Review Article

Stability Factors After Double-Jaw Surgery in Class III Malocclusion

A Systematic Review

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ABSTRACT

Objective: To identify the stability factors of skeletal Class III malocclusion after double-jaw surgery by a systematic review of the literature.

Materials and Methods: The survey covered the period from September 1959 to October 2007 and used the MeSH, Medical Subject Headings. The inclusion criteria were stability of bimaxillary surgery of the permanent dentition, adult patients with skeletal Class III malocclusion, a follow-up of at least 12 months, randomized and nonrandomized controlled clinical trials (RCCTs; CCTs), prospective and retrospective studies with and without concurrent untreated as well as normal controls, and clinical trials (CTs) comparing at least two treatment strategies without any untreated or normal control group.

Results: The search strategy resulted in 1783 articles. After selection according to the inclusion/exclusion criteria, 15 articles qualified for the final review analysis. Quality was low in two studies, medium in twelve, and medium/high in one article, which was represented by a RCT (randomized clinical trial). Most of the studies had sufficient sample size, method error analysis, and adequate statistical methods. Thus, the quality level of the studies was sufficient to draw evidence-based conclusions.

Conclusions: Surgical correction of skeletal Class III malocclusion after combined maxillary and mandibular procedures appears to be stable for maxillary advancements up to 5 mm and for the correction of presurgical sagittal intermaxillary discrepancies smaller than 7 mm.

KEY WORDS: Long-term stability; Skeletal Class III malocclusion; Bimaxillary surgery; Systematic review; Quality analysis

INTRODUCTION

Dentoskeletal Class III malocclusion is a structural deviation in the sagittal relationships of the maxillary and mandibular bony arches. It is characterized by maxillary retrusion, mandibular protrusion, or by their combination, molar and/or canine mesiocclusion, sometimes associated with anterior crossbite and increased or decreased divergency.[1] Class III malocclusion is considered one of the most complex and difficult orthodontic problems to diagnose and treat. The prevalence of this type of malocclusion in white populations is less than 5%, but it rises to as much as 12% in Chinese and Japanese populations, with a relatively high prevalence of Class III malocclusion observed also in Mediterranean and Middle Eastern populations.[2] Numerous studies have been conducted both to determine significant differences between subjects with Class III and Class I malocclusions, and to assess the morphologic variability of craniofacial complex in patients with this disharmony.[3–8] These investigations have shown that the term "Class III malocclusion" is not a single diagnostic entity, but it can result rather from numerous combinations of skeletal and dentoalveolar components.[2]

The correction of Class III malocclusion by means of orthopedic/orthodontic treatment in growing subjects can be achieved in about 70% of the patients.[9–12] Prognostic evaluation of treatment outcomes based on

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Table 1. Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Systematic reviews, meta-analysis, randomized and nonrandomized controlled clinical trials (RCCTs; CCTs), prospective and retrospective studies with and without concurrent untreated as well as normal controls and clinical trials (CTs) comparing at least two surgical treatment strategies without any untreated or normal control group involved.	Abstracts, case control studies, trials not comparing at least two treatment strategies (case series), case reports, descriptive studies, discussion or opinion articles, in vitro researches.
Articles written in the English language	Treatment in the mixed dentition and in growing patients
Articles published from September 1959 to October 2007	Studies concerning patients with skeletal Class III malocclusion associated with severe temporomandibular joint disorders, genetic syndromes, congenital or acquired craniofacial or dentofacial anomalies, degenerative and neoplastic craniomaxillofacial pathologies
Permanent dentition and adult patients with skeletal Class III malocclusion	Epidemiologic and growth prevision studies
Lateral cephalometric radiographs taken in natural head position	Studies not concerning surgical long-term stability
Bimaxillary surgery	
Follow-up: at least 12 months	

Table 2. The Articles Included in the Review and Their Study Design

Articles	Study Design[a]
Franco et al, 1989[21]	R, L, CT
Proffit et al, 1991[22]	R, L, CT
McCance et al, 1992[23]	R, L
Bailey et al, 1998[24]	R, L, CT
Marchetti et al, 1999[25]	R, L
Ayoub et al, 2000[26]	R, L, CT
Moldez et al, 2000[27]	R, L, CT
Costa et al, 2001[28]	R, L, CT
Politi et al, 2002[29]	P, L, RCT
Busby et al, 2002[30]	R, L, CT
Renzi et al, 2003[31]	R, L, CT
Politi et al, 2004[32]	R, L, CT
Choi et al, 2005[33]	R, L
Ueki et al, 2006[34]	R, L, CT
Costa et al, 2006[35]	R, L, CT

[a] R indicates retrospective study; P, prospective study; L, longitudinal study; CT, clinical trial, ie, comparison of at least two treatment modalities without any untreated or normal group involved; RCT, randomized clinical trial.

pretreatment craniofacial features has been attempted in Class III malocclusion.[13,14] This research has shown that one-fourth of Class III patients need surgery and the completion of active growth for the correction of the dentoskeletal disharmony, as they did not respond satisfactorily to orthopedic therapy. Orthognathic surgery for Class III malocclusion, however, presents with some limitations due to the possibility of incomplete surgical success or, more importantly, of postsurgical relapse.[15]

The goal of this review is to analyze the available scientific literature according to Cochrane Collaboration's principles[16] with regard to the stability/relapse factors of skeletal Class III malocclusion after double-jaw surgery. This systematic review was undertaken to answer the following questions: (1) is bimaxillary surgery of skeletal Class III malocclusion effective and (2) are there any stability/relapse factors of bimaxillary surgery of skeletal Class III malocclusion?

