Maxillary Protraction at Early Ages. The Revolution of New Bone Anchorage Appliances

Solano-Mendoza B*/Iglesias-Linares A**/ Yañez-Vico RM ***/ Mendoza-Mendoza A ****/ Alió-Sanz JJ *****/Solano-Reina E ******

Purpose: *An update is provided on the different types of early treatment for class III malocclusions of maxillary origin. There is an increasing tendency to prescribe maxillary orthopedic treatment with skeletal anchorage, with the purpose of enhancing the skeletal and reducing the dentoalveolar effects – offering a management option for children with important deformations that otherwise would have to wait until adult age to receive surgical treatment.* ***Method:*** *A literature review has been made of maxillary bone orthopedic traction appliances in growing children with class III malocclusions. A Medline (PubMed) search was made using the following MeSH terms: Cephalometric, Child, Malocclusion class III / therapy, Extraoral traction appliances, Palatal expansion, Bone plates, Skeletal anchorage, Orthodontic anchorage.* ***Results:*** *Many articles show that the greatest maxillary advances are obtained at very early ages, though with a greater tendency towards relapse. However, skeletal anchorage has been seen to afford a lesser relapse rate and greater dentofacial orthopedic efficiency due to its low dentoalveolar impact. In any case, further randomized clinical studies are needed to firmly establish the quantifiable differences in terms of maxillary advance, optimum traction age, optimum traction appliance and potential side effects. At present, the incorporation of surgically inserted bone anchorage appliances (miniplates and miniscrews) offers a purely orthopedic approach to treatment, with minimization of the undesirable side effects of traditional dentofacial orthopedic compensation based on dentoalveolar anchorage. Nevertheless, further studies are needed to consolidate the supporting scientific evidence in this field.*

INTRODUCTION

Class III malocclusion is characterized by maxillary deficiency (or set back position) or mandibular prognathism, though in most cases both conditions are seen to coexist.[1] Because of this anomalous relationship, the incisors may present anterior crossbite, edge-to-edge contact or, in the case of dentoalveolar compensation, retro-inclination of the lower incisors and proinclination of the upper incisors. Among the different class III malocclusions we can distinguish between dental, functional or pseudo-class III problems and skeletal or true problems. In skeletal presentations the origin of the malocclusion often consists of maxillary hypoplasia – maxillary orthopedic protraction presently being one of the most widely used treatment options in such cases.

The incidence of class III malocclusion varies according to the ethnic origin of the population. Different epidemiological studies have found the greatest prevalence of class III malocclusions to correspond to the Asian population, particularly of Chinese origin. According to some authors, 14% of the population is affected,[2-5] while others report a range of 9-19%.[6-7] In turn, in 70% of the cases the condition is attributable to maxillary retrognathia with a normal mandible, or to alterations of both maxillae.[8] The incidence in the Caucasian population is 1-5%,[9-11] and in this case two-thirds of all class III malocclusions are of maxillary origin or involve both maxillae combined12. Other studies in European populations have reported a prevalence of 3-8%.[9,10,13] In the Latin population the prevalence of class III malocclusions is reported to be 5%.[14]

The treatment of class III malocclusion in growing patients remains a challenge in orthodontic practice. The literature describes a range of orthodontic and orthopedic management approaches to these malocclusions, such as class III functional appliances,[15] chin guards,[16] splints with class III elastics[17] and cervical extraoral mandibular anchoring,[18] among others. Despite the many treatment options available, their individual therapeutic objectives and the skeletal, dentoalveolar and dental structures upon which they act differ considerably from one technique to another. In turn, although

* Solano-Mendoza B, Orthodontics Postgrade student. School of Dentistry. University of Seville.
** Iglesias-Linares A, Associate Professor of Orthodontics. School of Dentistry. University of Seville.
*** Yañez-Vico RM, Assistant Professor of Orthodontics. School of Dentistry. University of Seville.
**** Mendoza-Mendoza A, Full time Professor of Paedriatic Dentistry. School of Dentistry. University of Seville.
***** Alió-Sanz JJ, Full time Professor of Orthodontics. School of Dentistry. Complutense University of Madrid.
****** Solano-Reina E, Chairman, Department of Orthodontics. School of Dentistry. University of Seville.

Send all correpondence to: Alejandro Iglesias Linares, School of Dentistry. University of Seville. C/Avicena sn, 41009 Seville. Spain

