Craniofac Res. 2022; 1(2):88-102. Received: 2022-03-06 / Accepted: 2022-03-28

Dental crowding and/or spacing in orthognathic surgery: Incorporating premolar extractions in the treatment of class III malocclusion. A review and case series

Apiñamiento dental y/o espaciamiento en cirugía ortognática: Incorporación de extracciones de premolares en el tratamiento de maloclusión clase III. Una revisión y serie de casos

Asher Adamec[1,2] Waleed S Zaid[1,2] Víctor Ravelo[3,4] Ziyad S Haidar[4,5,6,7]

[1] Louisiana State University Health Sciences Center, Baton Rouge, New Orleans, Louisiana, USA.
[2] Department of Oral and Maxillofacial Surgery, Louisiana State University, Baton Rouge, New Orleans, Louisiana, USA.
[3] Grupo de Investigación de Pregrado en Odontología (GIPO), Universidad Autónoma de Chile, Temuco, Chile.
[4] BioMAT'X I+D+I (HAiDAR LAB), Universidad de los Andes, Santiago, Chile.
[5] Facultad de Odontología, Universidad de los Andes, Santiago, Chile.
[6] Centro de Investigación e Innovación Biomédica (CiiB), Universidad de los Andes, Santiago, Chile.
[7] Programa de Doctorado en BioMedicina, Facultad de Medicina, Universidad de los Andes, Las Condes, Santiago, Chile.

Correspondence
Prof. Dr. Ziyad S. Haidar
BioMAT'X R&D&I Research Group and Laboratory (HAiDAR LAB)
Centro de Investigación e Innovación Biomédica (CiiB)
Faculty of Medicine and Faculty of Dentistry
Universidad de los Andes
Avenida Mons. Álvaro del Portillo 12.455 - Las Condes
Santiago
CHILE

E-mail: zhaidar@uandes.cl

ADAMEC A, ZAID WS, RAVELO V, HAIDAR ZS. Dental crowding and/or spacing in orthognathic surgery: Incorporating premolar extractions in the treatment of class III malocclusion. A review and case series.*Craniofac Res*. 2022; 1(2):88-102.

ABSTRACT: Craniofacial profile, maxilla-mandibular relations, dento-alveolar bone discrepancies, skeletal maturation and dental asymmetries are important elements of an orthodontic and orthognathic diagnosis and treatment planning. For proper position and angulation of teeth, orthognathic surgery aims to correct dental crowding, spacing, misalignment and rotations of teeth, via tooth/teeth extractions for example, as part of the umbrella orthodontic and orthognathic interventional treatment plan. Indeed, exodontia is often needed to relieve moderate to severe crowding (arch-length discrepancies) and create the needed space for the proper alignment of the dentition and eventual functional occlusion. Herein, first and second premolar extractions are often prescribed, preferably when other methods have been exhausted. Yet the discussion regarding the use of premolar extractions is not whether exodontia should be performed, yet rather what malocclusion class, tooth-size and tooth-space discrepancy (including bi-maxillary protrusion and severe crowding in maxilla and mandible) indicate premolar extractions, when the intervention should be done, and whether to extract the first or second premolar. Therefore, in this article we highlight the premolar exodontia considerations for orthodontic and orthognathic treatment planning (pre-treatment) via discussing the basic mechanics and advantages of intra-/inter-arch movements. This is followed by presenting clinical cases exhibiting the incorporation of premolar extractions in (a) pre-surgical orthodontic treatment; (b) surgical plan and intervention; and (c) post-surgical outcome and prognosis. Alternative techniques and treatment options useful in tackling skeletal and dental malocclusion, including lateral body and sub-apical osteotomy(ies), that might consider integrating first and second premolar extractions, are also presented, herein.

KEY WORDS: Orthodontics; Orthognathic surgery; Corrective Jaw Surgery; Class III.

INTRODUCTION

Orthognathic surgery plays an important role in the craniofacial field to correct both functional and aesthetic problems (Park *et al*., 2020). Orthognathic treatment aims to optimize both, facial harmony and functional occlusion, via correcting mal-positions of basal bone and the associated or resulting malocclusions. Yet, today, facial aesthetics are stalwartly esteemed and pursued. Indeed, every so often, even more than occlusion, function and comfort, and hence, represent a vital conclusion of orthodontic and orthognathic treatment planning and intervention, for the patient and his/her family. However, for a patient presenting with a concave profile with class III malocclusion, most often due to a combination of maxillary hypoplasia and mandibular hyperplasia, surgical correction entails the normalization of jaw positions, hence, a much more challenging procedure in/for the setting of concurrent asymmetry and open bite. Therefore, orthognathic surgery for class III deformities occurs at skeletal maturity and should address all considerable aspects whilst preventing or lessening unnecessary emotional stress to the patient and his/her family. Indeed, recent trends in plastic and reconstructive surgery has been to minimize the period of treatment to reduce patient discomfort and improve compliance. Herein, dental extractions, in general and premolar exodontia, in specific, cannot be avoided, perhaps, and are often indicated and performed for severe crowding, excess dento-alveolar protrusion and skeletal/inter-arch discrepancies camouflage, with varying prevalence over time (Omar *et al*., 2018). While Edward Angle, based on the concept of the occlusion line, in the early twentieth century, supported and promoted the "non-extractionist theory", Orthodontist Charles Tweed, an Angle's faithful student and later a fierce opponent, was one of the first to introduce the concept of extracting four premolars to re-correct malocclusion (in cases where the lower incisors did not end in a vertical position relative to the bone base), when he noted that the majority of his previously-treated patients suffered from orthodontic relapse. Herein, premolar exodontia was successful in achieving better functional as well as aesthetic results. Indeed, his re-treatment results, in the 1940s, paved the way for the orthodontic and orthognathic communities to accept and indicate permanent tooth extractions and "extraction-based techniques". Further, Begg also embraced this technique via employing exodontia to create space and allow adequate anchorage (Brezulier *et al*., 2017). Remarkably, Proffit reviewed the data from clinical cases over 40 years at his university clinic and showed that in the 1950s, 30% of orthodontics cases needed/required extractions when compared to 76% in the late 1960s and 28% in the 1990s (Proffit, 1994;1995; 2000). Proffit attributed this decline in the need for premolar extraction to the unattractive soft tissue profile resulting from extractions and incisor retraction, questionable temporo-mandibular joint dysfunctions, and the overall improvement and advancement in the available orthodontic arch-wires (Proffit, 1994;1995; 2000). Since then, the opt for and use of premolar extractions became more widely accepted. Keim *et al*. (2002) reported in 2002 that of the 789 orthodontists surveyed, 95% had performed extractions that year (Kem *et al*., 2002). More recently, the discussion regarding the use of premolar extractions is not whether it should be done, but rather which class of malocclusions are candidates and indicated for its use and when the intervention should be done. Indeed, borderline cases (with total discrepancy variations ranging between -3 mm and -6 mm) can be challenging and the diagnosis of some malocclusions can be rather ambiguous, according to Dewel (1955), in terms of the need for extractions. Herein, it can be summarized that contemporary premolar exodontia is indicated in the treatment of cases of malocclusion, including severe crowding, uni-lateral agenesis, bi-maxillary protrusion, convex facial profiles and large cephalometric discrepancies. In a borderline case, particularly, it is essential to carefully evaluate the dental, facial and skeletal characteristics, for a successful treatment plan. This article aims to further examine such indications and decision-making means, especially in light of recent trends in craniofacial surgery, with the increased incorporation of rigid fixation and bone graft substitutes, sacrificing facial aesthetics to attain stability and achieve a normal occlusion is no longer necessary, resulting in that orthognathic surgery now can be envisioned truly as aesthetic surgery.

