Universidad Europea

GRADUATION PROJECT

Degree in Dentistry

TREATMENT OF CLASS III MALOCCLUSIONS IN GROWING PATIENTS

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ABSTRACT

Introduction: The treatment of Class III malocclusions is complex due to multifactorial components and represents a challenge for modern orthodontics since skeletal discrepancy can lead to functional alterations with abnormal occlusion and can even affect the patient psychologically through its aesthetic manifestations. Different protocols of treatment and early management of Class III patients improves the prognosis, reduces consequences and more complex or invasive treatment in the future; **Objectives:** The major objective was to identify the advantages and disadvantages of the different protocols available to treat Class III malocclusion caused by maxillary retrognathism; the minor objectives were to put forward the most suitable protocol including ideal age to start, daily wearing time, amount of applied orthopedic forces and treatment duration; **Material and Method:** Scientific research carried out through articles from the database PubMed, limited to in vivo studies directed towards the class III malocclusions from maxillary cause and that investigated different treatment protocols, published between 2012 and 2022, identified by a special search equation; **Results:** Out of 214 articles found initially, the results of 16 articles that met inclusion criteria and not exclusion criteria have been analyzed to study the cephalometric changes (SNA, ANB, Co-A, WITS, overjet, maxillary and mandibular incisors proclination, maxillary molars mesialization) produced by different protocols of treatment in growing patients; **Conclusion:** Both skeletal and dental anchorage protocols were effective to solve Class III malocclusion even if skeletal anchorage allowed greater maxillary advancement, greater skeletal changes, less dental movement, shorter treatment duration and less relapse. The treatment should ideally be started as early as possible during prepubertal and pubertal stage of growth.

Keywords: Dentistry; Skeletal Class III; Orthodontics; Treatments; Growing patients

RESUMEN

Introducción: El tratamiento de la maloclusión Clase III es complejo debido a componentes multifactoriales y representa un desafío para la ortodoncia moderna ya que la discrepancia esquelética puede llevar a alteraciones funcionales con oclusión anormal y puede afectar psicológicamente al paciente a través de sus manifestaciones estéticas. Diferentes protocolos de tratamiento y manejo temprano Clase III mejora el pronóstico, reduce las consecuencias y los tratamientos más complejos o invasivos en el futuro; **Objetivos:** El objetivo principal fue identificar las ventajas y desventajas de los diferentes protocolos disponibles para tratar la maloclusión Clase III causada por retrognatismo maxilar; los objetivos menores fueron proponer el protocolo más adecuado que incluye la edad ideal para comenzar, el tiempo de uso diario, la cantidad de fuerzas ortopédicas aplicadas y la duración del tratamiento; **Material y Método:** Investigación científica realizada a través de artículos de la base de datos PubMed, limitada a estudios in vivo dirigidos a las maloclusiones de Clase III de causa maxilar y que investigaron diferentes protocolos de tratamiento, publicados entre 2012 y 2022, identificados por una ecuación de búsqueda especial; **Resultados:** De los 214 artículos encontrados inicialmente, se han analizado los resultados de 16 artículos que cumplían criterios de inclusión y no criterios de exclusión para estudiar los cambios cefalométricos (SNA, ANB, Co-A, WITS, resalte, proinclinación de incisivos maxilares y mandibulares, mesialización de molares) producidos por diferentes protocolos de tratamiento en pacientes en crecimiento; **Conclusión:** Tanto los protocolos de anclaje esquelético como dentario fueron efectivos para resolver la maloclusión Clase III, aunque el anclaje esquelético permitió un mayor avance maxilar, mayores cambios esqueléticos, menor movimiento dental, menor duración del tratamiento y menor recidiva. Idealmente, el tratamiento debe iniciarse lo antes posible durante la fase de crecimiento prepuberal y puberal.

Palabras clave: Odontología; Clase III esquelética; Ortodoncia; Tratamientos; Pacientes en crecimiento

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INTRODUCTION

1. Generalities

1.1 Classification

In 1899, Edward Angle known as « the father of American orthodontics » defined the dental malocclusions into 3 types : Class I, Class II and Class III.(1) He based his classification taking as reference the occlusal relationship of the first permanent molars and canines into a sagittal plane. In ideal occlusion or molar Class I, the mesiobuccal cusp of the upper first permanent molar should occlude with the buccal groove of the lower first permanent molar. On the other side, in ideal occlusion or canine Class I, the tip of the cusp of the upper canine should occlude in front of the contact point existing between the lower canine and the lower first premolar. Following this classification, Class II appears when the lower first molar or lower canine occlude with their respective antagonists in a more distal position than they should. Class II is also known as distocclusion. Conversely, Class III appears when the lower first molar or lower canine occlude with their respective antagonists in a more mesial position than they should. Class III is also known as mesiocclusion (2) Angle's classification has been promptly proved to be limited by excluding the analysis of vertical and transversal relation as well as the skeletal relation. In fact, there was no differentiation between skeletal and dental malocclusion.(3)

A short time afterwards, other orthodontists attempted to provide more precisions to this classification by including skeletal parameters.

In 1966, Charles Tweed, a former student of E. Angle, divided the Class III malocclusion into two categories :

Category A or pseudo Class III is described by the absence of skeletal anomaly and by normal cephalometric values. There is an equilibrium in the

relation between maxilla and mandible. At last, this category refers to an anterior crossbite.(1)

Category B or skeletal Class III is described by skeletal anomalies reflected by a discrepancy in the relation between maxilla and mandible. Different patterns can be observed as a retrognathism of the maxilla, a prognathism of the mandible or a combination of both. This category relies on changes in cephalometric values.(1)

A while after, Moyers added a new category : Neuromuscular. This refers to a prematurity or interference that constrain the mandible to move forward to allow the patient to bite properly.(4)

1.2 Prevalence

The prevalence of Class III malocclusion is variable from one population to another. A higher prevalence is observed in Asian countries especially in Chinese, Japanese and Malaysians populations with a prevalence rate of 15,8%. The Middle Eastern countries have a slightly lower prevalence with a rate of 10,2%.(1) The lowest prevalence is observed in European countries with a prevalence rate of 4,9% and in North American Caucasian with a prevalence rate between 1 and 4%.(5)

Class III is by far the least frequent type of malocclusion with an average frequency of 7,2% compared to Class I and Class II malocclusions. (6)

Class III related to a combination of maxillary retrognathism and mandibular prognathism appears to be the most frequent (30%), before the maxillary retrognathism (19,5%) and mandibular prognathism (19,1%) according to Ellis and McNamara. More recently, Straudt & Killaridis put forward different frequencies. Class III related to a combination of maxillary retrognathism and

mandibular prognathism appears to be the least frequent (8,7%), behind the maxillary retrognathism (19,3%) and mandibular prognathism (47,4%).(7)

Male population seems to have a slightly higher prevalence of Class III malocclusion than female population.(8)

1.3 Etiology

The etiology of class III malocclusion is multifactorial and complex but it is associated with genetic and environmental factors.(3)

The genetic component seems to be the most important etiologic factor. It appears that the prognathic mandibular pattern is present in several members of a same family although it is difficult to put forward with exactitude the genes associated to bone, cartilage and muscular growth involved in the development of Class III malocclusion. The type of transmission, either dominant or recessive, is also unclear and requires more investigations.(3) In the diagnosis of a class III, it is recommended to see the parents and even to ask for pictures of ancestors to predict the probable evolution and growth of the patient and therefore to assess the severity of the case.(7)

However, some environmental factors may play a key role in the development of class III malocclusion and the most important one seems to be the tonsils, adenoids and tongue hypertrophies. In fact, this creates a posterior airway obstruction which produces difficulty in nasal breathing and so enhances oral breathing. This also forces the tongue in a downward and forward position that causes a sagittal and transversal maxillary hypoplasia and an increase in mandibular growth. Other environmental factors seem to be involved in this process such as muscular factors, habits as prolonged sucking or resting tongue, congenital anatomic defects as cleft lip and/or palate, posture or trauma provoking the premature loss of deciduous incisors.(4,7) Hormonal disturbances and disease of the pituitary gland may be associated to class III malocclusions.

An increase of growth hormone caused by an adenoma or some syndromes such as acromegaly stimulates mandibular growth and leads to mandibular prognathism.(9) Other syndromes are associated to class III malocclusion such as Crouzon syndrome, Cleidocranial dysostosis or Down syndrome.(10,11) Finally, the ectopic eruption of maxillary central incisors may be an etiologic factor of class III malocclusion. In fact, a palatal eruption of the upper central incisors could force the lower central incisors to occlude more labially which will result in anterior crossbite.(4)

1.4 Characteristics

Facial features are characteristic of Class III malocclusion. A concave profile is observed in both skeletal and pseudo Class III although it can be found straight when the patient is in centric relation in this last one.(4) Concavity can be assessed by the Gl.Sn.Pog which is the angle formed by the soft tissue glabella (Gl) corresponding to the area above the nose and between eyebrows, the subnasale (Sn) and the soft tissue pogonion (Pog) described below in the cephalometric section. Its normal value is between 165° and 175°.(12) In concave profile, Gl.Sn.Pog angle is increased.(13) There is a deficit of the medium facial third characterized by a retrusion of the nasomaxillary area and upper lip. The extraoral exploration also reveals lower lip and lower facial third protrusion. The lower lip is usually more voluminous than the upper lip.(4) There is an absence of mentolabial sulcus which determines the separation between lower lip and chin. The mentolabial sulcus can be evaluated by the angle formed by the soft tissue labrale inferius (Li) which is the most anterior and prominent point of the lower lip, the Submental (Sn) and the soft tissue pogonion (Pog) described below in the cephalometric section. In class III malocclusion, the mentolabial angle is obtuse.(14) Chin is also more voluminous than in other types of malocclusions.(15)

An incisal compensation of skeletal Class III can be observed in some cases described by a proclination of upper incisors and a retroclination of the lower

incisors. In some cases of Class III malocclusion related to an anterior crossbite, the patient can achieve an edge to edge position which decreases the severity of the case. Concerning the dental overbite, a normal or deep overbite is considered as a favorable parameter unlike openbite.(2)

Skeletal class III can be assessed by the analysis the cephalometric landmarks (Figure 1) and measurements (13) :

NAPog : Angle formed by the most posterior point between the anterior nasal spine and the alveolar crest called Point A or Subspinal (A), the most anterior point of the frontonasal suture called Nasion (N) and the most anterior point on the bony chin or symphysis called Pogonion (Pog). This angle describes facial convexity and has a normal value of 8° in mixed dentition and 2,5° in permanent dentition. In Class III malocclusion, the facial profile is concave and the value of NAPog is decreased and usually negative.

