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Original Article

Skeletal, Dental, and Soft Tissue Changes after Slow Maxillary Expansion in Early Mixed Dentition

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Main Points

- Nickel titanium memory leaf expanders provide an effective and comfortable approach for maxillary expansion in mixed dentition cases.
- Treatment with leaf expansion appliances during mixed dentition results in both skeletal and dental effects.
- Significant improvements in transverse width and area measurements are observed in patients treated with the leaf expander.

ABSTRACT

Objective: This study aimed to evaluate the skeletal, dental, and soft tissue effects of the nickel titanium memory Leaf Expander in a growing sample of patients with unilateral posterior crossbite compared with a control group using digital models and lateral cephalometric radiographs.

Methods: The research included a total of 24 patients, 12 of whom were treated and 12 untreated. The Leaf Expander group consisted of 4 males and 8 females (mean age= 8.6±10.7 years), and the control group consisted of 5 males and 7 females (mean age: 9.2±0.8 years). Changes during the observation period in both groups were evaluated using the Wilcoxon signed-rank test. We used the Mann-Whitney U test to compare the data between the groups.

Results: There was a significant increase in the values indicating the vertical position of the maxilla and mandible in the treatment group. The palatal surface area increased significantly in both groups, but the increase was significantly higher in the treatment group than in the control group. In addition, intermolar width and arch perimeter measurements were significantly higher in the treatment group than in the control group.

Conclusion: With the advantage that this device does not require parent compliance, the possibility of incorrect activation was eliminated, and effective expansion using the Leaf Expander was achieved in patients with unilateral crossbite.

Keywords: Leaf expander, posterior crossbite, mixed dentition, slow maxillary expansion

INTRODUCTION

Transverse discrepancy due to reduced maxillary width, which is usually accompanied by crowding and posterior crossbite, is one of the most common skeletal deformities in orthodontics.[1] The prevalence of posterior crossbite ranges from 8% to 22% in patients with deciduous/mixed dentition.[2] Because posterior crossbite can cause problems, such as insufficient maxillary arch width and crowding, this type of crossbite should be treated early.[3] Anchorage from permanent teeth may show negative results, such as root resorption, bone loss, and white spot lesions in permanent dentition. To prevent these complications, it is recommended to obtain anchorage from

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deciduous teeth in the mixed dentition period.[4] Since 1970, several authors have continued to report the advantages of slow maxillary expansion (SME) in opening the midpalatal suture at an early stage and minimizing pain and discomfort by allowing regeneration of the suture site.[1,3,5]

Recently, nickel titanium (NiTi) alloy has been used in some appliances to induce maxillary expansion. These NiTi-containing appliances have the advantage of the shape-memory characteristics of this alloy and exert a constant and continuous force, allowing for dentoskeletal effects.[6] Initially, Arndt[7] eliminated the need for patient compliance with SME appliances containing a NiTi alloy in 1993. Corbett[8] introduced a second example of a NiTi-containing expansion appliance called a Nitanium Palatal Expander 2 in 1997. The Memory Palatal Split Screw (MPSS), an expansion device, was introduced in 2004. This appliance contains super-elastic NiTi open coil springs that reduce the high expansion forces.[9]

In 2013, the Leaf Expander was first constructed in Florence, Italy.[10] The active elements in this appliance are represented by leaf-shaped NiTi springs that return to their original form upon deactivation, resulting in predictable expansion of the maxillary arch. The Leaf Expander is now available in two lengths (6 and 9 mm) and two forces generated by the NiTi springs (450 and 900 g). The 6 mm screw contains two leaf springs and can be activated up to 30 times. The 9 mm screw contains three leaf springs and can be activated up to 45 times. In both appliances, each turn produces a 0.1 mm expansion.[11]

The present study aimed to evaluate the skeletal, dental, and soft tissue effects of SME using the Leaf Expander in a sample of patients in their growth stages with unilateral posterior crossbite using digital models and lateral cephalometric radiographs. In addition, it was intended to confirm whether the maxillary width of treated crossbite patients could reach the same width as that of normal controls in this study.

METHODS

The study included 12 patients who underwent orthodontic treatment with the Leaf Expander and 12 control subjects who had not undergone orthodontic treatment at Karadeniz Technical University Faculty of Dentistry. The patients were treated according to the ethical guidelines for human experiments described by the Scientific Research Ethics Committee of the Faculty of Medicine at Karadeniz Technical University, and written informed consent forms were completed by all parents. The ethics committee approval was also obtained from the Karadeniz Technical University Faculty of Medicine of Scientific Research Ethics Committee (approval no.: 6, date: 28.06.2021) for the research. The Leaf Expander group consisted of four males and eight females (group 1; mean age: 8.6±0.7 years), and the control group consisted of five males and seven females (group 2; mean age: 9.2±0.8 years). The SME protocol with Leaf Expander was used in 12 patients with maxillary transverse deficiency in group 1. Group 2 included 12 untreated patients without maxillary transverse deficiency.

