Evaluation of skeletally anchored therapy using miniplates and micro-implants in skeletal Class III treatment

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Background/aim: To compare the outcomes of skeletally-anchored (SA) or face mask (FM) therapy in the management of patients presenting with maxillary retrognathia.
Methods: Forty-four consecutively treated maxillary retrognathic patients who underwent SA or FM therapies followed by fixed orthodontics were evaluated. Two micro-implants between the maxillary first molar and the second premolar and two mandibular miniplates were inserted to facilitate the use of Class III elastics in the SA group (23 patients). Facemasks with full occlusal-coverage acrylic appliances were applied in the FM group (21 patients). Lateral cephalometric radiographs obtained before treatment (T0), after orthopaedic treatment (T1), and after fixed orthodontic treatment (T2) were traced and 31 measurements compared.
Results: No statistically significant differences were found between the groups related to treatment duration and gender distribution. The mean age was significantly higher in the SA group (11.70±0.25 years) compared with the FM group (10.57±0.35 years) at T0. The mean ANB angle increased by 3.34° and 3.15° and the mean Wits value reduced by 6.16 mm and 4.13 mm in the FM and SA groups, respectively. Forward movement of the maxilla was similar between the groups. The vertical plane angle increased in both groups following maxillary protraction. However, it decreased in the SA group during fixed orthodontic therapy, which was contrary to what occurred in the FM group. The lower incisors were retracted/retroclined in the FM group and protracted/proclined in the SA group.
Conclusions/implications: Maxillary protraction was achieved in both groups and was maintained during fixed orthodontic therapy. Undesired lower incisor retraction and an increase of the vertical plane angle encountered with FM therapy were minimised by SA therapy.
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Introduction

The protraction of the maxilla using a face mask (FM), coupled with the associated combined effects of dentoalveolar and skeletal changes in the management of Class III cases, have been identified in previous studies.[1-4] It is well known that particular dentoalveolar and skeletal side effects are also associated with FM treatment, since the force needed for skeletal alteration is applied through the roots of the teeth, generating dental changes. Maxillary incisor proclination, mandibular incisor retroclination, maxillary molar extrusion and mesialisation, and mandibular posterior rotation have been previously reported.[3-6]

In recent years, clinicians have increasingly applied skeletal anchorage for maxillary protraction to avoid the side effects associated with tooth-borne devices.[7-13] Various mechanisms have been introduced to enhance maxillary projection by applying direct forces to the skeletal structures. Titanium miniplates have been used along with FMs for generating purely bone-borne orthopaedic forces.[9,10] The maxillary protraction methods necessitate extra-oral forces and require 12-hour daily use, which can lead to difficulties related to patient compliance.

De Clerck et al.[11] introduced a novel method for the treatment of maxillary retrognathia and achieved protraction by using intermaxillary elastics attached between miniplates placed in the maxillary zygomatic crests and in the anterior mandibular region.[14] In contrast to FM therapy, maxillary protraction using skeletal anchorage applies continuous forces to the maxilla and to the mandible.[11,14] Previous studies reported no side effects following the use of the bone-anchored system,[11,14] which increased the popularity of this intraoral protraction approach. However, this method requires four invasive surgical procedures to insert the miniplates.

The method investigated in the present study applied two micro-implants in the maxilla and two miniplates in the mandible with the aim to retrospectively compare the dentoalveolar and skeletal effects of FM therapy versus the modified skeletally anchored (SA) therapy using intermaxillary elastics to manage skeletal Class III patients with maxillary deficiency.

Materials and methods

The present retrospective study consisted of patients who presented with retrognathic maxillae, treated either by FM or SA therapy. The inclusion criteria were an absence of any craniofacial anomaly or systemic disorder, the presence of an anterior crossbite, the presence of a deficient midface and a concave profile, and the presence of a negative ANB angle or Wits appraisal identified in the cephalometric analysis. Patients treated with a combination of miniplates and micro-implants were included in the SA group. Patients exhibiting a functional Class III anomaly, and patients treated with a RME, the Alt-RAMEC protocol, 'fun-type' expanders, and Bone Anchored Maxillary Protraction (BAMP) method,[11] were excluded. Before commencement of the study, ethics committee approval was obtained, and the parents or legal guardians of all participants provided informed consent.

