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Skeletal and dentoalveolar effects of hybrid rapid palatal expansion and facemask treatment in growing skeletal Class III patients

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Introduction: The purpose of this study was to describe the skeletal and dentoalveolar changes in a group of growing skeletal Class III patients treated with hybrid rapid palatal expansion and facemask. **Methods:** Twenty-eight growing patients with skeletal Class III malocclusion were treated using a rapid maxillary expander with hybrid anchorage according to the ALT-Ramec protocol (SKAR III; E.P.), followed by 4 months of facemask therapy. Palatal miniscrew placement was accomplished via digital planning and the construction of a high-precision, individualized surgical guide. Pretreatment and posttreatment cephalometric tracings were analyzed, comparing dental and skeletal measurements. **Results:** Point A advanced by a mean of 3.4 mm with respect to the reference plane Vert-T. The mandibular plane rotated clockwise, improving the ANB (+3.41°) and the Wits appraisal (+4.92 mm). The maxillary molar had slight extrusion (0.42 mm) and mesialization (0.87 mm). **Conclusions:** The use of a hybrid-anchorage expander followed by 4 months of facemask treatment improves the skeletal Class III relationship with minimal dental effects, even in older patients (mean age, 11 years 4 months, ± 2.5 years). (Am J Orthod Dentofacial Orthop 2018;153:262-8)

One of the most challenging orthodontic treatments is the correction of a skeletal Class III malocclusion,[1] since a potentially unfavorable growth pattern usually requires early intervention to be effective.[2] However, early treatment using a protraction facemask with a rapid palatal expansion (RPE) appliance has proven successful in correcting skeletal Class III malocclusions that are due primarily to deficient maxillary development.[3,4] To correct a posterior crossbite and to obtain a slight protrusion of the maxilla and weakening of the circummaxillary sutures, the use of RPE combined with a facemask has also been proposed.[5,6]

Although a recent meta-analysis has indicated that preliminary RPE confers no apparent benefit in terms of facemask effectiveness,[7] this contrasts with findings by Foersch et al,[8] who in 2015 reported that weakening and opening the circummaxillary sutures by alternating expansion and compression of the maxillary complex can potentiate the mechanics of Class III therapy. The efficacy of this protocol was initially demonstrated in cleft palate patients,[9,10] and several authors have used it in growing patients with skeletal Class III malocclusion to improve the efficacy of the facemask.[11-13]

The goal of facemask therapy is to obtain purely skeletal changes with minimal effects on the dentition.[14] Previous studies have shown that these undesirable side effects, which include excessive forward movement and extrusion of the maxillary molars, excessive proclination of the maxillary incisors, and increased lower face height, can easily result from tooth-borne protraction facemask therapy,[15-18] a particular concern when preservation of arch length is necessary.[14] Although several strategies for minimizing dental effects have been proposed—ankylosed maxillary deciduous cnnines,[19] osteointegrated titanium implants,[20,21] onplants,[22] miniscrews,[23] and most recently miniplates[11-13,24-31]—the methods are often invasive and entail a surgical procedure.

To simplify the procedure for the treatment of Class III patients, Maino et al[12,13] developed a 3-dimensional

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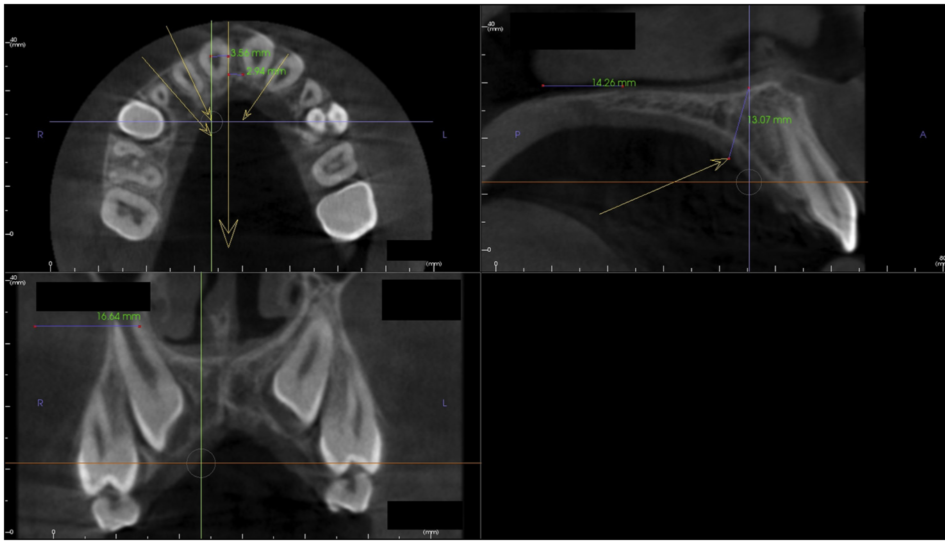

