Facial Growth: Does It Play a Role in Long-term Stability of Orthodontic Treatment?

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Recommended Citation
https://doi.org/10.38209/2708-2636.1339
Available at: https://www.tjo.org.tw/tjo/vol35/iss3/1

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Abstract
Following orthodontic treatment there is usually a period of retention to maintain the treatment result. This period can vary from a few years to even lifelong retention all depending upon the clinician, type of treatment and severity of the initial malocclusion. In most cases retention is planned for one to two years, but some clinicians routinely recommend continuous retention into adulthood. The retention planned for a patient is unfortunately often based on intuition rather than on scientific evidence. Furthermore, the retention is frequently not planned based on the initial malocclusion, the patient's facial growth pattern nor is attention paid to the etiology of the initial malocclusion. The literature clearly shows that numerous factors are involved in the post treatment changes that can be observed and one of the most important of these is late facial growth which is rarely studied. The growth changes that take place after treatment can result in relapse of the occlusion and of the tooth alignment. The traditional short-term retention of one or more years therefore needs to be more differentiated to improve the stability of the treatment result. It is our intention in this review to provide answers to questions about the role late growth changes play in the relapse so often seen. Besides growth there are numerous other factors involved which can affect the post treatment instability. These factors include, but are not limited to, unresolved airway problems, TMJ dysfunction and periodontal changes. In this review we focus on the normal facial growth changes and discus the individual variations as they relate to skeletal and dentoalveolar development. We shall further provide a historical review of some of the most relevant studies that have looked at the different factors that can be the cause of lack of stability post treatment. Finally, we shall recommend differentiated retention protocols based on the individual facial growth patterns to increase the chances of long-term stability.

Keywords
Late facial growth; overjet relapse; overbite relapse; residual growth; length of retention.

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Facial Growth: Does it Play a Role in Long-term Stability of Orthodontic Treatment?

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ABSTRACT

Following orthodontic treatment there is usually a period of retention to maintain the treatment result. This period can vary from a few years to even lifelong retention all depending upon the clinician, type of treatment and severity of the initial malocclusion. In most cases retention is planned for one to two years, but some clinicians routinely recommend continuous retention into adulthood. The retention planned for a patient is unfortunately often based on intuition rather than on scientific evidence. Furthermore, the retention is frequently not planned based on the initial malocclusion, the patient's facial growth pattern nor is attention paid to the etiology of the initial malocclusion. The literature clearly shows that numerous factors are involved in the post treatment changes that can be observed and one of the most important of these is late facial growth which is rarely studied. The growth changes that take place after treatment can result in relapse of the occlusion and of the tooth alignment. The traditional short-term retention of one or more years therefore needs to be more differentiated to improve the stability of the treatment result. It is our intention in this review to provide answers to questions about the role late growth changes play in the relapse so often seen. Besides growth there are numerous other factors involved which can affect the post treatment instability. These factors include, but are not limited to, unresolved airway problems, TMJ dysfunction and periodontal changes. In this review we focus on the normal facial growth changes and discuss the individual variations as they relate to skeletal and dentoalveolar development. We shall further provide a historical review of some of the most relevant studies that have looked at the different factors that can be the cause of lack of stability post treatment. Finally, we shall recommend differentiated retention protocols based on the individual facial growth patterns to increase the chances of long-term stability. 

Keywords: Late facial growth; Overjet relapse; Overbite relapse; Residual growth; Length of retention

INTRODUCTION

Lack of stability of orthodontic treatment has been recognized as far back in time as 1880 where Kingsley reported on changes after orthodontic treatment. He noted that even though he had obtained an excellent result of his treatment of a patient's malocclusion the changes post treatment left the patient in a worse condition than prior to treatment. Following treatment Kingsley provided the patient with a so-called “retaining plate” but to his disappointment found that after the patient had admitted that he had not been wearing the retainer as requested that the teeth were more disorderly than before. Kingsley stated after this bad experience that the occlusion of the teeth is the most potent factor in determining the stability in a new position, a statement that with some modification can be said to still holds true today.1

The problem with stability of the occlusion also was recognized by Edward Angle who wrote that “as the tendency of the teeth that have been moved into occlusion is to return towards their former malposition, the main principle is the antagonizing of this force in the direction of its tendency.”2 He offered further advice by stating that “the time of retention varies according to the age of the patient, occlusions gained, causes overcome, tooth movements accomplished,
LENGTH OF THE CUSPS, HEALTH OF THE TISSUES, ETC. FROM A FEW DAYS TO A YEAR OR TWO, OR OFTEN LONGER.

