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Short-term Anteroposterior Treatment Effects of Functional Appliances and Extraoral Traction on Class II Malocclusion

A Meta-analysis

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ABSTRACT

Objective: To evaluate the anteroposterior short-term skeletal and dental effects on Class II malocclusion in growing patients following treatment with functional appliances (activators or twin block), extraoral traction, or combination appliances (appliances with both functional and extraoral traction components), based on published data.

Materials and Methods: A literature search was carried out identifying a total of nine prospective clinical trials. The data provided in the publications underwent meta-analysis using the random effects model with regard to SNA, SNB, ANB, and overjet.

Results: All appliance groups showed an improvement in sagittal intermaxillary relationships (decrease in ANB) when compared to untreated subjects. Activators and twin block appliances accomplish this mainly by acting on the mandible (increases in SNB) while twin block appliances also seem to act on the maxilla (decrease in SNA). Extraoral traction appliances achieve this by acting on the maxilla (decreases in SNA). Combination appliances mainly act on the mandible (increase in SNB). Activators, twin block, and combination appliances also reveal a decrease in overjet, which is not the case in the singular use of extraoral traction.

Conclusions: Intermaxillary changes being present in all appliance groups, anteroposterior treatment response following the use of functional appliances and/or extraoral traction in growing class II malocclusion patients is most evident in one of the two jaws (mandible for activators and combination appliances and maxilla for extraoral traction) except for the twin block group, which shows changes on both jaws.

KEY WORDS: Class II malocclusion, Functional appliances, Extraoral traction, Meta-analysis.

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In the treatment of Class II malocclusion, treatment possessing the capability to alter patients' facial growth is of particular interest, namely by means of functional appliances, extraoral traction (EOT) appliances, or a combination of both. Over the years, numerous investigations have evaluated the possibility of growth modification with these appliances. However, the results are generally equivocal, with conflicting evidence as to their effectiveness. Studies suggest that the changes, albeit present, are not very predictable and not always significantly different from those occurring either without treatment or with conventional fixed appliance systems.[1] A large variation in interindividual response and small mean changes could mean that differences may be more attributable to study design than treatment.[2,3] In addition, any dentofacial change may be due to normal growth that occurs irrespective of therapy.

Recent reports demonstrate that some improvement in jaw relationships can be achieved during early treatment with headgear or functional appliances.[4–10] However, despite the long history of functional appliances, there continues to be much controversy related to their use, effectiveness, and mode of action.[11–14] Moreover, there is a large individual variation in the results of treatment.[12] Often, when there is lack of success of functional appliances, this is attributed to patient compliance as well as the inability to control the amount and direction of mandibular growth.[15] EOT appliances, or headgear, on the other hand, are used to redirect or restrain maxillary growth and to distalize maxillary molars.[16–19] As with functional appliances, practitioners often cite patient compliance as a critical role in treatment success with headgear, with this compliance being extremely variable among patients.[20]

The aim of this study was to evaluate, based on published data, short-term anteroposterior skeletal and dental effects on Class II malocclusion in growing patients following treatment with functional appliances and/or EOT, using lateral cephalograms. As sample sizes in investigations are relatively small, this study aimed to combine data from existing literature to increase the sample considerably.

MATERIALS AND METHODS Return to TOC

Literature Search

A literature search was performed using PubMed and Ovid (including OLDMEDLINE) as well as the Cochrane Library to identify orthodontic articles reporting treatment of Class II malocclusion using functional appliances or EOT. Terms used in the search were *functional appliances, extraoral traction* or *headgear*, and *Class II*, combined with *clinical trial* or *randomized controlled trial.* A further search, for the sake of verification that all articles had been located, was carried out using *activator, bionator, twin block*, and names of specific functional appliances as opposed to simply functional appliances. Other databases (Web of Science, Google Scholar Beta, Embase, Extenza, African Journals Online, Bandolier, Evidence-Based Medicine, Latin American and Caribbean Center on Health Sciences Information, Bibliografia Brasileira de Odontologia, ChinaInfo database) were also searched for completeness. The search was expanded by searching references of articles consulted. Full-text sources available on the Internet for the *American Journal of Orthodontics and Dentofacial Orthopedics, European Orthodontic Journal,* and the *Angle Orthodontist* were also searched to validate that the search had identified all relevant articles.[21]

Articles were selected for inclusion and analysis if the following criteria were met.

