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Review Article

Treatment considerations for skeletal Class III orthognathic surgery

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Abstract

Class III malocclusion treatment is challenging to orthodontists because of its genetic basis and tendency for relapse following treatment. In adult patients, this malocclusion can be treated by either camouflage or combined orthodontic and surgical treatment. Since there are complexity in several aspects for Class III malocclusion, particularly in the case where the surgery is required, the aim of this review was to gather information concerning the etiologies, treatment strategies, and treatment considerations, especially for the orthognathic surgical treatment of skeletal Class III patients.

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Key words: *adult Class III, orthognathic surgery, skeletal Class III, treatment consideration, treatment stability.*

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Introduction

Class III malocclusion is a common dentofacial characteristics which derives from both dental and skeletal etiologies. The dental etiologies are upper incisor retroclination, lower incisor proclination, or a combination of the two (Ngan and Tremont, 2012). The skeletal etiologies are deficient maxillary growth, excessive mandibular growth, or a combination of these (Mossey, 1999; Ngan and Tremont, 2012). This malocclusion can be treated by orthopedic treatment in growing children, by orthodontic camouflage in non-growing adults with mild to moderate Class III malocclusion, or by orthognathic surgery in moderate to severe skeletal Class III. The treatment of Class III malocclusion is challenging for orthodontists because of its high relapse tendency (Baik, 2007) and genetic inheritance. Although maxillary protraction in Class III patient with a retrognathic maxilla was successful, 25% of these patients relapsed into anterior crossbite (Ngan et al., 1997b). Subsequent study also came up with the similar finding, i.e. one third of the patients treated by protraction facemask relapsed due to unpredictable excessive mandibular growth (Hagg et al., 2003). Chin cup therapy improved skeletal profile during the initial stage of treatment, however, the improvement was not maintained during the pubertal growth spurt (Sugawara and Mitani, 1997). If early treatment is discontinued before growth completion, the mandible continues to grow to its genetically determined shape (Mitani, 2007), causing recurrence of the prognathic mandible and Class III malocclusion, necessitating orthognathic surgery. Moreover, some Asians also have flat upper face (Ishida, 1992) that accentuate the prognathic mandible, which may result in more Class III patients seeking orthognathic surgical treatment. However, surgical correction of skeletal Class III cases also have demonstrated relapse during the first year post-surgery regardless of the surgical method (Proffit et al., 2007; de Haan et al., 2013). Therefore, the aim of this review was to gather information concerning the combination of orthodontic and surgical treatment in skeletal Class III patients.

Prevalence of Class III malocclusion

The prevalence of Angle class III malocclusion varies greatly within different ethnic backgrounds (Nikopensius et al., 2013), ranging from 0% to 26.7% (Hardy et al., 2012). Southeast Asians showed the highest prevalence at 15.80%. Middle Easterners, Europeans, and Africans had mean prevalences of 10.18%, 4.88%, and 4.59%, respectively. Indians had the lowest prevalence at 1.19% (Hardy et al., 2012).

In a US population, most skeletal Class III patients had a combination of an underdeveloped maxilla and overdeveloped mandible, with a normal maxilla with an overdeveloped mandible presenting less frequently (Ellis and McNamara, 1984). However, in Asians, the majority of Class III patients have a combination of a normal maxilla and an overdeveloped mandible, while a combined underdeveloped maxilla and an overdeveloped mandible is less commonly observed (Baik, 2007).

Types of Class III malocclusion

Pseudo Class III malocclusions: Functional shift

Pseudo Class III malocclusion is characterized by skeletal Class I or mild skeletal Class III, anterior crossbite with retroclined upper incisors and proclined lower incisors (Ngan et al., 1997a), Class I or mild Class III molar and canine relationships, and a straight profile (Nakasima et al., 1986; Ngan and Moon, 2015). In centric relation, the incisors of pseudo Class III patients meet in an edge-to-edge relationship, causing premature contact, and disocclude the posterior teeth. The mandible shifts forward into an anterior crossbite to obtain maximum intercuspation, causing a prognathic mandible in centric occlusion. However, if left untreated, pseudo Class III can lead to true Class III during the growth period (Nakasima et al., 1986; Ngan and Tremont, 2012).