Inclusion and Exclusion Criteria

The inclusion criteria for the treatment group included several parameters: (1) early mixed dentition period, (2) mild transverse deficiency, (3) presence of upper deciduous second molars, (4) no history of orthodontic treatment, (5) good oral hygiene, and (6) no systemic or syndromic disorder. Patients without upper deciduous canine, molar, permanent first molar, or severe maxillary transverse deficiency were excluded from the study.

The control group consisted of growing individuals who were matched to the treatment group according to sex and maturation stage. All control subjects had normal overjet and overbite, no posterior crossbite, and normal sagittal and vertical skeletal configurations.

Leaf Expander Protocol

The expansion screw was pre-activated in the laboratory to produce 3 mm of expansion. The Leaf Expander was bonded to deciduous second molars, and the ligatures were cut to allow expansion (Figure 1A). The Leaf screw (6 mm) delivers 900 g of force during deactivation. Patients visited the clinic every four weeks for Leaf Expander activation. The screw was activated by 10 quarter-turns until a normal transverse relationship was achieved, with no overcorrection. After the completion of active expansion (three months), as shown in Figure 1B, the appliance was kept in place for 4.5 more months for retention. Therefore, the total treatment duration, including retention was 7.5 months.

In group 1, lateral cephalometric radiographs and digital models were obtained before treatment (T1) and after retention (T2). Records from the control group were obtained at intervals similar to those from the treatment group.

All lateral cephalometric radiographs were obtained using a Kodak 9000 Extraoral Imaging System (Carestream Health, Inc. Rochester, NY, USA). All measurements of the lateral cephalometric films were performed using Nemoceph Version 6.0 (Nemotec, Madrid, Spain) and ImageJ version 1.3 (National Institutes of Health, Bethesda, Md).

Dental models of all patients were scanned using a 3shape R700 series (3Shape, Copenhagen, Denmark) scanning device. 3Shape Ortho Analyzer (Copenhagen, Denmark) was used for linear and angular measurements, and ImageJ version 1.3 (National Institutes of Health, Bethesda, Md) for surface area measurements (Figures 2-5). Table 1 lists the measurements used in the digital model analysis.

To detect skeletal and dental effects in the radiographs, measurements were obtained using reference planes. Accordingly, seven degrees to the sella nasion plane (SN) through sella point was taken as the horizontal reference plane (Hor) and perpendicular to Hor through S point was taken as the vertical reference plane (Ver), as shown in Figure 6.

All definitions of lateral cephalometric measurements are presented in Table 2.

Statistical Analysis

The sample size was calculated using the G*Power software (version 3.1.9.2). Based on a study by Lanteri et al.[12], it was concluded that 10 subjects would be sufficient at α error=0.05, β error=0.20, effect size=0.9, and standard deviation=0.72. However, considering possible data losses (20% loss), approximately 12 patients per group (24 patients in total) were included in the study. The data obtained in this study were analyzed using SPSS 17.0 (Statistical Package for Social Sciences). Conformity of the data to normal distribution was evaluated using the Shapiro-Wilk test. The Wilcoxon signed-rank test was used to evaluate differences between the model and the cephalometric measurements during the treatment period. Finally, the Mann-Whitney U test was used to compare data between the groups.

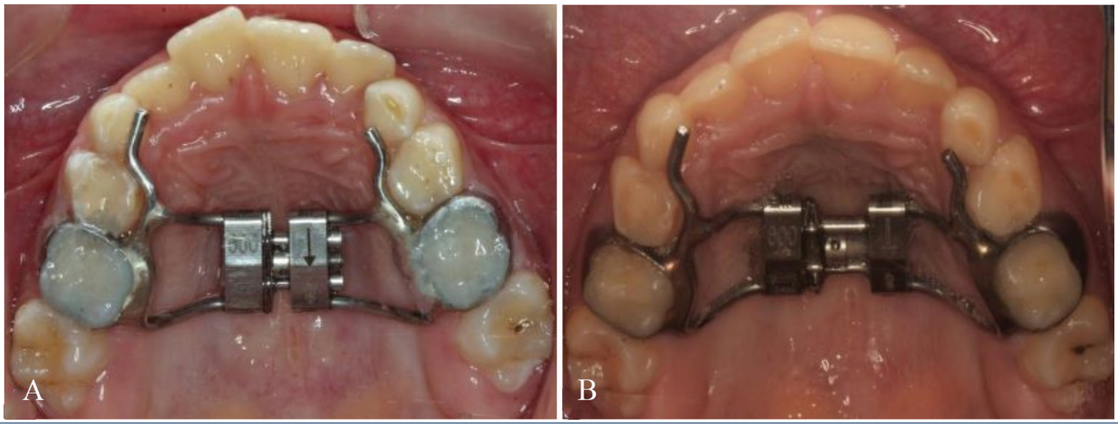

Figure 1. Leaf Expander in place (A) and completion of expansion (B)