MATERIALS AND METHODS

Search Strategy

The strategy for performing this systematic review was mainly influenced by the National Health Service (NHS) Centre for Reviews and Disseminations.[17] To identify all the studies that examined the stability of bimaxillary surgical correction of permanent dentition and adult patients with skeletal Class III malocclusion, a literature survey was done by applying the Medline database (Entrez PubMed, www.ncbi.nlm.nih.gov) followed by a manual search. The survey covered the period from September 1959 to October 2007, and using the Medical Subject Headings (MeSH) terms: "malocclusion, Angle Class III" and "prognathism" which were crossed with combinations of the following MeSH terms: "surgery," "surgical procedures, operative," and "long-term stability." In addition, a search in the Cochrane Controlled Clinical Trials Register was performed (www.cochrane.org/reviews). The inclusion and exclusion criteria are given in detail in Table 1.

Data Collection

To perform an analysis of the available scientific studies, according to the recommendations by Petrén et al,[18] data were collected for each selected article on the following items: year of publication, study design, sample size, treatment strategy, age, methods/measurements, surgical stabilization and/or surgical-orthodontic treatment time, follow-up, success rate, presurgical dentoskeletal features, correction of dentoskeletal features, relapse, and authors' conclusions. In ad-

Table 3. Analysis of the Selected Articles

Article Sample Size Treatment Strategy Age, y	Methods/ Measurements	Surgical Stabilization and/or Surgical-Orthodontic Treatment Time	Follow-Up	Success Rate	Presurgical Dentoskeletal Features	Correction of Dentoskeletal Features	Relapse	Factors Affecting Relapse (Authors' Conclusions)
Franco et al, 1989[21], R, L, CT	Lateral cephalometric radiographs at T1, T2, T3. Superimposition of lateral radiographs on the SN plane	MMF 3.6 days	21 months (T3)	Not declared	No information	No information	G1: forward movement of Pg (2.9 ± 3.2 mm, 53.4%, ≥ 2.7 mm in 45.4%); reduction of SAr^ArGo (−3.7 ± 3.1°, −4.44° in 45.4%).	Amount of backward repositioning of the mandible, especially due to rotation of the proximal segment ("stretching the muscles")
G1:11 (maxillary osteotomies + BSSRO with or without genioplasty + maxillary and mandibular RIF + MMF) ~24.1 y G2:14 (BSSRO with or without genioplasty + mandibular RIF + MMF) ~24.1 y		No information about orthodontic treatment time					G2: forward movement of Pg (1.8 ± 1.3 mm, 43.7%, ≥ 2 mm in 50%); reduction of SAr^ArGo (−2.8 ± 1.9°).	
Proffit et al, 1991[22], R, L, CT	Lateral cephalometric radiographs at T1, T2, T3. Relapse for cephalometric linear and angular changes ≥2	MMF + surgical interocclusal wafer splint 6 weeks	12 months (T3)	Not declared	G1: ANB (3.1 ± 2.1°); OVJ (−0.3 ± 2.9 mm); OVB (−2.8 ± 2.2 mm)	G1: ANB (2.5°); OVJ (1.5 mm); OVB (1.1 mm)	G1: posterior movement of ANS (−1.3 ± 1.3 mm); forward movement (≥4 mm in 15%) of B (2.5 ± 1.8 mm), Pg (2.6 ± 1.6 mm) and Go (3.2 ± 2.3 mm); upward movement of Go (−2.1 ± 1.7 mm); increase of ArGo^GoMe (4 ± 3.1°).	Two-jaw surgery more stable than mandibular surgery alone.
G1:14 (LFI + upward movement of the maxillary molars ≥2 mm + BSSRO + maxillary and mandibular rigid internal fixation in 14% of the cases, mandibular wire osteosynthesis with MMF in the rest of the patients + genioplasty 36% + surgical interocclusal wafer splint) ~24.4 ± 8.4 y					G2: ANB (5.7 ± 3.3°); OVJ (−5.1 ± 3.3 mm); OVB (−1.1 ± 2.9 mm)	G2: ANB (2°); OVJ (1.4 mm); OVB (1.2 mm)	G2: upward movement of A (−1.4 ± 2.2 mm, >2 mm in 50%); forward movement (>4 mm in 33.3%) of B (3.0 ± 3.0 mm), Pg (3.2 ± 3.2 mm) and Go (3.4 ± 2.6 mm); upward movement of B (−3.3 ± 2.3 mm) and Go (−2.4 ± 3.5 mm); increase of ArGo^GoMe (4.1 ± 3.7°). Posterior movement of A >2 mm in 20%; upward movement of PNS >2 mm in 25%.	
G2:21 (LFI + vertical repositioning of the maxillary molars <2 mm + BSSRO + maxillary and mandibular rigid internal fixation in 19% of the cases, mandibular wire osteosynthesis with MMF in the rest of the patients + genioplasty 19% + surgical interocclusal wafer splint) ~23.4 ± 7.9 y G3:16 (LFI + downward movement of the maxillary molars >2 mm, BSSRO, maxillary and mandibular rigid internal fixation in 31% of the cases, mandibular wire osteosynthesis with MMF in the rest of the patients + genioplasty 13% + surgical interocclusal wafer splint) ~23.4 ± 10.7 y		End of orthodontic treatment 12 months after the surgery			G3: ANB (5.7 ± 2.8°); OVJ (−7.9 ± 3.5mm); OVB (−1.1 ± 1.2 mm)	G3: ANB (1.9°); OVJ (0.2 mm); OVB (1.4 mm)	G3: upward movement of ANS (−2.0 ± 2.7 mm) and PNS (−1.1 ± 1.2 mm, >2 mm nel 25%); forward movement of B (5.3 ± 3.5 mm, >4 mm nel 66.7%), Pg (5.3 ± 4.1 mm; >4 mm nel 66.7%) and Go (5.8 ± 4.0 mm); upward movement of Pg (−3.2 ± 3.5 mm) and Go (−2.8 ± 4.8 mm); increase of ArGo^GoMe (7 ± 5.2°). Maxillary posterior movement >2 mm in 25%.	Better results with less vertical movements (maxilla)
McCance et al, 1992[23], R, L	Lateral cephalometric radiographs at T1, T2, T3. Superimposition of lateral radiographs according to Ekström[36] and Houston et al.[37]	IMF for a minimum period of 6 weeks	12 months (T3)	Not declared	G1: ANB (−4.8 ± 1.9°); M^M (35.2 ± 7.2°); LAFH (81.3 ± 5.1 mm); LPFH (43.9 ± 5.8 mm); OVJ (−4.1 ± 3.0 mm); OVB (−6.3 ± 3.8 mm)	G1: ANB (1.3 ± 1.2°); M^M (29.2 ± 6.4°); LAFH (75.2 ± 5.3 mm); LPFH (47.4 ± 6.6 mm); OVJ (−0.9 ± 1.1 mm); OVB (2.4 ± 1.2 mm)	G1: reduction of LPFH (−1.6 mm); increase of M^M (1.2°).	No factors identified
G1:11 (LFI with posterior impaction + maxillary RIF + wire/ BSSRO or VSO + IMF). Not declared		No information about orthodontic treatment time						

