



# Treatment options for Class III Malocclusions in growing patients: A Systematic Review

**Peer review status:**

No

**Corresponding Author:**

Dr. Gabriella Padalino,  
internist, Department of Oral and Maxillofacial Sciences, Sapienza University of Rome, viale ippocrate 146,  
00161 - Italy

**Submitting Author:**

Dr. Gabriella Padalino,  
internist, Department of Oral and Maxillofacial Sciences, Sapienza University of Rome, viale ippocrate 146,  
00161 - Italy

**Other Authors:**

Dr. Emanuele Fantasia,  
internist, Department of Oral and Maxillofacial Sciences, Sapienza University of Rome - Italy  
Dr. Martina Maria D'Emidio,  
internist, Department of Oral and Maxillofacial Sciences, Sapienza University of Rome - Italy  
Dr. Elisa Lombardelli,  
internist, Department of Oral and Maxillofacial Sciences, Sapienza University of Rome - Italy  
Dr. Giuseppe Rodi,  
internist, Department of Oral and Maxillofacial Sciences, Sapienza University of Rome - Italy

**Article ID:** WMC005212

**Article Type:** Systematic Review

**Submitted on:** 02-Nov-2016, 07:46:35 PM GMT **Published on:** 07-Nov-2016, 01:25:43 PM GMT

**Article URL:** [http://www.webmedcentral.com/article\\_view/5212](http://www.webmedcentral.com/article_view/5212)

**Subject Categories:** ORTHODONTICS

**Keywords:** Class III malocclusion; Orthodontics; Functional appliances; Skeletal discrepancy

**How to cite the article:** Padalino G, Fantasia E, D'Emidio M, Lombardelli E, Rodi G. Treatment options for Class III Malocclusions in growing patients: A Systematic Review. WebmedCentral ORTHODONTICS 2016;7(11):WMC005212

**Copyright:** This is an open-access article distributed under the terms of the [Creative Commons Attribution License \(CC-BY\)](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

**Source(s) of Funding:**

No found has been taken.

# Treatment options for Class III Malocclusions in growing patients: A Systematic Review

**Author(s):** Padalino G, Fantasia E, D'Emidio M, Lombardelli E, Rodi G

## Abstract

The class III malocclusion is defined when the lower first molar is more mesial than the upper first molar and it can be determined by maxillary retrusion, mandibular protrusion, or both.

The etiology is multifactorial, and it seems to be involved environmental and genetic factors. Indeed, class III malocclusion is the one most affected by genetic influences. Among these environmental factors considered responsible for its etiology there are: wrong postures, endocrine disturbances, congenital defects, trauma and nasobuccal obstruction. An early treatment is required to reduce the need of treatment in the permanent dentition because if the malocclusion is diagnosed early, a lot of treatment modalities will be available. In contrast, in adulthood, the only treatment options are orthodontic or surgery camouflage.

The aim of this study is to analyze the current therapeutic strategies for the treatment of Class III malocclusion in growing patients. Facemask therapy, Frankel III and Bionator III are recommended for patients with maxillary deficiency. Facemask can be combined with palatal expansion because it would seem to facilitate the orthopedic effect of the facemask. The Frankel III stimulates mandibular growth through the muscle-blocking effects and stretching of the periosteum.

The chin cup is used in growing patients with mandibular protrusion; the use determines clockwise rotation of the mandible and the retroinclination of mandibular incisors.

An important factor for treatment of Class III malocclusion is the origin of malocclusion. It's very important to make an early diagnosis for choosing the most appropriate device.

## Introduction

In 1900, Angle described three types of dental malocclusions<sup>1</sup>. The dental class III malocclusion is defined when the first lower molar is more mesial than the upper first one. Therefore, the class III is defined

as mesioocclusion situation. Indeed, the skeletal class III malocclusion is a deviation in the sagittal plane of the relationship between maxilla and mandible, due to a deficiency and/or a backward position of the maxilla, or a prognathism and/or forward position of the mandible<sup>2,3,4</sup>. However, the classification of Angle is not able to explain the mechanisms underlying this phenomenon. In fact, the condition might be characterized by mandibular prognathism, maxillary retrognathism, retrusive mandibular dentition, protrusive maxillary dentition, and a combination of the above<sup>5</sup>. The actual classification is the following: prognathic mandible with a normally positioned maxilla; retrognathic maxilla with a normally positioned mandible; both maxilla and mandible normally positioned; retrognathic maxilla, prognathic mandible.