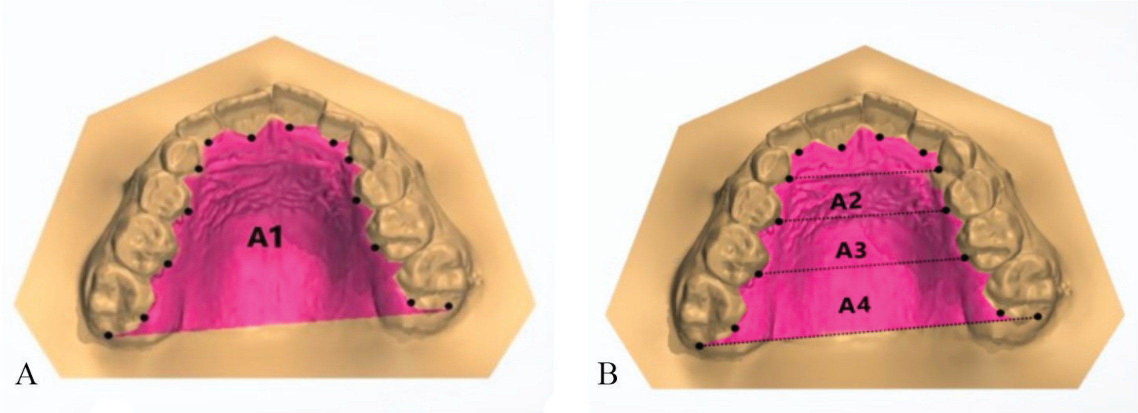

Figure 2. Area 1 measurements (A) and Areas 2, 3, and 4 measurements (B)

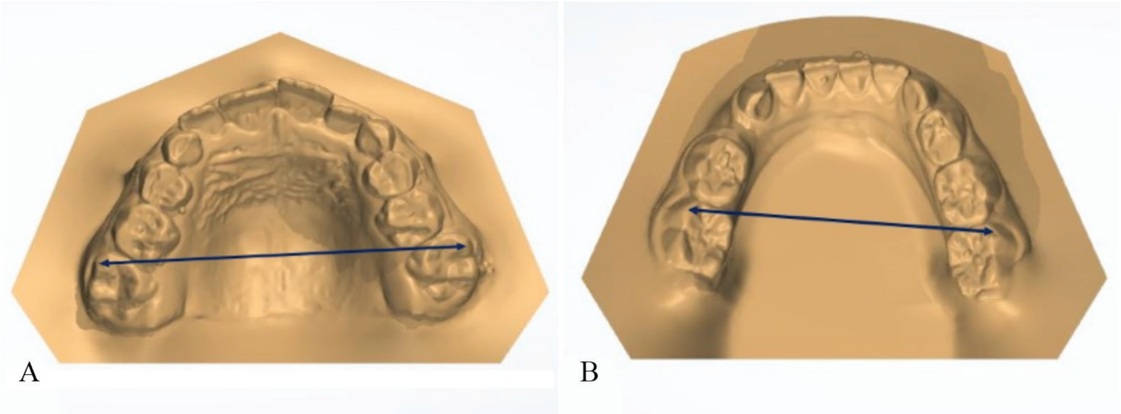

Figure 3. Upper (A) and lower (B) intermolar widths

RESULTS

A comparison of changes in cephalometric measurements and maxillary dental arch measurements on digital models in the post- and pre-observation (T2 and T1, respectively) periods for group 1 is presented in Table 3. In group 1, significant increases in A-Hor (0.98±0.56 mm; $p<0.01$), ANS-Hor (0.63±0.93 mm; $p<0.05$), and PNS-Hor (0.61±0.76 mm; $p<0.05$) distances from T1 to T2 (Table 4). Comparison of T2-T1 differences between the groups are presented in Table 5. Although the difference in A-Hor (0.97 mm; $p<0.001$) and PNS-Hor (0.79 mm; $p<0.01$) distances between the groups were significant, the difference in ANS-Hor distance was not significant ($p<0.05$), as shown in Table 5. For the mandibular skeletal measurements, a significant increase was observed in the B-Hor distance from T1 to T2 in group 1 (0.56±1.20 mm; $p<0.05$), as shown in Table 3. The differences between the groups were significant (0.40 mm; $p<0.05$), as shown in Table 5. Changes in B-Hor and overjet values were significant between the groups ($p<0.05$).