Contemporary Surgically-Assisted Corrective Strategies, Methods and Techniques

Spacing and Space Creation

An increasing percentage of patients are adults with challenging malocclusions. Indeed, dental crowding is

prevalent and can be considered the most common type of malocclusion. Briefly, it can be defined as a discrepancy or disparity in the relationship between tooth and jaw/arch size (tooth size-arch length discrepancy resulting in mal-alignment of dentition due to the limited or inadequate space). Actually, dental crowding is possible before as well as after the completion of orthodontic treatment. Therefore, the treating team must obtain reliable measurements for (deducing) the needed space/spacing via properly analyzing the patient's occlusion, whether through dental casts/models, directly from the teeth and/or radiographic imaging. Thereafter, several spacing and space creating strategies are available, including the utilization of the leeway space, distalization (moving - backwards) of the second molar, maxillary arch expansion (with a palatal expander appliance), orthognathic surgery to expand the maxillary arch (for example, surgically-assisted rapid palatal expansion or SARPE, also commonly known as surgically-assisted rapid maxillary expansion or SARME – indicated for adult patients with fused maxillary sutures that cannot be expanded otherwise), incisor advancement, inter-proximal enamel reduction, and/or creating space using dental extractions. The later strategy is usually utilized in moderate to severe cases, or when/if the previously-mentioned techniques were deemed unfruitful. It is worth-mentioning herein that the major contributing factors for predicting changes in/to the soft tissue profile of the patient during orthodontic treatment are: (a) amount of horizontal movement of the most anterior point of the maxillary incisor, (b) amount of bite opening, and (c) initial lip thickness. Thus, the need for practical diagnoses and treatment plans that assure good and stable results is real. As was mentioned, this article attempts to highlight the orthodontic and orthognathic considerations (vital for diagnosis and Rx plan) once opting for premolar/s exodontia.

Incisor Movement

An anterior crossbite could be dental, skeletal or functional, and so, a well-conceived treatment plan is essential for achieving a favorable outcome. In brief, anterior crossbite, a major esthetic and functional anomaly, can be defined as the reverse overlap of the incisors (resulting from the abnormal axial inclination of one or more anterior teeth), ensuing excessive attrition, deteriorated gingival health, TemporoMandibular Joint (TMJ) problems and poor masticatory efficiency. Now, in mild (1 mm - 4 mm) to moderate (4 mm - 7 mm) cases, a non-extraction strategy via inter-proximal enamel reduction or IER (using handheld abrasive strips, discs, burs and mechanical rotary systems, etc.) can be beneficial in spacing and creating space(s) without compromising the dental supporting structures. Overall, the lower and upper incisors antero-posterior (AP) position should be in a favorable position to attain stability over the basal bone. In class II, division I malocclusion, the upper incisors must be retracted for overjet reduction. Equally, in Class III malocclusion, the upper incisors may be advanced, and the lowers retracted to correct a reverse overjet. Herein, for every 1 mm, all four incisors are retracted, 2 mm of space is required, which entails borrowing 1 mm per hemi-arch. Another consideration during orthodontic treatment is the inclination of the incisors as the altering of this inclination uses arch length space. Herein, for every 5º of incisor proclination, approximately 1 mm of space is needed. Conversely, 0.5 mm of space is necessary to retrocline the incisors 5º. This is an essential element to consider, especially as it pertains to the overall amount of space required. It is worth-mentioning and to keep in mind that proclination and retroclination of anterior teeth can have significant impact and effects on both, facial profile as well as lip support. Some studies have shown that for every 1 mm of incisor retraction, there is 0.5 mm - 0.75 mm of upper lip retraction and 0.6 mm - 0.78 mm of lower lip retraction (Talass *et al*., 1987; Massahud & Totti, 2004; Ramos *et al*., 2005). Omar *et al*. conducted a retrospective clinical study concluding no statistically significant difference in soft tissue profile when compared to if all four first premolars were extracted versus second premolars (Omar *et al*., 2018; Park *et al*., 2020). Hereafter, an analysis of tooth size and arch length should be investigated. Amount of crowding can be measured via taking the mesio-distal width of the mis-aligned teeth and subtracting from the available space within the arch form. Henceforth, exodontia is often reserved for some moderate crowding (4 mm - 7 mm) if IER falls short in providing the required space for dentition alignment, and typically for each severe crowding (> 7 mm) case.

First versus Second Premolar Exodontia in Orthognathic Surgery: The Decision

It is commonly-suggested that the most common treatment

option for anterior cross-bite with severe crowding is extraction of upper second and lower first premolars. However, as discussed earlier, proper/correct diagnosis of malocclusion leading to the decision in favor of exodontia (first OR second premolars) is not a simple and trouble-free undertaking, with documented impact, and especially so in the afore-mentioned borderline cases. Hence, rigorous diagnostic assessment is critical for a successful treatment plan. Therefore, before embarking on the details of how to decide which premolar is indicated for exodontia, it is essential to understand the predictable patterns of compensation that occur in patients with class II skeletal malocclusion when compared to the dental compensation arising in patients with class III malocclusion. For patients with skeletal class II malocclusion, whether the etiology is due to maxillary hyperplasia, mandibular hypoplasia, or both (together), the classical pattern of compensation in these patients is proclination of the mandibular central incisors and retroclination of the maxillary incisors. On the other hand, patients with class III malocclusion resulting from maxillary hypoplasia, mandibular hyperplasia, or both, tend to have a different pattern of compensation that usually includes retroclination of mandibular incisors and proclination of the maxillary incisors. The treating orthodontist and attending oral and maxillofacial surgeon must understand (and communicate) such different/distinct patterns of dental compensation when formulating the overall treatment plan. If there is a significant degree of compensation, the orthodontist might recommend premolar extractions to create adequate space in order to decompensate the dental arches. This issue becomes more precarious in the case of orthognathic surgery as failure to decompensate the dental arches might result in limitations of the surgical movement, compromise the esthetic outcome, and might eventually lead to dental and periodontal compromise of the incisors, over time. Indeed, any exodontia decision during orthodontic therapy and orthognathics is not only dependent on the presence or absence of space in the dental arches, rather, the issues should be further evaluated in order to achieve proper malocclusion correction, maintenance or improvement of facial aesthetics and result stability. For example, other compensations that might require premolar extractions is when there is an excessive curve of Spee (or Spee's curvature of the mandibular occlusal plane beginning at the canine following the buccal cusps of the posterior teeth and continuing to the terminal molar), which is defined, anatomically, as an antero-posterior curved line drawn along the cusps and incisal edges of the mandibular and maxillary teeth in the sagittal view. Herein, leveling (of a deep curve)/ decompensating (dento-alveolar) the Spee's curve requires space, and in some cases premolar extractions might be indicated, to eventually place the teeth in the correct position that the jaws will have aligned. Furthermore, and generally speaking, it is noteworthy that first premolar extractions will result in maxillary incisor retroclination. This can be explained (on a mechanical basis) via that the posterior teeth are multi-rooted and do act/provide as a better anchorage point to retract the incisors and canines, which all are single-rooted (Miloro, 2004). Indeed, a survey regarding extraction patterns for orthodontic treatment showed that the first premolar was the most extracted tooth, at 59%, followed by the second premolar, at only 13% (Narendar *et al*., 2017). Yet, is this sufficient evidence for preference and an informed decision? Debatable. Safely, and to be (can be) considered a simple rule of thumb, one can suggest that the extracted teeth should be closer to the area where crowding is located and/or based on the desired movement. For instance, anterior crowding, excessive overjet and protrusion are all better treated with first premolar extraction versus opting for the second premolar. On the other hand, second premolar extractions are indicated for moderateanterior crowding when there is no protrusion and where the facial profile is considered satisfactory. Also, can be and are indicated for anterior open bite, posterior crowding and class III malocclusion (Proffit, 1995; 2000). Worth noting herein is that with the first premolar extraction, more anterior space is provided and created, when compared to that following the second premolar extraction.

