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Original Article

Evaluation of the effects of modified bonded rapid maxillary expansion on occlusal force distribution: A pilot study

Fatma Deniz Uzuner[1], Hande Odabasi[1], Secil Acar[1], Tuba Tortop[1], Nilufer Darendeliler[1]

Correspondence: Dr. Fatma Deniz Uzuner
Email: fduzuner@yahoo.com.tr

[1]Department of Orthodontics, Gazi University Faculty of Dentistry, Ankara, Turkiye

ABSTRACT

Objective: To evaluate the effects of modified bonded rapid maxillary expansion (RME) on occlusal force distribution. **Materials and Methods:** The sample included 12 patients (7 girls and 5 boys; mean age: 13.1 years) at the permanent dentition stage with bilateral posterior cross-bite. The patients were treated with a modified bonded RME appliance, activated twice a day. The study was terminated when the palatal cusps of the maxillary posterior teeth were occluding with the buccal cusps of the mandibular posterior teeth. The postretention period was 3 months. The T-Scan III device was used to analyze the percentages of occlusal force distribution, and records were taken at the pretreatment (T1), the postreatment (T2), and the postretention (T3) periods. Wilcoxon signed rank test was used for statistical analyses. **Results:** Incisors were most frequently without contact, followed by canines. The highest forces were seen in the second and first molar regions. A significant decrease was seen in total occlusal force during treatment (T1–T2); however, during retention, the force returned to its initial value, and no significant differences were found (T1–T3). No differences were found between right and left sides and in occlusal forces of the teeth in all time periods. **Conclusion:** The use of modified bonded RME decreases the total occlusal forces during the treatment period, but it does returns to its initial value after the postretention period.

Key words: Modified bonded rapid maxillary expansion, occlusal force, occlusal force distribution, T-Scan device

INTRODUCTION

Rapid maxillary expansion (RME) is a widely used treatment method to widen the maxillary arch. It operates through moving the right and left maxillary segments apart by opening the mid-palatal suture as well as by buccal tilting of the premolars and molars.[1,2] Many studies have evaluated the effects of RME, with banded and bonded appliances, on craniofacial structures, sutures, and dentoalveolar regions.[1-6] However, they mainly evaluated skeletal changes, dentoalveolar symmetry, dental tipping rates, and root resorption amounts.[1-6]

Clinical and radiographic evaluations are not intended to be adequate to evaluate the results of orthodontic treatment, and thus, the functional aspects of the therapy should also be taken into consideration.[7] The stomatognathic system includes the functional and physiologic entity of the teeth, the occlusal relationships, the periodontal tissues, the temporomandibular articulations, the craniofacial bones, and the neuromuscular system, whose biology and physiopathology are interdependent.[7,8]

Some studies have analyzed the alterations in other structures caused by RME treatment.[7,9-14] The results of these studies showed that RME provided an increase in the nasopharyngeal airway dimensions that facilitate nasal respiration.[13,14] There are few studies that have analyzed the electromyographic (EMG) activities of the masseter and temporalis muscles

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in children treated using RME with a bonded appliance.[7,9] These researchers reported increased activity in anterior temporal and masseter muscles. De Rossi *et al*.[7] indicated that their results do not suggest that RME harms the muscles, but there is a strong change in muscle activity after removing the disjunctive appliance. This is mainly attributed to occlusal instability and lack of musculature adaptation to this new condition of the stomatognathic system.

In addition, Arat *et al*.[11] evaluated the condylar response to RME using bilateral temporomandibular joint (TMJ) magnetic resonance images (MRIs), and observed a condylar response to RME. There were increased signal intensities, shown as bright areas on the MRIs, indicating the red bone marrow edema that is a sign of condylar remodeling. They concluded that the extensive orthopedic and the functional occlusal forces associated with RME also play roles in condylar and ramal responses.