True Class III

True Class III malocclusion is characterized by skeletal Class III, edge-to-edge or anterior crossbite with proclined upper incisors and retroclined lower incisors, Class III molar and canine relationships, and a straight to concave profile (Ellis and McNamara, 1984; Nakasima et al., 1986; Ngan et al., 1997a). The skeletal Class III phenotype exhibits an overdeveloped mandible (mandibular prognathism), an underdeveloped maxilla (maxillary retrognathism), or a combination of both (Nikopensius et al., 2013; Ngan and Moon, 2015). These morphologies are established pre-pubertally (Mitani, 1981), worsen during the pubertal growth spurt (Baccetti et al., 2007), and are maintained during the post-pubertal period (Mitani et al., 1993).

Etiology of Class III malocclusion

Class III malocclusion results from the interactions between susceptibility genes and environmental factors during the development of the mandible and maxilla.

Genetic Factors

Class III malocclusion predominantly demonstrates an autosomal dominant inheritance with incomplete penetrance or multifactorial inheritance (Litton et al., 1970; Cruz et al., 2008; Xue et al., 2010b). This phenotype can be recognized during childhood and becomes progressively more obvious during growth, motivating patients to seek orthodontic and surgical treatment (Nikopensius et al., 2013).

Numerous studies reported a significant genetic contribution to the development of Class III malocclusion. Patients with skeletal Class III malocclusion treated with orthognathic surgery had a high prevalence of Class III malocclusion in their families (Watanabe et al., 2005). Many chromosomal regions contain susceptibility genes for Class III malocclusion. For example, linkage to mandibular prognathism was found at chromosome 1 in a Chinese population (Xue et al., 2010a); chromosome 14 in Han Chinese (Li et al., 2011); and chromosomes 1, 6, and 19 in Korean and Japanese families (Yamaguchi et al., 2005; Jang et al., 2010). The genes found on these chromosomes are responsible for bone formation in the growth plate of long bones, and TMJ condyles (Xue et al., 2010b). There is also a relationship between a gene coding for Class I myosin and mandibular prognathism (Tassopoulou-Fishell et al., 2012). In contrast, linkage to both mandibular prognathism and maxillary deficiency with primary maxillary deficiency was found at chromosomes 1, 3, 11, and 12 in Columbian families (Frazier-Bowers et al., 2009); and chromosome 12 in Estonian families (Nikopensius et al., 2013). The genes on these chromosomes are involved in cell proliferation and differentiation, craniofacial development, and the premature fusion of the cranial sutures (craniosynostosis) (Frazier-Bowers et al., 2009; Nikopensius et al., 2013).

Environmental factors

Several environmental factors have also been suggested as contributing factors in the development of skeletal Class III. Those factors are enlarged tonsils, nasal blockage, congenital cleft lip and palate defects, hormonal disturbances or endocrine imbalances, such as those found in acromegaly, gigantism, and pituitary adenomas, abnormal tongue posture, and trauma or disease that cause an enlarged mandible or the forward positioning of the mandible (Mossey, 1999; Chang et al., 2006; Giancotti et al., 2003). Some dental factors also cause Class III malocclusion, e.g. premature loss of mandibular deciduous molars resulting in a Class III molar relationship, ectopic eruption of the maxillary incisors or premature anterior teeth contact that leads to a functional anterior crossbite (Nakasima et al., 1986; Giancotti et al., 2003).

Treatment strategies for skeletal Class III correction

The objectives for the treatment of Class III malocclusions are to maintain or improve a patient's facial esthetics, smile esthetics, function, and periodontal health; and a stable outcome (Ngan and Tremont, 2012). Class III malocclusion can be treated by orthopedic treatment, orthodontic camouflage, or orthognathic surgery. Treatment of Class III patients should be planned based on an individual's growth status, the severity of skeletal discrepancies in the antero-posterior, vertical, and transversal dimensions; incisor inclination, nasolabial angle, periodontal condition, change in occlusion, treatment planning preferences, and esthetic appearance after treatment (Baik, 2007). However, this review focuses on Class III treatment in adult patients, especially orthognathic surgery.

