Review Article

Bone- and dentoalveolar-anchored dentofacial orthopedics for Class III malocclusion: New approaches, similar objectives? *A systematic review*

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ABSTRACT

Objectives: To analyze the scientific literature and compare in the results of conventional orthopedic appliances with those obtained from recent bone-anchored orthopedics for Class III malocclusion.

Materials and Methods: The literature was systematically reviewed using PubMed/Medline, Scopus, and Scirus databases up to January 2012. Articles were selected by two different researchers (kappa index = 0.83), based on established inclusion/exclusion criteria. Methodologic quality was classified as high, medium, or low quality.

Results: The search strategy identified 1020 titles. Thirty studies were selected after applying the criteria (high quality = 9, medium quality = 21). Protraction rates differed within a range of one- to twofold between bone-anchored and dentoalveolar therapies ($P < .001$). All studies noted the effect of clockwise rotation on the mandible and an increase in inferior-anterior and total facial height; this was more obvious in dentoalveolar therapy than in bone-anchored orthopedics ($P < .001$).

Conclusions: Dental parameters like overjet increased significantly with both sets of groups, ranging from 1.7 to 7.9 mm with dentoalveolar therapy and from 2.7 to 7.6 mm with bone-anchored orthopedics. (*Angle Orthod.* 2013;83:540–552.)

KEY WORDS: Dentofacial orthopedics; Orthodontics; Bone-anchored orthopedics

INTRODUCTION

Treating Class III malocclusion is one of the most complex problems arising in orthodontic practice because the growth patterns in such patients are unpredictable and unfavorable. The components of a Class III malocclusion include dental compensation and skeletal problems. Maxillary retrusion (hypoplasia), mandibular protrusion (hyperplasia), or a combination of the two may form the skeletal origin of malocclusion,[1] leading to an anterior crossbite and a concave profile.[2]

The traditional orthopedic treatment for skeletal Class III malocclusion in children who have not yet reached the period of pubertal growth spurt involved correcting skeletal deficiencies.[3] The introduction of the new orthopedics based on bone-anchored systems has made it necessary to revise all of these previous concepts.[4] In modern orthodontic practice, it appears possible to apply pure bone-borne orthopedic forces between the maxilla and the mandible for 24 hours per day, avoiding dentoalveolar compensations.[5]

The aim of the present study is to compile and analyze the various possibilities of orthopedic treatment for Class III malocclusion in the scientific literature and to compare the results of conventional orthopedic appliances with those obtained from recent bone-anchored orthopedics.

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Accepted: July 2012. Submitted: May 2012.
Published Online: September 26, 2012

 DOI: 10.2319/051312-392.1

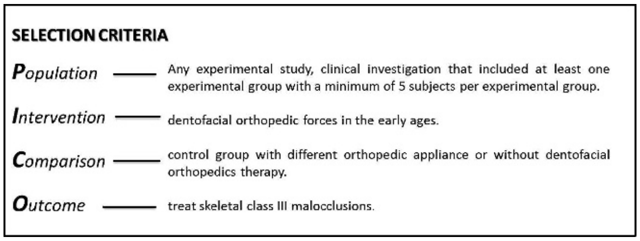

Figure 1. Criteria for inclusion in the review.

MATERIALS AND METHODS

Search Strategy

A literature search was carried out using the Medline (PubMed, www.ncbi.nlm.nih.gov), Scirus, and Scopus databases. The search strategy covered the period October 2001 to January 2012 and used the following MeSH (Medical Subject Heading) terms: "Malocclusion, Angle Class III" AND ("Extraoral Traction Appliances" OR "orthodontics, interceptive" OR "orthodontics, corrective" OR "Malocclusion, Angle Class III/therapy" OR "Orthodontics, Corrective/methods") NOT surgery.

Selection Criteria

Articles selected for this study fulfilled the following criteria for inclusion, according to PICO (Figure 1). We excluded case reports, case series, descriptive studies, technical descriptions, review articles, opinion articles, letters, and articles that did not correspond to the objectives of the review.

Data Collection and Analysis

The initial selection of articles was based on the title and abstract, the complete article being reviewed whenever there was doubt as to whether it should be included or not. Two reviewers independently applied the inclusion and exclusion criteria to every article, and good concordance was shown (kappa index = 0.83).

The methodologic quality of the selected articles was assessed using a modified version of the method reported by Antczak et al.[6] and Jadad et al.[7] Two investigators made independent quality assessments of the included studies using a modified Newcastle-Ottawa Scale. The