SNA : Angle formed by the midpoint of the Sella Turcica (S), the Nasion (N) and the point A or Subspinal (A). This angle describes the antero-posterior relation between the maxilla and the cranial base and has a normal value of 82°±3° in both dentitions. In Class III malocclusion caused by a maxillary retrognathism, the value of SNA is decreased and inferior to 79°.(16)

SNB : Angle formed by the Sella Turcica (S), the Nasion (N) and the most posterior point between the chin point and the alveolar crest called supramentale (B). This angle describes the antero-posterior relation between the mandible and the cranial base and has a value of 78° in mixed dentition and 80°±3° in permanent dentition. In Class III malocclusion caused by a mandibular prognathism, the value of SNB is increased.

SND : Angle formed by the Sella Turcica (S), the Nasion (N) and the central point of the mandibular symphysis (D). This angle describes the antero-posterior relation between the mandible and cranial base and has a normal

value of 73,5° in mixed dentition and 76,5°±2,5° in permanent dentition. In class III malocclusion caused by a mandibular prognathism, the value of SND is increased and confirms SNB.

ANB : Difference between SNA and SNB. It has a normal value of 4° in mixed dentition and 2° in permanent dentition. In class III malocclusion, the value of ANB is decreased and usually negative.(16)

Co-A : Distance between the most superior posterior point on the head of the mandibular condyle called Condylion (Co) and the point A. It describes the effective maxillary length. In Class III malocclusion caused by a maxillary retrognathism, the value of Co-A is decreased.

Co-Gn : Distance between the Condylion (Co) and the most anterior inferior point on the mandibular symphysis called Gnathion (Gn). It describes the effective mandibular length. In Class III malocclusion caused by a mandibular prognathism, the value of Co-Gn is increased.

Co-A and Co-Gn participate in the formation of McNamara's triangle. In class III malocclusion, the discrepancy between maxilla and mandible is increased.

N perpendicular (N⊥) : Distance between the Point A and the straight line passing through the Nasion and perpendicular to the straight line joining the uppermost point on the bony external auditory meatus called Porion (Po) and the most inferior point on the margin of the orbit called the Orbitale (Or). It describes the maxillary position and is measured in millimeters (mm). It has a normal value of 0 mm in mixed dentition and 1 mm in front of N perpendicular in permanent dentition. In Class III malocclusion caused by a maxillary retrognathism, the value of N perpendicular is decreased.

ANL : Angle formed by the most anterior point of the base of the nose called Columella (Cm), the point where the base of the columella joins the upper lip called subnasale (Sn) and the most anterior point of the upper lip called upper labrale (Ls). It describes the nasolabial angle and has a normal value between 90° and 105° in permanent dentition and confirms the maxillary position. In Class III malocclusion caused by a maxillary retrognathism, the value of ANL is increased.

Gonial angle : Angle formed by the intersection of the condyle and the base of the cranium called Articulare (Ar), the most posteroinferior point on the angle of the mandible called Gonion (Go) and the lowermost point of the mandibular symphysis in the midline called Menton (Me). It describes the proportion of the facial height and the ramus heigh and so predicts the patient's growth pattern. It has a normal value of 126°± 4° and is increased in ¾ of Class III.(3)

Mandibular plane is usually inclined. The more inclined it is, the more it will produce a dolichofacial pattern and prognathism.

WITS : Distance in millimeters between the straight line passing through point A perpendicular to occlusal plane and the straight line passing through point B perpendicular to occlusal plane. It describes the relation between points A and B. In Class III malocclusion, the value of WITS is negative.(3) The more negative it is, the more severe the case will be. When the value is greater than minus 7 mm, there will be no chance to treat it only with orthodontics nor orthopedic appliances and it will be a surgical case.

1.NA : Angle between the straight line joining the apical point of the upper central incisor (Aui) and the tip of the crown of the upper central incisor (Iui) with the straight line joining the Nasion (N) to the Point A. Distance between NA and the tangent passing through point A. It evaluates the angle and the distance together. In Class III malocclusion, there is usually a compensation between

upper and lower incisors and so it has an increased value that corresponds to a proclination of the upper incisors.

U1-SN : Angle between the straight line joining the apical point of the upper central incisor (Aui) and the tip of the crown of the upper central incisor (Iui) with the straight line joining the Nasion (N) to the Sella Turcica (S). In Class III malocclusion, it is usually increased due to the proclination of upper incisors.

1.NB : Angle between the straight line joining the apical point of the lower central incisor (Ali) and the tip of the crown of the lower central incisor (Ili) with the straight line joining the Nasion (N) to the Point B. Distance between NB and the tangent passing through point B. It evaluates the angle and the distance together. In Class III malocclusion, there is usually a compensation between upper and lower incisors and so it has a decreased value that corresponds to a retroclination of the lower incisors.

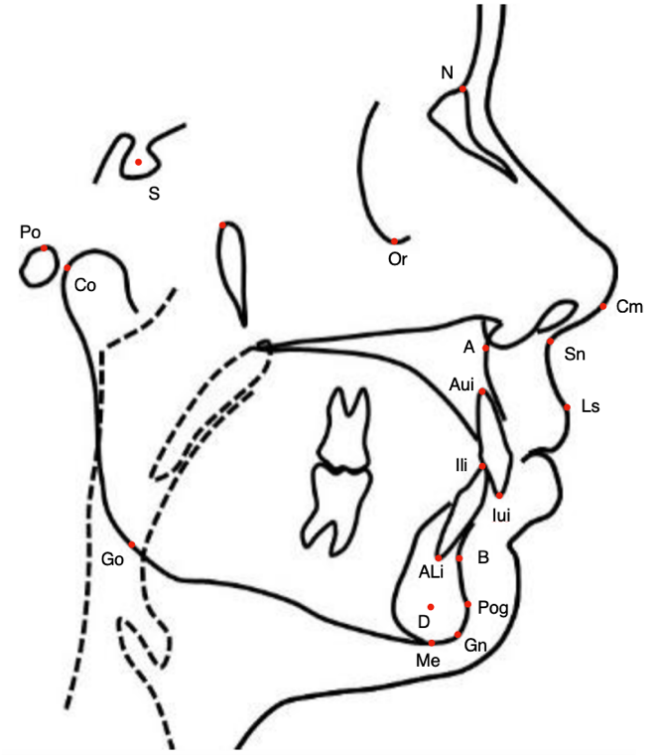

Figure 1. Cephalometric landmarks.

2. Early interceptive treatment factors

Interceptive orthodontics consist in early treatment to avoid later more complex procedures. Turpin defined some recommendations to consider in the planification of the treatment of class III malocclusion. (17)

On one hand, some characteristics appear to be favorable factors to early treatment and to prevent the malocclusion from becoming more severe. As positive factors, we find convergent profile, functional antero-posterior slipping, symmetrical condylar growth, young patient with moderate skeletal discrepancy, patient compliance, non genetic heritage or no history of prognathism in patient's family, positive facial esthetics.(3,17)

On the other hand, some characteristics appear to be unfavorable factors to early treatment and indicate a treatment after full growth achievement. As negative factors, we find divergent profile, non antero-posterior slipping, asymmetrical condylar growth, non growing patient, severe skeletal discrepancy, no patient compliance, genetic heritage or history of prognathism in patient's family, negative facial esthetics. (3,17)

3. Orthopedic appliances

Orthopedic therapy refers to the correction of a predominantly skeletal imbalance and to a lesser extent, a dentoalveolar malocclusion. For that, orthopedic appliances use what is called orthopedic forces which are around 400 grams. (18)

3.1 Protraction face mask

The protraction facemask (FM) or reverse headgear is often used in the early correction of class III malocclusion with maxillary retrognathism. It is

indicated in early mixed dentition and until 10 years old. After 10 years old, the effectiveness of the protraction mask is reduced.(3) The use of protraction facemask is not indicated in dolichofacial patient as it produces an elongation of the face.(18)

It is an appliance composed of intraoral and extraoral parts. There are two types of masks : Delaire face mask and Petit face mask.

