodontic appliances have long been associated with an increase in plaque accumulation, bacterial colonization, and resultant enamel decalcification (1-3). These appliances could alter the coronal anatomy of the tooth, thereby leading to an increased number of retentive surfaces and posing a difficulty in controlling the formation and adhesion of plaque (4-9). They might exacerbate preexisting periodontal diseases, cause enamel decalcification, and develop undesirable bacteremia or infections (10). The physiochemical characteristics of the orthodontic appliances are known to determine the effectiveness of the bacterial species in terms of quality and quantity.

Elastomeric ligatures, the components of the fixed appliances that play a crucial role in providing a mechanical connection between the orthodontic arch and the bracket slot that has been developed to speed up ligation procedure have also been found to harbor a number of microorganisms. Researchers have attempted to consistently evaluate the efficacy of these materials. A number of studies have been conducted on these ligatures with respect to their microbial colonization during orthodontic treatment. However, a thorough insight to the current scenario is needed to further plan and execute newer strategies for developing more efficient tools. Thus, the current review attempts to

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highlight the key studies accomplished on different types of elastomeric ligatures and addresses the need for further investigations and comparative interpretations to validate the newer versions of ligatures including colored elastomeric rings for biofilm formation. The findings could be a valuable gateway to evolve materials with minimal or anti-biofilm-forming surface chemistries.

ELASTOMERIC LIGATURES: A BACKGROUND

Elastomers have been quoted as the materials that return to their original configurations. The natural rubber, earlier known as elastomer, had demerits with regard to their water absorption and unfavorable temperature behavior. Earlier, Baker, Case, and Angle advocated the use of rubber; however, its usage increased with the advent of vulcanization by Charles Goodyear in 1839. Later, synthetic rubber polymers made of polyurethane (the thermosetting polymers; -(NH)-(C=O)-O-structural unit) and formed by step reaction polymerization was introduced in the early 1920s due to possible allergic natural rubber latex proteins. The present day elastomeric ligatures are high molecular weight amorphous polymers that exhibit physical properties such as visco-elasticity creep and stress relaxation, and they are manufactured in two basic forms, i.e, cut or injection molded. They are user friendly but tend to deteriorate in the mouth leading to subsequent loss of tooth control. They are said to have a tendency of high level of frictional resistance and are affected by the duration of force and environment (11-16). Elastomers have been the focus of studies pertaining to their force delivery and force degradation (17-21). However, they have also been studied with respect to their microbial colonization on elastomeric ligatures (22-28).

MICROBIAL ADHESION: MECHANISTIC APPROACH

A number of studies citing different mechanistic approaches of microbial adhesion to elastomeric ligatures have been performed. Specific lectin-similar reactions, electrostatic interactions, and Van der Waal's forces have been documented as some of the key factors responsible for the adhesion to the surfaces. A close relationship between microbial colonization and surface free energy, hydrophobicity, and zeta potential of interacting surfaces has also been studies (7, 9, 29). The surfaces with higher free energy have shown a favorable effect on bacterial adhesion (30, 31).

Microbial adhesion in the oral cavity is also influenced by saliva, by masking the overall surface energy of a given material and negating its surface chemistry. It is understood that with surface energies leveled between two materials bacterial adherence would decrease unless receptors for a given bacteria are within the salivary pellicle. The effect of saliva on bacterial adhesion has been reported to be species dependent, based on a binding pattern of the bacterium. Thus, the bacterial composition of the oral cavity along with any factors that could potentially change salivary flow and bacterial concentration is of great importance. The studies have described the increased bacterial counts in saliva during various orthodontic treatments (32-42).

Furthermore, the components of the appliances tend to reduce the physiological mechanism of self-cleansing by the tongue, cheeks, and saliva, thereby leading to increased accumulation of bacterial plaque and the number of retentive sites for the sub layers and cause compression effects damaging the oral mucosa (31). Orthodontic appliances have also been found to increase the stimulated salivary flow rate, buffer capacity, salivary pH, occult blood in saliva, and bacterial levels (43).