Email address: aiglesiaslinares@us.es

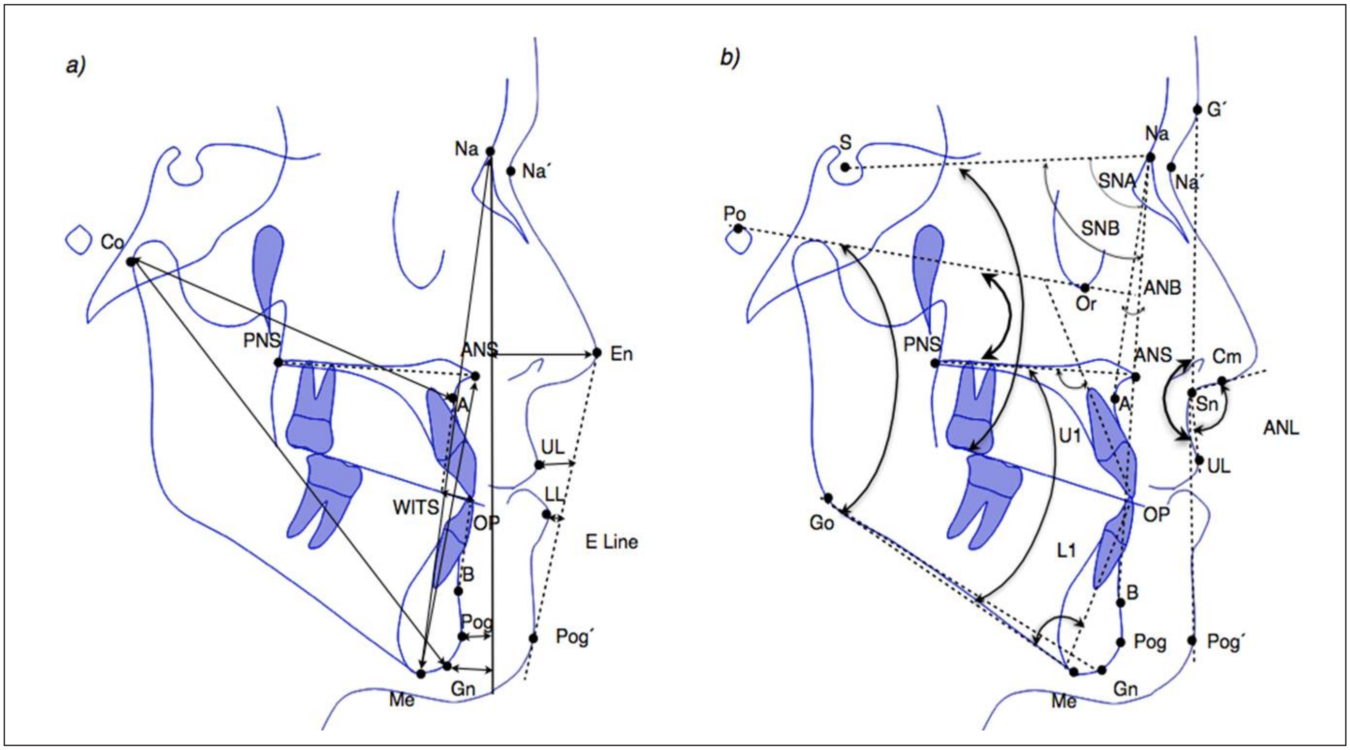

Figure 1: Graphic representation of the cephalometric points and linear and angular measures described by the different literature sources. Points and lines: S: Sella, Po: Porion, Ba: Basion, Or: Orbital, Pt: Pterygoid, Na: Nasion, Na´: Soft nasion, G: Soft glabella, Pog: Pogonion, Pog´: Soft pogonion, Gn: Gnathion, Ch: Chin, Go: Gonion, Co: Condylion, ANS: anterior nasal spine, PNS: posterior nasal spine, OP: Occlusal plane, Wits: Points A and B projected in the occlusal plane, SN: S-Na, FP: Frankfort plane (Po-Or), PP: Palatal plane (ANS-PNS), MP: Mandibular plane (Go-Ch), U1: Upper incisor, L1: Lower incisor, U6: First upper molar, L6: First lower molar, UL: Upper lip, LL: Lower lip, Sn: Subnasal, Cm: Columella, In: Nasal tip, E Line: In-Pog. a) Linear measures: Pog-perpendicular Na: Advance of Pog, Gn-perpendicular Na: Advance of Gn, A-perpendicular Na: Advance of point A, In-perpendicular Na: Advance of nasal tip, Co-A: Maxillary length, Co-Gn: Mandibular length, ANS-Ch: Lower facial height, N-Ch: Total facial height, UL-E Line, LL-E Line, Wits, U6 vertical (SN-perpendicular U6): Upper molar extrusion, L6 vertical (SN-perpendicular L6): Lower molar extrusion, U1-perpendicular A: Position of the upper incisor, L1/A-Pog: Position of the lower incisor. b) Angular measures: ANB, SNA, SNB, L1/Go-Gn: Angulation of the lower incisor, U1/ANS-PNS or U1-FP, Angulation of the upper incisor, PP-SN or PP-FP: Maxillary rotation, MP-SN or MP-FP: Mandibular rotation PP-MP: Intermaxillary rotation, OP/SN: Rotation of OP with respect to SN, NLA (Cm-Sn-UL): Nasolabial angle, G´-Sn-Pog´: Facial convexity, Facial axis: Ba-Na/Pt-Gn.

all orthopedic appliances ultimately seek the correction of malocclusion, the scientific literature shows great variability in the actual results obtained. This issue has gained even greater relevance with application of the new bone anchorage appliances in pediatric patients with the purpose of applying purely orthopedic forces. Review studies and critical reflection upon the results afforded by each system are required, based on the existing scientific evidence. In this context, the aim of the present study is to compile, analyze and critically examine the results obtained with the different appliances available in the studies conducted to date in relation to protraction of the maxillary bone at early ages.[19]

There are presently two major management options in protraction of the maxillary bone: traction with dental anchorage and traction with bone anchorage.

Protraction of the maxillary bone with dental anchorage

Protraction of the maxillary bone using a "tooth regulating machine" was first described by Potpeschnigg in 1875.[20] Posteriorly, in 1976, Delaire *et al* [21] showed new interest in this technique and created a face mask which in turn was modified by Petit[22] in 1983. This latter design increased the amount of force generated by the face mask and shortens the duration of treatment.

Traction of the maxillary complex in class III malocclusions has been shown to produce maxillary skeletal changes, increasing the sella-nasion-point A (SNA) and point A-nasion-point B (ANB) (Figure 1a) angle by a range of 3º and 2º, respectively.[23-27] Although these changes affect the mandible as well as the maxilla, on comparing the changes with normal controls not subjected to treatment, the sella-nasion-point B (SNB) angle is seen to decrease an average of 1.1º versus an increase of 0.7º in the controls. However, there are also some undesirable effects at dental level, such as lingual tipping of the lower incisors by 4.3º, proinclination of the upper incisors by about 2.6º, upper molar extrusion 0.4 mm and lower molar extrusion 0.8 mm[24] (Figure 1b). In contrast, dentoalveolar response to protraction face mask was be found no significant between the ages of 6 to 9 years and 9 to 12 years.[28] The different studies have obtained highly diverse results, since the latter can be affected by factors such as treatment time, the applied force, the force vector and patient age, among others.

On the other hand, it has been shown that the results obtained are not stable over the long term, with a 25-30% relapse rate