—Human studies

—Pertained to removable functional appliance and/or EOT appliance use in Class II malocclusion treatment

— In the form of prospective clinical trials

— Treatment carried out on growing patients with age ranges mentioned

— Duration of treatment mentioned (minimum duration of 9 months to avoid erroneous annualized values)

— Availability of a suitable control group (untreated Class II individuals)

— Measurable pretreatment and posttreatment cephalometric values, as well as changes during treatment, for SNA, SNB, ANB, and overjet

— Sufficient data available for statistical calculations

In the case of more than one publication about the same patient group, the most informative and relevant article was included. For studies stating one or more but not all of the desired variables (SNA, SNB, ANB, overjet), the corresponding author[22–24] was contacted, and values for these variables were also obtained from the raw data. A quality analysis was also carried out according to the methods described by Petrén et al.[25] Studies were described as being of low, medium, or high quality. Only those falling into the medium- and high-quality categories were included for analysis.

Data Analysis

The data provided in the included studies were divided into different patient groups, which were patients treated with activators, patients treated with twin block, patients treated with EOT, patients treated with combination appliances (including both functional and EOT components), and untreated Class II control groups. No distinction was made between different types of activators or EOT appliances. Herbst appliances were excluded as these often tend to be fixed and would bias the results with regard to compliance. Fränkel appliances were also excluded since they may differ from other functional appliances in their mode of action, probably by causing an increase in both apical bases and maxillary and mandibular arch widths.[11,26–29] From the identified studies, the changes referring to the maxilla (expressed by SNA), mandible (expressed by SNB), intermaxillary relationship (expressed by ANB), and overjet were analyzed.

Data were subsequently entered into the meta-analysis program of the Cochrane Collaboration's Review Manager Software (RevMan 4.2.8, released July 8, 2005). Descriptive statistics were calculated for the different variables in the different groups including arithmetic mean and standard deviation. Treatment time between studies varied from 9 to 24 months, and therefore, annualizing results standardized this variation.

Using the random effects model, forest plots were drawn and significance tests carried out (calculating *P* values). Heterogeneity tests were also performed. If confidence intervals for the results of individual studies (depicted graphically using horizontal lines) have poor overlap, this generally indicates the presence of statistical heterogeneity. More formally, statistical tests for heterogeneity are available. These include χ^2 tests as well as calculation of I^2. The χ^2 test is based on the sum of the squared difference between the treatment effect of each individual trial and overall treatment effect, weighted by the inverse of the variance in each trial. It assesses whether observed differences in results are compatible with chance alone. A low *P* value (or a large χ^2 statistic relative to its degree of freedom) provides evidence of heterogeneity of treatment effects (variation in effect estimates beyond chance).[30]

A more useful statistic for quantifying inconsistency, and present in the forest plots, is $I^2 = [(Q - df)/Q] \times 100\%$, where Q is the χ^2 statistic and *df* is its degrees of freedom.[31,32] This describes the percentage of the variability in effect estimates that is due to heterogeneity rather than sampling error (chance). A value greater than 50% may be considered substantial heterogeneity.[30]

RESULTS Return to TOC

Results of Search

The original search located 171 articles. From these, 168 were human studies. A total of 159 of these were carried out on growing patients. The articles were further narrowed down to 56 that contained relevant data for this study. These were read, and a total of 9 suitable studies[2,5,22–24,33–36] were identified following consideration of all inclusion criteria (Figure 1 and Table 1). The results described below are summarized in Table 2 and Figures 2 through 5.

Treatment Effects on the Maxilla

The twin block group showed a mean decrease of 1.03 degrees when compared to the control group (*P* = .02), with low homogeneity (I^2 = 81.2%), while the EOT group showed a mean decrease in SNA of 1.01 degrees when compared to the control group (*P* < .00001), but with high homogeneity (I^2 = 0%). No significant change in SNA was seen in the other groups when compared to controls.

Treatment Effects on the Mandible

With regard to SNB, activators revealed a mean increase of 0.66 degrees when compared to the control group (*P* = .04), but with a heterogeneous response (I^2 = 83.4%). A homogeneous (I^2 = 0%) mean increase of 1.53 degrees was seen for the twin block group (*P* < .0001), as well as a homogeneous (I^2 = 22.2%) mean increase of 1.05 degrees for the combination group (*P* < .00001). For the EOT, no significant change was found in SNB.