Until 1970 it was commonly believed that the classes III were caused solely by a jaw in the forward position<sup>82</sup>. However, it has been shown, that 30-40% of Class III are due to a development deficiency of the maxilla<sup>6-12</sup>.

Different races show a different rate of prevalence of class III malocclusion. The prevalence rate was reported to be around 1-3% in the Caucasians; in the Latin populations is approximately 5%; a higher prevalence rate (15-23%) has been observed in Asian populations of Taiwanese, Japanese,

Korean and Chinese<sup>13-30</sup>. The etiology of Class III malocclusion is multifactorial because it is due to the association of hereditary and environmental factors.

- hereditary factors: the class III malocclusion seems to be the one most affected by genetic influences. Numerous studies have shown a significantly higher incidence of this malocclusion between members of many generations<sup>31-34</sup>. An example of this inheritance is given by the European family of Habsburg; indeed, for 23 generations, some family members had a prominent jaw, to the point that the term "Habsburg jaw" has been coined to describe the prognathic mandible<sup>35,36</sup>. However, the pattern of transmission is controversial; according to some authors, the transmission is autosomal recessive<sup>37</sup>; according to others, it is autosomal dominant with complete<sup>38,39</sup> or incomplete penetrance<sup>15,40,41</sup>; yet, according to others follows a polygenic transmission mode<sup>42</sup>.

- environmental factors: many environmental factors are held responsible for this malocclusion. The

literature confirms the following:

- wrong postures which cause the sliding forward of the mandible (e.i. nail biking)<sup>43,44</sup>;
- endocrine disturbances such as gigantism or pituitary adenomas<sup>37,45-48</sup>;
- congenital anatomic defects (e.i cleft lip, cleft palate)<sup>46,49</sup>;
- trauma<sup>50,51</sup>;
- nasobuccal obstruction<sup>45,52</sup>.

The skeletal Class III malocclusion in growing patients is a complex problem of orthodontic practice. Early treatment is required to reduce the need of treatment in the permanent dentition, when the only available options are camouflage orthodontic treatment or surgery. Furthermore, early interventions can solve the little patient's facial looks, without upsetting the psychological aspects<sup>53</sup>. If the malocclusion is diagnosed in deciduous or mixed dentition, a lot of treatment modalities are available, including functional orthopedic appliances. Furthermore, it is also important to identify whether the etiology is dental, functional, or skeletal. If the problem is skeletal, the cause might be an underdeveloped maxilla, an overdeveloped mandible, or a combination of both. If the cause is an underdeveloped maxilla, its growth can be stimulated through orthopedic force or a functional appliance. Instead, if the cause is an overdeveloped mandible, the only alternative is surgery after growth. Various therapeutic modalities can be found in the literature regarding orthopedic treatment in Class III malocclusion<sup>54-57</sup>. The aim of this study is to analyze the current therapeutic strategies in the treatment of Class III malocclusion in growing patients.

## Materials and Methods

The prevalence of Class III malocclusion is a so important orthodontic topic that many articles have been published on international literature till now. The treatment of this type of malocclusion has represented a great challenge for all clinicians, for avoiding a final surgical treatment. So the systematic review of literature has been performed on the principal medical databases: PubMed (Medline), Embase and Scopus. The keywords used were: *class III malocclusion*, *skeletal discrepancy*, *vitious Habits* and *functional appliances* to identify all articles reporting on the topic of diagnosis and treatment of patients with single or multiple tooth agenesis till October 2016. No restrictions of time and languages have been fixed. The results have been filtered and valued following our eligibility criteria and then organized following the

PRISMA method. The search identified 9,754 abstracts, which were reviewed manually and each article of interest was marked for further review. The full text of the marked studies was retrieved and studies that satisfied our eligibility criteria were included in this review. At the end only 43 full articles have been selected.

## Review

### Treatment options

1) Facemask therapy: the use of facemask therapy is recommended for patients with maxillary deficiency. Maxillary protraction can be combined with palatal expansion because palatal expansion may destroy circummaxillary suture system, and presumably facilitates the orthopedic effects of the facemask<sup>4,44,58</sup>. Some authors reported the correction of class III malocclusions in only six months with early maxillary expansion and protraction<sup>59</sup>. When the maxilla moves forward and downward, the final effect is a posterior rotation of the the mandible<sup>60</sup>.