Significant increases were observed in group 1 in all area measurements from T1 to T2 ($p<0.01$), and this increase was

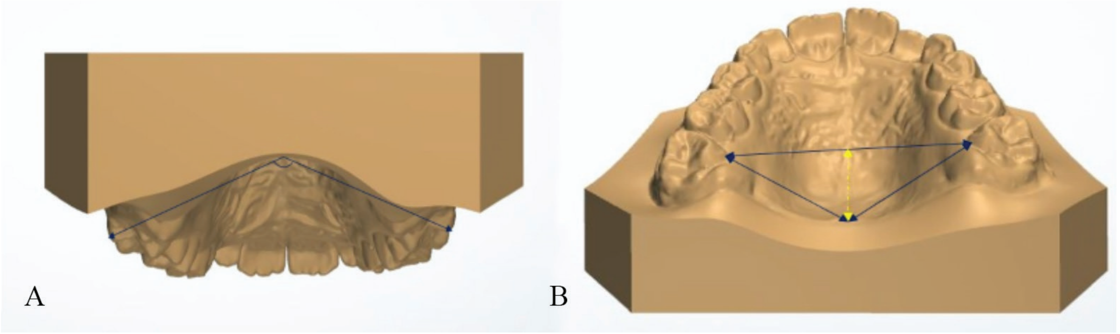

Figure 4. Molar angulation (A) and palatal depth (B) measurements

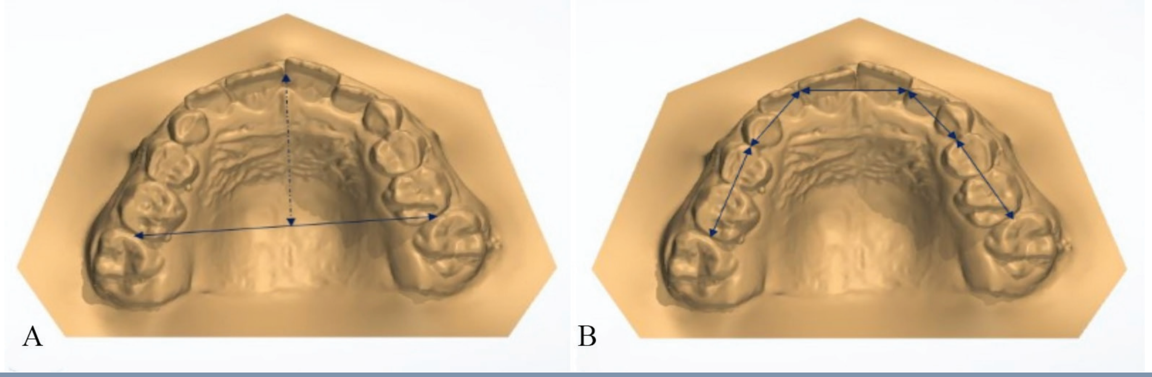

Figure 5. Arch length (A) and perimeter (B) measurements

Table 1. Measurements used in the digital model analysis

Area 1	The palatal area from the deepest points of the dentogingival junction of all teeth to the distal point of the permanent first molars.
Area 2	The palatal area between the deepest points of the dentogingival junction of the deciduous canines and first molars.
Area 3	The palatal area between the deepest points of the dentogingival junction of the primary and second molars.
Area 4	The palatal area between the deepest points of the dentogingival junction of the primary second molars and the distal end of the permanent first molars.
Upper intermolar width	Distance between the mesiobuccal cusps of the upper first permanent molars.
Lower intermolar width	Distance between the mesiobuccal cusps of the lower first permanent molars.
Molar angulation	Angle between the planes tangent to the buccal surfaces of the upper permanent first molars.
Palatal depth	The distance from a line passing through the gingiva of the permanent first molars to the deepest point in the palate.
Arch length	The distance from the midpoint of the upper central incisors to the plane passing through the mesiobuccal cups of the permanent first molars.
Arch perimeter	Perimeter between the mesial aspect of the first molars, over the contact points of the posterior teeth, and the incisal edge of the anteriors.

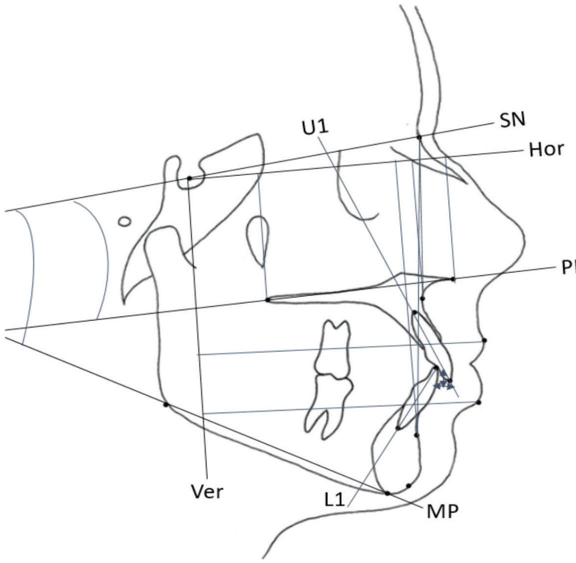

Figure 6. Lateral cephalometric measurements

significantly higher in Area 1 in particular (131.72±66.14 mm^2; p<0.01), as shown in Table 3. In addition, only slight increases observed in area measurements were found to be significant (p<0.01, p<0.05) in group 2, as shown in Table 4. Significant increases were observed in all area measurements in group 1 compared with group 2 (Area 1, 117.25 mm^2, area 2, 27.78 mm^2, area 3, 33.67 mm^2, and area 4, 53.28 mm^2; p<0.001), as shown in Table 5.