Besides, the microbial accumulation due to malocclusion, poor oral hygiene, and a cariogenic diet is compounded by fixed orthodontic appliances, which offer more surface area and mechanical overhangs (9, 31). The introduction of orthodontic appliances increase areas where food debris could collect and increase the number of bacterial niches. Early caries and demineralization along with white spot lesions were often seen in orthodontic patients with poor oral hygiene. It has been evidenced that appliances could aggravate an already compromised situation (1, 2, 44).

MICROBIAL ADHESION: CURRENT PERSPECTIVE

Voluminous research is underway to understand the microbial adhesion and its subsequent effect on the different orthodontic appliances including elastomeric ligatures. In general, the orthodontic appliances have been stated to reduce the efficacy of tooth brushing, reduce the self-clearance by saliva, change the composition of oral flora, and increase the amount of oral biofilm formed and the colonization of oral surfaces by cariogenic and periodontopathogenic bacteria, thereby complicating orthodontic treatment and illustrate the need for oral biofilm control during orthodontic treatment than usual (37). The isolation frequencies of opportunistic bacteria and fungi increase during orthodontic treatment, suggesting the importance of paying special attention to oral hygiene in orthodontic patients to prevent periodontal disease and the aggravation of systemic disease in immune compromised conditions (45). The concentration of the aerobic and anaerobic bacteria had increased during the first 3 months of orthodontic treatment. The oral streptococci and anaerobic bacteria, had also increased in the patients wearing orthodontic appliances (46).

Earlier, it was reported that the ligation with elastomeric rings was associated with increased microbial load compared to ligation using steel wires (31). In another study, stretched elastomers demonstrated a honeycomb pattern of filament detachment corresponding to strained areas. The high protein content of the biofilm organized on the surface of these materials as well as the calcification pattern found were similar to a nonspecific mechanism of film adsorption of biomaterials exposed to body fluids. The results of the study were stated to have clinical implications for the aspects of retraction control through sliding mechanics with the use of elastomeric ligatures, and the potential detrimental effects on dental and periodontal tissues, such as decalcification and gingival inflammation, respectively (38). In a study to assess bacterial plaque accumulation adjacent to orthodontic bracket, it was demonstrated that excess composite around the bracket base is the critical site for plaque accumulation due to its rough surface. However, the method of ligation did not appear to influence the bacterial morphotypes on both composites and enamel surfaces (5).

As a step ahead, the study examined the effect of fluoride-releasing elastomers on the salivary counts of *Streptococcus mutans* and showed a temporary decline in streptococcal counts with the release of fluoride-releasing elastomers (47). Another study on the development of biofilm and *Streptococcus mutans* counts with reference to steel wires and elastomeric rings in orthodontic patients with and without 0.4% stannous fluoride gel led to the conclusion that the topical application of the said gel and the two methods of ligature ties did not prevent dental decalcification, as no significant decline in the streptococcal counts was exhibited in the saliva as well as the biofilm (48). Similarly, a study has quoted the ineffectiveness of fluoridated elastomers in reducing streptococcal or anaerobic bacterial growth in local plaque surrounding an orthodontic bracket after a mean period of 40 days in the mouth (49). Fluoride-releasing elastomeric ligature ties are not advisable to reduce the incidence of enamel decalcification in orthodontic patients as per an *in vivo* study carried out to evaluate the efficacy of fluoride-releasing elastomers in the control of *Streptococcus mutans* levels in the oral cavity (50).