The most favorable period for initiation of therapy would appear to be the deciduous dentition. The earlier treatment produces a more effective result; however, the older children still have positive effects, so the orthopedic changes can be obtained until fourteen age.

Treatment in the deciduous dentition is able to produce a more significant anterior morphogenetic rotation of the mandible due to an upward-forward direction of condylar growth, leading to reduced mandibular protrusion and total length. Maxillary dento-alveolar protrusion induced by treatment is greater in subjects treated in later ages, whereas skeletal changes are more evident in children treated in the deciduous dentition.

The expansion of the palate advantages includes expansion of the maxilla with a posterior crossbite correction, increase arch length, the activation of circummaxillary sutures and a movement in forward and downward of the maxillary complex. Based on several studies, through the use of the face mask, there is an increases in SNA of about 2° and a reduction in SNB of about 1.7°<sup>61,62,63</sup>.

Some authors<sup>59</sup> reported correcting class III occlusion in six months with the use of facial mask and early maxillary expansion. At the end of treatment, the overcorrection is always recommended to stabilize the new position between two arches and to avoid recurrences. At the end of therapy, to maintain the posture of the orofacial muscles, it can be helpful to

use a functional device such as Bionator or Frankel. Facemasks have various clinical applications. The orthodontist can choose between Petit or Delaire face mask as an extraoral part of the device with or without palatal expansion. The Delaire is the facial mask most used in clinical practice.

2) Frankel III: the treatment of Class III malocclusion for patients in the growth and development period usually is based on growth modification with a lot of functional appliances. In children with an underdeveloped maxilla, the FR III seems to redirect and stimulate mandibular growth through the muscle-blocking effects and stretching of the periosteum<sup>54</sup>. The FR-3 appliance is based on the principle that resolution of maxillary retrusion may occur by using muscle forces<sup>64</sup>.

The appliance is composed of four acrylic parts. There are two upper labial pads, that are positioned in the labial vestibule, with the aim of eliminate the pressure of the lip and stimulate the maxillary growth; them two vestibolar shields, positionated in the mandibular vestibule, remove the forces generated by masticatory muscles, determine the apposition of alveolar bone.

The device determines skeletal changes and dental changes.

àskeletal changes: the FR-3 stimulates the growth of the maxilla and restricts mandibular development by counteracting the forces of the surrounding muscles. Frankel declared the bone apposition at point A with the use of the FR III appliance, instead McNamara and Hugu found that the device caused forward and downward movement of the maxilla.

Correction of Class III malocclusion through the use of the device, therefore, seems to take place by means the downward and backward rotation of the mandible caused by the appliance<sup>65,66</sup>.

àdental changes: the resolution of class III malocclusion also it occurs for linguoversion of the mandibular incisors, with a significant increase in overjet<sup>66-69</sup>. According to several studies, it is also a slight decrease in overbite, which seems to be due to the backward and downward rotation of the jaw<sup>66</sup>. The resolution of the skeletal class III malocclusion is also due, in part, to the downward and forward movement of the upper molars.

3) Chincup: the chincup can be used in growing patients with mandibular protrusion and with a normal maxilla<sup>70</sup>. The appliance can be used in deciduous or in mixed dentitions. If chincup has been used for a long time, several cases successfully treated have been described. The variables that can influence the success of the therapy are the duration of treatment,

the age of the patient and the entity of applied forces.

Several studies have confirmed that patients treated with chincup show an improvement of the class III thanks to the clockwise rotation of the mandible, the increase in their anterior facial height and the retroinclination of mandibular incisors<sup>6,71-74</sup>. Also it occurs a signivative reduction of the angle SNB, that can be caused by a brake on mandibular growth or an intense clockwise rotational effect<sup>6,73,75,76</sup>. In addition, several studies show an increase in the Wits index in patients treated with chincup, compared to those not treated.

The literature also supports the closure of the gonial angle<sup>70,72,73,75,77-81</sup>. This occurs because of the direction of force passing in the occipital region and in the glenoid fossa through and under the condyle, working as a fulcrum and causing the rotation of the ramus of the mandible.