1. Non-surgical treatment: Camouflage Treatment

Orthodontic camouflage treatment can be performed in adolescents whose growth is almost complete or in adults with mild skeletal discrepancies. Camouflage treatment includes selective tooth extraction (premolars, lower incisors, or lower second molars), the use of the multiple edgewise arch wire technique to induce generalized distal tipping of the mandibular posterior segment, and the application of mini-implants to distalize the entire mandibular teeth (Baik, 2007). It is important to evaluate the morphology and size of the alveolar bone when planning the incisor position (Yamada et al., 2007) because subjects with Class III malocclusion usually have narrow and lingually inclined alveolus (slender symphysis) and mandibular incisors (Handelman, 1996; Yamada et al., 2007). The additional compensation may exceed the envelope of tooth movement and affect periodontal health such as causing bone dehiscence or fenestration. In these cases and those who need to improve their facial esthetics or open the upper airway, surgical orthodontic treatment should be considered (Proffit and Sarver, 2007; Posnick, 2014).

2. Orthognathic surgery

The combination of orthodontic treatment and surgery is the treatment of choice for moderate to severe skeletal Class III in non-growing patients. The orthodontist should decide whether to camouflage or to correct the skeletal discrepancies by orthognathic surgery because tooth movement is usually in the opposite direction for surgical versus nonsurgical treatment (Larson, 2014).

2.1 Conventional orthognathic surgery

Conventional orthognathic surgery is composed of three phases; presurgical orthodontic treatment, surgery, and post-surgical orthodontic treatment.

2.1.1 Presurgical orthodontic treatment phase

The goal of presurgical orthodontic treatment is to align the teeth in the proper position relative to their respective underlying skeletal base (Proffit and Sarver, 2007; Troy et al., 2009; Ngan and Tremont, 2012) or to create a presurgical dental discrepancy as great as the skeletal discrepancy (Larson, 2014). This phase consists of tooth alignment, dentition decompensation, and arch coordination. The presurgical occlusion acts as a guide for the surgeon to produce the optimal position of the skeletal parts during surgery. Moreover, the treatment should be planned so that the orthodontic and surgical relapse tendencies are in opposite directions in all dimension (Larson, 2014).

Tooth alignment includes correction of crowding, spacing, or rotations. Decompensation is important in all three planes of space: vertical, transverse, and anteroposterior dimensions (Ngan and Tremont, 2012; Larson, 2014). The characteristic incisor compensations that must be removed are proclined upper incisors and retroclined lower incisors. The use of Class II elastic is helpful in this phase. Transverse compensation with buccally tipped maxillary posterior teeth and lingually inclined mandibular teeth must also be corrected (Larson, 2014). Arch leveling may be included in this phase based on the degree of the curve of Spee, the desired final chin position, and lower facial height. If the lower incisors are extruded and face height is normal or excessive, they must be intruded so that a normal face height can be obtained at surgery by counterclockwise rotation of the mandible. With a short face, deep bite patients who need additional face height, it is advantageous to maintain the curve of Spee and level it after surgery (Proffit and Sarver, 2007; Conley and Legan, 2015).

Arch coordination depends on the surgical plan. If the maxilla and mandible will be treated as single piece, the shape and dimension of the whole arches are made compatible so that they will reasonably occlude following surgery. If one or both jaws are to be treated segmentally, the individual segments should be arranged so that the arches will be compatible following the planned surgical movement of the segments (Larson, 2014).

2.1.2 Surgical phase

Surgically repositioning the jaws to their optimal positions results in facial harmony. The surgical procedures to correct skeletal Class III malocclusion should be planned together with the oral surgeon prior to the start of orthodontic treatment. Anteroposterior correction of skeletal Class III will simultaneously affect the transverse relationship of the arches, and the vertical proportion of the face.

Maxillary deficiency will require 1-, 2-, or, 3- piece Le Fort I osteotomy with horizontal advancement. The need for additional changes in the maxilla should always be considered (e.g., transverse widening, vertical adjustment, midline correction, occlusal cant correction, upward or downward maxillary plane rotation). Mandibular excess is corrected by sagittal/vertical split ramus osteotomies to place the mandible into ideal occlusion with the opposing arch. Two-jaw surgery is often performed in cases of maxillary deficiency with relative mandibular excess. Genioplasty with horizontal or vertical repositioning of the chin is also frequently desirable (Posnick, 2014). This procedure helps create labiomental fold, maintaining sufficient chin-throat length, correlating the chin midline to the facial midline, and obtaining appropriate vertical facial proportions (Huang and Chen, 2015).

