Skeletal and dentoalveolar effects of hybrid Rapid Palatal Expander and facemask treatment in a group of growing skeletal class III patients

Abstract

Objective: The purpose of this study was to describe the skeletal and dentoalveolar changes in a group of growing skeletal class III patients treated by means of a hybrid RPE and facemask.

Materials and methods: 28 growing patients affected by skeletal class III malocclusion were treated using rapid maxillary expander with hybrid anchorage according to the ALT-Ramec protocol (SKAR III), followed by 4 months of facemask therapy. Palatal miniscrew placement was accomplished via digital planning and the construction of a high-precision, individualised surgical guide. Pre- and post-treatment 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 index (+4.92 mm). The upper molar displayed slight extrusion (0.42 mm) and mesialization (0.87 mm).

Conclusions: The use of a hybrid-anchorage expander according to Liou's protocol followed by four months of facemask treatment improves the skeletal class III relationship with minimal dental effects, even in patients of relatively greater mean age (11 years 4 months, +/- 2.5 years).

Keywords: class III treatment; hybrid RPE; skeletal effects; palatal miniscrew; surgical guide

Introduction

One of the most challenging orthodontic treatments to perform is the correction of 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 in conjunction 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 posterior cross-bite and to obtain a slight protrusion of the maxilla and weakening of the circum-maxillary sutures, the use of rapid palatal expansion in combination 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 circum-maxillary sutures by alternating expansion and compression of the maxillary complex is able to potentiate the mechanics of class III therapy. The efficacy of this protocol was initially demonstrated in cleft palate patients[9,10], and several authors[11-13] have employed it in growing patients with skeletal class III malocclusion to improve the efficacy of the facemask.

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 pro-inclination of the maxillary incisors, and an increase in lower face height, can easily result from tooth-borne protraction facemask therapy[15-18], a particular concern in situations in which preservation of arch length is necessary[14]. Although several strategies for minimizing dental effects have been proposed, namely ankylosed maxillary deciduous canines[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.

In order to simplify the procedure for the treatment of class III patients, Maino et al.[12,13] developed a 3D surgical guide to provide a safe and reliable palatal miniscrew insertion. The associated protocol[12,13] proposed alternating expansion and compression of the maxillary complex by means of a hybrid palatal expander, anchored to both the bone and the teeth, to be followed by 4 months of facemask therapy. 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 males, 13 females, mean age 11 years and 4 months ±2.5) treated consecutively using the combined hybrid RPE/facemask protocol by two different operators. The inclusion criteria for patient selection were: growing patient with class III malocclusion according with the Wits appraisal. The exclusion criteria were craniofacial syndromes and prior orthopedic or orthodontic treatment. The regional ethical review board approved the study protocol.

Appliance design

As per Maino et al.'s protocol[12,13], the optimal site and direction of miniscrew insertion was identified on a 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 radio-opaque markers inserted along the median palatine raphe (Fig. 2). According to Kim and colleagues, palatal thicknesses measured from lateral cephalograms are comparable to those measured on CBCT scans taken about 5 mm from the midsagittal plane[32]. After scanning, a digital model of the upper arch (STL file) was superimposed onto the CBCT scan (Fig. 3A) or lateral cephalogram (Fig. 3B), using eXam Vision (KaVo, Biberach, Germany) and Rhinoceros (McNeel North America, Seattle, WA; USA) 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 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 3D printer[12].

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

Cephalometric analysis

Pre- and post-treatment (after 4 months of facemask protraction) cephalometric tracings were generated for each patient by the same operator. Cephalometric analysis was performed as per Baccetti et al.[34] and DeClerck et al.[30]. Specifically, the stable basicranial line (SBL), 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 SBL passing through point T, were traced. Neither the SBL nor the VertT change over

time after the age of 5, and both therefore provide stable reference points upon which to base all subsequent linear measurements[36].

The following landmarks, defined according to 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). The VertT–Ptm line was constructed as a line parallel to VertT passing through point Ptm. The following linear measurements were used to assess sagittal relationships: ANS–VertPtm, A–VertT, Pr–VertT, Id–VertT, B–VertT, Pg–VertT.

