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INVESTIGATION OF THE EFFECTS OF RAPID MAXILLARY EXPANSION WITH A LOCKED MODIFIED ACRYLIC BONDED APPLIANCE ON DENTOSKELETAL STRUCTURES IN MIXED DENTITION: A PROSPECTIVE CLINICAL STUDY*

KARMA DENTİSYON DÖNEMİNDE KİLİTLİ MODİFİYE AKRİLİK BONDED APAREY İLE YAPILAN HIZLI ÜST ÇENE GENİŞLETMESİNİN DENTOİSKELETSEL YAPILAR ÜZERİNE ETKİLERİNİN İNCELENMESİ: PROSPEKTİF KLİNİK ÇALIŞMA

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ABSTRACT
The objective of this study was to examine the effects of a locked rapid maxillary expansion appliance on the dentoskeletal structures of patients who experienced transverse maxillary constriction with a true unilateral posterior crossbite. The appliance used in this study was a modification of the tooth- and tissue-supported, fully covered acrylic rapid maxillary expansion appliance. To provide asymmetric expansion of the maxillary halves, an acrylic locking unit was constructed on the occlusal surface of the noncrossbite side of the appliance, anchored by the lower posterior teeth on the same side. This study included a total of 30 patients (14 girls and 16 boys; mean age 8.74 ± 0.56 years) with mixed dentition. Lateral and frontal cephalograms and plaster model records were taken before expansion, immediately after expansion, and 3 months after retention. Repeated measures analysis of variance was used to compare the measurements at various time points. Covariance analysis was also used to evaluate the differences between the crossbite and noncrossbite sides. The level of statistical significance was set at 0.05. The results indicated that the appliance produced statistically significant maxillary expansion on the crossbite side compared with the noncrossbite side ($p<0.05$). The maxilla exhibited greater skeletal movement in the transverse plane than in the sagittal and vertical planes. In the treatment of true unilateral posterior crossbites in mixed dentition, this appliance is effective and might be preferred.

Keywords: Crossbite, maxillary expansion, mixed dentition, orthodontic appliances.

ÖZ
Bu çalışmanın amacı, üst çene darlığıyla birlikte gerçek tek taraflı posterior çapraz kapanışı bulunan hastalarda kilitli hızlı üst çene genişletme apareyinin dentoiskeletsel yapılar üzerine etkilerini incelemekti. Çalışmada diş ve doku destekli, tam akrilik hızlı üst çene genişletme apareyinin bir modifikasyonu kullanıldı. Üst çene segmentlerinin asimetrik genişlemesini sağlamak amacıyla apareyin normal kapanış tarafının okluzal kısmına aynı taraftaki alt posterior dişlerden ankraj alan akrilik bir kilit mekanizması eklendi. Çalışma, karma dişlenme döneminde toplam 30 hasta (14 kız ve 16 erkek; ortalama yaş 8.74 ± 0.56 yıl) üzerinde yürütüldü. Lateral ve frontal sefalometrik röntgenler ile alçı model kayıtları üst çene genişletilmesinden önce, genişletmeden hemen sonra ve 3 aylık pekiştirme döneminden sonra alındı. Farklı zamanlarda alınan kayıtlarda yapılan ölçümlerin istatistiksel olarak karşılaştırılması, tekrarlayan ölçümlerde varyans analizi ile gerçekleştirildi. Çapraz kapanış ve normal kapanış tarafları arasındaki ölçümlerin karşılaştırılmasında ise kovaryans analizi kullanıldı. İstatistiksel olarak anlamlılık düzeyi 0.05 olarak belirlendi. Sonuçlar, apareyin çapraz kapanış tarafında normal kapanış tarafına göre istatistiksel olarak anlamlı maksiller ekspansiyon meydana geldiğini gösterdi ($p<0.05$). Üst çenenin transversal düzlemde, sagital ve dikey düzlemlere göre daha fazla iskeletsel olarak hareket ettiği tespit edildi. Karma dişlenme döneminde gerçek tek taraflı posterior çapraz kapanışların tedavisinde bu aparey etkilidir ve tercih edilebilir.

Anahtar kelimeler: Çapraz kapanış, üst çene genişletmesi, karışık dişlenme, ortodontik apareyler.

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INTRODUCTION

A complete buccal posterior crossbite (PCB) involves multiple teeth and is characterized by the buccal cusps of the upper teeth engaging lingually with the buccal cusps of the lower teeth in centric occlusion.[1,2] The presence of PCBs with more than one tooth indicates a transverse width inconsistency between the upper and lower dental arches.[3,4] This inconsistency can be caused by inadequate maxillary width, excessive mandibular width, or a combination of both,[5] but the most common cause is transverse maxillary deficiency.[6,7] The most widely recognized etiological factors related to PCBs are congenital, developmental (environmental factors, predominantly oral breathing[7] and persistent oral habits[8]), and traumatic or iatrogenic causes.[9]

In early dentition, PCBs can be of dental or functional origin and can lead to skeletal crossbite in mixed dentition.[2] PCBs can be clinically observed unilaterally (UPCB) or bilaterally during all periods of dentition.[2,9] UPCBs can also be classified into functional and true types.[1,4,6] Detailed examination of the mandible along its closure pathway helps in distinguishing between them. The functional UPCB, which accounts for approximately 67% to 79% of UPCB cases, characteristically represents a lateral displacement of the mandible toward the crossbite side.[10,11] This lateral displacement occurs during the transition of the mandible from the first tooth contact (centric relation) to maximal tooth contact (centric occlusion).[9,12,13] A crossbite in both a centric relation and centric occlusion, without lateral mandibular movement, can be termed a true UPCB.[4,6,9,12] True UPCB typically involves unilateral deficiency in maxillary width, whereas functional UPCB generally presents with symmetrical deficiency.[6]

It has been reported that PCBs usually do not improve spontaneously without intervention and need to be treated immediately.[4] The principal objective of PCB treatment is to increase the transverse dimension of the maxillary arch.[3] The treatment method for functional PCB is symmetrical expansion of the maxillary arch to eliminate the mandibular shift. However, asymmetric expansion is indicated for true UPCBs to expand the narrowed part of the maxillary arch and prevent overexpansion of the noncrossbite side. Therefore, several removable or fixed expansion appliances that are slowly or rapidly activated have been modified to produce differential effects on maxillary halves in the literature for true UPCBs.[6,9,14-17] Some of them are removable plates sectioned asymmetrically with jack screws,[18] the removable Nord appliance,[9,18] fixed lingual appliances (W-arches and quadhelix) with different arm lengths,[6] the asymmetric maxillary expansion appliance (AMEX)[16], the asymmetrical rapid maxillary expansion appliance (ARME)[19], and the modified mini-implant–assisted rapid palatal expander for unilateral expansion (U-MARPE)[20]. Patient cooperation is a crucial factor in the treatment of patients with removable appliances.[9] Fixed lingual appliances, including W-arches, quadhelix and AMEX, may result in undesirable tooth movements, such as extrusion, buccal tipping, and rotation of anchor teeth. In such cases, extraoral activation may also be necessary.[16] The primary objective of rapid maxillary expansion (RME), an effective orthopedic procedure commonly employed in growing patients, is to facilitate an appropriate and stable increase in maxillary width by opening the midpalatal suture.[7] Furthermore, initiating treatment with PCBs at the earliest possible stage is crucial to prevent unfavorable functional and asymmetric growth outcomes.[5] Although the effect of ARME has been evaluated in adolescents with true UPCB in permanent dentition,[19] there is a lack of evidence-based studies on its effectiveness in mixed dentition. Therefore, the aim of this study was to determine the specific dentoskeletal changes caused by asymmetric RME in patients with true UPCB during mixed dentition. This study also aimed to evaluate the relapse that occurred during the retention period. It was hypothesized that a locked modified acrylic bonded RME appliance would have equal effects on the crossbite and noncrossbite sides.