Numerous studies have dealt with the problem of the post treatment changes. Hellman concluded that there is a close relationship between active orthodontic treatment and retention, and he stated that “retention is not a separate problem but a continuation of what we are doing during treatment.” He further stated that we are almost completely ignorant of the specific factors causing the relapse and failures, a statement that still to some degree holds true today.

The early studies prior to the 1950's focused primarily on the post retention changes in overjet, overbite, intercanine width and intermolar width as well as on the changes in the occlusion of the teeth. One study by Walter examined the potential for changing the dental arch width and he concluded that in some instances it was possible to achieve a stable result after expansion of the lower arch. This was later discussed by Riedel, Shapiro and Joon-deph in several articles where they described various problems relating to lack of stability following orthodontic treatment in particular of the lower front teeth. According to Riedel there was no specific pattern in which the lower incisors moved after retention. He also reported that the maxillary incisors in 98 percent of the cases moved forward after retraction and warned against too much incisor retraction as it tended to relapse. Shapiro, studied the post treatment stability of extraction and non-extraction treatment of Class I and Class II malocclusions. He reported that Class II, Div. 2 cases had more stability of the intercanine width increase in the lower arch than Class II, Div. 1, and Class I cases. He further noted that arch length reduction in Class II, Div. 2 cases during treatment was less than in the other types of malocclusion. Rönnerman, in a ten-year study of overjet, overbite, intercanine distance and root resorption post treatment in orthodontic patients concluded that the overjet and overbite tended to relapse post retention. Similar findings were reported by Hellekant et al. who studied overbite and overjet correction in a Class II, Div. 1 sample of 20 children treated with extractions and 20 non-extraction. They concluded that both groups had benefitted from treatment and that there was no significant difference in terms of outcome between the two groups with respect to changes inter-canine width, space conditions and in mandibular incisor position but that these factors were important factors in treatment planning.

In a sample of 31 patients treated with four bicuspid extraction and Edgewise mechanics Bishara found that the percentage of overbite relapse was clearly greater than of overjet. He also noted that the intercanine width in the maxilla was more stable than in the mandible. This, he said could be explained by the fact “that whereas the mandible continues to grow downward and forward, the maxilla is more stable” and that “the lower dentition is confined within the maxillary arch thereby assuming a smaller arch length over time.” In a study of 65 patients treated with four fist bicuspid extraction and a minimum of 10 years out of retention, Little found considerable individual variation in the long-term response to treatment. Irrespective of Angle Classification, amount of crowding, age, and sex prior to treatment all cases showed a decrease in arch width and arch length over time. Two thirds of the patient had lower arch crowding out of retention, and some cases that had minimal crowding prior to treatment showed more crowding later. Little stated that the chance of maintaining lower arch alignment was less than 30 percent and that 20 percent of the cases showed marked crowding after retention had been discontinued.

Adult changes in selected occlusal parameters were studied by Sadowsky et al. in sample of 96 subjects with a history of malocclusion and treated orthodontically 12–35 years previously. Ninety of the ninety-six cases were within ideal range at the end of treatment. Long-term most of the cases showed improvement of their malocclusion at the long-term stage. Sixteen percent showed an increase in overbite and 9 percent an increase in mandibular crowding, only 5 percent showed an increase in overjet. They suggest that orthodontist should be aware that long-term changes in dental relationships can occur many years after treatment and take this into account when planning retention and when advising patients as to the potential benefits of orthodontic treatment. The long-term stability of non-extraction treatment with prolonged retention was studied by Sadowsky et al. The patients in their study were at least 5 years out of retention. All patients had been retained with a fixed lower retainer. Their findings were that relapse were seen of all variables measured except for the expanded maxillary canines and premolars. However, as they report, the mandibular anterior segment showed relatively good alignment at the long-term stage which they attribute to the long-term retention. Fidler et al. Studied long-term stability in successfully treated patients with Class II, Div. 1 malocclusion. Their patients were a minimum of 14 years out of retention, and some were treated with extraction and others without. The sample was intentionally limited to include only
successfully treated cases and included 78 patients. Interestingly they found that the molar and canine occlusions showed no change over time and relapse of overjet and overbite were on average 0.5 mm. They also noted that mandibular incremental growth was favorable both during and after treatment. The conclusion was that Class II, Div. 1 malocclusion can be successfully corrected through differential growth adaptation and tooth movements and be very stable.

