ABSTRACT

Introduction: The aim of this study was to determine the 3D airway changes that occur following mandibular setback surgery alone vs. bimaxillary surgery in patients with similar skeletal start forms.

Setting and Sample Population: The University of Michigan School of Dentistry and Medical Center. 85 patients undergoing mandibular setback with or without simultaneous maxillary advancement.

Materials and Methods: A retrospective evaluation of pre- and post-surgical CBCT scans for patients undergoing mandibular setback surgery alone (14) versus bimaxillary surgery (71) was performed. Cross sectional evaluation at standardized locations, minimum cross section, and volumetric analysis were performed (Dolphin Imaging TM Version 11.7).

Results: Patients who underwent mandibular setback surgery alone showed a statistically significant average increase of 47.5 mm2 in minimum axial area. Patients who underwent bimaxillary surgery showed a statistically significant increase in airway volume, minimum axial area, location of minimum axial area, and axial area at the retropalatal and retroglossal regions.

Conclusions: The results demonstrate that the mandible can be setback safely without decreasing airway dimensions. In borderline OSA patients, bimaxillary surgery remains the preferred approach due to the larger airway increases observed. Long-term follow up with polysomnography must be conducted to determine the full functional implications of both procedures.

Keywords: orthognathic surgery, airway remodeling, cone beam computed tomography

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3D Airway changes using CBCT in patients following mandibular setback surgery +/- maxillary advancement

INTRODUCTION

Patients who seek orthodontic care have either a dental malocclusion, skeletal malocclusion, or a combination of the two. Dental malocclusions are best described as improper alignment or relationship of the teeth with properly positioned maxillary and mandibular skeletal bases. Skeletal malocclusion is best described as an improper position of the bony bases of the maxilla, the mandible, or both, with normal alignment of the teeth over the bony bases. A combined dental and skeletal malocclusion is a combination of improper alignment/relationship of the teeth along with improper position of the bony bases of the maxilla and/or mandible.

Class III skeletal malocclusion is a condition frequently seen in orthodontic practice, but is less common than Class II malocclusion. According to data from the third National Health and Nutrition Examination Survey (NHANES III), a fraction of one percent of American adult patients present with Class III malocclusion.[1] Despite this relatively small figure, a high percentage of those patients seek treatment due to the resulting functional and esthetic concerns. Recent data indicates that over half of the patients presenting with skeletal Class III malocclusion will require surgical intervention.[2]

A Class III skeletal pattern involves a relative or absolute protrusion of the mandible compared to the maxilla. This can be due to true mandibular prognathism, true maxillary retrognathism, or a combination of the two.[3] A large percentage of patients will have some degree of both mandibular prognathism and maxillary retrognathism; yet a

Class III malocclusion resulting from hyperplasia of the mandible alone, or hypoplasia of the maxilla alone, is relatively rare. While on the surface Class III patients appear to have a larger-than-normal mandible, it is estimated that approximately 75% of patients diagnosed with a skeletal Class III malocclusion have maxillary retrognathism as a component of their diagnosis.[4] Class III malocclusion is widely believed to have an important genetic component, and studies have found multiple genetic loci associated with Class III malocclusion.[5-7] The term "Hapsburg jaw" has been used in the past as a descriptor for Class III skeletal malocclusion, named after the family dynasty which had a strong predilection for prognathic mandibles.[8]

Class III malocclusion can be treated by several different means depending on the diagnosis and age of the patient. During adolescence, orthopedic growth modification such as chin cup therapy[9] and reverse-pull facemask therapy[10] can be considered as well as a new technique involving bone-anchored maxillary protraction plates.[11]
Dental Class III can commonly be treated with full fixed appliances and elastic wear[12] with or without interproximal reduction.[13] Orthognathic surgery, while often thought of as a "last resort," can in fact be the only reasonable option in a case with a severe skeletal imbalance and compromised facial esthetics.