2.1.3 Postsurgical orthodontic treatment phase

Settling and finishing of the occlusion will be achieved during this phase. The orthodontist should see the patient within 24 hours after splint removal at approximately 5 weeks after surgery, and replace the sectional wires with a rigid continuous arch wire in cases that have undergone segmental osteotomy. The teeth are then ligated together to maintain the arch form. The use of a transpalatal wire or an acrylic palatal plate may also be used to stabilize the arch form if significant transverse expansion was carried out. Close monitoring for skeletal and dental relapse and detailing during the first 6 months after surgery is essential (Posnick, 2014). Occlusion settling can be achieved by archwire bending or using light round wires and posterior box elastics with Class III vectors. Elastics should be continued until a solid occlusion is established (Conley and Legan, 2015).

2.2 Surgery-first approach

In conventional orthognathic surgery, a decompensation procedure to help creating a predictable and precise final outcome can take 12 months or more, and the patient's occlusion and esthetics often becomes gradually worse as the dentition moves to a more optimal position in each jaw. Moreover, orthodontic tooth movements can also be difficult because of an improper environment, e.g. inappropriate jaw relationship, muscle strain, or occlusal interference from opposing teeth. Recently, orthodontists have promoted a surgery-first procedure to avoid this part of the treatment. The obvious advantages are a short preparation period and subsequently a shorter total treatment duration, psychosocial benefits, and rapid creation of a favorable environment for orthodontic tooth movement after surgery (Baek et al., 2010; Manosudprasit et al., 2012; Ngan and Moon, 2015; Sharma et al., 2015).

The presurgical procedures include both laboratory and pre-surgical clinical procedures. Setting up the models using a semi-adjustable articulator is recommended to separately plan the tooth and jaw movements, and facilitate surgical wafer fabrication (Baek et al., 2010). The molar relationship is a guide to predict the final occlusion, e.g. Class I molar relationship in non-extraction cases, Class III molar relationship for lower premolar extraction cases, and Class II molar relationship for upper premolar extraction cases (Liou et al., 2011a). These procedures are similar to those performed in conventional orthognathic surgery. In contrast to conventional method that use rigid arch wire with hooks for intermaxillary fixation, brackets are placed a few days before surgery with passive stainless steel wires (Liao et al., 2010) to prevent tooth movement, or nickel-titanium (NiTi) alloy wires to allow for immediate tooth movement after surgery (Nagasaka et al., 2009). Other methods for intermaxillary fixation are to directly bond the archwire to the teeth (Baek et al., 2010), to place miniscrews into the upper and lower alveolar processes (Hernandez-Alfaro et al., 2011), or to use preformed arch bar.

2.2.1 Surgical phase

In the surgery-first approach, the surgical procedure to correct the skeletal problem is performed prior to post-surgical orthodontic treatment. The surgery-first approach uses an osteotomy to correct most of the skeletal and dental problems to obtain a skeletal Class I relationship and an esthetically pleasing face. This procedure also simplifies postoperative orthodontic treatment by providing a treatable malocclusion where typically only anteroposterior orthodontic movement is required, with minimal transverse or vertical orthodontic movements (Huang and Chen, 2015).

There is a suggested surgical sequence where midline discrepancy, rotation of the arch around the axial plane (yaw), and occlusal cant (roll) should be corrected first to attain a correlation between the facial midline and the symmetry of all bilateral structures, and surgical correction of skeletal discrepancies along the sagittal plane should be performed last. The maxillary movement should be performed before the mandibular movement. The factors that need to be considered for vertical, anteroposterior, and transverse position are maxillary incisor display and lip incompetency, nasolabial angle, and smile arc for the anterior maxilla; and lower facial height, lower lip and chin contour, and the harmony of the smile arc for the mandible (Huang and Chen, 2015). Moreover, overcorrection is needed for de-crowding and the correction of proclined upper incisors and retroclined lower incisors after surgery (Liou et al., 2011a).

2.2.2 Postsurgical orthodontic treatment phase

Postoperative orthodontic treatment should also be planned to attain a positive overbite and overjet, as well as maximum intercuspation. A posterior open bite resulting from an excessive curve of Spee can be levelled through segmental osteotomy, or improved post-operatively through orthodontic movement and regional acceleratory phenomena (RAP), a transient increase in localized bone remodeling along the cut of the cortical bone during the surgical procedure, which results in PDL space widening and increasing the tooth movement rate (Yaffe et al., 1994; Wilcko et al., 2008; Liou et al., 2011b). Premature contact caused by transverse discrepancy in the canine or premolar areas can also be corrected through segmental osteotomy, or improved postoperatively through selective grinding, or RAP and orthodontic movement. Postoperative orthodontic treatment can typically be finalized within 12-18 months after orthognathic surgery (Huang and Chen, 2015).