Thus, RME treatment promotes increases in maxillary width and dental arch perimeters, and the new position of the maxilla and the dentition affects both muscles and occlusion.[2,7,10] It is well known that occlusion is an important factor influencing masticatory movement. Children with posterior cross-bites are thought to have irregular, complex chewing cycles, notably different from the pattern of patients with normal occlusion, and similar to those with TMJ dysfunctions. In previous studies, it has been reported that after treatment, chewing cycles generally became more regular and symmetrical, similar to those of normocclusive patients.[15,16]

To our knowledge, there are no previous studies considering the effect of bonded RME on occlusal forces, and thus, our aim in this preliminary study was to evaluate these effects on occlusal force distribution. We hypothesized that correction of the maxillary cross-bite with a modified bonded RME device would affect the occlusal forces while changing the dentoalveolar structure.

MATERIALS AND METHODS

This preliminary study included 12 patients (7 girls and 5 boys) between ages 11 and 15 years (mean age: 13.10 years) consecutively admitted to the orthodontic clinic at Gazi University Faculty of Dentistry.

Patients were in the permanent dentition stage, excluding third molars, and showed bilateral posterior cross-bite of both premolars and molars, with an indication for RME. In all patients, the maxillary buccal cusps occluded in the central fossa of the mandibular teeth. Additional selection criteria were angle Class I (ANB angle: 0–4°) or Class II (ANB angle: >4°); malocclusion with optimal growth pattern (mandibular plane angle: 26–32°);[17] minimum/mild crowding; no periodontal pathology; missing teeth; craniofacial deformation; crowns and great restorations; muscular disease; parafunctional habits (e.g., bruxism); and TMJ dysfunction. We excluded patients who received previous prosthetic and orthodontic treatment.

Written informed consent was obtained from each subject following a detailed explanation of the objectives and protocol of the study. The study was conducted in accordance with the ethical principles stated in the declaration of Helsinki and approved by the Ethics Committee of Gazi University (25901600/7867).

Patients were treated with a modified bonded RME appliance that covered the occlusal surface of the posterior teeth with an acrylic splint [Figure 1]. It was activated twice a day (0.25 mm per activation). When the palatal cusps of the maxillary posterior teeth were occluding with the buccal cusps of the mandibular posterior teeth, the screw was fixated using wire. The average activation time was 14 days, which approximately corresponded to 7 mm of opening of the screw. Same appliance was used for retention purpose. The postretention period was 3 months.

We used the T-Scan® III 5.2 device (Tekscan, Inc., South Boston, MA, USA) to analyze the occlusal force distribution [Figure 2]. The instrument was directly interfaced with a computer that presented the data on a screen during the examination and recorded it for further analysis [Figure 3].

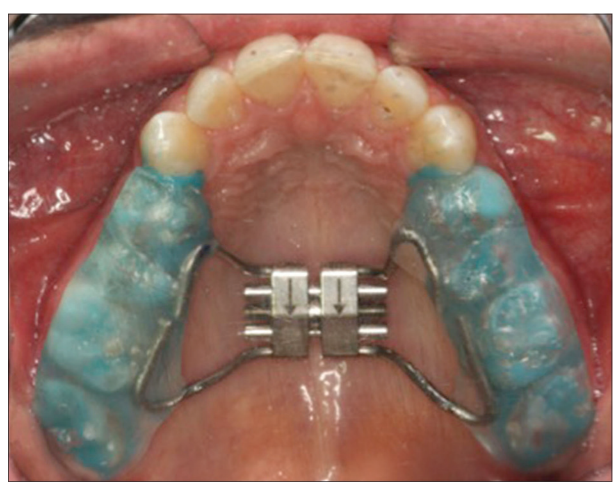

Figure 1: Modified bonded rapid maxillary device

During all examinations; the appliance was removed. Patients were instructed to sit upright on a chair, with their heads unsupported, the Frankfurt horizontal plane parallel to the floor, both feet on the floor, hands resting on the lap, and looking forward. After that, the central incisors' widths were measured using a digital caliper to determine the dental arch dimension. We initiated occlusal evaluation after determining the dental arch dimension and the intra-oral sensor calibration. The sensor was placed in patients' mouths whereas the central line of the sensor's support was aligned with the upper incisors' midline. Patients were instructed to clench the sensor as hard as possible at maximum intercuspidation. When patients bit the sensor, the resultant changes in electric resistance were converted into images on the screen, and we analyzed the value of the maximal voltage obtained in the registration of maximal clenching. The T-Scan III software automatically calculated the distribution of occlusal forces; the bite force data were expressed in percentages.

