Review Article

Orthopedic Treatment Outcomes in Class III Malocclusion

A Systematic Review

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ABSTRACT

Objective: To assess the scientific evidence on the effectiveness of early orthopedic treatment in Class III subjects.

Materials and Methods: A literature survey was performed by applying the Medline database (Entrez PubMed). The survey covered the period from January 1966 to December 2005 and used the Medical Subject Headings (MeSH). The following study types that reported data on the effects of Class III treatment with orthopedic appliances (facial mask, chincup, FR-3) on intermaxillary sagittal and vertical relationships were included: randomized clinical trials (RCTs), and prospective and retrospective longitudinal controlled clinical trials (CCTs) with untreated Class III controls.

Results: The search strategy resulted in 536 articles. After selection according to criteria for inclusion and exclusion, 19 articles qualified for the final review analysis. One RCT and 18 CCTs were retrieved.

Conclusion: The quality standard of the retrieved investigations ranged from low (four studies) to medium/high (five studies). Data derived from medium/high quality research described over 75% of success of orthopedic treatment of Class III malocclusion (RME and facial mask therapy) at a follow-up observation 5 years after the end of orthopedic treatment.

KEY WORDS: Systematic review; Class III malocclusion; Orthopedic treatment; Early treatment

INTRODUCTION

Class III malocclusion is associated with a deviation in the sagittal relationship of the maxilla and the mandible, characterized by a deficiency and/or a backward position of the maxilla, or by prognathism and/or forward position of the mandible.[1] The incidence of this malocclusion in the white population has been reported to be 1% to 5%.[2–4] In the Asian populations, however, the incidence ranges from 9% to 19%,[5–7] and in Latin populations the incidence is approximately 5%.[8,9]

The etiology of Class III malocclusion is multifactoral because of an interaction of both hereditary and environmental factors. The contributions of the cranial base, maxilla, mandible, and temporomandibular articulation have been described in detail in the literature.[10–13] Class III malocclusions associated with craniofacial disharmonies are much more difficult to treat and tend to relapse.[14–16]

Early treatment of Class III malocclusion has been advocated to reduce the need of treatment in the permanent dentition, when camouflage orthodontic treatment or surgery become the only options.[1] A series of treatment approaches can be found in the literature regarding orthopedic treatment in Class III malocclusion.

The aim of the present study is to analyze the scientific evidence on the actual outcomes of orthopedic treatment in Class III malocclusion as derived from the existing literature on peer-reviewed orthodontic journals according to the Cochrane collaboration principles. This systematic review was undertaken to answer the following relevant questions:

- Is early orthopedic treatment of Class III malocclusion effective?
- Which treatment modality is the most effective?

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Table 1. Search Strategy Results

MeSH Terms [a]	Search Strategy Results
Malocclusion, Angle Class III	1066 articles
Malocclusion, Angle Class III and orthodontics, interceptive	77 articles
Malocclusion, Angle Class III and orthodontics, corrective	459 articles

[a] MeSH indicates Medical Subject Headings.

- Are treatment results stable at a posttreatment observation?

MATERIALS AND METHODS

Search Strategy

The strategy for performing this systematic review was influenced mainly by the National Health Service (NHS) Centre for Reviews and Dissemination.[17] To identify all the studies that examined the relationship between early orthopedic treatment and Class III malocclusion, a literature survey was done by applying the Medline database (Entrez PubMed, www.ncbi.nim.nih.gov). The survey covered the period from January 1966 to December 2005 and used the Medical Subject Heading (MeSH) terms: ''malocclusion and Angle Class III,'' which was crossed with MeSH terms ''orthodontics, interceptive'' and ''orthodontics, corrective'' (Table 1). In addition, a search in the Cochrane Controlled Clinical Trials Register was performed.

Selection Criteria

The inclusion and exclusion criteria are given in detail in Table 2. The following study types that reported data on the treatment effects were included: meta-analysis randomized clinical trials (RCTs) and prospective and retrospective studies with concurrent untreated control groups (CCTs). The retrieved studies had to use cephalometrics to analyze the effects of orthopedic therapy on total mandibular length, total maxillary length, and intermaxillary vertical and sagittal relationship with respect to untreated Class III controls. No restrictions were set for sample size. Laboratory studies, descriptive studies, case reports, case series, reviews, and opinion articles were excluded.

