EFFECTIVENESS OF ORTHOGNATHIC SURGERY IN CLASS III MALOCCLUSION TREATMENT: A SYSTEMATIC REVIEW

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This study was conducted to determine the effectiveness in Class III malocclusion treatment by orthognathic surgery, using systematic review study. The database was English articles on online medical database such as PubMed, Cochrane Central Register of Controlled Trials (CENTRAL), Wiley Online Library, ScienceDirect, updated to December 2017. Researches after orthognathic surgery in Class III malocclusion treatment, clinical trial with or without control group were selected. There were 26 studies in the final analysis round, after filtering through the selection/exclusion criteria. Most of them had adequate sample size, variance analysis and statistic method. Therefore, the research qualities were sufficient to make conclusion. In conclusion, bi-maxillary surgery with Lefort I osteotomy and bilateral sagittal split ramus osteotomy is an effective and stable method for skeletal Class III malocclusion treatment. Less than 6 mm maxillary or mandibular movement in operation, and less than 7 mm preoperative inter - maxillary discrepancy reduce risk of relapse after surgery. Retraction factors of masticatory system would increase postoperative relapse.

Keywords: long-term stability, Class III skeletal malocclusion, bi-maxillary surgery, systematic review study, orthognathic surgery.

I. INTRODUCTION

Malocclusion is an incorrect relation among the teeth in a dental arch or between two dental arches. Malocclusion is divided into plenty of types, based on standards given by different authors. Edward H. Angle (1899), based on the relation between maxillary and mandibular first molars and the alignment of teeth, which should be all fit on a line of occlusion, divided malocclusion into 3 main types called I, II and III. According to a number of recent researches, Angle Class III malocclusion takes a quite high ratio in many countries and ethnic groups. The ratio of Angle Class III malocclusion is about 16% in 10-year-old American children group, 7.81% in 11-year-old Japanese girls group, 9.4%-19% in Chinese and Korean group [1; 2]. In Vietnam, the ratio of incorrect relation between teeth and jaws in children is quite high at about 96.1% in Hanoi and 83.25% in Ho Chi Minh City. Among those, the percentage of children who have Angle Class III malocclusion is about 21.7% [3]. Malocclusion may affect to individual health and social life in a lot of ways such as occlusion trauma, chewing function reduction, increasing the risk of some oral diseases, facial esthetic affection, pronunciation difficulties and psychological problems [4; 5]. Malocclusion forms on clinic are diversified. Among those, the most complicated form is Class III malocclusion. There are many ways of therapeutic methods due to time of treatment and etiology of Class III malocclusion. Soon diagnosis as Class III malocclusion at young patient can be treated by orthodontic to normalize the inter-maxillary discrepancy [6; 7]. For patients who passed the

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peak growth, camouflage orthodontic treatment with fixed orthodontic appliances can improve the occlusion and facial esthetic, balance the skeletal discrepancy [8; 9]. Orthognathic surgery should be recommended for severe skeletal discrepancy cases [8; 10; 11].

Orthognathic surgery for Class III malocclusion and skeletal discrepancy has been improved globally to achieve optimum three dimensional results. Lefort I osteotomy and bilateral sagittal split ramus osteotomy are applied globally, showing good esthetic and functional results on all three dimension, and acceptable postoperative stability. This review article has 2 purposes:

(1) Determining the effectiveness of orthognathic surgery in Class III malocclusion treatment.

(2) Determining the postoperative stability of orthognathic surgery in skeletal class III treatment.

II. RESEARCH METHODS

Databases: English articles on online medical database such as PubMed, Cochrane Central Register of Controlled Trials (CENTRAL), Wiley Online Library, ScienceDirect, updated till December 2017.

Keywords: “malocclusion, Angle Class III”, and/or “effectiveness”, and/or “orthognathic surgery”, and/or “long-term stability”.

Selection/exclusion criteria: detailed in Table 1

Table 1. Selection/exclusion criteria

Selection criteria	Exclusion criteria
Systematic review, integrated analysis, randomized and non-randomized controlled clinical trials (RCCTs; CCTs)	Clinical reports, presentations or discussions, in vitro studies.
Adult patients with permanent teeth, skeletal Class III malocclusion, have had Orthognathic surgery	The studies included Class III malocclusion patients with severe temporomandibular joint disorder, genetic syndromes, congenital or acquired skeletal or dental abnormalities, facial degeneration diseases and cancers.