Treatment Effects on the Intermaxillary Relation

Activators displayed a mean decrease in ANB of 0.92 degrees in comparison to the control group (*P* < .00001), with mild heterogeneity (I^2 = 54.5%). The twin block group showed a heterogeneous (I^2 = 77.9%) mean decrease of 2.61 degrees in ANB (*P* < .00001). A mean decrease in ANB of 1.38 degrees is seen for the EOT group when compared to the control group (*P* < .00001), with mild heterogeneity (I^2 = 53.6). Finally, the combination group also showed a mean decrease in ANB of 1.8 degrees (*P* < .00001) but was more homogeneous (I^2 = 44.8%).

Treatment Effects on Overjet

Concerning overjet, activators exhibited a large mean reduction of 3.88 mm when compared to the control group (*P* < .00001). This change, however, is highly heterogeneous (I^2 = 93.7). The twin block group showed a heterogeneous (I^2 = 83.3) 6.45-mm mean decrease in overjet when compared to the control group (*P* < .00001), while the combination group also showed a homogeneous ($I^2 = 5.6$) decrease in overjet, with a mean of 4.37 mm ($P < .00001$). The EOT group showed no significant change in overjet.

DISCUSSION Return to TOC

Functional appliances (activators and twin block) improve the sagittal intermaxillary relationship mainly by their effect on the mandible and show an important dental effect by overjet reduction. Twin block appliances also show a significant effect on the maxilla. The skeletal changes are brought about by stimulation of condylar growth[37–42] as well as a contribution by a certain amount of fossa advancement.[43–46] They also seem to display a growth-restraining effect on the maxilla.[44,47–50] Besides the small sagittal skeletal base improvement influencing overjet, the dentoalveolar effect on overjet is brought about by palatal tipping of maxillary and labial tipping of mandibular incisors, respectively.[44,48,51,52]

Differences were found for the different groups of functional appliances, namely, activators and twin block. To a large extent, these differences could be due to the amount of hours per day that the patients are instructed to wear their appliances, this being up to 24 hours per day for twin blocks.[23]

EOT appliances also improve the sagittal intermaxillary relationship, demonstrating a large effect on the maxillary skeleton. They appear to achieve this growth modification by means of a sutural response.[53–56] These appliances show very little clinical improvement in overjet.

Combination appliances (with both functional and EOT components) seem to affect the sagittal intermaxillary relationship by acting mainly on the mandibular skeleton as well as having a dentoalveolar effect on overjet. A possible reason as to why no significant change in the maxilla was seen is that dentoalveolar changes as recorded by the decrease in overjet have somewhat of a buffer effect and therefore reduce maxillary changes that may otherwise have taken place.

An accumulation of data from existing studies implies that the sample size will increase dramatically, and hence even small skeletal changes will be statistically significant. However, statistically significant changes do not necessarily correspond to noticeable therapeutic effects. Changes seen in our data analysis are often small but statistically significant, which has also been suggested by Proffit and Tulloch.[57] Thus, too much weight should not be placed on statistically significant changes but rather on clinically significant ones. A cutoff value for clinical significance was set at 1 degree for angular measurements and 1 mm for linear measurements, as it is often described to be the error in lateral cephalogram measurements.[58] For overjet measurements, there is also the concern of magnification. However, since studies do not usually mention this, and since the influence that this would have on measurements is minimal, this was not taken into account.

It is important to consider to what extent the results of studies are consistent. Consistency is estimated by the overlap of confidence intervals or more formally using statistical tests for heterogeneity (χ^2). Some argue that since clinical and methodological diversity always occur in a meta-analysis, statistical heterogeneity is inevitable whether or not we happen to be able to detect it using a statistical test. Methods such as I^2 have been developed for quantifying inconsistency across studies, and these methods move the focus away from testing whether heterogeneity is present to assessing its impact on the meta-analysis and describing the percentage of variability in effect estimates that is due to heterogeneity rather than sampling error.

The variation in treatment success undoubtedly is affected in part by patient compliance. Uniformity was desired with regard to compliance; thus, trials using appliances fixed to the mouth were excluded. Other factors contributing to variability include patient age, patient maturity, growth pattern, severity and etiology of the initial condition, treatment timing, soft tissue characteristics, and amount of force applied.