There are, however, some disadvantages with the surgery-first approach. It is difficult to match the dentition without proper orthodontic decompensation before surgery, especially when dental alignments do not coordinate well between the two arches. A surgical splint or wafer is often used for jaw positioning and precise prediction of postsurgical orthodontic movements. Therefore, careful surgical planning for proper jaw position allowing for postoperative orthodontic decompensation is essential and accurate wafer fabrication is critical. A major consideration for the surgery-first approach is overcorrection to compensate for the space required for final tooth alignment (Baek et al., 2010; Manosudprasit et al., 2012; Kim et al., 2014). Therefore, the indications for the surgery-first approach are mild to moderate crowding, flat to mild curve of Spee, normal to mild proclination of the upper incisors and retroclination of the lower incisors (Liou et al., 2011a), minimal transverse or vertical problems, and stable occlusal stops with minimum of 3 points of contact between the upper and lower arches (Baek et al., 2010). For patients requiring minimal decompensation, this technique is favorable. However, in patients requiring major postoperative orthodontic movement, treatment with a conventional method is advised (Ngan and Moon, 2015).

Stability of skeletal Class III orthognathic surgery

Neuromuscular adaptation is an important factor for stability post-surgery. Neuromuscular adaptation affects muscle length, not muscle orientation. Stability is greatest when soft tissues are relaxed during the surgery and least when they are stretched (Proffit and Sarver, 2007). A systematic review in 2007 described post-surgical relapse as the change in jaw position during the first post-surgical year, which relates directly to the surgical healing, post-treatment orthodontics, and short-term physiologic adaptation. The most highly stable surgical procedures (>90% of the patients) involved in skeletal Class III correction are maxillary impaction and correction of chin button position. Maxillary advancement is a stable procedure with little or no change in the position of the maxilla in approximately 80% of the patients. However, the combination of maxillary advancement and mandibular setback procedures, and correction of maxillary asymmetry will be stable only with rigid fixation. In asymmetric advancement or setback of the mandible cases, nearly 50% of the patients have a more than 2 mm relapse of the chin towards its original position. Surgical procedures associated with relapse include mandibular setback, maxillary downward movement, and maxillary expansion (Proffit et al., 2007).

Maxillary orthognathic surgery

Maxillary impaction procedures result in counterclockwise rotation of the mandible, relaxing the soft tissues. This procedure increases the occlusal force that tends to maintain the new maxillary position (Proffit and Sarver, 2007). In contrast, moving the maxilla downward is problematic because occlusal force tends to push it upward before bone healing is complete. Proffit and colleagues suggested three logical approaches to maintain the position of the maxilla until it heals; heavy rigid fixation, a rigid hydroxy apatite graft in the defect created by the downward movement, and simultaneous mandibular surgery to decrease the occlusal force (Proffit et al., 2007).

Segmental osteotomy to widen the maxilla tends to be unstable because of the pull of the stretched palatal tissues. Strategies to control relapse include overcorrection and careful retention with either a heavy orthodontic archwire or a palatal bar during the completion of orthodontic treatment, and then using a palate-covering retainer for at least the first postsurgical year. Surgically-assisted rapid palatal expansion (SARPE) improves stability because of a slower expansion rate and, perhaps more importantly, rigid retention. SARPE is preferred if only expansion is required. However, it is not an attractive approach if a second surgery is needed for antero-posterior or vertical change in the position of the maxilla (Proffit and Sarver, 2007; Proffit et al., 2007).