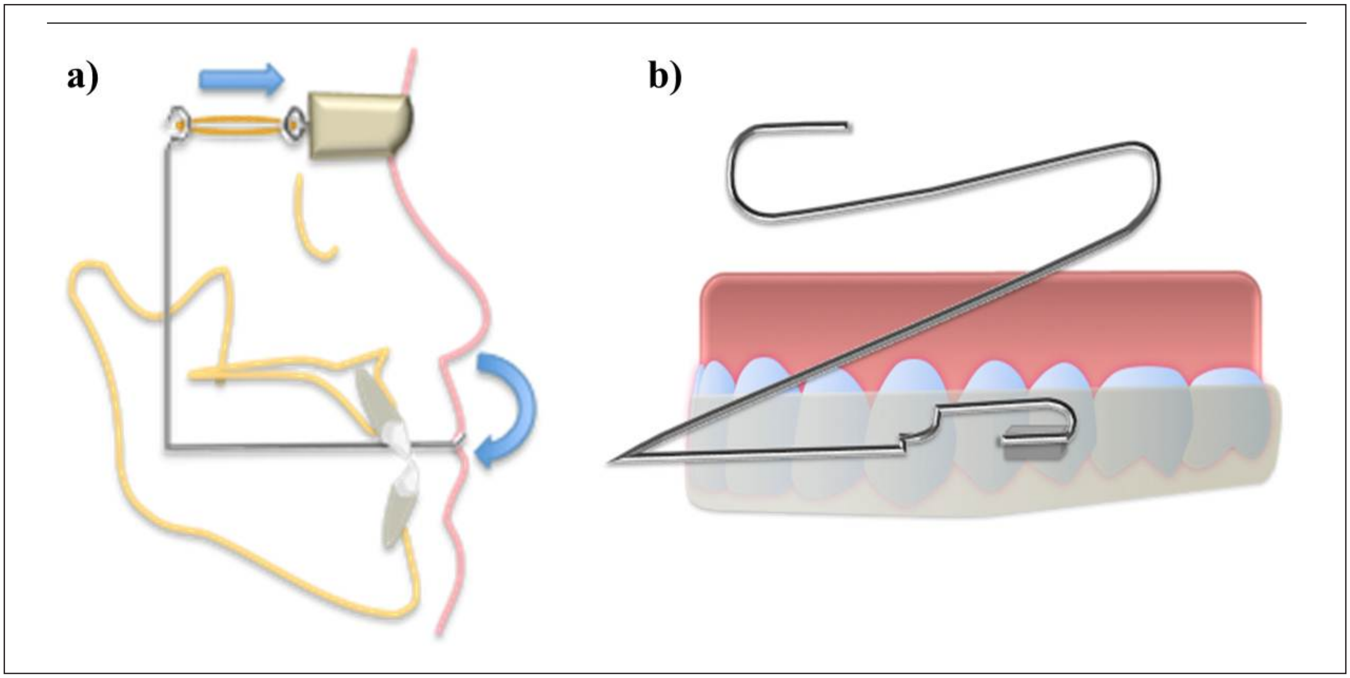

Figure 2: Modified maxillary protraction masks with force application above the center of maxillary resistance. a) Modified maxillary protraction mask, with the forehead as sole point of support. The force application point displaces above the center of resistance of the maxilla with the purpose of producing clockwise rotation of the maxilla. b) Petit mask modified by Ahmet Keles et al., with the horizontal bar of the extraoral anchorage 30º above the occlusal plane (20 mm above the occlusal plane).

once mandibular growth has ceased – the dentoalveolar changes being most susceptible to relapse.[24,29] Westwood *et al* [24] evaluated the changes obtained in 100 children with the use of a facemask, following the pubertal growth peak (vertebral maturation stages 4, 5 or 6 according to the method of Franchi *et al* [30]). These authors found 76% of the children to maintain a positive overjet and 9% an edge-to-edge relationship, the relapse rate therefore being 33% after the end of mandibular growth. In this context, the dentoalveolar changes showed the greatest relapse tendency, with SNB 1.9º, ANB 1.6º, inclination of the upper incisor by 5.9º, inclination of the lower incisor by 2.5º (Figure 1a), overjet 1.6 mm, molar extrusion 4.6 mm (Figure 1b), and no significant changes in SNA.[24]

Another possible consequence of maxillary protraction is enlargement of the pharyngeal space, since forward growth of the maxilla favors an increase in pharyngeal dimensions.[31,32] With the purpose of evaluating these changes, Oktay[32] carried out a study of 20 children with class III malocclusion treated with a maxillary protraction mask. Evaluations were made of the dimensions of the nasopharyngeal and upper and lower oropharyngeal areas, and of upper, middle and lower pharyngeal width, before and after treatment. Increments were observed in the nasopharyngeal and upper oropharyngeal areas, with an increase in upper and middle pharyngeal width of 2.67 mm and 1.10 mm, respectively. However, the lower oropharyngeal area did not increase significantly (only 0.47 mm).[32]

The use of bite plates has been proposed in order to avoid clockwise rotation of the mandible, particularly in dolichofacial patients with a tendency towards open bite.[33] These appliances reduce the possibility of extrusion of the posterior teeth, allowing even anterior rotation of the mandible and therefore a bite closure of 0.58º.[34] Pangrazio *et al* [35] carried out a study of the changes in the mid-third facial zone produced by maxillary protraction with expansion (disjunction), and expansion alone, using a cemented expander with bite plates. The authors found molar extrusion to be 1.2 mm and 2.4 mm when accompanied by protraction of the maxillary bone (Figure 1b). The mandible remains constant when no traction is applied, and rotates clockwise only 1º when traction is applied to the maxilla. The palatal plane (PP) remains practically constant with respect to the sella-nasion plane (SN), with an aperture of 0.7º in the group subjected to traction, and no changes in the group without traction (Figure 1a).

Other authors such as Cozza *et al* [25] propose the use of removable plates with bite plates in the lower arch, combined with a face mask in patients that do not have transverse maxillary problems, with the purpose of avoiding mandibular posterior rotation during maxillary protraction. The aim of these plates is to control molar eruption, limit intermaxillary divergence and prevent clockwise rotation of the mandible. These authors carried out a study of the effects of maxillary bone traction with lower removable bite plates in 22 children and 12 controls. In addition, the effects two years after treatment were evaluated. The investigators recorded a mean anticlockwise maxillary rotation of 1.2º, while mandibular clockwise rotation was limited to 0.9º and was not statistically significant. On evaluating the results two years after treatment, the maxilla was seen to tend to return to its original condition, rotating clockwise 0.9º, while the mandible rotated anticlockwise 0.6º. Thus, the angle between PP and the mandibular plane (MP) increased an average of 2.2º during treatment, but decreased 1.6º two years after treatment.

With this method it has been shown that there are no rotational changes at mandibular level, though anticlockwise rotational changes are observed at maxillary level, with an increase in intermaxillary divergence during treatment.[25]

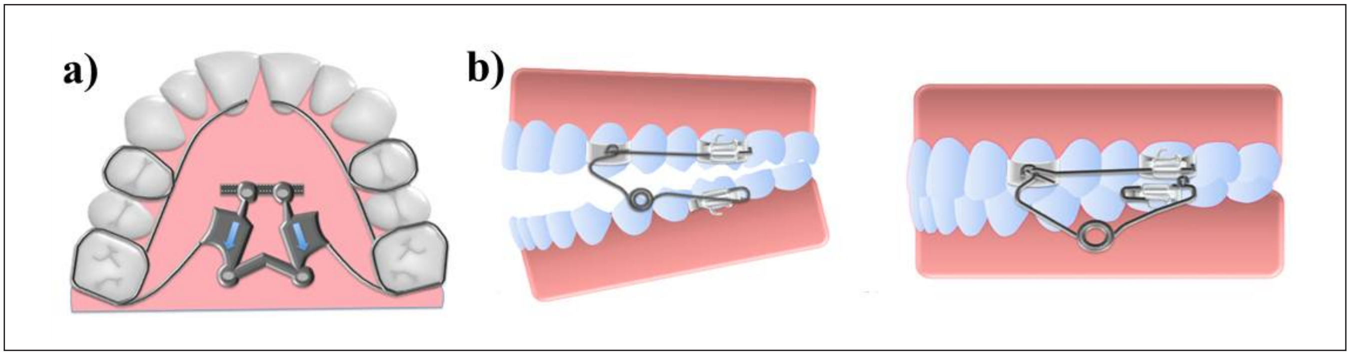

Figure 3: Maxillary propulsion with expansion and intraoral appliances. a) Modified “W” expander with two hinges and two anterior arms. b) Maxillary protraction TMA spring with a section of 0.036”. The open spring with an angle of 180º and the spring in compression (mouth close) with an angulation of 100-120º.