Article evaluation: Newcastle-Ottawa-Scale (NOS) tool was selected to assess the quality of collected articles. NOS tool has a score ranges from 0 to 9. Studies which were evaluated score as 5 or above, were considered to be selected for systematic - review.

Data collection and meta-analysis: publication year, sample size, surgical method, pretreatment discrepancy features, post treatment outcome, relapse, and conclusions of authors.

III. RESULTS

There were twenty six selected articles after filtering based on selection/exclusion criteria. These articles are listed in Table 2 with surgical method.

Table 2. Articles and Surgical method

Authors	Surgical method
Phillips et al 1986 [12]	BSSO
Kobayashi et al 1986 [13]	BSSO
Franco et al, 1989 [14]	LFI + BSSO
Law et al 1989 [15]	LFI + BSSO
Krekmanov et al 1989 [16]	BSSO
Sorokolit, Nanda 1990 [17]	BSSO
Proffit et al, 1991[18]	LFI + BSSO
McCance et al, 1992 [19]	LFI + BSSO
Schatz, Tsimas 1995 [20]	BSSO
Ingervall et al 1995 [21]	BSSO
Rodríguez, González 1996 [22]	BSSO
Harda, Enotomo 1997 [23]	BSSO
Marchetti et al, 1999 [24]	LFI + BSSO
Mobarak et al 2000 [25]	BSSO
Moldez et al, 2000 [26]	LFI + BSSO
Costa et al, 2001 [27]	LFI + BSSO
Politi et al, 2002 [28]	LFI + BSSO
Busby et al, 2002 [29]	G1: BSSO; G2: LFI + BSSO
Renzi et al, 2003 [30]	LFI + BSSO
Politi et al, 2004 [31]	LFI + BSSO
Choi et al, 2005 [32]	LFI + BSSO
Ueki et al, 2006 [33]	LFI + BSSO
Costa et al, 2006 [34]	LFI + BSSO
Aydemir H. et al, 2015 [35]	LFI + BSSO
Aydemir H., Ufuk T., 2015 [36]	G1:LFI, G2:BSSO, G3: LFI + BSSO
Ghassemi. M et al, 2016 [37]	LFI + BSSO

BSSO: bilateral sagittal split osteotomy; LFI: Le Fort I osteotomy; G: Group

Eleven articles were analyzed to assess the the effectiveness of orthognathic surgery. These articles containing the information including authors, sample size, surgical method, pre- and post-treatment characteristics, are shown in Table 3.

Table 3. Analyzing the effectiveness of orthognathic surgery in selected articles

Authors. year.	Sample size. surgical method	Pretreatment characteristics	Post-treatment outcomes
Proffit et al. 1991 [18]	G1:14 (LFI + BSSO) G2:21 (LFI + BSSO) G3:16 (LFI + BSSO)	G1: ANB (-3.1 ± 2.1°); OVJ (-0.3 ± 2.9 mm); OVB (-2.8 ± 2.2 mm) G2: ANB (-5.7 ±3.3°); OVJ (-5.1 ±3.3 mm); OVB (-1.1± 2.9 mm) G3: ANB (-5.7 ±2.8°); OVJ (-7.9 ±3.5mm); OVB (-1.1 ± 1.2 mm)	G1: ANB (2.5°); OVJ (1.5 mm); OVB (1.1 mm) G2: ANB (2°); OVJ (1.4 mm); OVB (1.2 mm) G3: ANB (1.9°); OVJ (0.2 mm); OVB (1.4 mm)
McCance et al. 1992 [19]	G1:11 (LFI + BSSO)	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)
Marchetti et al. 1999 [24]	G1:15 (LFI + BSSO)	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)
Moldez et al. 2000 [26]	G1:13 (LFI + BSSO + maxillary protrusion without rotation of palatal plane) G2:10 (LFI + BSSO maxillary protrusion with clockwise rotation of palatal plane) G3:11 (LFI + BSSO)	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) 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 ± 27 mm); OVB (-3.8 ± 1.7 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) 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