Table 3. Continued

Article Sample Size Treatment Strategy Age, y	Methods/ Measurements	Surgical Stabilization and/or Surgical-Orthodontic Treatment Time	Follow-Up	Success Rate	Presurgical Dentoskeletal Features	Correction of Dentoskeletal Features	Relapse	Factors Affecting Relapse (Authors' Conclusions)
Bailey et al,1998[24], R, L, CT	Lateral cephalometric radiographs at T1, T2, T3, T4. Relapse for cephalometric linear and angular changes >2	End of orthodontic treatment 42 months after the surgery	Mean 42 months (T4)	>90%	No information	No information	G1: forward movement of B (at 12 months: 3.36 ± 2.43 mm) and Pg (at 12 months: 4.06 ± 3.10 mm); upward movement of B (at 12 months: −3.04 ± 2.44 mm) and Me (at 12 months: −2.81 ± 2.38 mm). Decrease in OVJ long-term >2 mm only in 1 patient.	Two-jaw surgery more stable than mandibular surgery alone.
G1:34 (LFI or maxillary multiple segments with maxillary inferior movement + genioplasty in 18%) ~25.5 ± 11.4y							G2: forward movement of B (at 12 months: 4.10 ± 2.02 mm) and Pg (at 12 months: 3.67 ± 2.10 mm). Vertical or horizontal movement of Co >2 mm in 33.3%. Decrease in OVJ long-term > 2 mm only in 1 patient	
G2:18 (BSSRO + mandibular RIF in 44% + genioplasty in 22%) ~22.7 ± 9.2 y							G3: forward movement of B (at 12 months: 3.02 ± 2.79 mm), Go (at 12 months: 4.21 ± 3.11 mm) and Pg (at 12 months: 3.01 ± 3.21 mm); upward movement of B (at 12 months : −2.18 ± 2.87 mm) and Me (at 12 months: −2.22 ± 2.36 mm). Decrease in OVJ long-term >2 mm only in 2 patients.	Better results with less vertical movement (maxilla)
G3:40 (LFI or maxillary multiple segments with maxillary inferior movement + BSSRO + mandibular RIF in 67% + genioplasty in 23%) ~22.8 ± 8.3 y								
Marchetti et al, 1999[25], R, L	Lateral cephalometric radiographs at T1, T2, T3. Relapse for cephalometric linear and angular changes ≥2	Elastic maxillomandibular traction 5–15 days	18 months (T3)	Not declared	G1: ANB (−2.82°); ANS-PNS^MP (31.30°); OVJ (−4.04 mm); OVB (−0.58 mm)	G1: ANB (1.24°); ANS-PNS^MP (29.86°); OVJ (2.75 mm); OVB (1.24 mm)	G1: forward movement of Pg (2.2 mm)	No factors identified
G1:15 (LFI with bilateral maxillary superior movement in 13.3% of the cases + maxillary RIF + BSSRO + mandibular SRIF + intermediate splint + elastic maxillomandibular traction + genioplasty in 13.3%) ~24.5 y		No information about orthodontic treatment time						
Ayoub et al, 2000[26], R, L, CT	Lateral cephalometric radiographs at T1, T2, T3.	Light elastic bands 2–3 weeks	At least 12 months (T3)	Not declared	G1: MPA (35 ± 5.6°)	G1: MPA (35.6°)	G1: increase of SNB (1.5 ± 1.0°) and of x-Genion (2.5 ± 1.6 mm).	Inadequate orientation and "stretching of the muscles"
G1:3 (LFI + BSSO with or without genioplasty + RIF + light elastic bands) ~25 y		IMF 3–4 weeks			G2: MPA (35.3 ± 4.7°)	G2: MPA (33.4°)	G2: increase of MPA (−2.2 ± 3.3°); forward mandibular movement in 1 case	
G2:3 (LFI + IVSO with or without genioplasty + IMF) ~25 y		No information about orthodontic treatment time						
Moldez et al, 2000[27], R, L, CT	Lateral cephalometric radiographs at T1, T2, T3, T4, T5, T6	No information about surgical stabilization and orthodontic treatment time	60 months (T6)	Not declared	G1: ANB (−1.3 ± 2.7°); SN^MP (46.8 ± 5.5°); FH^MP (36.1 ± 4.9°); ANS-Me (79.1 ± 5.3 mm); OVJ (−1.9 ± 1.7 mm); OVB (−2.2 ± 2.1 mm)	G1: ANB (1.9 ± 2.9°); SN^MP (43.1 ± 6.6°); FH^MP (34.1 ± 7.6°); ANS-Me (77.6 ± 6.7 mm); OVJ (2.3 ± 1.0 mm); OVB (1.1 ± 0.9 mm)	G1: OVB <0 mm in 2 patients	Degree and direction of rotation of the palatal plane
G1:13 (LFI + maxillary superior repositioning without rotation of the palatal plane + BSSRO + wire/RIF)					G2: ANB (−1.7 ± 3.0°); SN^MP (44.5 ± 7.2°); FH^MP (35.4 ± 5.5°); ANS-Me (76.3 ± 4.6 mm); OVJ (−3.4 ± 2.7 mm); OVB (−3.8 ± 1.7 mm)	G2: ANB (4.6 ± 2.1°); SN^MP (42.1 ± 6.9°); FH^MP (33.8 ± 4.8°); ANS-Me (73.9 ± 3.7 mm); OVJ (2.7 ± 0.8 mm); OVB (1.7 ± 0.8 mm)		