Consecutive patients treated with SA and FM therapy followed by fixed orthodontics were evaluated and compared. The sample size was calculated by a power analysis using G*Power software version 3.0.10 (Franz Faul, Universität Kiel, Germany). At least 20 patients per group were required to achieve 90% power. Finally, 44 patients (21 in the FM group and 23 in the SA group) whose pretreatment skeletal maturity stages were either CS2 or CS3 according to cervical vertebral maturation were included in this study.

Lateral cephalometric films obtained at the beginning of treatment (T0), at the end of the orthopaedic treatment (T1), and at the end of the fixed orthodontic treatment (T2) were compared to determine the skeletal and dentoalveolar changes after maxillary protraction and fixed orthodontic treatment.

Treatment protocols

FM Group: FMs, delivering a force of 450–500 g on each side, were applied via a full-coverage acrylic plate that was cemented to the teeth.

SA Group: Titanium miniplates (Trimed Titanium Implant Systems; Trimed, Ankara, Turkey) were surgically inserted bilaterally between the mandibular lateral incisor and canine teeth in the SA group. The tissue sutures were removed after a week and, at the same session, micro-implants (1.6 mm diameter, 10 mm length; Absoanchor, Dentos Inc., Taegu City, Korea) were inserted between the maxillary second premolar and first molar teeth. Class III elastics, delivering 75 g of force, were applied on both sides after a week of consolidation. The force was increased to 225 g on both sides after three weeks.[15] A removable appliance was used to eliminate occlusal contacts and allow bite jumping for this group (Figure 1).

After a positive overjet was obtained, the miniplates were removed to prevent adverse bone remodelling and fixed orthodontic treatment was performed for all patients. The micro-implants were retained for continued use of Class III elastics. The length of the first phase of treatment was 7.48±0.42 months and 8.81±0.25 months and fixed orthodontic treatment time was 32.62±1.22 months and 35.60±1.21 months in FM and SA groups, respectively.

Cephalometric analysis

To minimise methodologic errors, all lateral cephalograms were digitised by one examiner. NemoCeph NX computerised cephalometric analysis system and program (Nemotech, Madrid, Spain) was applied and 28 variables were selected from the customised analysis (Steiner, McNamara, Jarabak, Tweed, Gianelly) for each tracing. Reference lines and the parameters used in the present study are depicted in Figures 2a and 2b.

Statistical analyses

Descriptive statistics were calculated for all measurements at T0, T1, and T2 for both treatment groups. All statistical analyses were performed using SPSS 17.0 (SPSS Inc., IL, USA). Changes in treatment at T0, T1, and T2 for both groups were assessed with repeated measurements and pairwise comparisons. Statistical significance of comparisons was assessed with independent sample *t*-tests. Statistical significance was tested at $p < 0.05$, $p < 0.01$ and $p < 0.001$. Forty-four cephalometric radiographs were retraced to determine the method error. Correlation analysis was used to evaluate intra-observer variability, which revealed no statistically significant error.

Results

The results were generated from an evaluation of 132 lateral cephalograms of 44 patients at T0, T1, and T2. No statistically significant differences were found between the groups related to treatment duration and gender distribution. The mean age was significantly higher in the SA group (11.70±0.25 years) compared with the FM group (10.57±0.35 years) at T0 (Table I) to allow for the eruption of the premolars and therefore safe placement of the micro-implants. The mean values of the parameters for treatment periods

Figure 1. Class III elastics used between micro-implants and miniplates and removable appliance used to bite jump in SA group.

