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Original Article / Araştırma Makalesi

The Effects of Two Different Daily Use Protocols in Skeletally Anchored Face-Mask Therapy on Maxilla

İskeletsel Ankrajlı Yüz Maskesi Tedavisinde Maksilla Üzerine Uygulanan İki Farklı Günlük Kullanım Protokolünün Etkilerinin Karşılaştırılması

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ABSTRACT: This study aimed to compare the effects of two different daily use periods on the maxilla during maxillary protraction. This study was conducted on pre (T0) and post (T1) lateral cephalograms of 38 patients with skeletal Class III malocclusion treated with a miniplate anchored maxillary protraction appliance. The patients were divided into two groups on the basis of their daily appliance wearing time. The first group consisted of 19 patients (ten females, nine males; mean age 11.48±1.30 years) who used their appliance all day to provide continuous force (C.F. group). In the second group, 19 patients (twelve females, seven males; mean age 10.47±1.54 years) used their appliance for approximately 14 hours daily to provide intermittent force (IF group). Intragroup comparisons were performed with paired t tests and Wilcoxon tests, and intergroup comparisons were performed with the Mann–Whitney U test. Significant forward movement of the maxilla was observed in both groups; however, the changes in the sagittal position of the maxilla were similar between the two groups. In the C.F. group, the treatment duration was 12.71 months, and in the IF group, it was 12.13 months, which was not significant. Full-time and part-time wearing of an extraoral appliance results in similar treatment outcomes. Therefore, breaks in wearing protraction devices during daily life might keep patients more cooperative for treatment.

Keywords: Extraoral traction appliances, orthodontic anchorage techniques, orthodontic appliances

ÖZET: Bu çalışma, maksiller protraksiyon sırasında iki farklı günlük kullanım süresinin maksilla üzerindeki etkilerini karşılaştırmayı amaçlamıştır. Bu çalışma, miniplak ankrajlı maksiller protraksiyon apareyi ile tedavi edilen iskeletsel Sınıf III maloklüzyona sahip 38 hastanın tedavi öncesi (T0) ve tedavi sonrası (T1) lateral sefalogramları üzerinde gerçekleştirilmiştir. Hastalar, apareylerini günlük kullanım sürelerine göre iki gruba ayrılmıştır. Birinci grup, apareyini tüm gün kullanarak sürekli kuvvet uygulayan 19 hastadan oluşmuştur (C.F. grubu; 10 kadın, 9 erkek; ortalama yaş 11,48±1,30 yıl). İkinci grup ise apareyini günde yaklaşık 14 saat kullanarak aralıklı kuvvet uygulayan 19 hastadan oluşmuştur (IF grubu; 12 kadın, 7 erkek; ortalama yaş 10,47±1,54 yıl). Gruplar içi karşılaştırmalar eşleştirilmiş t testi ve Wilcoxon testi ile, gruplar arası karşılaştırmalar ise Mann–Whitney U testi ile yapılmıştır. Her iki grupta da maksillanın anlamlı düzeyde öne hareketi gözlenmiştir; ancak maksillanın sagittal konumundaki değişiklikler iki grup arasında benzer bulunmuştur. CF grubunda tedavi süresi 12,71 ay, IF grubunda ise 12,13 ay olup aradaki fark anlamlı değildir. Ekstraoral apareyin tam zamanlı veya yarı zamanlı kullanımı benzer tedavi sonuçları vermektedir. Bu nedenle, protraksiyon apareylerinin günlük yaşamda ara ara çıkarılması, hastaların tedaviye uyumunu artırabilir.

Anahtar kelimeler: Ağız dışı çekme aletleri, ortodontik ankraj teknikleri, ortodontik gereçler

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INTRODUCTION

Anterior traction of the maxilla during the growth period has been investigated for treating skeletal Class III malocclusions with maxillary deficiency. The components of the protraction force (magnitude, direction, and duration) are among the most studied aspects of protraction treatment. Clinical studies have reported different results regarding maxillary protraction therapies, ranging from considerable changes to undesired results due to differences in force components (1-3).