Fig 1. CBCT scan of the upper jaw and reference points to select the miniscrew insertion direction.

surgical guide to provide safe and reliable palatal miniscrew insertion. The associated protocol proposed alternating expansion and compression of the maxillary complex with a hybrid palatal expander anchored to both the bone and the teeth, to be followed by 4 months of facemask therapy.[12,13] We set out to determine the skeletal and dentalaveolar changes brought about by this protocol in a group of growing patients.

MATERIAL AND METHODS

The study group consisted of 28 patients (15 boys, 13 girls; mean age, 11 years 4 months ± 2.5 months) treated consecutively using the combined hybrid RPE and facemask protocol by 2 operators (G.M., L.L.). The inclusion criterion for patient selection was growing patient with Class III malocclusion according to the Wits appraisal. The exclusion criteria were craniofacial syndromes and previous orthopedic or orthodontic treatment. The ethical review board of the University of Ferrara in Italy approved the study protocol.

As per protocol of Maino et al,[12,13] the optimal site and direction of miniscrew insertion were identified on a cone-beam computed tomography (CBCT) scan (Fig 1) or lateral cephalogram. In the case of the latter, a thermoplastic polyethylene terephthalate glycol-modified bite registration was made from the patient's plaster cast, and a series of radiopaque markers was inserted along the median palatine raphe (Fig 2). According to Kim et al,[32] palatal thicknesses measured from lateral cephalograms are comparable with those measured on CBCT scans taken about 5 mm from the midsagittal plane. After scanning, a digital model of the maxillary arch was

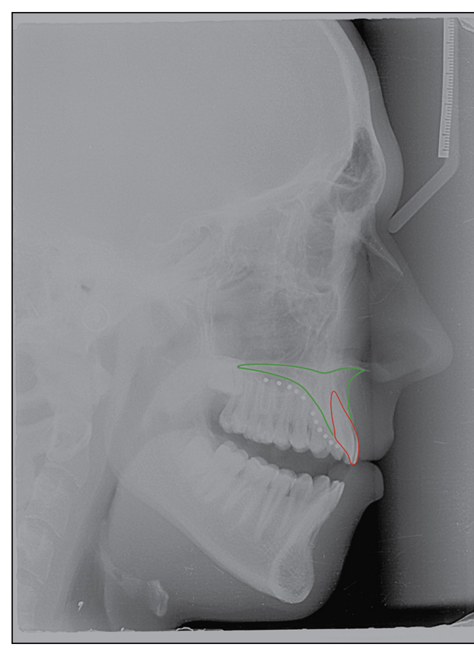

Fig 2. Cephalometric radiograph showing palatal reference points.

superimposed onto the CBCT scan (Fig 3, *A*) or lateral cephalogram (Fig 3, *B*), using eXam Vision (KaVo, Biberach, Germany) and Rhinoceros (McNeel North America, Seattle, Wash) software. This enabled identification of the most appropriate anteroposterior miniscrew placement sites (Fig 4). The same software was then used to design a virtual surgical guide to fit the morphology of the palate and the teeth. Two cylindrical sleeves were then designed to replicate the angle of insertion and