Delaire facemask was the first described and owe his name to Jean Delaire who was the first to define this type of appliance.(18) Extraoral anchorage is provided by a forehead cap and a chin cup joined by a metal framework composed of two vertical bars and one cross bar.(Figures 2,3) The intraoral anchorage can be either dental or skeletal.(19) Dental anchorage is provided either by a removable device or a fixed device with cemented bands on the first permanent maxillary molars. Hooks are placed at the level of the maxillary canines and elastics are placed to join the extraoral framework.(3,16) The elastics must be placed so as to exert a downward and forward traction of 30° with respect to the occlusal plane.(20)

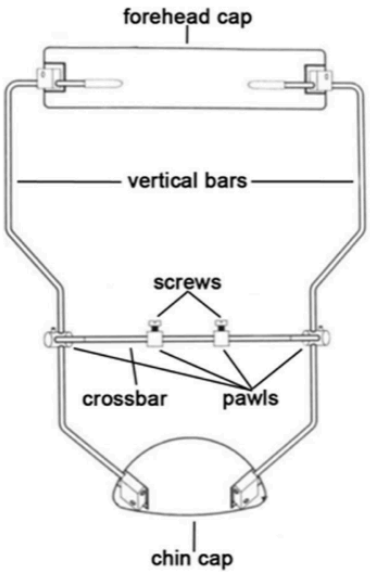

Figure 2. Structure and parts of Delaire-type facemask.(19)

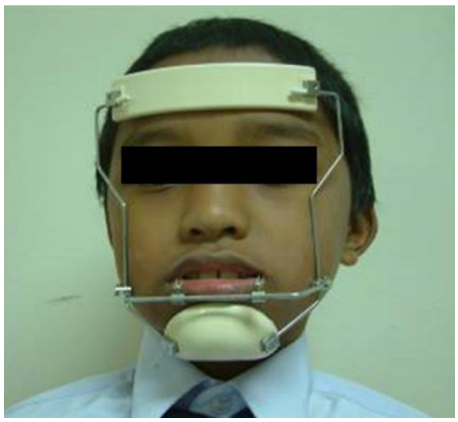

Figure 3. Extraoral photograph of the Delaire-type facemask.(21)

Petit face mask is a variation of the Delaire face mask (Figures 4, 5) where the metal framework is changed by a metal bar and increased forces.(16,22) A crossbar is fixed perpendicularly to the metal central bar to hook the elastics.(19)

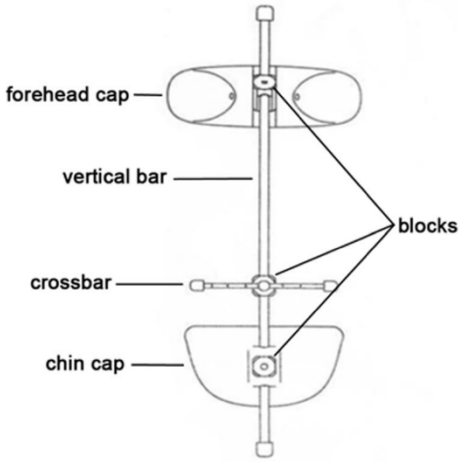

Figure 4. Structure and parts of Petit-type facemask.(19)

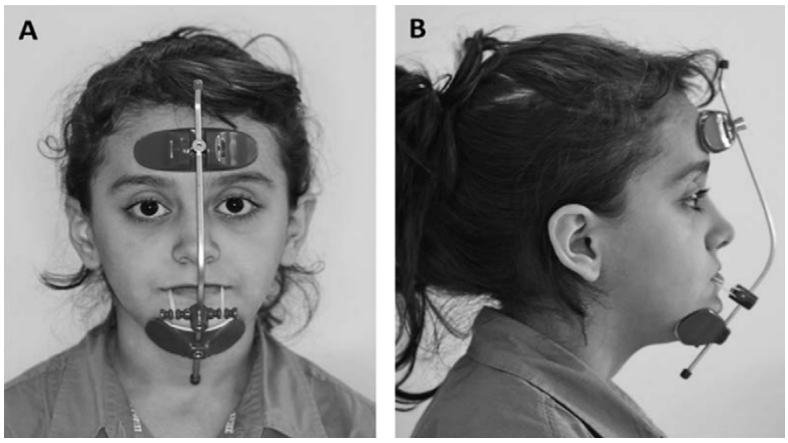

Figure 5. Extraoral photograph of the Petit-type facemask.(23)

The protraction face mask can be worn at night as it may be more efficient as the body releases a higher quantity of growth hormone during the night. The daily time as well as the total duration of treatment varies according to the severity of the case and the type of combination used with the face mask.(3)

The protraction face mask can be used in combination with a rapid maxillary expander (RME) activated once or twice a day. The use of RME is debated by some authors who believed it could cause a disarticulation of the maxilla.(16)

3.2 Chin cup

The chin cup is an extraoral appliance used to treat Class III with correct maxillary position but with mandibular prognathism in growing patients with deciduous or early mixed dentition.(20) It provides the backward and downward rotation of the mandible.(3) There are two types of chin cup depending on the direction of the force : occipital pull chin cup and vertical pull chin cup.(Figure 6) Occipital pull is used in brachyfacial patient while vertical pull is used in dolichofacial patient.(18,24) The force applied is 300-500 grams per side. The appliance must be worn for 12-14 hours per day. Some authors have shown that chin cup therapy was subjected to relapse and recommend to continue to wear the appliance until complete growth. (20)

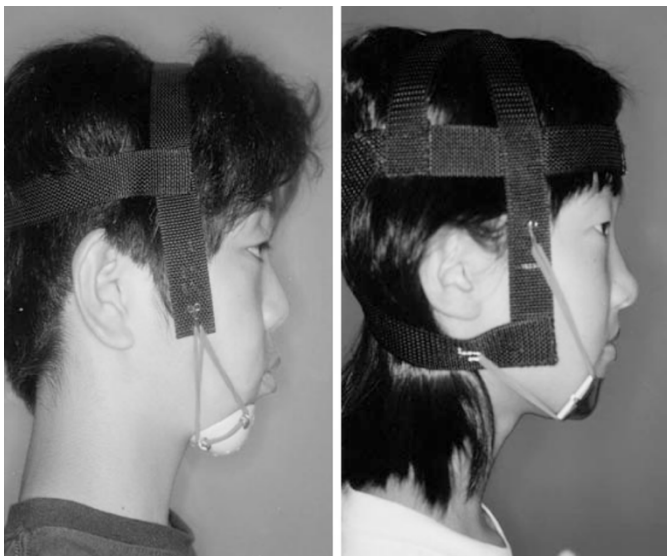

Figure 6. A, High-pull chin cup; B, Occipital pull chin cup.(24)

3.3 Bionator III or Reverse Bionator

The Bionator III also called Reverse Bionator (Figure 7) is a modification of the original Bionator designed by Balters to treat Class III malocclusion caused by maxillary retrognathism.(25) This appliance can be used alone or following facemask therapy during the retention period. (26) Several parameters need to be considered when choosing Reverse Bionator treatment. Bionator III is indicated in patients with favorable features including midfacial deficiency, hypodivergent growth pattern and reduced facial height. However, it is contraindicated in dolichofacial patients. The main advantages of the Reverse Bionator are its low cost and comfort provide to the patient. However, it is a removable appliance which require the patient compliance to be effective. (27)

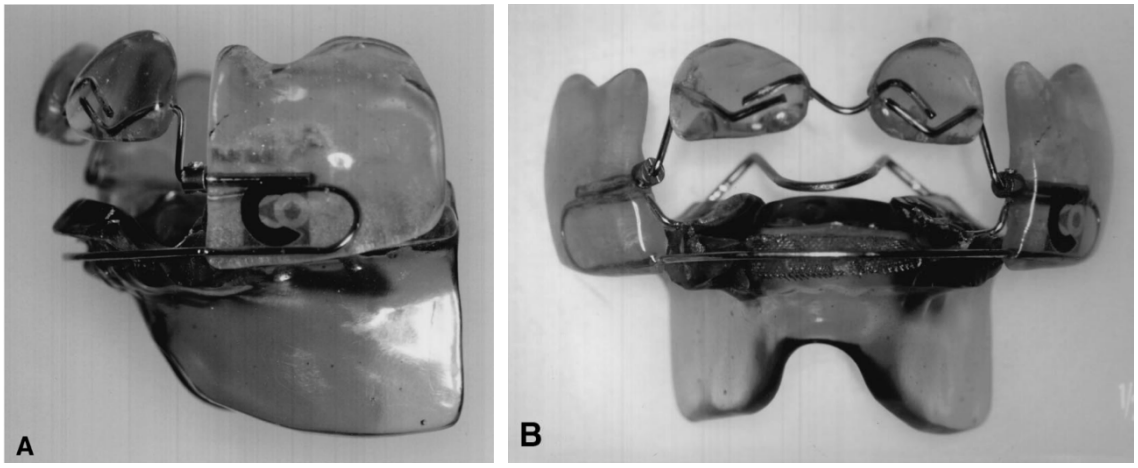

Figure 7. The modified Bionator III appliance. A, Lateral view; B, Frontal view (27).