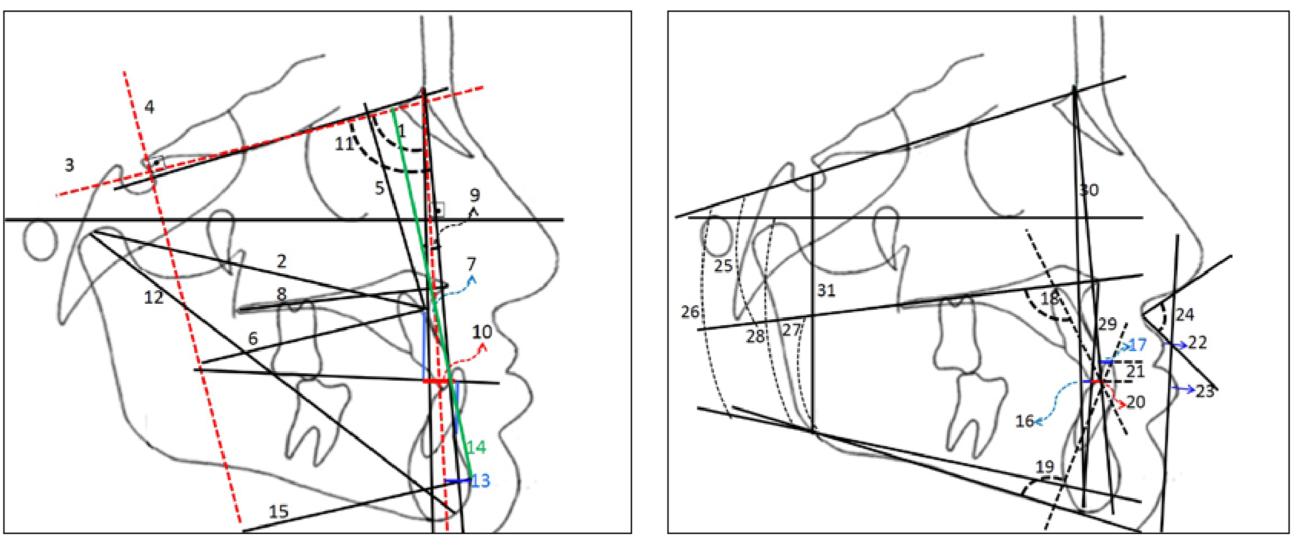

Figure 2. Linear and angular cephalometric variables used for this study. The horizontal reference line (HRL) was between the tuberculum sella and wing point of the sphenoid bone, and the vertical reference line (VRL) was a perpendicular line passing through the T point of the sphenoid bone. The horizontal and vertical perpendicular distances from the points A and Pg were calculated. a. Maxillary and Mandibular skeletal and maxillo-mandibular measurements, b. Dentoalveolar, soft tissue angular and facial height measurements.

Table I. Pretreatment age, gender distribution, treatment durations and method error (N (%); Mean±Std.Err).

	Face Mask (FM)	Skeletal Anchored (SA)	*p*
Patient (N, %)	21 (47.7)	23 (52.3)	
Female	11 (55.0)	9 (45.0)	0.345
Male	10 (41.7)	14 (58.3)	
Age (year)	10.57±0.35	11.70±0.25	0.045
Orthopedic treatment duration (month)	7.48±0.42	8.81±0.25	0.152
Fixed orthodontic treatment duration (month)	32.62±1.22	35.60±1.21	0.124
Method error – Intraclass correlation coefficient (r)	0.890-0.999		

and intragroup changes are shown in Table II and the comparisons of changes in the FM and SA groups are shown in Table III.

The cephalometric analysis showed that the mean ANB angle increased by 3.34° and 3.15° and the Wits value changed by 6.16 mm and 4.13 mm in the FM and SA groups, respectively ($p < 0.001$). Although significant increases in the mean SNA angle, Co-A, FH⊥N-A, and A-HRL values were observed (Table II) after the maxillary protraction, there were no significant differences between the groups related to these variables (Table III). The amount of mean maxillary protraction (FH⊥N-A) was 2.84 mm in the FM group and 1.93 mm in the SA group ($p < 0.001$) following the orthopaedic treatment. The changes were 3.90 and 3.61 mm in the groups during the overall treatment period and were not statistically different.

At the end of the orthopaedic phase, there were statistically significant decreases in the SNB angle, FH⊥N-Pg, and Pg-VRL values in both groups, but there were no significant differences between the groups, except relating to the Pg-VRL variable. Decreases in the SNB angle, FH⊥N-Pg, and backward movement of point Pg were significantly higher in the FM group throughout the entire treatment period (T2-T0; Table III).