Protraction of maxillary bone with and without expansion

It is very common for maxillary protraction to be combined with maxillary expansion, with the purpose of correcting transverse hypoplasias associated to posterior crossbites, and to loosen the circum-maxillary sutures[24,36,37] – thereby facilitating maxillary protraction with the mask. However, some patients are either too small or the transverse conditions of the maxilla are correct, and rapid maxillary expansion is therefore not needed. Few studies have been published on maxillary protraction without rapid expansion of the palate,[38] though Vaungh *et al* [27] have shown that maxillary advancement capacity is not influenced by aperture of the palatal suture. As a result, they insist that the use of a expander should not be regarded as essential for maxillary protraction, unless there is a transverse problem.

There are two main types of expanders: cemented band or with bite plates. The indication of one or the other depends on the type of facial pattern, since the advancement capacity is the same in both cases. In the presence of vertical patterns it is advisable to use expanders with bite plates, since good vertical control is afforded,[34,35] without significant differences referred to SN and PP, occlusal plane (OP) and MP – the respective increments being 0.5º, 1.7º and 1º[35] (Figure 1a). In contrast, cemented band expanders produce inclination of PP, with a 1.3 mm descent of the posterior nasal spine (PNS) and a 0.6 mm descent of the anterior nasal spine (ANS) – resulting in closure of the SN-PP angle. In addition, the mandible rotates posteriorly as a result of differential vertical growth between the pogonion (Pog) and gonion (Go), the Pog descending 2.7 mm and the Go 1.4 mm.[39]

Thus, if we seek important posterior rotation at mandibular level, it is better to use a cemented band expander. However, it has been shown that on evaluating the post-treatment changes, there is a tendency towards relapse at vertical level, with anticlockwise rotation of the mandible and a return to the original growth pattern, with a descent of 3.2 mm and 2.5 mm in Go and Pog, respectively.[39]

Age for maxillary protraction

It is important to determine the best time for starting the treatment of class III malocclusions in pediatric patients – though there is considerable controversy on this subject. Kajiyama[40] *et al*. carried out a study of 63 children subjected to maxillary protraction with a face mask and 57 controls. The 63 children were divided into two groups according to their dentition stage: temporary dentition (34 cases) and mixed dentition (29 cases). On comparing the effects produced by the face mask in the two groups, maxillary advancement was seen to be greater in the patients with temporary dentition, with the following increments: SNA 4.16º, SNB -3.66º and ANB 7.83º. In comparison, the increments recorded in the mixed dentition group were SNA 1.48º, SNB -3.66º and ANB 3.85º. Furthermore, clockwise rotation of the mandible was greater in the temporary dentition group (3.82º versus 2.74º in the mixed dentition group), and an increase in SNA-chin (Ch) distance of 7.41 mm versus 4.26 mm was recorded as a result (Figure 1b). In mixed dentitions, treatment has been shown to be more effective when carried out in an early stage (first mixed phase) than in a later stage (second mixed phase).[34,44] However, on considering post-treatment stability, an increased tendency towards relapse has been recorded in patients treated in the temporary dentition phase. As a result, some authors consider the ideal moment for maxillary protraction to be during the mixed dentition period, thereby ensuring a lesser relapse rate.[38]

Most authors have found early treatment[38,41] to be more effective for correcting the sagittal skeletal relationship. Saadia and Torres[42,43] studied changes in primary and mixed dentitions after maxillary protraction with expansion and concluded that the treatment should start as soon as the diagnosis is made and cooperation allows for it because younger patients need less time of treatment and more changes are observed.

It must be taken into account that most studies have analyzed the efficacy of maxillary protraction based on patient chronological age[45,46] instead of development stage, thus giving rise to a great diversity of results. In contrast, other authors have attempted to avoided this source of bias by choosing dental age,[38,40] which is more convenient and effective than chronological age.[47] Although the most reliable approach is to use skeletal age, very few studies have employed this method.[48] Nevertheless, in some cases the patient is not treated by a specialist until later in life. In these cases, some authors defend the possibility of conventional maxillary protraction with a face mask.[49,50] However, at present other investigators recommend maxillary protraction with skeletal anchorage, in order to maximize the orthopedic changes and minimize the dentoalveolar modifications, and thus secure progression of the maxilla.[51] In this way we can achieve important orthodontic benefits without the need for surgery, though there are some limitations.[52]