A single new sensor was used for each child, and all recordings were performed by the same operator (SA). Recordings were repeated twice, and the averages were calculated to use as the final values. Records were taken at the pretreatment (T1), the postreatment (T2), and the postretention (T3) periods.

We evaluated the percentage of occlusal force distribution of (1) the anterior teeth (incisors, laterals and canines); (2) the premolars (first and second premolars); (3) the molars (first and second molars); (4) the posterior teeth (both premolars and molars); and (5) all teeth (anteriors, premolars, and molars). The third molars are not present in the arch model created by the T-Scan, and thus their contacts were not taken into account.

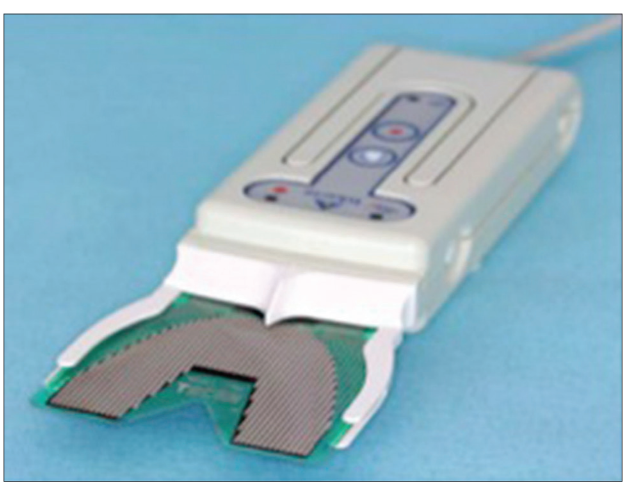

Figure 2: The T-Scan® III handpiece

The data were statistically analyzed by using SPSS 15.0 (SPSS, Inc., Chicago, IL, USA). Wilcoxon signed rank test was used for statistical assessment of the results. A $P < 0.05$ was considered statistically significant.

RESULTS

There were no differences in occlusal force distribution between the right and the left sides in all time periods. A significant decrease was found in the percentage of total occlusal force distribution between the pretreatment and the posttreatment period (T1–T2) (96.8% and 94.8%, respectively) ($P < 0.05$). However, during the retention, the percentage of force distribution increased (95.9%), and no significant differences were found between the pretreatment and the postretention period (T1–T3) [Table 1].

The highest percentage of force was observed in the molar region (71.3%). The central and lateral incisors were very frequently without contact, so the percentage of force was low.

There was no statistical difference in the occlusal forces of the premolars in all time periods.

DISCUSSION

The dental, skeletal, and muscular effects of RME have been well documented in the literature.[1-7,9,10,13,14] However, to our knowledge, there have been no studies considering the effect of this therapy on occlusal force distribution. It was the aim of this study to analyze the effect of modified bonded RME appliances on occlusal force distribution

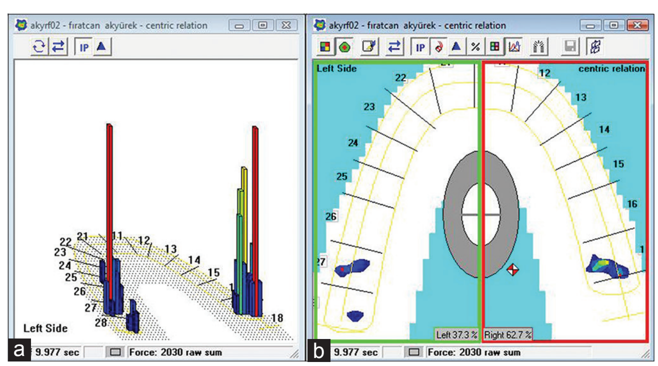

Figure 3: Digital images illustrating maximum intercuspidation using the T-Scan® III: (a) A 3-dimensional representation of the occlusion and the occlusal force. The red columns represent higher force, and the blue, lower force. (b) Bite force data expressed in percentages