An analysis of the GoGn-SN angle yielded a significant difference between the groups. The mean GoGn-SN angle increased in both groups following maxillary protraction ($p < 0.001$), but decreased in the SA group during fixed orthodontic therapy. The vertical plane angle remained stable in the SA group by the end of treatment, which made for a significant difference between the groups ($p < 0.001$). There were slight decreases in mean maxillary plane angle (SN/PP°) in both groups throughout treatment, but these changes were not statistically significant. The ratio of posterior facial height to anterior facial height (PFH/AFH) was unchanged in both groups following fixed orthodontic treatment.

When the dentoalveolar measurements were analysed, statistically significant increases in mean 1-NA value were found in both groups after orthopaedic treatment, but there was no significant difference between the groups. However, at T2, there was a significant between-group difference in the mean 1-NA value due to greater increases in the FM group compared with the SA group ($p < 0.05$). The mean U1-PP angle increased significantly by 2.55° in the FM group and 1.75° in the SA group; the between-group difference in mean U1-PP angle was not statistically significant. Furthermore, mean mandibular incisor inclination (IMPA) and mean sagittal position (1-NB) decreased in the FM group and increased in the SA group ($p < 0.001$); between-group differences were significant at both T1 ($p < 0.001$) and T2 ($p < 0.01$). The upper lip moved forward in both groups, whereas lower lip position remained unchanged in the FM group and retruded in the SA group following maxillary protraction and at T2 (Table III).

Discussion

Various skeletal anchorage-based methods for maxillary protraction have been introduced and reported.[11,14,16-21] In the present study, unlike other techniques, both micro-implants and miniplates were used for skeletal anchorage. In the maxilla, micro-implants inserted between the buccal side of the second premolar and the first molar were preferred over miniplates. In this way, anatomic limitations, such as the maxillary sinus or insufficient vertical maxillary growth, especially in patients with maxillary hypoplasia, were manageable when skeletal anchorage

Table II. Mean values at different treatment stages and intragroup changes.