Below, is a list of the main indications for first versus second premolar exodontia (summarized in Fig. 1) that might assist in deciding what would be best (and safest) for the given patient case:

Indications for First Premolar extractions:

- Dental crowding (moderate to severe – mild excluded)
- Excessive negative overjet (i.e. under-bite)
- Excessive overjet (≥ 10 mm)

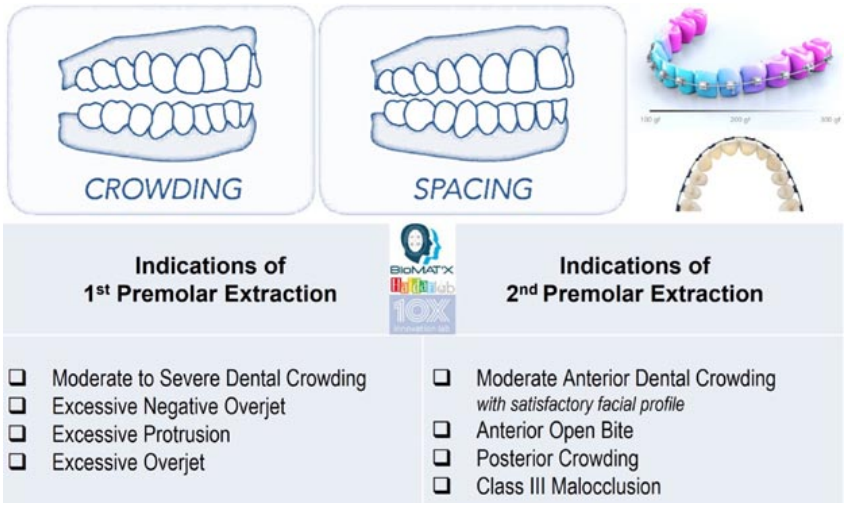

Fig. 1. Main indications for First versus Second premolar exodontia.

Indications for Second Premolar extractions:

- Moderate anterior dental crowding with a satisfactory facial profile
- Anterior open bite
- Posterior crowding
- Class III malocclusion

Advantages of Electing Premolar Exodontia: Clinical and Surgical Considerations

Extraction is a recognized and widely-accepted procedure in orthodontic and orthognathic treatment planning and intervention. Herein, the selection of which specific teeth are best-fit for exodontia is an important decision and is often modified according to the individual patient case. For malocclusions involving tooth- and arch-size discrepancies, premolar extractions are chosen. Yet, as presented earlier, the indication(s) for first or second premolar extraction is/are different and differ(s) with the presented malocclusion. Hence, treatment planning in such cases usually involves removing either first or second premolars. Simply, the anatomical location of premolars allows them to be utilized in alleviating anterior and posterior dental crowding. While removing the first premolar(s) is a straightforward way to correct anterior crowding, excessive overjet and protrusion, second premolar exodontia is a better choice in patients with moderate (sometime, mild) crowding, acceptable incisor positions, limited lingual migration of the mandibular anterior segment, minimal increase in the curve of Spee, satisfactory facial profiles, and/or overbite (for example, when less space would be needed/utilized for crowding and retraction to maintain the facial profile of the patient - because it helps in preserving the width/length ratio and zenith position). Second premolar extraction will also prevent the formation of the un-esthetic black triangles, post-orthodontic treatment, and often aids in rapid space closure whilst maintaining a good marginal relationship between the contact point of the mandibular first molar. Therefore, the decision regarding the choice of which teeth to be extracted is best determined by the degree of discrepancy and the amount of retraction required during treatment. Bordeline cases, explained earlier, are a good example, and opting for second premolar exodontia permits molar protraction and less incisor retraction. Furthermore, both, the first and second premolars have very similar clinical crown outlines and dimensions, and these similarities allow the orthodontist to achieve an acceptable inter-proximal contact point. Also, the benefit in selecting premolar exodontia in spacing or creating space is their convenient eruption time, which corresponds to the initiation of orthodontic treatment, to relieve dental crowding. Indeed, in many cases, the timing at which premolars are extracted can take place before orthodontic bonding; and therefore, adopting this approach gives the maxillofacial surgeon more space to develop the muco-periosteal flap and facilitate flap reflection, if and when indicated. Moreover, in some other cases, the orthodontic braces may be already placed prior to surgical extraction and in such a tricky clinical scenario, the orthodontist should not bond the premolars that are planned for extraction (Fig. 2). Overall, the correction aims to work via creating space, sufficient, for the proper alignment and retraction of incisors and canines. Finally, while deciding on an extraction pattern is a skill that requires vigilant diagnosis and careful analysis, interventional treatment needs to consider a watchful management (reconstruction, restoration and regeneration tissue engineering techniques) of the residual extraction space, in order to preserve normal lip support and facial profile of the patient.

Fig. 2. Clinical presentation of a case illustrating the interventional challenge where a patient was referred for right first premolar exodontia following the bonding of the orthodontic braces with an active arch-wire.

Case Presentation

Case (I). A 26-year-old African American female was referred to us by her attending orthodontist for orthognathic surgery intervention (Fig. 3). Briefly, the patient's chief complaint comprised that her anterior open bite was esthetically unappealing and caused functional compromise of her chewing and speech. Her past medical history was significant for mild asthma and ADHD or attention deficit hyperactivity disorder. Her surgical history was significant for adenoidectomy (the surgical removal of the adenoid for reasons which include impaired breathing through the nose, chronic infections and/or recurrent ear-aches), and a C-section (Cesarean delivery) with no complications reported. Lastly, no known drug allergy and no major social history were eminent.

Head and Neck Exam

The sequential head and neck examination followed by an intra-oral assessment enables the clinical and surgical team to consistently focus attention on careful and efficient observation of the relevant structures of the head and neck; thereby identifying abnormal versus normal conditions, with utmost awareness, every time. Herein, the patient did not suffer gross facial asymmetry and presented with a concave facial profile. Her extra-oral exam revealed a class III skeletal malocclusion, no significant maxillary cant, prognathic mandible and a retrognathic maxilla. Intra-orally, the maximal inter-incisal opening measured about 40 mm, with no deviation of mandible upon opening or closing. The performed TMJ exam detected no clicking or crepitus. The intra-oral

Fig. 3. Pre-operative presentation of a 26 years old African American female who was referred for Orthognathic consultation.

examination further confirmed an anterior open bite, 3 mm of negative overjet and 2.5 mm negative overbite, with a mild posterior crossbite on the left side. The mandibular dental mid-line was shifted to the right by 3 mm relative to the facial mid-line, while the maxillary mid-line was along the facial mid-line. A full diagnostics listing and interventional treatment plan followed.

The patient's problem list included:

- Skeletal open bite
- Dento-skeletal malocclusion (Class III) with hypoplastic maxilla and hyperplastic mandible
- Dental crowding
- Dental mid-line discrepancy

Treatment plan included:

o Pre-Orthodontic phase (Fig. 4):
- Upper maxillary first premolar and mandibular third molar extractions

o Pre-Surgical Orthodontic phase (Figs. 5, 6 and 7):
- Dental decompensation of upper incisors
- Leveling of the upper and lower dental arches
- Decompensation of the curve of Spee

o Surgical phase (Figs. 8 and 9):
- Placement of surgical hooks
- LeFort I surgical advancement
- Bi-lateral sagittal split osteotomy

o Post-Surgical phase (Fig. 10):
- Dental finishing

Fig. 4. Before the pre-surgical orthodontic reconstruction and after the 1st maxillary premolars were extracted along with the mandibular 3rd molars.

