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An application of virtual surgical planning in genial tubercle advancement using the mandibular trapezoid osteotomy

Andrew M. Henry[a,*], Peter B. Franco[a], Daniel D. Choi[b], Brian B. Farrell[a,c]

[a] Carolinas Center for Oral and Facial Surgery, Charlotte, NC, USA
[b] Department of Oral and Maxillofacial Surgery, Jefferson University Hospital, Philadelphia, PA, USA
[c] Department of Oral and Maxillofacial Surgery, Louisiana State University School of Dentistry, New Orleans, LA, USA

A R T I C L E I N F O

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A B S T R A C T

The treatment of obstructive sleep apnea includes multiple soft and hard tissue surgeries with the gold standard being orthognathic surgery. In this paper we describe a novel method of using virtual surgical planning to create custom cutting guides for the genial tubercle and associated genioglossus muscle. This then allows for precise genioglossus advancement while minimizing the risk of damage to the adjacent teeth or to the muscle itself.

1. Introduction

Obstructive sleep apnea syndrome (OSAS) is a clinical disorder involving nocturnal airway collapse leading to episodes of apnea, arousals and sleep fragmentation. The subsequent hypoxemia and hemodynamic instability are associated with sequelae including daytime somnolence, depression, hypertension, cardiac arrhythmias and pulmonary hypertension. An aggressive approach is advocated as mortality is increased in this patient population [1,2].

Currently the treatment of OSAS is initiated with medical management including nasal CPAP, which remains the gold standard. However, compliance remains an issue that may lead some to pursue surgical options [3].

The genioglossus muscle is a pharyngeal dilator for the oropharynx. During times of rest, there is loss of tone, which causes a collapse of the oropharynx [4]. By advancing the genial tubercle, tension is created on the muscle and tongue base, which prevents complete collapse of the oropharynx during sleep. The American Sleep Disorders noted the most beneficial method of widening the retrolingual region is genioglossus advancement with or without hyoid myotomy [5].

Genial tubercle advancement (GTA) in the setting of sleep apnea was first performed in 1983 [6]. The initial surgery was an inferior horizontal osteotomy that attempted to capture and advance the genial tubercle. Many other modifications including mortised genioplasty [7], rectangular genial tubercle osteotomy with rotation [8], isolated genial tubercle advancement [9], genial bone advancement trephination [10], elliptical window osteotomy [11] and 2-piece trapezoidal osteotomy [12] have been described in literature.

The goals of surgery [13] should include 1) accurate capturing of the genial tubercle and associated musculature, 2) avoidance of the apices of the mandibular anterior dentition, 3) maximal genial tubercle advancement and retrolingual airway expansion, 4) avoidance of mandibular fracture and 5) optimal facial esthetics. Technique can be varied based upon individual clinical and radiographic findings.

* Corresponding author. Carolinas Center for Oral and Facial Surgery, 8840 Blakeney Professional Dr. Suite 300, Charlotte, NC USA.
E-mail address: Ahenry@mycenters.com (A.M. Henry).

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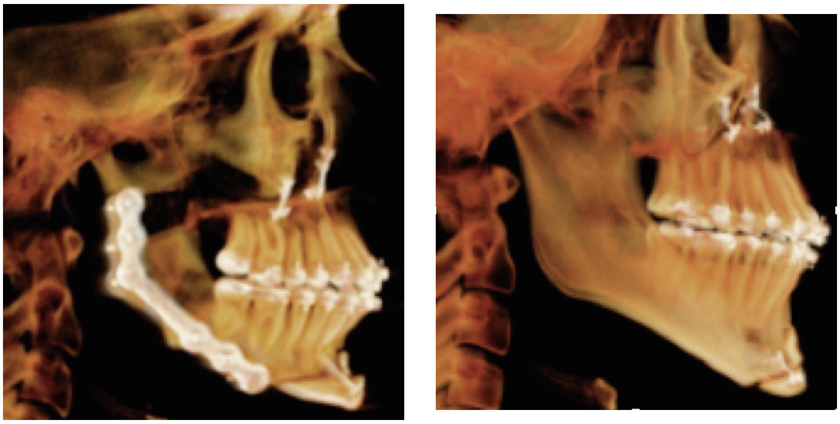

Fig. 1. (a) Class II mandible post-op lateral ceph and (b) Class III mandible post-op lateral ceph.