Data Collection and Analysis

According to the recommendations by Petrèn et al,[18] data were collected on the following items: year of publication, sample size, study design (meta-analysis, RCT, CCT), treatment duration, observation time, success rate, side effects, and authors' conclusion. In addition, to document the methodological soundness of each article, a quality evaluation modified from the methods described by Antczak et al[19] and Jadad et al[20] was performed with respect to preestablished characteristics. The following characteristics were used: study design, posttreatment evaluation, sample size and previous estimate of sample size, selection description, withdrawals (dropouts), method error analysis, blinding in measurements, and adequacy of statistics. The following systematic scores were assigned to individual retrieved articles:

- Adequacy of selection description: 2 points
- Study design (RCTs: 2 points, CCTs: 1 point)
- Posttreatment evaluation (No: 0 point; Yes: 2 points)
- Description of method error analysis (2 points)
- Adequacy of statistics (nonparametric tests used when appropriate: 2 points; parametric tests used when nonparametric tests would be more appropriate: 1 point)
- Blinding in measurements (1 point).

The quality of the studies was considered as follows:

- Low: with a total score $\leq$5 points
- Medium: with a total score $>$5 and $\leq$7 points
- Medium/high: with a total score $>$7 and $\leq$9 points
- High: with a total score $\geq$10 points.

Two independent reviewers (LDT, CP) assessed the articles separately. The data were extracted from each article without blinding to the authors, and interexaminer conflicts were resolved by discussion of each article to reach a consensus. Two independent reviewers performed the quality evaluation of the articles retrieved (LF and PC) with one author (TB) acting as the coordinator.

RESULTS

The search strategy resulted in 536 articles. After selection according to the inclusion/exclusion criteria stated in Table 2, Table 3 articles qualified for the review analysis.[21–39] The main reasons for exclusion were: case reports, reviews, opinion articles, studies concerning treatment in permanent dentition/adult patients, and studies about association between Class III malocclusion and malformation. Six of the studies were performed in the United States,[21,24,25,30,34,39] five in Japan,[28,29,31,33,37] four in Turkey,[22,26,32,38] two in the UK,[23,27] one in Korea,[35] and one in Italy.[36]

Table 2. Inclusion and Exclusion Criteria for the Retrieved Studies

Inclusion Criteria	Exclusion Criteria
Meta-analyses, randomized clinical trials (RCTs), prospective and retrospective studies (CCTs)	Case reports, case series, descriptive studies, review articles, opinion articles, abstracts
Articles in English	Laboratory studies
Articles published from January 1966 to December 2006	Studies on adults
Studies on growing patients	Studies about the association between Class III malocclusion and craniofacial malformations
Studies conducted on lateral cephalograms including measurements of total mandibular length, total maxillary length, intermaxillary vertical and sagittal relationship	Epidemiologic studies
Untreated Class III control subjects	Studies on growth prediction
	Studies concerning the comparison between different malocclusions
	Studies about the association between Class III malocclusion and TMJ diseases
	Studies without an untreated control group or with a normal control group
	Studies on dental casts or without cephalometric analysis
	Treatment combined with extractions
	Surgically assisted treatment
	Success of therapy as a criterion for case selection

Study Design and Treatment Modalities

The results of the review are summarized in Tables 3 and 4. No meta-analyses were found. The 19 articles included one RCT[39] and 18 retrospective CCTs.[21–38]

Three articles described the effects of chincup alone[27,29] or in association with fixed appliances.[33] Seven studies utilized a facemask alone[23,24,26,28,32,38,39]; four articles described the orthopedic effect of a facemask in association with rapid maxillary expanders,[21,25,30,39] and one in combination with fixed appliances[34]; one article described the effects of the facemask in combination with a Bionator III.[36] Two articles analyzed the effects of the FR-3 appliance of Fränkel,[22,35] two of a maxillary protractor bow appliance (MPBA),[31,37] one of double-plate appliance (DPA),[38] and one utilized a combination of an upper removable appliance in association with an extraoral traction to the mandibular dentition (EOT).[23]