Parameters	FM Group T0	FM Group T1	FM Group T2		SA Group T0	SA Group T1	SA Group T2	
Maxillary skeletal measurements	$\overline{X}$ ±Sx	$\overline{X}$ ±Sx	$\overline{X}$ ±Sx	*p*	$\overline{X}$ ±Sx	$\overline{X}$ ±Sx	$\overline{X}$ ±Sx	*p*
SNA°	77.27±0.74^{c}	79.02±0.75^{b}	79.68±0.76^{a}	***	78.35±0.72^{c}	80.00±0.74^{b}	80.87±0.74^{a}	***
Co-A (mm)	81.19±0.72^{c}	83.74±0.72^{b}	84.97±0.68^{a}	***	83.85±0.71^{c}	86.08±0.70^{b}	87.54±0.67^{a}	***
(FH⊥N)-A (mm)	-3.42±0.55^{c}	-0.61±0.57^{b}	0.46±0.55 ^{a}	***	-3.35±0.54^{c}	-1.48±0.56^{b}	0.19±0.54^{a}	***
ANS-PNS (mm)	50.22±0.53^{c}	52.41±0.56^{b}	53.16±0.58^{a}	***	51.52±0.52^{c}	52.64±0.54^{b}	54.00±0.56^{a}	***
A- HRL (mm)	52.73±0.67^{c}	54.13±0.65^{b}	55.56±0.63^{a}	***	56.64±0.65^{c}	58.04±0.64^{b}	59.33±0.61^{a}	***
A-VRL (mm)	50.97±0.48^{c}	51.94±0.51^{b}	53.04±0.55^{a}	***	56.58±0.47^{c}	57.81±0.50^{b}	58.45±0.54^{a}	***
Mandibular skeletal measurements								
SNB°	79.26±0.61^{a}	77.63±0.70^{b}	77.64±0.69^{b}	***	80.44±0.60^{a}	78.89±0.68^{c}	79.89±0.67^{b}	***
Co-Gn (mm)	112.69±0.83^{c}	114.06±0.87^{b}	114.57±0.85^{a}	***	116.38±0.86^{c}	118.01±0.85^{b}	119.26±0.83^{a}	***
(FH⊥N)-Pg (mm)	-1.49±0.91 ^{a}	-4.10±0.82^{b}	-4.13±0.81^{b}	***	-0.84±0.89^{a}	-3.28±0.81^{b}	-1.06±0.79^{a}	*
Pg-HRL (mm)	103.40±0.83^{c}	106.81±0.83^{b}	108.86±0.90^{a}	***	100.29±0.81^{c}	103.33±0.81^{b}	105.71±0.88^{a}	***
Pg-VRL (mm)	53.34±1.26 ^{a}	50.09±1.27^{b}	49.89±1.33^{b}	***	51.09±1.23^{a}	49.43±1.24^{b}	49.61±1.30^{b}	***
Maxillo-mandibular measurements								
ANB °	-1.91±0.39^{c}	1.42±0.39^{b}	1.93±0.41^{a}	***	-2.03±0.3^{b}	1.12±0.36^{a}	1.03±0.40^{a}	***
Witts	-7.23±0.52^{b}	-1.12±0.52^{a}	-1.94±0.49^{a}	***	-7.16±0.51^{b}	-3.04±0.51^{a}	-2.86±0.48^{a}	***
Dentoalveolar measurements								
1-NA (mm)	2.63±0.54^{c}	4.30±0.41^{b}	5.44±0.31^{a}	***	3.78±0.48^{b}	4.59±0.39^{a}	5.13±0.34^{a}	***
1-NB (mm)	3.21±0.46^{b}	1.65±0.45^{c}	4.58±0.47^{a}	***	3.92±0.42^{b}	5.01±0.43^{a}	4.17±0.46^{b}	***
U1/PP°	110.12±1.37^{c}	112.70±1.22^{b}	114.84±1.19^{a}	***	113.34±1.34^{c}	114.97±1.20^{b}	116.40±1.16^{a}	***
IMPA°	82.83±1.29^{b}	80.31±1.26^{c}	85.04±1.48^{a}	***	88.01±1.26^{b}	89.80±1.23^{a}	88.50±1.45^{ab}	*
Overjet (mm)	-3.06±0.37^{c}	4.49±0.39^{a}	2.89±0.23^{b}	***	-3.00±0.36^{c}	1.00±0.38^{b}	2.49±0.23^{a}	***
Overbite (mm)	2.74±0.59^{a}	1.20±0.51^{b}	0.89±0.23^{b}	*	3.34±0.58^{a}	0.28±0.50^{c}	1.30±1.12^{b}	***
Soft tissue measurements								
UL-S (mm)	-2.65±0.47^{c}	0.42±0.44^{a}	-1.25±0.43^{b}	***	-2.30±0.46^{b}	-1.14±0.43^{a}	-1.32±0.42^{a}	**
LL-S (mm)	0.97±0.54	1.14±0.54	0.81±0.53	NS	1.77±0.52^{a}	0.66±0.53^{b}	0.09±0.52^{b}	**
Nasolabial angle	111.54±8.76^{a}	109.83±10.21^{ab}	106.67±11.66^{b}	*	110.33±11.16	111.38±9.05	109.86±9.67	NS
Vertical plane measurements								
SN/PP°	10.29±0.64^{a}	9.58±0.67^{b}	9.60±0.78^{b}	**	10.42±0.62^{a}	9.81±0.65^{b}	8.96±0.77^{b}	**
GoGn/SN°	34.95±0.87^{b}	36.48±0.82^{a}	36.36±0.89^{a}	***	33.08±0.85^{b}	34.57±0.80^{a}	32.85±0.87^{b}	***
PP/MP°	21.03±0.92^{b}	22.57±0.87^{a}	21.88±1.07^{ab}	**	17.98±0.90^{b}	20.75±0.85^{a}	19.20±1.05^{b}	***
FMA°	28.25±1.09^{b}	29.65±1.00^{a}	29.49±1.00^{a}	**	29.12±0.97^{a}	26.87±0.97^{b}	29.12±1.07^{a}	***
Facial height measurements								
ANS-Me (mm)	63.75±1.00^{b}	68.45±1.09^{a}	69.05±1.30^{a}	***	63.41±0.98^{c}	68.21±1.06^{b}	70.05±1.27^{a}	***
PFH/AFH	64.89±0.87^{a}	64.41±0.77^{ab}	63.31±0.86^{b}	*	65.11±0.86^{a}	63.74±0.75^{b}	64.29±0.84^{b}	**

