Comparison of short-term effects between face mask and skeletal anchorage therapy with intermaxillary elastics in patients with maxillary retrognathia

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Summary

Introduction: The aim of this study was to compare the short-term dental and skeletal effects of a face mask (FM) with those of skeletal anchorage (SA) therapy with intermaxillary elastics in prepubertal patients with skeletal Class III malocclusion.

Methods: Fifty patients with skeletal Class III malocclusion and maxillary deficiency were divided into two groups. In the FM group, an FM was applied by a bite plate with a force of 400 g for each side. In the SA group, mini-plates were placed between mandibular lateral incisors and canines, and mini-implants were inserted between maxillary second premolars and first molars. A bite plate was inserted into the upper arch, and Class III elastics were applied with a force of 200 g between each mini-plate and mini-implant.

Results: Mean treatment durations were 0.52 ± 0.09 years for FM and 0.76 ± 0.09 years for SA. After the treatment, statistically significant increases in SNA°, ANB°, A-y, 1-NA, SnGoGn°, Co-A, Co-Gn, and A-Nperp, and reductions in SNB° and FH┴N-Pg were observed in both groups, and these changes were similar in both groups. In the FM group, 1-NB decreased significantly, and in the SA group, it increased significantly (P < 0.05).

Conclusions: The undesired dentoalveolar effects of the FM treatment were eliminated with SA treatment, except with regard to lower incisor inclination. Favourable skeletal outcomes can be achieved by SA therapies, which could be an alternative to the extraoral appliances frequently applied to treat skeletal Class III patients with maxillary deficiency.

Introduction

Skeletal Class III malocclusion is one of the most difficult malocclusions to treat in orthodontics. The prevalence of malocclusion varies within different races and ethnicities (1, 2). The incidence of Class III malocclusion ranges from 1 to 4 per cent in Caucasians (3, 4), while in Asian populations, the frequency is higher due to a large percentage of patients with maxillary deficiency (1, 5).

Class III malocclusion can entail hypoplasia of the maxilla, prognathism of the mandible, or a combination of both. The most common combination of variables is a retrusive maxilla, protrusive maxillary incisors, retrusive mandibular incisors, and a protrusive mandible (6). There are several options for the treatment of Class III malocclusions, based on their varying skeletal and dental properties. A face mask (FM) is the preferred appliance for the treatment of skeletal Class III patients with maxillary deficiency, as it stimulates...
maxillary development and prevents mandibular development (7).
However, there are many disadvantages associated with FM therapy
including a lack of aesthetics and discomfort. Many investigators
have also reported that the vertical dimension increases because of
counterclockwise rotation of the maxilla and clockwise rotation of
the mandible after FM treatment (8–10). Additionally, anchorage
problems can be encountered with tooth-borne appliances and FMs
during the mixed dentition period.

In recent years, in order to avoid these undesirable effects, some
clinicians and researchers have utilized skeletal anchorage (SA)
treatments (11, 12). There are many studies detailing the different
SA mechanisms for Class III malocclusions. Enacar et al. (13) used
titanium implants with an FM in a patient with a Class III skeletal
relationship with maxillary hypoplasia and severe oligodontia, to
achieve protraction of the maxilla. At the end of the treatment, a
significant amount of forward movement of the nasomaxillary com-
plex was detected.

Titanium mini-plates have been shown to provide absolute
anchorage for skeletal Class III treatment. In the literature, surgical
placement lateral to the nasal walls for maxillary forward movement
has been reported. Eventually, a considerable amount of forward
movement in the maxilla can be achieved with FM and SA treat-
ments (14). The effects of FM treatment with and without SA after
rapid maxillary expansion therapy have been compared, and report-
edly the disadvantages of conventional FM therapy were eliminated
with mini-plate anchorage, and efficient maxillary protraction was
achieved in a shorter treatment period (15).

De Clerck et al. (12) reported that maxillary protraction could be
achieved by intermaxillary elastics applied to mini-plates placed in
the infrayzygometric crests and anterior mandible, the bone-anchored
maxillary protraction (BAMP) method. They also reported that
titanium mini-plates facilitated the application of pure bone-borne
orthopedic forces, preventing dentoalveolar side-effects. To the best
of our knowledge, however, the use of mini-implants for maxillary
protraction has not been reported to date. This is the first study to
use a combination of mini-implants and mini-plates. The aim of
this study was to compare the short-term skeletal and dental effects
of FM and pure SA therapies in prepubertal patients with skeletal
Class III malocclusions. The null hypothesis was that there is no sig-
nificant difference in short-term treatment outcome between FM and
SA therapies.

Materials and methods
The sample size for the groups was calculated using G*Power soft-
ware (G*Power Ver. 3.0.10, Franz Faul, University of Kiel, Germany,
http://wwwpsycho.unidueseldorf.de/aap/projects/gpower, 15
December 2009). Twenty-five subjects in each group were required
to detect a clinically meaningful difference of 1 mm for the distance
from point A to line Y (passing through the tuberculum, perpendicu-
lar to the tuberculum–wing reference line) (16) with a power of 94
per cent at the 5 per cent level of significance. To account for possible
dropouts during the trial, an additional nine patients were initially
enrolled in the study. Ethical approval was obtained from the rele-
vant ethics committee for this prospective study.