		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)
Costa et al. 2001 [27]	G1:22 (LFI + PNS moved upwards> 2 mm +BSSO) G2:18 (LFI + PNS moved upwards <2 mm + BSSO)	G1: ANB (-3.6°); OVJ (-5.7 ± 2.4 mm); OVB (0.7 ± 1.8 mm) G2: ANB (-4.5°); OVJ (-6.3 ± 3.1 mm); OVB (0.4 ± 2.6 mm)	G1: ANB (1.9°) OVJ (2.8 mm); OVB (1.8 mm) G2: ANB (1.4°); OVJ (2.8 mm); OVB (1.2 mm
Politi et al. 2002 [28]	G1:23 (LFI ++BSSO) G2:19 (LFI + BSSO)	G1: ANB (-3.08°); OVJ (-5.18 ± 3.24 mm); OVB (0.27 ± 1.82 mm) G2:); ANB (-3.25°); OVJ (-5.12 ± 3.48 mm); OVB (0.88 ± 2.33 mm)	G1: ANB (2.02°); OVJ (2.82 mm); OVB (1.67 mm) G2: ANB (1.85°); OVJ (2.78 mm); OVB (1.88 mm)
Politi et al. 2004 [31]	G1:20 (LFI + +BSSO) G2:17 (LFI + BSSO)	G1: ANB (-4.2 ± 2.43°); OVJ (-5.7 ± 2.41 mm); OVB (0.5 ± 1.87 mm) G2: ANB (-3.3 ± 2.41°); OVJ (-4.6 ± 3.22 mm); OVB (0.9 ± 1.83 mm)	G1: ANB (1.50 ± 1.83°); OVJ (2.90 ± 0.84 mm); OVB (1.80 ± 1.17 mm) G2: ANB (1.20 ± 2.19°); OVJ (3.30 ± 1.19 mm); OVB (2.30 ± 1.20 mm)
Costa et al. 2006 [34]	G1:12 (LFI + BSSO G2:12 (LFI + BSSO)	G1: ANB (-3.5 ± 2.66°); OVJ (-4.60 ± 3.77 mm); OVB (1.10 ± 2.05 mm) G2: ANB (-2.9 ± 0.80°); OVJ (-5.10 ± 1.89 mm); OVB (0.80 ± 2.08 mm)	G1: ANB (1.00 ± 2.43°); OVJ (3.20 ± 1.31 mm); OVB (2.30 ± 1.40 mm G2: ANB (2.10 ± 1.86°); OVJ (2.00 ± 1.03 mm); OVB (2.80 ± 0.83 mm

Aydemir H. et al. 2015 [35]	G1:26 (LFI + BSSO)	G1: ANB (-4.27 ± 3.06); OVJ (-7.03 ± 3.46 mm); OVB (-2.29 ± 2.58mm)	G1: ANB (1.64±2.15°); OVJ (3.04 ± 0.97 mm); OVB (1.36 ± 0.63mm
Aydemir H.. Ufuk T.; 2015 [36]	G1:9 (LFI) G2:7 (BSSO) G3:32 (LFI + BSSO)	G1: SNA: 77.35 ± 1.5 SNB: 68.44 ± 3.9 ANB: -4.50 ± 0.6 G2: SNA: 78.48 ± 1.89; SNB: 66.03 ± 4.26; ANB: -2.23 ± 1.22 G3: SNA : 78.83 ± 0.60; SNB: 70.13 ± 1.32; ANB: -4.58 ± 0.52	G1: SNA: 81.97 ± 1.57; SNB: 67.16 ± 4.39; ANB: 0.87 ± 0.65 G2: SNA: 78.44 ± 1.72; SNB: 60.59 ± 3.76; ANB: 0.71 ± 0.89 G3: SNA : 81.73 ± 0.63; SNB 65.93 ± 1.16; ANB: 0.58 ± 0.38
Ghassemi. M et al 2016 [37]	G: 96 (LFI + BSSO)	SNA: 79.7 ± 4.8 SNB: 83.00 ± 5.5 ANB: -3.30 ± 3.4 Wits: -10 ± 5.5 Upper lip-E: −8.3 ± 3.3 Lower lip-E: −2.5 ± 3.3	SNA: 83 ± 5 SNB: 80.7 ± 5 ANB: 2.3 ± 3.3 Wits: -3 ± 4.4 Upper lip-E: −5.7 ± 3.7 Lower lip-E: −3.4 ± 3

Twelve articles shown in table 4 were analyzed to evaluate the stability of mandibular setback cases.