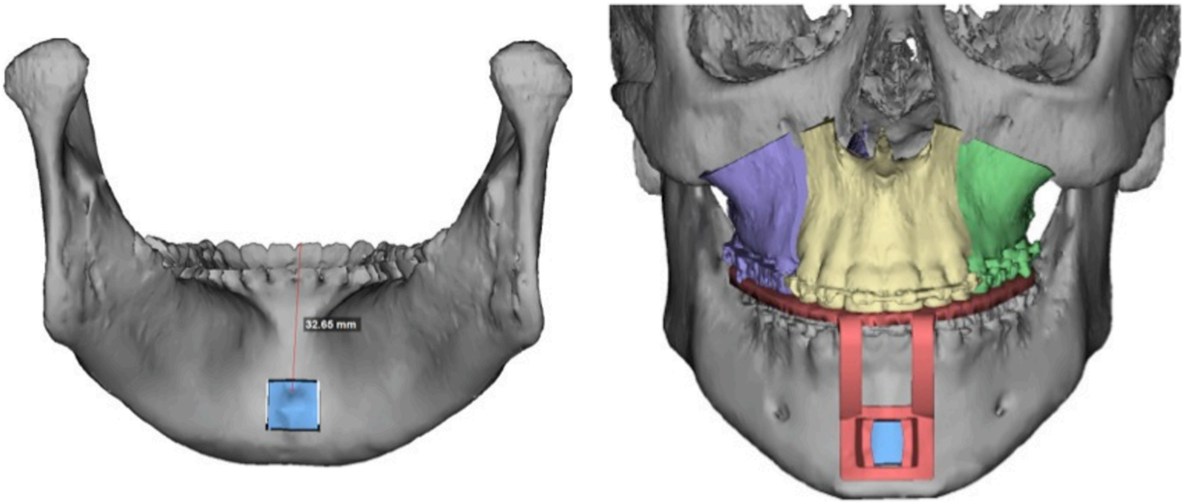

Fig. 2. (a) VSP with osteotomy of genial tubercles outlined from lingual and (b) VSP with cutting guide in place.

The lateral extent of the osteotomy should be spaced wide enough to capture the tubercle and musculature, yet narrow enough to avoid impinging upon the canine roots. On average, the width of the tubercle is 4.9–6.98 mm with the muscle fanning laterally an additional 2 mm [14–18]. Therefore, smaller width osteotomies will ineffectively capture the musculature, leading to greater tearing of the muscle and inefficient expansion of the retrolingual space [19]. The superior extent of the osteotomy is dependent upon the relationship of the apices of the dentition to the genial tubercle. Studies have shown this distance to vary from <5 mm to 15 mm from the root apices [13–16,20,21]. When considering osteotomy design, one should always allow for a safety zone of 3–5 mm below the apices of the mandibular incisors to maintain vascularity and vitality of the dentition although animal studies have not shown clinical significance if this is violated [22–24]. The position of the inferior horizontal osteotomy is dependent on the relationship of the inferior aspect of the tubercle to the inferior border of mandible. Classically, 10 mm was required to avoid fracture, but recent data supports 5–6 mm of inferior border is sufficient [12,13]. Average distance of the tubercle to the inferior border varies from 6.4 to 14 mm, thus dictating the height, but the risk of mandibular fracture remains low [13,14,16–18,25,26]. Average height of the genial tubercle is noted to range from 4.7 to 11.64 [14,16–18].

The amount of advancement should be maximized in the setting of OSAS and retrolingual obstruction. The genial tubercle advancement can efficiently expand the retrolingual region, but is limited by the thickness of the mandible. In this region, studies have shown average mandibular thicknesses ranging from 11.95 to 14.5 mm [13,14,16,18]. Therefore, the majority of techniques advocate the advancement of the lingual cortex to the buccal cortex of the mandibular symphysis to achieve maximal airway expansion.