Most studies that look at long-term changes in tooth alignment and occlusion have been less than 5 years post treatment. One study by Uhde et al., however, looked at the long-term stability of dental relationships after orthodontic treatment in 72 subjects with a history of malocclusion treated orthodontically 12–35 years previously. Retention was done with an upper Hawley appliance and lower fixed 3-3 retainer. The findings were that overjet and overbite tended to increase irrespective of the initial malocclusion. The molar relationships shifted slightly towards Class II with time, and the intercusp width was in general unstable in the lower arch but stable in the upper arch. Most of the corrections were retained, with a mean change towards the pretreatment values.17

Late growth changes of the jaws are among the factors that have been said to be responsible for posttreatment relapse. Riedel and Moyers felt that disharmonious growth after treatment may play a role in the instability of the occlusion post retention. However, no evidence was presented to support this notion.18,19 That these late growth changes are common has been shown by both Nanda and Björk.20–26 Until now little has been done to study the association between facial growth and long-term stability of treatment.

To improve stability several different approaches have been suggested. Overcorrection of the posterior occlusion as well as overjet and overbite have been the most common. Placing the lower incisors over basal bone, without changing the lower arch form, and treating the dental arches to a perfect intercuspitation has also been suggested as method to reduce the post treatment relapse and the influence from possible tongue lip imbalances.27–29 Following treatment, it has been recommended by Reitan that the teeth should be retained long enough to allow bone and adjacent soft tissue to reorganize.30,31

Few articles have so far dealt with effect of the natural growth changes and posttreatment stability. In the following we shall discuss the influence of late growth changes and of the role of maxillary and mandibular growth and the concomitant dentoalveolar development on the posttreatment changes. We shall also discuss the relationship between stability and timing of treatment, length of the subsequent retention period and posttreatment stability.

**GENERAL FACIAL GROWTH**

The great degree of variability in facial growth was demonstrated by Björk in 1955.21 Through his implant studies, where tiny metallic markers were placed in the jaws, he was able to show the variation in facial growth in a group of just six subjects that were part of his early studies. These small metallic or radiographic markers serve as fixed reference points that as they are placed under the surface of the jaw bones and remain unchanged over time. As there is no interstitial bone growth the markers maintain their position and relationship to each other within the respective jaw. With the aid of this technique Björk provided greater insight into the true growth pattern of the jaws which is something that had not be possible before the implant technique was developed. His implant studies have since shown not only great individual variation in the general facial growth pattern but also in maxillary and mandibular growth and the dentoalveolar development. An example of general facial growth in a subject from his implant study is seen in Figure 1.21–24 It should be mentioned that the

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**Figure 1.** General facial growth from age 8–25 yrs of a subject from the facial growth studies by Björk.21 Superimposition is done on stable structures in the anterior and median cranial base. Notice the downward and forward growth pattern of both maxilla and mandible (from Björk et al., 1983).
subjects in Björk’s implant study did not receive orthodontic treatment while they were in the study. The superimpositions seen here are made on stable structures in the anterior and median cranial base. The average growth direction of both maxilla and mandible is downward and forward. Notice the considerable amount of mandibular growth between age 14 and 25 yrs which often includes the retention period after orthodontic treatment. If this is not taken into consideration when planning the retention protocol, it is not surprising that changes in the dental alignment can take place. It is in particular important for the lower front teeth that can relapse if they are not supported or retained.

Prior to the study using metallic implants the consensus was that facial growth is an uncomplicated process and that the general direction of growth is downward and forward as seen in Figure 2 from the Bolton Atlas. The period shown includes the annual changes from age 1–18 years and the illustration shows the average facial growth in boys and girls.

The superimposition is done on the Bolton plane that connects nasion with the Bolton point defined as the deepest point behind the occipital condyles. Although these examples provide a general idea of the facial growth direction, they do not demonstrate the considerable degree of individual variation that exist in the untreated general population. An additional factor to take into consideration is that orthodontic treatment affects the growth pattern of the jaws as previously described by Nielsen. The mechanics of orthodontic treatment can offset the normal growth pattern temporarily and redirect the growth of both maxilla and mandible by promoting eruption of the teeth for instance in the posterior part of the dental arch all depending on the choice of mechanics. An example of this clinical challenge can be seen in Figure 3. In this patient, with a Class II, Div. 1 malocclusion and a deep overbite treatment.