The upper and lower intermolar widths and arch perimeter measurements increased significantly from T1 to T2 in group 1 (p<0.01) (Table 3). When these changes were compared between the groups, group 1 showed greater changes in the upper (2.86 mm; p<0.001) and lower intermolar widths (1.26 mm; p<0.01) and arch perimeter (3.31 mm; p<0.001), as shown in Table 5. A significant increase from T1 to T2 in the molar angulation measurement in group 1 (1.97°; p<0.05) was observed, as shown in Table 3. A significant difference was found in the molar angulation measurement between group 1 and group 2 (2.06°; p<0.05), as shown in Table 5.

Table 2. The lateral cephalometric measurements

SNA	Angle between the Sella-Nasion and NA lines
A-Hor (mm)	The perpendicular distance between points A and the horizontal reference plane
ANS-Hor (mm)	The perpendicular distance between the point ANS and the horizontal reference plane
PNS-Hor (mm)	The perpendicular distance between the point PNS and the horizontal reference plane
SN/PP	Angle between the Sella-Nasion and palatal planes
SNB	The angle between the SN and NB lines
B-Hor (mm)	The perpendicular distance between points B and the horizontal reference plane
SN/MP	Angle between the mandibular plane (Gonion-Gnathion) and the SN
ANB	The angle between the NA and NB lines
Overjet	Horizontal distance between the incisor points of the maxillary and mandibular central incisors
Overbite	Horizontal distance between the incisor points of the maxillary and mandibular central incisors
U1/SN	Angle between the axis of the maxillary anterior incisor and the Sella sinus
U1/PP	Angle between the axis of the maxillary anterior incisor and the palatal plane
IMPA	Angle between the mandibular plane and the axis of the mandibular central incisor
UL-Ver (mm)	The perpendicular distance between the most anterior dot and the convexity of the upper lip to the vertikal reference plane
UL-Ver (mm)	The perpendicular distance between the most anterior dot and the convexity of the lower lip to the vertikal reference plane

Table 3. Analysis of skeletal and dental changes (Wilcoxon signed-rank test) observed in the T1-T2 time interval in the treatment group

	T1	T2	t	p
Maxillary skeletal measurements				
SNA	78.50±2.50	78.58±2.53	0.08	
A-Hor (mm)	30.06±1.55	31.04±1.48	0.98	**
ANS-Hor (mm)	26.39±2.22	27.02±1.48	0.63	*
PNS-Hor (mm)	26.49±1.32	27.10±1.29	0.61	*
SN/PP	7.08±2.71	7±2.62	-0.08	
Mandibular skeletal measurements				
SNB	77.83±2.75	78±2.73	0.16	
B-Hor (mm)	56.99±2.55	57.55±2.13	0.56	*
SN/MP	34.50±5.17	34.75±5.34	0.25	

Table 3. Continued

	T1	T2	t	p
Maxillomandibular measurements				
ANB	0.66±1.66	0.58±1.31	-0.08	
Dentoalveolar measurements				
Overjet	1.03±1.52	1.02±1.49	-0.01	
Overbite	0.20±2.22	0.35±2.08	0.15	
U1/SN	104.52±4.28	104.41±4.18	-0.10	
U1/PP	111.75±4.59	111.58±4.60	-0.16	
IMPA	92.08±7.95	92.08±7.92	0	
Soft tissue measurements				
UL-Ver (mm)	53.92±3.30	55±3.23	1.08	
LL-Ver (mm)	53.33±3.71	53.30±3.70	-0.03	
Digital model measurements				
Area 1	904.10±116.59	1035.83±87.07	131.72	**
Area 2	165.16±18.98	194.39±15.92	29.23	**
Area 3	229.10±29.39	265.16±30.70	36.06	**
Area 4	390.91±68.66	452.62±61.21	61.71	**
Upper intermolar width	49.61±4.29	52.62±4.46	3.01	**
Lower intermolar width	45.81±2.55	47.19±2.57	1.37	**
Molar angulation	120.09±9.29	122.07±9.34	1.97	*
Palatal depth	12.52±1.20	12.60±1.08	0.08	
Arch length	27.22±1.54	27.22±1.59	0	
Arch perimeter	73.01±2.83	76.39±3.20	3.37	**

*p<0.05, **p<0.01
T1, preobservation; T2, postobservation; t, difference

Table 4. Analysis of skeletal and dental changes (Wilcoxon signed-rank test) observed in the T1-T2 time interval in the control group