MATERIALS AND METHODS

This split-mouth trial was approved by the Regional Ethical Committee of Selcuk University (protocol number: 90). This trial was also retrospectively registered (Jul 03, 2024) at Clinical Trials. gov (Ref no: NCT06486324). The sample size calculation was based on measurements from a previous study that considered the upper intermolar width.[21] Presuming an increase of 25% in this former result, with an α error of 0.05 and a power of 90%, the sample size was determined to be 30 subjects per group. All procedures performed in this study involving human participants were in accordance with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from each participant's parent or legal guardian.

The inclusion criteria for the patients were as follows: mixed dentition and true UPCB; eruption of all first permanent molars; no more than one deciduous molar missing in each quadrant; no history of orthodontic treatment; no systemic disease; and no pathological periodontal status. Subjects were assessed clinically and through diagnostic records acquired via bite wax at first tooth contact to ascertain whether it was a true UPCB. The mean age of the individuals in the sample group was 8.74 ± 0.56 years. The crossbite was on the right side in 17 children, and in the other children, it was on the left side.In this study, the crossbite side of the patients was considered the treatment group, whereas the side with a normal bite or noncrossbite was considered the positive control group. Thus, the study was conducted on those two groups. The formation of a negative control group in this study was not feasible due to ethical considerations. Addressing skeletal problems in pediatric patients is essential, as early diagnosis facilitates treatment of the disorder and directs growth in accordance with the patient's needs.[2]

Expansion Appliance and Expansion and Retention Procedures

The upper and lower plaster models were transferred to the fixator in accordance with the centric relationship record obtained with dental wax in the clinic, and the appliance was constructed in the laboratory. A modification of a fully occlusally covered acrylic-bonded RME appliance was used to widen the maxillary halves asymmetrically. An acrylic locking mechanism supported by the lower teeth was added to the posterior part of the appliance on the noncrossbite side. A hyrax screw (GAC, Bohemia, USA) was placed on the upper model at the level of the second deciduous molars, as close and parallel to the palate as possible, and its arms were bent such that they could make contact with the palatine of the upper teeth from the cervical region. The borders of the acrylic base extended to the cervical third of the vestibule surfaces of all erupted teeth in the upper jaw and continued by covering the entire occlusal surface from there and surrounding the entire dome of the palate (Figure 1-a). All maxillary teeth were included in the appliance because of the short crown length of the deciduous teeth and the risk of debonding during the maxillary expansion of the appliance. The border of the acrylic base on the normal closing side (locking mechanism) starts from 2-3 mm away from the palatial surfaces of the upper teeth (according to the projection of the lingual surfaces of the lower posterior teeth on the palate), extends in the vertical direction to the lingual surfaces of the lower teeth (permanent first molar, primary molars, and canine teeth), and covers the entire occlusal surfaces of the teeth in the relevant region, ending in the cervical third of the vestibule surfaces (Figure 1-b and 1-c). To prevent trauma to the gingiva in the lingual region of the appliance anchored from the lower jaw, 0.5 mm thick wax was placed in this area, and acrylic tamping was performed. The appliance was divided into two parts by cutting from the middle of the screw at the level of the midpalatal suture.

The thickness of the acrylic on the occlusal surface was kept within the limits of the freeway space (with a maximum thickness of 2-3 mm) that would break the occlusion lock on the crossbite side, and the maximum possible lower jaw-teeth contact was ensured. To prevent any locking on the crossbite side (in the segment which wanted to expand), no impressions of the lower jaw teeth were taken on the acrylic plate (Figure1-d). However, on the side where there was no crossbite, impressions of the lower jaw teeth were taken for the locking mechanism. During the bonding of the appliance to the teeth, holes were drilled in the parts of the appliance that were in contact with the chewing and cutting areas of the teeth to ensure the evacuation of excess cement.

The screwing process started one day after the appliance was bonded when the cement reached its full hardness. The screw was rotated a quarter turn (2 × ¼ turn = 0.5 mm) twice a day, in the morning and evening (every 12 hours as possible) during the first seven days, and the patient was called on the eighth day. An occlusal radiograph was taken to check the opening in the midpalatal suture, and after the opening was observed, the screw was rotated with one frequency. The expansion process was completed by performing overcorrection in the transverse direction beyond the normal relationship between the teeth on the crossbite side. For overcorrection, the alignment of the mesiopalatinal cusp of the upper first molar on the crossbite side with the mesiobuccal cusp of the lower first molar was taken as a reference. In this direction, the position of the hole drilled in the appliance for cement evacuation at the level of the mesiopalatinal cusp of the upper first molar was assessed. After the expansion was completed, the appliance was removed, and a Hawley plate was used for retention on the same day. Retention with the Hawley plate was continued for three months.

For the reliability of the assessments, data were collected from multiple sources, including lateral and frontal cephalograms and dental casts. In addition, the researcher (CI) performing the measurements on the records did not know which side of the patients the cross-

