

Original article

Comparison of short-term effects of mini-implant-supported maxillary expansion appliance with two conventional expansion protocols

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Summary

Objective: This study evaluates the dentoskeletal effects of a mini-implant-supported maxillary expansion (MISME) appliance in comparison with two types of conventional expansion methods.

Methods: Records of 42 patients with bilateral or unilateral posterior crossbite were included in this study. The patients were divided into three groups. In group 1, four miniscrews were placed to the palatal region and an acrylic expansion device was bonded on these screws. A bonded maxillary expansion appliance was used in group 2, while a banded expansion appliance was used in group 3. Measurements from cephalometric, postero-anterior radiographs, and dental casts taken before and after expansion were evaluated statistically.

Results: ANB angle increased significantly in group 1 and 3. MISME group also showed an increase of SNA angle. Measurements regarding the vertical dimension did not change with MISME but significant posterior rotation was found in group 2 and 3. Overbite value showed a significant decrease in group 2 and 3, but remained stable in group 1. The nasal, maxillary, maxillary intermolar widths showed significant increases in all groups. The difference between MISME group and other groups in maxillary width was significant indicating more skeletal expansion in MISME group. The maxillary molars showed significant buccal tipping in group 2 and 3, while lingual tipping of molars was found in MISME group.

Conclusions: MISME can be a better alternative to bonded expansion particularly in patients with vertical growth patterns and lack of anchorage teeth.

Introduction

Maxillary deficiency is a common problem in orthodontic patients and is usually accompanied by bilateral or unilateral posterior crossbite, narrow nasal cavity, and crowding (1, 2). Expansion of the maxilla or the maxillary arch is an accepted method of treatment

that was first outlined by Angle (3) in 1860 and popularized by Haas (4) 100 years later. Rapid maxillary expansion (RME) has become a routine procedure in orthodontic clinics and numerous studies confirmed its effectiveness in orthopaedic widening of the maxilla (5–8).

Various RME appliances have been widely used in adolescents with constricted maxillary arches such as tooth-borne Hyrax,

tooth-tissue-borne Haas, or bonded RME appliances (8–12). The conventional RME appliances widen the maxillary arch mainly by separating the maxillary halves opening the midpalatal suture. Along with the desired orthopaedic effect of midpalatal suture splitting RME unavoidably elicits an orthodontic effect of buccal movement or tipping of the posterior teeth supporting the appliance (4, 7, 13). Tipping and extrusion of the posterior teeth and alveolar bending usually enhances bite opening, posterior rotation of the mandible, and also increases the tendency to relapse due to the resistance to deformation from surrounding structures (5, 13). Tooth-borne expanders, in which the forces are concentrated at the dentoalveolar area, may cause iatrogenic effects to the periodontal tissues and cause root resorption, buccal dehiscences, and gingival recession at the buccal aspects of the supporting teeth (12, 14). Haas (5), suggested that more bodily movement and less dental tipping were produced when acrylic palatal coverage was added to support the appliance. Studies have demonstrated that both tooth-tissue-borne (Haas) or bonded RME appliances reduce the undesired effects of tooth-borne devices, but still lead to limited effects on the maxillary basal bone with significant dental tipping and relapse potential (7, 9, 15, 16).

Bone-borne transpalatal distractors which have been suggested to avoid all these aforementioned problems, require an invasive surgery and besides their high cost, carry a risk of infection and root damage (17–19). Recently, implant-supported or assisted expansion devices have been suggested as an alternative method for applying forces directly to the maxilla (20–23). These methods have some disadvantages, such as the need for a minimally invasive procedure for insertion of the screws, extra cost, and failure of the implants. Selection of the palatal region for insertion of the supporting miniscrews decreases the risk of root damage and the rates of miniscrew failure, because of its superior bone quality and attached mucosa. It is also reported that screw-supported expansion appliances can also be used for patients with missing deciduous teeth or premolars with underdeveloped roots (24, 25).

The aim of this study is to evaluate the effects of a mini-implant-supported maxillary expansion (MISME) appliance that incorporates four palatal mini-implants for bone anchorage in comparison with bonded and banded maxillary appliances.

Material and methods

The sample consisted of 20 female and 22 male total of 42 patients treated in Department of Orthodontics, Faculty of Dentistry University. All patients or parents consented to the treatment procedure and this retrospective study was approved by University Institutional Review Board (Project no: D-KA10/13).

Patients with indication of maxillary expansion due to transversal maxillary deficiency with unilateral or bilateral posterior crossbite

were included in the study group. The first group of patients consisted of 14 patients (eight males and six females) who treated with an acrylic expansion appliance bonded on four screws, inserted in anterior palate. The second and third group comprised of 14 patients (eight males, six females in group 2, six males and eight females in group 2) treated with a bonded and a banded maxillary expansion appliance, respectively. The mean chronological age at the beginning of the treatment was 13.2 ± 2.1 in group 1, 12.1 ± 2.1 in group 2, and 13.4 ± 1.7 in group 3 (Table 1). Distribution of malocclusions of patients in each group is given in Table 2.