	T1	T2	t	p
Maxillary skeletal measures				
SNA	79.08±1.72	79.33±1.66	0.25	
A-Hor (mm)	31.06±2.76	31.06±2.66	0.01	
ANS-Hor (mm)	27.84 ±2.45	28.02±2.30	0.18	
PNS-Hor (mm)	27.63±2.26	27.45±2.15	-0.18	
SN/PP	9±2.29	9.08±2.53	0.08	
Mandibular skeletal measures				
SNB	76.75±2.80	76.66±3.17	-0.08	
B-Hor (mm)	56.27±3.71	56.43±3.46	0.16	
SN/MP	34.66±5.59	34.83±5.71	0.16	
Maxillomandibular measures				
ANB	2.33±2.14	2.66±2.67	0.33	
Dentoalveolar measures				
Overjet	2.25±1.50	2.15±1.58	-0.1	
Overbite	1.30±1.35	1.46±1.27	0.15	
U1/SN	104.35±5.50	104.24±5.65	-0.10	
U1/PP	114.66±7.11	114.50±6.93	-0.16	
IMPA	95.33±6.51	95.25±6.01	-0.08	

Table 4. Continued

	T1	T2	t	p
Soft tissue measurements				
UL-Ver (mm)	57.13±4.38	57.19±4.24	0.05	
LL-Ver (mm)	55.74±4.55	55.89±4.61	0.15	
Digital model measures				
Area 1	935.83±115.87	950.31±112.74	14.47	**
Area 2	173.04±27.39	174.49±27.60	1.45	*
Area 3	237.24±36.07	239.63±36.21	2.39	**
Area 4	422.67±47.39	431.10±46.49	8.43	**
Upper intermolar width	52.10±4.03	52.26±3.31	0.15	
Lower intermolar width	45.80±3.27	45.92±2.57	0.11	
Molar angulation	126.08±4.79	125.99±4.49	-0.09	
Palatal depth	13.16±2.41	13.26±2.28	0.09	
Arch length	26.62±2.74	26.59±2.73	-0.02	
Arch perimeter	74.63±5.86	74.70±6.04	0.06	

T1, pretreatment; T2, posttreatment; t, difference; *p<0.05, **p<0.01

Table 5. Analysis of comparisons (Mann-Whitney U test, p<0.05) of T1-T2 changes in the treated group vs. T1-T2 changes in the control group

	Treatment group		Control group		TG-CG T1-T2	
	Mean±SD		Mean±SD		Net difference	p
Maxillary skeletal measurements						
SNA	0.08±0.51		0.25±0.45		-0.17	
A-Hor (mm)	0.98±0.56		0.01±0.19		0.97	***
ANS-Hor (mm)	0.63±0.93		0.18±0.39		0.45	
PNS-Hor (mm)	0.61±0.76		-0.18±0.40		0.79	**
SN/PP	-0.08±0.28		0.08±0.66		-0.16	
Mandibular skeletal measurements						
SNB	0.16±0.57		-0.08±0.90		0.24	
B-Hor (mm)	0.56±1.20		0.16±0.47		0.40	*
SN/MP	0.25±0.45		0.16±0.57		0.09	
Maxillomandibular measurements						
ANB	-0.08±0.66		0.33±0.98		-0.41	
Dentoalveolar measurements						
Overjet	-0.01	0.06	-0.1	0.15	0.99	*
Overbite	0.15	0.25	0.15	0.35	0	
U1/SN	-0.10	0.22	-0.10	0.55	0	
U1/PP	-0.16	0.57	-0.16	1.19	0	
IMPA	0	0.85	-0.08	0.79	0.08	
Soft tissue measurements						
UL-Ver (mm)	1.08	1.44	0.05	0.47	1.03	
LL-Ver (mm)	-0.03	0.12	0.15	0.41	-0.18	
Digital model measurements						
Area 1	131.72	66.14	14.47	10.27	117.25	***
Area 2	29.23	11.01	1.45	1.34	27.78	***
Area 3	36.06	14.50	2.39	2.59	33.67	***
Area 4	61.71	27.97	8.43	6.56	53.28	***
Upper intermolar width	3.01	1.09	0.15	0.31	2.86	***

Table 5. Continued

	Treatment group		Control group		TG-CG T1-T2	
	Mean±SD		Mean±SD		Net difference	p
Lower intermolar width	1.37	0.85	0.11	0.23	1.26	**
Molar angulation	1.97	2.44	-0.09	0.80	2.06	*
Palatal depth	0.08	0.53	0.09	0.39	-0.01	
Arch length	0	0.25	-0.02	0.15	0.02	
Arch perimeter	3.37	1.54	0.06	0.75	3.31	***

*p<0.05, **p<0.01, ***p<0.001
T1, pretreatment; T2, posttreatment

DISCUSSION

This study aimed to confirm the effectiveness of Leaf Expander in patients who were in the early mixed dentition period and to compare the results with those of the control group. There is a lack of information in the literature in terms of the detailed evaluation of linear and areal measurements on digital models after maxillary expansion with Leaf Expanders in the control group.