In a bid to compare the efficacy of steel ligatures to elastomeric rings, it was found that the fixed orthodontic appliances are instrumental in creating new retentive sites suitable for colonization of *Streptococcus mutans* and *Lactobacillus* and that teeth ligated with elastomeric rings exhibited slightly greater numbers of microorganisms than teeth ligated with steel ligature wires (40). Elastomeric ligatures have been found to form bacterial plaque on their surface and accumulate greater number of microorganisms on the tooth surface (51). Clinical reports have demonstrated that patients who received orthodontic treatment were more susceptible to enamel white spot formation. Further, no significant difference in *Streptococcus mutans* and *Lactobacillus* counts could be observed on using metallic ligature; however, increased bacterial levels were found with elastomeric ligatures with significant inter-group variation (33). Studies on polymerase chain reaction analysis for the presence of *Porphyromonas gingivalis*, *Tannerella forsythia*, *Actinobacillus actinomycetemcomitans*, *Prevotella intermedia*, and *Prevotella nigrescen,* showed that the elastomeric rings were associated with a higher score for plaque index and bleeding than steel ligatures and concluded that elastomeric rings promoted significant retention of the biofilm with clinical alterations on the plaque index and favored the peridontopathogens with a detrimental effect for the gingival conditions (39). Comparative studies on Super Slick and conventional elastomeric rings showed that the Super Slick type had statistically significant higher *Sreptococcus mutans* contamination than the conventional elastomeric rings. Moreover, scanning electron micrographs exhibited fissures only on the surface of Super Slick elastomeric rings, and the researchers found no clinical evidence that justified the effectiveness of Super Slick elastomers in controlling bacterial biofilm formation during orthodontic therapy (12). An *in situ* pilot study to assess enamel demineralization around orthodontic devices showed an increased pattern of demineralization around brackets ligated with elastomeric rings (52). Brackets ligated with elastomeric rings were found to retain more *Streptococcus mutans* biofilm, whereas this biofilm retention was lesser on steel wire (3). Moreover, the teeth ligated with elastomeric rings exhibited significantly greater number of both aerobic and anaerobic microorganisms compared with those ligated with steel ligatures (53). In another study, the teeth ligated with elastomeric rings; with split mouth technique using Super Slick ties, including TP orthodontics and dumbell ligatures leone on the right side and Aelastixs quick stick ties angulated ties 3M and Aelastixs easy to fit 3M on left side exhibited a greater number of aerobic as well as anaerobic microorganisms (17, 54). It was also observed that the stainless steel ligatures were less prone to adhesion compared with Teflon-coated and elastic ligatures and that the adhesion and growth could be accelerated by saliva (14). A study pointed toward sustained changes in plaque microbiota during orthodontic treatment. The major variation in plaque composition could be seen with self-ligating brackets with an elastomeric ligature (9). Studies also revealed that the fixed orthodontic appliances significantly increased the retention of biofilm regardless of the type of bracket system chosen and that the steel ligature had the least amount of biofilm retention compared to an elastomeric module and self-ligating bracket (21). The presence of fixed appliances influenced the quantity and quality of oral microbiota (26). Further, the plaque accumulation or periodontal problems by slide ligatures, covering the total surface of the bracket were not significantly higher than that by the conventional elastomeric ligatures (55).

Studies have explained differential bacterial adherence to the different orthodontic materials, and the increased level of bacterial adhesion have been attributed to increased incubation time, irrespective of the bacterial strains, and that the effect of saliva coating did not significantly alter the adhesion trend of cariogenic streptococci (24).

MICROBIAL ADHESION: FUTURE PERSPECTIVES

With the constant evolution in orthodontics, orthodontic materials with modified properties, intended to provide efficacious surface bacterial biofilm control are being introduced. A newer version of elastomeric ligature, i.e. Super Slick, TP Orthodontics Incla porte with a covalently bonded metafix coating, which the manufacturers claimed to have decreased bacterial adhesion have been studied with respect to force decay, dimensional change, ligature dimension, and force inter relationship. Few studies have also compared these Super Slick elastomeric ligatures to conventional ligatures with respect to their microbial load (14, 54, 56-58). The presence of Streptococcus mutans and its correlation with colony-forming units in saliva has been reported in biofilms around the elastomeric rings and stainless steel ligatures using scanning electron micrographs (59). Recent studies have shown a progressive increase in the colonization of Streptococcus mutans and Lactobacillus on elastomeric modules during orthodontic treatment (60). Although, there are varying reports on the extent of microbial adherence to Super Slick and conventional ligatures, no uniform conclusive inference could be made yet on a significant difference in microbial colonization of these elastomeric ligatures. Now-a-days, nanotechnology is being explored for the development of materials with a potential for decreased biofilm formation and anticaries properties. Recently, metallic silver nanoparticles using an extract of *Heterotheca inuloides* have been synthesized and their use in coating elastomeric ligatures has demonstrated improved physical properties of these ligatures compared to conventional ligatures. Moreover, this technology is suggested to decrease the incidence of dental enamel demineralization and ensure performance in orthodontic treatment (61).

