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EARLY TREATMENT OF CLASS III MALOCCLUSION

This article reviews the literature on the best time to start Class III treatment and the skeletal and dentoalveolar effects that can be achieved with functional/orthopedic treatment of this malocclusion.

The authors' clinical experience is also reflected through the clinical guidelines for the use of anterior traction with a face mask, the use of a chin cup for the treatment of mandibular prognathia, treatment with the Fränkel Functional Regulator 3, and the use of Class III orthodontic plates.

Key words: Class III malocclusions, early treatment, functional treatment.

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РАННЄ ЛІКУВАННЯ НЕПРАВИЛЬНОГО ПРИКУСУ КЛАСУ III

У цій статті розглядаються літературні джерела присвяченні питанню раннього лікування прикусу класу III та скелетних і зубощелепних змін, яких можна досягти за допомогою функціонального/ортопедичного лікування такого прикусу.

Клінічний досвід авторів також відображено в клінічних рекомендаціях щодо використання передньої тракції з маскою для обличчя, чаші для підборіддя для лікування прогнатії нижньої щелепи, лікування за допомогою функціонального регулятора Френкеля 3 та ортодонтичних пластин класу III.

Ключові слова: порушення прикусу класу III, раннє лікування, функціональне лікування.

Introduction. The literature review offers a great deal of controversy regarding the most appropriate moment to begin treatment of Class III malocclusion, but there is an agreement that early diagnosis is very important.

The length of this article does not allow to explain here the procedures for the diagnosis of Class III, but the author has reviewed the diagnostic methods extensively [1], and numerous authors have developed the specific diagnosis of Class III [2–6].

McNamara et al. [7] state, based on statistics from other authors, that the prevalence of Class III is much higher in Asia than in Europe or the United States.

Lew [8] reports 12% of Class III in China; Endo [9], Susami et al. [10], and Kitai et al. [11] report 2,3 to 13% of anterior crossbite, and 2,7 to 7,4% of anterior edge-to-edge occlusion in Japan. According to Mills [12], anterior crossbite affects 3,3% of males and 2,9% of females of northern Europeans. Additionally, edge-to-edge bite is seen in 5% of males and 3,8% of females. In the United States, the prevalence of anterior crossbite is 0,8% in whites, 2% in blacks, and 1,6% in Mexican-Americans 13, 14. The prevalence of edge-to-edge bite in the United States is 4,1% in whites, 6,1% in blacks, and 6,7% in Mexican-Americans.

McNamara summarizes that Class III malocclusions occur in 1 to 3% of the population,

although he points out that ethnic factors can influence these rates.

According to McNamara's studies in Michigan [13; 14], within Class III malocclusions there is:

– 20% of mandibular prognathism;
– 25% of maxillary retrognathism;
– 22% of combination of mandibular prognathism and maxillary retrognathism;
– 33% without skeletal alterations.

Forty percent (40%) of this study also showed increased lower facial height.

Tollaro et al. [15] found that Class III cranial characteristics can already be observed in patients with early primary dentition. This conclusion was based on a comparison between 69 individuals with Class III malocclusion and 60 individuals with normal occlusion. These features include maxillary retrusion, mandibular protrusion, a decreased anterior cranial base, increased mandibular ramus height, and increased mandibular body length. Therefore, early diagnosis of Class III is possible.

Regarding the growth of Class III patients, McNamara states that there are few studies in Europe or the United States with a sufficient number of individuals, X-rays, or sufficiently extended timeframes for the conclusions to be entirely definitive. However, these studies exist in the Asian population [16–18].

The Department of Orthodontics at the University of Florence conducted a study [19; 20] on untreated Class III Caucasian individuals, divided into two groups: one of 17 individuals aged 6,5 to 8,5 years (early mixed dentition), and another of 15 individuals aged 9,5 to 11,5 years (late mixed dentition). These two groups were used as a control group to determine the effect of face mask therapy. McNamara compared these groups to samples from individuals with normal occlusion from the University of Michigan Study [21]. The mean annual maxillary growth of Class III patients was 0,8 mm (Ptm-A) compared to the growth in the normal group of 1,1 mm in the early mixed dentition. In late mixed dentition, these values were 1,1 mm and 1,4 mm, respectively. The mean annual growth of the lower jaw (Co-Gn) was 4,5 mm in Class III individuals and 2,6 mm in normal occluding individuals during early mixed dentition and 4,4 mm and 2,8 mm respectively in late mixed dentition. The bottom line is that without treatment the upper jaw grows about 30% less in Class III than in Class I while the jaw grows about twice as long. Thus, Class III tends to worsen during tooth replacement and early treatment is indicated.

