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Impact on the Pharyngeal Airway Space of Different Orthognathic Procedures for the Prognathic Mandible: A Literature Review

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Abstract: ***Dentofacial deformity refers to deviations from normal facial proportions and dental relationships that are severe enough to be handicapping. These anomalies involve many aspects of patient's life and are sometimes also associated with a reduction of pharyngeal airspace (PAS). This episode of pharyngeal airway collapse effects breathing function of the patients. This leads to a condition called Obstructive Sleep Apnea (OSA). So patients who are undergoing orthognathic surgery should be screened for excessive daytime spmnolence, snoring, increased BMI and medical conditions related to OSA. OSA may be better following a maxillomandibular advancement surgery or may be worsened or developed after mandibular setback surgery. The purpose of this study is to review the changes of PAS and its important related structures such as hyoid bone, the tongues and soft palate after orthognathic surgery in dentofacial deformity patients. The change of head posture, the adaptation and the stability of PAS are also considered.Moderate evidence was found that PAS changes at the level of nasopharyngeal, oropharyngeal and hypopharyngeal. A statistical difference was found between BSSO & IVRO after treatment of mandibular prognathism. The results indicate that bimaxillary surgery in class 3 patients has less unfavourable effects, so it is considered as superior surgery compared to mandibular setback surgery.***

Keywords: Pharyngeal airspace, Obstructive Sleep Apnea, Orthognathic surgery, mandibular setback surgery

1. Introduction

Orthognathic surgery has gained wide popularity in maxillofacial surgery over the last 30 to 40 years. It comprises of several surgical procedures that allow the repositioning of the entire midface, mandible & the dentoalveolar segmants to their desired locations. These procedures are carried out as an isolated osteotomy or in various combinations. Class 3 skeletal pattern is characterized ny disharmony in antero-posterior direction with maxillary deficiency, mandibular excess or both. The treatment of these deformities is aimed at both restoring proper dental occlusion & facial harmony. In cases in which orthodontic compensation is not possible orthodontic surgical treatment is a therapeutic alternative usually mandibular setback combined or without maxillary advancement. It is found that hyoid bone is located posteriorly & superiorly in class 3 patients. The more hyoid backwards the narrower is the upper airway. After orthognathic surgery, the mandibular bone, tongue, hyoid bone & epiglottis move backward resulting in narrowing of the PAS. Therefore patients require postural adaptations to get accustomed to a narrow airway. The pharyngeal airway is a complicated structure. It cooperates with the surrounding structures to perform the physiologic processes of swallowing, speech and respiration. The pharyngeal airway is subdivided into 3 regions. Nasopharyngeal, orthopharyngeal airway (which contains retropalatal region and retrolingual region) and hypopharynx. The walls of pharyngeal airway consists only of soft tissue so the mechanism that maintains the patent airway results from tension& contraction of the surrounding muscles. Mandibular and maxillary advancement may offer larger space in phanryngeal airways whereas mandibular setback surgery may result in reduction of respiratory area in this region.

Orthognathic Surgery & Airway

An issue of orthognathic surgery, which has gained notice recently is the effect of jaw movements on pharyngeal airway. Researchers have shown the possibility of potential airway changes after orthognathic surgery and development of OSA. The surgical procedures that reposition the facial skeleton alter the soft tissues that are attached to the bone in order to effect the facial changes. These procedures not only have an influence on facial appearance, it changes PAS as well. (Doff, 2009). Research carried out in this area showed an assoiciation between PAS & OSA. Riley et al showed that PAS of less than 11mm and a mandibular plane to hyoid distance of more than 15.4 mm was indication of OSA. Muto et al 7 also identified a significant relationship between the PAS and the position of the maxilla, mandible and soft palate. Thus, it behaves us to believe that any of these features may provoke some airway disorder. Research has shown that orthognathic surgery affects the airway when there is a significant AP component.

Class 3 Deformity Surgery

It is common to combine surgery & orthodontic to treat skeletal class 3. Class 3 is the result of mandibular prognathism or maxilarry deficiency (Sammon, 1992). Class 3 is far more prevalent in Asia than in Caucasian (Cralier & Mosby, 2005). Accordingly, Class3 malocclusion is one of the main causes of seeking orthodontic treatment in these countries, for example, 33% of orthodontic patients in Japan and 20% in China. The orthognathic surgeries commonly used to correct this deformity are the mandibular setback and the maxillary advancement procedures. Mandibular setback surgery can improve occlusion, masticatory function

and esthetics by markedly changing the position of the mandible. However, mandibular setback surgery causes changes in the hyoid bone and the tongue and consequent narrowing of PAS, which might be the reason for OSA.