Table 4. Stability of only mandible setback surgery

Author	Number of patients	Relapse percentage (%)	Conclusion
Phillips et al 1986 [12]	19	47	Longer distance of mandibular setback rise the relapse percentage
Kobayashi et al 1986 [13]	44	16	Level of relapse was proportional to the horizontal distance of movement ($p < 0.01$)
Franco et al 1989 [14]	14	Not mentioned	Distance of mandibular setback was one factor to prognosis for relapse in single jaw surgery

Author	Number of patients	Relapse percentage (%)	Conclusion
Krekmanov et al 1989 [16]	14	7	Concluding that patients should had internal fixation with screws
Sorokolit and Nanda 1990 [17]	25	8	There was no relation between the distance of movement during surgery and level of relapse
Proffit et al 1991 [18]	40	60	Chin tended to relapse forward after surgery, surgery techniques should be adjused to reduce pressure on condyles.
Schatz and Tsimas 1995 [20]	13	Not mentioned	Horizontal movements increased risk of relapse.
Ingervall et al 1995 [21]	29	28	A large amount of mandibular setback increased risk of relapse.
Rodríguez and González 1996 [22]	14	50	Research determined that skeletal relapse was affected by amount of movement during surgery.
Harda and Enotomo 1997 [23]	20	Not mentioned	Fixation with titanium plate were more stable than poly – I – lactic plate
Mobarak et al 2000 [25]	80	36	The amount of setback had a little relation to relapse level, while clockwise rotation of ramus contributed early relapse.
Busby et al, 2002, [29]	18	B moved forwards (at the moment after 12 months: 3,24 ± 2,08 mm, 2 - 4 mm in 11% cases), Go moved forwards (at the moment after 12 months: 4,19 ± 2,76mm, 2 - 4 mm in 17% cases) and Pg moved forwards (at the moment after 12 months: 2,92 ± 2,51 mm, 2 - 4 mm in 22% cases). Co moved vertically/horizontally >2 mm in 33,3% cases; Co-Pg length increased 2 - 4 mm in 33,3% cases.	higher risk of relapse at cases that had more than 5mm of pre-operative anteroposterior deviation

IV. DISCUSSION

Effectiveness of Lefort I osteotomy and bilateral sagittal split ramus osteotomy in Class III malocclusion treatment

After 1986, bi-maxillary surgery combined with setting back the mandible by bilateral sagittal split ramus technique and bringing forward the maxilla by Lefort I osteotomy was widely applied for Class III malocclusion treatment due to better esthetic results, more stable and lower relapse rate. Lefort I osteotomy is indicated in cases that the maxilla needs to be moved forward and bilateral sagittal split ramus osteotomy is indicated in cases that the mandible needs to moved backward. In some situation, the mandible and chin position are actually too much forward, with a normal position of the maxilla, only mandibular setback surgery is needed.

In eleven articles, bi-maxillary osteotomy was applied [18; 19; 24; 26 - 28; 31; 34 - 37]. In these eleven articles, overjet was corrected from negative value before treatment to positive value after surgery. Additionally, the correlation between mandibular and maxillary bone was corrected from class III to class I. Subjects of two studies by McCance and Moldez were Class III malocclusion patients with dolicocephaly, open gonial angle, open bite [19; 26]. After two-jaw orthognathic surgery, they showed significant improvement in gonial angle, reduction of anterior facial lower third height, increasement of posterior facial lower third height. In McCance's study, overjet value was increased after twelve months following-up, but it was still negative. Overbite value was improved in five studies, from negative value to positive value [18; 19; 24; 26; 35]. Meanwhile, four other studies had pre-operative positive overbite value, and it was increased after surgery [27; 28; 31; 34]. In three studies by Aydemir, Ufuk, Ghassemi, the soft tissue post-operation correlation was more harmony [35 - 37]. Therefore, Lefort I osteotomy and bilateral sagittal split ramus osteotomy are an effective method for skeletal class III malocclusion treatment.

Nowadays, bimaxillary surgery is often performed in orthognathic surgery. In addition, the surgical plan has been further improved and supported by a three dimensional simulation application, thus bringing to more accurate planning and better postoperative outcomes [38 - 40].

Postoperative stability of Lefort I osteotomy and bilateral sagittal split ramus osteotomy for class III malocclusion treatment

Mandibular surgery only

Numbers of authors realized that an important factor that affects relapse was the amount of movement during surgery, while some others disagreed this relation. Phillips et al have noticed less relapse at the mandibular angle area in BSSO, but more relapse at point B [12]. Kobayashi et al have realized obvious relation between setback and relapse, especially in cases that have setback distance over 10mm [13].

Researches of Ingervall et al and Rodríguez and González had the same results with research of Franco et al. Ingervall et al also emphasized that personal technique of each surgeon in placing condyle in position was important for stability of treatment results [21]. Sorokolit and Nanda did not observe the relation between mandibular setback and relapse. They claimed that this result was due to large plate fixed anchorage in cortical bone after BSSO surgery and good occlusion after pre-surgery orthodontic [17]. According to Krekmanov and Harda, rigid fixation by titanium plates increased post-operation stability [16; 23].