In group I, four titanium miniscrew implants (Turquoise, Medikodental, Istanbul, Turkey) measuring 1.6 mm in diameter and 7 mm in length were placed under local anaesthesia by the two authors (AAÖ, AY) of this study to provide skeletal anchorage. Before placement of the implants the palatal region was rinsed with chlorhexidine (0.12 per cent). The two anterior palatal implants were placed in the anterior palate bilaterally, 3–4 mm lateral to the suture and 3–4 mm posterior to the incisive foramen. Two posterior implants were inserted in the palatal alveolus bilaterally, between the projection of the second premolar and first molar roots. Moreover, care was given to provide enough space for the expansion screw between the implants and not to damage the roots of neighbouring teeth. A self-drilling method was used for implant placement with an approximately 60–70 degrees of angulation to the long axis of the teeth (Figure 1a).

After placement of the implants, impressions and dental casts were obtained with the mini-implants in place. On the cast, the screw heads were blocked out with wax, and the acrylic expansion appliance was constructed. A maxi or midi jackscrew was embedded in the acrylic between the first premolars as close as possible to the palate, with the resin covering the mini-implants and the surrounding palatal surface. The biggest expansion screw, which can be placed in between the implants, was selected in order to provide greater amounts of expansion.

The acrylic appliance was connected to the screw heads using cold-curing, methyl methacrylate free acrylic resin (Ufi Gel hard; Voco GmbH, Cuxhaven, Germany). Small holes were made on the appliance for the excess resin to flow out (Figure 1b).

Strict instructions were given to the patients regarding oral hygiene and no medication was prescribed.

Table 2. Distribution of malocclusions of patients in each group.

	Group I	Group II	Group III
Class I	6	11	5
Class II	3	2	7
Class III	5	1	2

Table 1. Chronological ages at the beginning of treatment (T1) and duration of expansion (days). \bar{X} : average, *s*: standard deviation, min-max: minimum and maximum values.

	Group I (n:14)	Group II (n:14)	Group III (n:14)	<i>P</i>
Age (years)				
$\bar{X} \pm s$	13.2 ± 2.1	12.1 ± 2.1	13.4 ± 1.7	0.177
Median (min–max)	12.8 (8.2–15.7)	12.0 (8.1–15.3)	13.4 (10.6–15.6)	
Duration of expansion (days)				
$\bar{D} \pm s$	87.3 ± 45.9	55.3 ± 27.0	75.5 ± 35.1	0.079
Median (min–max)	71.0 (44–206)	45.5 (28–119)	70.5 (21–150)	

In group 2, a bonded expansion appliances with acrylic coverage was constructed on the cast. The acrylic part of the appliance extended over occlusal and middle third of the vestibular surfaces of all posterior teeth. The thickness of the occlusal acrylic surface was limited to the freeway space and was in contact with all lower

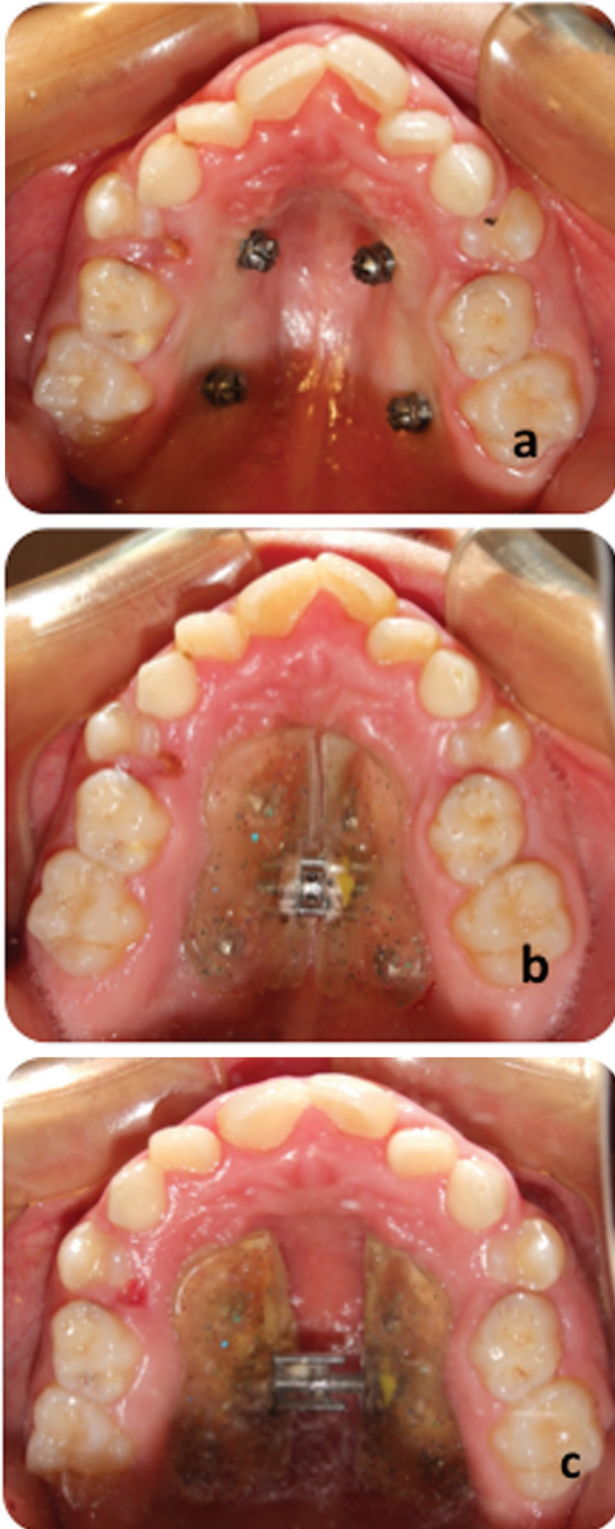


Figure 1. (a) Palatal implants, (b) MISME appliance, (c) MISME appliance after expansion. MISME, mini-implant-supported maxillary expansion.