Table 1. Quality assesment of the included articles

Study	Representative Sample of 20/Group	Method Error Analysis	Adequate Statistics Provided	Blinded Assessment Stated	Previous Power Calculation	Reporting Dropouts	Total	Risk of Bias[a]	Quality
Yüksel et al., 2001[10]	0	1	1	0	0	1	3	Moderate	Medium
Keles et al., 2002[1]	0	0	1	0	0	1	2	Moderate	Medium
Cha, 2003[11]	1	0	1	0	0	1	3	Moderate	Medium
Westwood et al., 2003[12]	0.5	1	1	0	0	1	3.5	Moderate	Medium
Cozza et al., 2004[13]	1	1	1	0	0	1	4	Low	High
Baccetti et al., 2004[14]	0.5	1	0.5	0	1	1	4	Low	High
Kajiyama et al., 2004[15]	1	0.5	1	0	0	1	3.5	Moderate	Medium
Franchi et al., 2004[16]	0	1	1	0	0	1	3	Moderate	Medium
Üçem et al., 2004[17]	0	1	1	0	0	1	3	Moderate	Medium
Vaughn et al., 2005[18]	1	1	0.5	1	0	1	4.5	Low	High
Kama et al., 2006[19]	0	1	1	0	0	1	3	Moderate	Medium
Arman et al., 2006[20]	0	1	0.5	0	0	1	2.5	Moderate	Medium
Yoshida and Shoji, 2007[21]	0.5	1	0.5	0	0	1	3	Moderate	Medium
Tortop et al., 2007[22]	0	1	1	0	0	1	3	Moderate	Medium
Lin et al., 2007[23]	1	1	0.5	0	0	1	3.5	Moderate	Medium
Kilinç et al., 2008[24]	0	1	1	0	0	0	2	Moderate	Medium
Pavoni et al., 2009[25]	0.5	1	0.5	0	1	1	4.5	Low	High
Yavuz et al., 2010[26]	0	1	0.5	0	0	1	2.5	Moderate	Medium
Lee et al., 2010[27]	1	0	1	0	0	1	3	Moderate	Medium
Kilic et al., 2010[28]	0.5	1	0.5	0	0	1	3.5	Moderate	Medium
Baccetti et al., 2010[29]	0.5	1	1	0	1	1	4.5	Low	High
Cozza et al., 2010[30]	0.5	1	1	0	1	1	4.5	Low	High
Mandall et al., 2010[31]	1	1	1	1	1	1	6	Low	High
Atalay and Tortop, 2010[32]	0	1	1	0	0	1	3	Moderate	Medium
Isci et al., 2010[33]	0	1	0.5	0	0	1	2.5	Moderate	Medium
De Clerck et al., 2010[2]	0.5	1	1	0	1	1	4.5	Low	High
Cevidanes et al., 2010[34]	1	1	1	0	1	1	5	Low	High
Baccetti et al., 2011[35]	0.5	1	1	0	0	1	3.5	Moderate	Medium
Sar et al., 2011[36]	0	1	1	0	0	1	3	Moderate	Medium
Jamilian et al., 2011[37]	0	1	0.5	0	0	1	2.5	Moderate	Medium

[a] One point was given for each criterion fulfilled; half a point was awarded when part of the criterion was met. Studies with fewer than 2 points were considered to be at high risk of bias. For studies receiving from 2 to less than 4 points, the risk for bias was considered moderate, and for studies receiving 4 points and above, the risk of bias was considered low.

Table 2. Linear measurements performed in the included studies[a]

Study	Groups (Appliance)	Maxillary Changes
Yüksel et al., 2001[10]	IA: FM (early treatment) IB: FM (later treatment) II: Control	Co-A = IA: 3.3; IB: 3.0; II: 0.3
Keles et al., 2002[1]	I: Modified FM II: Classical FM	A-VertT = I: 2.45; II: 3 A-Nperp = I: 5.36; II: 5.11
Cha et al., 2003[11]	RME + FM IA: Accelerating growth IB: High growth IC: Decelerating growth	Y-A = IA: 2.69; IB: 2.69; IC: 0.97
Westwood et al., 2003[12]	I: RME + FM + FxA II: Control	Co-A = I: 2.4; II: 1.3 A-Nperp = I: 1.5; II: −0.3
Cozza et al., 2004[13]	I: FM + B-3 II: Control	A-Nperp = I: 0.96; II: - PNS-A= I: 2.08; II: -
Baccetti et al., 2004[14]	I: FM + FxA IA: Successful group IB: Unsuccessful group	A-VertT = I: 62.8; IA: 62.0; IB: 64.8
Kajiyama et al., 2004[15]	IA: MPBA (deciduous) IB: MPBA (mixed) IIA: Control (deciduous) IIB: Control (mixed)	–
Franchi et al., 2004[16]	RME + FM + FxA IA: Early treatment IB: Later treatment IIA: Early control IIB: Later control	–
Üçem et al., 2004[17]	IA: DPA IB: FM II: Control	Co-A = IA: 2.2; IB: 3.7; II: 1.1
Vaughn et al., 2005[18]	IA: FM + RME (exp) IB: FM + RME (no exp) II: Control	A-Nperp = IA: 2.74; IB: 2.82; II: 0.33
Kama et al., 2006[19]	I: RME + FM + FxA II: Control	–
Arman et al., 2006[20]	I: RME + FM + FxA II: Control	Co-A = I: 3.3; II: 1.49
Yoshida and Shoji, 2007[21]	IA: MPA + CC (short face) IB: MPA + CC (long face)	A-Nperp = IA: 2.6; IB: 1.6
Tortop et al., 2007[22]	IA: FM + RME (exp) IB: FM + RIA (no exp) II: Control	Co-A= IA: 2.1; IB: 3.2; II: 0.6
Lin et al., 2007[23]	I: FM (OMA) + CC II: Control	A-x= I: 2.7; II: 0.9
Kilinç et al., 2008[24]	I: RME + FM + FxA II: Control	–
Pavoni et al., 2009[25]	I: BB + FM II: RME + FM	A-Nperp = I: 1.7; II: 1.0 Co-A = I: 4.4; II: 3.2
Yavuz et al., 2009[26]	FM + FxA IA: Adolescents IB: Young adults	Co-A = IA: 4.41; IB: 0.64 A-Nperp = IA: 2.27; IB: 0.90
Lee et al., 2010[27]	FM + RIA IA: Deciduous IB: Mixed	–
Kilic et al., 2010[28]	I: FM II: Control	A-y = I: 1.48; II: 0.49
Baccetti et al., 2010[29]	I: FM + BB II: Control	A-Nperp = I: 1.3; II: 1.2 Co-A= I: 5.2; II: 2.1
Cozza et al., 2010[30]	I: FM + BB II: Control	A-Nperp = I: 1.3; II: −1.2 Co-A = I: 4.9; II: 2.1
Mandall et al., 2010[31]	I: RME + FM II: Control	–