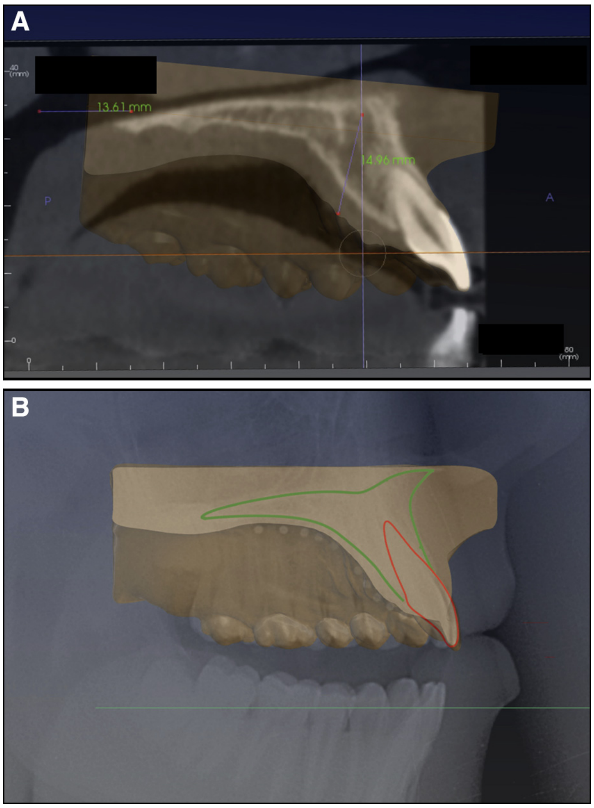

Fig 3. Superimposition of digital model on CBCT and lateral cephalogram.

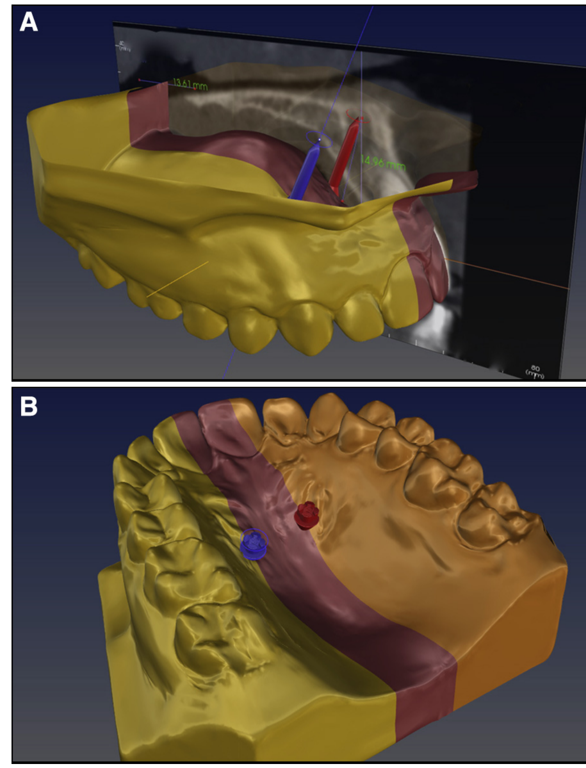

Fig 4. A, Sagittal plane of CBCT scan, showing miniscrews passing through ideal insertion point; **B,** stereolithographic model with ideal miniscrew insertion sites.

prevent the screws from penetrating beyond the required depth in the central portion of the palate. The cylindrical sleeves were joined to the template by virtual bridges (Fig 5), and the entire assembly was produced in transparent resin using a 3-dimensional printer.[12]

After insertion of the miniscrews (Spider Screw Regular Plus; HDC, Vicenza, Italy), the bridges were removed with a dental bur (Fig 6), and 2 plastic transfer copings were clicked onto the miniscrew heads. Silicon or vinyl polysiloxane precision impressions were then taken with a plastic tray. The expansion device used in all cases was SKAR III (Skeletal Alt-RAMEC for Class III; E.P.), which features mixed dental and skeletal anchorage and welded vestibular arms for attaching a facemask (Fig 7). The anterior metal arms of the RPE were welded to 2 metal abutments designed to fit over the heads of the miniscrews, each fixed in place with a microscrew. Maxillary expansion and mobilization were achieved by means of the protocol of Liou[33]: an alternation of 4 activations a day in expansion for 1 week, followed by 4 activations a day in constriction for 1 week. At the end of the fifth week, the RPE was activated until the transversal deficit was corrected. Maxillary protraction was achieved via facemask, to be worn 14 hour per day for 4 months. The protraction elastics (400 g per side) were attached near the maxillary canines, with a downward and forward pull of 30° from the occlusal plane.