Table 3. Continued

Article Sample Size Treatment Strategy Age, y	Methods/ Measurements	Surgical Stabilization and/or Surgical-Orthodontic Treatment Time	Follow-Up	Success Rate	Presurgical Dentoskeletal Features	Correction of Dentoskeletal Features	Relapse	Factors Affecting Relapse (Authors' Conclusions)
G2:10 (LFI + maxillary superior repositioning with clockwise rotation of the palatal plane + BSSRO + wire/RIF)					G3: ANB (−2.8 ± 1.5°); SN^MP (37.9 ± 5.9°); FH^MP (30.1 ± 3.7°); ANS-Me (75.9 ± 5.7 mm); OVJ (−4.5 ± 3.0 mm); OVB (2.0 ± 1.3 mm)	G3: ANB (2.1 ± 2.6°); SN^MP (38.9 ± 6.3°); FH^MP (30.0 ± 4.8°); ANS-Me (71.7 ± 5.2 mm); OVJ (2.3 ± 1.0 mm); OVB (1.8 ± 1.6 mm)		
G3:11 (LFI + BSSRO + wire/RIF) Not declared								
Costa et al, 2001[28], R, L, CT	Lateral cephalometric radiographs at T1, T2, T3, T4. Superimposition of lateral radiographs on the SN plane	MMF 6 weeks	12 months (T4)	Not declared	G1: ANB (−3.6°); OVJ (−5.7 ± 2.4 mm); OVB (0.7 ± 1.8 mm)	G1: ANB (1.9°); OVJ (2.8 mm); OVB (1.8 mm)	G1: backward (−0.95 ± 1.67 mm, >4 mm in 4%) and downward movement (0.72 ± 1.54 mm) of PNS; forward movement of Pg (2.97 ± 1.77 mm; 62% of mandibular setback, 2 to 4 mm in 54%, >4 mm in 22%), Me (3.38 ± 2.01 mm) and Go (2.47 ± 2.38 mm); increase of SNB (1.5 ± 0.82°) and reduction of ANB (−1.6 ± 1.47°); reduction of SN^ArPr (−2.97 ± 2.16°); reduction of OVJ (−0.7 ± 1.49 mm). Backward movement of maxillary landmarks of 2 to 4 mm in about 10%; OVB <1 mm in 13.6%.	Maxillary advancement >6 mm and/or excessive mandibular setback
G1:22 (1-piece LFI + upward movement of PNS ≥2 mm + RIF + BSSRO + wire-MMF + surgical interocclusal wafer splint) ~23.8 ± 5.2 y		Surgical splint 8 weeks			G2: ANB (−4.5°); OVJ (−6.3 ± 3.1 mm); OVB (0.4 ± 2.6 mm)	G2: ANB (1.4°); OVJ (2.8 mm); OVB (1.2 mm)	G2: backward movement (2 to 4 mm in 20%) of A (−0.64 ± 1.18 mm) and PNS (−0.61 ± 1.11 mm); upward movement (2 to 4 mm in 40%) of A (−1.19 ± 1.07 mm) and ANS (1.41 ± 1.48 mm); forward movement of Pg (3.41 ± 1.69 mm; 49.7% of mandibular setback, 2 to 4 mm in 55%, >4 mm in 28%), Me (3.5 ± 2.07 mm) and Go (2.52 ± 1.66 mm); upward movement of Pg (−2.58 ± 1.65 mm, 2 to 4 mm in 50%) and Me (−2.3 ± 1.47 mm, 2 to 4 mm in 60%); increase of SNB (1.8 ± 0.81°) and reduction of ANB (−2.1 ± 0.99°); reduction of SN^ArPr (−3 ± 2.02°). OVB <1 mm in 39%	
G2:18 (1-piece LFI + upward movement of PNS <2 mm + RIF + BSSRO + wire-MMF + surgical interocclusal wafer splint) ~25.2 ± 5.7 y		No information about orthodontic treatment time						
Politi et al, 2002[29], P,L, RCT	Lateral cephalometric radiographs at T1, T2, T3, T4. Superimposition of lateral radiographs on the SN plane	MMF 6 weeks	12 months (T4)	Not declared	G1: ANB (−3.08°); OVJ (−5.18 ± 3.24 mm); OVB (0.27 ± 1.82 mm)	G1: ANB (2.02°); OVJ (2.82 mm); OVB (1.67 mm)	G1: backward movement (2 to 4 mm in 20%) of A (−0.95 ± 1.03 mm; 17.4% of the surgical advancement), ANS (−0.78 ± 1.38 mm) and PNS (−1.22 ± 1.40 mm); forward movement of Pg (2.30 ± 2.35 mm, 2 to 4 mm in 30%, >4 mm in 22%, 75% of mandibular setback) and Me (2.50 ± 2.66 mm); reduction of SNA (−0.50 ± 1.03°) and increase of SNB (1.20 ± 1.27°); reduction of OVJ (−0.70 ± 1.42 mm). Downward movement of PNS >4 mm in 4%. OVB <1 mm in 26%.	Presence of presurgical sagittal intermaxillary discrepancies >7 mm.
G1:23 (1-piece LFI + RMF + BSSRO + wire-MMF + surgical splint) ~24.08 ± 6.05 y		No information about orthodontic treatment time			G2:); ANB (−3.25°); OVJ (−5.12 ± 3.48 mm); OVB (0.88 ± 2.33 mm)	G2: ANB (1.85°); OVJ (2.78 mm); OVB (1.88 mm)	G2: forward movement of Pg (2.81 ± 2.05 mm; 60.3% of mandibular setback, 2 to 4 mm in 63%, >4 mm in 15%) and Me (2.89 ± 2.37 mm); increase of SNB (1.40 ± 0.92°). Backward movement of maxillary landmarks of 2 to 4 mm in about 10%, downward movement 2 to 4 mm in the anterior maxilla in 10%, OVB <1 mm in 21%	Amount of mandibular setback
G2:19 (1-piece LFI + SRMF + circumzygomatic suspension of the posterior maxilla + BSSRO + wire-MMF + surgical splint) ~25.94 ± 3.97 y								