Table 2. Extended

Mandibular Changes		Maxillary-Mandibular Differential	Anterior Facial Height
Chin Projection	Mandibular Length		
–	Co-Gn = IA: 2.7; IB: 2.0; II: 1.9 Go-Me = IA: 2.0; IB: 1.5; II: 1.6	IA: −0.5; IB: −1.1; II: 1.5	N-Me = IA: −0.5; IB: −1.1; II: 1.5 ANS-Me = IA: 3.1; IB: 3.8; II: 1.0
–	–	–	ANS-Thr = I: 1.45; II: 0.44
Y-Pg = IA: −1.93; IB: −1.91; IC: −1.57	Go-Me = IA: 2.27; IB: 19; IC: 1.16	–	–
Pg-Nperp = I: −1.7; II: 1.1	Co-Gn = I: 1.5; II: 4.0	I: 1.0; II: 2.7	N-ANS = I: 1.2; II: 2.1 ANS-Me = I: 2.4; II: 1.5
Pg-Nperp = I: 2.48; II: -	–	–	N-Me = I: 2.65; II: -
Pg-VertT = I: 72.4; IA: 70.6; IB: 77.0	Co-Pg = I: 109.7; IA: 107.4; IB: 115.5	–	–
–	Go-Me= IA: 2.31; IB: 1.73; IIA: 2.91; IIB: 1.00	–	N-Me = IA: 7.55; IB: 5.07; IIA: 3.88; IIB: 1.92 N-ANS = IA: 1.67; IB: 1.38; IIA: 1.87; IIB: 0.94
–	Co-Gn = IA: 19.2; IB: 10.4; IIA: 22.8; IIB: 15.2	–	–
–	Co-Gn = IA: 0; IB: 2.4; II: 2.3	IA: −0.3; IB: −1.4; II: 1.2	N-Me = IA: 2.0; IB: 3.2; II: 2.5 ANS-Me = IA: 1.6; IB: 3.6; II: 1.1
Pg-Nperp = IA: −1.18; IB: −1.62; II: 0.99	IA: 2.51; IB: 1.71; II: 2.81	IA: −1.79; IB: −2.22; II: 1.62	ANS-Me = IA: 0.27; IB: 1.24; II: −0.02
–	Go-Gn = I: 0.30; II: 1.97	–	N-ANS = I: 1.33; II: 0.10 ANS-Me = I: 0.30; II: −0.13
–	Co-Gn = I: 3.08; II: 3.23	–	N-Me = I: 4.56; II: 3.25 ANS-Me = I: 3.7; II: 1.79
Pg-Nperp = IA: −2.4; IB: −2.1	Co-Gn = IA: 2.4; IB: 2.6	–	N-ANS = IA: 0.8; IB: 1.1 ANS-Me = IA: 3.9; IB: 3.0
–	Co-Gn= IA: 1.9; IB: 1.4; II: 2.1	IA: −0.3; IB: −1.6; II: 1.5	–
–	Co-Gn= I: 3.6; II: 4.4	–	–
–	–	–	–
Pg-Nperp = I: −0.7; II: −1.3	Co-Gn = I: 4.1; II: 4.4	I: −0.3; II: 1.2	ANS-Me = I: 4.0; II: 3.9
–	Co-Gn = IA: 3.73; IB: −0.58 Go-Me = IA: 3.04; IB: 0.84	–	N-Me = IA: 6.90; IB: 2.81 ANS-Me = IA: 6.60; IB: 3.36
–	–	–	–
Y-Pg = I: −2.06; II: 0.67	–	–	–
Pg-Nperp = I: −1.3; II: 0.2	Co-Gn = I: 5.1; II: 6.2	I: −0.2; II: 4.1	–
Pg-Nperp = I: −1.3; II: 0.2	Co-Gn = I: 4.6; II: 6.2	I: −0.2; II: 4.1	–
–	–	–	% Lower face height = I: 0.4; II: 0.6

Table 2. Continued

Study	Groups (Appliance)	Maxillary Changes
Atalay and Tortop, 2010[32]	Modified TTBA IA: Early treatment IB: Later treatment II: Control	Co-A = IA: 1.8; IB: 3.0; II: 1.3 N ⊥ FH–A = IA: 0.5; IB: −2.2; II: −0.1
Isci et al., 2010[33]	FM + RME I: Activation/deactivation RME II: Control	N ⊥ FH–A = I: 2.60; II: 1.90 VRL–A = I: 3.2; II: 2.03
De Clerck et al., 2010[2]	I: BAMP II: Control	A-VertT = I: 5.2; II: 1.3 Co-A = I: 5.3; II: 1.5
Cevidanes et al., 2010[34]	I: BAMP II: RME + FM	A-VertT = I: 5.2; II: 2.9 Co-A = I: 5.3; II: 2.4
Baccetti et al., 2011[35]	I: BAMP II: Control	–
Sar et al., 2011[36]	IA: FM + MP IB: FM + RME II: Control	A-Nperp = IA: 2.53; IB: 1.76; II: 0.30
Jamilian et al., 2011[37]	I: MS + RIA II: FM + RIA	–