In the literature, much controversy exists about the duration of the protraction force. Studies have reported various amounts of time regarding protraction device use, ranging from 10-12 hours up to 24 hours a day (4-10). Arguments about the duration of force application should be focused on achieving the highest possible skeletal effect. It has been reported that rest periods or breaks that demonstrate intermittent forces are needed to achieve biological adaptation of circummaxillary sutures (11). Mao (12) reported that oscillatory forces were more effective than continuous mechanical forces for craniofacial sutural growth. Additionally, it was experimentally shown that heavy intermittent protraction force provides anterior replacement of the nasomaxillary complex by stimulating bone appositions on midfacial structures (13).

The continuous forces in maxillary protraction therapy by tooth-borne anchorage units could cause undesired side effects, such as mesialization and proclination of maxillary dentition. Therefore, wearing a protraction device is usually limited to 14–16 hours daily to achieve more skeletal and fewer dental effects with tooth-borne anchorage units (2,4-10). In recent years, mini-plates have provided absolute anchorage by transmitting protraction forces directly to the maxilla and bypassing the dentition (14-18). These appliances lead clinicians to apply a more extended protraction force daily while avoiding dentoalveolar decompensation.

In the literature, few studies have compared the force durations of maxillary protraction therapy. Therefore, the present study compared the effects of two different force durations (continuous and intermittent forces) on the maxilla during maxillary protraction therapy with mini-plate anchorage.

MATERIAL AND METHOD

The sample size of the present study was estimated by G*Power Software (v3.1.3; Franz Faul, Universität Kiel, Germany). With an alpha significance level of 0.05 and a beta of 0.15 to achieve 85% power, 38 patients (19 per group) were needed to detect a minimum difference of 0.94 mm in the sagittal change in the CoA dimension (19). This retrospective study included pre-treatment (T0) and post-treatment (T1) lateral cephalograms and hand–wrist radiographs of 38 patients. All patients were treated with skeletally anchored maxillary protraction in the Orthodontic Department of Gazi University. The study was approved by the Ethical Committee of Ankara University Faculty of Dentistry (17.05.2017-09/09).

Patients who met the following inclusion criteria were included in the present study: (1) skeletal Class III malocclusion (ANB<0°, Wits<-2 mm) with maxillary retrusion (SNA<82°, Co-A<age norms); (2) developmental growth period of PP2 and

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MP3cap stages evaluated from hand-wrist radiographs; (3) any craniofacial anomalies; (4) no previous orthodontic treatment; (5) treatment with skeletally anchored maxillary protraction appliances; (6) well-documented daily timeline charts in patient records that show the use times of appliance in a day; and (7) use of the protraction appliance full time except for the meals or approximately 14 hours a day according to the information obtained from the patient records.

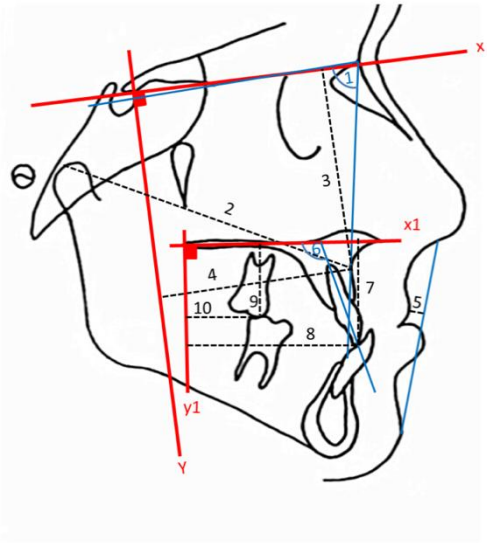

Figure 1. Cephalometric measurements evaluated in the present study: 1-SNA; 2-Co-A; 3-A-x; 4-A-y; 5-UL-S Line; 6-U1/PP; 7-U1-x1; 8-U1-y1; 9-U6-x1; 10-U6-y1

On the basis of the patient's anatomical structure, titanium mini-plates (Tasarımmed, Istanbul, Turkey) were inserted at the maxilla's left and right anterior nasal spine or zygomatic buttresses. An extraoral protraction mask was used for maxillary protraction, and elastics exerting 400 g force per side with a 30° angle to the occlusal plane were applied from the mini-plates to the extraoral appliance.