Subjects
The study population was selected from prepubertal patients with
skeletal Class III malocclusions according to the following crite-
ria: (1) skeletal class III malocclusion characterized by maxillary
deficiency and/or mandibular protrusion (ANB° < 0 or Wits < 1);
(2) retrusive nasomaxillary complex, anterior crossbite, and con-
cave profile; (3) positive overbite; (4) prepubertal period evaluated
by hand-wrist radiographs; and (5) vertically normal growth pattern
(SnGoGn < 40°). Exclusion criteria were functional Class III
malocclusion, cleft lip palate, craniofacial anomalies, or syn-
dromes, previous orthodontic treatment, and more than one fail-
ure of the mini-implant. All the patients and their parents were
informed about the purposes of the study and signed an informed
consent form.

Two experienced clinicians (CA and EE) performed examina-
tions of all patients. The patients were selected by agreement of
the two clinicians and were evaluated further by cephalogram. The
facial convexity angle was measured using NemoCeph NX software
(Nemotec, Madrid, Spain) (17).

Fifty-nine individuals selected according to these criteria
were divided into two groups by patients’ treatment preferences.
Nine patients were ultimately excluded: eight due to cooperation
problems (four FM, four SA), and one due to failure of the mini-
implant more than once (in the SA group). The average age of the
FM group was 11.21 ± 1.32 years (13 f, 12 m) and that of the SA
group was 11.75 ± 1.23 years (13 f, 12 m). Based on hand-wrist
radiographs, there were 16 patients in MP3 = 7 in S, and 2 in
PP2 = stages in the FM group; and 12 in MP3 = and 13 in S stages
in the SA group.

Treatment protocols
FM treatment protocol
The FM was applied to the first group via the hooks of a removable
appliance covering all the occlusal surfaces of the posterior teeth.
The appliance was fixed to the teeth by glass ionomer cement (Voco
GmbH, Cuxhaven, Germany). Protraction elastics were directed
20°–30° downward from the occlusal plane, to deliver 400 g of force
per side, as determined by a force gauge (Correx Tension Gauge,
Haag-Street, Bern, Switzerland).

SA treatment protocol
In the SA group, I-shaped titanium mini-plates (Trimed®, Titanium
Self Tapping Screw, Ankara, Turkey) were designed to be smaller
than normal, for ease of placement, and a hook was added to facili-
tate the use of elastics (Figure 1).

A mucoperiosteal incision was made at the labial vesti-
bule between the mandibular lateral incisor and canine, and a

Figure 1. I-shaped titanium mini-plates (Trimed®, Titanium Self Tapping
Screw).
mucoperiosteal flap was elevated. Mini-plates were shaped according to the symphysis shape. During placement of the mini-plates, particular care was taken not to damage the mental foramen, lateral-canine roots, or other anatomical structures. Each mini-plate (Trimed®, Ankara, Turkey) was fixed with 2 mini-screws (diameter, 2 mm; lengths, 7 and 9 mm, Trimed®, Titanium Self Tapping Screw, Ankara, Turkey), inserted between the mandibular lateral and canine teeth under local anesthesia by the same maxillofacial surgeon (YP). The incisions were sutured after fixation. Sutures were removed after a week, and in the same session, self-drilling mini-implants (Absoanchor, Dentos Inc. Taegu City, Korea) with a diameter of 1.6 mm and length of 10 mm were applied between second premolar and first molar teeth, to be situated under the mucogingival line. Seventy-five grams of elastics-derived force was used on each side. After 3 weeks, the force was increased to 200 g on each side. A removable appliance was used to eliminate anterior crossbite, and for using a similar appliance to that used in the FM group in order to facilitate comparability (Figure 2). During treatment, six patients lost their mini-implants. In all of these patients, mini-implants were re-inserted in the same vertical line within a week, and the use of intermaxillary elastics was continued.

All patients were asked to fill in a chart indicating the number of hours they wore the appliance. Moreover, patients were asked for general compliance. Patients who wore their appliances only at night and not regularly during daytime (less than 14 hours a day) were excluded from the final analysis. All other patients used their appliances for at least 18–20 hours a day. Overjet was measured at a monthly basis in all patients. The SA treatment was continued until a positive overjet was obtained, and the FM therapy was ended once at least 2 linear overjet was achieved. Patients in the SA group continued to use elastics, until the completion of permanent dentition. Sutures were left in a chart indicating the number of hours they wore the appliance. Moreover, patients were asked for general compliance. Patients who wore their appliances only at night and not regularly during daytime (less than 14 hours a day) were excluded from the final analysis. All other patients used their appliances for at least 18–20 hours a day. Overjet was measured at a monthly basis in all patients. The SA treatment was continued until a positive overjet was obtained, and the FM therapy was ended once at least 2 mm overjet was achieved. Patients in the FM group used chincaps, and those in the SA group continued to use elastics, until the completion of permanent dentition. Subsequently, all patients were treated with fixed appliances.

Cephalometric analysis

Lateral cephalograms were obtained at the beginning (T1) and at the end (T2) of treatment in both groups. Cephalometric records were obtained under standardized conditions. Anatomical reference points were hand-traced onto orthodontic tracing paper, using a conventional light box and a 0.3 mm lead pencil. The tracings were converted to jpeg image files via a scanner (Samsung SCX-3200, Shandong, China), and traced using NemoCeph NX software (Nemotech, Madrid, Spain). All measurements were obtained by the same author (CA).