Mandibular Setback

Bilateral Sagittal Split Osteotomy (BSSO) is the most common mandibular setback procedure. It is due to the versatility in treating mandibular abnormalities.. This technique was credited to Trauner & Obwegeser in 1957 and had undergone modifications by Dalpont in 1961, Hunsuck in 1968, Gallo in 1976 12 and Epker in 1977. Surgeons first noticed some patients developing OSA following mandibular setback and published case reports about this possible complications (Guilleminault, 1985; Riley, 1987; Liukkonem, 2002). According to the literature, changes in tongue position can be analyzed more precisely by measuring the changes in the hyoid bone position. The hyoid bone serves as an indicator of the size and position related to surgical jaw movements. These studies reported a change in the position of hyoid bone and reduction in dimensions of retrolingual and hypopharyngeal airway after mandibular setback surgery. In addition, Turnbull et al found that there was a decrease in the intermaxillary space (volume of the orla & oraopharyngeal region) and an increase in the tongue proportion. This equates to a lesse volume for the tongue and thus posterior displacement and a narrower PAS. On the otherhand, there are conflicting views on the degree and duration of the post operative changes in the hyoid bone position. There are also controversies about the degree and stability of the post operative changes in the PAS. Some studies suggested that the changes are temporary as the tissues readapt, resulting in partial or total resolution. However most of the other studies showed that the changes of the airway are stable over the long time. All the above studies were cephalometric studies that only assessed the 2 dimensional AP changes of the airway. Despite this, the results are still relevant as Riley & Powell showed a significant correlation between the PAS measured on the cephalographs and the volume of the airway calculated from computed tomography. Kawamata et al used actual three dimensional C.T (3D CT) to look at the airway changes after mandibular setback found that the lateral width decreased by 23.6%, the frontal width decreased by 11.4% and the hyoid bone was displaced downward and posteriorly. Another observation of several studies was the adaptive increased craniocervical inclination (counter clockwise rotation of the face or chin up movement) of the patients after mandibular setback procedures. Muto et al assessed the relationship between this change and the (PAS) dimension and determined that the PAS correlated with the inclination at the cervical vertebrae. They concluded that 10 degree rise in the inclination will result in an increase in PAS about 4mm. This was supported by Wimberg et al who found that the changes in the head posture influenced the position of the hyoid bone. Thus, the relapse of the hyoid bone position mentioned by some authors could be due to this phenomenon. The study with the longest follow-up of 12 years showed that the decrease in the lower pharyngeal airway was stable but the upper & middle pharyngeal airway continued to decrease over the 12 years.

Bimaxillary Surgery

In the last decade, mandibular setback surgery only declined in frequency to a fewer than 10% of classs3 patients, where as bimaxillary surgery is used in about 40% of class 3 patients (Busby, 2002). Contrary to logic deduction, the addition of maxillary advancement result in an increase in the retropalatinal dimension. This was postulated due to 2 key issues.

a) Firstly, maxillay advancement results in adaptive changes of soft palate in order to maintain velopharyngeal seal and palatal function.
b) The second matter concerns the posterior and superior movement of the tongue for the mandibular setback which comes into contact and displaces the soft palate backwards and upwards.

Combining 2 factors, the soft-palate becomes larger and thinner & palatal angle increases. Therefore, the maxillary advancement may not gain a significant enlargement of the retropalatinal dimension and coupled with the mandibular setback, there may even be a narrowing of the retropalatinal airway (Lye, 2008). However, it is still better to decrease the magnitude setback by performing simultaneous maxillay advancement to prevent the development of OSA (Hoekama, 2003) assuming that bimaxillary surgery might have less effect on reduction of the pharyngeal airway space than mandibular setback surgery only (Chen, 2007).

Class 2 Deformity Surgery

The main component of this deformity is usually the mandibular deficiency with infrequent maxillary protrusion. The milder cases can be treated with growth modification and orthodontic camouflage, while severe ones need orthognathic surgery. The prevalence of class 2 malocclusion in Asian population is about 29.5%. This is less than that of Caucasian population (35%). In this group of patients they may have already have snoring or OSA, as this deformity has already been shown to be a possible clinical feature of an OSA patient. Kuo (1979), Bear and Priest (1980) were the first to document that surgical advancement of the mandible improved OSA. Turnbull & Coworkers (2000) found that the advancement improved the retropalatinal and retrolingual dimension of the airway significantly. Furthermore, there was increased intermaxillary space and the decreased tongue proportion. This was also confirmed by several authors who noted on increased in the PAS after mandibular advancement. Mandibular advancement also leads to the advancement of the suprahyoid and tongue muscle as the hyoid bone is attached to the mandible via the geniohyoid, anterior digastrics and mylohyoid muscle. Mehra (2001) assessed the pharyngeal airway space changes with anterior rotation of the maxillary mandibular complex and found it an useful tool to complement maxillary mandibular advancements in patients with high occlusal plane (Mandibular retrognathism).