[a] FM indicates facemask; RME, tapid maxillary expansion; FxA, fixed appliances; B-3, Bionator III; MPBA, maxillary protraction bow appliance; DPA, double-plate appliance; exp, expansion; no exp, no expansion; MPA, maxillary protraction appliance; CC, chin cup; RIA, removable intraoral appliance; OMA, occipitomental anchorage; BB, bite-block appliance; TTBA, tandem traction bow appliance; BAMP, bone-anchored maxillary protraction; MP, miniplates; MS, miniscrew; Co-A, condylion-A; A-VertT, Point A-Vertical T; A-Nperp, A-nasion perpendicular; PNS-A, posterior nasal spine-A point; N ⊥ FH-A, nasion perpendicular Frankfort horizontal-A; VRL-A, vertical reference line (passing through sella)-A. Pg-Nperp, pogonion-nasion perpendicular; Pg-VertT, pogonion-vertical T; N ⊥ FH-Pg, nasion perpendicular Frankfort horizontal-pogonion; Co-Gn, condylion-gnathion; Go-Me, gonion-menton; Co-Pg, condylion-pogonion; VRL-B, vertical reference line (passing through sella)-B point; VRL-Pg, vertical reference line (passing through sella)-pogonion; N-Me, nasion-menton; N-ANS, nasion-anterior nasal spine; ANS-Me, anterior nasal spine-menton; ANS-Thr, anterior nasal spine-true horizontal (7° correction of SN plane).

variables were analyzed on the basis of Chen et al.[8] Based on this checkpoint analysis, the risk of bias and quality of each article was scored as low, medium, or high, as detailed in Table 1. Quality was classified as low, medium, and high as previously defined by others.[9]

RESULTS

Search and Quality Assessment Results

The search strategy yielded 1020 titles/abstracts: 726 from PubMed, 146 from Scopus, and 148 from Scirus. After applying the criteria for inclusion/exclusion, 984 articles were removed, largely because they were descriptive articles, case reports, or articles that did not correspond to the objectives of this review. The remaining 36 articles were then read in full, and a further 6 articles were excluded: 2 because there was no cephalometric study, 2 because no control group was used, 1 because no protraction device was fitted, and 1 because it did not correspond with the objectives of this study. Only 30 articles[1,2,10–37] therefore matched all the criteria for inclusion in the review.

All selected articles were based on human studies. Of the 30 articles, 9 were considered to be of high methodologic quality, and the remaining 21 articles were rated as medium quality (Table 1). The main quality defects were inadequate size of study-sample subgroups, absence of blinding in measurements, and no previous power calculation.

Skeletal Effects on the Upper Jaw

In spite of differences between treatment protocols and experimental design among the studies, a common trend was observed in the similar results for A-point advancement in the horizontal plane as a result of dentoalveolar or bone-anchored orthopedic treatment. Forward movement in the horizontal plane was noted in every study (Table 2), with a mean A-point advancement of around 0.81 mm with dentoalveolar therapy and 5.2 mm with bone-anchored orthopedics (Table 2), independent of whether or not there was maxillary expansion before the protraction facemask (Table 2).

Some comparative studies have claimed that protraction rates differ within a range of 0.45 and 0.24 mm/month ($P < .001$)[36] between bone-anchored and dentoalveolar therapies, respectively, so less treatment time (6.78 and 9.45 months, respectively) is required to move the maxilla forward 2.3 mm and 1.83 mm, respectively, in each group ($P < .001$).

In summary, despite the differences, shown in Table 3, the included studies indicated an increase in

Table 2. Continued Extended

Mandibular Changes		Maxillary-Mandibular Differential	Anterior Facial Height
Chin Projection	Mandibular Length		
N⊥FH–Pg = IA: −1.7; IB: −0.9; II: 0.5	Co-Gn = IA: 1.9; IB: 3.3; II: 2.9	–	ANS-Me = IA: 2.8; IB: 4.1; II: 1.4
–	VRL-B = I: −3.03; II: −2.47 VRL-Pg = I: −3.23; II: −2.57	–	N-ANS = I: 1.30; II: 1.13 N-Me = I: 5.13; II: 4.07
Pg-VertT = I: −0.6; II: 2.2	Co-Gn = I: 2.1; II: 4.1	I: 26.6; II: 34.2	–
Pg-VertT = I: −0.6; II: −1.1	Co-Gn = I: 1.8; II: 0.9	I: −3.2; II: −0.9	ANS-Me = I: 2.1; II: 3.4
–	–	–	–
Pg-Nperp = IA: −2.80; IB: −2.90; II: 0.96	Co-Gn = IA: −0.30; IB: 0.43; II: 1.86	IA: 5.66; IB: 5.06; II: −0.78	N-Me = IA: 2.73; IB: 4.63; II: 0.83 ANS-Me = IA: 2.10; IB: 3.96; II: 0.10
–	–	–	–

SNA angle of 1° to 3.09° with dentoalveolar traction. Of the studies analyzed here, the only study to date that reported SNA measurements for bone-anchored orthopedics registered an increase of 2.53°, compared to a 1.83° increase in the internal control group (dentoalveolar-anchored therapy).

Skeletal Effects on the Mandible

All studies noted the effect of clockwise rotation on the mandible and a subsequent increase in facial height with mandibular protraction; this was more obvious in dentoalveolar therapy than bone-anchored orthopedics (Table 3). Both the maxilla and the mandible moved forward significantly in the control group of every study (Table 2). However, the protrusion and mesialization of maxillary teeth with dentoalveolar therapy appears to have been eliminated in bone-anchored groups where these parameters were analyzed (Table 4).

Interestingly, although the main orthopedic effect was directed toward correcting maxillary deficiency, the studies noted substantial changes in angular and linear mandibular parameters during bone-anchored and orthopedic treatment (Tables 2 and 3). The backward movement of point B and the increase in angular parameters corresponding to facial height were observed in both treatments.

Despite the marked differences in upper jaw correction shown for dentoalveolar and bone-anchored orthopedics in Class III treatment, some studies[36] found no differences between groups for the results of final intermaxillary skeletal variables, such as Wits appraisal, ANB, and the like (Table 3).