teeth. The appliance bonded to the upper posterior teeth with glass ionomer luting cement (Ketac Cem radiopaque; 3m ESPE, Neuss, Germany). Holes were opened for the escape of excess cement during cementation (Figure 2a).

In group 3, after molar bands were placed on the upper left and right first molars, impressions and dental casts were obtained. Two banded hyrax expansion appliance (Leone; Sesto Fiorentino, Firenze, Italy) was constructed on the cast and bonded to the molar teeth with glass ionomer luting cement (Ketac Cem radiopaque; 3m ESPE) (Figure 2b).

Expansion appliances were activated with a semirapid protocol in all groups. After bonding of the expansion appliances, the patient's parents were instructed to activate it by turning the screw one turn in the morning and another turn in the evening in the first 7–10 days. After the confirmation of the opening of the suture *via* occlusal radiographs, the activation was continued once in every 3 days until the desired expansion was achieved as suggested by Işeri and Özsoy in 2004 (26). Each turn of the screw produced 0.2 mm of expansion.

Duration of the expansion depended on the amount of expansion needed. No overcorrection of the transversal relationship was done in MISME group, whereas expansion was continued until overcorrection was achieved in the bonded and banded groups.

Cephalograms, postero-anterior radiographs, and dental casts were obtained at the beginning of treatment (T1) and at the end of desired expansion (T2).

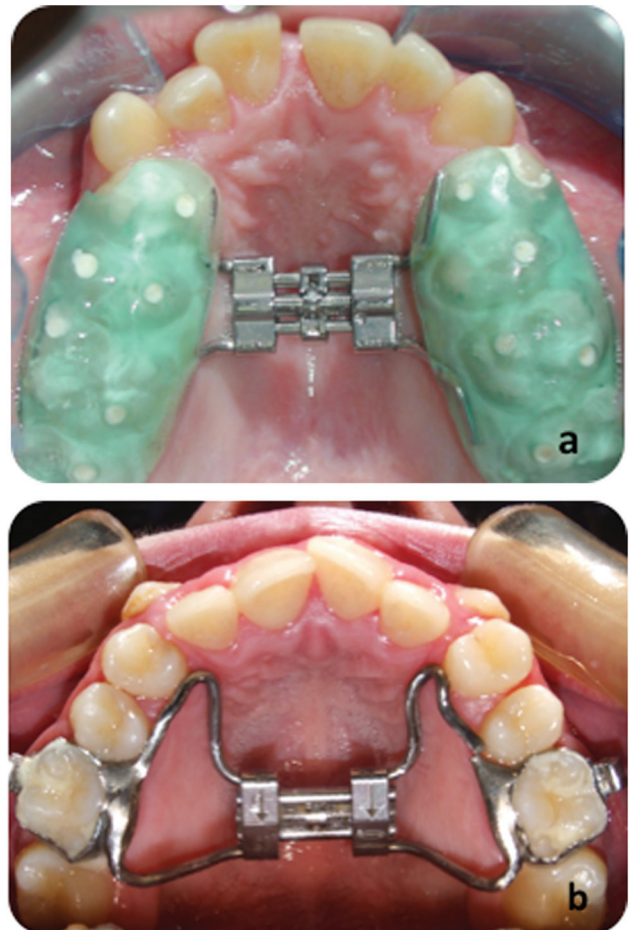


Figure 2. (a) Bonded maxillary expansion appliance used in the study. (b) Banded maxillary expansion appliance used in the study.

Cephalometric, PA, and cast analysis

Lateral cephalometric and postero-anterior radiographs were taken with the same cephalometer (Sirona, Siemens, Germany). In accordance with the As Low As Reasonably Achievable (ALARA) principles, the lowest dosage that can provide the appropriate image was chosen considering patient's age and size. The radiographs were traced and measured by one blind investigator (AY) in random order. In instances of bilateral structures, a single average tracing was made. The reference landmarks were marked simultaneously on the T1 and T2 films of each subject to obtain maximal agreement in the landmark determination. Fifteen measurements (10 angular, 1 linear) on cephalometric radiographs (Figure 3), six linear measurements on postero-anterior radiographs (Figure 4), and four measurements (one angular, three linear) on dental models (Figures 5 and 6), at a total of 27 measurements were made for each patient. The intercanine and intermolar widths were measured directly on the casts with a digital caliper, whereas the degree of tipping of the molars (molar angulation) and palatal width at the gingival height was determined from photocopy images taken after trimming the posterior of the casts up to the cusp tips of the first molars (Figure 6).