Daily usage duration was determined from the patient usage charts routinely kept in our clinic. At each follow-up visit, patients were asked to record their daily facemask-wearing duration in a structured diary, and parents were instructed to verify these entries. The clinician checked these records and confirmed consistency with clinical observations. Although this method is widely used in clinical settings, we acknowledge that it does not provide an objective measurement of compliance and may be subject to reporting inaccuracies.

Patients were divided into two groups on the basis of their daily appliance-wearing time. In the continuous force (C.F.) group, 19 patients (ten females, nine males) who used their appliance full time daily except for meals, and in the intermittent force (IF) group, 19 patients (twelve females, seven males) who used their appliance approximately 14 hours a day were included in the study. The mean pretreatment ages were 11.48±1.30 years and 10.47±1.54 years, respectively, in the groups.

The cephalometric radiographs, which were taken at the beginning (T0) and end (T1) of maxillary protraction, were traced by the same researcher (E.B.) by hand. The horizontal reference plane (x) was constructed on the tuberculum sella-wing (T-W) plane to evaluate vertical changes in the maxilla. A vertical plane perpendicular to the T-W plane at the T point was constructed as a vertical reference plane (y) to evaluate sagittal changes in the maxilla. The 'maxillary horizontal reference plane (x1)' was drawn along the ANS-PNS plane, and the 'maxillary vertical reference plane (y1)' was perpendicular to the ANS-PNS plane at the PNS point to evaluate the dentoalveolar changes. Eight linear and two angular measurements were performed on each lateral cephalometric radiograph (Figure 1).

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Table 1. Mean values of ages and cephalometric measurements before treatment and comparison of both groups.

	Continuous Force (CF) group				Intermittent Force (IF) group				p
	Mean	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mann Whitney U**
Chronological age (years)	11,48	1,30	8,58	13,42	10,47	1,54	8,00	12,42	0,061 NS
Skeletal age (years)	11,51	1,42	9,00	14,75	10,65	1,79	7,00	13,16	0,182 NS
SNA	77,45	2,78	71,00	82,00	76,63	2,77	71,00	81,00	0,370 NS
Co-A	85,45	4,93	78,00	97,50	79,66	3,47	73,50	85,50	0,001 **
Ax	59,68	5,01	48,50	66,50	57,92	4,91	50,50	67,50	0,198 NS
Ay	52,71	7,30	42,50	67,00	51,45	5,14	40,00	59,00	0,737 NS
U1/PP	114,95	7,11	100,00	126,00	109,13	5,62	99,00	120,00	0,011 *
U1-x1	27,45	2,54	22,00	32,50	27,97	2,58	23,00	33,00	0,537 NS
U1-y1	51,39	4,42	46,00	59,00	46,55	4,00	39,00	54,50	0,003 **
U6-x1	21,79	1,65	20,00	25,00	21,37	2,66	15,00	27,00	0,690 NS
U6-y1	20,18	3,15	15,00	26,00	16,26	3,23	12,00	25,00	0,001 **
UL-S line	-1,68	2,06	-6,00	3,00	-1,71	1,78	-4,00	2,50	0,872 NS