All lateral cephalograms performed at T1 and T2 were superimposed according to the total, maxillary regional, and mandibular regional structural superimposition method (18, 19). A horizontal reference plane tuberculumb wings [TW] constructed via the tuberculumb-wings line was used as the x-axis. A perpendicular line (TW-y), passing through the tuberculumb and perpendicular to the TW line served as the y-axis for the total superimposition method. A maxillary horizontal line (x-Mx) was constructed via the anterior nasal spine (ANS)–posterior nasal spine (PNS) line, and a vertical line passing through the PNS and perpendicular to x-Mx was the maxillary vertical line (y-Mx) for the maxillary superimposition method. For mandibular superimposition, a line passing through the gonion and gnathion was used as the mandibular horizontal plane (x-Md), and a vertical line passing through the gonion, perpendicular to the x-Md served as the mandibular vertical line (y-Md).

In order to evaluate skeletal, dental, and soft tissue changes, 33 linear and 10 angular measurements were used (Figures 3–7).

Statistical analysis

All statistical analyses were performed with MS Excel 2003, XLSTAT, and SPSS for Windows, version 16.0 (SPSS Inc., Chicago, Illinois, USA). The Kolmogorov–Smirnov test showed a normal distribution for all variables. The differences between pretreatment and post-treatment measurements were evaluated via the paired t-test, inter-group comparisons were analyzed via the t-test for independent groups, and P < 0.05 was considered statistically significant.

Method error

Cronbach’s reliability test was performed to detect method error. All measurements of 30 cephalograms randomly selected from the 100 cephalograms obtained during the study were repeated 1 month after the first tracing. Intra-class correlation coefficients were found to be within a range of 0.892–1.000. No statistically significant differences were found between the first and second measurements of the randomly selected cephalograms.

RESULTS

Age and gender were normally distributed, and did not differ significantly between the groups (P = 0.139). The treatment durations through the tuberculumb and perpendicular to the TW line served as the y-axis for the total superimposition method. A maxillary horizontal line (x-Mx) was constructed via the anterior nasal spine (ANS)–posterior nasal spine (PNS) line, and a vertical line passing through the PNS and perpendicular to x-Mx was the maxillary vertical line (y-Mx) for the maxillary superimposition method. For mandibular superimposition, a line passing through the gonion and gnathion was used as the mandibular horizontal plane (x-Md), and a vertical line passing through the gonion, perpendicular to the x-Md served as the mandibular vertical line (y-Md).

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**Figure 2.** Intraoral view of SA treatment.

**Figure 3.** Maxillary skeletal measurements: 1. SNA°; 2. Co-A (mm); 3. NPerp-A (mm); 4. ANS–PNS (mm); 5. SN/PP°; 6. Occl/SN°; 7. A-y; 8. A-x; 9. ANS-y; 10. ANS-x; 11. PNS-y; and 12. PNS-x.
were 0.53 ± 0.10 years in the FM group and 0.76 ± 0.09 years in the SA group and were not distributed normally. There was a significant difference in treatment duration between the groups (P < 0.001).

Inter-group comparisons of the pretreatment parameters revealed no significant differences (P > 0.05, Table 1).

Evaluation of the maxillary measurements revealed that the SNA°, Co-A, Nperp A, and ANS–PNS were increased significantly in both groups (P < 0.001). However, statistically significant differences between the groups were observed in terms of greater increases in sagittal movement of points A-y, ANS-y, and PNS-y in the SA group (P < 0.05). Minimal anterior maxillary rotation was observed in both groups according to A-x, ANS-x, and PNS-x (P > 0.05), and there were no significant differences between the groups (Table 3).

Only the SN/PP° was significantly reduced after the treatment in the SA group (P = 0.301), though there was not a statistically significant difference between the groups (P = 0.898).

The mandible displayed statistically significant downward and backward movement in both groups (SNB°, Co-Gn, Nperp-Pg; P > 0.05), but these effects were more evident in the FM group (B-y, Pg-y; P < 0.05). Both groups exhibited significant increases in SnGoGn° and B-x, and there was no significant difference between the groups (P > 0.05). Anterior, posterior, and total face heights (N-Me, S-Go, ANS-Me; P < 0.05) were increased significantly in both groups according to anterior rotation of the maxilla and posterior rotation of the mandible, and there were no significant differences in these parameters between the groups (Tables 2 and 3).

The maxillary anterior movement and mandibular posterior movement yielded significant improvements in the intermaxillary sagittal relationship. The ANB° was increased in both groups, and the inter-group difference was not statistically significant (P = 0.168). However, changes in Wits appraisal differed statistically significantly between the groups (P < 0.01). In the FM group, the increase in the occlusal plane angle was more prominent, and this might have contributed to the increase in Wits appraisal (Occl/SN°; P = 0.001).

Significant protrusion of the maxillary incisors was evident in both groups, but in the FM group all maxillary incisor measurements were at least double those of the SA group. Accordingly, statistically significant differences were observed between the groups (U1-N°, U1-N mm, U1-y; P < 0.05). With regard to the upper molar vertical position, the inter-group difference was significant due to greater extrusion in the
Table 1. Comparison of the pretreatment values (T1).