Soft tissues may be a reason for variability in treatment outcomes, following functional appliance treatment. Not all individuals respond similarly to this treatment, and considerable variation is present among patients. Given a certain mandibular advancement, the forces applied through the functional appliance by the soft tissues may differ due to myotatic reflexes or variation of the soft tissue viscoelasticity.[59] This is perhaps one of the reasons why there is higher heterogeneity in functional appliance treatment outcomes.

One area that has not been investigated much is that of long-term treatment changes. Appliances that have a supposed orthopedic effect may cause changes, but whether these changes are maintained long term and to what extent is a further question. Dermaut and Aelbers[60] concluded that on a long-term basis, the few studies that provide scientific data report that orthopedic changes induced by Class II therapy are only temporary. This does not, however, hold true for dentoalveolar changes that were generally found to be more stable. Stability is also suggested to be dependent on the age when treatment was carried out. If treatment is delayed, the treatment results tend to be more stable.[61]

The literature search in this investigation was executed mainly in PubMed and Ovid, resulting in a higher number of included articles than if only one database had been used. It should be borne in mind that there are limitations to the literature search. These limitations include the fact that some studies may not be included in Medline and others may not have been published (introducing publication bias). Medline is regarded, however, as a powerful and relatively accurate tool in retrieving orthodontic literature.[21] Data collection revealed that studies differed in areas such as age, sample size, control groups, and appliances. Data were, however, grouped as best as possible, weighting studies according to number of patients and annualizing mean changes. In the inclusion criteria, the treatment duration minimum was set at 9 months since any treatment time less than that would mean that the methodological error is likely to increase and would give an overestimation when annualized. The random effects model of meta-analysis was thus used. A control group was necessary, providing a comparison consisting of untreated growing Class II individuals displaying changes due to natural growth alone.

CONCLUSIONS Return to TOC

- Appliances believed to have a growth modification effect used in the treatment of Class II malocclusion growing patients, namely, functional and EOT appliances, are associated with an improvement of the sagittal intermaxillary relationship.
- Activators and twin block appliances accomplish this mainly by acting on the mandible. Twin block appliances also show a significant change in the maxillary skeleton.
- EOT achieves this by acting on the maxilla.
- Combination appliances mainly bring about changes in the mandibular skeleton.
- In addition, activators, twin blocks, and combination appliances reveal a large decrease in overjet, which is not the case in the singular use of extraoral traction.

REFERENCES Return to TOC

1. Tulloch JFC, Medland W, Tuncay OC. Methods used to evaluate growth modification in Class II malocclusion. *Am J Orthod Dentofacial Orthop.* 1990; 98:340–347.

2. Illing HM, Morris DO, Lee RT. A prospective evaluation of bass, bionator and twin block appliances. Part I: the hard tissues. *Eur J*

Orthod. 1998; 20:501–516.

3. Phillips C, Tulloch JFC. The randomized clinical trial as a powerful means for understanding treatment efficacy. *Semin Orthod.* 1995; 1:128–138.

4. Tulloch JFC, Phillips C, Koch G, Proffit WR. The effect of early intervention on skeletal pattern in Class II malocclusion: a randomized clinical trial. *Am J Orthod Dentofacial Orthop.* 1997; 111:391–400.

5. Tulloch JFC, Proffit WR, Phillips C. Influences on the outcome of early treatment for Class II malocclusion. *Am J Orthod Dentofacial Orthop.* 1997; 111:533–542.

6. Keeling SD, Wheeler TT, King GJ, Garvan CW, Cohen DA, Cabassa S, McGorray SP, Taylor MG. Anteroposterior skeletal and dental changes after early treatment with bionators and headgear. *Am J Orthod Dentofacial Orthop.* 1998; 113:40–50.

7. Ghafari J, Shofer FS, Jacobsson-Hunt U, Markowitz DL, Laster LL. Headgear versus functional regulator in the early treatment of Class II division 1 malocclusion: a randomized clinical trial. *Am J Orthod Dentofacial Orthop.* 1998; 113:51–61.

8. Ehmer U, Tulloch JFC, Proffit WR, Phillips C. An international comparison of early treatment of Class II/1 cases: skeletal effects of the first phase of a prospective clinical trial. *J Orofac Orthop.* 1999; 60:392–408.

9. Wheeler TT, McGorray SP, Dolce C, Taylor MG, King GJ. Effectiveness of early treatment of Class II malocclusion. *Am J Orthod Dentofacial Orthop.* 2002; 121:9–17.