In addition to Baccetti's analysis, we measured the horizontal position of the mesial cusp of the upper sixth (U6–VertT), and the perpendicular distance between the mesial cusp of the upper sixth 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 pre–post-treatment variation was calculated for each patient. In addition, the horizontal displacement of the upper first molar, net of the skeletal displacement of the upper jaw, was evaluated (U6 Mesialization), i.e., the difference between the variation in the horizontal position of U6 and the variation in the horizontal position of point A.

For each patient the means and standard deviations of each pre- and post-treatment measurement were calculated, as was the variation between the means. The t-student test was used to check whether the pre and post-treatment variation was significant ($p<0.05$).

Results

Table 1 shows the cephalometric measurements obtained for the sample at T0 and at the end of treatment (T1), alongside the respective standard deviations and variations between the two time-points and the statistical meaning. As the values show, after RPE according to Liou's protocol and 4 months of facemask protraction, point A advanced 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 the Pogonion advanced by 0.22 mm. Furthermore, the SNA angle increased by 2.5°, and the sagittal relationship significantly improved (ANB=+3.41° and Wits=+4.92 mm).

As regards the vertical measurements, the facial angle (SN–GoGn) increased by 1.64° over the course of treatment, while the SN–PP angle was reduced by -1.11°.

In terms of dental measurements, the upper incisor neck point (Pr) moved forward 3.62 mm with respect to VertT, while the upper incisor underwent retro-inclination of 2.26° with respect to the palatal plane, the mean inclination being reduced from 110° to 107.9°. The first upper molar was extruded 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, namely 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-analysis[7,8]. In a 28-patient sample treated by hybrid RPE and facemask, we successfully corrected class III 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 Baccetti's[34] "late" group, we found greater advancement of the upper jaw and upper incisor (2.07 mm versus 3.4 mm in our group) and, despite our sample being older (mean 11 years 4 months +/-2.5 with respect to 10 years 3 months +/-1) and our treatment duration significantly shorter (4 months +/- 1 versus 10 months +/-3). 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 Liou's protocol[12,13] to activate the maxillary sutures before facemask protraction played a role.

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

In the upper jaw we measured a mean forward displacement of the incisors of 3.62 mm, and their retro-inclination of 2.26 with respect to the palatal plane. This latter figure is in line with those reported by Sar[39] and Koh[40] and Ngan[14] in patients treated via a bone-anchored facemask, but Nienkemper[41], who studied a very similar device to that used to treat our sample, found no such dental effects. Nevertheless, a meta-analysis by Foersch[8] reported a labial inclination of the upper incisor of

2.51° in patients treated via facemask, and it is possible that the retro-inclination common to many patients treated by means of facemask relying on bone or hybrid tooth-skeletal system 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 two mini-implants in our study, we recorded a 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[14], 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, as regards 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 anti-clockwise (-1.11°) despite the use of skeletal anchorage. These findings are common to treatments using 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].

That being said, there are 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 two different operators relying on measurements made on images generated by two sets of radiographic apparatus (although measurements were adjusted to take into account the different magnification factors). Finally, the findings from this study result from a short-term period of observation immediately after active treatment. Hence, long-term studies are needed to assess the stability of protraction afforded by the protocol employed in this study, comparing them to those obtained by conventional RPE and facemask treatment. Nonetheless, the results obtained in our sample may be of interest, considering the short duration of treatment, the particularly high mean age of the patients treated, 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 Lou's protocol for opening the maxillary suture followed by facemask therapy enabled us to achieve correction of class III malocclusion through maxillary advancement with minimal dental effects over a short period of time and in relatively old patients.

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FIGURE LEGENDS

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

Figure 2. Chefalometric radiograph showing palatal reference points

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

Figure 4. Sagittal plane of CBCT scan, showing miniscrew passing through ideal insertion point (a). Stereolithographic (STL) model with ideal miniscrew insertion sites (b).

Figure 5. Connection bridges between cylindrical guides and template body (a). Section of insertion guide combining STL files of miniscrew and pick-up driver.

Figure 6. Removal of resin bridges from surgical guide using a dental bur

Figure 7. Orthodontic device SKAR III