Rakosi [22] studied the relationship between the length of the mandibular body and the anterior skull base: Sella-Nasion, observing a greater growth of the mandible in Class III cases, which can be understood as a genetic predisposition. In fact, the hereditary factor in this type of malocclusion is undeniable.

Eruption disorders, such as inversion of the eruption sequence (the upper incisors erupting before the lower incisors) can also cause an anterior shift of the mandible.

In a large number of Class III cases, a forward position of the mandible is observed and it can be assumed that the greater the functional component of Class III, the greater the mandibular growth and, therefore, the worse the evolution of this malocclusion.

It is also important to note the compulsive forward position of the mandible, observed especially in some patients who present mental disorders as well.

Forward tongue position has also been reported as an etiologic factor by Limbourg et al. and re-education of this tongue position is important for post-treatment stability.

Riolo et al. [21] have pointed out the importance of tonsil hypertrophy and mouth breathing in the forward position of the tongue and mandibular prognathism.

Linder-Aronson notes the importance of adenoid hypertrophy in the forward lingual position.

Kovero et al. [23] conducted a study on 26 individual professional violin and viola musicians showing that they have facial asymmetry, as well as decreased facial height, proclined upper incisors, and increased mandibular length. It is expected that

patients who play violin or viola with sufficient dedication, tend to make Class III malocclusion worse. Patients should be warned about this.

We can conclude that early diagnosis of Class III is not only possible but very important because the spontaneous evolution of this malocclusion goes towards a more severe Class III. It is also important to diagnose etiological factors that may further worsen Class III, such as the forward mandibular position due to occlusal interference, musical habits or practices such as violin or viola, or lingual forward position due to habit caused by hypertrophic adenoids and mouth breathing, hypertrophic tonsils, etc.

Prognosis in the Class III treatment

Factors to be considered in the Class III prognosis are:

1. Heritage. Class III patients often have a family history of Class III.

2. Dental or skeletal Class III. Evidently, dental Class III has a better prognosis than skeletal.

3. Skeletal Class III severity. The more negative the value of convexity (Ricketts) or ANB angle (Steiner), the worse the prognosis, although the Wits assessment proves to be the most accurate diagnostic factor in the diagnosis of Class III.

4. Advanced mandibular position. The greater the functional component of Class III (amount of anterior mandibular displacement), the better the prognosis.

5. Mandibular or maxillary Class III. Treatment of mandibular prognathism has a worse prognosis than treatment of maxillary retrognathism.

6. Number of affected planes. The prognosis is better if only the sagittal plane (skeletal Class III) is affected than if other planes, such as the vertical and the transverse, are also affected (Skeletal Class III with asymmetry in a dolichofacial patient).

7. Affected esthetics. The forehead, nose, cheekbones, lips, chin, etc. affect the esthetics of the patient. The more altered the esthetics, the worse prognosis the treatment will have.

8. Overbite. Exclusively orthodontic Class III treatment tends to reduce overbite, which is important for case stability. This way, a reduced overbite is a negative factor in the prognosis.

9. Upper incisor position. The compensation treatment is based on the protrusion and proclination of the upper incisors; therefore, crowding in the upper incisor area and the negative torque of these teeth are more favorable.

10. Lower incisor position. The compensation treatment is based on the retrusion and retroclination of the lower incisors; therefore, spacing in the lower incisor area and the positive torque of these teeth are more favorable.

11. Mouth breathing, atypical swallowing, tongue thrust, hypertrophic tonsils, adenoids. These are negative factors for the prognosis.

What is the most appropriate time for Class III treatment?

There are different opinions about the most suitable time for the initiation of Class III treatment.

The arguments in favor of early treatment are the spontaneous evolution of Class III malocclusion for the worse without treatment and the fact that the younger the patient, the better the results obtained with orthopedic treatment.

Those who are against early treatment point out that complete correction of the malocclusion is not always achieved and that there is frequently a relapse due to delayed growth. These authors prefer to wait until the growth is complete and perform orthodontic treatment combined with orthognathic surgery.