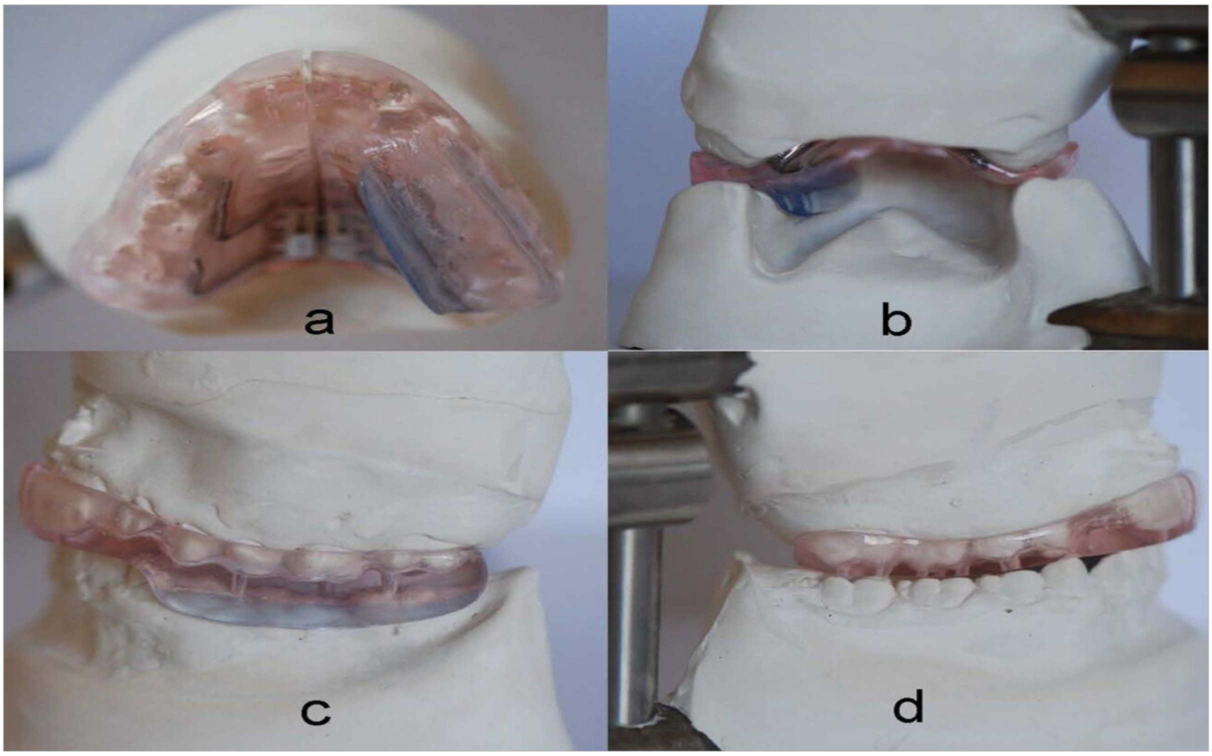

Figure 1. The locked modified acrylic bonded appliance used for asymmetric RME. a) occlusal, b) lingual, c) noncrossbite, and d) crossbite views of the appliance.

bite was on. Records were obtained for each patient before asymmetric RME (T1), after asymmetric RME (T2), and three months after completion of the retention phase (T3). The landmarks and measurements are illustrated in Figures 2-4.