Figure 2. Average facial growth from age 1–18 years in a sample of boys and girls. The serial headfilms are superimposed on the Bolton plane that connect nasion with the Bolton point defined as the deepest point on the occipital bone behind the occipital condyles (from Broadbent Bolton standards of dentofacial developmental growth. 1975).

Figure 3. General facial growth in a patient treated with cervical headgear and a maxillary Hawley retainer with and anterior bite plane to help correct the deep bite. The headfilms are superimposed on stable structures in the anterior cranial base.
was carried out with a maxillary Hawley bite plate and a cervical headgear. Due to the lack of posterior tooth contact the normal upper molar eruption increased resulting in a vertical descend of the mandible. We have previously discussed the importance of the normal balance between the posterior and anterior factors that can be altered by treatment and how this can result in undesirable changes in a patient’s facial growth pattern adding to the potential for instability of the occlusion.34

MANDIBULAR GROWTH

Normal mandibular growth has been studied extensively by Björk and Björk and Skieller using the metallic implant as fixed reference markers.22,24,26 Their studies showed a large variation in condylar growth direction with a range of as much as 42° and that a slight upward and forward growth direction was the most common. Associated with these variations were distinct variations in the direction of eruption of the teeth. The implant studies further showed that in some subjects there is extensive remodeling of the lower border of the mandible. With conventional analysis techniques these changes would have been missed as the modeling masks the actual changes and results in incorrect interpretation of the tooth movements as demonstrated by Isacson.35 This modeling on average disguises as much as 50 percent of the growth rotations of the lower jaw. Evaluating the growth and dentoalveolar changes without taking this into consideration would clearly lead to incorrect interpretations of the actual changes. The mandibular superimposition seen in Figure 4 is of the subject previously seen in Figure 1.

The upward forward condylar growth direction over time resulted in as much as 14 degrees of anterior or forward rotation of the mandible. The dentoalveolar development in this subject is upwards and forwards during the whole growth period from age 8–18 years. To further illustrate this problem, we can look at the mandibular change in the same subject. This example demonstrates that the dynamic facial development, previously shown in Figure 1, and the changes in the mandible continue throughout the growth period. In other words, if a patient with this type of growth pattern is not retained throughout the growth period until mandibular growth is completed it is not surprising that both the occlusion still can undergo change, and that crowding can develop.

Mandibular growth and dentoalveolar development

The mandibular dentoalveolar development varies from patient to patient all dependent upon their facial growth pattern and the anterior occlusion. The three mandibular superimpositions from Björk’s study (1963) of mandibular growth demonstrate the range of variation that can be seen in subjects with normal mandibular growth (Figure 5).22

In the subject with the upward and forward growing condyle seen in Figure 5A, there is a pronounced mesial migration of the lower dentition and very limited forward movement of the incisors. A more average vertical eruption pattern of the posterior teeth is seen in the example in Figure 5B with some degree of mesial migration and limited forward movement of the anterior teeth. The subject with the posterior condylar growth direction Figure 5C had vertical eruption of the posterior teeth with no mesial movement of the posterior teeth and the incisors erupted vertically and posteriorly. Whereas the occlusion in Figure 5A was characterized by a deep bite the patient seen in Figure 5C had a severe anterior open bite.

To get a better understanding of the association between the general facial growth pattern and the dentoalveolar development in two of the subjects in Figure 5A and C, we have included their respective general superimpositions in Figure 6. As it can be seen here the mandible of the patient, seen previously in Figure 5A, underwent pronounced forward
growth rotation which resulted in a deepening of the overbite. In the patient seen in Figure 5B, the rotation was posteriorly resulting in a progressively deteriorating open bite.