Therefore, the orthopaedic results of chin-cup therapy may not only influence mandibular growth but they seem to induce posterior displacement of craniofacial structures. It was shown that the force directed backwards generated by the chincup, is transmitted to the condyle, with the risk of development of temporomandibular disorders (TMD)<sup>82,83</sup>. In fact, the therapy would seem to determine the displacement of the condyle in the glenoid fossa with anterior dislocation of the articular disc, with the appearance of articular clicks.

4)Bionator III: This appliance is a modified device of the traditional Bionator. It can be used in the tratment of class III malocclusion in growing patients., The modified Bionator differs in various characteristics from the original Bionator. The labial arch is placed in the middle of the lower teeth; upper labial buttons and vestibular shields that deepen into upper fornix, in order to allow expansion of the maxillary arch; the lingual wire is in a different position to control the position of the tongue up to the upper first molar; the presence of an upper incisor inclined plane. The device should be worn for the whole day, about twenty-two hours.

The goal of the treatment of patients with skeletal class III is not just about the correction in the sagittal plane of the relation between the jaw, and the resolution of a decreased overjet. It must stabilize the occlusal relations at the end of the orthopedic or functional therapy with a long follow-up during the patient's adolescence and even in the early years of his adult life.

## Conclusion(s)

An important factor for treatment of Class III malocclusion in growing patient is the origin of malocclusion. Need to identify if the clinician is in the presence of a skeletal or dental class III and, in the cases of class III skeletal, if it is due to the mandibular prognathism or to the maxillary deficiency. So, it is very important to make an early diagnosis for choosing the most appropriate device.

## References

- 1) Angle EH. *Treatment of Malocclusion of the Teeth and Fractures of the Maxillae*, 6th edition. Philadelphia: SS White Dental Mfg Co, 1900.
- 2) Proffit WR. *Contemporary Orthodontics*. 4th ed. St Louis, Mo: Mosby; 2007:689–707.
- 3) Enlow, 1968; Enlow *et al.*, 1977; Delaire, 1976; Ellis and McNamara, 1984; Guyer *et al.*, 198.
- 4) Haas AJ. Palatal expansion: just the beginning of dentofacial orthopedics. *Am J Orthod* 1970;57:219-55.5B.
- 5) Celikoglu and H. Oktay, "Effects of maxillary protraction for early correction of class III malocclusion," *European Journal of Orthodontics*, vol. 36, no. 1, pp. 86–92, 2014.
- 6) A. Arman, T. U. Toygar, and E. Abuhijleh, "Profile changes associated with different orthopedic treatment approaches in class III malocclusions," *Angle Orthodontist*, vol. 74, no. 6, pp. 733–740, 2004.