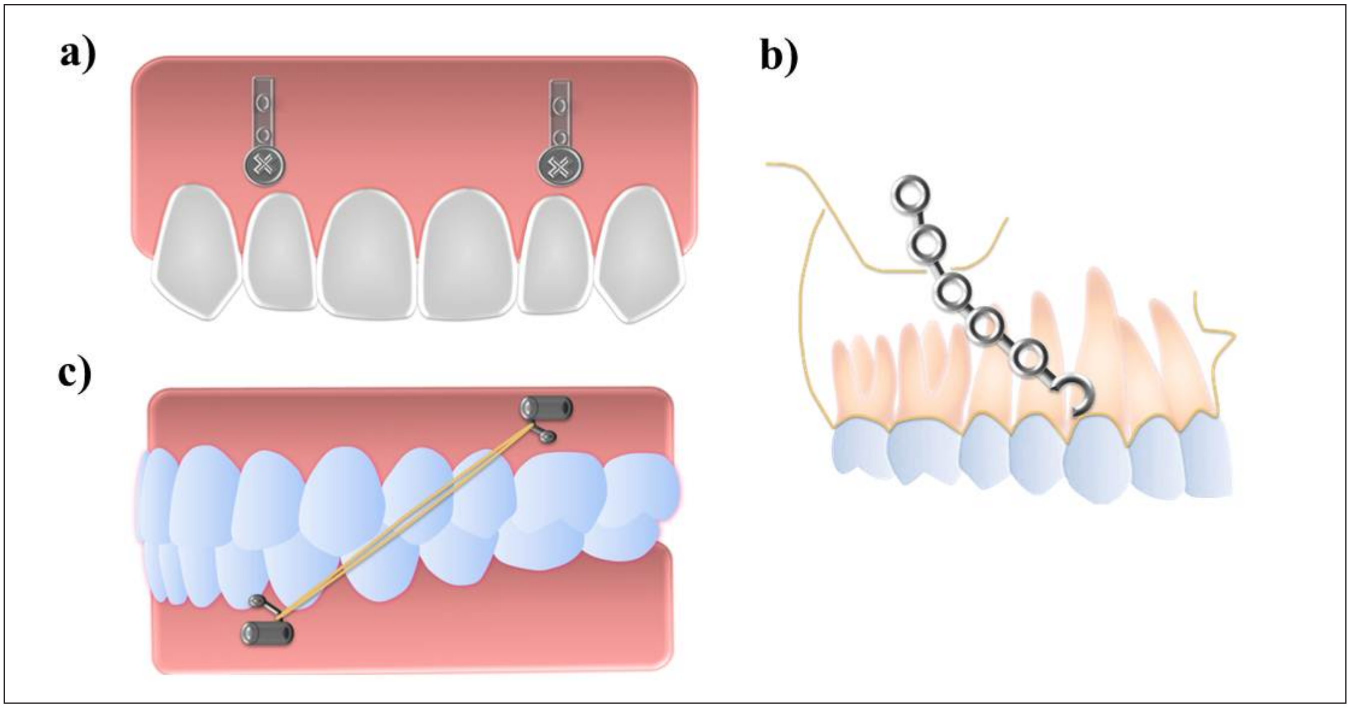

Figure 4: Distribution of the miniplates as bone anchorage for maxillary protraction. a) Miniplates in the anterior maxillary zone, between the lateral incisors and canines bilaterally. b) Miniplates in the maxillary zygomatic process. c) ZAS (Zygoma anchorage system) or BAMP (Bone anchor maxillary protraction): skeletal anchorage using upper and lower miniplates with intermaxillary elastics.

Characteristics of the maxillary bone traction force

The studies of the required maxillary bone protraction forces have yielded a great diversity of results. Some authors such as Lee[38] have found that 350 g per traction side suffices to produce orthopedic forces. However, other investigators use greater forces of between 400-600 g *per* side,[35,53] or even 600-800 g *per* side,[39,40,54] and all agree that the mean application time should be approximately 14±2 hours a day.[35,40,53]

As regards the direction of the force, most studies use an antero-inferior force vector, angled 30º below the occlusal plane, in order to reduce the anticlockwise rotation of the maxilla that occurs upon applying traction to the latter. While such anticlockwise rotation is beneficial in patients presenting a brachyfacial pattern with deep overbite, is counterproductive in those with open bite and an enhanced facial height.[41,55-57] With the aim of eliminating these undesired effects, some authors have investigated the center of resistance of the maxilla with the purpose of controlling the rotation. Hata[58] considered the center of resistance to be located 5 mm below the nasal floor. Based on this idea, he used the skull of a 12-year-old child to apply force vectors from three different locations for maxillary protraction: 1) 10 mm above the Frankfort plane; 2) 5 mm above the palatal plane; and 3) at the height of the maxillary arch. The results suggested that force application 5 mm above the palatal plane and 15 mm above the occlusal plane can eliminate anterior rotation of the maxilla.

Nanda[59] was the first to create a modified maxillary protraction arch that eliminated the mentioned anticlockwise rotation of the maxilla. His work was followed by the studies of authors such as Alcan, Keles and Erverdi,[60] who designed a new mask referred to as a modified maxillary protraction mask, with the forehead as sole point of support (Figure 2a). With this mask the authors aimed to displace the force application point above the center of resistance of the maxilla, in order to produce clockwise rotation of the latter.

Keles *et al* [53] in turn developed a modified Petit mask incorporating an extraoral arch, varying the position of the horizontal bar to 30º above the occlusal plane (20 mm above the latter), and adjusting the horizontal bar to the height of the extraoral arch for placement of the elastics (Figure 2b). Thanks to this mechanism, the maxilla does not rotate anticlockwise and progresses without rotation of any kind. However, the maxillary occlusal plane rotates clockwise, with extrusion and back tilting of the upper incisors.[53]

Maxillary propulsion with expansion and intraoral appliances

Exclusively intraoral dental anchorage appliances recently have been proposed, replacing the extraoral anterior traction vector with a set of intermaxillary action-reaction forces. Liou *et al* [61,62] propose expansion and propulsion of the maxilla using dental appliances only in the absence of patient collaboration. Maxillary propulsion is carried out using a modified expander (Figure 3.1), with the capacity to expand and contract in order to “loosen” the mid-palatal suture, followed by the application of propulsion to the maxilla with a 0.036” TMA spring anchored to the lower molar (Figure 3.2a and b). The expander used in this therapeutic method is similar to the “W” expander consisting of two hinges and two anterior arms, allowing rotation of the two halves of the palate.[55]

According to these authors,[61] the success of this treatment depends on the capacity to expand and constrict upon the maxilla in order to “loosen” the mid-palatal suture before applying maxillary protraction. The investigators point to the need to perform cyclic maxillary expansion-contraction, with a maxillary expansion rate of 1 mm/day during 7 days, followed by compression for an equivalent

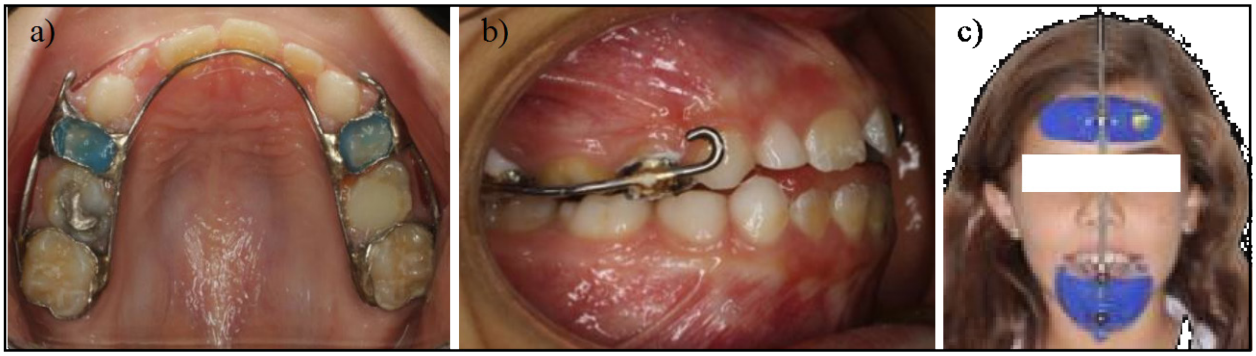

Figure 5: Facemask protraction without expansion. a) Occlusal view of palatal arch with anterior protraction hooks. b) Lateral view of the appliance. c) Extraoral photograph with facemask appliance.

period at the same rate. These alternating cycles are maintained for 7-9 weeks until the maxillary bone has "loosened". Following this treatment, maxillary propulsion is carried out using springs with an angle of 180º (Figure 3a) and in compression (mouth closed) at 100-120º (Figure 3b), making use of the first lower molars as anchorage, with the fitting of a lingual bar. On closing the mouth, the spring propels the maxilla upwards with a force of 400-500 g *per* side. The final phase involves stabilization with passive fit for three months.