With the increasing focus on esthetic consciousness, the colored elastomeric rings have also been introduced. However, scientific studies advocating their judicious use with reference to the microbial colonization and its subsequent effect on oral health are still awaited. There seems to be a dearth of the available significant data on these ligatures with respect to microbial adherence, biofilm formation, and their subsequent tendency to deteriorate and develop periodontal infections. Thus, there is a further need to explore the microbial biofilm formation on orthodontic ligatures based on their surface chemistries to re-design conventional and modified elastomeric rings as orthodontic ligation accessories and ascertain their clinical efficacy. Moreover, requisite modifications for hampering microbial biofilms on ligatures need to be explored and executed to evolve efficacious oral health-friendly orthodontic ligatures.

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CASE REPORT

Intraoral Molar Distalization with Intraosseous Mini Screw

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ABSTRACT

The aim of the present study was to evaluate the effects of the miniscrew-supported, modified Hyrax appliance on bilateral distalization of posterior teeth. A 15-year-old girl with Class II malocclusion (end-to-end molar relationships, space deficiency for maxillary canine) underwent orthodontic treatment. The patient rejected tooth extraction. Then, she was treated with the miniscrew-supported, modified Hyrax appliance. An activation of 1 mm per month was planned. Lateral cephalometric views were used to evaluate distal movement. Distalization was successfully achieved at 4 months. No anchorage loss and incisor protrusion were noted. It would be beneficial to choose this appliance for the distalization of maxillary molars in patients with maxillary incisor protrusion, as this appliance does not cause anchorage loss in the upper jaw.

Keywords: Mini distalization, mini screw, anchorage

INTRODUCTION

Class II malocclusion is the most common type of malocclusion encountered in the practice of orthodontics. Class II malocclusion characterized by proclination of the maxilla and/or upper dental arch or retroclination of the mandible and/or lower dental arch or combination of these is a type of malocclusion in which accurate diagnosis and appropriate treatment can yield successful outcomes (1). Distalization of the upper buccal segment is one of the treatment options in cases with dental Class II and skeletal Class I or II malocclusion in which lower dental arch is aligned properly (2). In addition to, when space deficiency is combined with missing or previous extracted teeth and a tendency toward molar Class II relationship, the first choice for providing space and solve the problem is distal movement of posterior teeth.

Extraoral traction, one of the traditional techniques for molar distalization, is often a method to distalize maxillary molar teeth (3). The application of various maxillary distalization appliances has recently shown clinical success. Classical intraoral molar distalization techniques such as Schwartz plaque-type appliances, Wilson distalization arches, coil spring appliances, distal jet, repelling magnets, and pendulum appliances are commonly used (4-7). Herein, we report a female case with class II malocclusion in whom orthodontic treatment was applied and distalization was successfully achieved at 4 months.

CASE PRESENTATION

A 15-year-old female patient presented to our clinic complaining of crowded anterior teeth. Her past medical history was unremarkable. She had facial symmetry and balanced appearance with a slightly convex profile. During intraoral examination, maxillary canine teeth were localized in the vestibule due to space deficiency in the dental