Prediction of mandibular growth rotation

It is to some degree possible to predict the growth rotations of the jaws in the more pronounced cases.
Predicting Mandibular Rotation (Anterior or Forward Rotation)

Predictors of anterior growth rotation:
- Short anterior face height w. concave profile
- Anterior inclination of mandibular symphysis
- Thick cortical bone below the symphysis
- Downward convex ant. lower border of mandible

Figure 7. Predictors of anterior or forward mandibular growth rotation.

as the two examples seen in Figures 7 and 8 (Björk 69, 83). This is not only helpful when planning treatment but also when making decisions about the retention period. By looking at certain structural signs in the mandible it is possible to predict the rotational tendencies which can greatly affect the stability of the occlusion post treatment. The predictors of anterior growth rotation (towards the cranial base) include the following: Short anterior face height, a concave profile, forward inclination of the mandibular symphysis (blue), thick cortical bone below the symphysis (green) and a convex shape of the anterior lower border of the mandible (red).

The predictors of posterior or backward rotation (away from the cranial base) include the following: increased anterior face height with a convex profile, posterior inclination of the mandible, posterior inclination of the symphysis (blue) and a straight lower border of the mandible (green) (Figure 8).

To better understand the role of the anterior occlusion in the late changes of the dentition and why

Predictors of posterior growth rotation:
- Increased ant. face height w. convex profile
- Posterior inclination of mandible
- Post. Inclination of mandibular symphysis
- Thin mandibular Symphysis
- Straight ant. lower border of the mandible

Figure 8. Predictors of posterior mandibular growth rotation.
it is critical to support the front teeth post treatment we shall look at a subject with a stable anterior occlusion to see how the natural tooth movements make this possible. This subject seen in Figure 9 is once again from Björk's studies. The period shown includes 6 years around the puberal growth spurt where the anterior occlusion did not change despite pronounced forward rotation of the mandible. Looking at the mandibular superimposition gives us a better idea of how this was possible. Notice also that the interincisal angle remained unchanged and that the continued proclination of the lower incisors made it possible for the anterior occlusion to remain stable (red arrow).

An important factor in this late development of the occlusion is the change over time in the sagittal jaw relationship (A-N-Pg) as shown in Figure 10. This is the result of the fact that maxillary sutural growth completes on average about 2 years prior to completion of condylar growth.

The skeletal relationship changes between the maxilla and mandible are important factor in terms of change after treatment. The angle A-N-Pg that describes the sagittal jaw relationship changes continuously on average as long as there is mandibular growth. This is an important detail as the dentition must respond to the changing jaw relationship in order to remain in occlusion. In other words, dentoalveolar compensations are critical when the maxilla has completed growing and the mandible continues to grow increasing the chances for undesirable changes in the anterior occlusion, especially in the more extreme growth types we have shown previously.

The close relationship between growth in height, condylar and sutural growth of boys is illustrated in Figure 11. Notice that sutural growth on average is completed at age 17 whereas condylar growth on average is completed at age 19. However, both graphs show a range of variation and as seen in some cases condylar growth can continue until age 22–23. This difference in completion of growth, as previously mentioned, can greatly influence changes in occlusion of the teeth.

Patient D. H. Age 12 years 9 months

The patient seen in Figure 12 was treated non-extraction with extensive use of Class II elastics. The dental arches were initially expanded using upper

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Figure 9. A young patient with a stable anterior occlusion. The study period include 6 years around the puberal growth spurt. Notice that the interincisal angle remained unchanged despite the pronounced anterior rotation of the mandible. This was possible because of the continued proclination of the lower anterior teeth (red arrow) (from Björk and Skieller, 1972).
and lower quad helix to eliminate the crowding. The post treatment results seen in Figure 13 shows a Class I occlusion with a normal overjet and overbite. General facial growth and maxillary and mandibular growth during treatment is seen in Figure 14. The superimpositions are made on stable structures and show downward forward mandibular growth during treatment. Maxillary growth was redirected vertically by the treatment mechanics. Mandibular growth was vertical at the condyle and associated with some forward rotation of the mandible. Notice some proclination of the lower incisors that helped correct the overjet. The out of retention records seen in Figure 15 show the occlusion to be stable two and a half years out of retention. Only a minor amount of lower anterior crowding has developed. The cephalometric superimpositions seen in Figure 16 show that general facial growth continued after treatment in a downward forward direction for both maxilla and mandible. “Structural superimposition” of the maxilla and mandible show more pronounced anterior or forward rotation of the mandible. Maxillary growth direction has now changed from vertical to a more forward direction. Notice the uprighting of the lower incisors that took place in the post treatment period.