On applying this technique in a sample of 10 children between 9-12 years of age, the authors reported a maxillary advancement of about 5.8 mm at point A level (Figure 1b), with 3 mm being generated at the expense of maxillary expansion-contraction, and the remaining 2.8 mm through intraoral maxillary protraction. Other skeletal effects are anticlockwise rotation of the palatal plane, in which ANS ascends 0.3 mm, and clockwise rotation of the mandible, in which Pog descends 4.3 mm. The dental effects in turn comprise protrusion of the upper incisors by 7.1 mm, retrusion of the lower incisors by 4.2 mm, and distal tipping of the lower molars, which according to the authors resolve on their own upon removing the appliance.[61]

Two years after treatment, the results were found to be stable, though the authors recommend over-protraction due to the remaining growth potential of the mandible.[57] This method moreover can be used in children with palatal fissures,[61,63] being even more effective than conventional rapid maxillary expansion.

Protraction of the maxillary bone with skeletal anchorage

The introduction of the new bone anchorage appliances in dentofacial orthopedic practice offers promising perspectives for the future and substantial improvements in the outcome of orthopedic maxillary traction therapy. This is particularly the case in growing patients with severe maxillary hypoplasias. In such situations, some authors such as Kircelli[64] attach great importance to early treatment and avoid postponing therapy until adult age for orthognathic surgery, since there are psychological effects that depend upon the degree of deformation,[65] and functional deficiencies such as speech problems.[66] In these cases maxillary traction with a face mask and expansion is not the best management choice, since the forces are applied to the teeth, making it impossible to transmit forces directly to the circumaxillary sutures and thus obtain a greater skeletal effect.[64] Undesired dentoalveolar changes are thus observed,[67] such as proinclination of the upper incisors and retroinclination of the lower incisors[68-70] – in addition to a significant loss of anchorage in the posterosuperior pieces and extrusion of the latter.[23,71]

In order to avoid all these undesired effects, Kokich *et al* in 1985[72] introduced the use of bone anchorage to facilitate maxillary protraction, transmitting the force directly to the maxillary bone. To this effect, the authors applied the anterior traction forces of the face mask to intentionally ankylosed temporary canines serving as natural implants in a patient with maxillary deficiency. These "natural implants" were seen to protract the maxilla 4 mm. Posteriorly, Smalley *et al* [73] experimented with this same idea but using Branemark-type osseointegrated implants in *Macaca nemestrina*, obtaining 8 mm of maxillary advancement after applying 600 g of force *per* side.

A number of temporary bone anchorage techniques are currently available for maxillary traction, such as implants, onplants, miniscrews, and miniplates. However, in this review we will only consider those methods that use miniplates as anchoring elements, since these are the procedures most widely cited in the literature to date. Maxillary traction involving bone anchorage is divided into two groups or categories: maxillary traction with miniplates and a face mask on one hand, and maxillary traction with upper and lower miniplates and intermaxillary elastics on the other.

Maxillary traction with miniplates and facemask

Authors such as Kircelli *et al* [64,74] propose using the facemask with an expander, employing miniplates and miniscrews for temporary maxillary anchorage. With this method the authors aim to transfer the extraoral forces directly to the circumaxillary sutures, thereby maximizing the skeletal effects obtained. In turn, they suggest placing the miniplates in the nasal wall of the maxilla, located anterior to all the sutures that join the maxilla to the base of the skull and positioned ahead of the center of resistance of the maxilla. In the year 2006 these authors published the clinical case[64] of an 11-year-old girl subjected to this procedure with full-time forces of 350 g (except during meals), during 12 months. Point A was seen to advance 8 mm, with an SNA increment of 7º. The maxilla showed an anticlockwise rotation of 2º, and the facial axis opened 2º as a consequence of the clockwise rotation of the mandible, together with a 3º decrease in SNB. At soft tissue level,

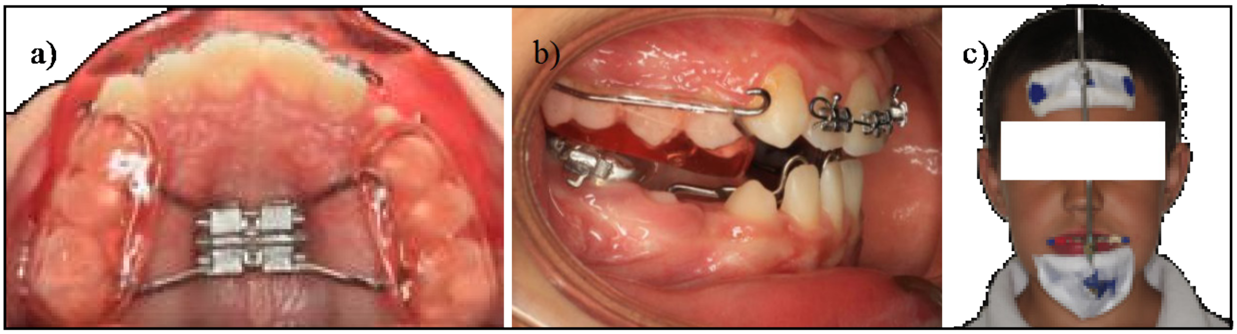

Figure 6: Facemask protraction with rapid maxillary expansion. a) Oclusal view of McNamara´s disjunctor with anterior protraction hooks. b) Lateral view of the appliance. c) Extraoral photograph with facemask appliance.

the nasal point advanced 5 mm, with a nasolabial angle (NLA) increment of 7º after the 12 months of treatment (Figure 1).

Two years later[74] these same authors published a pilot study of 6 patients between 10-13 years of age subjected to the same protocol from 2005.[62] The results reflected lesser maxillary advancement, with 4.8 mm of progression of point A, an SNA increment of 3.7º, maxillary anticlockwise rotation of 0.9º, and an SNB reduction of 2.3º, together with 1.2º aperture of the mandibular plane.