Until the 1980's mandibular setback using the Bilateral Sagittal Split Osteotomy (BSSO) or and Intraoral Vertical Ramus Osteotomy (IVRO)[14] was the standard form of surgical correction.[15] More recently, practice trends have shifted to maxillary advancement with or without mandibular setback in part due to concern that mandibular setback surgery, while beneficial to the facial profile and occlusion may have a negative impact on a patient's pharyngeal airway space (PAS).[16] Studies have used two dimensional (2D) lateral cephalometric films pre- and post-operative radiographs of patients undergoing mandibular setback surgery to measure airway changes, and many reports suggest setback leads to a decreased PAS in the short term[17-33].

While 2D lateral cephalograms are reproducible, the airway is a dynamic three-dimensional (3d) structure. Cone beam computed tomography (CBCT) is an imaging modality that is becoming more widespread in orthodontic, and orthognathic surgery discipline because it provides an accurate 3D representation of the airway and surrounding structures while also exposing the patient to significantly less radiation than would be experienced with conventional medical computed tomography or a combination of other normal dental diagnostic imaging.[34] More study is clearly needed in this area. The goal of this study is to evaluate the amount and location of airway changes resulting from mandibular setback surgery compared to bimaxillary surgery for the correction of Class III skeletal deformity. The hypothesis is that mandibular setback surgery will result in airway reduction while bimaxillary surgery will result in airway increase.

Materials and Methods

Institutional review board exemption (#HUM00083483) was granted for this retrospective study. Inclusion criteria included adult patients with preoperative and postoperative CBCT scans who underwent either mandibular setback alone or mandibular setback with maxillary advancement for the correction of Class III skeletal malocclusion. To account for variability in head position, only patients with consistent head posture (<5°) as assessed by measuring the craniocervical angle (N-S-Ba) were included. Chart review identified 124 Class III surgical patients; eighty-five (85) patients met the inclusion criteria. The final groups included 14 mandibular setback alone and 71 two-jaw surgery patients. (Table 1)

All scans were obtained with an EWOO Master 3DS™ CBCT scanner (EWOO Technology USA Inc., Houston, TX). The scan parameters were 90.0kV, 3.3mA, 20x19cm field of view, 15-second exposure time, normal quality mode, 0.2mm slice thickness, and isotropic voxel size of 0.40mm. All CBCT scans were de-identified, labeled, and saved in DICOM format.

Pre- and post-surgical cephalograms were extracted from the CBCT for every patient. The cephalograms were digitally traced and analyzed using the COGS Analysis (Dolphin Imaging ™ Version 11.7).

THREE-DIMENSIONAL ANALYSIS

Prior to analysis, all scans were reoriented. In the coronal plane, the right and left inferior orbital borders were leveled. Sagittaly, the best fit of the zygomatic arch was leveled. Axially, the lateral walls of the orbits were aligned.

The airway volume (Figure 1) was bounded superiorly by the line extending from posterior nasal spine (PNS) to the posterior pharyngeal wall and inferiorly by a parallel line from the anterior-inferior border of C3 to the base of the tongue. The posterior limit was the posterior pharyngeal wall and the anterior boundary was created by the soft palate and base of the tongue. Three seed points were placed in the region of interest and airway sensitivity was set to 73. Each scan was assessed for "bleed through" and identified areas were removed by adjusting the sensitivity and seed points.

Minimum axial airway was determined for entire airway as well as the retropalatal (anterior-inferior border of C1), retroglossal (anterior-inferior of C2), and retropharyngeal (anterior-inferior C3) regions.

STATISTICAL ANALYSIS

Paired t-tests were performed for 2D and 3D comparison of preoperative to postoperative changes within groups. Welch's unpaired t-test was used to compare the changes pre and post surgically between the mandibular setback alone and the two jaw surgery groups.

For intra- and inter-examiner reliability, a random number generator was used to select 10 subjects from both groups. The measurements were repeated 2 months after the initial measurements. Both intra and inter-examiner reliability tests exhibited high correlation ranging from 0.99 to 0.987 for all measures.