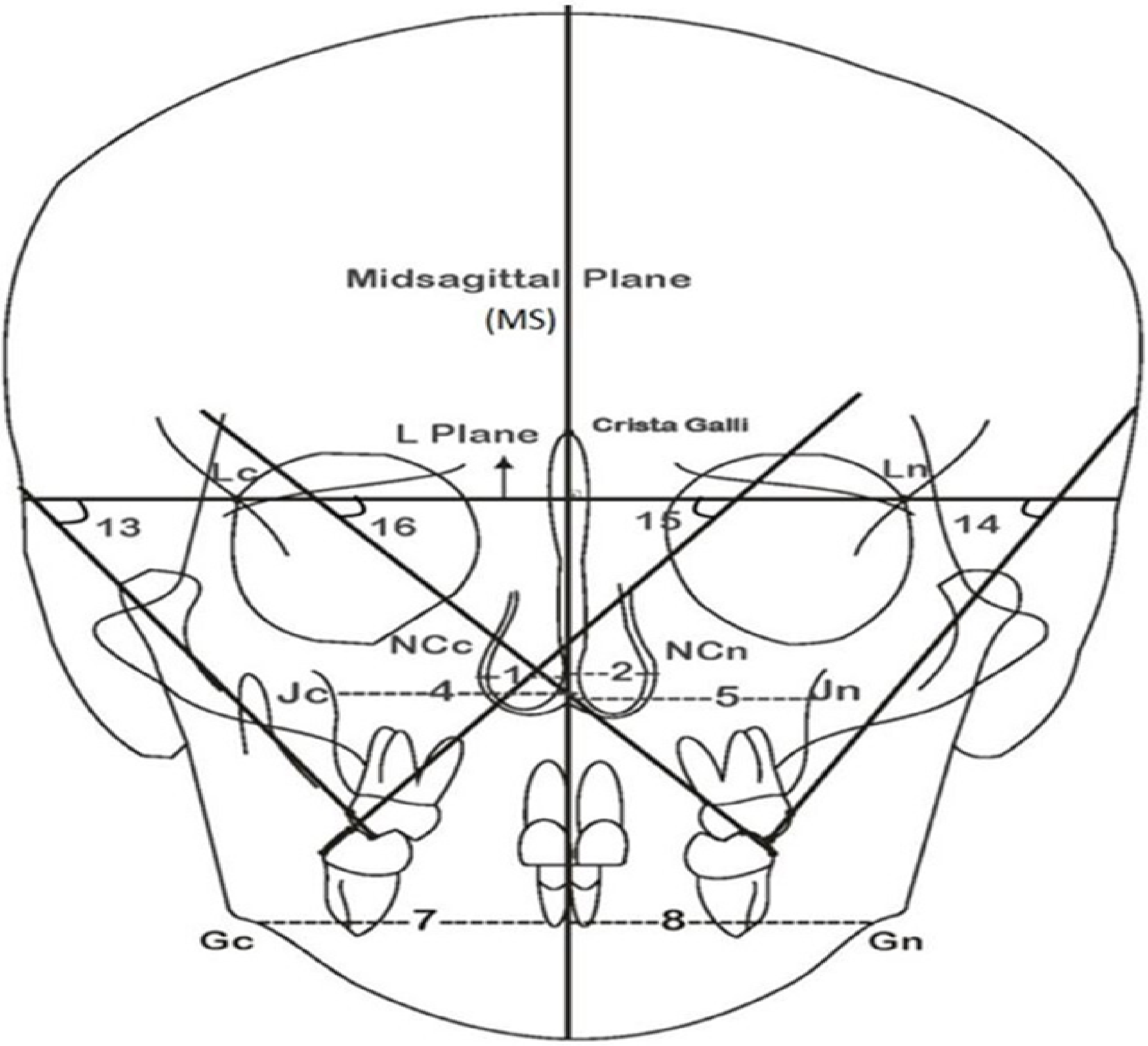

Figure 2: Frontal cephalometric landmarks and measurements: The horizontal reference plane (**L plane**) was constructed through the Lo points (Lateroorbital) on the crossbite (c) and noncrossbite (n) sides. Midsagittal plane (**MS**): The vertical reference plane was constructed through the Crista Galli (CG) perpendicular to the L plane. **1) NCc-MS (mm):** Nasal cavity (NC) width on the crossbite side (c); perpendicular distance of the lateral piriform rim to the MS plane on the crossbite side. **2) NCn-MS (mm):** Nasal cavity (NC) width on the noncrossbite side (n); perpendicular distance of the lateral piriform rim to the MS plane on the noncrossbite. **3) NCc-NCn (mm):** Effective nasal cavity width; the distance between the lateral piriformis on both sides. **4) Jc-MS (mm):** Skeletal maxillary width on the crossbite side; the perpendicular distance of the Jugale point (Jc) to the MS plane on the crossbite side. **5) Jn -MS (mm):** Skeletal maxillary width on the noncrossbite side; the perpendicular distance of the Jugale point (Jn) to the MS plane on the noncrossbite side. **6) Jc-Jn (mm):** Effective maxillary skeletal width; the distance between the Jugale points on both sides. **7) Gc -MS (mm):** Skeletal mandibular width on the crossbite side; the perpendicular distance of the Gonial notch point (Gc) to the MS plane on the crossbite side. **8) Gn-MS (mm):** Skeletal mandibular width on the noncrossbite side: the distance of Gonial notch point (Gn) to the MS plane on the noncrossbite side. **9) Gc-Gn (mm):** Effective mandibular width; the distance between the gonial notch points on both sides. **10) Jc-MS/Gc-MS (%):** Skeletal maxillary and mandibular width ratio on crossbite side. **11) Jn- MS/Gn -MS (%):** Skeletal maxillary and mandibular width ratio on noncrossbite side. **12) Jc-Jn/Gc-Gn (%):** The ratio between effective maxillary and mandibular widths. **13) U6c-L°:** Inclination of the upper first molar (U6) on the crossbite side; the angle formed between the L plane and the U6 long axis, which was constructed through the buccal cusp of U6 and its buccal surface. An increase in this angle indicates that U6 is buccally tipped. **14) U6n-L°:** Inclination of U6 on the noncrossbite side; the angle formed between the L plane and the U6 long axis, which was constructed through the mesiobuccal cusp of U6 through its buccal surface. An increase in this angle indicates that U6 is buccally tipped. **15) L6c- L°:** Inclination of the lower first molar (L6) on the crossbite side: the angle formed between the L plane and the L6 long axis, which was constructed through the buccal cusp of L6 and its buccal surface. An increase in this angle indicates that L6 was buccally tipped. **16) L6n-L°:** Inclination of the lower first molar (L6) on the noncrossbite side; the angle formed between the L plane and the L6 long axis, which was constructed through the buccal cusp of L6 and its buccal surface. An increase in this angle indicates that L6 was buccally tipped.

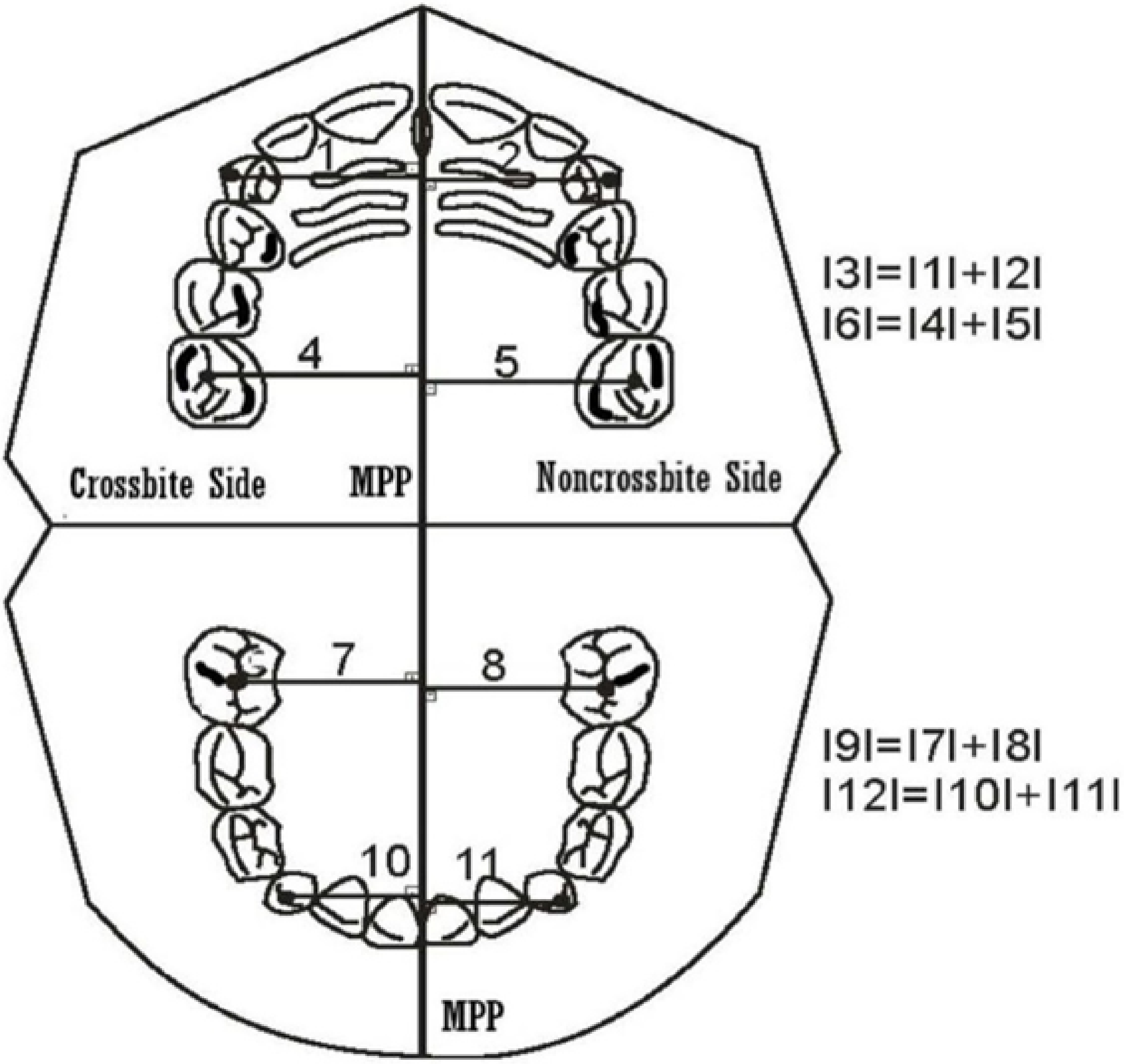

Figure 3: Dental cast landmarks and measurements: The median palatal plane (MPP) was constructed through the anterior and posterior raphe points. A mirror image of the angle between the MPP and the back of the maxillary cast was transferred to the mandibular cast to establish the mandibular median plane. **1)U3c-MPP (mm):** Perpendicular distance of the cusp of the upper deciduous canine (U3) to the MPP on the crossbite side**. 2) U3n-MPP (mm):** Perpendicular distance of U3 to the MPP on the noncrossbite side. **3) U3c-U3n (mm):** The width between the upper deciduous canines. **4) U6c-MPP (mm):** The perpendicular distance from the central fossa of the upper permanent first molar (U6) to the MPP on the crossbite side. **5) U6n-MPP (mm):** Perpendicular distance of U6 to the MPP on the noncrossbite side. **6) U6c-U6n (mm):** The width between the upper first molars. **7) L6c-MPP (mm):** Perpendicular distance of the central fossa of the lower permanent first molar (L6) to the MPP on the crossbite side. **8) L6n-MPP (mm):** Perpendicular distance of L6 to the MPP on the noncrossbite side. **9) L6c-L6n (mm):** The width between the lower first molars. **10) L3c-MPP (mm):** Perpendicular distance of the cusp tip of the lower deciduous canine (U3) to the MPP on the crossbite side. **11) L3n-MPP (mm):** Perpendicular distance of L3 to the MPP on the noncrossbite side. **12) L3c-L3n (mm):** The width between the lower deciduous canines.