Zhou *et al* [75] in turn defined the anterior maxillary zone between the lateral incisors and canines as a point of bone anchorage for maxillary traction (Figure 4a). These authors reported the case of an 11.7-year-old patient with skeletal class III malocclusion secondary to maxillary hypoplasia, subjected to gradually progressing forces: treatment was started with 450 g *per* side and was then increased to 500-600 g one month after the start of traction, with part time application during 6 months. The results revealed a Wits reduction of 7.52 mm, with an upper incisor increase of only 0.1º, and a 2º aperture of the mandibular plane.[75]

In contrast to the above, other investigators have proposed the use of miniplates in the maxillary zygomatic process[76,77] (Figure 4b), in view of the adequate quality and thickness of the bone in this region,[78,79] and the proximity to the center of resistance of the nasomaxillary complex – the force vector therefore passing close to the center of rotation of this complex. These authors recommend this anchoring method in children with maxillary deficiency and palatal fissure, and advocate over-correction until reaching molar class II malocclusion, with a 10-month retention period in which the face mask must be worn at night. This technique was described in a series of three patients: one with palatal fissure in the absence of lip alterations; another with unilateral fissure of the lip and alveolar process; and a third patient with unilateral fissure of the lip and palate. The authors combined maxillary traction using fixed upper multibrackets with forces of 500 g per side during an average of 12 hours a day. A significant advance in point A was noted in all cases, and proved greater in the patient with involvement only of the palate (5 mm) than in the other two children (3 mm). In addition, minimal undesirable effects were recorded, such as vestibular tipping of the upper incisors (2º on average) and clockwise rotation of the mandibular plane, which varied in the three cases (negligible in the second and third cases, versus 4.5º in the first patient). In view of this low incidence of adverse effects, the authors proposed the use of this technique in patients with palatal fissure and compromised facial height.[77]

Maxillary traction with miniplates and intermaxillary elastics

De Clerck *et al* [80] proposed skeletal anchorage using upper and lower miniplates, together with intermaxillary elastics, as a method for correcting skeletal class III malocclusions. This technique is referred to as ZAS (Zygoma anchorage system) or BAMP (Bone anchor maxillary protraction)[80] (Figure 4c), and involves four orthodontic miniplates (two on each side): the upper plates are inserted at first and second molar level (in the infrazygomatic crest), while the lower plates are inserted between the lateral incisor and the canine. The authors proposed more apical insertion with respect to the insertion of traction miniplates, in order to minimize possible root damage.[71] Surgical placement of the miniplates in young patients is complicated, since the maxillary alveolar height is limited and the lower canines have not yet erupted. As a result, orthopedic treatment with miniplates usually does not begin before 10 years of age. Delaying maxillary traction offers the advantage of a shorter post-orthopedic and adult treatment period, thereby reducing the influence of the skeletal class III pattern.[80]

These miniplates have been shown to yield a low failure rate, and are highly stable. De Clerck *et al* [82] carried out a study of 25 children with an average age of 12 years, involving the placement of a total of 100 miniplates. A full 97% of the miniplates proved stable, with no mobility of any kind, while only 3% showed mobility and had to be repositioned.

The ZAS technique uses intermaxillary elastics from the upper miniplate to the lower miniplate, with one elastic on each side (Figure 4 c). A force of 100 g per side is initially applied, followed by an increase to 200 g after one month and 250 g after two months. The patients must be instructed to change the elastics once a day. In contrast to the facemask, which is worn for approximately 14 hours a day, this technique keeps the elastics in place for 24 hours a day – over-correction and nocturnal retention with intermaxillary elastics being required.

In 2009, De Clerk *et al* [80] published three clinical cases treated with the ZAS technique. The three patients were between 10 and 11 years of age, and initially received a full time force of 100 g per side, followed by 200 g after 1-2 months. The results showed improvement of the profile, with reduction

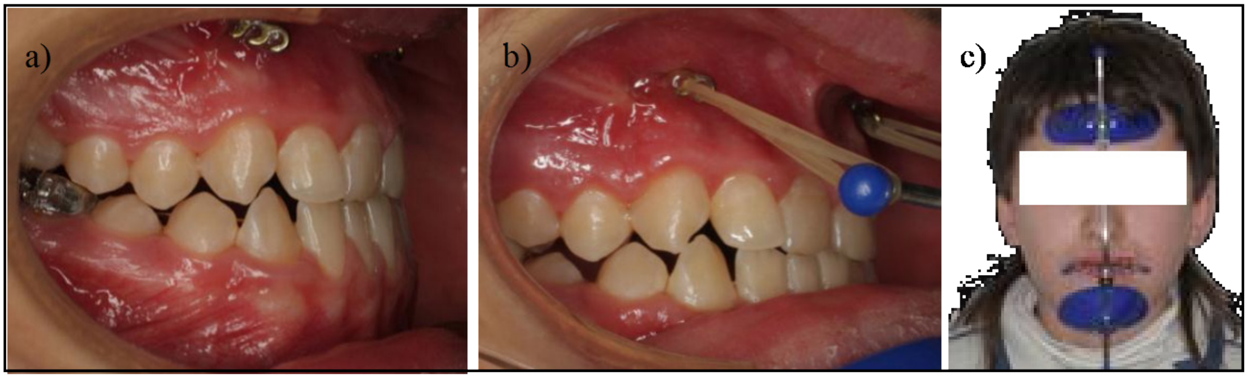

Figure 7: Bone-anchored facemask protraction. a) Lateral view of the bone anchored appliance b) Lateral view of the bone anchored appliance with elastics. c) Extraoral photograph with the facemask appliance.

of the concavity, and few changes in the soft tissues of the chin and lower lip. The lateral cranial X-rays in turn showed maxillary advancement, with a mean SNA increment of 6.1º accompanied by anticlockwise rotation of the maxilla (mean of 2.5º in the three patients); only one patient showed mandibular clockwise rotation (2º), with no changes in the rest. The upper incisor remained constant in one of the patients, while in the other two it suffered 4.5º of proinclination. In contrast, the lower incisor underwent proinclination in all three cases (5.8º on average). After one and two years of follow-up, the correction of the class III malocclusion was seen to remain stable, with only 1.3 mm of relapse at Wits appraisal level.[80]

Cone-beam computed tomography studies[81] have shown that the BAMP technique advances the zygomatic process with a positive change in the anterior region of the maxilla - point A advancing 2.8 mm and SNA increasing by 2º. However, the changes in the anterior mandibular region are highly variable both in magnitude and in direction. Specifically, the SNB angle decreases an average of 0.96º, though always with bone appositioning in the posterior part of the condyle and reabsorption in the anterior part – this suggesting posterior repositioning of the mandible as well as remodeling of the glenoid fossa. At dental level, the upper incisors show highly variable behavior ranging from vestibular tilting (2.8º) to retroinclination (-4º), while the lower incisors always show about 3º of proinclination[81] (Figure 1a).