Age of Groups

Treated Class III patients were 4 years 2 months[28] to 12 years 4 months[23] old, whereas the age range in untreated groups was wider, as it varied from 4 years 2 months[28] to 17 years 11 months.[33]

Treatment Duration and Class III Skeletal Correction

Treatment duration varied between 5 years 2 months[37] and 7 years 2 months,[33] depending upon treatment modalities. Twelve studies declared that treatment was discontinued after the correction of Class III malocclusion. Of these studies, six studies interrupted active treatment after achieving a positive overjet,[24,26,27,28,31,37] one study after obtaining a Class I molar relationship,[32] and four after achieving both goals.[32,34,38,39]

Success Rate

A 100% success rate was reported in five studies,[21,26,32,33,35] 85% in one study,[28] and a 76% rate in another study.[34] The other articles did not declare the success rate.

Correlation Between Gender and Treatment Outcomes

Only three studies[23,31,37] analyzed the influence of gender on treatment outcomes. In two studies[31,37] no significant differences between genders were found, suggesting that gender had little influence on treatment effects. In one study[23] values for each sex were given separately, as statistically significant differences were found, even if the composition of the groups with regard to severity of malocclusion and age was more difficult to manage. Three studies[22,35,39] combined the sexes because statistical significance was not found between them.

Correlation Between Timing and Treatment Outcomes

Only one study[26] declared the skeletal age of subjects at the beginning of treatment, but omitted the method used to evaluate it. One study[34] considered only subjects that attained a skeletal maturity stag-

Table 3. Summarized Data of the 19 Studies Included in the Review [a]

Article Material and Age	Study Design	Gender Distribution	Treatment Time	Observation Time	Success Rate	Side Effects	Authors' Conclusion
Ngan et al 1992[21]	CCT				Almost 100%	Not declared	Correction of Class III primarily due to forward and downward movement of the maxilla, downward and backward rotation of the mandible
10 RME + FM (8.06y)		3M; 7F	6m				
10 No treatment (not declared)		10 Matched		6m			
Ulgen and Firatli 1994[22]	CCT				Not declared	Retrusion of lower incisors	Increase ANB, decrease SNB, retrusion lower incisors
20 FR3 (9.5y)		10M; 10F	1.9y				
20 No treatment (9.3y)		10M; 10F		1.8y			
Battagel and Orton 1995[23]	CCT				Not declared	Not declared	Both therapies are effective. In FM group, forward development of the maxilla is seen
44 EOT + upper removable appliance (12.4y)		27M; 17F	2.1y				
39 FM (10.8y)		19M; 20F	2.0y				
30 No treatment (12.4y)		12M; 18F		3.0y			
Chong et al 1996[24]	CCT				Not declared	Retroclination of mandibular incisors	Significant skeletal and dentoalveolar changes
16 FM (6.8y ± 1.13y)		8M; 8F	0.61y treatment	1.66y			
13 No treatment (6.36y ± 0.54y)		8M; 5F	3.57y post treatment	5.38y			
Baccetti et al 1998[25]	CCT				Not declared	Not declared	Treatment in early mixed dentition induces more skeletal adaptation than in late mixed dentition
23 Early treated RME + FM (6y 9m ± 7m)		20M; 26F	1y ± 5m				
23 Late treated RME + FM (10y 3m ± 1 y)			10m ± 3m				
17 Early untreated (6y 5m ± 8m)		14M; 18F		1y 11m ± 1y			
15 Late untreated (9y 6m ± 1y)				1y 8m ± 10m			
Kiliçoglu and Kirliç 1998[26]	CCT				16/16	Not declared	Soft tissue facial angle and facial convexity decreased
16 FM (8.65y ± 1.4y)		16F	0.99y ± 0.06y				
10 No treatment (9.29y ± 1.4y)		10F		1.03y ± 0.06y			
Abu Alhaija and Richardson 1999[27]	CCT				Not declared	Proclination upper incisors, retroclination lower incisors	Proclination upper incisors, retroclination lower incisors, redirection mandibular growth in a downward direction