3.4 Frankel III regulator

Frankel III regulator is a functional appliance designed to stimulate the maxillary growth and to limit mandibular growth.(16) It is composed of two posterior lateral acrylic pads and one anterior pad above the upper anterior teeth and at distance from the maxilla. The pads are extended to the bottom of the vestibule. In the lower arch, a labial arch wire is joining the two posterior lateral pads to restrict the advancement of the mandible.(3)

3.5 Hyrax expander

Rapid maxillary expander using hyrax screw is commonly used to correct maxillary constriction found in Class III malocclusion with maxillary retrognathism. The most common appliances are the Hyrax type rapid maxillary expander, the transverse sagittal maxillary expander and the Hybrid Hyrax.(28)

The conventional Hyrax type rapid maxillary expander (Figure 8) is anchored on the first permanent maxillary molars and first permanent maxillary premolars through cemented bands.(29) The Hyrax screw is positioned at the level of the second maxillary premolars. The appliance is activated by turning the screw ¼ turn twice per day for 15 days. After reaching the desired expansion, the appliance must remain passive for 6 months.(28)

Figure 8. Conventional Hyrax expander.(30)

The transverse sagittal maxillary expander is anchored on the first permanent maxillary molars through cemented bands.(Figure 9) A hyrax screw is also placed at the level of the midpalatal suture. The difference with the previous appliance is that two other hyrax screws are included in wires extended to the palatal surfaces of the central incisors. The appliance is activated by turning the screw ¼ turn twice per day for 15 days then ¼ every 7 days for 6-8 months. After reaching the desired expansion, the appliance must remain passive for 4 months.(28)

Figure 9. Transverse sagittal maxillary expander.(28)

The Hybrid hyrax is a modification of the traditional hyrax type maxillary expander where the hyrax screw is only attached to the molars.(Figure 10) This device is usually used in combination with the protraction facemask to provide intraoral anchorage. The hybrid hyrax seems to be more efficient than the traditional hyrax appliance by producing greater maxillary width.(30)

Figure 10. Hybrid Hyrax expander.(30)

3.6 Mandibular cervical headgear

The mandibular cervical headgear also called reverse pull headgear is a variation of the headgear appliance to treat mild to moderate Class III malocclusion with a mandibular prognathism.(Figures 11, 12) The aim is to distalize the permanent lower molars and to provide a backward and downward rotation of the mandible.(31) The appliance is composed of a facebow with

outer bow and inner bow joined together. The inner bow is inserted to buccal tube cemented on the lower first permanent molars.(18) Elastics can be added to promote maxillary protraction. A neck strap completes the device to allow traction. The main advantage of the reverse headgear is its small size which makes it more comfortable and better tolerated by patients.(31)

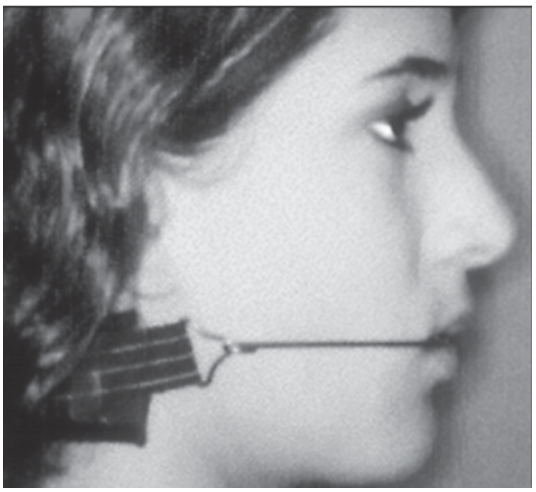

Figure 11. Extraoral part of the mandibular cervical headgear.(31)

Figure 12. Outer bow and inner bow of the mandibular cervical headgear.(31)

3.7 Temporary skeletal anchorage devices

Temporary skeletal anchorage devices (TSAD) have been recently used as skeletal anchorage to reduce skeletal discrepancy and avoid the undesirable dentoalveolar effect such as incisors inclination that can be produced by the usual appliances requiring dental anchorage.(32) However, they show to

improve some dental parameters as overjet and molar class relationship.(3) Among these devices are found the miniscrews and the miniplates.(32)

Titanium miniscrews (Figures 13,14) are small screws of 1,2 to 2,2 mm diameter and 5 to 15 mm length directly inserted to the maxillary bone between the roots of the teeth without realizing a previous gingival flap. Thus, they can be placed by orthodontists. The major risks of this technique are the failure of the screw due to unattached gingiva and root damage during the placement.(32) Another type of miniscrews used as skeletal anchorage are the palatal miniscrews. In growing patient, they are used to support rapid maxillary expander such Hyrax type as the palate is immature. For this reason, they are placed in the paramedian palatal area and in the clinical study of Karagkiolidou et al. at 3-6 mm away from the midpalatal suture and 6-9 mm posteriorly to the incisive foramen.(33)

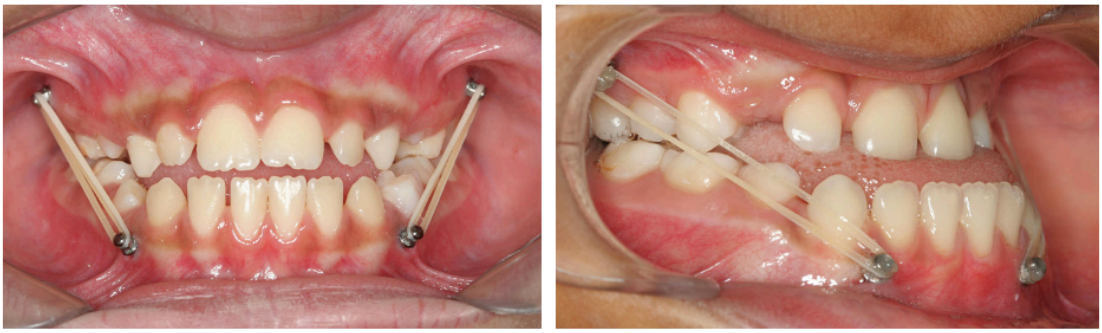

Figure 13. Temporary skeletal anchorage provided by miniscrews.(34)

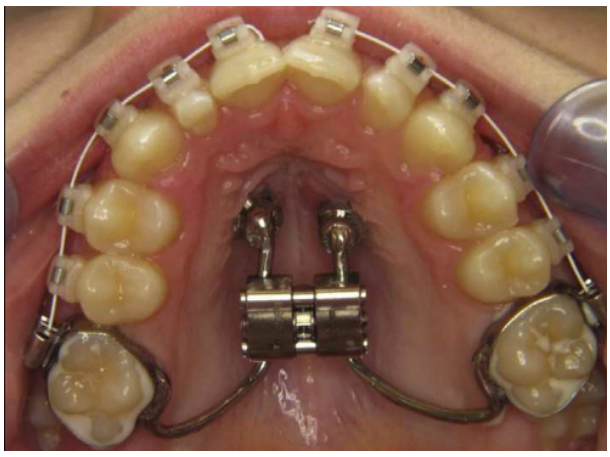

Figure 14. Hyrax-type expander supported by paramedian miniscrews.(33)

The miniplates can be fixed by bone screws to the infrazygomatic crest apically to the roots of the teeth. They are preferably placed and removed by oral surgeons. Other miniplates can be fixed to the mandibular symphysis and can be joined to the maxillary ones by elastics.(3) The elastics must be placed to exert a force at a 30° with respect to the occlusal plane.(16) The miniplates can also be used in combination with the protraction facemask.(32) They are made of titanium and there are principally two designs : the Bollard device and the C tube. (Figures 15,16)

The Bollard device is composed of a flat portion containing three fixation holes for the maxillary version and two fixation holes for the mandibular version, a connection bar joining the bone to the oral cavity and an attachment portion for orthodontic devices.(32)

The C tube is composed of a flat portion containing two fixation holes, a connection bar and a tube for orthodontic devices attachment.(32)

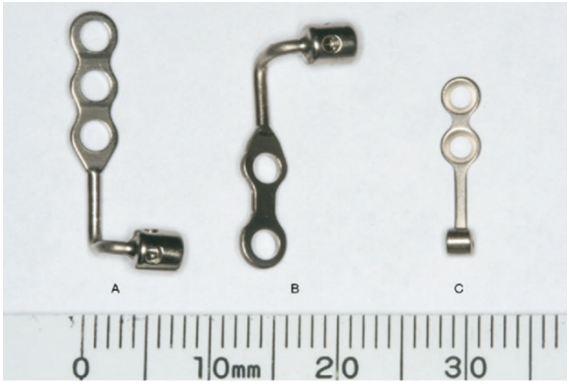

Figure 15. A, Maxillary and B, Mandibular Bollard devices; C, C-tube.(32)

Figure 16. Intraoral photograph showing miniplates with elastics.(35)

The success of the skeletal anchorage depends on the quality and thickness of the bones. For this reason, there is generally a better success rate in the mandible as the bone is thicker. It is recommended to use them in patients over 11 years old as the bone anchorage is more stable.(3) Titanium miniplates by its design can adapt to the bone structure. They are able to support orthopedic forces directly after being fixed.(36)

4. Orthodontic appliances

Orthodontic therapy refers to the correction of strictly dentoalveolar malocclusions although orthodontic appliances can be used in combination with orthopedic appliances.(18) They can be classified into fixed and removable.