This second position condemns the patient to poor chewing, possible abrasions of the upper and lower incisal edges and/or the labial surfaces of the upper incisors, possible atypical deglutition, aggravation of Class III, muscular imbalance, in addition to the possible psychological implications due to the esthetic appearance of Class III during adolescence.

Mitani [24] points out that in some cases, early Class III treatment does not achieve the desired results and that studies investigating this problem can be summarized in the following groups:

– Patients who present mandibular prognathism at young ages do not fundamentally change, so spontaneous correction is not expected.

– There is no evidence that Class III mandibles present growth spurts at different ages, larger

growth spurts, or a longer total growth period than Class I mandibles.

– The entire skull and face should be studied when studying Class III mandibles because the spheno-occipital synchondrosis compensates for a large amount of the differential anteroposterior growth between the mandible and maxilla. Hitani's studies demonstrate the importance of the growth of this suture in the possible aggravation of Class III during growth. In fact, in some prognathic profiles, the problem is not in the mandible itself but in the skull base.

In summary, it can be argued against the early treatment of Class III that it is difficult to achieve significant changes in mandibular growth, that mandibular growth is quite unpredictable, and that the skull (especially at the level of the sphenoid-occipital synchondrosis) sometimes compensates for the growth deficiency of the lower jaw.

In favor of early treatment, we can say that all studies reveal that the younger the patient, the more effective the treatment.

Mitani [24] also emphasizes that treatments aimed at inhibiting or redirecting mandibular growth are only effective during deciduous or early mixed dentition.

Cephalometric and morphometric studies [19; 25; 26] clearly demonstrate that treatment with the face mask during early mixed dentition has greater skeletal effects than if the treatment is performed later. The most notable effect is the increased maxillary growth, but there is also an anterior shift of the maxillary tuberosity in relation to the pterygoid process of the sphenoid. Melsen and Melsen [27] have demonstrated this fact through human autopsies. This study further demonstrates that disarticulation of the palatal bone and pterygoid process is only possible in the deciduous or early mixed dentition.

Growth studies [21] show an average annual forward growth of the upper jaw, measured at the level of point A, of approximately 1 mm per year in both the early and late mixed dentition. With anterior traction during the early mixed dentition, we can achieve an advancement of 4,1 mm, while in the late mixed dentition, we can reach only 2,1 mm [28].

Regarding the effects of mandibular treatment [29], we can say that the mandibular growth in Class III patients (Co-Gn distance) is 4,5 mm. In the treated groups in the early mixed dentition, the growth was 2 mm; in the late mixed dentition, it was 3,5 mm. This decrease in growth is caused by a mechanism called "morphogenetic anterior rotation" by Lavergne and Gasson [30], consisting of an increased upward and forward growth of the condyle that causes a clockwise mandibular rotation, one of the Class III correction mechanisms.

On the other hand, comparing the studies of normal facial growth [32] and Class III growth [33], it is beyond doubt that the evolution will be directed towards a more severe Class III.

Class III treatment

As Klempner [34] points out, numerous authors have determined that the therapeutic options for skeletal Class III are:

– Treatment with extractions to compensate the skeletal alteration.

– Wait until growth is complete for a treatment combined with orthognathic surgery.

– Upper protrusion with a face mask.

– Inhibition of mandibular growth with a chin cup and high-pull anchorage.

– Treatment with Class III functional appliances.

Skeletal Class I or Mild Class III and Anterior Crossbite

Exclusively orthodontic or orthodontic compensation treatment of skeletal malocclusion.

This treatment is possible at any age but is most recommended after the eruption of the permanent incisors is complete.

On the other hand, the author [35] states that, for orthodontic treatment of anterior crossbite with skeletal Class I in mixed dentition, it is very important to perform the differential diagnosis between:

– Anterior crossbite with a normal overbite, treated with an upper Class III plate.

– Anterior crossbite with an increased overbite, treated with upper and lower Class III plates.

– Anterior crossbite with a reduced overbite, treated with an upper Clas III plate with metallic guide planes for posterior occlusion.

– The upper Class III plate consists of an Eschler-type Class III arch, a three-way Bertoni expansion screw, and Adams clasps [35].

The lower Class III plate consists of an anterior resin Class III inclined plane and Adams clasps [35].