Effect on Dental and Dentoalveolar Parameters

Bone-anchored orthopedic treatment at an early age was observed to lead not to compensation for upper incisor inclination but to their effectively protruding along the upper jaw bone. Dental parameters like overjet increased significantly with both sets of groups using bone- and dentoalveolar-anchored treatment (Table 4); considerable increases were reported with the use of bone-anchored orthopedics, between +2.7 mm[2] and +7.6 mm,[36] and substantial variations in changes in overjet, ranging from 1.7 mm to 7.9 mm, were also described for dentoalveolar therapy. Analyses of maxillary incisor position and angulation, however, showed significant differences between the two types of anchoring treatment. Some studies[36] noted statistically significant differences of maxillary incisor position ($P < .001$) between the treatment groups, with a notable protrusion in the dentoalveolar group and even retrusion in the bone-anchored group ($P < .05$).[36] Other authors found a slight upper incisor proclination of +0.6° with bone-anchored therapy.[34] The effects on the maxillary molars followed the same trend, with significant mesialization from dentoalveolar therapy ($P < .05$) and no changes of significance in the bone-anchored group.[36]

Some studies using a conventional orthopedic approach found a reduced horizontal position for the lower incisors, which meant that the lower incisors were significantly retruded and tipped lingually.[20,32,33] So, at the end of the observation period, some authors recorded differences of lower incisor inclination and found significant retroinclination of these in the treated group compared with the control group.[12,31] In the

Table 3. Angular measurements performed in the included studies [a]

		Maxillary Changes	
Study	Groups (Appliance)	SNA Angle (°)	Vertical Changes (°)
Yüksel et al., 2001[10]	IA: FM (early treatment) IB: FM (later treatment) II: Control	IA: 1.9; IB: 1.65; II: 0.0	–
Keles et al., 2002[1]	I: Modified FM II: Classical FM	I: 3.09; II: 3.11	SN-PP I: 0.27; II: −2.44
Cha et al., 2003[11]	RME + FM IA: Accelerating growth IB: High growth IC: Decelerating growth	IA: 2.18; IB: 2.03; IC: 0.53	FH-PP IA: −1.13; IB: −1.12; IC: −0.80
Westwood et al., 2003[12]	I: RME + FM + FxA II: Control	I: 1.6;II: 1.3	FH-PP I: 1.0; II: −1.0
Cozza et al., 2004[13]	I: FM + B-3 II: Control	I: 2.04; II: -	PP-GoGn I: 1.81; II: -
Baccetti et al., 2004[14]	I: FM + FxA IA: Successful group IB: Unsuccessful group	–	NL-SBL I: −1.0; IA: −0.8; IB: −1.5
Kajiyama et al., 2004[15]	IA: MPBA (deciduous) IB: MPBA (mixed) IIA: Control (deciduous) IIB: Control (mixed)	IA: 4.16; IB: 1.48; IIA:0.49; IIB: 0.05	–
Franchi et al., 2004[16]	RME + FM + FxA IA: Early treatment IB: Later treatment IIA: Early control IIB: Later control	–	FH-PP IA: −1.5; IB: 0.1; IIA: −1.2; IIB: 0.3
Üçem et al., 2004[17]	IA: DPA IB: FM II: Control	IA: 1.2; IB: 2.8; II: 0.3	–
Vaughn et al., 2005[18]	IA: FM + RME (exp) IB: FM + RME (no exp) II: Control	IA: 2.77; IB: 2.51; II: −0.24	SN-PP IA: −0.72; IB: −0.89; II: 0.54
Kama et al., 2006[19]	I: RME + FM + FxA II: Control	I: 1.50; II: 0.67	PP-Go-Gn I: 1.94; II: 1.40 SN-PP I: 0.24; II: −0.60
Arman et al., 2006[20]	I: RME + FM + FxA II: Control	I: 1.83; II: 0.14	SN-PP I: 1.25; II: −0.33
Yoshida and Shoji, 2007[21]	IA: MPA + CC (short face) IB: MPA + CC (long face)	I: 2.5; II: 1.7	–
Tortop et al., 2007[22]	IA: FM + RME (exp) IB: FM + RIA (no exp) II: Control	IA: 1.0; IB: 2.1; II: −0.3	FH-PP IA: 1.3; IB: 0.7; II: 0.2
Lin et al., 2007[23]	I: FM (OMA) + CC II: Control	I: 1.8; II: 0.5	SN-PP I: −0.6; II: 0.3
Kilinç et al., 2008[24]	I: RME + FM + FxA II: Control	I: 1.90; II: 1.10	–
Pavoni et al., 2009[25]	I: BB + FM II: RME + FM	I: 1.7; II: 1.4	FH-PP I: −1.4; II: −0.7
Yavuz et al., 2009[26]	FM + FxA IA: Adolescents IB: Young adults	IA: 2.31; IB: 0.78	SN-PP IA: −2.45; IB: −1.39
Lee et al., 2010[27]	FM + RIA IA: Deciduous IB: Mixed	I: 2.24; II: 2.07	I: −0.71; II: −0.36
Kilic et al., 2010[28]	I: FM II: Control	–	–
Baccetti et al., 2010[29]	I: FM + BB II: Control	–	–