- 7) Deguchi, T. and Kitsugi, A. (1996) Stability of changes associated with chin cup treatment. *The Angle Orthodontist*, 66, 139–145.
- 8) Mitani, H. (2002) Early application of chin cap therapy to skeletal Class III malocclusion. *American Journal of Orthodontics and Dentofacial Orthopedics*, 121, 584–585.
- 9) Mitani, H., Sato, K. and Sugawara, J. (1993) Growth of mandibular prognathism after pubertal growth peak. *American Journal of Orthodontics and Dentofacial Orthopedics*, 104, 330–336.
- 10) Yoo, Y.K., Kim, N.I. and Lee, H.K. (1971) A study on the prevalence of malocclusion in 2378 Yonsei University students. *Korean Journal of Orthodontics*, 2, 35–40.
- 11) Lee, S.J., Kim, T.W. and Suhr, C.H. (1994) Study of recognition of malocclusion and orthodontic treatments. *Korean Journal of Orthodontics*, 24, 367–394.
- 12) Ko, Y.I., Baek, S.H., Mah, J. and Yang, W.S. (2004) Determinants of successful chin cup therapy in skeletal class III malocclusion. *American Journal of Orthodontics and Dentofacial Orthopedics*, 126, 33–41.
- 13) Nakasima A, Ichinose M, Nakata S, Genetic and environmental factors in the development of so-called pseudo-and true mesioclusions. *Am J Orthod Dentofac Orthop* 1986; 90: 106–116.
- 14) Haynes S. The prevalence of malocclusion in English children aged 11–12 years. *Rep Congr Eur Orthod Soc*. 1970:89–98.
- 15) Foster TD, Day AJ. A survey of malocclusion and the need for orthodontic treatment in a Shropshire school population. *Br J Orthod*. 1974;1:73–78.
- 16) Thilander B, Myrberg N. The prevalence of malocclusion in Swedish schoolchildren. *Scand J Dent Res*. 1973;81:12–21.
- 17) Irie M, Nakamura S. Orthopedic approach to severe skeletal Class III malocclusion. *Am J Orthod*. 1975;67:377–392.
- 18) Baik HS, Han HK, Kim DJ, Proffit WR. Cephalometric characteristics of Korean Class III surgical patients and their relationship to plans for surgical treatment. *Int J Adult Orthodon Orthognath Surg*. 2000;15:119–128.
- 19) Chan GK. Class III malocclusion in Chinese: etiology and treatment. *Am J Orthod*. 1974;65:152–156.
- 20) Cozza P, Di Girolamo R, Nofroni I. Epidemiologia delle mal occlusioni su un campione di bambini delle scuole elementari del Comune di Roma. *Ortognatodonzia Ital*. 1995;4: 217–228.
- 21) Silva RG, Kang DS. Prevalence of malocclusion among Latino adolescents. *Am J Orthod Dentofacial Orthop*. 2001; 119:313–315.
- 22) Susami R, Asai Y, Hirose K, et al. The prevalence of malocclusion in Japanese school children. *J Jpn Orthod Soc* 1972; 31:319–24.
- 23) Chang HP. Components of Class III malocclusion in Taiwanese. *Kaohsiung J Med Sci* 1985;1:144–55.
- 24) Kang HK, Ryu YK. A study on the prevalence of malocclusion of Yonsei University students in 1991. *Korean J Orthod* 1992;22:691–701.
- 25) Tang EL. The prevalence of malocclusion amongst Hong Kong male dental students. *Br J Orthod*