Table 1: Percentage force distributions on the right and left sides of the teeth at the pre-treatment (T1), post-treatment (T2), and post-retention (T3) periods (n=12)

Teeth	T1		T2		T3		P		
	Mean±SD	Median (Min-Max)	Mean±SD	Median (Min-Max)	Mean±SD	Median (Min-Max)	T1-T2	T2-T3	T1-T3
Anteriors	8.5±5.24	1.3 (0.0-63.5)	5.8±5.47	0.0 (0.0-66.0)	8.7±6.14	0.0 (0.0-75.0)	0.910	0.051	0.889
Premolars	11.0±2.76	12.8 (0.0-30.0)	6.7±2.48	0.0 (0.0-23.0)	9.5±1.15	5.0 (0.0-32.5)	0.306	0.374	0.624
Molars	71.3±5.63	68.3 (34.5-101.5)	69.4±8.61	77.8 (21.0-100.0)	74.4±7.58	84.0 (21.5-100.0)	0.875	0.182	0.695
Posteriors	82.3±5.89	82.0 (36.5-115.0)	76.1±7.67	82.5 (27.0-100.0)	83.9±6.06	95.0 (46.0-100.5)	0.388	0.142	0.480
Total	96.8±0.69	97.2 (91.2-9.7)	94.8±1.06	94.7 (85.6-100)	95.9±0.77	96.3 (90.4-99.8)	0.034*	0.158	0.117

SD: Standard deviation; median, minimum-maximum values. *$P<0.05$

using a T-Scan computer-assisted dental occlusion analyzer.

Occlusal force can be affected by age,[18,19] gender,[19-21] dentition stage,[19] and facial structure,[22,23] among other factors.[24,25] However, differences in bite force between males and females are not found in children,[24,26] probably because body structure and muscle strength are very similar in this population. Similarly, Owais *et al*.[19] found no significant gender differences in the early primary and permanent dentition stages. In the light of their findings, we did not consider gender differences during case selection.

The relationship between the bite force and the angle classification has been evaluated by Sonnesen and Bakke.[27] The authors concluded that bite force did not vary significantly between the angle malocclusion types in children aged 7–13 years. Contrary to their findings, another study[28] found that the masticatory performance was reduced in subjects with malocclusions, especially in those with Class II and III, when compared to those with normal occlusion. In this study, we only included patients with Class I and II malocclusions.

A significant positive relationship between the maximum occlusal bite force (MOBF) and the dentition stage were reported. This was found to be related to the development of the masticatory system throughout the growth cycle and was explained by the increase in the number of occlusal contacts during the transition to different dentition stages.[19]

Correlations between maximum bite force and facial morphology have also been found in pediatric populations.[22,23] It has been reported that the maximum molar bite force is nearly twice that of dolichofacial subjects in individuals of normal facial types; further, that the brachiofacial types showed greater values.[22] This result has also been confirmed by Abu Alhaija *et al*.,[25] who reported that subjects with short faces had the highest MOBF whereas those with long faces had the lowest.

In this study, all subjects were in a limited age range (11–15 years) and at the same dentition stage (permanent dentition), an optimal growth pattern providing sample homogeneity. The scope of this study was not to compare subjects with posterior cross-bite to those with normal occlusion but to verify the occlusal force changes associated with modified bonded RME. Thus, there was no control group of normocclusive patients.