Table 3. Continued

Article Material and Age	Study Design	Gender Distribution	Treatment Time	Observation Time	Success Rate	Side Effects	Authors' Conclusion
23 CC (8.11y ± 0.96y)		14M; 9F	3.01y ± 1.61y treatment				
23 No treatment (not declared)		23 Matched	3.34y ± 1.8y post treatment	4.12y ± 1.86y			
Deguchi et al 1999[28]	CCT				85%	Not declared	Advancement of maxilla, backward rotation of mandible, correction of anterior crossbite
40 FM (4y 2m)		40F	3y 3m treatment	3y 3m			
28 No treatment (4y 2m)		28F	3y 7m post retention	4y 1m			
Deguchi and McNamara 1999[29]	CCT				Not declared	Proclination upper incisors; retroclination lower incisors	Reduction mandibular growth increments
22 CC (9y 4m)		22F	1y 9m				
20 No treatment (9y 7m)		20F		30m			
Baccetti et al 2000[30]	CCT				Not declared	Not declared	Treatment in early mixed dentition induces more skeletal adaptation than in late mixed dentition
16 RME + FM (early treatment group) (7y ± 7m)		14M; 15F	10m ± 4m early treatment	1y 11m ± 8m early control1			
13 RME + FM (late treatment group) (8y 8m ± 1y)			1y 3m ± 7m post treatment	1y 9m ± 10m late control 1			
17 Early untreated control group1 (6y 5m ± 8m)		17 Matched					
15 Late untreated control group1 (9y 6m ± 1y 6m)		15 Matched	10m ± 2m Late treatment	1y 10m ± 1y early control 2			
11 Early untreated control group2 (7y 7m ± 7m)		11 Matched					
10 Late untreated control group2 (10y 3m ± 1y 5m)		10 Matched	1y 3m ± 7m post treatment	1y 9m ± 10m late control 2			
Kajiyama et al 2000[31]	CCT				Not declared	70% skeletal movement 30% incisor movement (labial inclination of maxillary incisors, lingual inclination of mandibular incisors)	Favorable changes in craniofacial skeleton and alveolus
29 MPBA (8y 7m ± 1y 5m)		11M; 18F	10.2m ± 4.5m				
25 No treatment (8y 10m ± 1y 4m)		10M; 15F		8.4m ± 2.3m			
Yuksel et al 2001[32]	CCT				17/17	Significant forward movement of upper incisors	No significant difference between the two treated groups

Table 3. Continued

Article Material and Age	Study Design	Gender Distribution	Treatment Time	Observation Time	Success Rate	Side Effects	Authors' Conclusion
17 Early FM (9y 8m)		11M; 6F	7m		17/17		
17 Late FM (12y 6m)		9M; 8F	7m				
17 No treatment (9y 5m)		17 Matched		9m			
Deguchi et al 2002[33]	CCT		2y 7m short term;		36/36 Long term	Not declared	Long-term therapy resulted in an inhibition of ramus height and body length growth than short-term therapy
20 CC force 500g short term + edgw (8y 4m)		20F	7y 2m long term;				
36 CC force 250g–300g long term + edgw (8y 4m)		36F	3y 3m retention short term;				
177 No treatment (1302 no treatment (8y) 3y 10m)		302F		5y 10m (T1–2)			
83 No treatment (17y 11m)		177F 83F	4y 8m retention long term	4y 1m (T2–3)			
Westwood et al 2003[34]	CCT		10m ± 4m (T1–2)		26/34 (76%)	Retrusion of the lower incisors in the first phase of treatment	Significant response of craniofacial skeleton (forward movement of the maxilla, downward and backward movement of the mandible)
34 RME + FM + edgw (8y 3m ± 1y 10m)		14M; 20F	5y 7m ± 2y 3m (T2–3)				
12 Untreated T1–2 (8y 1m ± 2y 2m)		6M; 6F		1y 2m ± 4m (T1–2)			
15 Untreated T2–3 (8y 10m ± 2y 4m)		8M; 7F		6y ± 2y 2m (T2–3)			
22 Untreated T1–3 (8y 8m ± 2y 5m)		9M; 13F		6y 5m ± 2y 2m (T1–3)			
Baik et al 2004[35]	CCT				Almost 100%	Linguoversion of the mandibular incisors	Backward and downward rotation of mandible, linguoversion of the mandibular incisors
30 FR3 (8.0y ± 1.2y)		13M; 17F	1.3y ± 0.6y				
20 No treatment (8.2y ± 1.1y)		10M; 10F		1.5y ± 0.6y			
Cozza et al 2004[36]	CCT				Not declared	Not declared	Satisfactory correction of class III by a significant maxillary forward movement
30 FM + BIO3 (5.85y)		17M; 13F	1y 8m				
24 No treatment (5.97y)		14M; 10F		2y			