10. O'Brien K, Wright J, Conboy F. et al. Effectiveness of treatment for Class II malocclusion with the Herbst or twin-block appliances: a randomized, controlled trial. *Am J Orthod Dentofacial Orthop.*

2003; 124:128–137.

11. Bishara SE, Ziaja RR. Functional appliances: a review. *Am J Orthod Dentofacial Orthop.* 1989; 95:250–258.

12. Woodside DG. Do functional appliances have an orthopaedic effect?. *Am J Orthod Dentofacial Orthop.* 1998; 113:11–14.

13. Kluemper GT, Spalding PM. Realities of craniofacial growth modification. *Atlas Oral Maxillofac Surg Clin North Am.* 2001; 9:23–51.

14. Meikle MC. Guest editorial: what do prospective randomized clinical trials tell us about the treatment of class II malocclusions? A personal viewpoint. *Eur J Orthod.* 2005; 27:105–114.

15. Schudy FF. The control of vertical overbite in clinical orthodontics. *Angle Orthod.* 1968; 38:19–39.

16. Ricketts RM. The influence of orthodontic treatment on facial growth and development. *Angle Orthod.* 1960; 30:103–133.

17. Poulton DR. A three-year survey of Class II malocclusions with and without headgear therapy. *Angle Orthod.* 1964; 34:181–193.

18. Brandt S, Root TL. Interview. Dr Terrell Root on headgear. *J Clin Orthod.* 1975; 9:20–31.

19. Baumrind S, Molthen R, West E, Miller DM. Mandibular plane changes during maxillary retraction. *Am J Orthod.* 1978; 74:32–40.

20. Guray E, Orhan M. Selcuk type headgear timer (STHT). *Am J Orthod Dentofacial Orthop.* 1997; 111:87–92.

21. Mavropoulos A, Kiliaridis S. Orthodontic literature: an overview of the last 2 decades. *Am J Orthod Dentofacial Orthop.* 2003;

124:30–40.

22. Courtney M, Harkness M, Herbison P. Maxillary and cranial base changes during treatment with functional appliances. *Am J Orthod Dentofacial Orthop.* 1996; 109:616–624.

23. O'Brien KD, Wright J, Conboy F. et al. Effectiveness of early orthodontic treatment with the twin-block appliance: a multicenter, randomized, controlled trial. Part I: dental and skeletal effects. *Am J Orthod Dentofacial Orthop.* 2003; 124:234–243.

24. Mäntysaari R, Kantomaa T, Pirttiniemi P, Pykäläinen A. The effects of early headgear treatment on dental arches and craniofacial morphology: a report of a 2 year randomized study. *Eur J Orthod.* 2004; 26:59–64.

25. Petrén S, Bondemark L, Söderfeldt B. A systematic review concerning early orthodontic treatment of unilateral posterior crossbite. *Angle Orthod.* 2003; 73:588–596.

26. Fränkel R. The treatment of Class II, division 1 malocclusion with functional correctors. *Am J Orthod Dentofacial Orthop.* 1969; 55:265–275.

27. Lubit EC. Functional orthodontic therapy with the Fränkel appliance. *J Pedod.* 1983; 7:257–275.

28. Turner PJ. Functional appliances: a systematic approach. *Dent Update.* 1991; 18:72–76.

29. Janson GR, Toruño JL, Martins DR, Henriques JF, de Freitas MR. Class II treatment effects of the Fränkel appliance. *Eur J Orthod.* 2003; 25:301–309.

30. Higgins JPT, Green S. eds. *Cochrane Handbook for Systematic Reviews of Interventions 4.2.5* (updated May 2005). In: *The*

Cochrane Library, Issue 3. Chichester, UK: John Wiley & Sons; 2005.

31. Higgins JPT, Thompson SG. Quantifying heterogeneity in a meta-analysis. *Stat Med.* 2002; 21:1539–1558.

32. Higgins JPT, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analysis. *BMJ.* 2003; 327:557–560.

33. Kjellberg H, Kiliaridis S, Thilander B. Dentofacial growth in orthodontically treated and untreated children with juvenile chronic arthritis (JCA): a comparison with angle Class II division 1 subjects. *Eur J Orthod.* 1995; 17:357–373.