NS nonsignificant; * p<0.05; ** p<0.01; *** p<0.001

Table 2. Cephalometric changes after treatment and comparison of both groups

	Continuous Force (CF) group					Intermittent Force (IF) group					p
	Mean	**SD**	**Min**	**Max**	**p**	**Mean**	**SD**	**Min**	**Max**	**p**	**Mann W-U**
Treatment time (mo)	12,71	4,15	6,96	18,96	<0,001***	12,13	3,85	4,92	18,96	<0,001***	0,802 NS
SNA	2,21	1,40	-1,00	5,00	<0,001***	2,29	1,55	0,00	5,50	<0,001***	0,977 NS
Co-A	3,97	1,87	1,00	7,00	<0,001***	4,39	1,39	1,50	7,00	<0,001***	0,518 NS
Ax	1,97	1,33	-1,00	4,00	<0,001***	1,58	1,10	0,00	4,00	<0,001***	0,352 NS
Ay	3,34	1,26	0,50	6,00	<0,001***	3,13	0,91	2,00	5,50	<0,001***	0,432 NS
U1/PP	1,82	3,52	-3,00	9,00	0,085 NS	1,84	5,77	-9,00	10,00	0,184 NS	0,693 NS
U1-x1	0,50	1,09	-1,00	2,50	0,062 NS	0,53	1,33	-3,00	2,50	0,071 NS	0,699 NS
U1-y1	0,55	1,08	-2,00	3,00	0,078 NS	0,73	1,45	-2,00	3,50	0,058 NS	0,582 NS
U6-x1	1,47	1,12	0,00	4,00	<0,001***	1,29	1,10	-1,00	3,50	0,001**	0,664 NS
U6-y1	0,00	1,17	-2,00	2,50	0,886 NS	0,05	1,40	-2,00	3,50	0,214NS	0,524 NS
UL-S line	1,74	1,35	-1,50	4,00	<0,001***	2,47	1,62	-1,00	5,00	<0,001***	0,132 NS

NS nonsignificant; * p<0.05; ** p<0.01; *** p<0.001

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To evaluate intraobserver reliability, 10 randomly selected cephalograms were retraced by the same examiner (E.B.) two weeks after the initial measurements. Dahlberg's formula was used to calculate method error, and intraclass correlation coefficients (ICC) were computed.

SPSS 24 (IBM SPSS Statistics for Windows, Version 24.0. Armonk, New York: I.B.M. Corp.) was used to evaluate the data. The Shapiro–Wilk test was performed for the distribution of the variables. The intragroup comparisons were made with a paired t test for the parametric variables and a Wilcoxon test for the nonparametric variables. The Mann–Whitney U test was used for intergroup comparisons, and P<0.05 was considered statistically significant.

RESULTS

The reliability assessment demonstrated high reproducibility for all cephalometric measurements. ICC values ranged between 0.91 and 0.97, indicating excellent intraobserver agreement. Dahlberg's method errors ranged from 0.21 to 0.49 mm for linear variables and from 0.24° to 0.63° for angular variables.

Table 1 compares the age and cephalometric measurements of both groups at T0. A statistically significant difference was observed in the Co-A, U1-y1, and U6-y1 dimensions (p<0.01) and U1/PP angle (p<0.05) between the two groups at T0 (Table 1).

The changes in the treatments and the differences between the two groups are shown in Table 2. The treatment time was 12.71±4.15 months in the C.F. group and 12.13±3.85 months in the IF group, which was not significantly different between the groups (Table 2).

When the sagittal changes in the maxilla were analyzed, the SNA angle increased significantly by 2.21° in the C.F. group and 2.29° in the I.F. group (p<0.001). The Co-A and A-y dimensions significantly increased by 3.97 mm and 3.34 mm in the C.F. group and 4.39 mm and 3.13 mm in the IF group, respectively (p<0.001). When the two groups were compared, similar changes were observed in the sagittal position of the maxilla (Table 2).

The A point (A-x) showed significant vertical movements in both groups (p<0.001); however, these changes were found to be nonsignificant between groups.

The maxillary incisor angle (U1/PP) and maxillary incisor vertical (U1-x1) and sagittal (U1-y1) positions did not significantly differ between the two groups.

The vertical positions of the maxillary first molars (U6-x1) significantly increased in both groups, with values of 1.47 mm (p<0.001) and 1.29 mm (p<0.01) in the C.F. and I.F. groups, respectively, which was not significant between the groups. The sagittal positions of the maxillary first molars (U6-y1) remained stable in both groups.