Skeletal Class III

Following Proffit [36], skeletal Class III can result in:

– Normal maxilla, and mandibular protrusion.

– Maxillary retrusion, and normal mandible.

– Combination of maxillary retrusion and mandibular protrusion.

– According to the author [35], in the orthopedic treatment of anterior crossbite with skeletal class III in mixed dentition, it is very important to carry out the differential diagnosis among:

– Class III due to maxillary retrognathism, treated with protraction using a facemask.

– Mixed Class III (maxillary retrognathism and mandibular prognathism), treated with a protraction using a reverse chin cup with high-pull anchorage.

– Class III due to mandibular prognathism, treated with a chin cup with high-pull anchorage.

– Functional Class III with anterior mandibular displacement, treated with mandibular repositioning to centric relation.

Functional appliance treatment: Fränkel Functional Regulator 3

Fränkel [37] proposed Functional Regulator 3 (FR-3) for the Class III malocclusion treatment. This appliance repositions the mandible backward correcting the functional component of Class III, stimulates the development of the upper anterior alveolar edge through its labial shields, proclines the upper incisors, and retroclines the lower incisors.

McNamara [38] identifies the FR-3 as the most effective appliance for the Class III malocclusion treatment. McNamara indicates it for the early treatment of mild, moderate, or severe dentoalveolar or skeletal Class III malocclusions with muscle imbalance. He recommends full-time treatment for 18 to 24 months.

McNamara and other authors also recommend it as a retention device after the use of anterior traction with a face mask.

In the author's experience, this appliance is very effective, but it is not as well tolerated by patients as McNamara suggests. Additionally, it needs to be very well constructed and adjusted to achieve its maximum therapeutic effect.

Proffit [36] states that good results have been observed with FR-3 with a constructive bite that positions the mandible backward. Theoretically, the Fränkel labial shields traction the periosteum causing bony apposition in the vestibular area of the premaxilla. Clinical experience suggests that results are variable.

McNamara and Huge [39] state that functional Class III appliances usually also allow the upper molars to erupt and move mesially while maintaining the lower molars both vertically and anteroposteriorly. Rotation of the occlusal plane and movement contribute to the change of the molar Class III to Class I.

In addition, mandibular clockwise rotation occurs with improved chin position. The only possible effect on the maxilla is given by upper shields.

On the other hand, Robertson [40] points out that most functional appliances for the treatment of Class III fail to increase the size of the maxilla or to position the maxilla more anteriorly, but correct the malocclusion by the labial inclination of the upper incisors and the lingual inclination of the lower incisors.

Kerr et al. [41], Kerr and Tenhave [42], Ülgen and Firatli [43], and Baik et al. [44] among others, also recommend the FR-3.

However, some authors, such as Garattini et al. [45], prefer the Balters Class III Bionator for the treatment of this malocclusion.

Anterior Traction Treatment: Face Mask

The most indicated treatment for the correction of Class III due to maxillary retrognathism is anterior traction with a face mask.

Delaire [46; 47] was one of the pioneers in using anterior traction, and Petit [48] was not only one of the people responsible for popularizing this therapy in the United States, but he also modified the original face mask with forehead and chin support, by adding malar supports.

McNamara et al. [49] say that the effects of the face mask are:

1. Correction of the discrepancy between the centric relation and maximal intercuspation. An immediate correction of mandibular position in Class III malocclusion with a functional component.
2. Skeletal protrusion of the maxilla. An anterior maxillary movement of 1–3 mm is usually observed.
3. Anterior movement of upper teeth.
4. Lingual inclination of lower incisors.
5. Clockwise mandibular rotation.
6. A reduction of mandibular growth is observed. It is only apparent in the short term.

Nanda [50], among other authors, has demonstrated that the anterior maxillary displacement is produced due to the stimulation of numerous sutures of the facial middle third.

Sung and Baik [51] of Yonsei University (Seoul, Korea) compared 129 Class III subjects treated with anterior traction with a face mask in 9 males and 12 females from the Class I patient growth data sample of this University. The results were that anterior traction of the maxilla causes increased maxillary growth, although no statistical evidence was found of changes in growth direction or growth in relation to different ages.

Numerous authors [52–74] have demonstrated the effectiveness of treatment with anterior traction with a face mask, including studies in primates, clinical studies, and mathematical or three-dimensional finite element models, so it is beyond any doubt.