Lefort 1 Surgery:

During 1970s, the procedure became increasingly popular because it can be used to mange discrepancies in all 3 planes of space (Bell, 1975). This versatility, in addition to a fewer

side effects, has made the Lefort 1osteotomy the procedure of preference for the treatment of many skeletal class3 patients. Esthetic considerations have also contributed to the increasing use of this approach (Proffit, 1991). Intra or post operative bleeding is the main complications of Lefort 1 ostetomy. But progress in surgical procedures as well as technical development has significantly reduced the risk of major bleeding, so that today, a Lefort 1 osteotomy has a lower potential for complications than the Bilateral Sagittal Split Osteotomy.

Maxillomandibular Advancement (MMA) :
MMA is desired as the advancement of the maxilla and mandibule via the Lefort 1 and BSSO. MMA is the most successful acceptable surgical treatment for OSA. The rationales of these procedures are the advancement of the skeletal attachment of the suprahyoid and velopharyngeal muscle and tendons. This leads to the anterior movement of the soft palate, tongue, anterior pharyngeal tissues and the chin which contains the genial tubercles resulting in an increase in volume of the nasopharynx, oropharynx and hypopharynx, therefore increase the PAS. MMA is successful because it actually increases the space of the upper airway at many levels. MMA has been shown to reduce upper airway resistance by nearby 2/3 rds (Louise, 2007). A statistically significant was found in all the airway dimensions in the linear, area, volumetric analysis performed after surgery. The average increases were 34% for PAS area, 56% for PAS volume and 112% for the PAS minimum axial area. Some studies showed that the airway gain after MMA is stable. Souza Carvatho stated that there is a partial relapse after 6 months and the airway gain after 6 months is only 80% that of immediate post operation. Since its inception, there have been several publications that demonstrated a more than 96% success rate for causing severe OSA. There is also strong evidence of its long term efficacy as Li et al showed a 90% Success rate for a group of patients with a mean follow-up period exceeding 50 months. As for the PAS, Fairburn et al studied patients who had CT scans pre-operation and after MMA. They demonstrated significant increase in both AP- & lateral PAS dimensions at all levels. The maximal increase was at the tongue base level, with an increase of 179% in AP dimension and 37% in the lateral dimension.

Maxillomandibular Expansion:
Other than procedures that affect the AP position of the facial skeleton, Conley et al suggested the use of maxillomandibular expansion in treatment of OSA. This is transverse widening of dental arches and jaws via orthognathic surgery or distraction osteogenesis. The transverse expansion will create increased space for the tongue and oral tissues which prevent thin displacement posteriorly. In addition, the expansion of the maxilla may widen the nasal floor, enlarge the nasal cavities and decrease the nasal resistance. However, the recent research done in this area did not agree with this. Studies have shown that the increased nasal patency and decreased nasal resistance did not last over the long term and the maxillary and mandibular expansion did not result in significant AP and lateral widening of the airway.

2. Discussion

Narrowing of the PAS after orthognathic surgery has gained increasing attention in recent decades. The changes in PAS after mandibular setback osteotomy remain controversial, with some studies reporting controversial, with some studies reporting no changes and others showing decrease in PAS dimensions. Some studies have examined the changes in the pharyngeal airway by using lateral cephalometric radiograph while some studies used CBCT. However, CBCT has significant advantages because it allows better delineation of soft tissue and air. Therefore it has given a greater power of analysis to orthodontists and oral surgeons, providing accurate 2D & 3D measurements of the PA – for example, cross-sectional area and volume, respectively. Few studies tried to correlate the surgical displacement of the jaws with the PA's dimension alterations and most used 2D cephalometric radiographs in their evaluations but cephalometric provides no information about the lateral structures and cross sectional area of the upper airway. Although the fact that lateral cephalometric radiograph provides only 2 dimensional information of the pharyngeal airway, it is still a popular method in the assessment of craniofacial structures and sleep apnea. This has its own advantages like simplicity, low cost, availability, easily comparison with other studies. Sears et al found a weak, but statistically significant, correlation between linear and volumetric measurements in nasopharynx and oropharynx but not in hypopharynx. Head posture has also been suggested to influence the dimensions of the oropharyngeal airway change in the angle of odontoid process to the head posture is one of the important variables and showed that 10 degree of head extension can improve the oropharynx airway by 4mm. The assessment of PAS between genders, snoring and OSA are more common in men than in women changes in PA are different for each gender. A possible explanation is difference in muscle tone around PA. A common assumption is that the muscle tone of the genioglossus is greater in females PA is greater in females than in males, suggesting that the female PA is more stable. Samman et al showed a reduction in the minimal airway dimension after mandibular setback surgery only in males whereas Degerliyurt et al did not observe any distance between the two genders. The objection of this study was to evaluate the changes in PAS after different orthognathic surgeries for the treatment of the prognathic mandible. Concerning BSSO versus IVRO, the studies showed that there was a significant reduction in the PAS after IVRO compared to BSSO. This is due to the proximal segments in IVRO patients usually move forward during surgery and both the proximal and distal segments translate backward after the release of intermaxillary fixation (IMF), where as both segments move backward during BSSO surgery and might relapse forward after IMF release. Comparing, bimaxillary versus mandibular setback surgery, the studies showed that a significant reduction in the PAS volume in both the A-P dimension and crosssectional area at nasopharynx, oropharynx and hypopharunx after one-jaw surgery (mandibular setback) compared to two-jaw surgery (bimaxillary). From the meta-analysis reports it was indicated that there is a significant increase in the PAS at oropharyngeal level in patients undergoing bimaxillary surgery, which appears to justify the indication of this type