34. Lund DI, Sandler PJ. The effects of twin blocks: a prospective controlled study. *Am J Orthod Dentofacial Orthop.* 1998; 113:104–110.

35. Üçüncü N, Türk T, Carels C. Comparison of modified Teuscher and van Beek functional appliance therapies in high angle cases. *J Orofac Orthop/Fortschr Kieferorthop.* 2001; 62:224–237.

36. Sari Z, Goyenc Y, Doruk C, Usumez S. Comparative evaluation of a new removable Jasper jumper appliance vs an activator-headgear combination. *Angle Orthod.* 2003; 73:286–293.

37. Baume LJ, Derichsweiler H. Is the condylar growth center response to orthodontic therapy? An experimental study in *Macaca mulatta*. *Oral Surg Oral Med Oral Pathol.* 1961; 14:347–362.

38. Charlier JP, Petrovic A, Herrmann-Stutzmann J. Effects of mandibular hyperpropulsion on the prechondroblastic zone of young rat condyle. *Am J Orthod.* 1969; 55:71–74.

39. McNamara JA, Carlson DS. Quantitative analysis of temporomandibular joint adaptations to protrusive function. *Am*

J Orthod. 1979; 76:593–611.

40. Williams S, Melsen B. Condylar development and mandibular rotation and displacement during activator treatment: an implant study. *Am J Orthod.* 1982; 81:322–326.

41. Woodside DG, Altuna G, Harvold E, Herbert M, Metaxas A. Primate experiments in malocclusion and bone induction. *Am J Orthod.* 1983; 83:460–468.

42. Rabie ABM, She TT, Hägg U. Functional appliance therapy accelerates and enhances condylar growth. *Am J Orthod Dentofacial Orthop.* 2003; 123:40–48.

43. Birkebaek L, Melsen B, Terp S. A laminagraphic study of the alterations in the temporomandibular joint following activator treatment. *Eur J Orthod.* 1984; 6:267–276.

44. Vargervik K, Harvold EP. Response to activator treatment in Class II malocclusions. *Am J Orthod.* 1985; 88:242–251.

45. Woodside DG, Metaxas A, Altuna G. The influence of functional appliance therapy on glenoid fossa remodeling. *Am J Orthod Dentofacial Orthop.* 1987; 92:181–198.

46. Voudouris JC, Woodside DG, Altuna G, Angelopoulos G, Bourque PJ, Lacouture CY, Kuftinec MM. Condyle-fossa modifications and muscle interactions during Herbst treatment, part 2. Results and conclusions. *Am J Orthod Dentofacial Orthop.* 2003; 124:13–29.

47. Harvold EP, Vargervik K. Morphogenetic response to activator treatment. *Am J Orthod.* 1971; 60:478–490.

48. Pancherz H. The mechanism of Class II correction in Herbst appliance treatment: a cephalometric investigation. *Am J Orthod.* 1982; 82:104–113.

49. Macey-Dare LV, Nixon F. Functional appliances: mode of action and clinical use. *Dent Update.* 1999; 26:240–244. 246.

50. Collett AR. Current concepts on functional appliances and mandibular growth stimulation. *Aust Dent J.* 2000; 45:173–178.

51. Björk A. The principle of the Andresen method of orthodontic treatment: a discussion based on cephalometric x-ray analysis of treated cases. *Am J Orthod.* 1951; 37:437–458.

52. Trayfoot J, Richardson A. Angle Class II, division 1 malocclusion treated by the Andresen method: an analysis of 17 cases. *Br Dent J.* 1968; 124:516–519.

53. Triftshauser R, Walters RD. Cervical retraction of the maxillae in the *Macaca mulatta* monkey using heavy orthopedic force. *Angle Orthod.* 1976; 46:37–46.

54. Brandt HC, Shapiro PA, Kokich VG. Experimental and postexperimental effects of posteriorly directed extraoral traction in adult *Macaca fascicularis*. *Am J Orthod.* 1979; 75:301–317.

55. Jackson GW, Kokich VG, Shapiro PA. Experimental and postexperimental response to anteriorly directed extraoral force in young *Macaca nemestrina*. *Am J Orthod.* 1979; 75:318–333.

56. Godfrey K. Extra-oral retraction mechanics: a review. *Aust Orthod J.* 2004; 20:31–40.

57. Proffit WR, Tulloch JFC. Preadolescent class II problems: treat now or wait?. *Am J Orthod Dentofacial Orthop.* 2002; 121:560–562.