Mandibular orthognathic surgery

During sagittal split osteotomy of the mandible, rigid fixation procedures might alter the position of the proximal segments. These segments tend to move back towards their presurgical positions following surgery (Cho, 2007) because of the pull of the stretched muscles (Proffit et al., 2007). Condylar sagging during mandibular surgery is common because the patient is in a supine position during the operation, and the condyles move posteriorly in their fossae. After inter-maxillary fixation is removed, the condyles reposition, and the mandible moves anteriorly, mimicking surgical relapse. Downward movement of the maxilla also creates downward-backward rotation of the mandible, displacing the condyles from its fossae. This change in condylar position can cause relapse similar to condylar sagging (Ngan and Moon, 2015). Moreover, relapse may occur if the pterygomandibular sling is stretched by changing the inclination of the mandibular ramus when the mandible is rotated to close an open bite as it is set back (Proffit and Sarver, 2007). It is possible that postsurgical restriction of the tongue space may be a factor in mandibular relapse and that maxillary advancement surgery would provide more space for the tongue (Cho, 2007). Several studies (Proffit et al., 1990a; Proffit et al., 1990b, 2012) of the surgical management of most skeletal Class III patients confirmed that relapse at the ramus osteotomy site is a common occurrence, and better long-term skeletal and occlusal stability is achieved with two-jaw surgery (i.e., maxillary advancement with limited mandibular setback). Therefore, almost all US Class III patients now receive maxillary advancement, either alone or (more frequently) combined with mandibular setback (Ngan and Moon, 2015). Another possible factor in relapse after mandibular setback surgery is the expression of some remaining mandibular growth potential as occurs in condylar hyperplasia (Cho, 2007).

Muscular adaptation

Differences in gene expression resulting in different muscle fiber types in each individual is also believed to be an important factor in postsurgical stability. Orthognathic surgery improves the quality and efficiency of the occlusion, which may induce less muscle activity because of the increased number of tooth contacts, but equally, it may facilitate the development of greater force dissipation through the greater number of tooth contacts (Harzer et al., 2007). There is a tendency to have more muscle fiber types present in less stressful situations after surgery due to increased occlusal contacts, and lead to greater muscle volume and higher muscle force development (Harzer et al., 2010). A study of the alteration of masticatory electromyographic activity and the stability of orthognathic surgery in patients with skeletal Class III malocclusion found that larger sagittal relapse of mandibular setback occurred in patients with greater masticatory muscle activity. Modifications in surgical design and overcorrection should be considered in patients with greater initial masticatory muscle activity (Ko et al., 2013).

Comparison between surgery-first and conventional orthognathic surgical approaches

Mandibular setback without presurgical orthodontic treatment was less stable compared with conventional orthognathic surgery for patients with mandibular prognathism. Although the mean setback of the mandible at the B point was similar, the horizontal relapse in the surgery-first group (2.4 mm) was significantly greater than that in the conventional surgery group (1.6 mm). Moreover, there were twice in number of patients with a greater than 3 mm horizontal relapse in the surgery-first group (39.1%) compared to the conventional surgery group (15.8%) (Kim et al., 2014). Because occlusion cannot be used as a guide for the surgical correction of skeletal discrepancies, postsurgical occlusal instability during the postsurgical bone healing phase was inevitable in the surgery-first group and may have led to potential skeletal instability (Kim et al., 2014). However, for two-jaw surgery, there was no significant difference in mandibular relapse after treatment between conventional and surgery-first approaches (Ko et al., 2011). A systematic review reported that correcting skeletal Class III by two-jaw surgery whether using a surgery-first approach or an orthodontics-first approach had similar long-term outcomes in dentofacial relationships in the transverse, vertical, and sagittal dimensions, except for slightly increased upward mandibular movement following surgery in the surgery-first approach (Huang et al., 2014).

Treatment considerations for orthognathic surgery in skeletal Class III patients

Deciding to treat skeletal Class III patients with orthodontic camouflage or combined orthodontic and surgical treatment

Orthodontists should decide whether to compensate or to correct the skeletal discrepancies by a combination of orthodontic treatment and surgery because tooth movement is usually in the opposite direction for surgical versus nonsurgical treatment (Larson, 2014). Poor results are likely to happen with orthodontic camouflage and orthognathic surgery should be performed in patients with moderate to severe Class III patterns (>4 mm of reverse overjet), moderate to severe vertical or transverse skeletal discrepancies, significant dental crowding (>4-6 mm.) in the lower jaw, and significant anterior dental protrusion in the upper jaw (Proffit and Sarver, 2007). In addition to these general guidelines, some studies (Stellzig-Eisenhauer et al., 2002; Tseng et al., 2011) attempted to identify the decisive variables to distinguish the skeletal Class III patients who can be treated by orthodontic therapy alone from those who require combined orthodontic and surgical treatment.