Data Analysis

The analysis of the data obtained from the measurements was performed using IBM SPSS Statistics (version 21). Since the data derived from radiographic and cast model records at baseline (T1), after asymmetric expansion (T2), and after retention (T3) followed a normal distribution according to the Shapiro-Wilk test, repeated measures ANOVA was used for statistical analysis. If the test result was significant, a Bonferroni correction was conducted as a secondary (post hoc) test. For the comparison of differences between crossbite (c) and noncrossbite (n) data in the after treatment (T2-T1) and after retention (T3-T1) periods, the data did not follow a normal distribution; therefore, a non-parametric covariance analysis test (GLM Rank ANCOVA) was applied. A p-value of <0.05 was considered statistically significant.

Method Error

The same author (CI) randomly selected and remeasured 30 records approximately one month after obtaining the data to confirm the initial measurements. The method error was calculated via Dahlberg's formula

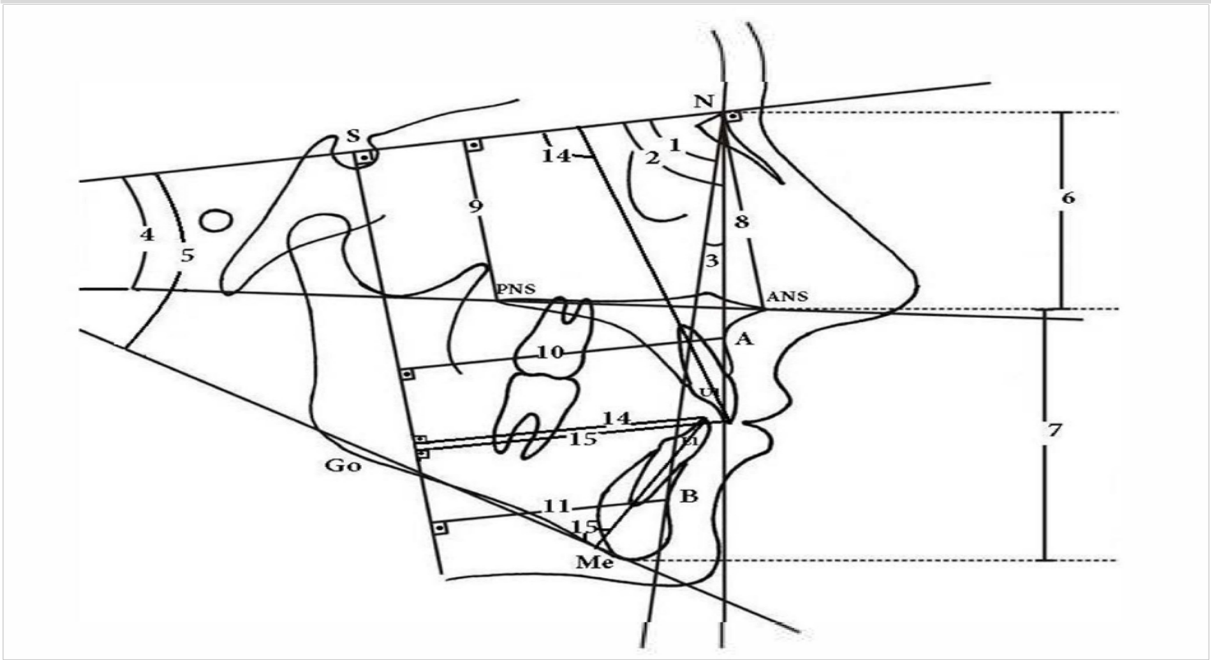

Figure 4: Lateral cephalometric landmarks and measurements: **l) SNA°:** The angle between the anterior cranial base (SN plane) passing through the Sella (S) and Nasion (N) points and the NA plane passing through the N and A points. It shows sagittal position of the maxilla relative to the SN plane. **2) SNB°:** The angle between the SN plane passing through the S and N points and the NB plane passing through the N and B points. It shows the sagittal position of the mandible relative to the SN plane. **3) ANB°:** The angle formed between the NA and NB planes. It shows the positions of the maxilla and mandible relative to each other in the sagittal direction. **4) SN-PP°:** The angle between the SN plane and the palatal plane (PP) [anterior nasal spine (ANS)- posterior nasal spine (PNS)]. It shows the position of the maxilla relative to the SN and maxillary rotation. **5) SN-MP°:** The angle between the SN plane and the mandibular plane (MP) (Gonion-Menton). It gives information about mandibular rotation and vertical growth. **6) N-ANS (mm):** The distance between the N and the ANS points. It shows the skeletal midface height. **7) ANS-Me (mm):** The distance between the ANS and the Menton (Me) points. It shows the skeletal lower face height. **8) SN⊥ANS (mm):** The perpendicular distance of the ANS to the SN plane. It gives the position of the ANS in the vertical direction. **9) SN⊥PNS (mm):** The perpendicular distance of the PNS to the SN plane. It gives the position of the PNS in the vertical direction. **10) SV⊥A (mm):**The perpendicular distance from point A to the Sella Vertical plane (SV). The SV was constructed through the S perpendicular to the SN plane. It gives the position of the A point in the sagittal direction. **11) SV⊥B (mm):** The perpendicular distance of point B to the SV plane. It gives the position of the B point in the sagittal direction. **12) U1_SN°:**The angle between the long axis of the upper central incisor (U1) and the SN plane. It shows the angulation of the U1 relative to the SN plane. **13) L1_MP°:** The angle between the axis of the most anteriorly located incisor tooth in the mandible (Ll) and the MP plane. It gives the angulation of the L1. **14) SV⊥U1 (mm):** The perpendicular distance from the incisal edge of U1 to the SV plane. It gives the position of the U1 in the sagittal direction. **15) SV⊥ L1 (mm):** The perpendicular distance from the incisal edge of L1 to the SV plane. It gives the position of the L1 in the sagittal direction.

($\sqrt{\Sigma d^2/2n}$). The smallest measurement error was 0.11% for Jc-MS/Gc-MS, whereas the largest was at L6c-MP° (1.14°). The changes in the values were within acceptable limits.

RESULTS

The mean expansion and retention times were 27.47±4.91 days and 93.17±3.26 days, respectively. The averages and comparisons of the measurements made on radiographs and dental casts at the T1, T2, and T3 time points are listed in Table 1. Comparisons of the differences between the crossbite and noncrossbite sides are detailed in Table 2.

The crossbite side was corrected in all patients via the asymmetric RME appliance. Although most patients tolerated the appliance well, a few patients experienced spontaneous debonding of the appliance during expansion. In those instances, the appliance was rebonded either on the same day or the following day, and then asymmetric expansion then continued. Following the completion of the asymmetric RME procedure, some patients presented signs of inflammation in the palatal mucosa and lingual gingiva of the lower posterior teeth on the noncrossbite side. However, they disappeared by the end of the first week of the retention period.