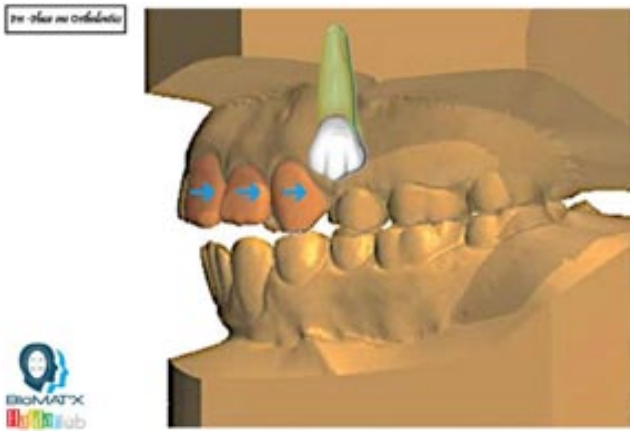

Fig. 5. Dental decompensation of upper incisors, can be achieved after the 1st premolar extraction along with mandibular 3rd molar extraction.

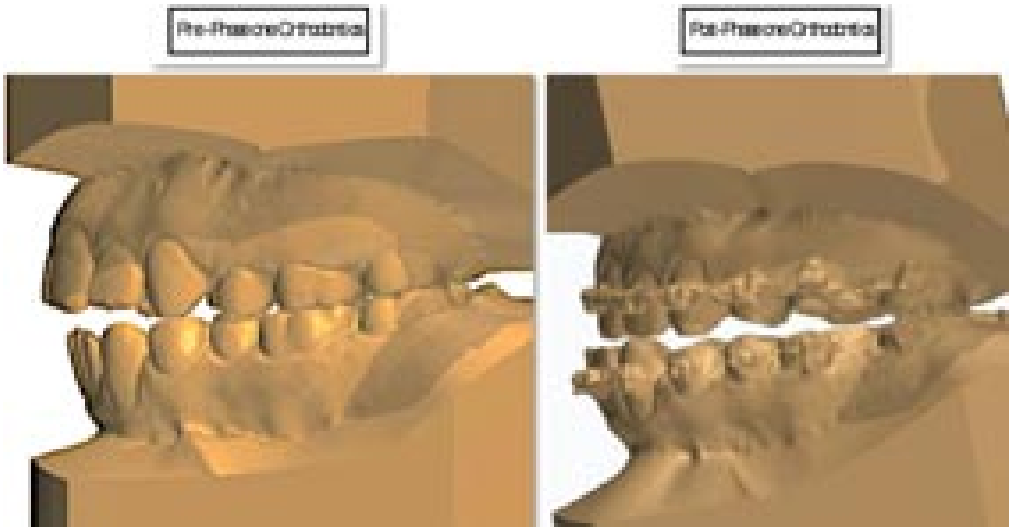

Fig. 6. Comparing Pre-Orthodontics with final results of the pre-surgical orthodontic phase, after dental decompensation of upper incisors and with leveling of the upper and lower dental arches and finally decompensation of the curve of Spee.

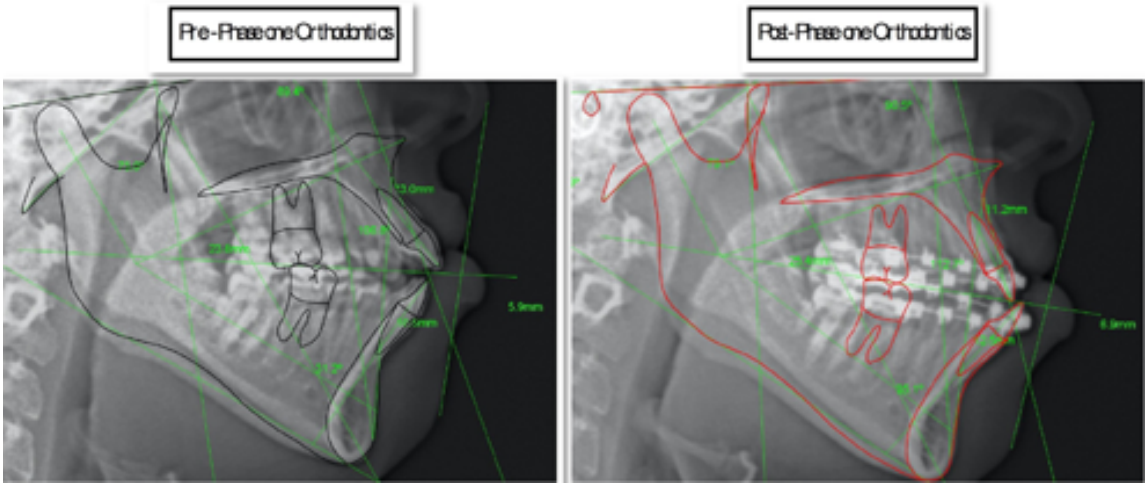

Fig. 7. Lateral cephalogram showing the Dental decompensation.

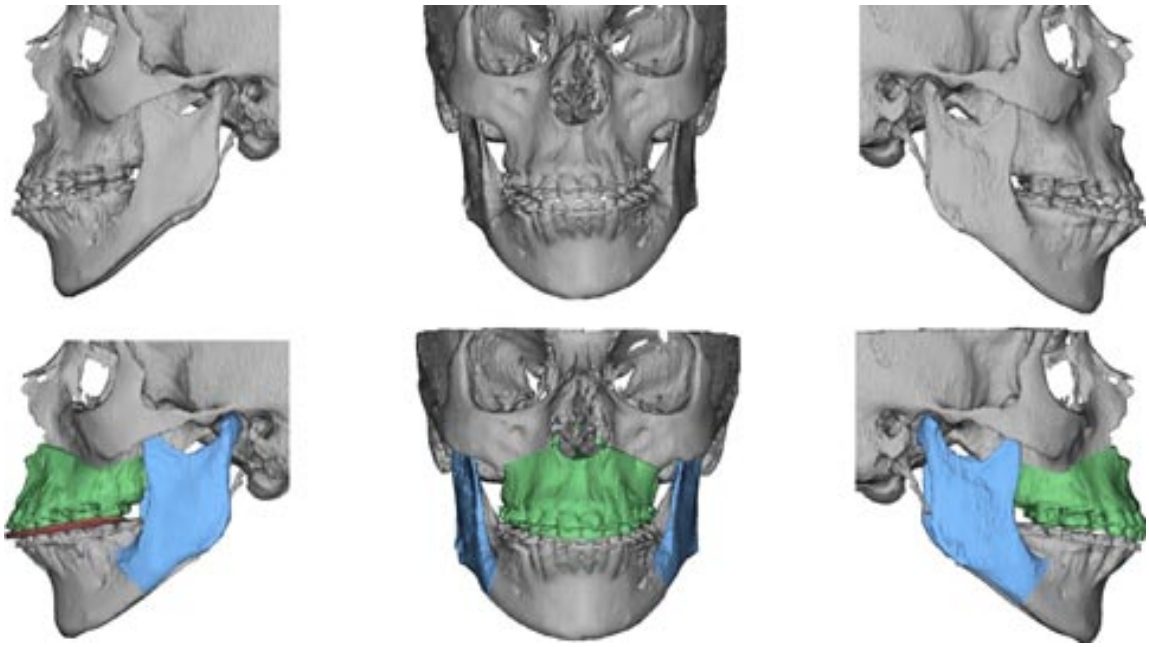

Fig. 8. Comparison of pre surgical Maxillary and Mandibular position with the virtual planned orthognathic movement which included LeFort I Maxillary advancement and Bi-lateral sagittal split osteotomy set-back.