Table 3. Continued

Article Sample Size Treatment Strategy Age, y	Methods/ Measurements	Surgical Stabilization and/or Surgical-Orthodontic Treatment Time	Follow-Up	Success Rate	Presurgical Dentoskeletal Features	Correction of Dentoskeletal Features	Relapse	Factors Affecting Relapse (Authors' Conclusions)
Busby et al, 2002[30], R, L, CT	Lateral cephalometric radiographs at T1, T2, T3, T4. Relapse for cephalometric linear and angular changes >2	No information about surgical stabilization and orthodontic treatment time	~83 months (T4)	G1, G2:85%	No information	No information	G1: forward movement of B (at 12 months: 3.98 ± 2.66 mm, 2 to 4 mm in 19%) and Pg (at 12 months: 4.80 ± 2.97 mm, >4 mm in 13%); upward movement of B (at 12 months: −3.01 ± 2.96 mm) and Pg (at 12 months: −2.90 ± 3.41 mm). Superior movement of A and ANS 2 to 4 mm in 25–30%; backward movement of PNS >4 mm in 15% and of A 2 to 4 mm in 10%; reduction of OVJ 2 to 4 mm in 3%.	More relapse in patients with more severe sagittal discrepancies
G1:32 (LFI or maxillary multiple segments in 34% + maxillary downward movement + RIF in 50% + genioplasty in 9%) ~26.9 ± 11.7 y				G3:80%			G2: forward movement of B (at 12 months: 3.24 ± 2.08 mm, 2 to 4 mm in 11%), Go (at 12 months: 4.19 ± 2.76mm, 2 to 4 mm in 17%) and Pg (at 12 months: 2.92 ± 2.51 mm, 2 to 4 mm in 22%). Vertical or horizontal movement of Co >2 mm in 33.3%; increase in length of Co-Pg 2 to 4 mm in 33.3%.	
G2:18 (BSSRO + RIF in 50% + genioplasty in 28%) ~23.1 ± 9.7 y							G3: forward movement of B (at 12 months: 2.83 ± 2.24 mm), Go (at 12 months: 3.97 ± 3.08mm) and Pg (at 12 months: 2.86 ± 2.65 mm); upward movement of Go (a 12 mesi: −2.19 ± 2.95 mm) and Pg (at 12 months: −2.47 ± 2.90 mm). Upward movement of A 2 to 4 mm in 15%; increase in length Co-Pg > 4 mm in 15%; decrease in OVJ >2 mm in 7%	
G3:29 (LFI or maxillary multiple segments in 38% + maxillary downward movement + maxillary RIF in 52% + BSSRO + mandibular RIF in 62% + genioplasty in 21%) ~24.5 ± 9.8 y								
Renzi et al, 2003[31], R, L, CT	Cephalometric measures on PA, LL radiographs, bilateral. TMJ tomography, and RX-submentovertex at T1 and T2. RX-OPT relapse for cephalometric linear and angular changes >2	Presurgical orthodontic treatment 6–8 months	12 months (T2)	Not declared	No information	No information	G2: intercondylar distance >2 mm in 40%; right condyle angle >2° in 6.7%; left condyle angle >2° in 20%	Excessive posterior reposition of the mandibular condyle
G1:15 (LFI for maxillary intrusion with maxillary advancement in 73.3% + SRMF + BSSRO + RIF + CPD) ~25.3 y								
G2:15 (LFI for maxillary intrusion with maxillary advancement in 66.7% + SRMF + BSSRO + RIF + without CPD) ~25.7 y								
Politi et al, 2004[32], R, L, CT	Lateral cephalometric radiographs at T1, T2, T3, T4. Superimposition of lateral radiographs on the SN plane	G1:wire-MMF 6 weeks + surgical splint 8 weeks	12 months (T4)	Not declared	G1: ANB (−4.2 ± 2.43°); OVJ (−5.7 ± 2.41 mm); OVB (0.5 ± 1.87 mm)	G1: ANB (1.50 ± 1.83°); OVJ (2.90 ± 0.84 mm); OVB (1.80 ± 1.17 mm)	G1: downward movement of PNS (0.63 ± 1.27 mm, in15%); forward movement of Pg (2.92 ± 1.64 mm; 48.6% of mandibular setback, 2 to 4 mm in 65%, >4 mm in 20%), Me (2.95 ± 1.96 mm) and Go (2.04 ± 1.76 mm); upward movement of Pg (−2.03 ± 2.13 mm, 2 to 4 mm in 30%), Me (−1.98 ± 1.88 mm, 2 to 4 mm in 30%) and Go (−1.47 ± 1.90 mm); increase of SNB (1.50 ± 0.71°) and reduction of ANB (−1.50 ± 1.06°); counterclockwise rotation of the proximal segment (−3.20 ± 1.79°). Backward movement of maxillary landmarks of 2 to 4 mm in 15%; downward movement of ANS 2 to 4 mm in 15%; OVB <1 mm in 20%.	Amount of mandibular setback and intraoperative changes in ramus position