Lastly, special consideration is paid towards skeletal and facial analysis of the patient as this may point towards an underlying contributing factor. Retrognathic mandibles and significant anterior-posterior discrepancy between maxilla and mandible have been associated with high apnea-hypopnea indices [27]. This should be accounted for when considering maxillomandibular advancement as a treatment option. In the setting of skeletal class 2 or microgenia, effort is made to produce an appropriately balanced facial profile with an advancement genioplasty or mandibular advancement (Fig. 1a). In those with skeletal class I/III, the technique is altered to

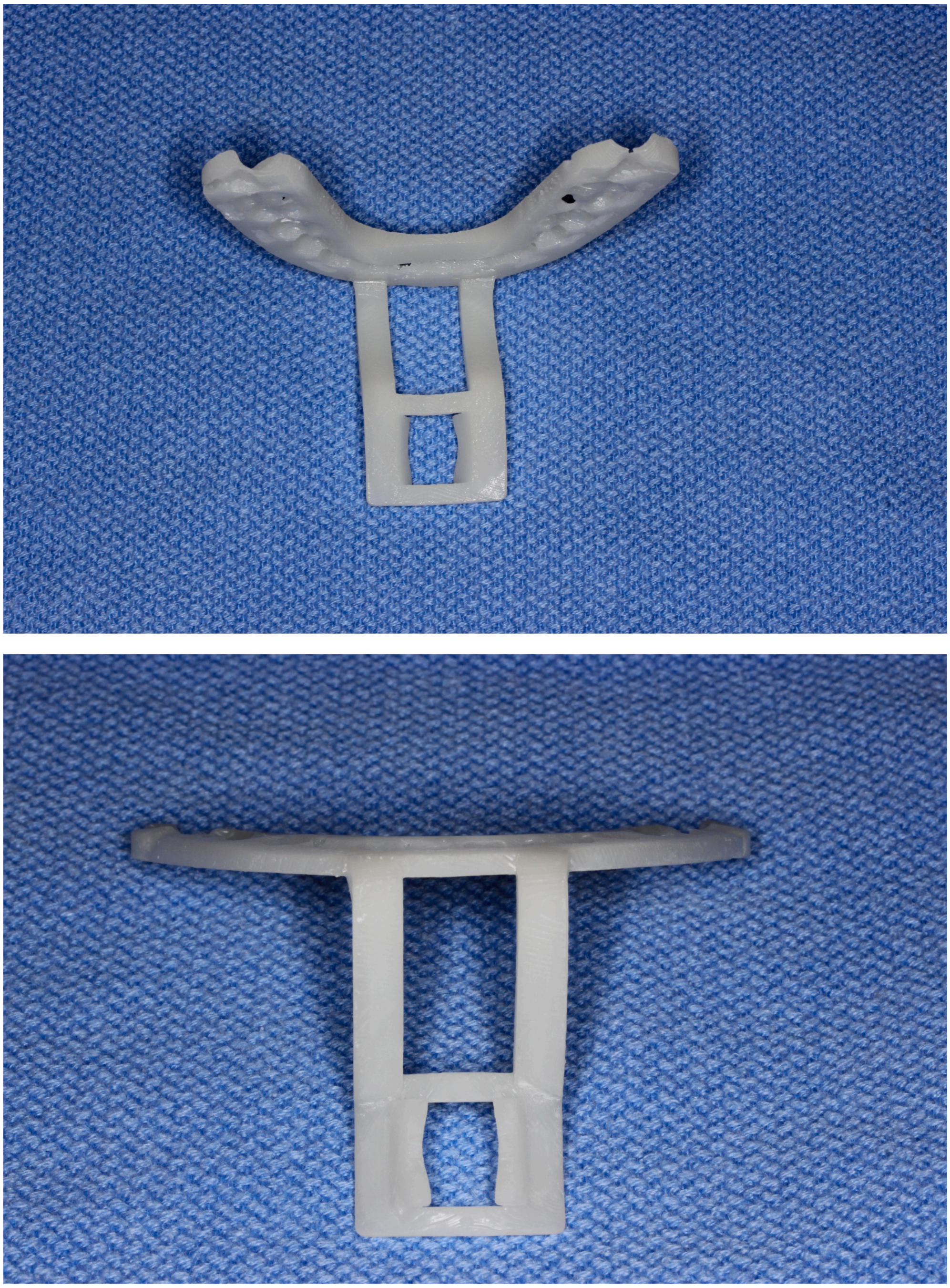

Fig. 3. (a)–(c) Views of prefabricated cutting guides incorporated into final splint.

allow for maximal retrolingual expansion with minimal change in facial contour (Fig. 1b). Multiple modifications to the genioplasty have added to its versatility to correct the lower face in all three dimensions [28–31].

With the advent of VSP (virtual surgical planning), orthognathic and craniofacial surgery has become more predictable and reliable [32,33]. VSP allows the surgical team to walk through the procedure preoperatively, predict bony interferences and accurately correct asymmetry and yaw deformities. VSP also effectively eliminates the lab work associated with model surgery. Intermediate splints, final splints, cutting guides and repositioning guides are fabricated based on a single virtual planning session.