The use of discriminant analysis (Stellzig-Eisenhauer et al., 2002) correctly classified 92% of cases, whether the patients would be successfully treated by orthodontic treatment alone or by a combination of orthodontic and surgical treatment. The variables involved in the regression models were Wits appraisal, length of the anterior cranial base, maxillary/mandibular (M/M) ratio, and lower gonial angle. Among these four variables, Wits appraisal was the most decisive parameter. Another study using receiver operating characteristic analysis (Tseng et al., 2011) reported that for a Class III malocclusion patient with any 4 of these 6 measurement criteria: overjet ≤ -4.73 mm, Wits appraisal ≤ -11.18 mm, L1-MP angle ≤ 8 0.8°, M/M ratio ≤ 65.9%, overbite ≤ -0.18 mm, and gonial angle ≥120.8°; the sensitivity was 88% and the specificity was 90% in determining the need for surgical treatment: From these studies, Wits appraisal, M/M ratio, and gonial angle are important factors in determining the appropriate treatment for skeletal Class III patients.

Presurgical orthodontic decompensation

Orthodontists should assess the level of the attached gingiva, the position of the labial and lingual plates, and the alveolar crest heights in planning orthodontic movement (Posnick, 2014). To decompensate all the discrepancies in skeletal Class III patients, it is important to consider the envelope of tooth movement for the anterior and posterior teeth (Proffit and Sarver, 2007; Graber et al., 2011).

Patients with mandibular prognathism usually have lingually inclined mandibular central incisors, and lingually inclined and slender symphysis. The mandibular central incisor root apices are closer to the inner contour of the labial cortical bone than to the lingual cortical bone. A slight labial tipping of the mandibular central incisors, which moves the root apex close to the center of the alveolar bone, may be acceptable. However, lingual tipping of the incisors may cause problems. In a patient whose incisor root apex is very close to or attaches directly to the inner contour of the labial cortical bone, lingual tipping of the incisors for orthodontic camouflage is not a reasonable treatment alternative (Yamada et al., 2007).

Periodontally accelerated osteogenic orthodontics (PAOO), or corticotomy, suggested by Wilcko and colleagues (Wilcko et al., 2008) is also recommended for de-crowding and protraction of incisors in thin alveolar bone, intrusion or extrusion of incisors, and expansion for correcting a posterior crossbite with a more stable outcome (Ferguson et al., 2015). This procedure creates cuts in the labial and lingual alveolar cortical bone in the area of the desired tooth movement. These cuts increase the soft and hard tissue turnover, resulting in faster tooth movements for 4-6 months after corticotomy procedure, and remarkable stability. Bone grafting is also placed at the corticotomy sites, which expands the hard and soft tissue limits for tooth movement (Murphy et al., 2009). PAOO expands the limit of orthodontic tooth movement described by Proffit (Proffit and Sarver, 2007) by 2-3 fold in all dimensions except for retraction. Therefore, presurgical orthodontic treatment could be finished faster with less risk of cortical plate perforation. For severe mandibular excess with deficient overjet, only orthognathic surgery is applicable because PAOO cannot move the jaw in the anteroposterior spatial plane (Ferguson et al., 2015).

A case report described using microimplants for anchorage to intrude the molars, rather than using maxillary surgical impaction, and the resultant rotation of the maxillary occlusal plane clockwise to increase the surgical mandibular setback and reduce the posterior vertical dimension. The 15-month retention records showed good occlusion without obvious relapse. However, the author suggested that to intrude molars more than 2-3 mm, surgical correction rather than orthodontic intrusion should be considered. Moreover, the use of clear retainers on both arches may retain the vertical position of the posterior teeth because the bite force generates an intrusive force to the posterior teeth through the appliance while patients wear it. Microimplants can also work as retention devices after the intrusion of posterior teeth by providing attachments for vertical elastics (Park et al., 2010).