Statistical analysis

The primary aim of this study was to compare by the differences in maxillary molar angulation among groups. Total sample size of 42 (14 per group) achieve 85 per cent power to detect a difference of 3.2 degrees between the null hypothesis that both group means are 41.3 and the alternative hypothesis that the mean of another group is 38.1 with estimated group standard deviations of 3.19 and 2.78 and with a significance level (alpha) of 0.025 using a two-sided Mann-Whitney test assuming that the actual distribution is double exponential. The difference of 3.2 degrees was taken from literature (27). Sample size estimation was performed by using NCSS and PASS 2000 software.

Statistical analysis was performed using SPSS for Windows, version 11.5 (SPSS Inc., Chicago, Illinois, USA). Whether the continuous variables were normally distributed or not were determined by using Shapiro-Wilk test. Homogeneity of variances was evaluated

by Levene test. Data were shown as mean \pm standard deviation. While, the differences between pre- and post-treatment measurements regarding for normally distributed parameters were analyzed by Bonferroni-adjusted paired samples *t*-test. Wilcoxon sign rank test was used for not normally distributed parameters (treatment duration, U1-NA, U1-PP, overjet, overbite, incisors apex, and palatal width). The mean differences among groups regarding for normally distributed parameters were compared by one-way analysis of variance (ANOVA). Kruskal-Wallis test was used for not normally distributed data. When the *P* value from the one-way ANOVA or Kruskal-Wallis test are statistically significant to know which group differ from which others by using *post hoc* Tukey Tukey's honest significant difference or Conover's non-parametric multiple comparison test were used. Intraclass correlation coefficient and 95 per cent confidence intervals were calculated for evaluation of reliability. A *P* value less than 0.05 was considered statistically significant. But all possible multiple comparisons, the Bonferroni correction was applied for controlling type I error.

To calculate the error of measurements, cephalometric/posteroanterior films and study casts of 15 randomly selected patients were retraced and remeasured 2 weeks later by the same clinician. Intraclass correlation coefficients were found to be close to 1.00, thus the difference between the first and the second measurements was insignificant.

Results

Clinically successful amount of expansion was achieved in all patients (see online supplementary Figures 1 and 2). There were no

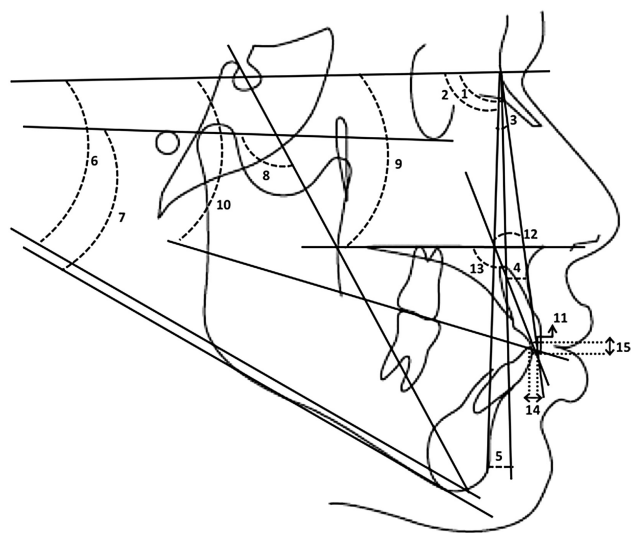


Figure 3. Lateral cephalometric measurements used in the study. 1. SNA, 2. SNB, 3. ANB, 4. Nperp-A, 5. Nperp-Pg, 6. GoGn-SN, 7. FMA, 8. Y axis, 9. SN/PP, 10. SN/OP, 11. U1-NA (mm), 12. U1-NA (degree), 13. U1-PP, 14. Overjet, 15. Overbite.

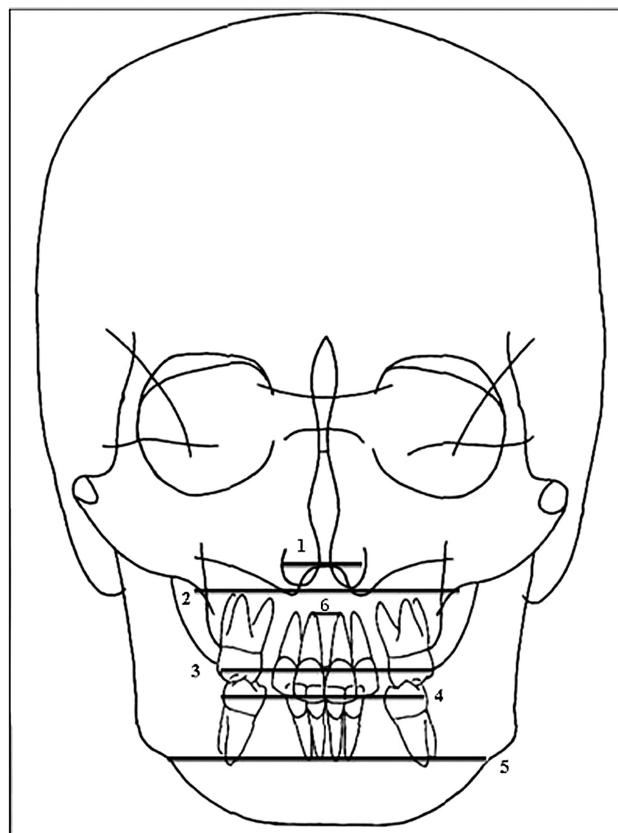


Figure 4. PA measurements used in the study. 1. Nasal cavity width, 2. Maxillary width, 3. Maxillary intermolar width, 4. Mandibular intermolar width, 5. Mandibular width, 6. Incisors apex.