4.1 Fixed appliances

4.1.1 Inclined plane

It is a functional appliance used to correct dental anterior crossbite characterized by maxillary incisors retroclination but without mandibular incisors proclination. It composed of a bonded resin composite bite plane placed at the lever of anterior teeth. This bite block represents the only contact in the mouth and can be made of composite, glass ionomer resin or acrylic and is cut with an angle of 45° from the longitudinal edge of the lower incisors. When biting, the upper incisors receive a pressure towards buccal. (3,4)

4.1.2 Modified inclined plane

This appliance is a variant of the inclined plane and is used in the case of anterior crossbite where the upper anterior teeth are inclined towards lingual and the lower anterior teeth are inclined towards labial. The inclined portion covers the incisal surface of the lower anterior teeth and create an elevation of

the bite that promotes the proclination of the upper anterior teeth. Contrary to the previous inclined plane, the lingual surface of the lower anterior teeth is free of acrylic to allow retroclination.(3)

4.1.3 Brackets 2x4

The 2x4 (Figure 17) is a fixed appliance where bands are cemented on the first permanent maxillary molars and brackets are bonded on the vestibular surface of maxillary incisors. A continuous protrusion arch wire is joining one band to another.(3,37,38)

Figure 17. 2x4 appliance.(4)

4.1.4 Quad helix

The Quad helix (Figure 18) is a fixed appliance where two bands are cemented on the first permanent maxillary molars. A continuous wire composed of four loops is cemented to the bands as well as two anterior protrusion arms.(4) The design of the appliance allows the expansion of the maxilla and the early correction of anterior crossbite.(39)

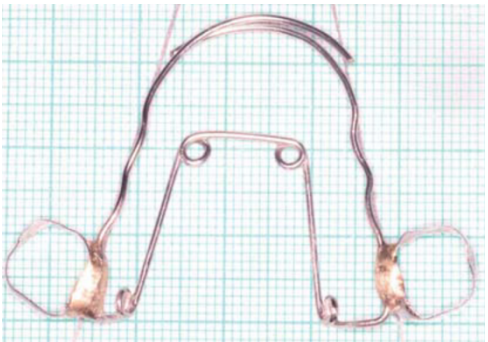

Figure 18. Quad helix with anterior extension arms.(39)

4.2 Removable appliances

4.2.1 Reverse twin block

The reverse twin block (RTB) is a removable device composed of inclined occlusal planes which are reversed to promote maxillary advancement and limit mandibular advancement.(40) The inclined planes are drawn with an angle of 70° in relation to the occlusal plane with biting blocks placed at the level of the upper premolars or upper temporary molars and the lower molars.(41) To correct the retroclination of the upper incisors, retroincisive springs or a three-pin expander can be incorporated into the structure.(42) The whole appliance is retained by Adam and ball clasps on posterior teeth.(Figure 19) Anterior retention can also be provided by an acrylic lower labial bow that can help to accomplish the retroclination of lower incisors once activated. The reverse twin block is usually comfortable and well tolerated by the patients.(41)

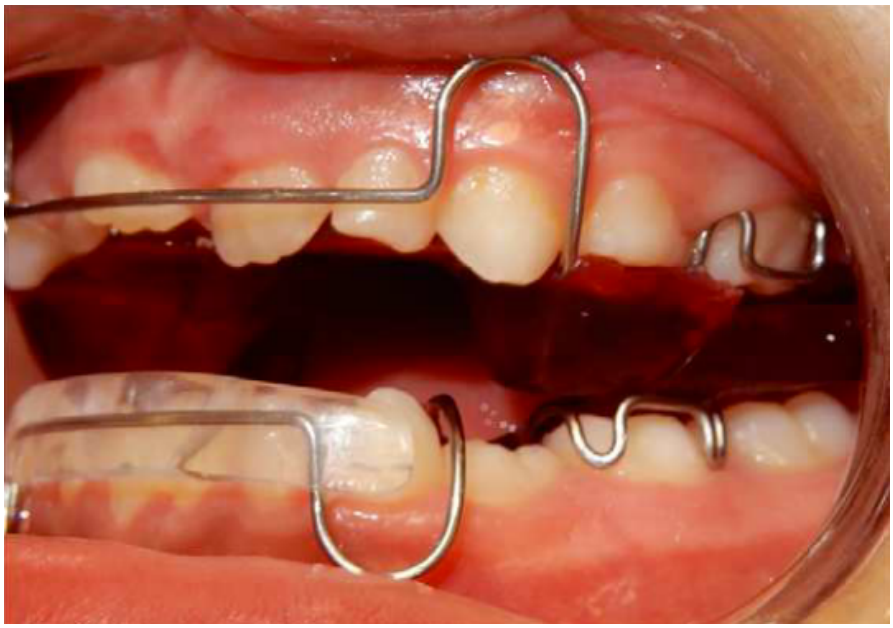

Figure 19. Lateral view of a Reverse Twin Block.(41)

4.2.2 Hawley plate

Removable appliance composed of ball and / or Adam clasps on the posterior teeth, anterior protrusion springs behind maxillary incisors in anterior crossbite made of stainless steel and included into an acrylic framework.(Figures 20, 21) A screw can be included to expand the palate. To correct a labial position or proclination of lower incisors, an inverted labial bow can be added to the Hawley plate.(43) Once activated, the inverted labial bow plate will act to retrocline or lingualize the lower incisors and so slow the mandibular growth.(4,44) The appliance must be worn at least 22 hours per day to be efficient.(45) The main advantages of the Hawley plate is its fast correction. Moreover, it can be used to provide retention after an orthopedic treatment.(4)

Figure 20. Inverted labial bow.(44)

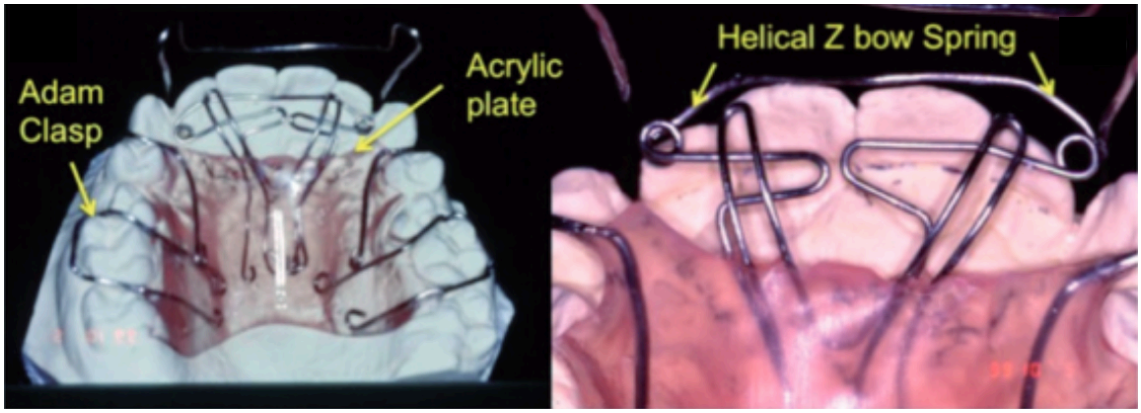

Figure 21. Hawley plate with helical Z Springs.(43)

5. Justification

The treatment of Class III malocclusion thus represents a challenge for modern orthodontics since skeletal discrepancy can lead to functional alterations with abnormal occlusion and can even affect the patient psychologically through its aesthetic manifestations. For this reason, it is of significant interest to be updated about the different protocols available for this type of malocclusion to provide the best functional and aesthetic outcomes to the patient.

In growing patient presenting Class III malocclusion caused by maxillary retrognathism, are there differences between treatment through skeletal and dental anchorages in terms of effectiveness and protocols ?

OBJECTIVES

The major objective of this study is to identify which are the main advantages and disadvantages of the appliances used to solve a class III malocclusion caused by maxillary retrognathism in growing patient.

The minor objectives are to establish the ideal period to start the treatment of class III malocclusion caused by maxillary retrognathism and to determine the most suitable protocol of use including the daily wearing time, amount of applied orthopedic forces and the treatment duration.

MATERIALS AND METHODS

Bibliographic research of scientific articles was carried out in the database of PubMed. A time limit has been set and only the most up to date articles having been published in the last decade (from 2012 to 2022) have been selected. Three languages were accepted : English, Spanish and French. This research was directed towards the class III malocclusions with maxillary cause and special attention was given to the most recent treatment methods: facemask, rapid maxillary expander, mini implants, mini screws and reverse twin block. The population studied included male and female patients in growing stage. The keywords used during this research were : dentistry, Class III malocclusion, growing patient, orthodontics, orthopedics, treatment, skeletal discrepancy, maxillary retrognathism, hyrax, skeletal anchorage devices, protraction facemask, rapid maxillary expander.

The search equation resulted in : ((((((((((class III) AND ((((growing) OR (growth)) OR (pubertal)) OR (children))) AND ((treatment) OR (correction))) AND (skeletal)) AND ((((((((((skeletal anchorage) OR (mini implants)) OR (miniscrew)) OR (miniplate)) OR (hybrid hyrax)) OR (hyrax)) OR (rapid maxillary expander)) OR (reverse twin block)) OR (fixed appliance)) OR (removable appliance)) OR (facemask))) AND (((((maxillary cause)) OR (maxillary retrusive patient)) OR (maxillary retrusion)) OR (maxillary protrusion)) OR (maxillary protraction) AND ((orthodontic) OR (orthopedic))) NOT (adult)) NOT (orthognathic surgery))) NOT (((cleft lip) OR (cleft palate)) OR (syndrome) AND (2012:3000/12/12[pdat])).

Randomized controlled trials (RCT), case controlled studies, retrospective and prospective studies were favored as they represent the higher level of evidence resources. Studies including Class III related to syndromes, non growing patients and in vitro or animal studies have been excluded. Case reports, case series and literature reviews have been excluded from this review

as they represent the lowest level of evidence resources. These inclusion and exclusion criteria are listed below (Table 1).

Inclusion criteria	Exclusion criteria
Skeletal Class III malocclusion Maxillary retrognathism Growing patients Orthopedic treatment Human studies Randomized controlled trials, retrospective, prospective studies Publication dates : 2012-2022	Class III related to syndromes Absence of maxillary cause Non growing patients Orthognathic surgery In vitro or animal studies Case reports, case series, literature reviews

Table 1. Inclusion and exclusion criteria.