Pretreatment and posttreatment (after 4 months of facemask protraction) cephalometric tracings were generated for each patient by the same operator (A.A.). Cephalometric analysis was performed according to the method of Baccetti et al[34] and DeClerck et al.[30] Specifically, the stable basicranial line, through the most superior point of the anterior wall of sella turcica at the junction with the tuberculum sellae (point T),[35] drawn tangent to the lamina cribrosa of the ethmoid bone, and then the vertical T (VertT), a line perpendicular to the stable basicranial line passing through point T, were traced. Neither the stable basicranial line nor the VertT changes over time after the age of 5 years, and both therefore provide stable reference points on which to base all subsequent linear measurements.[36]

The following landmarks, defined according to the methods of Bjork[37] and Ødegaard,[38] were used in the cephalometric analysis: point A (A), point B (B), prosthion (Pr), infradental (Id), gnathion (Gn), anterior nasal spine (ANS), and posterior nasal spine (PNS).

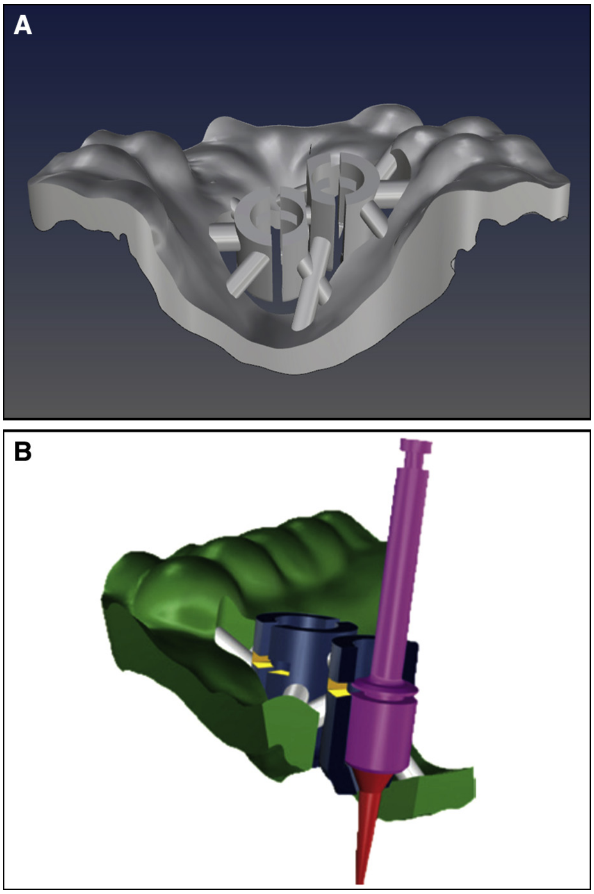

Fig 5. **A,** Connection bridges between cylindrical guides and template body; **B,** section of insertion guide combining stereolithographic files of miniscrew and pickup driver.

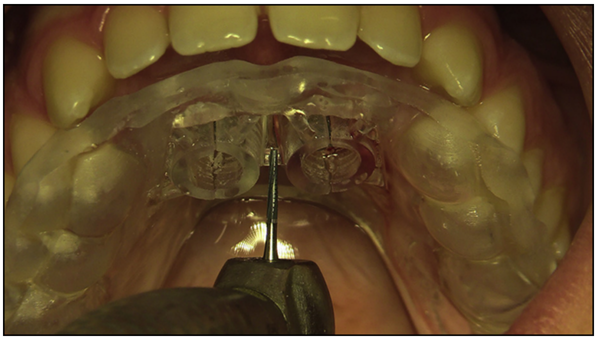

Fig 6. Removal of resin bridges from surgical guide with a dental bur.