The upper lip protruded significantly by 1.74 mm in the C.F. group and 2.47 mm in the I.F. group (p<0.001), and these changes were not significant between the two groups (Table 2).

DISCUSSION

The forces exerted by orthopedic appliances can alter the shape and relationship of facial bones during the growth period, and most of these alterations occur at craniofacial sutures. These biological processes are

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necessary for adaptation to the new functional environment; therefore, the force generated by orthopedic appliances is the most critical factor for initiating this process. For this purpose, clinicians have constantly been challenged in identifying the optimal force to achieve the desired results in orthodontic practice, and results have been reported (1,20,21). On the basis of the variety of force magnitudes. direction and duration, the authors reported different times of appliance wear per day. Liu et al. (22) reported that greater sutural separation, mineral accumulation, and osteogenesis rates could be achieved during maxillary expansion with continuous rather than intermittent forces. Additionally, De Clerck et al. (14) reported that moderate continuous forces could be preferable to heavy interrupted forces for a favorable maxillary response during protraction therapy. On the other hand, Mao (12) reported that oscillatory forces were more effective than continuous forces for craniofacial sutural growth. In maxillary protraction therapy, the optimal force can be defined as the minimum effective force that provides the desired skeletal growth in less time (23). This study was designed to compare the effects of two different durations of force on the maxilla during protraction therapy.

Appliance-wear duration was derived from patient diaries and parental confirmation rather than an objective monitoring device. Although this method is commonly used in routine clinical practice and is considered an acceptable surrogate for estimating patient compliance, it nonetheless carries an inherent risk of reporting bias. Therefore, the potential inaccuracy of self-reported wear time should be taken into account when interpreting the findings, as unrecorded variability in true appliance usage may have influenced the observed results between the two force-duration protocols.

The mini plates used in the present study were inserted on the maxillary zygomatic buttresses and lateral walls according to the patients' anatomical structures. Both the zygomatic buttresses of the maxilla (14,18) and the lateral walls of the anterior nasal spine (15,16,24) are preferred for miniplate insertion in maxillary protraction therapy. The main advantages of these two areas are that they are close to the center of resistance of the nasomaxillary complex, which provides a pure forward movement of the maxilla without any rotation and has enough bone thickness for mini-plate insertion (15,24-27).

In the present study, patients were in the pre-pubertal or pubertal stage of growth, and their mean chronologic ages were 11,48 and 10,47 years in the C.F. and I.F. groups, respectively, which was not significant between the groups at T0. Many authors have recommended starting maxillary protraction at earlier ages to achieve more skeletal effects (5,8,28), whereas others have reported similar skeletal responses in different skeletal developmental stages (7,29).

The protraction force was applied directly on the maxilla all day except for the meals in the C.F. group and approximately 14 hours per day in the IF group. In the literature, mini-plate anchored maxillary protraction therapies reported different daily uses of the device. Continuous force application was reported by Kircelli and Pektas (24) and Kaya et al. (15) with facemasks. Also Sar et al. (30), De Clerck et al. (31), Cevidanes et al. (32) and Coscia

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et al. (33) reported continuous forces with intermaxillary elastics. However, Lee et al. (18) reported 12–14 hours, Cha and Ngan (34) reported 14–16 hours, and Sar et al. (16) reported 16 hours of daily facemask use with miniplate anchorage. These findings suggest that clinicians often prefer continuous force application in intraoral systems. Patient tolerance, however, remains a key factor in determining daily wear duration.

Despite the daily use of the C.F. group being greater than that of the IF group, the total treatment time was similar between the two groups. The average treatment time was between 7.6 and 18 months in continuous force-applied studies (15,24,30,31,33) and between 7.4 and 12 months in intermittent force-applied studies (16,18,34).