<table>
<thead>
<tr>
<th>Metric</th>
<th>FM</th>
<th>SA</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\bar{x} \pm S$ $\bar{x}$</td>
<td>$\bar{x} \pm S$ $\bar{x}$</td>
<td></td>
</tr>
<tr>
<td>SNA°</td>
<td>77.63 ± 4.74</td>
<td>78.20 ± 3.96</td>
<td>0.661</td>
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<tr>
<td>Co-A (mm)</td>
<td>82.71 ± 4.59</td>
<td>84.34 ± 3.40</td>
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<tr>
<td>Nperp-A (mm)</td>
<td>-2.96 ± 3.21</td>
<td>-2.79 ± 2.83</td>
<td>0.180</td>
</tr>
<tr>
<td>ANB°-PNS (mm)</td>
<td>31.45 ± 3.23</td>
<td>51.45 ± 2.74</td>
<td>0.996</td>
</tr>
<tr>
<td>SN/P' (mm)</td>
<td>10.27 ± 4.05</td>
<td>10.75 ± 3.01</td>
<td>0.636</td>
</tr>
<tr>
<td>Occl/SN°</td>
<td>18.28 ± 5.02</td>
<td>17.07 ± 3.20</td>
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<tr>
<td>SNA°</td>
<td>79.34 ± 4.75</td>
<td>80.16 ± 3.48</td>
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</tr>
<tr>
<td>Co-Gn (mm)</td>
<td>113.96 ± 5.44</td>
<td>115.85 ± 3.96</td>
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</tr>
<tr>
<td>Nperp-Pog (mm)</td>
<td>-2.97 ± 5.53</td>
<td>-0.77 ± 4.68</td>
<td>0.135</td>
</tr>
<tr>
<td>SN/Go (mm)</td>
<td>35.15 ± 4.41</td>
<td>33.40 ± 4.48</td>
<td>0.171</td>
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<tr>
<td>ANB°</td>
<td>-1.70 ± 2.40</td>
<td>-1.92 ± 1.76</td>
<td>0.709</td>
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<tr>
<td>Wits (mm)</td>
<td>-7.10 ± 2.64</td>
<td>-6.78 ± 2.68</td>
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<tr>
<td>S-Go (mm)</td>
<td>74.07 ± 5.85</td>
<td>76.07 ± 4.59</td>
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<tr>
<td>N-Me (mm)</td>
<td>116.50 ± 7.41</td>
<td>117.64 ± 4.77</td>
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<tr>
<td>ANS-Me (mm)</td>
<td>63.21 ± 4.55</td>
<td>63.34 ± 4.73</td>
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<tr>
<td>U1-NA (mm)</td>
<td>3.60 ± 2.48</td>
<td>3.63 ± 1.85</td>
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<tr>
<td>L1/NA°</td>
<td>23.68 ± 6.38</td>
<td>23.16 ± 5.12</td>
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<tr>
<td>L1-NB° (mm)</td>
<td>3.39 ± 1.89</td>
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<td>L1/NB°</td>
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<td>U1/P' (mm)</td>
<td>111.60 ± 5.72</td>
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<td>Overjet (mm)</td>
<td>-1.91 ± 1.59</td>
<td>-2.78 ± 1.69</td>
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<tr>
<td>Overbite (mm)</td>
<td>2.47 ± 2.69</td>
<td>3.22 ± 2.17</td>
<td>0.280</td>
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<tr>
<td>Nasolabial angle</td>
<td>108.86 ± 13.33</td>
<td>109.30 ± 10.58</td>
<td>0.898</td>
</tr>
</tbody>
</table>

Table 1. Comparison of the pretreatment values (T1).

FM group (U6-x; $P = 0.006$). The mandibular incisors showed significant protrusion in the SA group, whereas significant retrusion was evident in the FM group, and the inter-group difference was also significant (L1-NB°, L1-NB mm, FMIA°; L1-y; $P < 0.05$). Reduction of the interincisal angle was statistically significant in both groups, and the difference between the groups was not statistically significant. Neither the increase in overjet nor the reduction in overbite was statistically significant in either group, and there was no statistically significant difference between the groups (Tables 2 and 3).

In both groups, favorable changes in the soft tissue profile were achieved by the orthopedic therapy. The upper lip moved forward significantly in both groups (Ls-x, Ls-y; $P < 0.05$) but the difference was not significant between the groups. In the FM group, the lower lip was slightly retrusive due to retrusion of the mandibular incisors (Li-x; $P < 0.05$). However, there was no statistically significant difference between the groups.

Discussion

In this prospective clinical study, a new intraoral SA treatment for maxillary protraction was compared to FM treatment, which is frequently used to treat skeletal Class III malocclusion. These treatment protocols differ in terms of force application vectors, magnitude of force, and treatment duration, but they can both be applied to achieve ideal skeletal effects.

The ANB° and the Wits appraisal are the key parameters for the diagnosis of skeletal Class III malocclusion (20, 21). However, the use of ANB° has been questioned since it is sensitive to the position of the anterior cranial base and may vary according to the divergence of the jaws (22, 23). This is also the case with Wits appraisal, which can be affected by the cant of occlusal plane and by its variations due to tooth eruption (21). In this study, ANB° and Wits appraisal were used as one of the inclusion criteria to diagnose skeletal Class III malocclusion since these are commonly used parameters for cephalometric evaluation of Class III malocclusion (16, 21, 24).

Similar to this study, many other studies have evaluated skeletal parameters only (16, 24), but Angle’s Class III molar relationship is also often used to indicate Class III malocclusion (25, 26). In this study, Angle Class III molar relationship was not considered as an inclusion criterion because it could be affected by extractions, high vestibule canines, and dental crowding (27).