RESULTS

The bibliographic research led to identification of 214 articles found on PubMed. 158 articles have been excluded because the titles and abstracts did not include our research criteria. After reading the full text articles, 40 have been excluded because they were case reports or case studies. Finally, 16 articles have been selected to answer the objectives of this work. The process realized is summarized below through the PRISMA flow chart.(Figure 22)

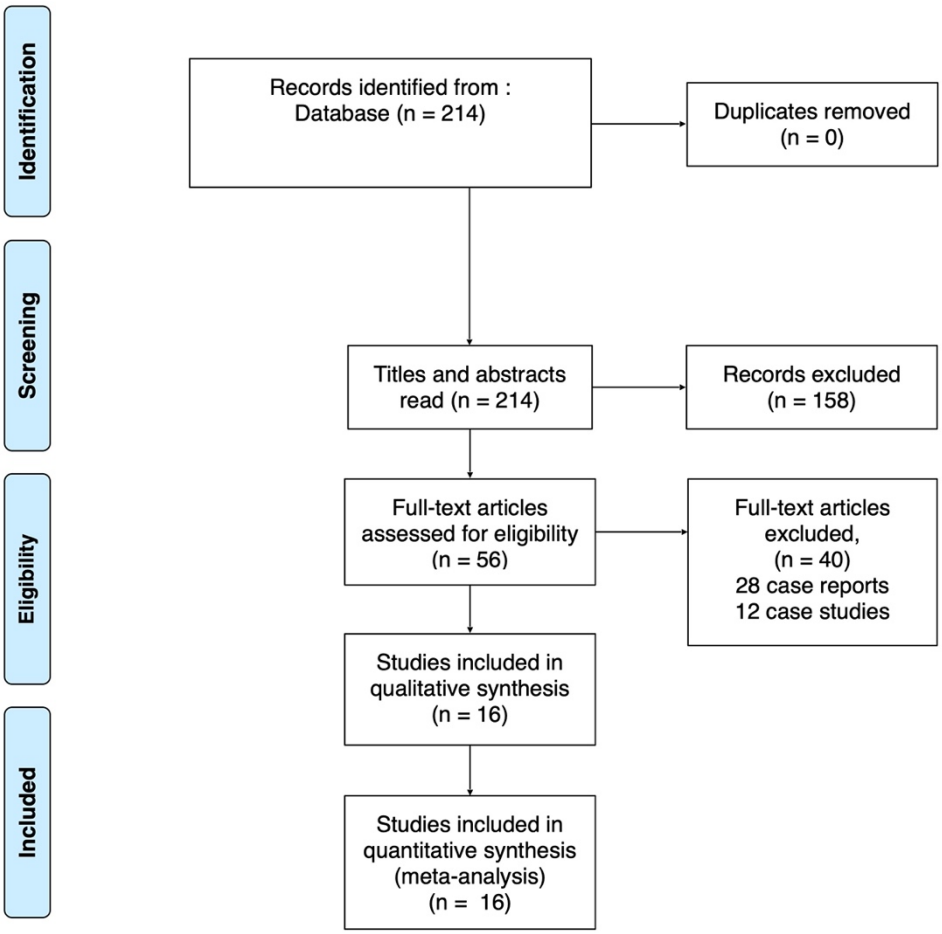

Figure 22. PRISMA flow diagram for the identification and selection of eligible studies.

All the results are listed in the following table (Table 2) including the appliances used, the treatment protocol and the results obtained. Two diagrams summarized the results obtained by facemask combined either with skeletal or dental anchorages through the different studies. (Figures 23, 24)

Table 2. Summary of results of the selected articles.

Authors / Date	Type of Study	Participants	Appliances used	Treatment protocol	Results
Elnagar et al. (46) 2016	Controlled clinical study	**Facemask with skeletal anchorage (FM/MP)** 10 patients : 4 girls and 6 boys Mean age : 11,9 ± 1,3 years **Miniplates (MP)** 10 patients : 3 girls and 7 boys Mean age : 12,24 ± 1 years	Facemask + miniplates Miniplates	**FM/MP** Elastics : 3 weeks after MP placement 400-500g/side Facemask : 14-16h/day Total duration : 8 months **MP** Elastics : 2-3 weeks after MP placement 250g/side and 24h/day Total duration : 8,9 months	**FM/MP** • SNA : +4,78° • ANB : +5,99° • Overjet : +7,1mm • Co-A : +4,8mm • Lower incisors inclination : -2,6° • Maxillary molars mesialization : +0,14 mm **MP** • SNA : +5,65° • ANB : +6,04° • Overjet : +7,1mm • Co-A : +5,74mm • Lower incisors inclination : +0,2° • Maxillary molars mesialization : +0,06 mm

Tripathi et al. (47) 2016	Retrospective study	**Skeletal anchored facemask (SAMP)** 10 patients Mean age : 10,1 ± 1,1 years **Conventional facemask (CFMP)** 10 patients Mean age : 9,9 ± 1,1 years	Facemask + miniplates Facemask	**Both groups** Previously treated by RME activated 2 times/day for 7 days Elastics : 400 g/side Facemask : 12-14h/day Total duration : 5,8 months (SAMP), 10 months (CFMP)	**SAMP** • SNA : +3,8° • ANB : +3,6° • Overjet : +5,6mm • Co-A : +3,2mm • U1-SN : +2° • Mesialization of maxillary molars : +0,6 mm **CFMP** • SNA : +3,4° • ANB : +3,3° • Overjet : +5,8mm • Co-A : +2,8mm • U1-SN : +6,4° • Mesialization of maxillary molars : +6 mm

Lee HJ et al. (48) 2022	Retrospective study	**Facemask + miniplates (FM-MP)** 20 patients : 14 girls and 6 boys Mean age : 10,6 ± 1,1 years **Facemask + Rapid maxillary expander (FM-RME)** 23 patients : 15 girls and 8 boys Mean age : 10,0 ± 1,5 years	Facemask + miniplates Facemask + Rapid maxillary expander	**FM-MP** Elastics : 400g/side Facemask : >14h/day Treatment duration : 9,7 months **FM-RME** Activation : 1-2 times/day Until achievement of maxillary expansion Elastics : 400g/side Facemask : >14h/day Treatment duration : 9 months	**FM-MP** • SNA : 3,1° • ANB : 4,4° • WITS : 5,7mm • Overjet :5,7mm • Upper incisors inclination : +2,1° • Lower incisors inclination : -0,9° **FM-RME** • SNA : 2,1° • ANB : 3,8° • WITS : 5,2mm • Overjet : 6,3mm • Upper incisors inclination : +2,8° • Lower incisors inclination : -2,0°

	FM-MP (long term changes) • SNA : 0,8° • ANB : -1,1° • WITS : 0mm • Overjet : -0,9mm • Upper incisors inclination : +5,2° • Lower incisors inclination : 4,9° **FM-RME (long term changes)** • SNA : -2,4° • ANB : -2,4° • WITS : -2,1mm • Overjet : -2,5mm • Upper incisors inclination : +5,1° • Lower incisors inclination : 4,7°

Koh et al. (49) 2014	Retrospective study	**Skeletal anchored facemask (SAFM)** 19 patients : 11 girls and 8 boys Mean age : 11,21 years **Tooth-borne facemask (TBFM)** 28 patients : 21 girls and 7 boys Mean age : 10,09 years	Facemask + miniplates Facemask + Hyrax palatal expander	**SAFM group** Elastic force : 400-500 g/side Facemask : 24h/day except during meals **TBFM group** Hyrax : activated 1-2 times/day Until achievement of maxillary expansion Facemask : 12-14h/day	**SAFM group** • SNA : +2,3° • ANB : +3,3° • Maxillary length : +4,6mm • U1-SN : -1,1° • Lower incisors inclination : -2,9° **TBFM group** • SNA : 1,8° • ANB : +3,0° • Maxillary length : +3,1mm • U1-SN : +4,1° • Lower incisors inclination : -3,6°

Souza et al. (34) 2019	Prospective clinical trial	**Facemask (FM)** 12 patients : 6 girls and 6 boys Mean age : 8 years **Mini-implants (MI)** 12 patients : 8 girls and 4 boys Mean age : 10 years	Petit-type facemask + Hyrax-type rapid maxillary expander Mini-implants	**FM** Hyrax : activated 2 times/day 8 to 12 days Elastics : 400g/side Facemask : 14-16h/day Total duration : 16 months **MI** Elastics : 100g/side the 1st month After 200g/side 24h/day Total duration : 12,5 months	**FM** • SNA° : +3,00° • ANB° : +2,50° • WITS : +2mm • Co-A : +3,5mm • Overjet : +2mm **MI** • SNA° : +2,75° • ANB° : +2,50° • WITS : +3,75mm • Co-A : +3,75mm • Overjet : +3mm

Lee NK et al. (50) 2012	Retrospective study	**Facemask + Miniplates (FM-MP)** 10 patients : 5 girls and 5 boys Mean age : 11.2 ± 1.2 years **Facemask + RME (FM-RME)** 10 patients : 6 girls and 4 boys Mean age : 10.7 ± 1.3 years	Facemask + miniplates Facemask + rapid maxillary expander (bonded and banded types)	RME : activated 2 times/day Until achievement of maxillary expansion **Both groups** Elastics : 400g/side Facemask : 12-14h/day	**FM-MP** • SNA° : +2,7° • ANB° : +3,8° • Overjet : +5,8 mm • WITS : +2,9 mm • Upper incisors inclination : +2,3° • Lower incisors inclination : -2,0° **FM-RME** • SNA° : +1,2° • ANB° : 3,5° • Overjet : +7,7 mm • WITS : +4,8 mm • Upper incisors inclination : +5,3° • Lower incisors inclination : -2,2°