of surgery for patients with OSA. It is duew to the refinement of Lefort 1 down fracture technique and the increased diagnostic awareness of maxillary hypoplasia. The combination of Lefort 1 osteotomy and BSSO should be considered in patients with mandibular prognathism who have factors predisposing them to the development of OSA (overweight men with short necks, macroglossia, a large uvula and excessive soft tissue around the nasopharynx area or a large AP discrepancy or both) to reduce the amount of mandibular setback and to avoid the development of post operative OSA. However, there are controversies about the PAS changes after bimaxillary surgery. Some studies reported a significant decrease in linear measurements and in the retrolingual axial sectional area, where as Jackobsone observed a substantial increase in volume in the oropharynx and hypopharynx areas. Bimaxillary surgery with counter clockwise rotation of maxillo mandibular complex and mandibular advancement significantly increases the post surgical PAS and velopharyngeal anatomy. The esthetical important point is that the AP position of the maxilla stays almost the same in contrast to the MMA technique, where the maxilla has to be anteriorly repositioned up to 10mm. Further better-designed RCT studies investigating the long-term changes in PAS (cross-sectional area and A-P measurement) after different orthognathic procedures (maxillary advancement versus mandibular setback and one-jaw surgery versus two-jaw surgery), using three-dimensional analysis such as Cone beam CT, are required to substantiate the results of the present study.

3. Conclusion

Analysis of literature reveals there are no significant changes in the upper airway of patients with skeletal class 3 pattern after bimaxillary orthodontic surgery and mentoplasty. There is significant decrease in all pharyngeal air volumes before surgery to 6 months and 1 year after isolated mandibular setback surgery. There is significant decrease in AP at oropharyngeal and hypopharyngeal up to 1 year after isolated mandibular setback surgery. No significant correlation exists between the amount of mandibular setback surgery and pharyngeal airway volumes. In conclusion, it is evident that mandibular setback surgery may cause narrowing of posterior airway and may be causative factor in gradual development of a breathing disorder like OSA. This may particularly occur if predisposing factors such as specific craniofacial type or obesity are present or individual neuromuscular adaptation is significant to compensate for reduction in airway size. Therefore careful airway analysis should be performed, particularly in correction with large antero-posterior discrepancies. The posterior airway space after the rotation of maxillomandibular complex was not decreased much we could achieve acceptable results in terms of facial aesthetics and occlusal function without huge change of posterior airway pharyngeal space. Prediction of the minimal cross-sectional area percentage variation on the maxillary advancement associated with mandibular setback is not reliable when considering the maxillary and mandibular displacements. On the other hand the maxillary displacement proved to be a reliable prediction of the minimum CSA% variation in maxillary mandibular advancement surgery. If the patient has a history of snoring, breathing problem or decreased airway size and requires mandibular setback. Bimaxillary advancement is definitely preferred, this may in fact prevent future problems in airway patency. Patients who are undergoing orthognathic surgery should be screened for excessive daytime somnolence, snoring, increased BMI and medical conditions related to OSA. The proposed treatment plan may be modified according to risk of posterior airway compromise and even to improve it. In contrast advancement procedures of facial skeleton, especially MMA have been shown to effectively open up PAS and cure existing OSA. The literature has not yielded a unanimous stand on the effect of mandibular setback surgery on posterior airway. The evidence points to a detrimental effect on the airway but most studies have not taken all the factors into consideration. This means that more research needs to be done with better technology to look at the airway volume and its implications in terms of airway resistance, obstruction, collapsibility and the resultant effect on OSA.

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