RESULTS

The initial sample yielded 14 mandibular setback and 71 two-jaw surgery patients. The sample was refined to establish groups with identical start forms and confirmed using Anova. The final sample included 14 mandibular setback and 41 two-jaw surgery patients. (Table 2)

Cephalometric Results (Table 2)

The mandible was setback 6.2mm in the mandibular setback alone group. Within the two jaw surgery group, the mandible was setback a similar amount (5.6mm) and the maxilla was advanced 4.5mm.

Three-Dimensional Results

Three-dimensional measurements were taken to assess several parameters of the pre- and post-operative airway, including airway volume, minimum axial area, minimum axial area distance superior to inferior border, axial area at inferior border of C1 (retropalatal), and axial area at inferior border of C2 (retroglossal). Measurement of the craniocervical angle was also recorded. The results are shown in Table 3. Mandibular setback alone patients experienced a statistically significant increase in minimum axial area. All of the other airway measures were unchanged and no airway reductions were observed. Two-jaw patients experienced statistically significant increases in airway volume, minimum axial area, vertical location of the minimum axial area, and the axial areas at both C1 (retropalatal region) and C2 (retroglossal region). The only statistically significant difference between groups was a change in axial area at the inferior border of C1 (or retropalatal region) only.

DISCUSSION

Cephalometric Evaluation

Because all patients underwent orthognathic surgery, it was expected that several skeletal cephalometric measurements would show statistically significant changes consistent with the surgery performed. Patients who underwent a 1-jaw surgical procedure showed statistically significant sagittal reductions in measurements mandibular landmarks, such as B-point, pogonion, and gonion. The measurements involving maxillary structures, such as Nasion to A-point, remained unchanged. The average amount of mandibular setback, based on cephalometric change, was 6.2mm for the 1-jaw group.

Patients undergoing 2-jaw surgery showed statistically significant changes in measurements that involved both the maxilla and mandible. The average amount of mandibular setback, for the 2-jaw group, was 5.6mm. The average amount of maxillary advancement for the same group was 4.5mm.

Three-Dimensional Evaluation

Previous studies have suggested that mandibular setback without maxillary advancement leads to a decreased pharyngeal airway space (PAS).[18] In the present investigation, the mandibular setback group showed a statistically significant increase in minimum axial area post-operatively of 47.54 mm^2. The difference between investigations may result from the 2D versus 3D techniques employed. 2D studies are unable to visualize airway shape changes fully. A change from circular to elliptical especially if the long axis of the ellipse extends medio-laterally would not be possible to view in 2D. It was unexpected that setback surgery alone did not cause any statistically significant change at the inferior border of C2, the retroglossal region, which is the region most anticipated to be negatively affected.

Patients undergoing 2-jaw surgery demonstrated comprehensive statistically significant airway increases between time points. The airway volume increased by 5.31 cm^3, the minimum axial area increased by 52.02 mm^2, the minimum axial area distance superior to inferior border moved inferiorly by 6.07 mm, the axial area at the inferior border of C1 (retropalatal region) increased by 70.49 mm^2, and the axial are at the inferior border of C2 (retroglossal region) increased by 65.35 mm^2. The axial area in the retropalatal region increased significantly, which should be expected due to the supporting structures being moved anteriorly. It was interesting that the minimum axial area increased, as well as the axial area in the retroglossal region. While we cannot explain exactly why this occurred, a plausible explanation could involve the anterior displacement of the maxilla, which could lead to anterior displacement of the soft palate and thus the tongue due to its contact with the soft palate. Anterior displacement of the musculature could easily cause, at least in the short term, an increase in the entire PAS. However, future work would be needed in this area to determine exactly the cause for such changes.

All patients had a bite jig used for accurate positioning in the pre-operative CBCT scans. This jig props the bite open a small amount, so the results may have been affected slightly. However, all patients had the bite jig present in the pre-operative scans. In the 3D analysis, the slight opening of the bite could have theoretically led to a more compressed pre-operative airway due to the downward and backward rotation of the mandible. A subsequent study demonstrated 2mm of AP reduction and 2mm increased vertical displacement of pogonion but no airway changes from the splint.[35]

Once the final groups were refined to statistically similar starting forms, the only airway measurement which showed a statistically significant airway difference following surgery was axial area at inferior of C1—or retropalatal region. The greater airway increase makes sense, due to the different surgical techniques employed. The maxillary advancement would be expected to increase the retropalatal axial area.