Proper transverse dental relationships are necessary to achieve maximum occlusal function. The expansion or constriction of the maxillary dental arch by surgical procedures is necessary in some cases. Because transverse maxillary deficiency is often seen in mandibular prognathism patients, it can be corrected with 3- or 4-segmental maxillary osteotomy simultaneously for intermaxillary arch congruity in those who require maxillary advancement. However, segmentation of the maxilla increases the risk for skeletal, dental, and periodontal complications, and an unstable outcome. SARPE has been recommended for older patients. In patients with mild transverse maxillary deficiency, maxillary premolar extraction with greater surgical jaw repositioning is recommended rather than surgical transverse correction. Maxillary premolars are often extracted to resolve incisor proclination and crowding. Therefore, it is essential to assess arch width and posterior tooth inclination as well as maxillary crowding and alveolar protrusion to discriminate between maxillary premolar extraction and non-extraction patients (Lee et al., 2006).

In Thai population, we noticed that skeletal Class III patients sometimes present with good posterior occlusion because of a wider maxillary arch that needed to be constricted together with a mandibular set back procedure. Although there are no reports comparing dental arch width in Thai Class III patients and other ethnic groups, a study comparing dental arch width between Thai and US Angle Class I patients found that although Thai had a slightly larger maxillary intermolar width, both groups demonstrated a similar mandibular intermolar width (Dechkunakron et al., 1995). The larger maxillary width in the Thai population might be the reason for good posterior occlusion in Thai Class III patients. However, there is a lack of research on methods and stability of maxillary arch constriction. From current knowledge, envelope of discrepancies should be applied, i.e. orthodontic constriction is possible if the amount of constriction required is less than 4 mm, otherwise surgical constriction of the maxilla should be considered (Graber et al., 2011). Maxillary premolar extraction to constrict the maxillary arch in Class III presurgical orthodontic treatment might be a good option if the maxillary incisors are proclined and the posterior teeth are buccally inclined. The use of miniscrews might also help to constrict maxillary posterior teeth. However, if the maxillary posterior teeth are properly inclined and occlude with the lower posterior teeth with a normal buccal overjet, a 3-piece Le Fort I maxillary osteotomy to constrict upper posterior teeth may be needed. Never the less, the complication and stability of this method should be considered.

Class III correction and airway problems

A study comparing airway changes between mandibular setback procedures and combined maxillary advancement and mandibular setback found that bimaxillary surgery can prevent narrowing of the upper airway in the correction of Class III deformities compared with mandibular setback surgery used as the sole treatment (Degerliyurt et al., 2008) in both males and females (Degerliyurt et al., 2009). Patients who underwent bimaxillary surgery showed an increase in upper airway and a decrease in lower airway size. Patients who received mandibular setback surgery showed an insignificant decrease in airway size, and those who underwent maxillary advancement showed a significant increase of the airway dimension that remained stable during the evaluation period. Consequently, maxillary advancement seems to be the most stable surgical movement in relation to airway dimensional gain. A mandibular setback procedure pushes the tongue posteriorly, resulting in narrowing of the pharyngeal airway (Greco et al., 1990; Pereira-Filho et al., 2011). In patients with a compromised airway, mandibular setback can sometimes further restrict the airway. Two-jaw surgery or subapical segmental osteotomy can be considered for these patients (Ngan and Moon, 2015).

Conclusion

Asian populations show the highest prevalence of Class III malocclusion, and the majority of these patients have mandibular prognathism. Class III malocclusion results from the interactions between susceptibility genes and environmental factors during the morphogenesis of the mandible and maxilla. Several genes on chromosome 1 and 12 have been linked to the development of maxillary retrognathism and mandibular prognathism.

For mild to moderate skeletal Class III patients, orthodontists should consider the severity of the malocclusion (degree of existing compensation), and decide whether to camouflage or to correct the malocclusion by orthognathic surgery. However, moderate to severe skeletal Class III patients, including those who did not respond to orthopedic treatment, orthognathic surgery should be considered (Hagg et al., 2003; Posnick, 2014). Presurgical decompensation can be performed with less risk of cortical plate perforation using corticotomy with bone graft for de-crowding and proclination of the lower incisors in patients with a slender symphysis. Moreover, some surgical movement can be replaced with orthodontic treatment, e.g. using temporary anchorage devices for correcting a mild degree of occlusal plane canting, or vertical maxillary excess. However, orthognathic surgery treatment should be planned based on the severity of the skeletal discrepancies in the sagittal, vertical, and transversal dimensions, facial pattern, incisor inclination, nasolabial angle, periodontal condition, airway size, esthetic and treatment planning preferences for patients, and stability of each orthognathic surgery procedure.

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