Table 3. Continued

Article Material and Age	Study Design	Gender Distribution	Treatment Time	Observation Time	Success Rate	Side Effects	Authors' Conclusion
Kajiyama et al 2004[37]	CCT		5.2 m ± 2.9m (deciduous dentition)	2 y 1m ± 9.3m) (deciduous dentition	Not declared	Labial inclination of maxillary incisors in the deciduous dentition group might contribute to a more rapid correction of the anterior crossbite	Greater forward displacement of maxilla and clockwise relocation of the mandible in the deciduous dentition group than in the mixed dentition group
34 MPBA in deciduous dentition (5y 6m ± 10m)		11M; 23F					
29 MPBA in mixed dentition (8y 7m ± 1y 5m)		11M; 18F		8.4m ± 2.3m (mixed dentition)			
32 No treatment in deciduous dentition (4y 8m ± 12m)		10M; 22F	10.2m ± 4.5m (mixed dentition)				
25 No treatment in mixed dentition (8y 10m ± 1y 4m)		10M; 15F					
Uçem et al 2004[38]	CCT				Not declared	Significant protrusion of maxillary incisors and retrusion of mandibular incisors in the DPA group	Sagittally, skeletal changes were greater in FM group.
14 DPA (10y 3m)		7M; 7F	9m				
14 FM (10y 5m)		7M; 7F	9m				
14 No treatment (9y 8m)		8M; 6F		11m			
Vaughn et al 2005[39]	RCT				Not declared	Not declared	Facemask therapy with or without palatal expansion produced equivalent changes in the dentofacial complex
15 + 6 RME + FM (7.38y ± 0.50y)		7M; 8F	1.16y				
14 + 8 FM (8.10y ± 0.52y)		7M; 7F	1.15y				
17 No treatment (6.62y ± 0.47y)		10M; 7F		At least 12m			

[a] CCT indicates controlled clinical trial; RCT, randomized clinical trial; RME, rapid maxillary expansion; FM, facemask; FR3, Fränkel's function regulator FR-3; EOT, extraoral traction; CC, chincup; MPBA, maxillary protractor bow appliance; edgw, fixed appliance; BIO3, Bionator III; DPA, double-plate appliance; y, years; m, months; F, female; M, male.

ing Cvs4, Cvs5, or Cvs6 at a long-term observation, considering the developmental staging of the cervical vertebrae proposed by Franchi et al.[40]

Other studies[25,27,28,30,31,35,37] considered the dental stage at the beginning of treatment, varying from primary dentition,[28,35,37] eruption stage of first molars and incisors,[25,27,30,35] completed eruption of molars and incisors,[31,37] and eruption stage of canines and/or premolars.[25,30]

Treatment in deciduous dentition produces greater skeletal changes than those produced in the mixed dentition stage[37]; moreover, when therapy begins in the early mixed dentition, it seems to induce more favorable changes in the craniofacial skeleton, compared with the same treatment started in the late mixed dentition.[25,30]

One study compared treatment outcomes in two different chronologic age groups[32] without finding any

Table 4. Quality Evaluation of the 19 Selected Studies [a]