This present study was the first to use a combination of miniimplants and mini-plates for maxillary protraction. No untreated control group was incorporated into this study, due to the ethical considerations associated with delaying the treatment of Class III subjects (28). Total, maxillary, and mandibular regional structural superimposition methods were performed to eliminate growth and development differences among the subjects.

In the SA group, mini-plates were preferred in the mandibular anterior region due to benefits such as a variety of shapes and dimensions, high success rate, ease of adaptation to the bone, biocompatibility, low risk of root damage, high anchorage value, and the fact that they are generally well tolerated by patients (12, 24, 29). In this study, mini-plates were designed to be smaller than normal, to facilitate ease of adaptation and prevent root damage (Figure 1). Mini-plates were maintained successfully and remained quite stable during the treatment in all patients. Nonetheless, irritation of the buccal region caused by mini-plates was noted in some of the patients.

It has been stated that mini-plates and mini-implants actually function best when they are working in combination with each other (21, 24, 25). In this study, ANB° and Wits appraisal were used as one of the inclusion criteria to diagnose skeletal Class III malocclusion since these are commonly used parameters for cephalometric evaluation of Class III malocclusion (16, 21, 24).

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It has been stated that mini-plates and mini-implants actually function best when they are working in combination with each other (29). In the literature, successful results have been reported for mini-plates placed in the region of the infrrazygomatic crests (8, 12, 30). However, it is difficult to place mini-plates in some patients due to anatomical limitations, especially during the prepubertal period. Difficulty is encountered placing mini-plates in the region of the infrrazygomatic crests, particularly in the maxillary sinus, and insufficient vertical maxillary
growth can be restrictive in this area (31). In this present study, mini-implants were preferred for the maxilla. The number of flap surgeries required was reduced, as mini-plates were only used for the mandibles. Mini-implants were not preferred for the anterior region of the mandible due to close proximity to the root. It is recommended orthodontic mini-implants not exceeding 6mm in length be placed at a height of 11mm from the bone crest, between the mandibular incisor and the canine, but only with utmost care (32). It was not suitable to place a mini-implant between the mandibular lateral incisor and the canine using such conditions to apply a force of 200g.

It has been stated that forces in the physiological range could stimulate bone formation around the mini-implant (33). Melsen et al. (34) reported increase in bone density when light forces were applied in the same session as insertion. Consistent with the literature, during the first 3 weeks after the insertion of the mini-implants, 75g of elastic force was applied on each side in the present study, and thereafter it was increased to 200g. Similarly, in the BAMP method, after initially applying light force the applied force was increased (8, 12, 30).

Fifty mini-implants were inserted and 6 mini-implants were lost during treatment; a success rate of 88 per cent for mini-implant stability was obtained in the present study. This rate is consistent with previous reports. In a study investigating the stability of 260 mini-implants inserted between the second premolar and first molar, as
in the current study, reported a success rate of 84.6 per cent (33). Wiechmann et al. (35) obtained a comparatively high success of rate of 95.9 per cent in the maxillary buccal region.

Various factors affect the stability of mini-implants. Generally, the importance of implant length, implant diameter, surgical procedure, and anatomical variation has been noted (36, 37). However, it has been suggested that oral hygiene and cortical bone density are the most important factors (38–40). The reasons for mini-implant failure were not formally evaluated as part of this study. However, the clinical observation of patients exhibiting mini-implant failure suggested that poor oral hygiene may have been a contributing factor.

The SA method used in the present study has certain limitations. Upper second premolars and lower canine teeth were required to be erupted, or at least to have started erupting, for insertion of the mini-implants and mini-plate. Compared to other SA methods, this necessity may limit treatment indications according to the stage of dentition. However, given that all the patients in the SA group were almost in the permanent dentition stage, the phase 1 and phase 2 dentition. However, given that all the patients in the SA group were almost in the permanent dentition stage, the phase 1 and phase 2 intervals could be shortened. Patients could also commence fixed orthodontic treatment straight after the completion of functional treatment. Thus, it may be considered advantageous for reducing the risk of skeletal Class III relapse (41).

One of the main purposes of this study was to evaluate the effect of this new SA method on forward maxillary movement and compare it with FM treatment in this respect. Maxillary anterior displacement was evident in both treatment groups, consistent with previous studies (8, 9, 42). However, a statistically significant difference between the groups was observed, in that there was a greater increase in sagittal movement of points A and ANS in the SA group. Further, double the amount of maxillary advancement was achieved in the SA group (A-y: 2.72 mm, ANS-y: 2.07) as compared to the FM group (A-y: 1.11 mm, ANS-y: 0.96) in the present study. This difference may be associated with anchorage loss in the FM group, due to the forces being applied directly from the teeth.

The amount of forward maxillary movement observed after FM treatment in the present study is similar to that reported in previous FM studies (43, 44). In addition, many studies have reported point-A advancement by SA devices (12, 13, 15, 24). In the SA group in the present study, the amount of maxillary protraction per month (0.29 mm) was similar to that reportedly achieved via the BAMP method (0.31 mm) (41, 43). However, when the results of this study were compared with those of previously reported mini-plate in FM studies, the approximate amount of maxillary protraction (0.44 mm) was found to be lower in our SA group (15). This could be because lower forces (400 g) were applied in the current study than in the aforementioned FM and mini-plate studies (800 g) (14, 15). A significant difference has been reported when comparing a SA group with a group that underwent maxillary protraction by SA and corticotomy. Yilmaz et al. (24) achieved approximately 3.6 mm maxillary protraction in 3.8 months. This dramatically faster rate of maxillary protraction due to Le Fort I osteotomy was performed to release the maxilla under general anesthesia.