Occlusal bite force values can be directly influenced by the accuracy of the measuring apparatus. In this study, we used the T-Scan® III to analyze the occlusal force distribution. We preferred the T-Scan system as a quantitative occlusal analysis technique, rather than the qualitative conventional methods, such as articulating paper, waxes, and silicone impression.[29-31] These methods are not ideal occlusal analyzers due to their static nature, subjective interpretation, and limiting factors. Some researchers have defined the T-Scan system as providing nonsubjective, precise, and reliable occlusal analysis that offers improved information to clinicians.[8,32-36] It has been claimed that the T-Scan III system measures the relative occlusal force of the subjects instead of the numerical values of absolute occlusal force.[32,33] However, some studies of this system found that it produced more comprehensive and evidence-based results; thus, it has been suggested for use as a measurement tool in clinical experiments.[8,34,36]

Studies have been performed to determine the relationship between MOBF and masticatory efficiency, which concluded that MOBF is one indicator of the functional state of the masticatory system that results from the action of jaw elevator muscles modified by the craniofacial biomechanics.[19,37] The occlusal contact patterns of the teeth were found to exert a significant influence on the activity of masticatory muscles.[38]

Orthodontic treatment modalities have also resulted in changes to occlusal contact and muscle activity. Antonarakis *et al*.[39] have performed the only study that evaluated maximum bite force changes during orthodontic treatment. They reported decreased maximal molar bite force with functional appliance treatment of Class II patients. The authors explained that this decrease with the mild muscular atrophy was caused by the decreased functional activity of masticatory muscles, and was related to occlusal instability.

Similarly, bonded RME treatment can also cause occlusal contact changes and occlusion instabilities. In this study, we were not surprised to find a significant decrease in total occlusal force distribution during treatment (T1–T2). In addition, there were decreases in the percentages of force distribution of the anterior and the posterior teeth at the end of the modified bonded RME treatment (T1–T2), although we observed no statistically significant difference.

From another point of view, the decrease might be due to the sensitivity of the periodontal ligament as related to the orthodontic tooth movement during maxillary expansion. As orthodontic tooth movements alter the periodontal ligament's vascularity and blood flow and cause inflammatory reactions in the periodontium and dental pulp, they will stimulate the release of various biochemical mediators and cause pain.[40,41] This pain sensation might affect patients' bite forces.

The nonsignificant increase in the force distribution percentage at T3 could be related to the masticatory system. Masticatory muscles might adapt to the new position during the retention period. Decreased functional activity showed a certain amount of recovery after the interruption of appliances, and the percentage of total force distribution at T3 (95.9 ± 0.77) seemed to return to the initial values at T1 (96.8 ± 0.69). This increase in occlusal forces was in accordance with the findings of Antonarakis *et al*.,[39] who found that increases in maximal molar bite forces were likely associated with a general increase in muscle force. Similarly, other researchers argued that the jaw-closing muscles might have benefited from a "training effect," resulting in stronger muscles.[42,43] In support of these findings, two studies that evaluated the EMG activity of the masseter and temporalis muscles of children treated with RME using a bonded appliance[7,9] reported increased activity in anterior temporal and masseter muscles activity after the appliance was removed.

Although both the dental and skeletal effects of RME have been evaluated, the effects of this therapy on occlusal force distribution have not been considered, thus limiting direct comparison of our results with other studies.

This study was limited to the evaluation of occlusal force distribution. It would be beneficial to also evaluate the bite forces with temporal and masseter muscle activations. Thus, further studies are needed to verify the influence of occlusal changes on all the muscle activations during modified bonded RME. Further, this study was based on a small sample size; future studies with larger sample sizes are needed. Finally, studies comparing the effects of the banded and the bonded types of RME on occlusal forces and muscle activity might be beneficial in determining the most effective, harmless method to provide more stable results for maxillary expansion.

CONCLUSIONS

In this preliminary study, we concluded that, considering the sample and the methodology used, modified bonded RME treatment decreased the percentage of total occlusal force distribution during the treatment period; however, it returned to its initial value after the postretention period.

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Nil.

Conflicts of interest
There are no conflicts of interest.

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