Article Sample Size Material and Age		Post-treatment Observation	Previous estimate of Sample Size	Selection Description	Withdrawals	Method Error Analysis	Blinding In Measurements	Statistics Provided	Adequacy of Statistics	Judged Quality Standard	Quality Score
Ngan et al 1992[21] 10 RME + FM (8.06y) 10 No treatment (not declared)	CCT	No	No	Adequate	No	Yes	No	Yes	*t*-Test	6	Medium
Ulgen and Firatli 1994[22] 20 FR3 (9.5y) 20 No treatment (9.3y)		No	No	Adequate	No	Yes	No	Yes	Wilcoxon rank test/ Mann-Whitney *U*-test (nonparametric)	7	Medium
Battagel and Orton 1995[23] 44 EOT + upper removable appliance (12.4y) 39 FM (10.8y) 30 No treatment (12.4y)		No	No	Adequate	No	Yes	No	Yes	*t*-Test/Tukey's HSD (nonparametric)	7	Medium
Chong et al 1996[24] 16 FM (6.8y ± 1.13y) 13 No treatment (6.36y ± 0.54y)		Yes	No	Adequate	No	Yes	No	Yes	*t*-Test/ Bonferroni correction & Wilcoxon Ranked Sum test (nonparametric)	9	Medium-high
Baccetti et al 1998[25] 23 RME + FM (Early treatment group) 23 Late treated RME + FM (10y 3m ± 1 y) 17 Early untreated (6y 5m ± 8m) 15 Late untreated (9y 6m ± 1y)		No	No	Adequate	No	Yes	No	Yes	Mann-Whitney *U*-test (nonparametric)	7	Medium
Kiliçoglu and Kirliç 1998[26] 16 FM (8.65y ± 1.4y) 10 No treatment (9.29y ± 1.4y)		No	No	Adequate	No	No	No	Yes	*t*-Test	4	Low
Abu Alhaija and Richardson 1999[27] 23 CC (8.11y ± 0.96y)		Yes	No	Adequate	No	Yes	No	Yes	*t*-Test	8	Medium-high

Table 4. Continued

Article Sample Size Material and Age	Post-treatment Observation	Previous estimate of Sample Size	Selection Description	Withdrawals	Method Error Analysis	Blinding In Measurements	Statistics Provided	Adequacy of Statistics	Judged Quality Standard	Quality Score
23 No treatment (not declared)										
Deguchi et al 1999[28]	Yes	No	Adequate	No	No	No	Yes	*t*-Test/F test	6	Medium
40 FM (4y 2m)										
28 No treatment (4y 2m)										
Deguchi et al 1999[29]	No	No	Adequate	No	No	No	Yes	*t*-Test/F test	4	Low
22 CC (9y 4m)										
20 No treatment (9y 7m)										
Baccetti et al 2000[30]	Yes	No	Adequate	No	Yes	No	Yes	Mann-Whitney *U*-test (nonparametric)	9	Medium-high
16 RME + FM (Early treatment group) (7y ± 7m)										
13 RME + FM (Late treatment group) (8y 8m ± 1y)										
17 Early untreated control group1 (6y 5m ± 8m)										
15 Late untreated control group1 (9y 6m ± 1y 6m)										
11 Early untreated control group2 (7y 7m ± 7m)										
10 Late untreated control group2 (10y 3m ± 1y 5m)										
Kajiyama et al 2000[31]	No	No	Adequate	No	No	No	Yes	*t*-Test	4	Low
29 MPBA (8y 7m ± 1y 5m)										
25 No treatment (8y 10m ± 1y 4m)										
Yuksel et al. 2001[32]	No	No	Adequate	No	Yes	No	Yes	Wilcoxon test/Mann-Whitney *U*-test (nonparametric)	7	Medium