Table 3. Extended

Mandibular Changes		Maxillary-Mandibular Changes
SNB Angle (°)	Vertical Changes (°)	ANB Angle (°)
IA: −0.4, IB: −1.0; II: 0.3	SN-GoGn IA: 0.8; IB: 1.3; II: 0.1	IA: 2.3; IB: 2.7; II: −0.3
I: −2.1; II: −0.78	–	I: 5.18; II: 3.89
IA: −1.09; IB: −1.33; IC: −1.03	LFH IA: 0.91; IB: 1.73; IC: 1.30	IA: 3.44; IB: 3.48; IC: 1.77
I: 1.1; II: 0.7	–	I: 2.7; II: −0.7
I: −1.31; II: -	SN-GoGn I: 1.38; II: -	I: 2.69; II: -
–	NL-ML I: 25.7; IA: 25.9; IB: 25.3	–
IA: −3.66; IB: −1.37; IIA: 0.35; IIB: 0.82	SGn-SN IA: 3.98; IB: 1.90; IIA: 0.24; IIB: −0.78	IA: 7.83;IB: 2.85; IIA: 0.15; IIB: −0.77
–	–	–
IA: −0.4; IB: −0.2; II: 0.3	SN-GoGn IA: 0.2; IB: 0.6; II: 0.1	IA: 1.5; IB: 3.0; II: 0.1
IA: −1.06; IB: −1.43; II: −0.2	SN-GoGn IA: 1.12; IB: 1.35; II: 0.2	IA: 3.82; IB: 3.95; II: −0.05
I: −1.81; II: 0.10	SN-GoGn I: 2.17; II: 0.80	I: 3.31; II: −0.10
I: −1.11; II: 0.45	–	I: 2.94; II: −0.31
I: −1.6; II: −1.1	S-N-Ba I: 1.5; II: 0.5	I: 4.1; II: 2.8
IA: −1.4; IB: −1.0; II: 0.3	SN-GoGn IA: 2.0; IB: 1.2; II: 0.1	IA: 2.4; IB: 3.2; II: −0.6
I: −0.6; II: 1.3	–	I: 2.4; II: −0.8
I: −.53; II: 1.37	–	I: 3.43; II: −0.30
I: −0.7; II: −0.8	PP-MP I: 1.7; II: 1.5	I: 2.3; II: 2.4
IA: −1.38; IB: −1.48	–	IA: 3.65; IB: 2.25
I: −1.75; II: −0.78	SN-GoGn I: 1.81; II: 1.21	I: 4.00; II: 2.85
–	SN-GoMe I: 2.48; II: 0.17	–
–	PP-MP I: 2.1; II: −0.6	–

Table 3. Continued

Study	Groups (Appliance)	Maxillary Changes	
		SNA Angle (°)	Vertical Changes (°)
Cozza et al., 2010[30]	I: FM + BB II: Control	I: 2.1; II: −0.6	SN-PP I: −1.9; II: −0.1 FH-PP I: −1.2; II: 0.7
Mandall et al., 2010[31]	I: RME + FM II: Control	I: 1.4; I: 0.3	SN-PP I: −0.5; II: −0.3
Atalay and Tortop, 2010[32]	Modified TTBA IA: Early treatment IB: Later treatment II: Control	IA: 0.7; IB: 1.5; II: 0.5	SN-PP IA: −0.7; IB: −0.8; II: −0.1
Isci et al., 2010[33]	FM + RME I: Activation/deactivation RME II: Control	I: 3.10; II: 1.87	SN-PP I: −1.23; II: −0.70
De Clerck et al., 2010[2]	I: BAMP II: Control	–	NL-SBL I: −2.4; II: 0.2
Cevidanes et al., 2010[34]	I: BAMP II: RME + FM	–	NL-SBL I: −0.4; II: 0.9
Baccetti et al., 2011[35]	I: BAMP II: Control	–	–
Sar et al., 2011[36]	IA: FM + MP IB: FM + RME II: Control	IA: 2.53; IB: 1.83; II: 0.26	HR-PP IA: 0.91; IB: 1.63; II: −0.20
Jamilian et al., 2011[37]	I: MS + RIA II: FM + RIA	I: 1.8; II: 1.5	SN-PP I: −1.3; II: −0.6

[a] FM indicates facemask; RME, tapid maxillary expansion; FxA, fixed appliances; B-3, Bionator III; MPBA, maxillary protraction bow appliance; DPA, double-plate appliance; exp, expansion; no exp, no expansion; MPA, maxillary protraction appliance; CC, chin cup; RIA, removable intraoral appliance; OMA, occipitomental anchorage; BB, bite-block appliance; TTBA, tandem traction bow appliance; BAMP, bone-anchored maxillary protraction; MP, miniplates; MS, miniscrew; SN-PP, sella nasion-palatal plane; FH-PP, Frankfort plane-palatal plane; PP-GoGn, palatal plane-gonion gnathion; NL-SBL, nasal line-stable basicranial line; HR-PP, horizontal reference-palatal plane. SN-GoGn, sella nasion-gonion gnathion; LFH, lower facial height; NL-ML, nasal line-mandibular line; SGn-SN, sella gnathion-sella nasion; S-N-Ba, sella-nasion-basion; PP-MP, palatal plane-mandibular plane; SN-GoMe, sella nasion-gonion menton; MM angle, maxillary-mandibular angle.

literature, therefore, conventional orthopedic treatment has sought to reduce dentoalveolar effects, making corresponding changes in the appliance to minimize the side effects.[30] This study also found that the mandibular incisors were significantly retracted with both bone and dentoalveolar orthopedic treatment, while the other studies of bone-anchored therapy that were included found a slight proclination of the mandibular incisors.[2,34,37] Surprisingly, it was reported that bone-anchored orthopedic treatment had a slight compensatory effect on the inferior incisors, although the effect was in the opposite direction to what was expected, with proclination of the lower incisors, which might be defined as decompensation in a Class III malocclusion (Table 4).