Transversal Assessment and Skeletal Proportions in Frontal Cephalometric Radiographs

Asymmetric RME (T2-T1) was associated with statistically significant increases in the mean values for all nasal cavity distances, all skeletal maxillomandibular ratios, and upper first molar angular measurements ($p<0.05$; Table 1).

The increase in the nasal cavity, maxillary width, and maxillomandibular ratio were significantly greater on the crossbite side than on the noncrossbite side ($p<0.001$; Table 2). Additionally, there was a statistically significant difference in the gonial distance between the crossbite and noncrossbite sides ($p<0.05$; Table 2). There was no statistically significant difference between the sides with and without crossbite in terms of buccal tipping of the upper or lower first molars ($p>0.05$; Table 2).

Retention (T3-T2) induced a statistically significant decrease in the mean values for all nasal cavity dis-

Table 1. Comparison of measurements at T1, T2, and T3 periods.

Frontal cephalometric measurements	n	T1 (Mean±SD)	T2 (Mean±SD)	T3 (Mean±SD)	F value	p value
NCc-MS (mm)	30	15.18 ± 1.53	17.13 ± 1.87 [a]	16.45 ± 1.63 [a, b]	45.39	<0.001
NCn-MS (mm)	30	16.22 ± 1.59	17.08 ± 1.58 [a]	16.83 ± 1.49 [a, b]	15.27	<0.001
Nc-Nn (mm)	30	31.53 ± 1.63	34.32 ± 2.23 [a]	33.42 ± 1.98 [a, b]	41.55	<0.001
Jc-MS (mm)	30	30.27 ± 1.81	32.82 ± 1.97 [a]	32.17 ± 1.84 [a, b]	73.62	<0.001
Jn-MS (mm)	30	31.45 ± 1.52	32.55 ± 1.40 [a]	32.18 ± 1.42 [a, b]	28.71	<0.001
Jc-Jn (mm)	30	61.77 ± 2.06	65.52 ± 1.96 [a]	64.47 ± 2.05 [a, b]	152.03	<0.001
Gc-MS (mm)	30	40.88 ± 3.48	40.40 ± 3.64	40.80 ± 3.25	1.85	.117
Gn-MS (mm)	30	40.42 ± 2.33	40.90 ± 2.55	40.62 ± 2.21	2.18	.122
Gc-Gn (mm)	30	81.33 ± 4.09	81.34 ± 4.11	81.43 ± 4.17	1.09	.347
Jc-MS/Gc-MS (%)	30	74.35 ± 5.30	81.63 ± 6.00 [a]	79.10 ± 4.78 [a, b]	71.24	<0.001
Jn-MS/Gn-MS (%)	30	78.00 ± 4.84	79.80 ± 4.83 [a]	79.44 ± 5.17 [a]	10.37	<0.001
Jc-Jn/Gc-Gn (%)	30	76.13 ± 4.52	80.73 ± 4.43 [a]	79.35 ± 5.58 [a, b]	159.69	<0.001
U6c-L (°)	30	72.38 ± 9.51	78.93 ± 8.16 [a]	77.33 ± 8.34 [a]	10.81	<0.001
U6n-L (°)	30	73.90 ± 7.79	78.70 ± 8.42 [a]	77.78 ± 5.96 [a]	8.22	.001
L6c-L (°)	30	49.13 ± 7.96	50.93 ± 5.67	50.22 ± 7.74	1.65	.200
L6n-L (°)	30	51.28 ± 6.08	51.97 ± 6.90	52.10 ± 6.80	0.25	.783
Dental cast measurements						
U3c-MPP (mm)	30	14.01 ± 1.61	17.55 ± 1.81 [a]	16.88 ± 1.90 [a, b]	243.85	<0.001
U3n-MPP (mm)	30	15.34 ± 1.87	17.49 ± 1.91 [a]	16.94 ± 2.04 [a, b]	139.40	<0.001
U3c- U3n (mm)	30	29.37 ± 2.88	35.08 ± 2.99 [a]	33.85 ± 3.41 [a, b]	323.53	<0.001
U6c-MPP (mm)	30	20.24 ± 1.59	24.93 ± 2.24 [a]	24.15 ± 2.00 [a, b]	178.28	<0.001
U6n-MPP (mm)	30	22.52 ± 1.63	24.36 ± 1.54 [a]	24.57 ± 1.99 [a]	26.35	<0.001
U6c-U6N (mm)	30	42.83 ± 2.53	49.28 ± 2.85 [a]	48.76 ± 3.00 [a, b]	356.59	<0.001
L6c-MPP (mm)	30	21.66 ± 1.63	21.67 ± 1.37	21.46 ± 1.41	0.437	.648
L6n-MPP (mm)	30	21.07 ± 1.84	21.67 ± 1.58 [a]	21.59 ± 1.94	4.67	.013
L6c-L6n (mm)	30	42.42 ± 2.11	43.34 ± 2.27 [a]	43.05 ± 2.29 [a, b]	37.47	<0.001
L3c-MPP (mm)	30	12.98 ± 1.68	13.22 ± 1.69 [a]	13.09 ± 1.70	6.54	.003
L3n-MPP (mm)	30	12.62 ± 1.96	12.89 ± 1.90 [a]	12.87 ± 1.99 [a]	9.73	<0.001
L3c-L3n (mm)	30	25.63 ± 2.56	26.09 ± 2.64 [a]	25.97 ± 2.64 [a]	36.60	<0.001
Lateral cephalometric measurements						
SNA°	30	78.20 ± 2.92	79.00 ± 2.94 [a]	78.63 ± 2.92 [a, b]	19.64	<0.001
SNB°	30	75.27 ± 3.17	74.65 ± 3.17 [a]	75.25 ± 3.23 [b]	8.55	.001
ANB°	30	2.93 ± 1.88	4.32 ± 2.15 [a]	3.38 ± 2.2 [a, b]	37.46	<0.001
SN-PP°	30	8.40 ± 3.41	8.67 ± 3.28	8.63 ± 3.23	0.77	.469
SN-MP°	30	37.47 ± 4.00	39.67 ± 4.34 [a]	38.90 ± 4.10 [b]	12.93	<0.001
N-ANS (mm)	30	49.18 ± 3.42	50.42 ± 3.22 [a]	50.42 ± 3.41 [a]	29.49	<0.001
ANS-Me (mm)	30	63.12 ± 3.38	64.42 ± 3.78 [a]	63.51 ± 4.36 [b]	7.68	.001
SN⊥ANS (mm)	30	49.05 ± 3.41	50.23 ± 3.12 [a]	50.18 ± 3.36 [a]	25.44	<0.001
SN⊥PNS (mm)	30	41.78 ±2.76	42.83 ± 2.94 [a]	42.63 ± 2.84 [a]	14.39	<0.001
SV⊥A (mm)	30	56.15 ± 3.56	57.07 ± 3.66 [a]	56.53 ± 3.38 [a, b]	19.12	<0.001
SV⊥B (mm)	30	43.57 ± 5.38	42.68 ± 5.62 [a]	43.16 ± 5.46	4.51	.015
U1_SN°	30	100.57 ± 4.68	101.90 ± 4.81 [a]	100.80 ± 4.99 [b]	6.71	.002
L1_MP°	30	88.33 ± 4.72	89.62 ± 4.54 [a]	88.68 ± 4.63	4.71	.013
SV⊥U1 (mm)	30	54.40 ± 4.67	55.63 ± 5.18 [a]	54.71 ± 4.49	3.53	.043
SV⊥L1 (mm)	30	53.15 ± 4.67	51.72 ± 4.75	52.18 ± 4.69	1.32	.282

T1: Before asymmetric expansion, T2:After asymmetric expansion, T3: After retention period,[a]: p< 0.05 according to T1, [b]: p< 0.05 according to T2, n: number of subjects, SD: standard deviation. Test statistic: Repeated measures ANOVA.