Table 4. Continued

Article Sample Size Material and Age	Post-treatment Observation	Previous estimate of Sample Size	Selection Description	Withdrawals	Method Error Analysis	Blinding In Measurements	Statistics Provided	Adequacy of Statistics	Judged Quality Standard	Quality Score
17 Early FM (9y 8m) 17 Late FM (12y 6m) 17 No treatment (9y 5m)										
Deguchi et al 2002[33]	Yes	No	Adequate	No	No	No	Yes	*t*-Test	6	Medium
20 CC force 500g short term + edgw (8y 4m) 36 CC force 250g–300g long term + edgw (8y 4m) 302 No treatment (8y) 177 No treatment (13y 10m) 83 No treatment (17y 11m)										
Westwood et al 2003[34]	Yes	No	Adequate	No	Yes	No	Yes	Hotelling t^2 test/statistics	9	Medium-high
34 RME + FM + edgw (8y 3m ± 1y 10m) 12 Untreated T1–2 (8y 1m ± 2y 2m) 15 Untreated T2–3 (8y 10m ± 2y 4m) 22 Untreated T1–3 (8y 8m ± 2y 5m)										
Baik et al 2004[35]	No	No	Adequate	No	Yes	No	Yes	2 Sample *t*-test	6	Medium
30 FR3 (8.0y ± 1.2y) 20 No treatment (8.2y ± 1.1y)										
Cozza et al 2004[36]	No	No	Adequate	No	Yes	No	Yes	Friedman 2-way ANOVA & Wilcoxon Ranked Sum test Mann-Whitney *U*-test (nonparametric)	7	Medium
30 FM + BIO3 (5.85y) 24 No treatment (5.97y)										

Table 4. Continued

Article Sample Size Material and Age		Post-treatment Observation	Previous estimate of Sample Size	Selection Description	Withdrawals	Method Error Analysis	Blinding In Measurements	Statistics Provided	Adequacy of Statistics	Judged Quality Standard	Quality Score
Kajiyama et al 2004[37] 34 MPBA in deciduous dentition (5y 6m ± 10m) 29 MPBA in mixed dentition (8y 7m ± 1y 5m) 32 No treatment in deciduous dentition (4y 8m ± 12m) 25 No treatment in mixed dentition (8y 10m ± 1y 4m)	CCT	No	No	Adequate	No	No	No	Yes	ANOVA/*t*-test	4	Low
Uçem et al 2004[38] 14 DPA (10y; 3m) 14 FM (10y 5m) 14 No treatment (9y 8m)		No	No	Adequate	No	Yes	No	Yes	Wilcoxon test/Duncan test (nonparametric)	7	Medium
Vaughn et al 2005[39] 15 + 6 RME + FM (7.38y ± 0.50y) 14 + 8 FM (8.10y ± 0.52y) 17 No treatment (6.62y ± 0.47y)		No	No	Adequate	Yes (3)	Yes	Yes	Yes	*t*-Test	8	Medium-high

[a] RME, rapid maxillary expansion; FM, facemask; FR3, Fränkel's function regulator FR-3; EOT, extraoral traction; CC, chincup; MPBA, maxillary protractor bow appliance; edgw, fixed appliance; BIO3, Bionator III; DPA, double-plate appliance; y, years; m, months.

significant difference in the orthodontic and orthopedic effects.

Side Effects

Ten articles* considered the modifications in the inclination of the upper and lower incisors as a dental compensation during skeletal movement. In all these articles a retrusion and linguoversion of the mandibular incisors, a protrusion and labioversion of the maxillary incisors, or a combination of these two dental movements was found. Three articles did not report changes in the inclination of the incisors.[25,30,33] No studies performed a cost-analysis.

Stability of Treatment Outcomes

Six studies gave information about the stability of treatment,[24,27,28,30,33,34] reporting cephalometric results at a posttreatment observation.

One study[30] included a later cephalometric observation at about 1 year from the end of active treatment.

* *References 22, 24, 27, 29, 31, 32, 34, 35, 37, 38.*

This study reported that relapse tendency in early treatment subjects primarily affected the maxillary region, whereas late treatment subjects exhibited a significant rebound in mandibular sagittal position.