Baccetti et al. (46) showed that maxillary advancement was more marked at the ANS and at A point, yet forward movement of the maxilla was also noted at the PNS and at pterygomaxillary fissure points. Advancement of the PNS differed statistically significantly between the groups, due to the remarkable increase in the SA group. Based on this result, it might be hypothesized that the maxilla was displaced anteriorly. Nguyen et al. (45) evaluated the BAMP method by cone-beam computed tomography, and reported that the zygomas, maxilla, and midface were moved forward as a unit. In addition, the opening of circummaxillary sutures in some patients was reported in their study.

Many studies have reported maxillary counterclockwise rotation after FM therapy, and slight counterclockwise rotation was observed in both groups in this present study (SN/PP; FM: −0.36°, SA: 0.57°). This amount of maxillary rotation could be considered insignificant, clinically. This finding is similar to that of studies reporting maxillary protraction by corticotomy-assisted SA, BAMP, and FM with SA treatments (15, 24, 45). Based on negligible amounts of anterior rotation in these contexts, it has been suggested that the centre of resistance of the midface might be located posterior and inferior to that defined by Nguyen et al. (45).

Both the treatment methods conducted in this study prevented the advancement of mandibular prognathism, as has been reported in similar previous studies (12, 41, 42). Many studies have reported that effective mandibular length could be restricted by both these methods (30, 42, 47). Increases in the effective mandibular length in the SA group (2.25 mm) compared favourably to the results reported using the BAMP method (2.1 mm). Furthermore, in another study (30), an increase in effective mandibular length of 4 mm was reported in untreated individuals of a similar age to the patients in the present study, which is approximately double that observed in the SA group. Despite these results, some researchers have reported that increases in mandibular length could not be prevented (48, 49).

Significant downward and backward rotation of the mandible was evident in both groups, and it was more evident in the FM group. This rotation in the FM group might be due to the combination of a force vector applied to the chin under the condyle and extrusion of the maxillary first molars (50, 51). Similar to this study, many authors have shown significant posterior rotation by FM treatment (14, 48, 52).

In contrast to our findings, a slight anterior mandibular rotation has been associated with the BAMP method (41). These different results might be due to variation in the vertical components of the elastics. Elastics are applied distal to the first molar in the BAMP method. The vertical effect of the elastics may have been increased in this present study, due to the fact that they were applied distal to the second premolar.

The maxillomandibular relationship improved, depending on the forward movement of the maxilla and backward rotation of the mandible, in both groups. The ANB° was increased in both groups, and the inter-group difference was not statistically significant. However, the changes in Wits appraisal differed statistically significantly between the groups. The increase in the occlusal plane angle was more prominent in the FM group, and this might have contributed to the increase in Wits appraisal. As in our study, maxillomandibular improvement has been achieved by BAMP and FM with SA therapies (14, 41). Prominent increases in Wits appraisal have been reported for the BAMP method (41).

The dentoalveolar side-effects of FM with tooth-borne appliances have been reported previously by several authors (48, 52, 53). A significant protrusion of the maxillary incisors was found in the both groups in the present study, but in the FM group all maxillary incisor measurements were at least double those of the SA group (U1-NA [mm], U1/PP, U1-y). Thus, statistically significant differences were observed between the groups. The 0.92 mm protrusion in the SA group may be considered negligible, clinically. Therefore, it is reasonable to suggest that the undesired upper incisor protrusion associated with FM treatment could be minimized by the SA method used in this study.

It has been reported that FM and SA therapies can eliminate upper incisor protrusion and retrusion during maxillary protraction.
Table 3. Comparison of the changes between the groups (T2 – T1).