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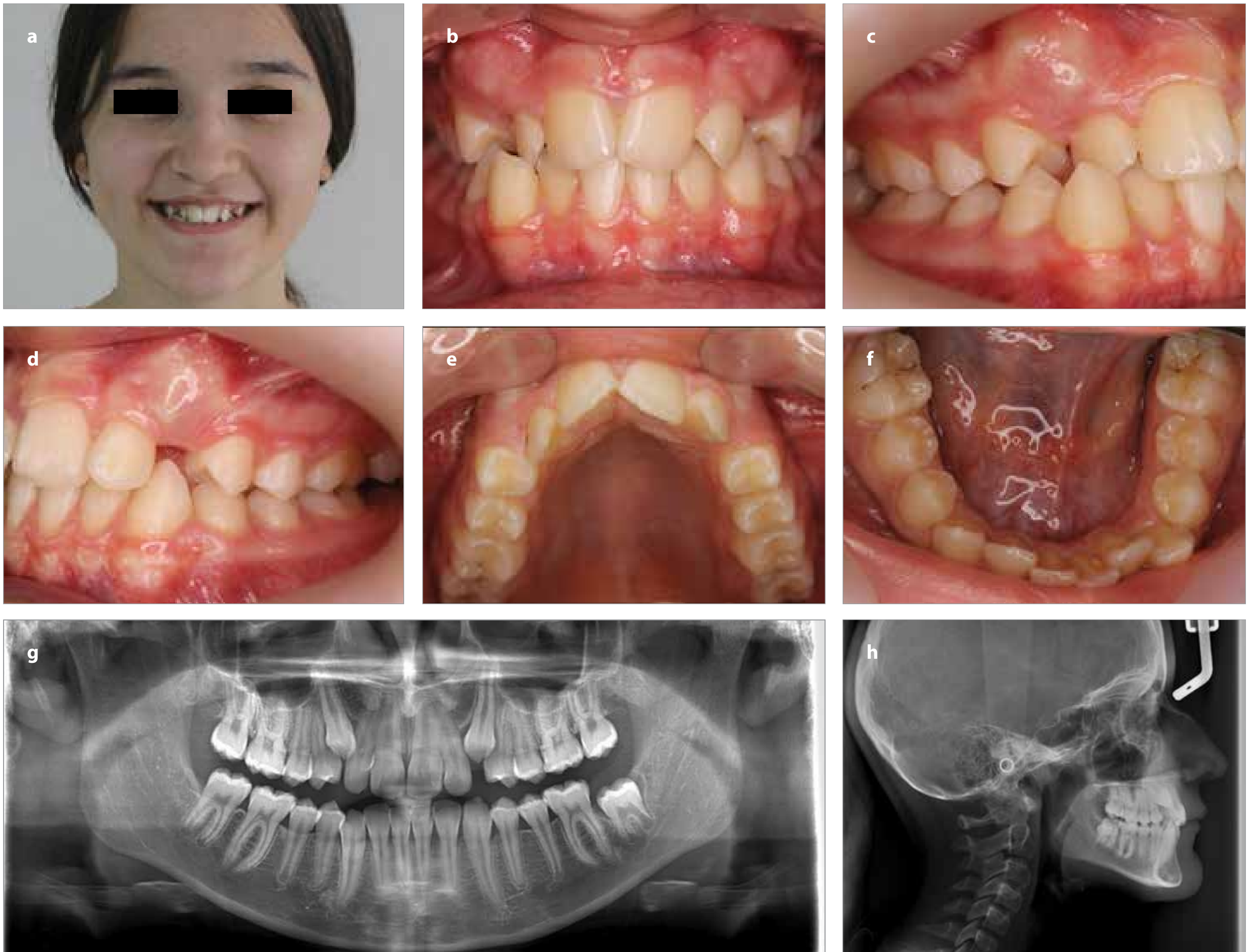

Figure 1. a-h. Pretreatment-intraoral and extraoral photographs, lateral cephalometry, and panoramic radiograph; pretreatment photograpghs of the patients (a); intraoral frontal image (b); intraoral right image (c); intraoral left image (d); intraoral photographs of the patients (e); intraoral photographs of the patients (f); pretreatment panoramic film (g); pretreatment lateral cephalometric film (h)

arch, and with the exception of these teeth, all teeth including second molar teeth erupted. The wisdom teeth were unable to be visualized on panoramic view. There was space deficiency in the maxillary arch and mildly crowded teeth in the mandibular arch (Figure 1). The patient had dental class II relationship. Cephalometric examination revealed no skeletal problems.

The patient was offered two treatment options. The first option involved the extraction of premolar teeth, and the second option involved distalization of maxillary posterior teeth, and the patient accepted the second option.

Treatment Progress

The appliance was designed to produce a distalization force in the upper molar teeth. The placement of two palatal miniscrews (1.7´8 mm^2) (Tomas Anchorage System, Dentaurum, Ispringen, Germany) under local anesthesia was planned to be used as an anchor unit of the appliance. The miniscrews were placed 6 to 8 mm distal to the incisive papilla and 3 mm distant to the midpalatal suture, and orthodontic bands were applied on the first molar teeth.

Laboratory Process

A silicon impression was then taken after application of transfer caps. Laboratory analogues were placed on the transfer caps, the bands were positioned in the impression, and a plaster model was made. Afterward, two standard abutments were screwed on top of the laboratory analogues. Posterior legs of Hyrax were welded to first maxillary molar bands. Anterior legs of Hyrax and two screws were connected by welding anteriorly onto the two abutments. The expansion vector was set anteroposteriorly.