Fig. 9. Post-operative CT scan 3D reconstruction showing the Maxillary LeFort I advancement, along with bilateral sagittal split osteotomy set back and with dental midline correction.

Fig. 10. Presentation showing progression from the first row which was the pre orthodontic start point were the 1st maxillary premolars where extracted, in the middle row showing the successful space utilization by decompensating the dental arches, and the bottom row showing the final results with after the post-surgical orthodontic finishing phase has been completed and debonding the braces.

Case (II) . A 35-year-old Asian male was diagnosed using polysomnography, with severe obstructive sleep apnea (OSA); recurrent/repetitive episodes of upper airway obstruction that occur during sleep. Instead of opting for the classical maxillary-mandibular advancement or MMA (also referred to as bi-maxillary advancement or double jaw advancement; an effective treatment for OSA where the bones of the upper and lower jaw are repositioned to relieve airway obstruction, and MMA also suspends the attached pharyngeal airway muscles in an anterior position and simultaneously increases pharyngeal soft tissue tension), the patient requested us to solely address his malocclusion. Similar to the previous case, first premolar extractions were performed prior to pre-surgical orthodontics. It was decided to extract the maxillary first premolar to retract the anterior maxillary teeth (central incisors, lateral incisors and canines) and to decompensate the anterior dentition flaring (maxillary anterior labial flaring). Note here the one other orthodontic complicating factor is the congenitally-missing left mandibular canine (a case of tooth agenesis or hypodontia).

Head and Neck Exam

From a frontal view, the patient neither had any occlusal plane canting (vertical smile esthetics: rotation upwards or downwards in the transversal plane of one side over the other) nor gross asymmetry in the upper, middle or lower facial thirds. The maxillary and mandibular mid-lines were coinciding with the facial mid-line. He displayed 2 mm of maxillary incisor show at rest and 5 mm with animation. The facial profile examination revealed a concave profile due to the hypoplastic maxilla, normal labio-mental fold and lip incompetence that was overcome with mentalis strain. The intra-oral examination revealed a class III malocclusion with an anterior open bite, an edge-to-edge posterior occlusion, and both, the maxilla and the mandible were U-shaped. The patient presented -2 mm of overjet (negative overjet), 1 mm of open bite, and 0 mm of overbite.

For this OSA patient, his pre-operative home-based sleep study revealed the following:

- An AHI (Apnea-Hypopnea Index for apnea severity) of 6 events per each hour of sleep;
- Lowest O2 saturation of 85% (normal SpO2 is usually between 95% - 100% for most healthy adults);
- 12.6% snoring during the test; and
- A heart rate ranging between 55 - 111 bpm.

Fig. 11. Panoramic X-ray after, the bi-lateral 1st premolars have been extracted and the upper and lower dental arches have been decompensated.

The patient's problem list included:

- Minor skeletal open bite
- Dento-skeletal malocclusion (Class III) with a hypoplastic maxilla
- Narrowing of the posterior airway space

Treatment plan included:

o Pre-Orthodontic phase:
- Upper maxillary first premolars extraction

o Pre-Surgical Orthodontic phase (Fig. 11):
- Dental decompensation of upper incisors
- Leveling of the upper and lower dental arches
- Decompensation of the curve of Spee

o Surgical phase (Figs. 12 and 13):
- Placement of surgical hooks
- LeFort I surgical advancement and impaction
- Mandibular auto-rotation and a bi-lateral sagittal split osteotomy.

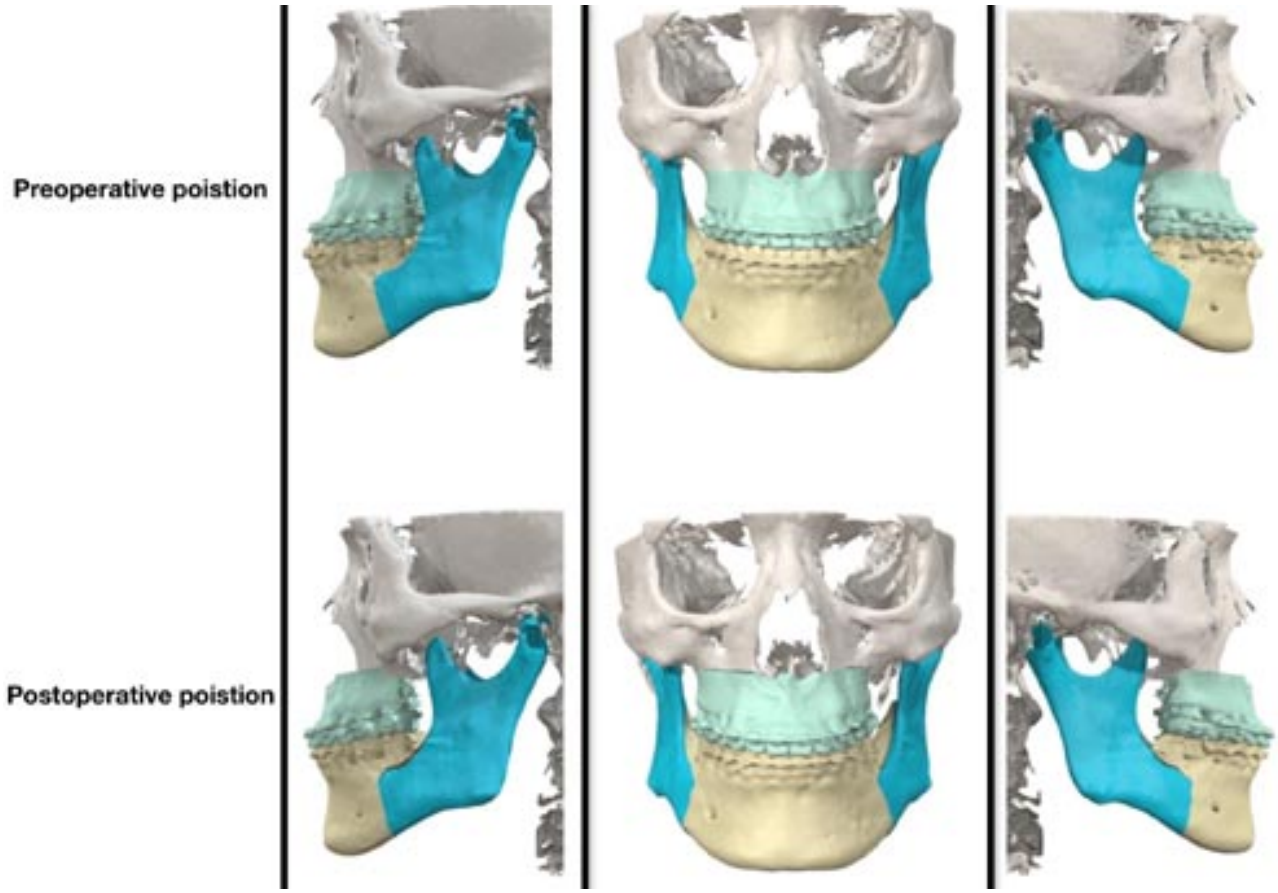

Fig. 12. Pre-operative position of the maxilla and mandible compared to the post-operative position.