Table 3. Continued

Article Sample Size Treatment Strategy Age, y	Methods/ Measurements	Surgical Stabilization and/or Surgical-Orthodontic Treatment Time	Follow-Up	Success Rate	Presurgical Dentoskeletal Features	Correction of Dentoskeletal Features	Relapse	Factors Affecting Relapse (Authors' Conclusions)
G1:20 (1-segment LFI with or without maxillary superior repositioning ≥2 mm + RIF + BSSRO + wire-MMF + surgical splint) ~23.1 ± 3.74 y		G2:MMF 1 week + surgical splint 3 weeks			G2: ANB (−3.3 ± 2.41°); OVJ (−4.6 ± 3.22 mm); OVB (0.9 ± 1.83 mm)	G2: ANB (1.20 ± 2.19°); OVJ (3.30 ± 1.19 mm); OVB (2.30 ± 1.20 mm)	G2: forward movement of Pg (1.96 ± 2.13 mm; 55% of mandibular setback, 2 to 4 mm in 55%, >4 mm in 11%), Me (2.02 ± 2.16 mm) and Go (3.97 ± 4.65 mm); upward movement of Go (−1.76 ± 1.86 mm); increase of SNB (0.80 ± 0.95°) and reduction of ANB (−1.00 ± 1.13°); counterclockwise rotation of the proximal segment (−3.50 ± 1.66°). Backward movement of maxillary landmarks of 2 to 4 mm in 10%; downward movement of A 2 to 4 mm in 4%; OVB <1 mm in 11.7%	
G2:17 (1-segment LFI with or without maxillary superior repositioning ≥2 mm + BSSRO + maxillary and mandibular RIF + MMF + surgical splint) ~26.35 ± 5.67 y		No information about orthodontic treatment time						
Choi et al, 2005[33] R, L	Lateral and posteroanterior cephalometric radiographs at T1, T2, T3. Superimposition of lateral radiographs on the SN plane	Wire-IMF + surgical splint 1–2 weeks	21.7 months (T3)	Not declared	No information	No information	G1: forward movement of B (1.7 ± 2.0 mm); increase in Ar-B length (1.0 ± 1.0 mm); reduction of IGW (−1.6 ± 1.5 mm) in 87.5%; decrease in left angle (−0.8° ± 1.7°), right angle (−0.6 ± 1.5°) and total angle (−1.4 ± 2.2°)	Amount of mandibular setback
G1:42 (LFI + BSSRO + maxillary and mandibular RIF + wire-IMF + surgical splint) ~21.4 y		No information about orthodontic treatment time						
Ueki et al, 2006[34], R, L, CT	Lateral cephalometric radiographs at T1, T2, T3, T4, T5, T6	G1, G2:MMF several days; after elastics.	12 months (T6)	Not declared			G1,G4: slight tendency for vertical impaction of PNS-point (S-PNS ⊥ SN: 45.0 ± 4.6 mm, 42.3 ± 2.3 mm respectively)	No factors identified
G1:12 (LFI + BSSRO + maxillary and mandibular RIF in titanium miniplates + MMF + elastics) ~21.8 y		G3, G4:MMF 1–3 weeks; after elastics.						
G2:12 (LFI + BSSRO + maxillary RIF in PLLA + MMF + elastics) ~21.6 y		No information about orthodontic treatment time						
G3:14(LFI + RIF in titanium miniplates + IVRO + MMF + elastics) ~26.5 y								
G4:9 (LFI + RIF in PLLA + IVRO + MMF + elastics) ~21.1 y								
Costa et al, 2006[35], R, L, CT	Lateral cephalometric radiographs at T1, T2, T3, T4. Superimposition of lateral radiographs on the SN plane	MMF 1 week	12 months (T4)	Not declared	G1: ANB (−3.5 ± 2.66°); OVJ (−4.60 ± 3.77 mm); OVB (1.10 ± 2.05 mm)	G1: ANB (1.00 ± 2.43°); OVJ (3.20 ± 1.31 mm); OVB (2.30 ± 1.40 mm)	G1: forward movement of Pg (2.04 ± 2.44 mm; 47.5% of mandibular setback), Me (2.25 ± 2.44 mm) and Go (2.79 ± 2.22 mm); upward movement of Go (−1.92 ± 1.70 mm); increase of SNB (0.92 ± 1.08°) and reduction of ANB (−0.94 ± 1.27°); counterclockwise rotation of the proximal segment (−3.29 ± 1.88°). OVB <1 mm in 16%.	Amount of mandibular setback
G1:12 (1-piece LFI with or without maxillary superior repositioning ≥2 mm + RIF in titanium miniplates and screws + BSSRO + RIF-MMF + surgical splint) ~27.8 ± 5.89 y		Surgical splint 3 weeks			G2: ANB (−2.9 ± 0.80°); OVJ (−5.10 ± 1.89 mm); OVB (0.80 ± 2.08 mm)	G2: ANB (2.10 ± 1.86°); OVJ (2.00 ± 1.03 mm); OVB (2.80 ± 0.83 mm)	G2: backward movement of ANS (−1.25 ± 1.40 mm) and PNS (−1.15 ± 1.43 mm); forward movement of Pg (2.45 ± 1.21 mm; 37% of mandibular setback), Me (2.95 ± 1.26 mm) and Go (2.05 ± 2.65 mm); upward movement of Go (2.30 ± 1.64 mm); increase of SNB (1.11 ± 0.64°) and reduction of ANB (−1.66 ± 0.98°); counterclockwise rotation of the proximal segment (−2.70 ± 2.99°). OVB <1 mm in 20%.	
G2:12 (1-piece LFI with or without maxillary superior repositioning ≥2 mm + RIF in resorbable miniplates and screws + BSSRO + RIF-MMF + surgical splint) ~26.9 ± 7.12 y		No information about orthodontic treatment time						

[a] Y indicates years; BSSRO, bilateral sagittal split ramus osteotomy; RIF, rigid internal fixation; MMF, maxillomandibular fixation; LFI, Le Fort I; IMF, intermaxillary fixation; UPFH, upper posterior facial height; LPFH, lower posterior facial height; M^M, maxillary mandibular planes angle; MPA, mandibular plane angle; AFH, anterior facial height; SRIF, semirigid internal fixation; IVSO, intraoral vertical subsigmoid osteotomy; CPD, condylar positioning device; IGW, intergonial width; PLLA, Poly-L-lactic acid; IVRO, intraoral vertical ramus osteotomy.