Proffit [36] states that, for maxillary retrusion, the best treatment is to move the maxilla with anterior traction, which not only increases its size as a bone but also stimulates posterior sutures.

In children under the age of 8, this treatment can be performed with a face mask anchored to the forehead and chin and exerts force through elastics, which go from the mask to the maxillary appliance.

In children older than 9 years of age, this treatment performs more dental movement and minimal skeletal change, resulting in more of a compensatory movement than an ideal orthopedic movement.

Although bands can be bonded to deciduous teeth, the best results are obtained with bonded resin splints (McNamara separation appliance for anterior traction). Proffit recommends the use of removable appliances for better hygiene, but the author's experience is that they have poor retention for anterior traction.

Proffit recommends 12 ounces per side for 14 hours a day.

The elastics should be pulled from the canine-first temporary molar area to avoid maxillary rotation.

As most maxillary deficiencies are not only sagittal but also vertical, a forward and downward traction direction is desirable. This increases the maxillary and facial height and the mandible rotates clockwise, shifting the chin backward, which also contributes to the Class III correction. This is contraindicated in accentuated or severe dolichofacial patients.

Once the desired effect has been achieved, retention can be performed with a Class III plate or with an FR-3 (Fränkel Function Regulator 3).

As Haas [75] indicates, and as many authors such as McNamara support, to initiate anterior traction, it is advisable to start with transverse separation, since the traction effect is then much greater.

For anterior traction in the early mixed dentition, the author [35] recommends the McNamara-Alpern separation appliance, which is a combination of both separation appliances. As Alpern indicated, occlusal screws are incorporated into McNamara's appliance to facilitate the removal of the appliance. An occlusal line is also added in the resin as a reference that indicates when the transverse correction is achieved.

The author [76] has also published a clinical chart outlining the different intraoral appliances that should be used depending on the characteristics of the case.

Numerous devices have been suggested for anterior traction such as the reverse Nanda facebow [77].

Nanda designed a protraction facebow whose intraoral arch must enter the tubes of the molar bands from the distal to the mesial. The protraction elastics go from the extraoral arm to the facemask or reversed chin cup.

The best advantage of this device is that the traction direction can be directed better.

The purpose of a study, conducted at the University of Marmara (Istanbul, Turkey) by Keles et al. [59], was to determine the effect of force direction on anterior maxillary traction.

A group of 20 patients with skeletal Class III maxillary retrognathism was randomly divided into two groups: Group 1 consisted of nine patients with a mean age of 8,58 years, and Group 2 had 11 patients with a mean age of 8,51 years.

Both groups were treated with acrylic splints adapted to all upper teeth with a midline cut, with a Hyrax screw and canine hooks in Group I, and with premolar tubes in Group II for Nanda facebow; a protraction was carried out 20 mm above the occlusal plane, from extraoral arms (conveniently raised) of Nanda facebow to face mask.

First, separation was performed by activating the screw 2 turns per day for 10 days, and then the anterior traction was applied to a face mask 16 hours per day for 3 months, and then 12 hours per day for the next 3 months. In Group I, the force was applied from the canine zone forward and downward at 30º of the occlusal plane. In Group II, the force was applied forward and upward, 20 mm above the occlusal plane. On both sides, a 500 g force per side was used.

The conclusions were that:

1. Both systems were equally effective in maxillary protraction.
2. In Group I, the maxilla was advanced by counter clockwise rotation.
3. In Group II, the maxilla was advanced without any rotation.
4. The maxillary occlusal plane in Group I did not rotate.
5. The maxillary occlusal plane in Group II rotated in the clockwise direction.
6. In Group I, the upper incisors were slightly proclined.
7. In Group II, the upper incisors were retroclined and slightly extruded.
8. Consequently, the traction performed in Group I (downward and forward) is effective in reducing the protraction side effects.
9. The traction in Group II (upward and forward) is effective in Class III cases with anterior open bite.

Several authors such as Chong et al. [78], Takada et al. [79], Turley [80], Wang [81], etc. propose different models of reverse facebows for anterior maxillary traction.