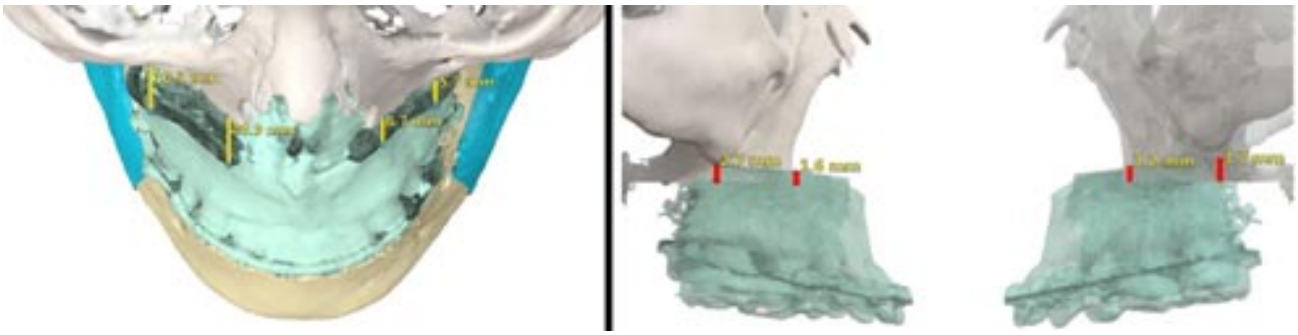

Fig. 13. Maxillary advancement of about 10.9 mm on the right and 6.7 mm on the left with Maxillary impaction of about 3.7 mm posteriorly and 2.2 mm on the left and 2.7 mm posterior and 1.6 anterior on the right.

Figure 14 displays the immediate post-operative CT scan, showing a very accurate positioning of the maxilla and the mandible when compared to the pre-operative virtual surgical planning. Note that the extraction of the premolars allowed the retraction of the anterior maxillary dentition, which in turn allowed further auto-rotation and advancement of the maxilla and mandible. All these movements helped increase the posterior airway space and to treat the severe OSA of the patient.

Fig. 14. Immediate post-operative CT Scan showing very accurate positioning of the maxilla and the mandible when compared to the preoperative virtual surgical planning.

Alternative Corrective Strategies Techniques and Methods: Orthognathic Jaw Surgery

Lateral Body Osteotomy of the Mandible and Mandibular Sagittal Split Osteotomy.

For the correction of mandibular prognathism, mandibular body ostectomy is often avoided, today, mainly due to complications including inferior alveolar nerve injury. Yet, the procedure continues to used effectively in some cases with a large mandibular body (Mori *et al*., 2012). Historically, this technique was illustrated by two surgeons, Blair and Dingman (Posnick, 2014). Nakajima *et al*. described a sliding lateral body osteotomy of the mandible in 1978 (Nakajima *et al*., 1978). Then, Björk & Eliasson (1979) described the use of lateral body osteotomy of the mandible to correct apertognathia (openbite) in 1979. Not commonly used currently, as mentioned earlier, the indication for the lateral body osteotomy is in select cases of mandibular prognathism while having a molar class I occlusion or anterior open bite with mandibular prognathism. Herein, this osteotomy might be facilitated by first or second mandibular premolar extraction. Having a class I molar occlusion is not absolutely required since molar occlusion will likely be class III if premolars are to be extracted to make space for the posterior positioning of the anterior segment; however, the posterior occlusion must inter-digitate in maximum intercuspation pre-operatively. It is possible to narrow the overall width of the mandible during this procedure while the distal segment is mobile. This can be part of the treatment plan. Further, there are few benefits of this procedure; in select cases, where it might be substituted instead of the commonly-used sagittal split osteotomy, especially if there is no need to change the posterior occlusion; this procedure has a comparable if not increased stability when compared to the sagittal split osteotomy due to the unchanged posterior occlusion bearing the occlusal forces, decreased risk of damage to the

inferior alveolar neurovascular bundle and possible decreased morbidity to the patient. Bansal *et al*. (2013) demonstrated using 10 cases in which the mandibular body osteotomy procedure was successfully used to correct skeletal class III malocclusion, improve cosmetics/esthetics of the smile and improve the soft tissue profile of the patient. First, pre-surgical orthodontic treatment must be done so that the mandibular anterior teeth are decompensated and placed appropriately in relation to basal bone. Also, up righting of the premolar roots can be useful for the surgeon via aligning the premolar root to follow the projected ostectomy (often, should not exceed 5 mm; in order to reduce healing time and consequently improve the prognosis of the periapical surgery) outline (Fonseca, 2000). Piezoelectric surgery is recommended to outline the step-wise osteotomy while decreasing the risk of nerve injury; the inferior alveolar nerve should be identified and mobilized, therefore. A step-wise sliding osteotomy may be used to evade the inferior alveolar nerve and mental nerve without the need for lateralization of the nerve in certain cases (Bansal *et al*., 2013). Blocks of mandibular bone located at the premolar region are resected while paying attention to protect the lingual mucosa and while protecting the lateralized segment of the inferior alveolar nerve (Ehrenfeld *et al*., 2012). Nakajima *et al*. (1978) and Sandor *et al*. (1982) suggested extracting the premolars prior to making ostectomy cuts; however, Bansal *et al* (2013) performed the ostectomy with the premolars in-place before extracting; advocating that the premolars help guide the ostectomy outline. In the case that the posterior setback of the anterior segment is less than the width of the premolar being extracted, it may be beneficial to extract the tooth prior to surgery to allow maximum conservation of the crestal/ interproximal bone. The anterior mandibular segment is positioned posteriorly, and the patient is placed in maxilla-mandibular fixation with the aid of an occlusal splint. The mandibular segments are fixated with the appropriate osteo-synthesis. Finally, the mandibular premolar extraction will allow the surgeon to set back the anterior segment of the mandible around 4 mm - 10 mm, depending on the width of extracted tooth (Nordenram & Waller, 1968; Bansal *et al*., 2013). To recap, mandibular body ostectomy (Fig. 15) is an effective method, in particular, for a large mandibular body. Special consideration to preserve the inferior alveolar nerve is necessary; indeed, to protect the nerve during ostectomy and following bone detachment.

Anterior Maxillary and Mandibular Subapical Osteotomies for bi-MAX Protrusions.

Briefly, the anterior maxillary osteotomy procedure is used to reposition the anterior dento-osseous segment posteriorly and also move it superiorly or inferiorly as indicated by the case. Likewise, segmentary subapical osteotomy, for example is another technique commonly employed in orthognathic surgery to achieve occlusal stability via dento-alvelar movement; hence, primarily when tackling cases of

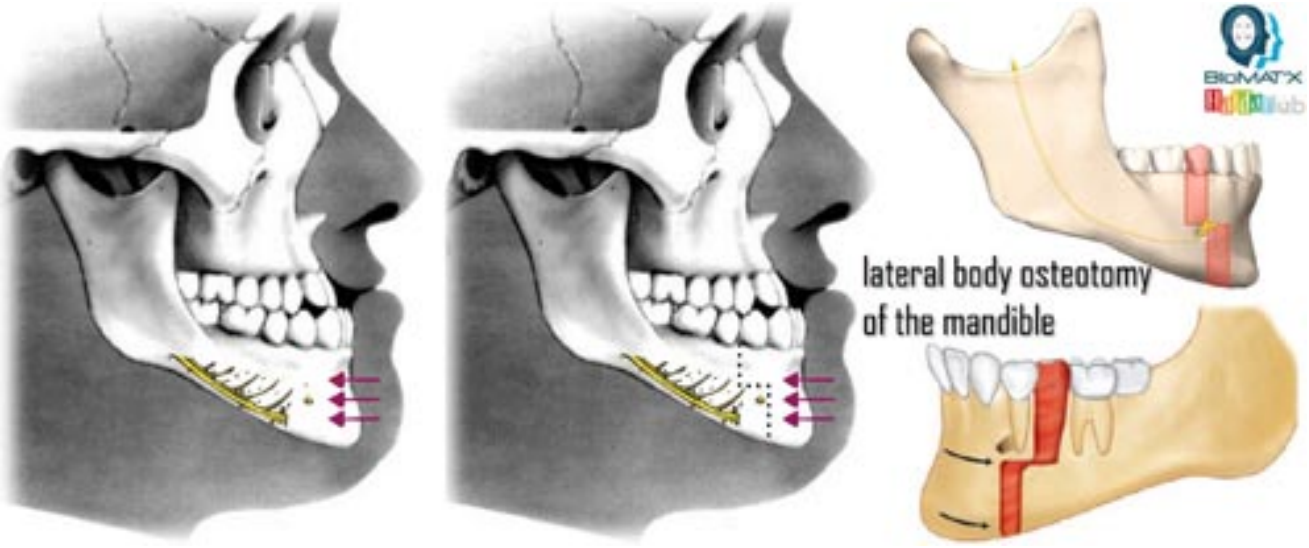

Fig. 15. Orthognathic Jaw Surgery alternative corrective option - lateral body osteotomy of the mandible.