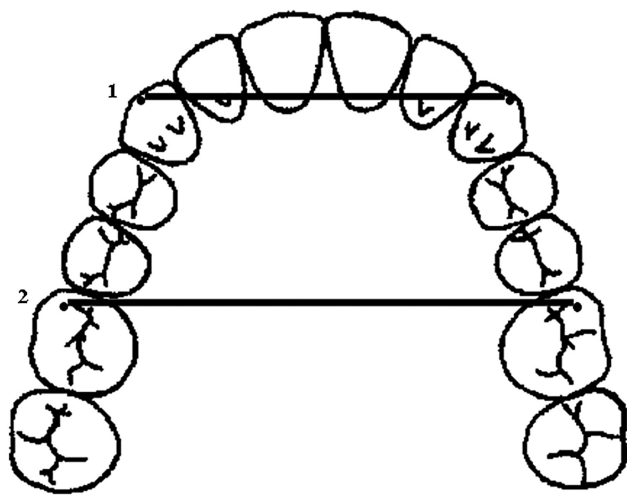


Figure 5. Dental cast measurements used in the study. 1. Intercanine width, 2. Intermolar width.

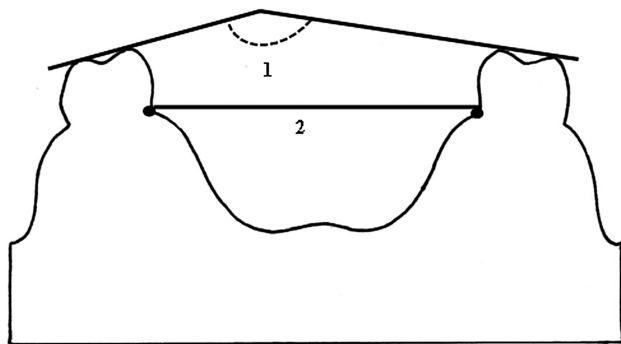


Figure 6. 1. Maxillary molar angulation, 2. Palatal width at gingival height.

dropouts or appliance failures. Only in one patient in group 1, the appliance needed to be remade because of a problem of the expansion screw and the treatment duration was elongated. No negative side effects were recorded.

Descriptive statistics for the chronological age and treatment duration, and cephalometric, PA, and model measurements at T1, T2 and treatment changes (T2-T1) obtained with maxillary expansion are given in Tables 1 and 3, respectively.

The duration of expansion was 87.3 ± 45.9 in group 1, 55.3 ± 27.0 in group 2 and 75.5 ± 35.1 in group 3 and showed no statistically significant difference between groups (Table 1).

Skeletal sagittal measurements demonstrated significant increases in ANB angle in screw-supported and banded expansion groups. SNA angle showed a significant increase demonstrating forward movement of the maxilla only in group I. While the increases in Nperp-A measurement were not statistically significant, a significant decrease in Nperp-Pg distance was found in group II and III. There was no statistically significant difference between groups concerning skeletal sagittal measurements except Nperp-Pg measurement (Table 3).

Skeletal vertical parameters showed significant increases in bonded and banded expansion groups indicating posterior rotation of the mandible. However, vertical measurements did not change in MISME group. Statistically significant differences were found between MISME and other groups regarding the vertical measures (Table 3).

None of the dentoalveolar measurements demonstrated a significant change in group I. Significant increase was found in overjet only in the third group. Overbite value showed a slight non-significant increase in group I, while there was a significant decrease in group II and III, and significant differences between MISME and the other two groups were found. Upper incisors showed a retrusion according to NA line and palatal plane, in bonded and banded expansion groups (Table 3).

PA measurements showed significant increases in the nasal width, maxillary width, and the maxillary intermolar width in all groups. The difference between MISME and other groups was statistically significant in maxillary width measurement. Mandibular width measurements increased significantly in group I and group III, while mandibular intermolar width measurements increased significantly only in group I. Incisor apex measurement showed a significant increase in all groups and significant difference between all groups (Table 3).

Model measurements also revealed expansion in the maxillary dental arch. Both the intermolar and intercanine width increased significantly in all groups. The maxillary molar angulation increased significantly in the second and third groups demonstrating buccal tipping of the first molars. The first group showed significant palatal tipping of the maxillary first molars. There was a significant difference between the MISME and the other groups. The palatal width at the gingival height increased significantly in the first and second groups. The differences between group 1-3, and 2-3 were significant (Table 3).

Discussion

Introduction of bone anchorage *via* orthodontic implants has made a great revolution in orthodontics. Therefore many reports were published on orthodontic absolute anchorage systems incorporating miniscrews, reflecting their increasing popularity and importance (28-30).