Table 4. Quality Analysis of the Selected Studies

Article	Study Design	Previous Estimate of Sample Size	Selection Description	With-drawals (Dropouts)	Method Error Analysis	Blinding in Measure	Statistical Analysis	Statistical Adequacy	Quality Judgment
Franco et al, 1989	R, L, CT	No	Adequate	No	No	No	Unpaired *t* tests (parametric) Spearman's correlation coefficient (R values, nonparametric test) Stepwise regression analysis (parametric) Level of significance ($P < .05$)	Yes	Medium
Proffit et al, 1991	R, L, CT	No	Adequate	No	Random error <2 mm or degrees	No	Paired *t* tests (parametric) Level of significance ($P < .01$)	Yes	Medium
McCance et al, 1992	R, L	No	Adequate	No	Method error: standard deviation standard calculated from the error variance Minitab statistical software	No	Standard nonparametric analyses	Yes	Medium
Bailey et al, 1998	R, L, CT	Yes	Adequate	No	Method error ≤2 mm and/or 2°	No	Absent	Absent	Medium
Marchetti et al, 1999	R, L	No	Adequate	No	Method error ≤2 mm and/or 2°	No	Absent	Absent	Low
Ayoub et al, 2000	R, L, CT	No	Adequate	No	Student's *t*-test (parametric) for random error Correlation coefficients of Pearson (r; parametric) for systematic error	No	Paired Student's *t*-test (parametric) Correlation coefficients of Pearson (r; parametric) Level of significance ($P < .05$)	Yes	Medium
Moldez et al, 2000	R, L, CT	No	Adequate	No	Method error <0.4 mm for the linear and x-y coordinate measurements, <0.5 for the angular measurements	No	Analysis of variance (ANOVA; parametric) Scheffe's post hoc test (parametric) Level of significance ($P < .01$)	Yes	Medium
Costa et al, 2001	R, L, CT	No	Adequate	No	Dahlberg's formula for the method error Paired *t* test at the 10% for the systematic error	No	Paired Student's *t*-test (parametric) Correlation coefficients of Pearson (r; parametric)	Yes	Medium
Politi et al, 2002	P, L, RCT	No	Adequate	No	Dahlberg's formula for the method error	No	Ryan-Joiner test (nonparametric) F test (variance analysis; parametric) Linear regression analysis (parametric) Confidence interval, values for the range of equivalence, Δ, and the probabilities α e β Equiv Test software	Yes	Medium/High

Table 4. Continued

Article	Study Design	Previous Estimate of Sample Size	Selection Description	With-drawals (Dropouts)	Method Error Analysis	Blinding in Measure	Statistical Analysis	Statistical Adequacy	Quality Judgment
Busby et al, 2002	R, L, CT	Yes	Adequate	No	Method error ≤2 mm and/or 2°	No	Absent	Absent	Medium
Renzi et al, 2003	R, L, CT	No	Adequate	No	Method error ≤2 mm and/or 2°	No	Absent	Absent	Low
Politi et al, 2004	R, L, CT	No	Adequate	No	Dahlberg's formula for the method error; paired *t* test at the 10% for the systematic error	No	Shapiro-Wilk test (nonparametric) Paired Student's *t*-test (parametric) Correlation coefficients of Pearson (r; parametric) Unpaired *t* tests (parametric)	Yes	Medium
Choi et al, 2005	R, L	No	Adequate	18	Dahlberg's formula for the method error	No	Paired *t* tests (parametric) Bivariate density ellipses Correlation coefficients of Pearson (r; parametric)	Yes	Medium
Ueki et al, 2006	R, L, CT	No	Adequate	No	No	No	Analysis of variance (ANOVA; parametric) Level of significance ($P < .05$) StatView 4.5 software	Yes	Medium
Costa et al, 2006	R, L, CT	No	Adequate	No	Dahlberg's formula for the method error Paired *t* test at the 10% for the systematic error	No	Shapiro-Wilk test (nonparametric) Paired Student's *t*-test (parametric) Correlation coefficients of Pearson (r; parametric) Unpaired *t* tests (parametric)	Yes	Medium

dition, to document the methodological soundness of each article, a quality evaluation modified by the methods described by Antczak et al[19] and Jadad et al[20] was performed. The following characteristics were used: study design, previous estimate of sample size, selection description, withdrawals (dropouts), method error analysis, blinding in measurements, statistical analysis, and its adequacy. The quality was categorized as low, medium, and high. Two independent reviewers assessed the articles separately. The data were extracted from each article with blinding to the authors, and interexaminer conflicts were resolved by discussion on each article to reach a consensus. One author performed the quality evaluation of the statistical methods used in the articles.

RESULTS

The search strategy resulted in 1783 articles. After selection according to the inclusion/exclusion criteria stated in Table 1, 15 articles[21–35] qualified for the final review analysis.

The study design of the 15 articles is shown in Table 2. They included: one prospective longitudinal clinical trial (P, L, RCT), eleven retrospective longitudinal clinical trials (R, L, CTs) and three retrospective longitudinal studies without concurrent untreated as well as normal controls (R, Ls). No systematic review or meta-analysis was found.

Data concerning the surgical treatment modalities reported in each article are given in detail in Table 3.

The same table reports the age of the treated patients, the methods of measurement, the duration and type of surgical-orthodontic therapy, the amount of follow-up, the success rate, the presurgical dentoskeletal features and the correction of these features by means of surgery, and the amount of relapse in the movements of both the maxilla and/or the mandible. Finally, Table 3 summarizes also the conclusions by the authors of the retrieved studies with regard to factors accounting for stability or relapse after orthognathic surgery in the Class III patients.