In previous facemask studies utilizing mini plates, the increase in SNA° was reported to range between 1.7° and 3.7° (12, 13, 15, 20,34). In the present study, SNA° increased significantly by 2.2° in the C.F. group and 2.26° in the I.F. group, which were similar between the groups. The Co-A and A-y dimensions significantly increased, with 3.97 mm and 3.31 mm in the C.F. group at 12.91 months and 4.44 mm and 3.26 mm in the I.F. group at 11.79 months, respectively. The protraction rate was 0.26 mm per month in the C.F. group and 0.28 mm per month in the IF group. Although the protraction rate was slightly greater in the IF group, these results showed that the two force durations had similar effects on the maxilla. However, in the literature, different results have been reported with different force durations. Kircelli and Pektas (24) reported 4.8 mm maxillary advancement with a protraction rate of 0.44 mm/month when facemasks were used full time. Kaya et al. (15) found a smaller effect, reporting 2 mm advancement and a rate of 0.20 mm/month. With 16 hours of daily facemask wear, Sar et al. (30) reported 3.11 mm maxillary advancement with a protraction rate of 0.45 mm/month. Similarly, Lee et al. (18) observed 3.18 mm advancement of the A point and a rate of 0.26 mm/month. These differences could be due to the different age ranges, severities of malocclusions or applied force amounts used in the mentioned studies.

In conventional maxillary protraction therapies, the use of tooth-borne devices could cause side effects, including the proclination of upper incisors and the medialization of maxillary molars, and inhibit the dentoalveolar growth of these teeth (9,28). The increased duration of force could increase the effects, which restricts the use of continuous forces with these appliances. Therefore, intermittent forces were necessary to minimize these effects. Using mini plates, transmitting the protraction force to the maxilla by bypassing the dentition overcomes these side effects and provides more force durations per day (14-18). The results of the present study support these findings. While the sagittal positions of the maxillary incisors (U1/PP; U1-y1) and molars (U6-y1) remained stable, the vertical dentoalveolar growth of these teeth (U1-x1; U6-x1) increased significantly.

This study is the first to compare the effects of two different force durations during skeletally anchored maxillary protraction therapy. To eliminate possible dentoalveolar influences and to evaluate the pure skeletal effects, we utilized skeletal anchorage throughout treatment. The similarity of outcomes between the

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continuous and intermittent force protocols may be explained by the use of skeletal anchorage, which minimizes dentoalveolar side effects that are typically more sensitive to variations in daily wear duration. In contrast, previous studies reporting more pronounced differences between force regimens often relied on tooth-borne anchorage systems, where changes in wear time more directly influenced incisor proclination or molar mesialization (9,16,28,29). Additionally, variations in patient age, force magnitude, and timing of treatment among previous studies may contribute to inconsistent findings across the literature.

The present results suggest that continuous and intermittent protraction forces yield comparable skeletal responses of the maxilla. Considering that earlier studies have demonstrated successful outcomes with both continuous forces in intraoral systems (30–32) and intermittent forces in extraoral systems (16,18,34), clinicians should prioritize patient comfort and cooperation when determining daily wear duration for facemask therapy. Allowing short breaks in daily use may enhance patient compliance without compromising skeletal correction.

The present study evaluated the clinical outcomes of two different durations of force applied to the maxilla during maxillary protraction therapy. The histological and psychological outcomes of these patients must be evaluated in larger samples for more comprehensive results. Another limitation of this study is that appliance-wear duration was based on patient diaries and parental confirmation rather than an objective monitoring device. Despite this method is routinely used in clinical practice, patient-reported compliance may introduce variability, and this should be considered when interpreting the results.

CONCLUSION

The continuous and intermittent forces used during maxillary protraction therapy yielded similar clinical results. Clinicians should consider patient cooperation and comfort when deciding the force duration during maxillary protraction therapy with an extraoral appliance. From the patient's perspective, wearing the appliance all day could not be tolerated easily and could cause them to refuse treatment.

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Ethical Approval: The study was approved by the Ethical Committee of Ankara University Faculty of Dentistry (17.05.2017-09/09). All methods in this study were carried out by the Declaration of Helsinki. Participation was voluntary, and all data were processed anonymously. The informed written consent was obtained from all the participants who participated in the study.

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Author Contributions: All authors have contributed substantially to the conception, design, data collection, analysis, and/or

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