MISME is an appliance that incorporates four miniscrews for bone anchorage. Many intraoral sites can be used for mini-implant placement; however, the palate is a frequently used site because it is easily accessible, is relatively safe to work on, is less susceptible to inflammation and has good bone quantity (31). Previous studies indicate that cortical bone thickness has a strong impact on primary stability and overall success rates of implants. The midpalatal area (32), anterior paramedian area (31), palatal area between the level of the first and second premolars (33) were reported to be the most favourable areas for implant placement. There are studies indicating that the thickest bone is located 3-4 mm distal to the incisive foramen and 3 mm paramedian to the palatal suture (14, 34).

A self-drilling method was preferred during implant placement because of easier application and higher primary stability (35, 36). Angular placement of 60-70 degrees to the long axis of teeth was performed in order to avoid root damage and enable more cortical bone contact for better primary stability (37).

The primary stability of the implants is also proportional to increased length and diameter (38). Orthodontic miniscrews (1.6 mm collar diameter and 7 mm length) used in the presented appliance were shorter and/or thinner than the palatal implants, used in other bone-anchored palatal appliances (21, 30). However, two bilaterally placed implants at the anterior and two at the posterior provided sufficient anchorage without any complications. The head of the miniscrews was approximately 3.5 mm and secured with the acrylic part, which also enhanced the stability of the appliance. The MISME appliance may be classified as a bone-tissue-borne appliance as the

Table 3. The descriptive statistics of cephalometric, PA and dental cast measurements at the beginning of the treatment (T1) and at the end of expansion (T2), significance of treatment changes in groups and statistical comparison of treatment changes between groups. \bar{X} : average, D : difference, s : standard deviation.

Parameter	Group I			Group II			Group III		
	T1 $\bar{X} \pm s$	T2	P	T1 $\bar{X} \pm s$	T2 $\bar{X} \pm s$	P	T1 $\bar{X} \pm s$	T2 $\bar{X} \pm s$	P
Cephalometric measurements (n = 14)									
Skeletal measurements									
SNA (°)	77.32±5.07	78.11±5.41	0.009	77.61±4.46	77.71±4.61	0.664	81.11±3.87	81.61±3.58	0.068
SNB (°)	76.14±3.68	75.75±4.15	0.174	75.14±5.19	74.18±4.41	0.065	77.71±4.41	77.11±4.10	0.112
ANB (°)	1.25±3.26	2.36±3.64	0.006	2.46±2.61	3.54±2.14	0.046	3.39±3.00	4.50±2.81	0.004
Nperp-A (mm)	-3.19±4.29	-2.26±3.66	0.020	-2.86±4.54	-2.50±4.61	0.231	1.25±3.41	1.89±3.72	0.039
Nperp-Pg (mm)	-7.94±6.83	-7.61±5.85	0.666	-8.00±8.00	-10.07±7.42	0.004	-2.50±8.98	-4.00±9.18	0.008
GoGn-SN (°)	38.82±6.14	38.82±6.54	1.000	37.86±3.62	39.54±3.45	<0.001	34.61±5.05	36.64±5.40	<0.001
FMA (°)	32.32±6.60	32.04±6.45	0.503	30.96±4.20	33.64±4.95	0.005	26.75±5.23	28.71±5.58	<0.001
Y axis (°)	61.04±4.74	61.14±4.47	0.795	61.18±3.71	62.86±3.44	<0.001	58.54±3.57	60.14±4.27	<0.001
SN/PP (°)	8.25±2.85	8.39±2.88	0.770	8.68±4.10	8.86±4.47	0.513	8.54±2.22	8.57±2.38	0.909
SN/OP (°)	18.54±4.83	18.71±5.47	0.814	18.68±4.32	19.36±3.23	0.163	17.36±3.89	18.00±3.57	0.092
Dentoalveolar measurements									
U1i-NA (mm)	6.09±2.92	5.54±2.19	0.170	4.61±2.00	3.93±1.92	0.009	4.18±1.40	3.25±1.44	0.011
U1-NA (°)	23.75±6.87	21.61±5.68	0.039	21.64±6.61	19.04±5.42	<0.001	19.89±5.54	17.46±6.04	<0.001
U1-PP (°)	109.89±5.16	108.75±3.87	0.270	108.25±6.59	104.36±10.25	0.023	109.43±6.25	107.68±6.61	0.009
Overjet (mm)	2.54±3.29	3.36±2.45	0.024	2.68±3.83	3.75±2.52	0.258	2.54±2.36	3.32±2.27	0.005
Overbite (mm)	0.22±2.65	0.49±2.66	0.329	2.14±2.59	0.93±2.85	0.009	1.14±1.47	-0.29±2.19	0.002
PA measurements (n = 14)									
Nasal width (mm)	29.65±2.65	33.36±2.89	<0.001	29.64±2.66	32.32±3.53	<0.001	31.82±3.47	34.18±3.93	<0.001
Maxillary width (mm)	64.04±3.79	69.58±4.01	<0.001	65.79±3.70	68.93±3.76	<0.001	67.00±4.75	70.50±4.55	<0.001
Max. intermolar width (mm)	58.14±4.28	63.94±3.05	<0.001	58.54±3.19	65.00±3.80	<0.001	60.68±4.35	67.43±3.71	<0.001
Mandibular width (mm)	86.49±5.91	87.26±5.99	<0.001	86.68±6.02	87.25±5.95	0.007	88.21±5.07	88.64±5.02	0.068
Mand. intermolar width (mm)	62.77±5.30	63.56±4.87	<0.001	63.32±4.84	63.46±4.46	0.537	63.61±3.37	64.04±3.58	0.040
Incisors apex	6.81±1.79	14.63±2.68	0.002	7.96±2.27	10.43±2.67	0.003	7.39±1.11	12.04±2.82	<0.001^{†††}
Dental cast measurements (n = 12)									
Max. intermolar width (mm)	46.56±2.87	52.12±2.83	<0.001	48.96±2.25	55.66±2.44	<0.001	48.26±2.56	55.42±2.15	<0.001
Max. intercanine width (mm)	31.91±2.66	37.10±2.27	<0.001	33.30±3.16	37.50±3.87	<0.001	33.24±3.34	37.55±4.22	<0.001
Max. molar angulation (°)	151.42±14.27	154.96±12.85	<0.001	154.67±9.85	142.96±8.81	0.005	153.42±10.83	143.21±12.61	<0.001^{††}
Palatal width (mm)	31.53±3.59	36.75±2.19	0.002	32.91±2.78	38.51±4.12	0.002	32.82±3.44	34.60±1.25	0.002^{††}