FM: face mask therapy; SA: skeletally anchored therapy. a,b,c: means with the same letters are not significantly different in each group for studied character.
NS: Not significant; *: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$

was provided. De Clerck and Proffit[22] stated that, especially in young children, the thickness and the density of the bone in the infrazygomatic crest might be insufficient for good mechanical retention of osteosynthesis screws. Therefore using micro-implants in the upper jaw may provide more flexibility for the clinicians in treating younger patients and reduce the extent of surgical involvement. The outcomes of this modified skeletal anchorage method in pre-pubertal patients were presented in a previous study, in which it was stated that successful maxillary protraction without undesired dentoalveolar effects was produced.[15]

It is well known that conventional FM treatment requires tooth anchorage and the application of approximately 400-500 g of force. Using this modified SA therapy, enough anchorage was observed because the force was applied directly on the alveolus of the maxilla. There is a common perception that miniplates are much more robust than micro-implants and that micro-implants are not capable of resisting the high forces required to remodel the circum-maxillary sutures. However, in the present study, a 225 g force applied between micro-implants in the maxilla and miniplates in the mandible allowed for maxillary protraction and a positive overjet in all patients. Miniplate failure during maxillary protraction may interrupt treatment and necessitate surgical re-insertion. Although failure of a miniplate depends on many factors, related to oral hygiene, surgeon experience, and anatomic configuration of the maxilla, based on current clinical experience, there may be a greater risk of maxillary miniplate failure during the early growth period. In the present study, 66 micro-implants were inserted, and 11 micro-implants showed mobility. Therefore, a success rate of 84% for micro-implant stability was achieved, which is in the range of micro-implant success reported in previous studies.[23-24] Micro-implant failure is one of the limitations of this technique. However, the failures are manageable through re-insertion of the micro-implant under local anesthesia at a different gingival vertical level without a surgical procedure. While this allows for uninterrupted therapy, safe micro-implant insertion depends on the eruption status of the second premolars. Furthermore, active bone turnover during the eruption of the premolars may be another contributor to micro-implant failure. These factors are limitations of this technique, particularly in patients with delayed dental eruption or early growth. In the present study, some of the patients were in the mixed dentition period, while others were in the permanent dentition. It may be preferable to begin orthopaedic treatment using the modified SA therapy during the late mixed or early permanent dentition periods. These stages may provide an advantage regarding not only safe mandibular miniplate insertion (considering the canine eruption status), but also in allowing patients to reach phase II of treatment (fixed orthodontic treatment) without waiting for orthopaedic retention.

Maxillary protraction rates between 1.5 mm and 3.8 mm have been reported for skeletal anchorage-based orthopaedic treatments, with values depending on the differing mechanics, pretreatment negative overjet, patients' growth periods, and treatment duration.[6,11,12,14-21] In the present study, the mean maxillary protraction (FH⊥N-A) was 2.84 mm in the FM group and 1.93 mm in the SA group after orthopaedic treatment, and this forward advancement improved during fixed orthodontic therapy in both groups. In contrast to previous studies that reported greater maxillary protraction with skeletal anchorage compared with FM therapy, the protraction gained in the present study was not significantly different between the groups.[6,20,25,26] The values found were within the range of maxillary protraction reported previously. Also, the ANB angle and Wits values were improved by protraction therapy in both groups, and these changes were maintained during fixed orthodontic treatment. However, forward movement of A point (A-VRL; 1.66 mm and 1.23 mm in the FM and SA groups, respectively) was found to be less than that reported elsewhere.[11,12,14,17,21] The amount of maxillary protraction may depend on the overcorrection of a negative pretreatment overjet. In the present study, the mean pretreatment negative overjet was approximately 3 mm for both groups. As the criterion for ending maxillary protraction was obtaining a positive overjet, and overjet was not overcorrected in the present study, the forward movement of A point was less than that reported previously.[11,12,14,17] Significant restraining effects at Pg point were observed, with a noted decrease in the SNB angle. Soft tissue profiles were improved in all patients due, in part, to the favourable skeletal modifications of the maxilla and the corresponding dentoalveolar changes. In addition, soft tissue balance was maintained during fixed orthodontic treatment.