Fig 7. Orthodontic device SKAR III.

The VertT-Pterygomaxillary fissure (Ptm) line was constructed parallel to VertT passing through point Ptm. The following linear measurements were used to assess sagittal relationships: ANS-VertT-Ptm, A-VertT, Pr-VertT, Id-VertT, B-VertT, and Pg-VertT.

In addition to the analysis of Baccetti et al,[34] we measured the horizontal position of the mesial cusp of the maxillary first molar (U6-VertT) and the perpendicular distance between the mesial cusp of that tooth and the palatal plane (U6-PP). The following lines and angles were also measured: SNA, SNB, ANB, SN-GoGn, SN-PP, PP-GoGn, and U1-PP, as well as performing a Wits appraisal.

For each of the above cephalometric measurements, the pretreatment to posttreatment variation was calculated for each patient. In addition, the horizontal displacement of the maxillary first molar, net from the skeletal displacement of the upper jaw, was evaluated (U6 mesialization): ie, the difference between the variation in the horizontal position of the maxillary first molar and the variation in the horizontal position of point A.

For each patient, the means and standard deviations of each pretreatment and posttreatment measurement were calculated, as was the variation between the means. The Student t test was used to check whether the pretreatment and posttreatment variations were significant ($P < 0.05$).

RESULTS

The Table shows the cephalometric measurements of the sample before treatment and at the end of treatment, with the respective standard deviations and variations between the 2 time points and the statistical meaning. As the values show, after RPE according to the protocol of Liou[33] and 4 months of facemask protraction, point A advanced by a mean 3.4 mm with respect to VertT in our sample, with a significant variation, while the position of point B remained relatively stable and pogonion advanced by 0.22 mm. Furthermore, the SNA angle increased by 2.5°, and the sagittal relationship significantly improved (ANB, +3.41°; Wits, +4.92 mm).

Table. Pretreatment and posttreatment cephalometric measurements (P <0.05)

	Pretreatment (T0)	*SD*	*Posttreatment (T1)*	*SD*	*T1–T0*	*P level*
A-VertT (mm)	55.2	4.5	58.6	5.5	3.4	<0.001
B-VertT (mm)	52.5	5.2	52.2	7.4	−0.26	NS
ANS-Ptm (mm)	47.0	3.3	49.5	4.4	2.44	<0.001
PNS-Ptm (mm)	1.9	1.2	2.7	1.4	0.72	0.004
Pr-VertT (mm)	57.1	5.2	60.7	6.4	3.62	<0.001
Id-VertT (mm)	55.6	5.7	55.8	7.9	0.12	NS
Pg-VertT (mm)	53.0	5.6	53.2	8.0	0.22	NS
SNA (°)	79.7	3.7	82.2	3.5	2.50	<0.001
SNB (°)	79.2	3.8	78.3	3.6	−0.92	0.005
ANB (°)	0.6	1.8	4.0	1.5	3.41	<0.001
Wits (mm)	−3.3	3.6	1.6	3.5	4.92	<0.001
PP-GoGn (°)	26.6	4.8	29.7	4.7	3.19	0.001
U1-PP (°)	110.2	6.6	107.9	6.5	−2.26	NS
SN-PP (°)	7.7	3.4	6.6	3.2	−1.11	0.011
SN-GoGn (°)	34.7	4.8	36.3	4.7	1.64	0.001
U6 vert PP (mm)	19.4	2.1	19.9	2.1	0.42	0.001
U6 mesialization (mm)	-	-	-	-	0.87	

NS, Not significant.

For the vertical measurements, the facial angle (SN-GoGn) increased by 1.64° during treatment, and the SN-PP angle was reduced by 1.11°.

In terms of dental measurements, the maxillary incisor neck point (Pr) moved forward by 3.62 mm with respect to VertT, and the maxillary incisor underwent retroclination of 2.26° with respect to the palatal plane, with the mean inclination reduced from 110° to 107.9°. The maxillary first molar was extruded by 0.42 mm with respect to the palatal plane and advanced slightly by 0.87 mm with respect to VertT.