Table 2. Comparison of the differences in the crossbite and noncrossbite sides after treatment (T2-T1) and after retention (T3-T1).

		After Treatment (T2-T1)				***After Retention (T3-T1)***			
Frontal cephalometric measurements	**n**	**Crossbite Side Mdn (min,max)**	**Noncrossbite Side Mdn (min,max)**	**Wald χ^2**	**p value**	**Crossbite Side Mdn (min,max)**	**Noncrossbite Side Mdn (min,max)**	**Wald χ^2**	**p value**
N-MS (mm)	30	1.75 (0, 4.5)	0.75 (0, 3.5)	15.40	<0.001	1 (0,3)	0.5 (-0.5, 3)	6.23	0.013
J-MS (mm)	30	2.5 (0, 6)	1 (0, 3)	32.38	<0.001	2 (-0.5, 4.5)	0.75 (-0.5, 0.75)	17.30	<0.001
G-MS (mm)	30	0 (-4, 3)	0 (-3, 4)	4.26	0.039	0 (-2.5, 2)	0 (-2, 2.5)	1.61	0.204
J-MS/G-MS (%)	30	6.78 (0, 15.79)	2.10 (-6.15, 5.84)	33.63	<0.001	4.76 (-1.35, 9.7)	1.23 (-1.90, 5.55)	34.01	<0.001
U6-L °	30	7 (-15, 23)	5 (-7.5, 18)	0.37	0.543	3.25 (-20.5, 24)	3.5 (-6.5, 15)	0.17	0.676
L6-L °	30	1.75 (-12, 12)	0.75 (-19, 14.5)	0.09	0.754	1.5 (-11.5, 10.5)	0 (-13, 16)	0.007	0.935
Dental cast measurements									
U3-MPP (mm)	30	3.45 (1.79, 5.31)	2.06 (0.88, 3.49)	31.6	<0.001	3.01 (0.6, 5.05)	1.41 (-1.15, 3.68)	10.94	<0.001
U6-MPP (mm)	30	4.56 (-0.2, 1.19)	1.82 (-4.23, 5.13)	17.49	<0.001	3.83 (-0.2, 6.87)	2.11 (-3.14, 6.95)	7.24	0.007
L6-MPP (mm)	30	0.04 (-4.47, 2.99)	0.47 (-4.47, 2.68)	1.67	0.195	0.06 (-6.72, 1.79)	-0.13 (-1.94, 3.27)	1.09	0.295
L3-MPP (mm)	30	0.21 (-0.44, 0.95)	0.28 (-0.32, 0.83)	0.48	0.487	0.11 (-0.7, 0.61)	0.10 (-0.41, 1.13)	1.68	0.195

Mdn: median of differences, min: minimum of differences, max: maximum of differences, n: number of subjects, Wald χ^2:nonparametric ANCOVA (GLM Rank ANCOVA) test statistics.

tances, all maxillary skeletal distances, and skeletal maxillomandibular ratios (%) (Jc-MS/Gc-MS and Jc-Jn/Gc-Gn) (p<0.001; Table 1).

Retention and asymmetric RME (T3-T1) were associated with statistically significant increases in all nasal cavity distances, all maxillary skeletal distances, all skeletal maxillomandibular ratios, and upper first molar angular measurements (p<0.05; Table 1).

The increases in the nasal cavity width, maxillary width, and maxillomandibular ratio on the crossbite side were significantly greater than those on the noncrossbite side (p<0.05; Table 2).

Dental Cast Analysis

Asymmetric RME (T2-T1) was associated with statistically significant increases in all deciduous canine and permanent first molar measurements except for the lower molar measurement (L6c-MPP) on the crossbite side (p<0.05; Table 1). The increase in the distance from the upper deciduous canine (U3c-MPP) and upper permanent first molar (U6c-MPP) teeth to the reference plane (MPP) on the crossbite side was significantly greater than that on the noncrossbite side (p<0.001; Table 2).

Retention (T3-T2) induced a statistically significant decrease in the mean values for all upper deciduous canine measurements (U3c-MPP, U3n-MPP, U3c-U3n), upper first molar measurements (U6c-MPP, U6c-U6n) and lower intermolar measurements (L6c-L6n) (p<0.001; Table 1).

Retention and asymmetric RME (T3-T1) were associated with statistically significant increases in all upper deciduous canine distances (U3c-MPP, U3n-MPP, U3c-U3n), upper molar distance (U6c-MPP, U6n-MPP, U6c-U6n), lower intermolar distances (L6c-L6n), and lower canine distances (L3n-MPP, L3c-L3n) (p<0.001; Table 1). The increases in the upper canine (U3c-MP) and upper molar (U6c-MP) distances on the crossbite side were significantly greater than those on the noncrossbite side (p<0.05; Table 2).

Sagittal and Vertical Assessment in Lateral Cephalometric Radiographs

Asymmetric RME (T2-T1) resulted in statistically significant increases in the mean SNA, ANB, SN-MP, U1-SN, and L1-MP angles and N-ANS, ANS-Me, SN⊥ANS, SN⊥PNS, SV⊥A, and SV⊥U1 distances and statistically significant decreases in the mean SNB angle and SV⊥B and SV⊥L1 distances (p<0.05; Table 1). At the end of the retention period (T3-T2), there was a statistically significant increase in the mean SNB angle and a statistically significant decrease in the SNA, ANB, SN-MP, and U1-SN angles as well as the ANS-Me and SV⊥A distances (p<0.05; Table 1). Retention and expansion (T3-T1) were accompanied by statistically significant increases in the SNA and ANB angles and the N-ANS, SN⊥ANS, SN⊥PNS, and SV⊥A distances (p<0.05; Table 1). No statistically significant differences were found in the SN-PP angle or SV⊥L1 distance at T1, T2, or T3 (p>0.05; Table 1).

DISCUSSION

The effect of RME on dentoskeletal structures has been the subject of extensive investigations in the literature.[7,22] Additionally, studies have examined the effects of the asymmetric expansion of the upper dental arch[16,20] and maxilla[15,19] in patients with true UPCB in permanent dentition. However, no study to date has focused on using asymmetric expansion with RME in mixed dentition. In this respect, this study represents a unique contribution to the literature. The findings of this study indicate that asymmetric RME treatment, with the modification of a fully occlusally covered acrylic-bonded RME appliance, may represent a suitable and successful method to achieve asymmetric effects in narrowed maxillary halves with upper arch widths in mixed dentition. On the basis of the evidence presented, the null hypothesis was rejected.