dento-skeletal malocclusions that cannot be only dealt with conventional orthodontics. Further, the anterior subapical osteotomy technique can be utilized to reposition the anterior section of the maxilla and mandible in the superior and posterior direction. Hullihen first described this technique in 1848 (Hullihen, 1849). Later, Köle (1959), Obwegesser (1968) and others continued to add onto the method and applications. Although the procedure is typically only cited in case reports and not commonly performed, the extraction of either the maxillary and mandibular premolars might increase the amount of anterior maxillary or mandibular set-back. The procedure is done via a trans-oral vestibular approach. Following a sub-periosteal dissection, the mental nerve is identified and skeletonized, and the flap should provide and have good access to the premolar region. Herein, the skilled maxillofacial surgeon should refrain from excessive dissection on the lingual or palatal side(s) in order to avoid compromising the vascular supply to the bone. The horizontal osteotomy is placed at least 5 mm subapical to the root apices and then connected with two vertical osteotomies between the canines and the first premolars. Inter-dental osteotomy is performed with care to avoid injury to the roots and to the lingual soft tissue (Posnick, 2014). Sowray & Haskell (1968) described an adaptation to the subapical osteotomy in which they made an ostectomy at the inferior border of the mandibular symphysis so that the posterior segments of the mandible would rotate medially in addition to the posteriorset-back of the anterior segment. This technique reduces the horizontal width of the mandible and could be useful and beneficial if there was a pre-existing posterior crossbite, although there is limited data available on the long-term effect/efficacy/efficiency of this procedure on the TMJ. It is noteworthy that Hyum-Hye Kim *et al*. (2015) used mandibular subapical osteotomy to decompensate dental malocclusion, under local anesthesia, in the pre-operative phase prior to orthognathic surgery. Similarly, Choi *et al*. (2017) also described a mandibular subapical osteotomy post-premolar exodontia for the same indication. Such treatment is especially helpful if there is limited bone in the anterior segment that would not anatomically allow for proclination or retroclination, while in addition having the added benefit of shortening the pre-surgical orthodontic treatment time and possibly reduce the risk of progressive root resorption. For cases of class II (division I) malocclusions where the facial profile appears convex with a receding chin and lower lip (+ an accentuated curve of Spee, increased overjet, severe overbite and either bucally-proclined or normally-inclined maxillary incisors / diagnosed primarily by the incisor relationship) and mainly for the correction of an anterior open bite, the most common dento-facial deformities in clinical practice, the total mandibular subapical alveolar osteotomy technique including a horizontal and medial ramus cut above the lingula, is recommended. It can also be used as an alternative way for correcting mandibular deficiency, with excellent functional and aesthetic results. Stabilizing the osteotomized segments can be maintained using plates and screws. Expect (with your patient) paresthesia in the mental region. This technique is indicated, as well, when ample correction in the mento-labial sulcus is desired. Often, facial esthetics remain the primary concern of patients.

Closing Remarks

Historically, orthognathic surgery aimed at addressing both stability and aesthetics. While stability relates to establishing a healthy and functional occlusion,aesthetics related to normalizing the facial balance and proportions. Thus, orthognathic surgery is a powerful method to improve the profile. In closing, the decision to extract, whether to align or retract teeth/dentition, will often not only depend on the presence or absence of space in the dental arches. To achieve functional occlusion and facial esthetics with properly-maintained outcome stability (and relapse prevention), it is recommended that the orthodontic and orthognathic team evaluate other diagnostic elements, parameters, factors and issues, for incorporation into their treatment plan, including, tooth-arch discrepancy (maxillary and mandibular), dental asymmetry (harmonious positioning of the upper and lower dental midlines relative to each other as well as to the face), skeletal age (growth and antero-posterior relationships, to assess need for growth redirection), facial profile (and cephalometric discrepancy, where its noteworthy that facial profile becomes more concave with age), facial pattern (brachyfacial or dolichofacial, for example), pathologies (caries/decay, ageneses, endo-perio lesions and/or ectopias, to list a few) and patient compliance (maintaining adequate oral hygiene and regular appointments). Yet, and on a final note on the matter of first versus second premolar exodontia, and despite this suggestion, the attending team will absolutely face cases

where a single factor can be the crucial key for an "exodontia decision".

In the future, and with the recent accruement (and increased implementation) of more precise/accurate technological developments, rapidly paving way into our diagnostics and armamentarium, including image-navigation technology, advanced virtual surgical planning, artificial intelligence, augmented reality as well as robotic-assisted surgery, orthognathic surgery might be more aided to promise perfect results, correcting both functional and aesthetic problems.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Funding

This work was supported by operating grants provided to the HAiDAR R&D&I LAB/BioMAT'X (Laboratorio de Biomateriales, Farmacéuticos y Bioingeniería de Tejidos Cráneo Máxilo-Facial), member of CiiB (Centro de Investigación e Innovación Biomédica), Faculties of Medicine and Dentistry, Universidad de los Andes, Santiago de Chile, through the ANID-NAM (Agencia Nacional de Investigación y Desarrollo, Chile and National Academy of Medicine, USA) Grant#NAM21I0022, CORFO Crea y Valida I+D+i Grant#21CVC2-183649 and FONDEF CONCURSO IDEA DE I+D, FONDEF/ SUBDIRECCIÓN DE INVESTIGACIÓN APLICADA/ANID 2022, Grant código # ID22I10215."

ACKNOWLEDGMENTS

Special thanks to our attending staff at the Dept. of OMFS, Louisiana State University Health Sciences Center, Baton Rouge, LA, USA and the LebanoCanadian polyClinic Center in Dubai, UAE.

ADAMEC A, ZAID WS, RAVELO V, HAIDAR ZS. Apiñamiento dental y/o espaciamiento en cirugía ortognática: Incorporación de extracciones de premolares en el tratamiento de maloclusión clase III. Una revisión y serie de casos. *Craniofac Res. 2022; 1(2)*:88-102.