Table III. Mean differences between time periods and comparisons between the groups.

Parameters	FM Group T1-T0	FM Group T2-T1	FM Group T2-T0	SA Group T1-T0	SA Group T2-T1	SA Group T2-T0	FM-SA difference T1-T0	FM-SA difference T2-T1	FM-SA difference T2-T0
Maxillary skeletal measurements	$\overline{X}$ ±Sx	$\overline{X}$ ±Sx	$\overline{X}$ ±Sx	$\overline{X}$ ±Sx	$\overline{X}$ ±Sx	$\overline{X}$ ±Sx	*p*	*p*	*p*
SNA°	1.75±0.20	0.65±0.13	2.40±0.26	1.66±0.16	0.79±0.23	2.45±0.27	NS	NS	NS
Co-A (mm)	2.54±0.26	1.24±0.23	3.79±0.25	2.22±0.22	1.48±0.20	3.70±0.54	NS	NS	NS
(FH┴N)-A (mm)	2.84±0.37	1.06±0.24	3.90±0.37	1.93±0.32	1.67±0.39	3.61±0.39	NS	NS	NS
ANS-PNS (mm)	2.19±0.19	0.74±0.13	2.93±0.22	1.13±0.20	1.38±0.22	2.52±0.22	***	*	NS
A-HRL (mm)	1.39±0.09	1.42±0.09	2.82±0.13	1.40±0.12	1.30±0.11	2.70±0.17	NS	NS	NS
A-VRL (mm)	1.66±0.20	0.41±0.11	2.07±0.23	1.23±0.14	0.64±0.14	1.87±0.21	NS	NS	NS
Mandibular skeletal measurements									
SNB°	-1.63±0.18	0.01±0.14	-1.61±0.17	-1.55±0.21	0.94±0.20	-0.60±0.29	NS	***	**
Co-Gn (mm)	1.34±1.18	0.51±0.07	1.86±0.21	1.56±0.20	1.30±0.13	2.86±0.22	NS	***	**
(FH┴N)-Pg (mm)	-2.59±0.44	-0.02±0.10	-2.61±0.49	-2.30±0.71	2.06±0.85	-0.23±0.81	NS	*	*
Pg-HRL (mm)	3.42±0.17	2.03±0.25	5.46±0.32	3.06±0.15	2.35±0.11	5.41±0.20	NS	NS	NS
Pg-VRL (mm)	-3.24±0.17	-0.17±0.18	-3.42±0.25	-1.60±0.20	0.12±0.27	-1.47±0.33	***	NS	***
Maxillo-mandibular measurements									
ANB °	3.34±0.24	0.50±0.22	3.85±0.29	3.15±0.25	-0.08±0.25	3.06±0.24	NS	NS	NS
Witts	6.16±0.52	-0.83±0.47	5.32±0.62	4.13±0.48	0.16±0.36	4.30±0.49	**	NS	NS
Dentoalveolar measurements									
1-NA (mm)	1.67±0.34	1.14±0.33	2.81±0.46	0.86±0.29	0.66±0.33	1.53±0.42	NS	NS	*
1-NB (mm)	-0.56±0.30	1.93±0.35	1.37±0.42	1.05±0.23	-0.77±0.30	0.28±0.35	***	***	**
U1/PP°	2.55±0.54	2.08±0.77	4.63±0.93	1.75±0.59	1.63±0.59	3.39±0.67	NS	NS	NS
IMPA°	-2.50±0.62	4.77±0.88	2.26±0.99	1.76±0.57	-1.16±0.65	0.60±0.81	***	***	**
Overjet (mm)	7.57±0.42	-1.61±0.52	5.95±0.45	4.12±0.40	1.50±0.35	5.62±0.35	***	***	NS
Overbite (mm)	-1.55±0.60	-0.30±0.69	-1.85±0.73	-2.98±0.39	0.95±0.28	-2.03±0.40	*	NS	NS
Soft tissue measurements									
UL-S (mm)	3.10±0.45	-1.66±0.37	1.43±0.41	1.20±0.28	-0.19±0.42	1.01±0.44	***	*	NS
LL-S (mm)	0.19±0.42	-0.33±0.35	-0.14±0.40	-1.07±0.38	-0.66±0.45	-1.73±0.42	**	NS	**
Nasolabial angle	-1.71±1.24	-3.15±1.65	-4.87±1.72	1.05±1.44	-1.52±1.65	-0.47±1.93	NS	NS	NS
Vertical plane measurements									
SN/PP°	-0.70±0.30	0.02±0.30	-0.68±0.44	-0.60±0.25	-0.88±0.44	-1.48±0.51	NS	NS	NS
GoGn/SN°	1.54±0.23	-0.13±0.21	1.40±0.26	1.37±0.34	-1.72±0.34	-0.34±0.33	NS	***	***
PP/MP°	1.54±0.44	-0.65±0.40	0.89±0.48	2.57±0.42	-1.70±0.56	0.86±0.58	NS	NS	NS
FMA°	1.39±0.27	-0.13±0.41	1.25±0.57	2.13±0.62	-2.73±0.55	-0.59±0.55	***	***	*
Facial height measurements									
ANS-Me (mm)	4.69±0.44	0.61±0.49	5.31±0.65	4.67±0.47	2.08±0.75	6.75±0.81	NS	NS	NS
PFH/AFH	-0.47±0.30	-1.06±0.67	-1.53±0.69	-1.20±0.37	0.49±0.31	-0.71±0.34	NS	*	NS