Maxillary expansion in mixed dentition provides advantages in terms of tooth and skeletal changes and allows space for permanent teeth.[5,6,11] Various expansion protocols are available. The first protocol is the rapid palatal expansion (RPE) protocol, characterized by high intermittent forces applied over short periods of time, and the second protocol is the SME protocol, in which continuous lighter forces are applied over long periods of time. Therefore, SME using fixed expanders may be advantageous in terms of both lower force and cooperation in the mixed dentition period.[5,12,13]

The Leaf Expander is typically anchored by deciduous teeth, with the upper first permanent molars left to expand spontaneously.[1] Conventional fixed expansion screws are usually anchored to permanent teeth, a process that has some drawbacks, such as buccal tipping, alveolar bone resorption, root resorption, and periodontal damage to the anchorage teeth.[10-15] In addition, the Leaf Expander has the advantage of applying a constant light force as a result of NiTi sheets over conventional expansion appliances; thus, this method is easier for patients to tolerate. Patients report experiencing significantly less pain and discomfort with this appliance.[16] Parents often have difficulty turning a screw in the activation of expansion appliances. This problem can also be eliminated with Leaf Expanders. However, we aimed to observe the skeletal, dental, and soft tissue effects of expansion using the Leaf Expander and compare it with the control group. To compare the expansion efficiency of the appliance with the growth effect, a control group was included in the study. For ethical reasons, the control group included normal subjects, as treatment was indicated only indications for treatment immediately after the diagnosis of maxillary discrepancy in individuals during the mixed dentition period existed.

Commonly used reference planes in cephalometric evaluation are the Sella-Nasion and Frankfort horizontal planes. Both of these approaches have certain shortcomings, which make their use a reference plane questionable.[17-19] Several authors have concluded that the natural head position (NHP) has clinically acceptable reproducibility, and it has also been documented that the horizontal reference planes (Hor) derived from the NHP registration represent a more valid craniofacial reference system.[20-22] In light of this information, we preferred to use the Hor in this study, as in previous studies.[23-25]

In this study, the position of the maxilla in the sagittal direction did not significantly change. The results for this group are similar to those of Lanteri et al.[12] The A-Hor and ANS-Hor distances, which indicate the vertical position of the maxilla, increased significantly among treated patients. At the end of the study, the change in the A-Hor distance was significantly higher in the treatment group than in the untreated group, but the changes in the ANS-Hor distance did not differ significantly.

Considering these values, we observed a significant vertical downward displacement after the treatment. In addition, the PNS point of our treated patients was significantly displaced downward (0.61 mm), similar to the ANS point. Moreover, the change in the PNS-Hor distance was significantly higher in the treatment group than in the control group (T2-T1). The absence of a significant change in the SN/PP angle in the treatment group could be associated with a similar downward displacement of the PNS and ANS points (+0.61 and +0.63 mm, respectively). This finding can be explained by the fact that the palatal plane descends almost parallel after expansion and does not exhibit any rotational changes. Similar to the study of Lanteri et al.,[12] increases in SNB, ANB, and SN/MP angles were not significant in the current study, and no difference was found compared with the control group. The B-Hor distance, which shows the vertical position of the mandible, was significantly increased after treatment. In addition, the change in the B-Hor distance of the treatment group was found to be significantly higher than that of the control group. This finding suggests that the downward movement of the maxilla after SME in the early period and the cusp relationships of the maxillary posterior teeth cause vertical size increases in the mandible.

There were no significant changes in the dentoalveolar values of either group in the measurements on the lateral cephalometric radiographs. When the changes in dentoalveolar measurements were compared between the groups, the reduction in overjet was significantly greater in the control group than in the treatment group. Contrary to the findings of the current study, Akkaya et al.[26] found a significant increase in the amount of overjet in patients who underwent SME. However, the authors detected no significant change in overbite levels, which is similar to the findings of the present study. Because patients are in the early mixed dentition period, a slight increase in the amount of overbite can be expected as the incisors continue to erupt. However, we hypothesize that the increase in overbite levels is compensated by the buccal tipping of posterior teeth. Contrary to a study[12] that showed significant retroclination of the upper incisors after expansion with the Leaf Expander, no change was observed in the inclination of the upper incisors in the current study. Küçükkeleş and Ceylanoğlu[27] reported that the pressure of the upper lip on the buccal side of the upper incisors significantly increased after maxillary expansion. Conversely, tongue pressure on the lingual side of the upper incisor significantly decreased following palatal expansion. This finding agrees with findings from a study by Proffit[28] who reported the theory of equilibrium, which demonstrates the natural alignment and retraction of the maxillary incisors. Moreover, Grob[29] reported retroclination of the upper incisors during diastema closure resulting from RPE. In this study, it was estimated that the inclination values of the upper incisors did not change due to the predominance of the dental expansion effect of the Leaf Expander.