- 1994;21:57–63.
- 26) Jacobson A, Evans WG, Preston CB, et al. Mandibular prognathism. *Am J Orthod* 1974;66:140–71.
- 27) McNamara JA Jr, Brudon WL. Orthodontic and orthopedic treatment in the mixed dentition. 1st ed. Ann Arbor, MI, Needham Press; 1992.
- 28) M. Fu, D. Zhang, B. Wang, Y. Deng, F. Wang, and X. Ye, “The prevalence of malocclusion in China—an investigation of 25,392 children,” *Chinese Journal of Stomatology*, vol. 37, no. 5, pp. 371–373, 2002.
- 29) M. T. Bukhary, “Comparative cephalometric study of Class III malocclusion in Saudi and Japanese adult females,” *Journal of Oral Science*, vol. 47, no. 2, pp. 83–90, 2005.
- 30) M. Celikoglu, S. Akpinar, and I. Yavuz, “The pattern of malocclusion in a sample of orthodontic patients from Turkey,” *Medicina Oral, Patologia Oral y Cirugia Bucal*, vol. 15, no. 5, pp. e791–e796, 2010.
- 31) Iwaki H. Hereditary influence of malocclusion. *Am J Orthod Oral Surg* 1938;24:328–36.
- 32) Stiles KA, Luke JE. The inheritance of malocclusion due to mandibular prognathism. *J Hered* 1953;44:241–5.
- 33) Kraus BS, Wise WJ, Frie RA. Heredity and the craniofacial complex. *Am J Orthod* 1959;45:172–217.
- 34) Schulze C, Wiese W. On the heredity of prognathism. *Fortschr Kieferorthop* 1965;26:213–29.
- 35) Wolff G, Wienker TF, Sander H. On the genetics of mandibular prognathism: analysis of large European noble families. *J Med Genet* 1993;30:112–6.
- 36) Hodge GP. A medical history of the Spanish Habsburgs—as traced in portraits. *JAMA* 1977;238:1169–74.
- 37) Downs WG. Studies in the causes of dental anomalies. *J Dent Res* 1928;8:367–79.
- 38) Kraus BS, Wise WJ, Frie RA. Heredity and the craniofacial complex. *Am J Orthod* 1959;45:172–217.
- 39) Keeler CE. Heredity in dentistry. *Dent Cosmos* 1935;77: 1147–63.
- 40) Stiles KA, Luke JE. The inheritance of malocclusion due to mandibular prognathism. *J Hered* 1953;44:241–5. 57.
- 41) El-Gheriani AA, Maher BS, El-Gheriani AS, et al. Segregation analysis of mandibular prognathism in Libya. *J Dent Res* 2003;82:523–7.
- 42) Litton SF, Ackermann LV, Isaacson RJ, et al. A genetic study of Class III malocclusion. *Am J Orthod* 1970;58:565–77.
- 43) Diewert VM. A morphometric analysis of craniofacial growth and changes in spatial relations during secondary palatal development in human embryos and fetuses. *Am J Anat* 1983;167:495–522. 70.
- 44) McNamara JA Jr. An orthopedic approach to the treatment of Class III malocclusion in young patients. *J Clin Orthod* 1987;21:598–608.
- 45) Chang HP, Liu PH, Chang HF, et al. Thin-plate spline (TPS) graphical analysis of the mandible on cephalometric radiographs. *Dentomaxillofac Radiol* 2002;31:137–41.
- 46) Pascoe JJ, Hayward JR, Costich ER. Mandibular prognathism: its etiology and a classification. *J Oral Surg* 1960; 18:21–4. 65.
- 47) Gold JK. A new approach to the treatment of mandibular prognathism. *Am J Orthod* 1949;35:893–912.
- 48) Chang HP, Tseng YC, Chou TM. An enlarged sella turcica on cephalometric radiograph. *Dentomaxillofac Radiol* 2005; 34:308–12.
- 49) Chang HP, Chuang MC, Yang YH, et al. Maxillofacial growth in children with unilateral cleft lip and palate following secondary alveolar bone grafting: an interim evaluation. *Plast Reconstr Surg* 2005;115:687–95.
- 50) Monteleone L, Duvigneaud JD. Prognathism. *J Oral Surg* 1963;21:190–5.
- 51) Schoenwetter RF. A possible relationship between certain malocclusions and difficult or instrument deliveries. *Angle Orthod* 1974;44:336–40.
- 52) McNamara JA Jr. A method of cephalometric evaluation. *Am J Orthod* 1984;86:449–69.
- 53) Ngan P, Hägg U, Yiu O, Merwin D, Wei SHY. Soft tissue and dentoskeletal profile changes associated with maxillary expansion and protraction headgear treatment. *Am J Orthod Dentofacial Orthop* 1996;109:38–49.
- 54) Frankel R. Maxillary retrusion in Class III and treatment with the function corrector III. *Trans Eur Orthod Soc.* 1970;46: 249–259.
- 55) Tollaro I, Baccetti T, Franchi L. Mandibular skeletal changes induced by early functional treatment of Class III malocclusion: a superimposition study. *Am J Orthod Dentofacial Orthop.* 1995;108:525–532.
- 56) Graber TM, Rakosi T, Petrovic AG. *Dentofacial Orthopedics with Functional Appliances*. 2nd ed. St Louis, MO: CV Mosby; 1997:468.