DISCUSSION

The effects on the craniofacial skeleton induced by facemask therapy—forward dislocation of the maxilla, backward movement of the mandible, clockwise rotation of the mandibular plane, and counterclockwise rotation of the maxillary plane—have already been well demonstrated by meta-analyses.[7,8] In a 28-patient sample treated by hybrid RPE and facemask, we successfully corrected Class III malocclusions by maxillary skeletal advancement, increasing the divergence via clockwise rotation of the mandible, without clinically significant side effects on the maxillary dentition.

In comparison to the "late" group of Baccetti et al,[34] we found greater advancement of the upper jaw and maxillary incisor (2.07 vs 3.4 mm in our group), even though our sample was older (mean, 11 years 4 months ±2.5 months vs 10 years 3 months ±1 month) and our treatment duration was significantly shorter (4 months ±1 month vs 10 months ±3 months). With the data at hand, it is not easy to pinpoint the reasons behind this difference, but it is likely that the systematic application of the protocol of Liou[33] to activate the maxillary sutures before facemask protraction played a role.[12,13]

Similarly, the increase in maxillary divergence in our sample was greater than that reported by Baccetti et al[34] (2.96° vs 1.99°); this could be interpreted as a drawback of the greater maxillary advancement. Our cephalometric analysis results were similar to those reported in the meta-analysis of 3 randomized controlled trials conducted by Cordasco et al[7] in terms of both sagittal (SNA, SNB, ANB) and vertical (SN-PP, SN-MP) measurements. However, the mean duration of treatment in the articles cited by Cordasco et al was approximately 1 year, whereas ours was completed in 4 months. Moreover, the mean age of our sample was considerably greater (11 years 4 months vs 8 years 5 months).

In the upper jaw, we measured a mean forward displacement of the incisors of 3.62 mm, and their retroclination was 2.26 with respect to the palatal plane. This latter figure is in line with those reported by Sar et al,[39] Koh and Chung,[40] and Ngan et al[14] in patients treated via a bone-anchored facemask, but Nienkemper et al,[41] who studied a similar device to that used to treat our sample, found no such dental effects. Nevertheless, a meta-analysis by Foersch et al[8] reported a labial inclination of the maxillary incisor of 2.51° in patients treated with a facemask, and it is possible that the retroclination common to many patients treated with a facemask relying on bone or hybrid tooth-skeletal anchorage is due to the lack of molar mesialization to counteract the pressure of the upper lip on the underlying incisors.[42]

However, despite the anchorage provided by the 2 mini-implants in our study, we recorded forward movement of the maxillary molars (albeit by less than 1 mm in all cases). This is in line with the movement reported by Ngan et al[14] and Wilmes et al,[43] who used the hybrid hyrax appliance, and by other investigators relying on bone-anchored devices for maxillary protraction.[20,21,27-29]

Finally, for the vertical measures, we found clockwise rotation of the mandible (1.64°) in our sample, contributing to correction of the ANB angle. The bispinal plane, on the other hand, was rotated counterclockwise (−1.11°) despite the use of skeletal anchorage. These findings are common to treatments with tooth-anchored facemasks,[7] but are also in line with those reported by investigators using bone-anchored devices for maxillary protraction.[20,21,27-29]

There were several limitations to the design of this descriptive study. First and foremost, there was no control group, and patients were not selected at random. Furthermore, the patients in the sample were treated by 2 operators relying on measurements made on images generated by 2 sets of radiographic apparatus (although the measurements were adjusted to take into account the different magnification factors). Finally, these findings resulted from a short period of observation immediately after active treatment. Hence, long-term studies are needed to assess the stability of protraction afforded by the protocol used in this study, comparing them with those obtained by conventional RPE and facemask treatment. Nonetheless, our results may be of interest, considering the short duration of treatment, the particularly high mean age of the patients, and the innovative system used to simplify miniscrew placement.[12,13]

CONCLUSIONS

The association of a hybrid expansion device with combined dental and skeletal anchorage and the protocol of Liou[33] for opening the maxillary suture followed by facemask therapy enabled us to achieve correction of Class III malocclusions through maxillary advancement with minimal dental effects over a short period of time and in relatively old patients.

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