Craniocervical angle change was used to assure consistent head position during their CBCT scan. This was essential because head angulation can cause changes in airway form (e.g. head tilt chin lift maneuver in CPR). By controlling head position, the observed differences reported can only be the result of surgery.

Based on the results of this study, fear of decreasing of patient's PAS following mandibular setback surgery alone does not appear to be warranted. However, it is possible that long-term follow up of these patients could yield a different conclusion. The post-operative scans used in this study were taken, on average, 2 months post-surgery. A study analyzing the same patients at 1 year, 5 years, and 10 years post-operatively, for example, may yield a different result entirely.

The results of this study suggest that during treatment planning if a patient's facial appearance would benefit from a mandibular setback surgery alone there seems to be no harm in doing so. If there are signs or symptoms of OSA, surgeons may elect to perform bimaxillary surgery, or even maxillary advancement alone. A preferred approach would be to screened for OSA prior to surgery and perform PSG. If OSA is diagnosed, revision of the surgical plan with the sleep team and the orthodontist should be considered.

Retrospective studies are unable to control all variables. The results reported may not be generalizable to other surgical centers if weight, magnitude of surgery, age, or gender characteristics are different.

CONCLUSIONS

Based on the results of this study, fear of decreasing of patient's PAS following mandibular setback surgery alone does not appear to be warranted. Specific conclusions include:

1) Class III patients undergoing mandibular setback surgery alone showed a statistically significant increase minimum axial area of the PAS after surgery.
2) Patients who undergo bimaxillary surgery showed a significantly increased retropalatal axial area after surgery compared to patients undergoing mandibular setback alone.
3) Patients who undergo bimaxillary surgery show no other significant difference in airway volume, minimum axial area, minimum axial area location, or retroglossal axial area after surgery compared to patients undergoing mandibular setback alone.

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Figure 1: A representative CBCT airway segmentation.
Mid-sagittal slice from CBCT depicting the "seed" points (yellow dots), airway region of interest (yellow box) and airway volume (purple area).

Table 1:

Group	Type of Surgical Procedure Performed	Pre Anova	Post-Anova
1 Jaw	IVRO/BSSO	14	14
2 Jaw	Lefort +BSSO/IVRO	71	41
		85 total	**55**

Table 1: Surgical groupings. The full group of patients who underwent the assigned procedures was collected. Prior to subgroup analysis, ANOVA was performed to establish similar start forms for the two groups yielding the final study population.

TABLE 2:

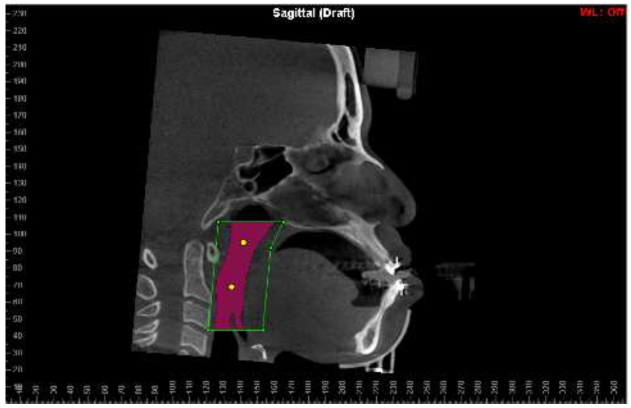
Comparison of 1-Jaw vs. 2-Jaw Cephalometric Sub-groups			
	1-Jaw (n=14) Pre-Op Mean ± Std. Dev	**2-Jaw (n=41) Pre-Op Mean ± Std. Dev**	**p-value**
Ar-PTM (HP) (mm)	32.09 ± 2.64	31.52 ± 3.31	0.6998
PTM-N (HP) (mm)	55.94 ± 3.66	56.14 ± 3.99	0.7200
N-A-Pg (°)	-1.11 ± 6.29	-7.40 ± 7.65	0.0835
N-A (HP) (mm)	-1.04 ± 3.23	-2.59 ± 4.39	0.3741
N-B (HP) (mm)	-1.49 ± 5.70	0.94 ± 9.50	0.5681
N-Pg (HP) (mm)	-1.16 ± 7.59	2.90 ± 11.39	0.4532
N-ANS (perp HP) (mm)	56.27 ± 4.66	56.44 ± 4.05	0.6827
ANS-Gn (perp HP) (mm)	72.19 ± 6.11	77.76 ± 8.40	0.1122
PNS-N (perp HP)	54.85 ± 4.44	56.65 ± 4.39	0.8689
Mand Plane-HP (°)	31.87 ± 5.99	31.20 ± 6.67	0.7443
U1-NF (perp NF) (mm)	29.55 ± 3.33	30.83 ± 4.63	0.8374
U6-NF (perp NF) (mm)	25.05 ± 2.94	26.72 ± 3.25	0.4089
L6-MP (perp MP) (mm)	29.53 ± 3.90	31.19 ± 3.85	0.4530
L1-MP (perp MP) (mm)	39.96 ± 5.03	41.08 ± 3.73	0.7756
PNS-ANS (HP) (mm)	54.47 ± 5.36	55.30 ± 4.60	0.6270
Ramus Height (Ar-Go) (mm)	54.24 ± 5.98	58.99 ± 9.59	0.3394
Go-Pg (mm)	75.46 ± 7.56	76.39 ± 10.16	0.8380
B-Pg (MP) (mm)	8.65 ± 2.28	10.62 ± 2.67	0.2716
Ar-Go-Gn (°)	131.49 ± 4.62	131.85 ± 6.55	0.5367
OP-HP (°)	9.36 ± 5.55	7.32 ± 6.29	0.3470
U1-NF (°)	118.59 ± 7.13	118.16 ± 8.11	0.6345
L1/Go-Me (°)	90.64 ± 5.81	84.46 ± 7.44	0.0157*
A-B (//OP) (mm)	6.76 ± 2.37	9.69 ± 4.99	0.1817

Table 2. Cephalometric pre-operative mean start forms for both 1-jaw and 2-jaw patients after sub-group creation. ***The lower incisor to mandibular plane measurement was disregarded as this is considered a dental component.

Table 3:

Comparison of Similar 1-Jaw and 2-Jaw Patients Undergoing Different Surgical Procedures							
	1-Jaw (n=14)			2-Jaw (n=41)			p-values
	Pre-op	**Post-op**	**Chg**	**Pre-op**	**Post-op**	**Chg**	
Airway volume (cm^3)	21.47 ± 7.36	22.60 ± 7.31	1.13	20.45 ± 7.89	24.73 ± 8.94	4.28	0.0672
Min. axial area (mm^2)	264.08 ± 111.97	311.61 ± 115.12	47.53	229.22 ± 117.39	272.32 ± 91.36	43.10	0.8649
Min. axial area distance S-I (mm)	22.00 ± 12.52	22.25 ± 17.12	0.25	23.88 ± 14.41	16.66 ± 15.57	-7.22	0.2088
Axial area at inf. C1 (mm^2)	372.95 ± 118.26	397.17 ± 129.89	24.22	354.51 ± 145.64	427.86 ± 138.63	73.35	*0.0472
Axial area at inf. C2 (mm^2)	345.30 ± 129.67	384.91 ± 141.57	39.61	316.60 ± 180.06	369.33 ± 156.58	52.73	0.7428
Craniocervical Angle (^{o})	107.18 ± 10.03	106.86 ± 8.21	-0.32	103.03 ± 8.09	102.57 ± 7.94	-0.46	0.9074

Table 3. Airway mean measurements after 2-jaw patient exclusions. P-values represent a comparison of how significant of a change occurred between pre-and post-operative measurements of 1-jaw patients compared to 2-jaw patients. *p<0.05



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