After the maxillary molar teeth are temporarily inserted, the modified Hyrax appliance (Forestadent memory screw, Pforzheim, Germany) was fixed on the mini-implants followed by the final seating on the molars. While screwing the abutment screws, the modified Hyrax was gently pressed onto the mini-implants to facilitate the fixation. This distalization unit, with its two miniscrews and two molar bands, provided stable and 4-point support for the appliance when placed parallel to occlusal plane (Figure 2).

The modified Hyrax appliance (Forestadent memory screw, Pforzheim, Germany) was used for the distalization of maxillary molar teeth. According to the manufacturer, the memory screw delivers a total force of 800 grams in activation of every 1 millimeter. The Hyrax opening rate was 1.0 mm per month.

Lateral cephalometry was used to determine the amount of distal movements. The stability of the appliance, miniscrews, and oral hygiene were evaluated at each one of the monthly appointments. After 4 months, the molars had distalized by 3-4 mm,


Figure 2. The appliance used in the study

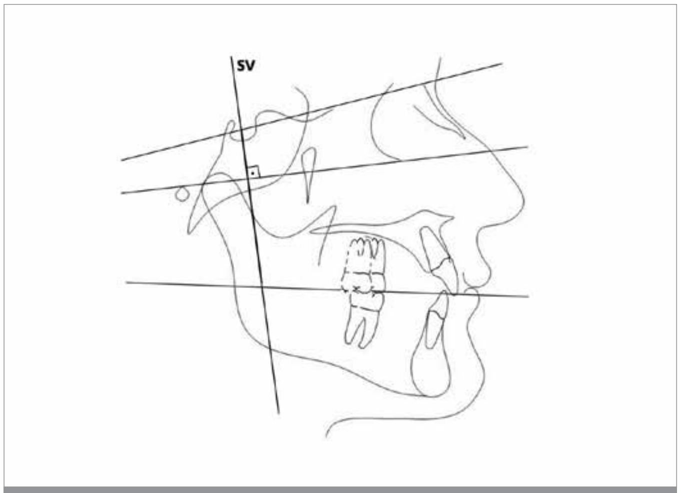

Figure 4. Vertical reference plane perpendicular from S to FH (SV)