Klempner [34] suggests a very interesting device for the early treatment of Class III, the Tandem, which consists of a separation device welded to the bands of the first molars. Labial hooks are also welded to the bands up to the height of temporary canines for anterior traction. In the mandible, a removable active plate with labial tubes is used at the level of the lower first molars. A labial archwire with hooks is placed in these for anterior maxillary traction. The author reports achieving the same results as with the facial mask, without affecting the TMJs, but with less patient cooperation required.

Treatment of mandibular prognathism: Mentonera

Proffit [36] states that mandibular protrusion, mandibular excess, is very difficult to treat. The treatment of choice would be the mandibular size reduction, or at least size increase prevention, but there is little evidence of achieved mandibular growth reduction. Functional appliances and chin cups have been used for this purpose. In theory, the chin cup inhibits condyle growth, but comparative studies between treated and untreated subjects do not present great differences.

However, Langlade [82], based on a Lee W. Graber's [83] study carried out on 30 children, establishes the effects of the chin cup as follows:

1. Posterior mandibular rotation.
2. Delayed vertical development of the posterior part of the mandibular corpus.
3. Delayed vertical growth of the mandibular ramus.
4. Closure of the gonial angle.

5. Delayed vertical development of the posterior part of the maxilla causing anterior rotation of the palatal plane.

6. A change in the direction of condylar growth from a horizontal direction to a more vertical direction.

7. A shift from negative convexity towards more normal values.

8. An improvement in the molar, canine, and incisor relationship.

9. An absence of measurable effects of the chin cup on the lower incisors and symphysis.

10. A better development of the profile due to the skeletal changes achieved.

Opinions about the use of the chin cup and the effects that can be obtained, as well as the possible effects of this therapy on the joints are controversial.

On the one hand, Sakamoto et al. [84] state that chin cups cause lingual inclination of the lower incisors due to the pressure the appliance exerts on the lower lip and that they also change the mandibular growth direction downward and backward. He states that 16–24 ounces of force should be applied on each side and affirms that the results achieved with the chin cup and Class III functional appliances are similar.

On the other hand, Mitani et al. [17], claim that after the use of a chin cup during the growing stage, a collapse of the occlusion and an improvement of the patient's prognostic profile are observed, although it is not effective in all cases.

Clinical studies by Hideo Mitani indicate that the chin cup can alter the mandibular shape and slow condylar growth. His studies also show that although the desired results are obtained in the initial 2-year period, their use should be continued until the end of facial growth to maintain those results. These studies also reveal that the chin cup is useful in vertical problems, and affirm that, after the age of two, the force has to be increased because the cartilage "gets used" to it allowing bone growth, and that, if the chin cup is removed before facial growth is complete, this reduction in pressure may stimulate and accelerate condylar growth.

Ritucci and Nanda [85] and Matsui [86] among other authors are also in favor of the use of the chin cup.

The author [35] recommends the use of a temporary anchorage chin cup for the treatment of skeletal Class III due to the mandibular prognathism with a force equivalent to age plus two ounces on each side (e.g., for an 8-year-old patient, a 10-ounce force would be applied on each side). It should be used approximately 12 hours a day.

Mirzen et al. [87] published a study conducted on 32 individuals with Class III and treated with a chin cup comparing them with 39 untreated Class III individuals and 53 dental students with acceptable occlusion, and found no differences in signs and symptoms of possible craniomandibular dysfunction. This study concludes that the chin cup does not represent a risk factor for TMJ.

Treatment with anterior traction and chin cup: the reverse chin cup

The author [35] and Ishi et al. [88], among others, recommend the reverse chin cup with high-pull anchorage and anterior traction for the treatment of skeletal Class III with maxillary retrusion and mandibular prognathia.

Stability of the Class III Treatment

The changes produced by face mask treatment are stable, as similar growth is observed in treated and untreated patients [31].

Westwood et al. [89] claim that Class III treatment with rapid palatal expansion and anterior traction with a face mask followed by fixed orthodontic treatment is stable and overcorrection is not recommended.

Regarding the treatment with a chin cup, Mitani et al. [17] and other authors claim that its use should be maintained until growth is complete to ensure the results of treatment with this appliance.

Ferro et al. [90] studied 52 patients through a series of post-treatment radiographs at least 3 years after retention. Significant increases in *Wits appraisal* and increase in mandibular ramus length were observed. However, it is much more stable if sufficient overbite and anterior rotation of the mandible are achieved, and overcorrection of the skeletal class is recommended [91].

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