According to the Bonferroni Correction $P < 0.017$ was considered as statistically significant. Statistically significant P values are shown in boldface.

[†]Group I versus group II ($P < 0.05$), ^{††}Group I versus group III ($P < 0.05$), ^{†††}Group II versus group III ($P < 0.01$).

miniscrews provide bone anchorage while the acrylic palatal coverage adds tissue support to the appliance. Moreover the forces exerted on the screws are purely compressive in nature, applying a 'push-in' force vector not a 'pull-out' one, which increases the stability.

Bioglass-coated aluminum oxide implants (39), titanium plates with osteosynthesis screws (18), and onplants with miniscrews (22) have been used to anchor bone-borne distractors. Disadvantages of these applications are their invasiveness, higher risk of infection, and expensive cost. On the other hand, MISME can be applied easily by an orthodontist and easily be constructed in a clinic laboratory. Lee *et al.* (23), Garib *et al.* (21), and Wilmes *et al.* (24) demonstrated successful results with palatal implant-assisted maxillary expansion devices. These appliances were tooth-bone-borne hybrid appliances and the patients still received a banded hyrax appliance. Increased patient comfort and oral hygiene compared to conventional tooth-borne or bone-tooth-borne appliances are the other advantages of MISME. This appliance may also be used when the patient is missing permanent posterior teeth or otherwise the health of the anchorage teeth can be compromised.

In this study, the treatment results of three maxillary expansion appliances were examined *via* cephalometric, PA radiographs, and model analysis. From the parameters demonstrating the sagittal position of the maxilla (SNA, Nperp-A), the increase in SNA was statistically significant only in MISME group. Forward movement of maxilla during the expansion period may be an advantage particularly in Class III cases with maxillary retrusion. Five of the subjects included in the study sample presented skeletal Class III malocclusion at the initiation of the treatment and spontaneous correction of the sagittal relationship was clinically evident. Haas (4) was the first to mention the forward positioning of the maxilla after expansion. Thereafter, some studies collaborated these results (9, 40), whereas other studies did not show forward displacement, instead noted variable sagittal behaviour that was clinically insignificant (13, 41).

ANB angle showed a significant increase in MISME and banded expansion group. A significant sagittal movement of the mandible was not found in MISME group, so the increase of ANB angle may be due to the anterior movement of the maxilla. Significant decrease in Nperp-Pg measurements and significant posterior rotation of the mandible may be result in increase of ANB angle in banded group.

Given the assumption that RME opens the bite, many clinicians consider an anterior open bite or a steep mandibular plane angle to be an outright contraindication to RME use. In support of this assumption, the literature is replete with studies that affirm the notion that RME opens the bite and also moves the maxilla downward and forward (5, 9). Bonded RME appliances with full occlusal coverage have been reported to have advantages in controlling the vertical dimension but they still have a significant bite-opening effect (7, 10). In this study, while skeletal vertical measurements indicating posterior rotation of the mandible showed no change in MISME group, significant increases were found in bonded and banded expansion groups. The differences between MISME and both bonded and banded groups were statistically significant.

The average decrease in overbite was 1.21 mm in bonded and 1.43 mm in banded expansion group. In MISME group, negative overbite values were noted in four of the patients at T1, seven of the positive values were only between 0 and 1.1. Eight of the subjects were high angle with GoGn-SN angle more than 39. Eventhough high-risk patients or patients who are considered as poor candidates for expansion treatment were selected; the change in overbite was not significant. Again, if the data were examined individually only three patients showed a decrease in overbite, whereas six showed an increase. Overbite values remained stable in other five patients.

As the MISME appliance is a bone-tissue-borne one, the tipping or extrusion of maxillary teeth is prevented providing usage in open bite cases.