Effects on the Vertical Dimension

Vertical analysis of changes in the lower third of the face highlights the fact that both bone- and dentoalveolar-anchored therapies increased the facial angle of the lower facial height (Table 3). The increase in the vertical dimension was brought about by posterior rotation of the mandible, which was more marked in the dentoalveolar-anchored group (Table 3). When other orthopedic methods were used, such as the chin cup or a Class III functional appliance, a slight +1.8° increase, and even a decrease of −0.4°, was reported associated with this therapy. Similarly, significant changes in inferior anterior and total facial height, ranging between −0.5 mm[10] and +4.9 mm were found in most studies on dentoalveolar-anchored therapy[10,26]; the situation was similar for bone-anchored orthopedic therapy, with ranges of between 2 and 3 mm (Table 2).[34,36] However, studies that compared the two groups in parallel[36] also found statistically significant differences ($P < .001$) between the two types of therapy, with increased measurements for dentoalveolar-anchored therapy.[36]

DISCUSSION

Because of the high degree of maxillary retrusion in skeletal Class III malocclusion, several studies dealt with maxillary protraction using a facemask combined with a functional appliance (Bionator III),[13] with a bite-

Table 3. Continued Extended

Mandibular Changes		Maxillary-Mandibular Changes
SNB Angle (°)	Vertical Changes (°)	ANB Angle (°)
I: −0.1; II: 0.0	PP-MP I: 2.1; II: −0.3 SN-GoGn I: 0.4; II: −0.3	I: 2.2; II: −0.6
I: −0.7; II: 0.8	MM angle: I: 1.8; II: −0.2	I: 2.1; II: −0.5
IA: −1.1; IB: −0.5; II: 0.4	SN-GoGn IA: 0.9; IB: 1.1; II: 0.27	IA: 1.7; IB: 2.1; II: 0.0
I: −1.60; II: −1.43	PP-MP I: 3.23; II: 2.37	I: 4.70; II: 3.30
–	NL-ML I: −8; II: 0.3	–
–	NL-ML I: −0.8; II: 2.1	–
–	–	–
IA: −1.93; IB: − 2.30; II: 0.65	SN-GoGn IA: 1.46; IB: 3.06; II: − 0.40	IA: 4.46; IB: 4.20; II: −0.38
I: 0.5; II: 0.2	SN-GoGn I: 0.0; II: −0.2	I: 1.4; II: 1.3

block appliance,[30] or after rapid maxillary expansion.[20] These studies reported forward movement of the maxilla, maxillary incisor advancement, increased measurements for vertical parameters, and posterior movement of the mandible.

Dentofacial orthopedics using chin-cup therapy for a Class III malocclusion has also been studied in the literature, although its effects are not reported as orthopedic therapy as such. This treatment may be used to make improvements to both jaws by inhibiting mandibular growth and inducing remodeling the mandible with closure of the gonial angle or posterior rotation and distal displacement of the mandible.[38,39]

The basis of chin-cup therapy consists of applying a force to the temporomandibular joint in order to inhibit or redirect condylar growth, which causes morphologic changes at this region.[40]

In recent times, orthopedic therapy with bone anchoring has become the new paradigm for early treatment of skeletal Class III malocclusions. In some studies, orthopedic treatment was initiated with bone anchoring, using an extraoral appliance for maxillary protraction.[41,42] Later, a new orthopedic protocol appeared using bone anchoring and intermaxillary elastics applied from four miniplates in each patient to maintain a constant pull force.[43] Cevidanes et al.[34] compared the bone-anchored maxillary protraction (BAMP) and rapid maxillary expansion and facemask protocols, reporting that the BAMP protocol produced greater maxillary advancement and fewer vertical changes. Also, this group of patients did not show clockwise rotation of the mandible or dental compensation.

Although the timing of treatment for facemask therapy is a subject that is not fully clarified in the articles included in the present study, because the permanent incisors continue erupting until 10 years of age maxillary protraction can be prescribed.[44] On the other hand, the BAMP protocol should be performed on late mixed or permanent dentition because there is no alveolar bone development or inferior canine eruption.[34,43]

There is substantial variability regarding the magnitude of force used to obtain orthopedic results. In an overview of the literature, the force magnitude applied to each side is usually between 300*g* and 600*g* for the maxilla and 300–500*g* per side for the mandible. De Clerck et al.,[43] using the bone-anchored maxillary protraction protocol, used 150*g* on each side in the initial phase, 200*g* after 1 month of treatment, and 250*g* after 3 months to avoid possible clinical failure. This new orthopedic approach produced significant skeletal changes.[34,43]

Different protocols are used in the literature according to whether or not there was previous expansion or disjunction of the upper jaw combined with facemask therapy. The literature describes various benefits of maxillary expansion combined with a protraction appliance. Maxillary expansion also corrected cross-