Results of Quality Analysis

The results of the quality analysis are given in detail in Table 4. The analysis revealed that the research quality or methodological soundness was low in two studies,[25,31] medium in twelve studies,[21–24,26–28,30,32–35] and medium/high in one article.[29] This article was represented by a RCT, and it specified the probabilities of type-1 (α) and type-2 (β) errors. The lack of blinding in measurement (a common feature of all retrieved studies) provides explanation for a medium/high score instead of a high score for this study.[29]

DISCUSSION

Effectiveness of Bimaxillary Surgery

In this systematic review, the literature search was aimed to select all randomized and nonrandomized controlled clinical trials (RCCTs; CCTs) that examined the stability of bimaxillary surgical correction of skeletal Class III malocclusion. Bimaxillary surgery is the major surgical technique for Class III patients, even if some patients may require modifications or more limited surgical approaches. Fifteen studies were retrieved, and several of them showed consistent results.

Seven articles[23,25,27–29,32,35] showed correction of the sagittal intermaxillary relationships after surgery and follow-up. Only two studies[23,27] considered skeletal Class III patients with a long face, increased intermaxillary angle, and anterior open bite; after the longest follow-up period these articles showed an improvement in the values for facial divergence, a reduced lower anterior facial height, and an increased lower posterior facial height. In seven papers[22,25,27–29,32,35] presurgical OVJ value was negative and it appeared positive after the longest follow-up period; in one article[23] OVJ value increased after 12 months of follow-up, but it resulted still negative. OVB value was corrected in the four studies[22,23,25,27] in which it was negative before surgery, while it was improved in the other four articles[28,29,32,35] where it had a small but positive value before surgery. Only two studies[24,30] declared the success rate of bimaxillary surgery in Class III malocclusion; a >90% success rate was reported in one article,[24] and an 80% rate in the second article.[30]

Despite of the not negligible percentages of patients reported in several studies with relapse changes large enough to be outside the range of method error, and thus clinically significant, bimaxillary surgical therapy could be considered an effective procedure in skeletal Class III malocclusion correction.

Factors of Stability After Bimaxillary Surgery

The analysis of the 15 retrieved studies suggested that horizontal stability of surgical outcomes in the maxilla might be negatively influenced by its surgical advancement greater than 6 mm[28] and by the use of semirigid fixation[29] or resorbable plates and screws[35] to stabilize its advancement when this was greater than 5 mm.[33] The data indicated also that double-jaw surgery improved vertical stability of the maxilla, when it was to be moved down at surgery.[22,24,30]

Factors accounting for mandibular relapse were several: the degree of intraoperative clockwise rotation of the mandibular proximal segment,[21,32] the amount of mandibular setback (measured at Pg,[28,32] Go,[22,32] B-point, and Ar-B length[33]) and the excessive posterior condylar displacement in the glenoid cavity.[26,31] One of the common factors was the altered orientation and stretching of the pterygomasseteric sling that exerted an upward and forward force at the gonial angle accounting for mandibular relapse.[21,26] The one study with the greatest methodological soundness[29] indicated that a larger amount of relapse has to be expected in patients presented with presurgical sagittal intermaxillary discrepancies greater than 7 mm, thus requiring a large amount of mandibular setback.

From a speculative point of view, the analysis of the results of this systematic review suggests that one of the objectives of early orthopedic intervention in Class III patients can be seen as the reduction of the sagittal intermaxillary discrepancy in order to enhance the stability of the outcomes of orthognathic surgery, when needed at the completion of growth. Even in those Class III patients who do not show a complete resolution of the discrepancy after orthopedic therapy, early intervention may entail the favorable effect of creating more suitable candidates for a stable surgical correction.

Quality of the Studies

As proposed in a previous article[38] the quality of the articles was judged as low, medium, or high according to the characteristics in Table 4. In some studies, there were shortcomings such as small sample size,[22,24,30] thus implying low power with high risk to achieve in-significant outcomes as declared by the authors themselves. Other frequent limitations were the absence of previous estimate of sample size (present only in two studies[24,30]) or of discussion on the possibility of type II (β) error occurring (calculated in one article[29]). Problems of lack of method error analysis[21,34] and systematic error analysis (present only in four studies[26,28,32,35]) blinding in measurements, and lack of statistical methods[24,25,30,31] were other examples of drawbacks in some of the analyzed articles.

However, comprehensive analysis of retrieved articles revealed that the research quality was low only in two studies,[25,31] medium in twelve studies,[21–24,26–28,30,32–35] and medium/high in one article,[29] which was represented by a RCT. Therefore, the quality of the retrieved articles allows for some conclusions on the factors affecting the outcomes of surgery in Class III malocclusion.

CONCLUSIONS

- Surgical correction of skeletal Class III malocclusion after combined maxillary and mandibular procedures appears to be a fairly stable procedure independent of the type of fixation used to stabilize the mandible,[32] for maxillary advancements up to 5–6 mm[35] (especially with superior repositioning[22]) and for the correction of presurgical sagittal intermaxillary discrepancies smaller than 7 mm.[29] This result highlights the role of orthopedic treatment of Class III malocclusion in growing subjects aimed to reduce the amount of sagittal disharmony before the completion of active growth.
- A limited degree of intraoperative clockwise rotation of the mandibular proximal segment[21,32] along with a limited "stretching" of the muscles[21,26] are additional factors of postsurgical stability.

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Erratum

Vol. 77, No. 5, September 2007, pages 909–912.

''Short-term Anteroposterior Treatment Effects of Functional Appliances and Extraoral Traction on Class II Malocclusion. A Meta-analysis.''
Gregory Stylianos Antonarakis and Stavros Kiliardis
Angle Orthod. 2007;77:907–914

In Figures 2 through 5, the terms 'Favours treatment' and 'Favours control' placed below the x-axis of the forest plots should not be taken into consideration upon observation of the Figures. These terms are placed automatically by the meta-analysis program used, i.e. all reduction of values measured are considered by the program as favouring the treatment group, while the opposite as favouring the control group. For Class II treatment, these categories are correct for changes in SNA, ANB and OJ, but incorrect for changes in SNB (since an increase of SNB favours treatment).