Upper incisors showed a retrusion in bonded and banded expansion groups, while dentoalveolar measurements did not change in MISME group. Although upper incisors showed a significant retrusion, overjet significantly increased in group III. This may be due to posterior rotation of mandible.

The PA measurements revealed significant increases in the nasal, maxillary, and maxillary intermolar widths in all groups. Increase in the width of the nasal cavity after RME has been demonstrated by using PA cephalograms and computed tomography studies (4, 7, 8). Treatment results with MISME point to significant skeletal (5.54 mm) and dental (5.80 mm) expansion in a parallel manner. In bonded and banded expansion groups the greatest widening was found in the dentoalveolar area and the widening effect gradually decreased through the upper structures in a triangular pattern, as reported in previous studies with conventional tooth-borne RME appliances (5, 7, 13, 42).

A small amount of palatal tipping of maxillary molars (3.5 degrees) was found in MISME group while molar angulation measurements showed 11.75 and 10.25 degrees buccal tipping in bonded and banded groups, respectively. Kiliç *et al.* (16) reported that both tooth-borne and acrylic-bonded expanders produced significant buccal tipping of the supporting teeth, but the amount of tipping was less in the tooth-tissue-borne appliance. Christie *et al.* (8) in a cone beam computed tomography (CBCT) study also demonstrated significant buccal tipping with a bonded expansion appliance. Lagravère *et al.* (22), in a CBCT study, compared the effects of a bone-anchored expansion device with a conventional one and found similar results with two appliances. They also noted more dentoalveolar response than skeletal in both groups, whereas Tausche *et al.* (20) reported more skeletal response than dental with a bone-borne RME appliance. The palatal tipping of the molars may be due to the lack of tooth support of the MISME appliance. The movement of the molars without buccal tipping may reduce the risk of negative periodontal sequelae such as gingival recession or root resorption.

While the maxillary intermolar width and palatal width measured on the dental cast found very similar in screw-supported group; intermolar width increased much more than the palatal width in banded expansion group. This finding clearly demonstrates that the dental expansion is more significant compared to the skeletal expansion in this group.

The increases of intermolar (5.56 mm) and intercanine (5.20 mm) widths are similar in screw-supported group indicating a parallel dentoalveolar expansion in the antero-posterior direction. The MISME incorporates two anterior and two posterior miniscrews for anchorage and this could be the reason of the parallel dental arch expansion. In bonded and banded groups, the posterior dentition showed the greatest expansion with a gradually lessening effect towards the anterior dental arch as reported previously (11).

A number of researchers have considered the stability of conventional RME therapies. These studies claim that the degree of relapse might be related to such factors as age of the patient, rate of expansion, design of the device, length of the retention phase, severity of the maxillary collapse and response of the midpalatal suture and surrounding structures of the maxilla, cooperation during the retention period, and adaptation of the soft tissues (13, 42, 43). Researches have proven the stability of RME, but overcorrection and a retention phase of 3 months is suggested. The buccolingual tipping should be corrected and the overexpansion be reduced in the fixed appliance stage. The MISME appliance was activated until the

desired expansion was attained whereas expansion was continued until overcorrection was achieved in the bonded and banded expansion groups. Overcorrection of the transversal relationship was not required as the molars expanded in a bodily fashion without buccal tipping in MISME expansion group. Therefore the transversal changes are not directly comparable to the short-term changes obtained with tooth-borne expanders in which overexpansion is inevitable to overcome the relapse potential.

At the end of the expansion period all appliances were left in place for retention. After 3–6 months the expansion appliance was removed and then fixed appliance therapy was initiated in bonded and banded expansion groups. Banded expansion appliances may seem like not preventing the initiation of fixed orthodontic therapy but because of buccal tipping of first molars it is not possible to make an accurate levelling with the appliance in place. The MISME appliance allows usage of fixed appliances at the same time so there is no need to wait for a retention period. Elimination of the retention phase will also shorten the total treatment duration. The appliance was removed 3–6 months after initiation of fixed appliance therapy, when rigid rectangular arch wires were applied. Removal of the appliance was quite easy under topical and/or infiltrative anaesthesia and only a slight soft tissue irritation was observed which was later solved by routine oral maintenance.

MISME appliance should be preferred in patients with missing anchorage teeth, cases with severe skeletal discrepancies and particularly in high-angle cases. It may also be used in adult orthognathic surgery cases together with necessary corticotomies to achieve the skeletal expansion. MISME provides a better alternative for RME in adult cases as it is easily tolerated by the patients because of its smaller size.

In this study, the short-term effects of a MISME appliance were evaluated in comparison with conventional RME appliances. Given the promising results of this new system, prospective studies with larger sample sizes, integrating three-dimensional images and long-term results should be conducted.

Conclusion

The MISME showed successful expansion of the maxilla without side effects such as buccal tipping of molars and bite opening. Similar increases in dental and skeletal widths provided a parallel expansion of the maxilla. The bone-tissue-borne appliance can be considered as a simple and economic alternative to transpalatal distraction. Usage of MISME is especially suggested in patients with missing posterior teeth and high-angle cases with decreased overbite values.

Supplementary material

Supplementary material is available at *European Journal of Orthodontics* online.

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