58. Aelbers CMF, Dermaut LR. Orthopedics in orthodontics: part I, fiction or reality? A review of the literature. *Am J Orthod Dentofacial Orthop.* 1996; 110:513–519.

59. Kiliaridis S. A step towards the postempirical era of functional dentofacial orthopaedics. In: Carels C, Willems G, eds. *The Future of Orthodontics.* Lueven, Belgium: Lueven University Press; 1998:97–102.

60. Dermaut LR, Aelbers CMF. Orthopedics in orthodontics: fiction or reality? A review of the literature—part II. *Am J Orthod Dentofacial Orthop.* 1996; 110:667–671.

61. Pancherz H. The effects, limitations, and long-term dentofacial adaptations to treatment with the Herbst appliance. *Semin Orthod.* 1997; 3:232–234.

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Table 1. Details of Studies Included for Data Analysis[a]

	Twin Block			
Study	Sample Size	Treatment Duration, mo	Age, y	Type
Courtney et al, 1996				Harvold
Illing et al, 1998	16	9	11.5	Bionator
Kjellberg et al, 1995				Schwarz
Lund and Sandler, 1998	36	11	12.4	
Mäntysaari et al, 2004				
O'Brien et al, 2003	73	15	9.7	
Sari et al, 2003				
Tulloch et al, 1997				Bionator
Üçüncü et al, 2001				
Total	125			
Average		12	10.7	

[a] The data are divided into activator, twin block, extraoral traction (EOT), combination applian groups. Shown for each study are the type of appliance (where applicable), sample size, avera age of patients at the beginning of treatment in years. For each group, the total sample size treatment duration weighted according to sample size.

Table 1. Extended

Extraoral Traction				Combination Appliances		
Type	Sample Size	Treatment Duration, mo	Age, y	Type	Sample Size	Treatmen… Duration, …
				Bass	13	9
Cervical	30	24	7.6			
				Removable Jasper-J/headgear	20	9
				Activator/headgear	20	9
High pull/Cervical	52	15	9.4			
				Teuscher	12	13
				van Beek	10	13
	82				75	
		18	8.7			10

Table 2. Summary of Meta-analysis Results Showing the Annualized Mean Change and 95% Confidence Interval (CI) for the Different Appliance Groups When Compared to Controls[a]

	SNA		SNB		AN…
Appliance	Mean Change	95% CI	Mean Change	95% CI	Mean Change
Activator	−0.31	−0.65, −0.04	**0.66**	0.03, 1.29	**−0.92**
Twin block	**−1.03**	−1.94, −0.13	**1.53**	1.18, 1.87	**−2.61**
Extraoral traction	**−1.01**	−1.34, −0.69	0.11	−0.76, 0.97	**−1.38**
Combination	−0.41	−1.33, 0.52	**1.05**	0.62, 1.49	**−1.8**

[a] Changes in the SNA, SNB, and ANB categories are changes in degrees, while in the ove… Mean change values in bold denote statistical significance ($P < .05$).

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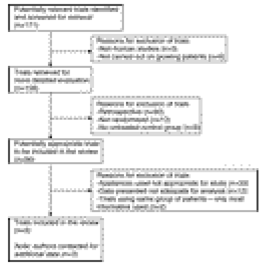

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Figure 1. Flow diagram summarizing literature search

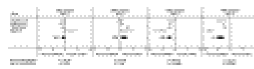

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Figure 2. Forest plots representing the effect of activator type appliances on SNA, SNB, ANB, and overjet (OJ). The studies are listed in chronological order and refer to the studies summarized in Table 1. Shown for every study is the weighted mean difference (WMD) between the treatment and control groups based on the random effects meta-analysis model, as well as the 95% confidence interval (95% CI) for each variable. The diamonds represent the overall WMD and 95% CI. I^2 values (for heterogeneity) and *P* values (for statistical significance) are shown below each forest plot

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Figure 3. Forest plots representing the effect of twin block appliances on SNA, SNB, ANB, and overjet (OJ). For further information, see Figure 2

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Figure 4. Forest plots representing the effect of extraoral traction appliances on SNA, SNB, ANB, and overjet (OJ). For further information, see Figure 2

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Figure 5. Forest plots representing the effect of combination appliances on SNA, SNB, ANB, and overjet (OJ). For further information, see Figure 2

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