In this article we look at the role of VSP in genial tubercle advancement. Studies have compared measurements from CT studies to anatomic specimens and noted no significant difference [14,16]. The authors in this study follow the technique described by Dattillo

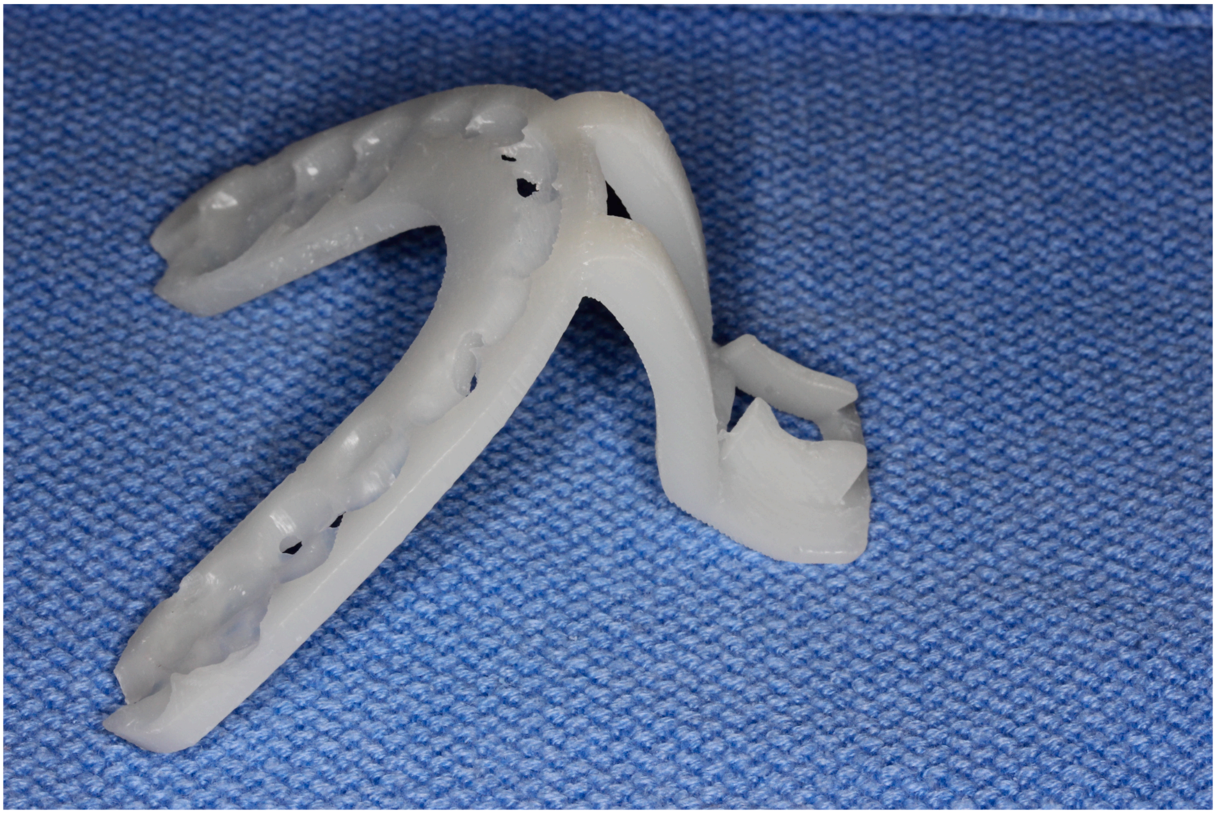

Fig. 3. (*continued*).

[12]. Based on a preoperative CBCT, computer-designed surgical cutting and repositioning guides are fabricated based on the individual's anatomy. The 2-piece trapezoidal osteotomy allows the authors to directly visualize and confirm the accuracy of the surgical cutting guide. With the assistance of VSP, the surgeon can accurately capture the genial tubercle, minimize dental complications, correct any chin asymmetries, and achieve optimal facial esthetics (Fig. 2a and b).

2. Technique

2.1. Preoperative planning

Workup begins with a thorough clinical evaluation. Obesity, large neck circumference, nasal obstruction, male gender, smoking and ETOH are all known risk factors for OSAS [34]. An intraoral examination reveals Mallampati and Friedman classifications associated with disease severity [35,36]. Polysomnography diagnoses OSAS and grades the severity of the disorder.