- 57) 4. Garattini G, Levrini L, Crozzoli P, Levrini A. Skeletal and dental modifications produced by the Bionator III appliance. *Am J Orthod Dentofacial Orthop.* 1998;114:40–44.
- 58) Turley PK. Orthopedic correction of Class III malocclusion with palatal expansion and custom protraction headgear. *J Clin Orthod* 1988;22:314–25.
- 59) Takada K, Petdachai S, Sakuda M. Changes in dentofacial morphology in skeletal Class III children treated by a modified maxillary protraction headgear and a chin-cap: a longitudinal cephalometric appraisal. *Eur J Orthod* 1993;15:211–21.
- 60) Williams S, Andersen CE. The morphology of the potential Class III skeletal pattern in the growing child. *Am J Orthod* 1986;89: 302–11.
- 61) Mandall N, DiBiase A, Littlewood S, et al. Is early Class III protraction facemask treatment effective? A multicentre, randomized, controlled trial: 15-month follow-up. *J Orthod.* 2010;37:149–161.
- 62) Gallagher RW, Miranda F, Buschang PH. Maxillary protraction: treatment and posttreatment effects. *Am J Orthod Dentofacial Orthop.* 1998;113:612–619.
- 63) Ngan P, Ha'gg U, Yiu C, Merwin D, Wei SH. Treatment response to maxillary expansion and protraction. *Eur J Orthod.* 1996;18:151–168.
- 64) McNamara JA Jr, Hugu SA. The functional regulator (FR-3) of Fränkel. *Am J Orthod* 1985;88:409–24.
- 65) Kerr WJ, Ten Have TR. Changes in soft tissue profile during the treatment of Class III malocclusion. *Br J Orthod* 1987;14:243–9.
- 66) Ülgen M, Firatli S. The effects of the Fränkel's function regulator on the Class III malocclusion. *Am J Orthod Dentofacial Orthop* 1994;105:561–7.
- 67) Loh MK, Kerr WJ. The function regulator III: effects and indications for use. *Br J Orthod* 1985;12:153–7.
- 68) Kerr WJS, Ten Have TR. A comparison of three appliance systems in the treatment of Class III malocclusion. *Eur J Orthod* 1988;10:203–14.
- 69) Kerr WJS, Ten Have TR, McNamara JA Jr. A comparison of skeletal and dental changes produced by functional regulators (FR-2 and FR-3). *Eur J Orthod* 1989;11:235–42.
- 70) Deguchi T, McNamara JA Jr. Craniofacial adaptations induced by chincup therapy in Class III patients. *Am J Orthod Dentofacial Orthop* 1999;115:175–82.
- 71) Mitani, H. (2007) Recovery growth of the mandible after chin cup therapy: fact or fiction. *Seminars in Orthodontics*, 13, 186–199.
- 72) Deguchi, T., Kuroda, T., Minoshima, Y. and Graber, T.M. (2002) Craniofacial features of patients with Class III abnormalities: growth-related changes and effects of short-term and long-term chincup therapy. *American Journal of Orthodontics and Dentofacial Orthopedics*, 121, 84–92.
- 73) Sugawara, J. and Mitani, H. (1997) Facial growth of skeletal Class III malocclusion and the effects, limitations, and long-term dentofacial adaptations to chincap therapy. *Seminars in Orthodontics*, 3, 244–254.
- 74) Gökalp, H. and Kurt, G. (2005) Magnetic resonance imaging of the condylar growth pattern and disk position after chin cup therapy: a preliminary study. *The Angle Orthodontist*, 75, 568–575.
- 75) Graber W. Chin cup therapy for mandibular prognathism. *Am J Orthod.* 1977; 72:23–41.
- 76) Abu Alhaija ES, Richardson A. Long-term effect of the chincap on hard and soft tissues. *Eur J Orthod.* 1999; 21:291–8.
- 77) Chang HP, Lin HC, Liu PH, Chang CH. Geometric morphometric assessment of treatment effects of maxillary protraction combined with chin cup appliance on the maxillofacial complex. *J Oral Rehabil.* 2005; 32:720–28.
- 78) Lu YC, Tanne K, Hirano Y, Sakuda M. Craniofacial morphology of adolescent mandibular prognathism. *Angle Orthod.* 1993; 63:277–82.
- 79) Alarcón JA, Bastir M, Rosas A, Molero J. Chincup treatment modifies the mandibular shape in children with prognathism. *Am J Orthod Dentofacial Orthop.* 2011; 140:38–43.
- 80) Sakamoto T, Iwase I, Uka A, Nakamura S. A roentgenocephalometric study of skeletal changes during and after chin cup treatment. *Am J Orthod.* 1984; 85:341–50.
- 81) Liu ZP, Li CJ, Hu HK, Chen JW, Li F, Zou SJ. Efficacy of short-term chincup therapy for mandibular growth retardation in Class III malocclusion. *Angle Orthod.* 2011; 81:162–8.
- 82) J. Mermigos, C. A. Full, and G. Andreasen, "Protraction of the maxillofacial complex," *American Journal of Orthodontics and Dentofacial Orthopedics*, vol. 98, no. 1, pp. 47–55, 1990.
- 83) Tanne, K., Tanaka, E. and Sakuda, M. (1996) Stress distribution in the temporomandibular joint produced by orthopedic chincup forces applied in varying directions: a three-dimensional analytic

approach with the finite element method. *American Journal of Orthodontics and Dentofacial Orthopedics*, 110, 502–507.