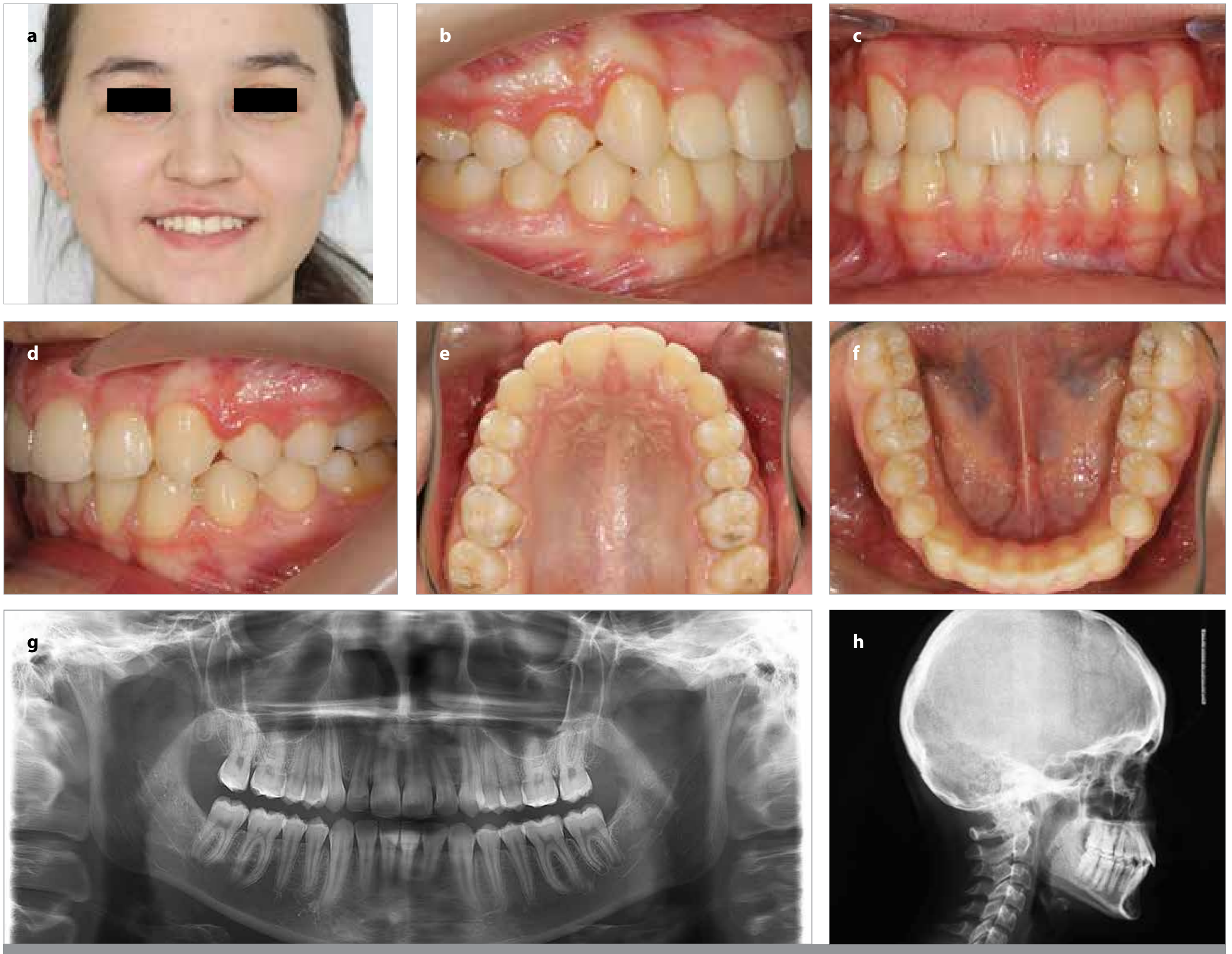

Figure 3. a-h. Posttreatment-intraoral and extraoral photographs, lateral cephalometry, and panoramic radiograph; posttreatment photographs of the patients (a); intraoral frontal image (b); intraoral right image (c); intraoral left image (d); intraoral photographs of the patients (e); intraoral photographs of the patient (f); posttreatment panoramic film (g); posttreatment lateral cephalometric film (h)

Table 1. Cephalometric variables at pretreatment (TO) and post-treatment (T1)

Measurement	Pre treatment (T0)	Post treatment (T1)
SNA(°)	82	82.2
SNB(°)	78.9	80.4
SN-MP (°)	30	30.7
FMA (°)	26.1	27.8
Y angle (°)	59.5	60.9
SV-U1(mm)	70.3	68.7
SV-U6(mm)	42	39.3
SV-U7(mm)	32	28
Over-jet (mm)	3.8	3.4
Over-bite (mm)	1.6	2.2
UL-E (mm)	-6.2	-6.2

SNA: angle between S-N and N-A; SNB: angle between S-N an N-B; SN-MP: angle between SN and mandibular planes; FMA: angle between FH and mandibular planes; Y angle (°): angle between SN to SGn; SV-U1(mm): SV (from sella, perpendicular to Frankfort Horizontal Plane); SV-U6(mm): distance from SV (from sella, perpendicular to Frankfort Horizontal Plane) to U6; SV-U7(mm): distance from SV (from sella, perpendicular to Frankfort Horizontal Plane) to U7v

and class I relationship in molars and premolars was obtained. Post-distal driving extra-intraoral views were seen in Figure 3. Cephalometric analysis was used to evaluate changes of molar position, inclination, and mandibular plane angle (Figure 4). Orthodontic treatment was completed in a 13-month period. Molar teeth were distalized, arch-length was increased at buccal position, and malpositioned canine teeth were placed in the dental arch. Dental class I relationship was established. Cephalometric parameters before and after distalization and after treatment are shown in Table 1. Written informed consent was obtained from patients' parents for the publication of treatment results.

DISCUSSION

In the present case, we evaluated the effects of the miniscrew-supported, modified Hyrax appliance on bilateral distalization of posterior teeth. The aim of the case was to remind clinicians and update information about miniscrew-assisted memory screw unit for distalization of maxillary molars as a noncompliance therapy.