Table 4. Dental parameters measured in the included studies

Study	Groups (Appliance)	Overjet	Overbite	Molar Relationship
Yüksel et al., 2001[10]	IA: FM (early treatment)	IA: 1.7	IA: −1.9	–
	IB: FM (later treatment)	IB: 2.7	IB: 1.99	
	II: Control	II: −0.13	II: 0.44	
Keles et al., 2002[1]	I: Modified FM	–	–	–
	II: Classical FM			
Cha et al., 2003[11]	RME + FM			–
	IA: Accelerating growth	IA: 5.53	IA: 0.27	
	IB: High growth	IB: 5.48	IB: −0.56	
	IC: Decelerating growth	IC: 4.00	IC: −0.27	
Westwood et al., 2003[12]	I: RME + FM + FxA	I: 4.6	I: −0.6	I: 3.2
	II: Control	II: 1.5	II: 0.9	II: 0.6
Cozza et al., 2004[13]	I: FM + B-3	–	–	–
	II: Control			
Baccetti et al., 2004[14]	I: FM + FxA	I: −1.9	I: 0.2	I: 3.8
	IA: Successful group	IA: −2.2	IA: 0.4	IA: 3.7
	IB: Unsuccessful group	IB: −1.1	IB: −0.4	IB: 4.2
Kajiyama et al., 2004[15]	IA: MPBA (deciduous)	–	–	–
	IB: MPBA (mixed)			
	IIA: Control (deciduous)			
	IIB: Control (mixed)			
Franchi et al., 2004[16]	RME + FM + FxA	–	–	–
	IA: Early treatment			
	IB: Later treatment			
	IIA: Early control			
	IIB: Later control			
Üçem et al., 2004[17]	IA: DPA	IA: −6.5	IA: −1.5	IA: 4.7
	IB: FM	IB: 4.9	IB: −2.0	IB: 4.9
	II: Control	II: −0.1	II: 0.4	II: 0.0
Vaughn et al., 2005[18]	IA: FM + RME (exp)	–	–	–
	IB: FM + RME (no exp)			
	II: Control			
Kama et al., 2006[19]	I: RME + FM + FxA	–	–	–
	II: Control			
Arman et al., 2006[20]	I: RME + FM + FxA	I: 6.11	I: −1.29	–
	II: Control	II: −0.17	II: 0.12	
Yoshida and Shoji, 2007[21]	IA: MPA + CC (short face)	–	–	–
	IB: MPA + CC (long face)			
Tortop et al., 2007[22]	IA: FM + RME (exp)	IA: 4.6	IA: −1.1	IA: 2.6
	IB: FM + RIA (no exp)	IB: 5.1	IB: −1.7	IB: 5.2
	II: Control	II: −0.2	II: 0.8	II: −0.4
Lin et al., 2007[23]	I: FM (OMA) + CC	I: 5.6	I: −2.1	–
	II: Control	II: −0.1	II: 0.6	
Kilinç et al., 2008[24]	I: RME + FM + FxA	–	–	–
	II: Control			
Pavoni et al., 2009[25]	I: BB + FM	I: 3.0	I: 1.5	I: −2.6
	II: RME + FM	II: 3.9	II: 0.6	II: −2.5
Yavuz et al.. 2009[26]	FM + FxA	–	–	–
	IA: Adolescents			
	IB: Young adults			
Lee et al., 2010[27]	FM + RIA	–	–	–
	IA: Deciduous			
	IB: Mixed			
Kilic et al., 2010[28]	I: FM	–	–	–
	II: Control			
Baccetti et al., 2010[29]	I: FM + BB	–	–	–
	II: Control			
Cozza et al., 2010[30]	I: FM + BB	I: 3.1	I: 0.7	I: −3.0
	II: Control	II: 0.5	II: 1.0	II: 1.7
Mandall et al., 2010[31]	I: RME + FM	I: 4.4	–	–
	II: Control	II: 0.3		

Table 4. Continued

Study	Groups (Appliance)	Overjet	Overbite	Molar Relationship
Atalay and Tortop, 2010[32]	Modified TTBA			
	IA: Early treatment	IA: −3.6	IA: −1.2	IA: 2.7
	IB: Later treatment	IB: 4.4	IB: 2.5	IB: 3.6
	II: Control	II: 0.3	II: 0.3	II: −0.1
Isci et al., 2010[33]	FM + RME			–
	I: Activation/deactivation RME	I: 7.53	I: −1.77	
	II: Control	II: 5.07	II: −1.77	
De Clerck et al., 2010[2]	I: BAMP	I: 3.7	I: 1.4	I: −0.6
	II: Control	II: −0.1	II: −0.1	II: −0.2
Cevidanes et al., 2010[34]	I: BAMP	I: 3.7	I: 1.4	I: 4.6
	II: RME + FM	II: 4.6	II: 1.1	II: 3.2
Baccetti et al., 2011[35]	I: BAMP	–	–	–
	II: Control			
Sar et al., 2011[36]	IA: FM + MP	IA: 7.66	IA: 0.33	–
	IB: FM + RME	IB: 7.93	IB: −0.90	
	II: Control	II: −0.33	II: 0.26	
Jamilian et al., 2011[37]	I: MS + RIA	–	–	–
	II: FM + RIA			

bite and Class III malocclusion, and the orthopedic effect was increased by splinting the maxillary arch and separating the circumaxillary sutures.[45]

Some clinicians have suggested that expansion and a protraction facemask leads to more of an anteroposterior skeletal effect, which is intensified depending on the timing, and less dental change.[44] Others have found a backward and downward rotation of the mandible, as well as an increase in lower facial height and a positive overjet, a reduced overbite, and an improvement in the sagittal lip relationship.[20] However, rapid palatal expansion before maxillary protraction should only be performed if there is a transversal problem.

CONCLUSIONS

Based on the findings of the 30 selected articles:

- The recent orthopedic approach using temporary bone anchoring on late mixed or early permanent dentition results in effective skeletal changes with minimal dental compensation. The lack of long-term studies, however, means that further research, using well-designed studies and better clinical evidence, is necessary to assess the stability of orthopedic therapy in skeletal Class III malocclusions.
- Although all such studies ought to be compared quantitatively, there is wide variability and heterogeneity in the methodologies of the scientific literature in the field. There are also various limitations, such as malocclusion variants among patients, different growth patterns, different levels of patient cooperation, duration of treatment, time spent wearing the appliance daily, and the diverse nature of the appliances used.
- Differences in the efficiency parameters of bone- and dentoalveolar-anchored orthopedics were found, with a reduced treatment time using the bone-anchored approach.

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