<table>
<thead>
<tr>
<th>Measurements</th>
<th>FM</th>
<th>SA</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNA°</td>
<td>1.34 ± 0.91</td>
<td>1.63 ± 1.30</td>
<td>0.369</td>
</tr>
<tr>
<td>Co-A (mm)</td>
<td>2.54 ± 3.17</td>
<td>3.42 ± 2.12</td>
<td>0.253</td>
</tr>
<tr>
<td>NPerp-A (mm)</td>
<td>1.61 ± 1.39</td>
<td>1.76 ± 1.72</td>
<td>0.755</td>
</tr>
<tr>
<td>ANS-PNS (mm)</td>
<td>1.60 ± 1.36</td>
<td>1.81 ± 1.37</td>
<td>0.313</td>
</tr>
<tr>
<td>SNIPP°</td>
<td>-0.36 ± 1.68</td>
<td>-0.57 ± 1.23</td>
<td>0.898</td>
</tr>
<tr>
<td>Occl/SN°</td>
<td>-2.56 ± 2.84</td>
<td>-0.04 ± 1.88</td>
<td>0.001</td>
</tr>
<tr>
<td>A − y</td>
<td>1.11 ± 1.44</td>
<td>2.07 ± 1.89</td>
<td>0.050</td>
</tr>
<tr>
<td>A − x</td>
<td>1.65 ± 1.94</td>
<td>1.40 ± 1.92</td>
<td>0.664</td>
</tr>
<tr>
<td>ANS − y</td>
<td>0.96 ± 1.82</td>
<td>1.03 ± 1.50</td>
<td>0.276</td>
</tr>
<tr>
<td>ANS − x</td>
<td>1.56 ± 1.76</td>
<td>1.10 ± 1.67</td>
<td>0.017</td>
</tr>
<tr>
<td>PNS − y</td>
<td>0.06 ± 1.11</td>
<td>1.10 ± 1.67</td>
<td>0.017</td>
</tr>
<tr>
<td>PNS − x</td>
<td>1.52 ± 0.95</td>
<td>1.82 ± 0.86</td>
<td>0.764</td>
</tr>
<tr>
<td>SNB°</td>
<td>-1.16 ± 1.30</td>
<td>-1.54 ± 1.60</td>
<td>0.352</td>
</tr>
<tr>
<td>Co-Gn (mm)</td>
<td>2.51 ± 2.52</td>
<td>2.35 ± 2.47</td>
<td>0.716</td>
</tr>
<tr>
<td>NPerp-Pog (mm)</td>
<td>-1.88 ± 3.53</td>
<td>-2.69 ± 3.83</td>
<td>0.441</td>
</tr>
<tr>
<td>SN/GoGn°</td>
<td>1.30 ± 2.11</td>
<td>1.66 ± 1.87</td>
<td>0.326</td>
</tr>
<tr>
<td>b − y</td>
<td>-3.46 ± 2.73</td>
<td>-1.49 ± 2.99</td>
<td>0.025</td>
</tr>
<tr>
<td>b − x</td>
<td>4.13 ± 2.79</td>
<td>3.62 ± 3.47</td>
<td>0.452</td>
</tr>
<tr>
<td>P − y</td>
<td>-3.73 ± 3.06</td>
<td>-1.39 ± 3.49</td>
<td>0.020</td>
</tr>
<tr>
<td>P − x</td>
<td>4.46 ± 3.05</td>
<td>3.98 ± 3.02</td>
<td>0.843</td>
</tr>
<tr>
<td>ANB°</td>
<td>2.50 ± 1.32</td>
<td>3.08 ± 1.56</td>
<td>0.168</td>
</tr>
<tr>
<td>Witts (mm)</td>
<td>5.03 ± 2.23</td>
<td>3.87 ± 2.55</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>S-Go (mm)</td>
<td>1.85 ± 3.20</td>
<td>1.74 ± 2.93</td>
<td>0.738</td>
</tr>
<tr>
<td>N-Go (mm)</td>
<td>4.59 ± 3.44</td>
<td>4.70 ± 4.12</td>
<td>0.738</td>
</tr>
<tr>
<td>ANS-Go (mm)</td>
<td>4.01 ± 2.93</td>
<td>4.18 ± 2.85</td>
<td>0.834</td>
</tr>
<tr>
<td>U1-NA (mm)</td>
<td>2.07 ± 1.25</td>
<td>1.02 ± 1.81</td>
<td>0.020</td>
</tr>
<tr>
<td>U1/NA°</td>
<td>4.89 ± 3.47</td>
<td>2.06 ± 4.23</td>
<td>0.013</td>
</tr>
<tr>
<td>U1/PP°</td>
<td>5.90 ± 3.68</td>
<td>3.01 ± 4.14</td>
<td>0.659</td>
</tr>
<tr>
<td>U1 − y</td>
<td>3.12 ± 1.55</td>
<td>0.92 ± 2.17</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>U1 − x</td>
<td>1.02 ± 1.04</td>
<td>0.96 ± 1.10</td>
<td>0.869</td>
</tr>
<tr>
<td>U6 − y</td>
<td>1.69 ± 1.72</td>
<td>0.58 ± 1.32</td>
<td>0.018</td>
</tr>
<tr>
<td>U6 − x</td>
<td>1.42 ± 1.20</td>
<td>0.59 ± 0.66</td>
<td>0.006</td>
</tr>
<tr>
<td>L1-NB (mm)</td>
<td>-0.61 ± 1.16</td>
<td>1.19 ± 1.27</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>L1/NB°</td>
<td>-2.25 ± 2.90</td>
<td>2.69 ± 3.03</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>L1 − y</td>
<td>-1.96 ± 0.81</td>
<td>1.13 ± 0.96</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>L1 − x</td>
<td>1.22 ± 0.86</td>
<td>1.46 ± 1.10</td>
<td>0.415</td>
</tr>
<tr>
<td>L6 − y</td>
<td>0.12 ± 0.72</td>
<td>0.48 ± 0.88</td>
<td>0.189</td>
</tr>
<tr>
<td>L6 − x</td>
<td>0.40 ± 0.54</td>
<td>0.79 ± 1.10</td>
<td>0.132</td>
</tr>
<tr>
<td>Overjet (mm)</td>
<td>6.03 ± 2.06</td>
<td>3.92 ± 1.89</td>
<td>0.607</td>
</tr>
<tr>
<td>Overbite (mm)</td>
<td>-1.60 ± 2.35</td>
<td>-2.76 ± 1.71</td>
<td>0.406</td>
</tr>
<tr>
<td>Nasolabial Angle</td>
<td>-0.41 ± 13.40</td>
<td>3.48 ± 9.64</td>
<td>0.245</td>
</tr>
<tr>
<td>Ls − y</td>
<td>2.40 ± 2.99</td>
<td>3.57 ± 2.19</td>
<td>0.136</td>
</tr>
<tr>
<td>Ls − x</td>
<td>3.51 ± 2.97</td>
<td>2.45 ± 2.98</td>
<td>0.233</td>
</tr>
<tr>
<td>Li − y</td>
<td>-0.89 ± 2.71</td>
<td>0.93 ± 3.66</td>
<td>0.061</td>
</tr>
<tr>
<td>Li − x</td>
<td>3.25 ± 3.40</td>
<td>3.17 ± 2.77</td>
<td>0.923</td>
</tr>
</tbody>
</table>

Bold values indicate significant difference.