Three studies included a cephalometric observation about 3 years from the end of active orthopedic treatment[24,27,28]: two of these[24,28] reported a lack of significant differences between treated and control groups, suggesting that the favorable treatment effects on the maxillomandibular relationship were maintained. However, the treatment effect of increased overjet was diminished, mainly due to proclination of the mandibular incisors. Successfully treated cases demonstrated a significantly greater change in overjet during treatment, suggesting that some overcorrection may be necessary for maintenance of a successful correction. One study[27] reported no statistically significant skeletal or soft-tissue differences between the groups at the end of posttreatment observation, except for the increased overjet and overbite in the chincap subjects.

Two articles[33,34] evaluated the posttreatment effects of an initial phase of orthopedic treatment followed by comprehensive edgewise therapy, with a follow-up observation at about 5 years from the end of orthopedic treatment. Favorable skeletal change observed post treatment was due almost entirely to the orthopedic correction: during the posttreatment period, craniofacial growth in treated subjects was similar to that of untreated class III controls. Thus, aggressive overcorrection at a skeletal level appears to be advisable and essential to the stability of the treatment outcome.[34]

Quality Analysis

Research quality was low in four studies,[26,29,31,37] medium in 10 studies,† and medium/high in five.[24,27,30,34,39] The selection description was adequate in all studies. Withdrawals (dropouts) were declared only in the RCT study,[39] and in this study the number of dropouts was three. Nine articles used proper statistical methods[22–24,25,30,32,34,36,38]; in the remaining studies the choice of a parametric test without data distribution analysis was inadequate. Thirteen studies included a method error analysis,‡ and only one article used blinding in measurements.[39] No study declared the presence of ethical approval with regard to the employment of an untreated control group with a Class III malocclusion. No article declared a previous estimate of sample size.

DISCUSSION

In this systematic review, an exhaustive literature search attempted to find all randomized and controlled clinical trials with concurrent untreated controls that compared different treatment modalities for orthopedic treatment in Class III malocclusion.

RCTs have been used rarely in orthodontics, and this systematic review shows that only one RCT on the outcomes of orthopedic Class III therapy was found.[39] In fact, several items required in quality reviews are applicable scarcely in orthodontics (ie, patients blinded or observer blinded to treatment). Another reason can be defined as ''ethical'' or ''logistic'' because RCT patients are not able to choose treatment, and some subjects may be designated to an untreated control group (in which the treatment is postponed after the study period), and these subjects may refuse to participate in the trial.

For these reasons both retrospective and prospective CCTs were included in this review. In most of the studies, there were serious shortcomings, such as no previous estimate of sample size, or no discussion on the possibility of type II error occurring. Problems of bias, lack of method error analysis, lack of blinding in measurements, and deficient or lack of statistical methods were other examples of drawbacks in most of the studies. Withdrawals (dropouts) were well declared in only one study.

The groups of Class III subjects analyzed in the articles retrieved for this review were considered very heterogenic with regard to age (especially in untreated control groups), to treatment modality, and to treatment duration. Cephalometric measurements performed in the 19 studies were not comparable because different studies used different cephalometric analyses (for instance, not all studies used ANB angle to evaluate the skeletal sagittal relationship). Moreover, those studies that used the same cephalometric analysis did not apply the same treatment timing, or they did not show the same treatment duration, thus rendering quantitative analysis of outcomes practically impossible and clinically useless.

With regard to the quality standard of the retrieved investigations, it ranged from low (four studies[26,29,31,37]) to medium/high (five studies[24,27,30,34,39]). The only RCT[39] analyzed a very specific aspect of orthopedic treatment of Class III malocclusion (use of rapid maxillary expansion [RME] in combination with a facial mask vs no use of the RME), and the reported results were in the short term. Therefore, even in the presence of data derived from medium/high quality research[34] that described over 76% of success of orthopedic treatment of Class III malocclusion (RME and facial mask therapy) at a follow-up observation 5 years after the end of orthopedic treatment, high quality investigations are still needed to perform a definitive assessment of effectiveness of Class III treatment at the skeletal level. An RCT on the effects of different orthopedic treatment

† *References 21–23, 25, 28, 32, 33, 35, 36, 38.*
‡ *References 21–25, 27, 30, 32, 34, 35, 36, 38, 39.*

modalities with a long-term observation at the end craniofacial growth would be desirable.

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