With the purpose of comparing the effects of this technique versus children not subjected to treatment, De Clerck, Cevidanes and Baccetti[83] carried out cone-beam evaluations of the dentofacial effects of BAMP treatment. Large differences were observed on comparing the groups, particularly as refers to the A-Vertical distance and the Condylion (Co)-A length, with large increments of at least 4 mm in the treated group versus the control group. At mandibular level, restrictions in point B and Pog were observed in the treated group (Figure 1b). The intermaxillary relationships suffered very significant changes as a result of treatment, with a Wits increment of 6.7 mm, as well as posterior repositioning of the condyle and anterior re-directioning of its growth. Therefore, with this strictly skeletal treatment approach, the maxillary-mandibular changes lead to improved intermaxillary relationships in patients with skeletal class III malocclusions,[84] without vertical changes in the craniofacial structures.[85]

In comparison with conventional dentofacial orthopedics using a facemask, the ZAS technique has been shown to induce greater maxillary advancement with fewer vertical changes – increasing maxillary length (Co-A) 2.9 mm more than with the face mask. No differences have been found in the sagittal position of the mandible between the two groups, though the ZAS technique affords better vertical control, with no dentoalveolar compensations.[86]

The BAMP method has been shown to produce few changes one year after treatment, with a decrease in SNA and ANB of 1.5º and 0.6º, respectively, while SNB remains constant. A 1 mm Wits reduction is moreover observed, with an upper incisor proinclination of 2º and a lower incisor retroinclination of less than 1º at dentoalveolar level.[80]

Orthopedic treatment with a maxillary protraction mask ideally should be carried out at an early age (first mixed dentition phase). However, surgical placement of the miniplates in young patients is complicated, since the maxillary alveolar height is limited and the canines have not yet erupted. As a result, orthopedic treatment with miniplates usually does not begin before 10 years of age. Delaying maxillary traction offers the advantage of a shorter post-orthopedic and adult treatment period, thereby reducing the influence of the skeletal class III pattern.[80] Some authors have reported success with maxillary protraction in the late mixed dentition or early permanent dentition phase (about 10-12 years of age), using the new bone anchorage techniques with class III elastics.[80,86]

Another factor to be taken into account is the level of patient collaboration needed for achieving the skeletal changes with both techniques. Most authors recommend an average of 12-16 hours of treatment a day during 9-12 months for maxillary protraction using a face mask with either bone anchorage or dentoalveolar anchorage.[35,40,53,76,77] However the BAMP technique recommends use for 24 hours during 12 months.[80]

Cevidanes *et al*[86] compared the results obtained with the BAMP technique and the facemask with expander and dental anchorage. They selected a sample of 55 patients with skeletal class III malocclusion in the mixed or permanent dentition phase, with a Wits appraisal of -1 mm or less. The skeletal anchorage (BAMP) group consisted of 21 patients subjected to cone-beam computed tomography before treatment (T1) and approximately one year after treatment (T2). The mean patient age at T1 was 11 years and 10 months, versus 12 years and 10 months at T2, with an average of one year of treatment. The facemask and expander group in turn consisted of 34 patients subjected to cephalometric analysis before treatment (T1) and again one month after removal of the mask and expander (T2).

The skeletal anchorage group received forces of 150 g, followed one month later by an increase to 200 g, and a further increase to 250 g after three months, applied 24 hours a day. The face mask with expansion group activated the expander once or twice a day until correction of the transverse situation was achieved, applying forces of 300 g the first two weeks, followed by 500 g *per* side, for a minimum of 14 hours every day.

The analysis of the differences between T1 and T2 in the two groups showed greater changes with the bone anchorage technique – the maxillary length (Co-A) increasing 2.9 mm more than with the facemask. The changes in skeletal intermaxillary variables were also greater following the bone anchorage technique, with a Wits appraisal of 2.3 mm more than in the face mask group. There were no significant differences between the two groups in the sagittal position of the mandible, though improved vertical control of the mandible was afforded by bone anchorage – the ANS-Ch distance increasing 2.1 mm with the BAMP technique, versus 3.4 mm with dental anchorage. In turn, upper incisor proinclination was similar in both groups (0.6º versus 0.9º with dental anchorage), while lower incisor inclination behaved differently in the two groups: the incisor showed an average proinclination of 1.9º with the BAMP technique, while use of the mask and expander produced an average retroinclination of 4.3º.[86]

Șar *et al* [87] evaluated the differences between maxillary traction with dental anchorage and skeletal anchorage, using a facemask in both cases. They selected 45 prepubertal and pubertal children. In the skeletal anchorage group two miniplates were positioned lateral to the piriform aperture of the maxilla. Both groups underwent maxillary expansion using an expander with bite plates prior to traction.

On analyzing the changes, the maxilla was seen to have advanced 2.3 mm with skeletal anchorage versus 1.82 mm with dental anchorage – the difference being statistically significant. The advancement rate was 0.45 mm per month in the miniplates group and 0.24 mm per month in the dental anchorage group. Differences were also found in terms of anterior maxillary rotation, which proved greater in the dental anchorage group and was nonsignificant in the skeletal anchorage group. Posterior rotation of the mandible with an increase in facial height was recorded in both treatment groups, but was more manifest in the dental anchorage group. At dental level, the protrusion and mesialization seen with dental anchorage was not observed in the skeletal anchorage group.

Lastly, an important aspect of the recent introduction of temporary bone anchorage appliances in dentofacial orthopedic practice refers to patient perception. After one year of treatment, Cornelis *et al* [85] found 72% of the patients to accept these appliances, and 82% described the surgical experience as being better than expected, with little or no pain sensation. The most frequently reported problems were postoperative swelling, which lasted an average of 5 days, and irritation of the cheeks – initially experienced by over one-third of the patients, though this problem later subsided. It therefore can be affirmed that the miniplates are satisfactorily accepted by the patients and constitute a safe and effective complement in complex orthodontic treatments.

CONCLUSION

The treatment of class III malocclusions in growing patients remains a challenge in orthodontics, due to the high tendency towards relapse. At present, the incorporation of surgically inserted bone anchorage appliances (miniplates and miniscrews) offers a purely orthopedic approach to treatment, with minimization of the undesirable side effects of the compensations achieved with traditional dentofacial orthodontics based on dentoalveolar anchorage. Nevertheless, these promising surgical miniplate-based orthopedic traction protocols must be contrasted by studies offering solid scientific evidence in order to optimize the age ranges, types of forces and types of orthopedic systems, among other factors. This will help to maximize the orthopedic changes at maxillary and mandibular bone level, minimize the dentoalveolar effects, and thus secure greater stability of the results obtained.

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