Much research has reported vertical plane angle and lower facial height increase following FM therapy.[26-27] These side effects have resulted not only from mandibular posterior rotation but also from maxillary anterior rotation, as tooth-borne appliances exert a force that is far from the centre of resistance of the maxilla. However, it has been reported that, when compared with tooth-anchored maxillary protraction, posterior rotation of the mandible can be significantly decreased by SA treatment.[6,26,28,29] Similar to previous studies and in contrast to the FM group, there was no significant change in the vertical plane angle in the SA group in the present study. Less than 1° of counterclockwise rotation of the palatal plane was observed, which was in agreement with past studies.[11,12] Although the mean vertical plane angle increased following maxillary protraction, it returned to the baseline value after fixed orthodontic treatment in the SA group. This slight posterior rotation might have resulted from an unbalanced occlusion or primary contacts following the use of an acrylic plate with elastics. This finding was significantly different from that of the FM group. Therefore, this method can be an alternative for treating maxillary retrognathia characterised by an increased vertical plane angle or vertical facial height.

In the present study, differences in lower incisor position between the FM and SA groups were observed. Lower incisor protrusion was seen in the SA group, while retrusion was noted in the FM group, which was in agreement with previous studies.[11,12,20] The lower anterior protrusion seen in SA therapies can result from the absence of a chin-cup effect on the lower incisors, since there is no need to use an extra-oral appliance. An alternative reason for the lower incisor movement may be the hooks in the miniplates, localised 2–3 cm from the labial mucosa, acting as a lip bumper.[30] The dental relationship of the incisors and the molars was improved significantly by the fixed orthodontic treatment. In the SA group, mandibular incisor protrusion and minimal maxillary incisor protrusion (relative to the FM group) after maxillary protraction provided more flexibility for the clinician to resolve arch length discrepancies with non-extraction treatment during phase II.

The modified SA method used in the present study did not require an extra-oral appliance, and patient co-operation was limited to the use of elastics. Therefore, this approach can be considered a suitable alternative for the treatment of skeletal Class III anomalies. However, the limitations of this strategy should be kept in mind. Upper second premolars and lower canine teeth must be fully erupted to allow uncomplicated insertion of the micro-implants and miniplates. Compared with other SA methods, this necessity may limit treatment indications depending on the patient's stage of dental development

Conclusion

FM treatment and the modified SA treatment using a combination of miniplates and micro-implants provided effective maxillary protraction in cases characterised by maxillary retrognathia.

The SA treatment was minimally invasive (in the maxilla) and the micro-implants had a success rate of 84%.

The side effects encountered in the tooth-borne appliances, related to mandibular incisor protrusion and increased vertical plane measurements, were not observed in the SA group.

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