RESUMEN: El perfil craneofacial, las relaciones maxilomandibulares, las discrepancias óseas dento-alveolares, la maduración esquelética y las asimetrías dentales son elementos importantes de un diagnóstico y planificación del tratamiento ortodóncico y ortognático. Para la posición y la angulación adecuadas de los dientes, la cirugía ortognática tiene como objetivo corregir el apiñamiento dental, el espaciado, la desalineación y las rotaciones de los dientes, a través de extracciones dentales, por ejemplo, como parte del plan general de tratamiento de ortodoncia e intervención ortognática. De hecho, la exodoncia a menudo se necesita para aliviar el apiñamiento de moderado a severo (discrepancias en la longitud del arco) y crear el espacio necesario para la alineación adecuada de la dentición y la eventual oclusión funcional. Aquí, a menudo se prescriben extracciones de primeros y segundos premolares, preferiblemente cuando se han agotado otros métodos. Sin embargo, la discusión sobre el uso de extracciones de premolares no es si se debe realizar una exodoncia, sino qué tipo de maloclusión, tamaño del diente y discrepancia en el espacio entre dientes (incluida la protrusión bi-maxilar y el apiñamiento severo en el maxilar y la mandíbula) indican extracciones de premolares, cuando se debe realizar la intervención, y si extraer el primer o segundo premolar. Por lo tanto, en este artículo destacamos las consideraciones de exodoncia de premolares para la planificación del tratamiento de ortodoncia y ortognático (tratamiento previo) mediante la discusión de la mecánica básica y las ventajas de los movimientos intra-/inter-arco. A esto le sigue la presentación de casos clínicos que muestran la incorporación de extracciones de premolares en (a) tratamiento de ortodoncia prequirúrgico; (b) plan quirúrgico e intervención; y (c) resultado y pronóstico posquirúrgicos. En este documento también se presentan técnicas alternativas y opciones de tratamiento útiles para abordar la maloclusión esquelética y dental, incluidas las osteotomías laterales y sub-apicales, que podrían considerar la integración de extracciones de primeros y segundos premolares.

PALABRAS CLAVE: Ortodoncia, cirugia ortognática, cirugia mandibular corrective, clase III.

REFERENCES

Bansal P, Singh V, Anand SC, Bansal S. Relevance of anterior mandibular body ostectomy in mandibular prognathism. Natl J Maxillofac Surg. 2013; 4(1):57-65. https://doi.org/10.4103/0975-5950.117886

Brezulier D, Fau V, Sorel O. Influence of orthodontic premolar extraction therapy on the eruption of the third molars: A systematic review of the literature. J Am Dent Assoc. 2017; 148(12):903-12. https://doi.org/10.1016/j.adaj.2017.07.023

Björk N, Eliasson S. Ostectomy in the mandible. Swed Dent J. 1979; 3(4):119-28.

Choi BJ, Lee BS, Lee HJ, Park KH, Kim SH. Double anterior segmental osteotomy under local anesthesia for correcting adult protrusion with thin alveolus and ankylosed tooth. J Craniofac Surg. 2017; 28(3):821-5. https://doi.org/10.1097/SCS.0000000000003432

Dewel BF. Second premolar extraction in orthodontics. Principles procedures and case analysis. Am J Orthod. 1955; 41(2):107-20.

Ehrenfeld M, Manson PN, Prein J. Principles of internal fixation of the craniomaxillofacial skeleton. 1ra ed. Thieme Verlag KG; 2012.

Fonseca JR. Oral and maxillary facial surgery. Vol. 2. Philadelphia, WB Saunders, 2000. Genial procedures; p. 405.

Hullihen SP. Case of elongation of the under jaw and distortion of the face and neck, caused by a burn, successfully treated. Am J Dent Sci. 1849; 9(2):157-8.

Keim RG, Gottlieb EL, Nelson AH, Vogels DS 3rd. 2002 JCO study of orthodontic diagnosis and treatment procedures. Part 1. Results and trends. J Clin Orthod. 2002; 36(10):553-68.

Kim HH, Ha HR, Ahn HW, Kim SJ. Anterior decompensation using segmental osteotomy for patients with mandibular asymmetry. J Oral Maxillofac Surg. 2015; 73(7):1392.e1-22. https://doi.org/10.1016/j.joms.2015.03.046

Köle H. Surgical operations on the alveolar ridge to correct occlusal abnormalities. Oral Surg Oral Med Oral Pathol. 1959; 12(3):277-88 contd. https://doi.org/10.1016/0030-4220(59)90177-x

Massahud NV, Totti JIS. Estudo cefalométrico comparativo das alterações no perfil mole facial pré e pós-tratamento ortodôntico com extrações de pré-molares. J Bras Ortodon Ortop Facial. 2004;9(50):109-19.

Miloro MD, G E Ghali MD, Larsen PE, Ghali GE, Waite DP. Peterson's principles of oral and maxillofacial Surgery. 2da ed. Hamilton London UK, BC Decker Inc. 2004.

Mori Y, Susami T, Saijo H, Okubo K, Uchino N, Hoshi K, Takato T. Mandibular body ostectomy for correction of mandibular prognathism – A technical note. Oral Sci Int. 2012; 9(1):21-5. https://doi.org/10.1016/S1348-8643(12)00005-5

Narendar R, Balakrishnan G, Kavin T, Venkataraman S, Altaf SK, Gokulanathan S. Incidence of Risk and Complications Associated with Orthodontic Therapeutic Extraction. J Pharm Bioallied Sci. 2017;9(Suppl 1):S201-S204. https://doi.org/10.4103/jpbs.JPBS_160_17

Nakajima T, Kajikawa Y, Ueda K, Hanada K. Sliding osteotomy in the mandibular body for correction of prognathism. J Oral Surg. 1978; 36(5):361-8.

Nordenram A, Waller A. Oral-surgical correction of mandibular protrusion. Br J Oral Surg. 1968; 6(1):64-74. https://doi.org/10.1016/s0007-117x(68)80028-9

Obwegesser H. Movement of the lower alveolar process for correction of malocclusions. Dtsch Zahnaerztl Z. 1968; 23(11):1075-84.

Omar Z, Short L, Banting DW, Saltaji H. Profile changes following extraction orthodontic treatment: A comparison of first versus second premolar extraction. Int Orthod. 2018; 16(1):91-104. https://doi.org/10.1016/j.ortho.2018.01.017

Park KE, Maniskas S, Allam O, Pourtaheri N, Steinbacher DM. Orthognathic Surgery to Improve Facial Profile: Assessment, 3-Dimensional Planning, and Technique. Aesthet Surg J Open Forum. 2020; 3(1):ojaa051. https://doi.org/10.1093/asjof/ojaa051

Proffit WR. Forty-year review of extraction frequencies at a university orthodontic clinic. Angle Orthod. 1994; 64(6):407-14. https://doi.org/10.1043/0003-3219(1994)064<0407:FROEFA>2.0.CO;2

Proffit WR, Fields JRW. Ortodontia contemporânea. 3ª ed. Rio de Janeiro, Guanabara Koogan, 1995.

Proffit W. Contemporary orthodontics, 3rd ed. St Louis, CV Mosby Company, 2000.

Posnick JC. Principles and Practice of Orthognathic Surgery. 1ra ed. United State of America, Elsevier Health Sciences, 2014.

Ramos AL, Sakima MT, Pinto Ados S, Bowman SJ. Upper lip changes correlated to maxillary incisor retraction--a metallic implant study. Angle Orthod. 2005; 75(4):499-505. https://doi.org/10.1043/0003-3219(2005)75[499:ULCCTM]2.0.CO;2

Sandor GK, Stoelinga PJ, Tideman H. Reappraisal of the mandibular step osteotomy. J Oral Maxillofac Surg. 1982; 40(2):78-91. https://doi.org/10.1016/s0278-2391(82)80031-1

Sowray JH, Haskell R. Ostectomy at the mandibular symphysis. Br J Oral Surg. 1968; 6(2):97-102. https://doi.org/10.1016/s0007-117x(68)80005-8

Talass MF, Talass L, Baker RC. Soft-tissue profile changes resulting from retraction of maxillary incisors. Am J Orthod Dentofacial Orthop. 1987; 91(5):385-94. https://doi.org/10.1016/0889-5406(87)90391-x