Hino et al. (51) 2013	Controlled clinical study	**Facemask + Rapid maxillary expander (RME/FM)** 21 patients : 16 girls and 5 boys Mean age : 8,1 ± 1,5 years **Bone anchored miniplates (BAMP)** 25 patients : 13 girls and 12 boys Mean age : 11,9 ± 1,8 years	Facemask + Hyrax-type rapid maxillary expander Miniplates	**RME/FM** Activation : 2 times/day → 0,25 mm/turn Elastics : 600-800 g/side Facemask : 14-16h/day **BAMP** Elastics : 100g/side initially, up to 250g/side 24h/day	**RME/FM** • Maxillary skeletal changes : 2,6mm • Maxillary dental changes : 3,2mm **BAMP** • Maxillary skeletal changes : 3,7mm • Maxillary dental changes : 4,3mm

Ağlarcı et al. (52) 2016	Prospective study	**Facemask (FM)** 25 patients : 13 girls and 12 boys Mean age : 11,2 ± 1,3 years **Skeletal anchorage (SA)** 25 patients : 13 girls and 12 boys Mean age : 11,8 ±1,2 years	Facemask L-shaped miniplates	**FM** Elastics : 400g/side Facemask : 18-20h/day Total duration : 0,52 years **SA** Elastics : 75g/side the 1st week, 200g/side after 3rd week 18-20h/day Total duration : 0,76 years	**FM** • SNA° : +1,34° • Co-A : +2,54mm • N⊥ : +1,61mm • WITS : + 5,03mm • Overjet : +0,1mm • U1/NA :+ 4,89° • L1/NB : - 2,25° **SA** • SNA° : +1,63° • Co-A : +3,42mm • N⊥: +1,76mm • WITS : + 3,87mm • Overjet : +1,2mm • U1/NA : +2,06° • L1/NB : + 2,69°

Bozkaya et al. (36) 2017	Controlled clinical trial	**Treated group** 18 patients : 10 girls and 8 boys Mean age : 11.4 ± 1.28 years **Untreated control group** 18 patients : 9 girls and 9 boys Mean age : 10.6 ± 1.12 years	L-shaped maxillary miniplates + Petit-type facemasks	Elastic force : 1 week after miniplates placement 400 g/side Facemask : 24h/day except during meals Treatment duration : 1.08 ± 0.28 years	**Treated** • SNA° : +2,2° • Co-A : +3,97mm • ANB° : +3,81° • WITS : +5,44mm • Overjet : +5,72° • U1/NA : +0,22° • L1/NB : -3,69° **Untreated** • SNA° : -0,25° • Co-A : +1,82mm • ANB° : -0,17° • WITS : -0,17mm • Overjet : -0,06° • U1/NA : +0,94° • L1/NB : +0,33°

Seiryu et al. (53) 2020	Prospective randomized controlled trial	**Facemask (FM)** 20 patients : 8 girls and 12 boys Mean age : 10 years, 5 months ± 1,year, 8 months **Facemask + Miniscrews (FM+MS)** 19 patients : 7 girls and 12 boys Mean age : 11 years, 1 month ± 1 year, 3 months	Facemask alone joined by elastics to hooks extend from the lingual arch Facemask with lingual arch fixed by a miniscrew placed in the anterior palate	**Both groups** Elastics : 250 g/side Facemask : 12h/day Total duration : >1,5 years	**FM** • SNA : +1,1° • SN-ANS : +1,2° • ANB : +1,2° • Proclination of maxillary incisors: +4,6° **FM+MS** • SNA : +2,2° • SN-ANS : +2,5° • ANB : +2,0° • Proclination of maxillary incisors: -0,4°

Ge et al. (54) 2012	Randomized controlled trial	**Facemask + Miniscrews (FM-MS)** 20 patients : 11 girls and 9 boys Mean age : 10 years, 4 months **Facemask + Rapid maxillary expander (FM-RME)** 23 patients : 12 girls and 11 boys Mean age : 10 years, 6 months	Petit-type facemask + miniscrews Petit-type facemask + Hyrax-type rapid maxillary expander	**FM-MS** Elastics : 200-250g/side Facemask : 14h/day Total duration : 11 months **FM-RME** Hyrax : activated 2 turns/day Until achievement of maxillary expansion Elastics : 400-500g/side Total duration : 1 year, 1 month	**FM-MS** • SNA° : +2,58° • Co-A : +4,93 mm • ANB : +4,37° • WITS : +4,83 mm • U1-SN : -1,88° **FM-RME** • SNA° : +2,62° • Co-A : +5,04 mm • ANB : +4,42° • WITS : +5,33 mm • U1-SN : +6,41°

Nienkemper et al. (55) 2014	Controlled clinical study	**Treated group** 16 patients : 6 girls and 10 boys Mean age : 9,5 ± 1,6 years **Untreated / Control group** 16 patients : 8 girls and 8 boys Mean age : 9,4 ± 1,1 years	Facemask + Hybrid Hyrax rapid maxillary expander supported by miniscrews	Hybrid hyrax : activated by 90° turn, 4 times/day → 0,8mm/day of expansion Elastics : 400g/side Facemask : 16h/day	**Treated group** • SNA : +2,0° • ANB : +3,4° • WITS : +3,8mm • Co-A : +2,2mm • Overjet : +3,3mm **Untreated group** • SNA : -0,4° • ANB : -0,7° • WITS : -0,7mm • Co-A : +1,2mm • Overjet : +0,1mm

Ngan et al. (56) 2015	Retrospective study	**Tooth borne RPE + facemask (TBFM)** 20 patients : 12 girls and 8 boys Mean age : 9,8 ± 1,6 years **Bone anchored RPE + facemask (BAFM)** 20 patients : 12 girls and 8 boys Mean age : 9,6 ± 1,2 years	Facemask + Hyrax-type RPE Facemask + Hybrid Hyrax supported by miniscrews	**TBFM** Hyrax : activated 2 times/day, 1-2 weeks → 0,25mm/turn Elastics : 380g/side Facemask : 12-14h/day **BAFM** Hyrax : activated 2 times/day, 1-2 weeks → 0,25mm/turn Elastics : 380g/side Facemask : 12-14h/day	**TBFM** • SNA° : +0,39° • ANB° : +2,58° • WITS : +2,19mm • Overjet : +5,5mm • Upper incisors inclination : -0,2° **BAFM** • SNA° : +1,29° • ANB° : +2,17° • WITS : +2,31mm • Overjet : +3,4mm • Upper incisors inclination : -4,4°

Fischer et al. (57) 2018	Prospective study	**Facemask + Rapid maxillary expander (RME/FM)** 20 patients : 12 girls and 8 boys Mean age : 6,3 ± 0,8 years **Facemask + Alternating rapid maxillary expansion and constriction (Alt-RAMEC/FM)** 20 patients : 11 girls and 9 boys Mean age : 6 ± 0,9 years	Petit-type facemask + rapid maxillary expander	**RME/FM** Activation : 1-2 times/day → 0,2 to 0,4mm/day of expansion Until achievement of maxillary expansion Elastics : 400-500g/side Facemask : 14h/day for 6 months and by night only for the next 6 months **Alt-RAMEC/FM** Activation : 2 times/day for 1 week → 0,4mm/day of expansion Deactivation : 2 times/day for 1 week Total alt-RAMEC duration : 7 weeks Elastics : 400-500g/side Facemask : 14h/day for 6 months and by night only for the next 6 months	**RME/FM** • Maxillary protraction : +2,0mm • Maxillary inferior displacement : 2,1mm **Alt-RAMEC/FM** • Maxillary protraction : +2,0mm • Maxillary inferior displacement : 2,4mm

Liu et al. (58) 2015	Randomized controlled trial	**Facemask + Rapid palatal expansion (RPE)** 21 patients : 11 girls and 10 boys Mean age : 9,8 ± 1,7 years **Facemask + alternating rapid palatal expansion and constriction (RPE/C)** 22 patients : 12 girls and 10 boys Mean age : 10,1 ± 1,4 years	Facemask + Hyrax rapid palatal expanders	**RPE** Activation : 4 times/day → 1mm/day of expansion Duration : 1 week Elastics : 400-500g/side Facemask : >14h/day Total duration : 10,8 months **RPE/C** Activation/deactivation (alternation each week) : 4 times/day Duration : 7 weeks Elastics : 400-500g/side Facemask : >14h/day Total duration : 9 months	**RPE** • SNA : +1,93° • ANB : +4,29° • WITS : +3,28mm **RPE/C** • SNA : +2,67° • ANB : +4,15° • WITS : +3,65mm

Seehra et al. (37) 2012	Retrospective study	**Reverse Twin Block (RTB)** 13 patients : 7 girls and 6 boys Mean age : 8,8 ± 0,56 years **RTB + Facemask (PFM)** 9 patients : 7 girls and 2 boys Mean age : 9,9 ± 0,99 years	Reverse Twin Block Facemask + Reverse twin block	**RTB** 24h/day except during meals **PFM** Patients previously treated with RTB	**RTB** • SNA : +1,2° • ANB : +1,0° • Upper incisors proclination : +9,0° • Lower incisors retroclination : -5,3° **PFM** • SNA : +2,1° • ANB : +3,8° • Upper incisors proclination : +4,0° • Lower incisors retroclination : -2,2°

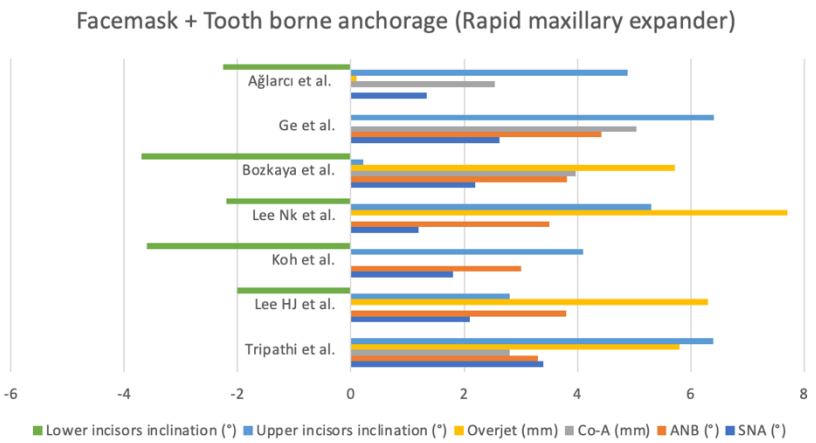

Figure 23. Diagram of changes in cephalometric values in patients treated with facemask and tooth borne anchorage.