(14, 15). Maxillary protrusion might be masked by a rapid maxillary expansion protocol applied with a FM and SA method. Furthermore, no significant changes in upper incisor position were reported with the BAMP method (54), whereas significant upper incisor protrusion has been associated with corticotomy-assisted maxillary protraction by SA and intraoral appliances (24). Similar to this result, upper incisor protrusion has been reportedly attained by SA and rapid maxillary expansion for maxillary protraction (26). These differing results may be due to not using pure SA, wherein elastics are applied from a tooth borne acrylic cap splint in the maxilla.

The difference between the two groups in post-treatment lower incisor position was remarkable. Consistent with the literature, lower incisor retrusion was observed in the FM group, while lower incisor protrusion was observed in the SA group. This can be explained by the increasing tongue pressure on lower incisors after eliminating anterior crossbite (12). However, the absence of a chin-cup effect may also have contributed substantially to the lower incisor protrusion in the SA group.

The hooks in the mini-plate were localized 2–3 cm from the labial mucosa, in order to prevent irritation of the mucosa and enable the elastics to be used easily. Many previous studies have reported that a lip bumper appliance enabled lower incisor protrusion, by moving the lip away from the teeth (55, 56). Şar et al. (26) suggested that the protrusion might be due to the retraction of lip force from the mandibular anterior teeth; a ‘lip bumper effect’.

Overjet was enhanced significantly in the both groups, but the factors contributing to the positive overjet differed between the groups.
Local superimpositions revealed that positive overjet was obtained by a combination of maxillary incisor protrusion and mandibular incisor retraction in the FM group (Table 3). Orthopedic Class III treatment by FM has been recommended in the early phase of growth rather than the late phase, because maxillary sutural structures present less resistance to orthopedic force (7, 53, 57). Another reason for the observed reduced skeletal effect might be that less force is delivered to maxillary sutures. Mesialization of the maxillary dentition revealed that since the deciduous premolars were the anchorage unit for FM in this study, root resorption started in the late mixed dentition period. Concordant with the results of this study, reduced skeletal effects of FM treatment have been reported in similarly aged patients in previous studies (7, 53), whereas increased skeletal effects have been associated with FM treatments in the permanent dentition (10, 58).

The overjet observed in the SA group (3.92 mm) was 35 per cent less than that of the FM group (6.03 mm). Because the amount of maxillary incisor protrusion was similar to the amount of mandibular incisor protrusion, the contribution of dental movement to overjet was negligible in the SA group. Therefore, the positive overjet in the SA group was achieved almost solely by skeletal movement of the maxilla and mandible. In the literature, studies incorporating SA intraorally with a rapid maxillary expander or corticotomy and SA with FM have reported significant dental movement in the maxillary or mandibular incisors, improving overjet (24, 26).

Improvements in the soft tissue profile were achieved in both groups, due to the skeletal and dental changes after the treatment. Upper lip forward movement was obtained in both treatment groups. Similar to this study, many previous studies have reported that maxillary protrusion affects upper lip position (12, 26, 53). Depending on mandibular protrusion, non-significant lower lip protrusion (0.93 mm) occurred. The amount of lip protrusion associated with the BAMP method is quite similar that observed in this present study (0.4 mm). However, comparing the results with an untreated, similarly aged Class III group protrusion by growth (2.1 mm) draws attention (30).

The undesirable effects associated with FM treatment, such as anchorage problems in mixed dentition, unaesthetic appearance, discomfort, patient compliance problems, increased vertical dimensions, excessive maxillary incisor protrusion, and mandibular incisor retraction were eliminated with the SA method used in this present study. Furthermore, greater maxillary protraction was achieved. Patients treated with the mini-implants and mini-plates exhibited skeletal improvements with little effect on mandibular position. This new SA method may be preferable for many orthodontists and patients, given that it does not involve an extraoral appliance during treatment, compliance requirements are limited to the use of elastics and maintenance of oral hygiene, and it may reduce the frequency of surgery. Therefore, the null hypothesis was rejected.

This new SA method may be preferable for many orthodontists and patients, given that it does not involve an extraoral appliance, it limits compliance requirements to the use of elastics and maintenance of oral hygiene, and it may reduce the frequency of surgery. This study has some limitations. First, SA treatment comprises two surgical operations, which not all patients are willing to do. For this reason, random allocation was not performed, and the study was designed as a prospective clinical study. However, pretreatment values were similar in the two groups. Hence, the criterion by which patients were allocated to a treatment group (i.e. their willingness to undergo SA or FM treatment) did not determine differences in baseline characteristics. Second, the study results were limited by the fact that two-dimensional cephalometric images were used to evaluate three-dimensional structures. In order to be able to evaluate a range of variables such as treatment starting age of patients, optimal forces, and treatment duration, and to observe long-term treatment effects, further longitudinal studies and three-dimensional evaluations are needed.

Conclusions

Patients treated with mini-implants and mini-plates exhibited skeletal improvements, with little effect on mandibular position. The undesirable effects associated with FM treatment were eliminated with the above-described SA method.

References