Accurate diagnosis is essential for correct treatment. The diagnosis of transverse discrepancies can be a complex process that typically requires the integration of multiple diagnostic tools, including clinical assessment, dental cast analysis, occlusograms and/or craniofacial radiographs.[23] In a retrospective study, three maxillary arch morphologies were identified on the crossbite side of patients with unilateral PCBs: symmetrical (47.5%), contracted (49.2%), and expanded (3.4%). The authors suggested that different arch forms require different maxillary expansions to achieve a symmetrical maxillary arch in these patients.[24] Individuals with unilateral PCB on the same side in both a centric relationship and centric occlusion were included in our study. The determination of true unilateral PCB was made clinically at first tooth contact. An evaluation of the records confirmed that the dentoskeletal structures on the crossbite side were narrower than those on the noncrossbite side. Therefore, an asymmetric RME was planned for the narrowed maxilla, especially to widen the narrow part of the maxilla.

The total skeletal maxillomandibular width ratio in 9-year-old children with a normal transverse width was reported to be 78.7% in the literature.[25] In our study, this rate was 76% before treatment. In addition, this ratio was 74% on the crossbite side and 78% on the noncrossbite side before treatment. With asymmetric RME, the maxillomandibular width ratio increased to 80.7%. Therefore, this ratio was 81.6% on the crossbite side and 79.8% on the noncrossbite side after expansion. With the relapse that occurred during the retention period, these ratios decreased to 79.3%, 79.1%, and 79.4%, respectively, and became closer to normal values. However, the skeletal mandibular width remained stable during both the expansion and retention periods. The asymmetric RME also increased the lower nasal cavity and maxillary widths by 2.79 mm and 3.75 mm, respectively. Even though approximately 30% relapse occurred during the retention period, 1.89 mm and 2.7 mm expansions were obtained in the relevant regions, respectively. In addition, increases in these anatomical regions with bonded RME have been reported by many researchers in the literature and are consistent with the findings of this study.[21,25] Conversely, the increase in the width of the inferior nasal cavity and maxillary width on the crossbite side was approximately 2 and 2.5 times greater than that on the noncrossbite side, respectively. These findings suggest that the force generated by the screw during expansion was asymmetrically distributed on the crossbite and noncrossbite sides, depending on the characteristics of the appliance. If the appliance does not have a locked mechanism (which increases the resistance of the noncrossbite side to expansion), perhaps the maxillary segments would be separated symmetrically or asymmetrically depending on the rigidity of the anatomical structure, and the maxillary width would increase.[9] However, this locked mechanism encouraged the controlled asymmetric expansion of the maxilla, limiting the expansion of the noncrossbite side and preventing the formation of buccal nonocclusion on the noncrossbite side. Furthermore, during asymmetric expansion, the mandible temporarily shifted 0.48 mm toward the noncrossbite side resulting from muscle adaptation because of the locked mechanism. However, this situation disappeared at the end of the retention period.

Asymmetric RME caused buccal tipping of the upper first molars on both sides, mostly on the crossbite side, whereas the appliance did not affect the tipping of the lower first molars. However, the difference in the degree of tipping of the upper first molars was not significant. The locked mechanism of the appliance may have caused the first molar on the noncrossbite side not to tilt more toward the buccal side. Although this is consistent with the study of Toroglu et al., the amount of expansion that occurred on the noncrossbite side was less than that on the crossbite side in this study.[16]

Dental cast analyses demonstrated significant increases in the means of all linear dental measurements after expansion, except for the lower first molar distance to the reference plane on the crossbite side. Increases in upper intercanine width and intermolar width have been reported in the literature, which used an acrylic-bonded RME appliance in mixed dentition.[21,22,26] The results of this study are consistent with those findings. In comparing the alterations between the two sides of the maxillary teeth, owing to the biomechanics of the appliance, the upper first molar and deciduous canine on the crossbite side presented more buccal movement than did those on the noncrossbite side. Although the loss of anchors occurred on the noncrossbite side, the upper posterior teeth presented a greater degree of symmetry both after the appliance was used and after the retention period. These results are generally similar to those of Toroglu et al.[16] Significant increases in the lower intermolar width and intercanine width were also recorded with treatment. Although the results of this study, including the lower intercanine width, are consistent with the findings of previous studies,[21,26] there was an inconsistency in the lower intermolar width. On the other hand, a comparison of the changes between the two sides of the mandibular teeth revealed that mandibular first molars on the noncrossbite side moved more buccally than did the opposing teeth on the crossbite side. The observed increase and inconsistency in the lower intermolar width can be attributed to the acrylic locking mechanism of the appliance. In addition, a negligible increase in mandibular intermolar arch width has been reported.[16] This could be explained by differences in the subjects' ages and appliance-related factors.

The comparison of lateral cephalometric measurements at three-time points revealed no significant differences in only two measurements (the SN-PP angle and the SV⊥L1 distance). However, statistically significant findings were observed for all the other measurements. Although relapse was observed during the retention period, the maxilla moved anteriorly and inferiorly without any rotation. The mandibula displayed clockwise rotation after expansion and returned to its initial position after retention. A few studies have reported changes in maxillary and mandibular responses after RME with acrylic-bonded RME in mixed dentition.[21,26] The increase in the SNA angle was associated with the anterior position of point A. However, Da Silva et al. reported that the maxilla did not change in the sagittal plane but moved downward after RME in primary or mixed dentition.[27] These different results can be attributed to differences in the position of the centers of rotation of the maxillary halves in the horizontal plane during RME.

A negative control group was not formed in this study. Although this may seem a shortcoming at first sight, the group was not formed due to an important ethical reason: A study such as this requires time, and children go through developmental stages. If any child was diagnosed with PCB during the study and needed treatment but could not be treated at all because of being in the negative control group, the researchers considered it unethical to form a negative control group of children. This study presents the early outcomes of asymmetric RME efficacy in the mixed dentition period based on linear and angular measurements obtained from two-dimensional records. Further research is required to gain a more comprehensive understanding of the treatment's effectiveness. Specifically, long-term studies and assessments of volumetric changes in maxillary segments using three-dimensional diagnostic tools are necessary.

CONCLUSION

With a locked modified bonded RME appliance, the maxillary halves were expanded asymmetrically in a short period of approximately one month by reducing patient cooperation. Asymmetric RME resulted in marked enlargement of both the inferior nasal cavity and the maxilla, which was more pronounced for the anatomical structures on the crossbite side. During the retention period, although relapse occurred, the width of the transverse dimension of both the anterior and posterior sections of the upper dental arch increased, more so on the crossbite side. The transverse enlargement of the maxilla exceeded the movement observed in the other two planes.

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethics Committee of Selcuk University Faculty of Dentistry (Date: 26/03/2007, Number: 90).

Informed Consent: Written and/or verbal consent was obtained from 30 participating in the study.

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