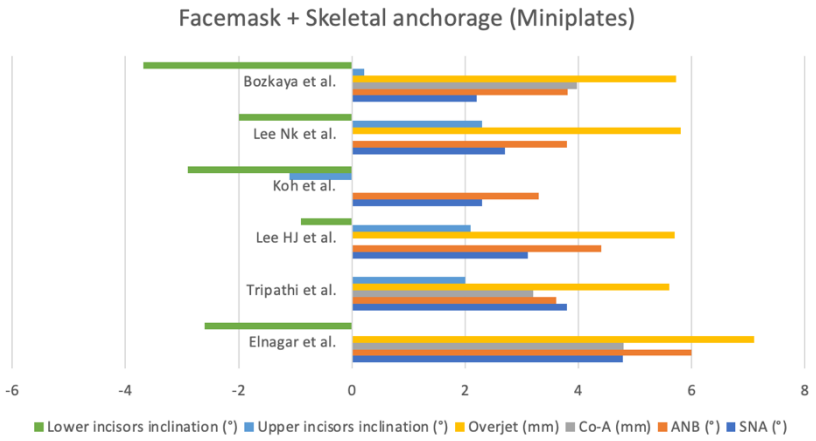

Figure 24. Diagram of changes in cephalometric values in patients treated with facemask and skeletal anchorage.

DISCUSSION

Koh et al., Souza et al., Seiryu et al. and others studied different protocols including different appliances, orthopedic forces and wearing times to treat Class III malocclusion. (34,49–53,56) They widely used protraction facemask, usually defined as the appliance of reference to solve Class III. According to Koh et al., Souza et al., Seiryu et al. and others, protraction facemask combined with dental anchorage appeared to be efficient and helped to increase SNA, ANB, overjet, WITS and the position of point A in a significant way.(34,49–53,56) However, they appeared to produce undesirable dental effects as maxillary incisors proclination, mesialization of maxillary molars and lower incisors retrusion.(Figure 23) To avoid these side effects, skeletal anchorage has been introduced to accomplish skeletal changes without compensatory dental movement.(Figure 24) Ge et al. studied how FM-RME protocol resulted in a significant increase of maxillary incisors proclination and maxillary molars mesialization while FM-MS resulted in a slight retrusion of maxillary incisors and no mesialization of maxillary molars.(54) Bozkaya et al. reported insignificant proclination of the maxillary incisors as well as insignificant mesialization of the maxillary molars when the petit-type facemask was used combined to L-shaped maxillary miniplates.(36)

According to Tripathi et al., Ağlarcı et al. and Elnagar et al., facemask combined either with tooth borne anchorage such as rapid maxillary expander or with skeletal anchorage such as mini implants or mini screws such as hybrid hyrax rapid maxillary expanders supported by mini screws appeared to be efficient to treat Class III malocclusion.(46,47,52) There is usually no significant cephalometric difference between both protocols concerning skeletal values even if skeletal anchorage shows slightly greater forward advancement of the maxilla. Tripathi et al. reported mean forward advancement of point A of 3,2mm in SAMP and 2,8mm in CFMP.(47) Ağlarcı et al. reported mean forward advancement of point A of 2,54mm in FM and 3,42mm in SA.(52) Elnagar et al. reported the greatest forward maxillary advancement with a value of Co-A of

5,74mm produced by miniplates placed in both maxillary and mandible.(46) However, there seems to be a difference concerning the displacement of the mandible. According to Souza et al., Lee NK et al. and Bozkaya et al., facemask combination protocols may produce an opening rotation of the mandible in more backward and downward directions that leads to an increase of lower facial height. This rotation can be the result of the chin cap effect produced by the facemask but also by the extrusion of molars due to the dental anchorage.(34,36,50) Souza et al. put forward a less opening rotation of the mandible in patient treated with skeletal anchorage and specifically with miniplates not combined to facemask(34). In consequence, they recommend avoiding facemask with tooth borne anchorage in high angle patient and skeletal anchorage should be preferred as alternative.

On another hand, skeletal anchorage may require less orthopedic forces to achieve similar or greater results than dental anchorage according to Souza et al., Ge et al. and Ağlarcı et al.(34,52,54) Ge et al. applied a force of 200-250g per side to FM-MS group and 400-500g per side to FM-RME group. Both groups resulted in a significant increase of SNA, ANB and Co-A but without significant differences in the values obtained. (54) Both Souza et al. and Ağlarcı et al. applied orthopedic forces to skeletal anchorage group that were twice less than the forces applied to the facemask group and both treatment protocols were effective without significant differences in the skeletal cephalometric results. (34,52)

Concerning the treatment duration, Tripathi et al. and Souza et al. put forward that skeletal anchorage helps to reduce the treatment time and shows higher protraction rate than dental anchorage.(34,47) In Tripathi et al. study, the treatment of class III patients was achieved in 5,8 months in the skeletal anchored facemask group while it was achieved in 10 months in the conventional facemask group. The total treatment duration was almost reduced by two with skeletal anchorage. The protraction rate of the maxilla also significantly differed between both groups. The rate of maxillary advancement

had a mean of 0,61mm/month in the skeletal anchored facemask group while it had a mean of 0,28mm/month in the conventional facemask group.(47) In Souza et al. study, the treatment duration significantly differed between both groups to achieve similar cephalometric results. It reported a total duration of 16 months for conventional facemask protocol and a total duration of 12,5 months for mini implants protocol.(34)

Lee HJ et al. investigated the long term post treatment changes. The study reported more stable cephalometric values 3-4 years after the end of treatment in FM-MP group than in FM-RME group. Facemask combined with skeletal anchorage helps to accomplish more desirable and predictable outcomes than facemask combined with dental anchorage.(48) Ge et al. stated that the chance of relapse was reduced in facemask with skeletal anchorage as the effects produced by the appliance were strictly skeletal.(54)

Fischer et al. and Liu et al. investigated the effect of alternating expansion/constriction and facemask with conventional protocol. Both authors concluded that these two protocols were effective in the treatment of Class III malocclusion but none of them was significantly more successful than the other.(57,58)

According to Seerha et al. facemask used in combination with reverse twin block seems to be an effective protocol to treat class III. Seehra et al. reported significant skeletal changes produced by facemask with RTB. However, RTB without facemask resulted in significant dental changes but insignificant skeletal changes. In consequence, RTB can be used to support facemask anchorage to treat skeletal Class III malocclusion but not alone.(37)

Concerning the ideal age of treatment, Elnagar et al., Tripathi et al., Ge et al. and others included patients with a mean value obtained around 10 years old.(36,37,46–58) Regarding the skeletal maturation, there is a general consensus about the stage as patients included were in prepubertal or

circumpubertal stages corresponding to cervical vertebra maturation stage between the cervical stage 1 and 3 (CS1-CS3) as reported by Nienkemper et al., Ge et al, and Tripathi et al.(47,54,55) However, Souza et al. included patients whom have not reached the prepubertal growth spurt and the treatment by mini implants resulted in improvement of cephalometric values and mini implants stability.(34)

CONCLUSION

Various appliances or combination of them can be used to treat class III malocclusion and can be classified between dental and skeletal anchorage depending on their support. The main advantage of skeletal anchorage is to produce skeletal changes without negative dental effects : less opening rotation, greater maxillary forward displacement, greater skeletal changes, better facial profile, less mesialization of molars, less proclination of upper incisors, less retrusion of lower incisors. Skeletal anchorage also has the advantages of reducing the treatment duration and orthopedic forces as their direction is better controlled. However, the main disadvantage of this latter is the need for surgery to place the device and the possible failure. The main advantage of dental anchorage is to produce skeletal changes without the need of any surgical procedure. However, dental anchorage as the disadvantage to generate undesirable dental movement during the treatment process.

Class III malocclusion should be treated as soon as possible in prepubertal and circumpubertal stage of growth which corresponds to cervical vertebra maturation stage between CS1-CS3. It is recommended to start protraction of the maxilla with facemask combined to dental anchorage in early mixed dentition, before 8 years old and to wait until 10 years for skeletal anchorage combined or not with facemask as the bone will be more stable.

The most suitable protocol includes wearing elastics for at least 14 hours per day and preferably during nighttime with a load of 200-250g/side for skeletal anchorage and 400-500g/side for dental anchorage for an average duration of at least 12 months.

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ANNEXES