In previous studies, significant increases in the total palatal area were observed in the treatment group after SME in the early period, similar to the current study's findings.[30,31] Although no increase was observed in the total palatal area in the control group in the study by Bukhari et al.[30], the increase in all area measurements was found to be significant in this study. Primožic et al.[31] Explained the increase in the total palatal area due to the increase in transversal dimensions with the opening of the midpalatal suture after expansion. In the treatment group, Area 4 showed a greater increase than Areas 2 and 3. This finding can be explained by the fact that the increase occurred as a result of anchoring the deciduous second molars with the Leaf Expander. Likewise, the greater increase in Area 4 relative to the other areas in the control group could be explained by the fact that the transverse dimension increases less anteriorly and more posteriorly in patients during the growth period due to sutural growth. The increase in all area measurements was significantly higher in the treatment group than in the control group. Aside from the opening of the midpalatal suture, the movements in the teeth during expansion are also thought to be effective in terms of increasing the palatal area. Because the individuals in the control group were in the mixed dentition period, the increases in all palatal areas were significant.

Lanteri et al.[32] reported a significant increase in upper intermolar width in patients with unilateral posterior crossbite after treatment with Leaf Expander, which was similar to our findings. The increase in upper intermolar width was significantly greater in the treatment group than in the control group. In the present study, the significant increase in the width of the permanent first molars (despite the anchoring of the Leaf Expander from the deciduous second molars) could be due to early application of the SME protocol, which produced minimal skeletal effects and moved the permanent first molars buccally in the transverse direction. Furthermore, a statistically significant increase in the lower intermolar width was observed in the treatment group. However, unlike our findings, Lanteri et al.[32] reported no significant change (-0.02 mm) in the lower intermolar width among patients treated with the Leaf Expander. The increase in the lower intermolar width was significantly greater in the treatment group than in the control group. Cossellu et al.[33] reported that the increase in the lower intermolar width (1.24 mm) was lower in the group treated with the Leaf Expander compared with the group using the Haas appliance (1.43 mm), although the difference remained significant compared with the beginning of the treatment. This finding may be explained by the fact that the increase in the lower intermolar width as a result of treatment could have occurred with buccal tipping due to an increase in the upper intermolar width due to cusp relationships.

Although permanent first molars were not used as an anchorage source with the Leaf Expander, a significant increase in permanent molar angulation measurements was observed in the treatment group. However, Kartalian et al.[34] reported no statistically significant buccal tipping in posterior teeth after expansion.

Although Ladner and Muhl[35] reported an increase in palatal depth due to continued eruption of teeth after both SME and RPE, no significant changes were observed in our study. This finding can be explained by the fact that the measurement was performed after the passive expansion period rather than immediately after the active expansion period. This finding can be explained by the fact that although the depth decreased with the downward movement of the palatal processes after expansion, no significant change due to continued eruption of the teeth during treatment was observed.

In addition, we also found no significant changes in arch length between the groups. Wong et al.[36] the arch length measurements after applying a slow expansion protocol between treated and untreated patients with unilateral posterior crossbite. Similar to our findings, the authors did not detect any significant difference between the two groups in terms of arch length measurements. The absence of change in arch depth can be explained by the absence of a significant decrease in the inclination of the upper incisors. Akkaya et al.[26] examined the changes in arch perimeter between patients who underwent SME and RPE. Results showed significant increases in both groups, although no significant difference was found between the two groups.

Study Limitations

The lack of long-term follow-up was the most significant limitation of this study. In addition, more studies with long-term follow-up and comparisons with traditional expansion screw systems are needed in the future.

CONCLUSION

The NiTi memory Leaf Expander is a comfortable alternative to conventional RPE screws for maxillary expansion in mixed dentition cases. Significantly greater transversal width and area measurements were observed in treated patients compared with controls. The increase in maxillary intermolar width after expansion also resulted in an increase in lower intermolar width due to the cup relationship. Digital model area measurements showed that the Leaf expansion appliance provided skeletal and dental effects during the mixed dentition period.

Ethics

Ethics Committee Approval: We obtained the ethics committee report from the Karadeniz Technical University Faculty of Medicine of Scientific Research Ethics Committee (approval no.: 6, date: 28.06.2021) required for the research.

Informed Consent: Written informed consent forms were completed by all parents.

Footnotes

Author Contributions: Surgical and Medical Practices - Ö.K.; Concept - N.K.; Design - N.K.; Data Collection and/or Processing - Ö.K.; Analysis and/or Interpretation - Ö.K.; Literature Search - Ö.K., N.K.; Writing - Ö.K., N.K.

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