This patient is an example of the typical post treatment difficulty in maintaining the alignment of the lower front teeth, especially if the lower incisors have been proclined during treatment. It also shows

Figure 10. The average change in the sagittal jaw relationship (A-N-Pg) angle over time in girls and boys. The graph shows a decrease from an average of 4.7° in girls and 4.1° in boys at age 7 to 1° in girls and 0.5° in boys at age 21 (from Ingerslev and Solow, 1975).37

Figure 11. Growth in body height, mandibular condyles and maxillary sutures in 25 boys from age 9–23 yrs. Notice the close relationship between growth in height and of the jaws. Completion of sutural growth occurs on average at age 17 yrs (red arrow), whereas condylar growth on average is completed at age 19 but can continue until age 23 yrs (blue arrow) (From Björk, 1963).22
how continued facial growth after treatment can increase the risk of change in alignment in particular of the front teeth. In cases with a strong potential for forward or anterior growth rotation these changes lead to uprighting of the anterior teeth as they follow the rotation of the mandible and increase in crowding of the incisors and shortening of the inter-canine width.
Figure 15. Two years and six months out of retention. The occlusion has remained unchanged and there is a normal overjet and overbite. Some mild lower anterior crowding has developed after retention.

Figure 16. Out of retention records. The patient was in retention with a maxillary Hawley appliance and a lower bonded 3-3 retainer. General facial growth continued in a downward forward direction in both maxilla and mandible. The maxillary incisors erupted along their axis without further proclination. Mandibular growth was characterized by continued forward or anterior rotation and vertical growth at the condyle. The lower incisors uprighted during this period from their proclined position.
In cases where more vertical growth and posterior rotation is to be expected long-term retention is also indicated as the uprighting of the lower incisors through the effect of the lower lip can result in return of the crowding seen before treatment.28

DISCUSSION

Considerable effort has been made in the past to study and understand the changes in the occlusion and alignment of the teeth over time. Little effort has been made, however, to associate these changes with the facial growth pattern. Past studies have focused heavily on the dental changes especially in relation to the stability of the anterior occlusion. Most studies have shown that over time the anterior occlusion in our patients undergo changes in both alignment of the teeth and in the occlusion. The focus has often been on one of the most critical components namely the lower incisors but rarely addressed is the reason for the tendency to see increased crowding of these teeth. The reported changes in overjet and overbite long-term vary from study to study and surprisingly little effort has been made to relate these changes to late mandibular growth and the associated tooth movements that take place after treatment. Many of the post retention changes such as crowding, of the mandibular and maxillary incisors, relapse of overbite and overjet and return towards a previous Class II malocclusion, can be explained as being primarily due to post treatment growth changes. However, other long-term changes such as relapse of a single tooth or an anterior open bite, and so on, may be explained as primarily due to more local factors. These factors include inability of the periodontal fibers to reorganize, compromised airways, and lack of adaptability of the soft tissues. In this article the main focus has been on reviewing normal facial growth in general and the associated dento-alveolar changes over time. It was also the goal to provide guidelines with respect to predicting the future mandibular growth pattern in order to better plan the retention protocol. One can ask if it is possible to anticipate these facial changes so as to minimize their influence on the occlusal and dentoalveolar changes, and to some degree it is. In the more pronounced cases of anterior or posterior rotation an extended retention protocol is highly recommended in order to ensure greater stability of the treatment result. To enhance long-term stability, the anticipated facial growth changes in a patient should always be considered and should be included in the planning not only of orthodontic treatment but also of the retention period after treatment. We have in this review focused primarily on information gathered from the longitudinal growth studies of Björk et al. using metallic implants in subjects without orthodontic treatment.22–24 These studies are some of best documented in the literature of normal facial growth and its variations and can help us better understand the post treatment changes. Other studies of facial growth by Broadbent,33 Ricketts,39 Houston,40 Mauchamps,41 and Behrents,42 have in most cases been cross-sectional, not longitudinal, and therefore not so helpful in understanding the influence of facial growth on long-term stability. To better understand the relationship between the late growth changes and stability further studies are needed.

FUNDING

The author declares that the study has received no financial support.

ETHICAL APPROVAL

Not required.

PATIENT CONSENT

The historical photographs of patients that shown in this review article were the treatment records of the author in his private and university practice decades ago.

CONFLICT OF INTEREST STATEMENT

The author declares no conflicts of interest.

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