Proffit et al observed large tendency of relapse related to level of clockwise rotation of ramus segment during surgery [18]. Schatz and Tsimas had the same conclusion, despite of lower level of relapse [20; 21]. Recently, Mobarak et al has reported 3-year post-operation stability cases with bigger sample size (80 patients) [25]. They also noticed the relation between setback surgery and relapse, while clockwise rotation of ramus caused relapse mainly in the first six month after surgery. In Busby's research, more than 5mm mandibular setback increased risk of post-operation relapse [29]. However, Class III malocclusion treatment by only mandibular setback surgery should be clinically limited for cases with less than 3 - 4mm reverse overjet. It is important to remember that setting back the mandible can lead to aesthetically impaired soft tissue underneath the chin, reduce the airway and increase the risk of sleep apnea.

In conclusion, most of the authors observed that the amount of setback distance played an important role in affecting long-term stability, while other authors found out the relation between relapse and level of clockwise rotation of mandibular ramus along with condyle reposition.

Combination of Maxillary advancement and Mandibular setback surgery

Franco et al realized the amount of setback distance have little effect on mesial segment in single-jaw surgery, but remarkable effect on both-jaw surgery [14]. They claimed that once the distal segment has been moved backward, the conjunction between mesial and lateral segment would be more tensive, tends to mandibular relapse. Although there were steps to prevent clockwise rotation of mesial segment in both single-jaw and double-jaw surgery, mandibular in double-jaw surgery was more likely relapse. Authors concluded that the more mandibular setback, the more tendency of rotating mesial segment. Proffit et al observed this relation, especially in cases of minimum maxillary vertical changing [18]. Mandibular stability in patients with long face was better with advancing maxilla rather than mandibular setback only.

Four studies by Costa, Politi, Busby and Choi shown that protruding the maxilla more than 6mm and great pre-operative deviation between two-jaw, can increase risk of relapse [27 - 29; 32]. Renzi stated that excessive backward position of mandibular condyle increased the hazard of relapse [30].

For more than 4mm reverse overjet cases, bimaxillary orthognathic is preferred due to better stability in bone and muscles, releasing the masseter. Factors that needs to be considered in vertical direction are the ratio between facial middle third and lower third, dentolabial relationship and gummy smile. Vertical over-growth of the maxilla is shown clinically by open mouth, gummy smile, excessive incisor exposed, suggesting that the maxilla should be moved upward. In contrast, a few cases of poor maxillary vertical growth, less exposing of the incisors, a mandibular rotating surgery should be performed. In cases of vertically increased facial lower third, genioplasty is necessary to reduce vertical dimension of occlusion. Horizontal correlations, occlusion relationship and aesthetic standards also need to be determined while planning the surgery. There are only a few specific cases, splitting the maxilla into two or more segments is considered; with this kind of surgery, the maxilla can only be changed 4-5mm horizontally because of inelastic palatal fibro-mucosa. The ratio between zygomatic bone peaks distance and mandibular angle distance is the horizontal aesthetic measuring scale. In Class

III malocclusion cases, the distance between zygomatic bone peaks is often reduced, and there are some methods proposed to increase the distance, such as artificial material implantation

To sum up, factors that may cause relapse can be mentioned about: clockwise self-rotation of the anterior segment due to muscles retraction, an over setting back of the mandible (measured at Pg, Go, B and Ar-B segment) and excessive backward movement of the mandibular condyle. Another relapse factor is the change in direction and magnitude of masseter and pterygoid muscle, causing an upward and forward force at gonial angle. In more than 7 mm anteroposterior deviation, the risk of relapse is higher because the mandible needs to be set back further. Therefore, early stage orthodontic treatment for class III malocclusion patients in their developing period to reduce bimaxillary deviation can help improve postoperative stability for orthognathic surgery at adult age.

V. CONCLUSION

Lefort I osteotomy and bilateral sagittal split ramus osteotomy are effective and stable ways for skeletal class III malocclusion treatment.

Less than 6 mm maxillary or mandibular movement in operation, and less than 7 mm preoperative inter - maxillary discrepancy reduce risk of relapse after surgery. Two-jaw operation is likely more stable than one-jaw only. Muscles retraction can cause postoperative relapse. Orthodontic at early stage for class III malocclusion patients in their developing period may reduce the deviation between maxilla and mandible, thus improving the stability for orthognathic surgery at adult age.

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