Extraoral appliances such as headgear appliances offer the advantage of stabilizing the anterior teeth, whereas these appliances are associated with patient complaints and distal tipping and extrusion of molar teeth. Furthermore, these appliances may cause psychological problems and neck pain in the patients (2, 8).

The most significant disadvantage associated with classical intraoral distalization techniques is the anchorage loss. These appliances use anterior teeth or palate as the anchorage unit similar to Schwartz plaque-type appliances, Wilson distalization arches and distal jet (3, 4, 6). This results in protrusion of incisors and anchorage loss. The reason is that teeth move in response to the repelling forces (9). To prevent undesired tooth movement, additional measures are often required during to support anchorage teeth when maximum anchorage is needed during orthodontic treatment (10). Thus, many interventions have been performed for the use of tooth implants as an anchorage unit for orthodontic appliances (11). According to many authors, hard palate is an appropriate and temporary anatomic location for the placement of implants (12).

The use of miniscrew-supported appliance in the present study avoided these complications. The rigid arms of the screw did not allow a spontaneous upright position of the molars during the distalization period. The distal tipping of the molar crowns may be disadvantageous for anchorage but, as shown in the present study, the distalization appliance can be used as a retention appliance, and thus any possible anchorage loss can be prevented by leaving the appliance. In this case, the treatment corrected molar class I relationship with distalization of molar teeth in a short period of 4 months and provided space for normal positioning of canine teeth in the dental arch that are thought to erupt in the vestibule without need for further intervention. There are different views regarding distalization speed and therefore treatment time in the presence of second molar teeth. Some authors suggested that distaliziation speed was not affected by the presence of second molar teeth, whereas others reported decreased distalization speed (13, 14). Many studies on distalization of upper molar teeth reported upper molar distalization between 2.5 and 6.4 mm within an approximate duration of 1.5 to 13 months depending in the requirements of the individuals (15). As distalization of molar teeth was achieved in a parallel manner avoiding deviation in our case and second molar teeth had already erupted, the mean distalization time in our case was longer than those reported in the aforementioned studies. Although deviation of molar teeth during distalization seems to be reducing the treatment time, correcting deviated molar teeth would be time consuming and would also cause anchorage loss as mentioned previously.

No complication occurred related to the miniscrews during the distalization process. The most important advantage of the distalization system used in the present study is the lack of need for patient cooperation during the treatment and lack of anchorage loss due to minimum protrusion of the incisors. It would be beneficial to choose this appliance for the distalization of maxillary molars in patients with maxillary incisor protrusion, as this appliance does not cause anchorage loss in the upper jaw.

CONCLUSION

In conclusion, miniscrew-supported, modified Hyrax appliances provide distalization of posterior teeth by reducing the treatment time and avoiding undesired anterior teeth movement. Therefore, as in our case, we suggest that miniscrew-supported intraoral distalization appliances can be used in patients of all ages with angle class II malocclusion in whom the upper first molar teeth have erupted.

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

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - M.A.; Design - F.A.; Supervision - M.A.; Materials - F.A.; Writing Manuscript - M.A.; Other - U.O.

Conflict of Interest: No conflict of interest was declared by the authors.

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Errata

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In the article entitled "Effects of Ozone and Prophylactic Antimicrobial Applications on Shear Bond Strength of Orthodontic Brackets" by Alkan et al. that was published in December 2017 issue of our journal, one of the author's name was written erroneously as Betül Oktay Çöven. The name of the author was corrected as Burcu Oktay Çöven on the online version of the article.

The aforementioned manuscript can be accessed through the following link: http://www.turkjorthod.org/sayilar/92/buyuk/101-1052.pdf

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In the review article by Ayşe Tuba Altuğ, entitled "Presurgical Nasoalveolar Molding of Bilateral Cleft Lip and Palate Infants: An Orthodontist's Point of View" (Turkish J Orthod 2017; 30: 118-25; DOI: 10.5152/TurkJOrthod.2017.17045) that was published in the December 2016 issue of Turkish Journal of Orthodontics, the presence of an error in the "Informed Consent" section has been detected. The error at the end of the manuscript has since been corrected in accordance with the main text.

You may access the corrected PDF file through the following link: http://www.turkjorthod.org/sayilar/92/buyuk/118-1251.pdf