Fiberoptic nasopharyngoscopy with Muller's maneuver helps identify site-specific areas of airway collapse.

Radiographic studies are helpful adjuncts in assessing OSAS. Lateral cephalometric studies reveal posterior airway space (PAS), hyoid positions and dentofacial deformities that are associated with higher likelihood of sleep apnea [27,37]. Computed tomography scans allow for volumetric analysis of the airway which help determine the severity of OSAS and direct the surgeon towards site specific obstructions [38,39].

If planning concurrent MMA or orthognathic surgery, DICOM data and diagnostic casts or intraoral scans are sent to third party vendors. During a web meeting, the 3D rendering is reviewed and calibrated to the clinical evaluation. The surgical plan is then virtually tailored to the patient's specific needs. Significant bony interferences are visualized preoperatively on the 3D predictions, allowing the surgeon to alter osteotomy design and adjust yaw deformity to allow for a smoother intraoperative experience. Precise measurements of osteotomy movements are visualized to allow the surgeon to confirm appropriate intraoperative movements.

Intermediate and final splints are fabricated by third party vendors, which eliminate the need for model surgery and decrease preoperative workup time [40]. With the genial tubercle advancement, cutting and repositioning guides are incorporated within the final occlusal splint (Fig. 3a–c). The cutting guide is designed to create a superior osteotomy that correlates to the superior aspect of the genial tubercle and stays more than 3 mm apical to the roots of the mandibular dentition. In the 2-piece trapezoidal osteotomy, the vertical osteotomies are designed to diverge anterior-posteriorly for a wider lingual cortical window (Fig. 4a). The inferior osteotomy captures the genial tubercles at its most inferior extent to maintain a maximal height of inferior border of mandible. If significant chin asymmetry exists, indexing and repositioning guides can accurately correct for significant chin asymmetries.

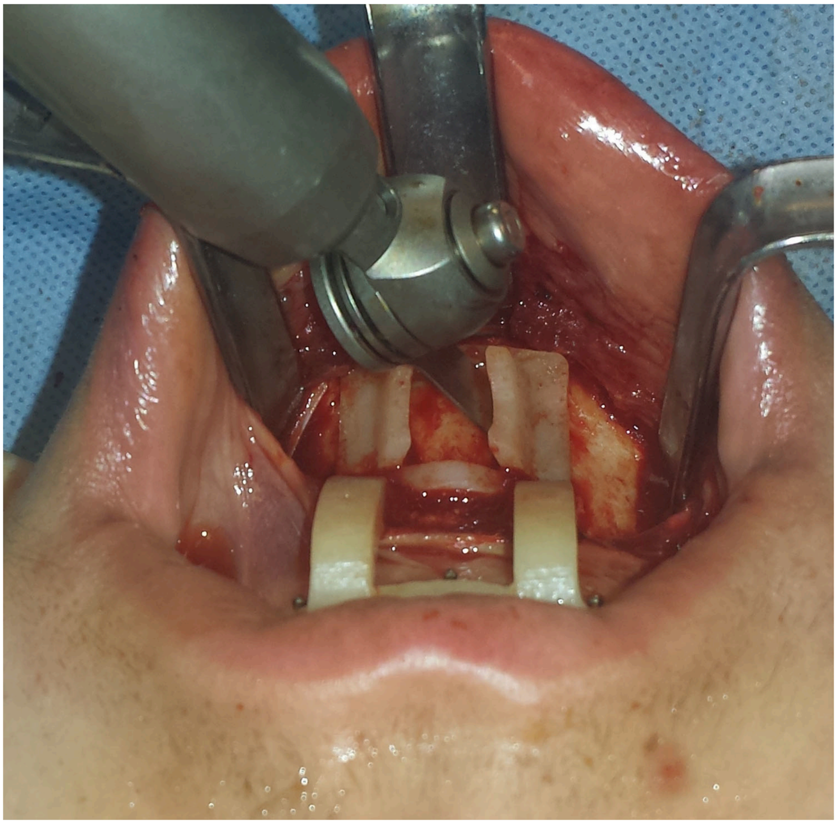

Fig. 4. (a) Divergent cuts with sagittal saw utilizing cutting guide; (b) Cutting guide held in place using patient's occlusion and wires/elastics; (c) Genial Tubercle and genioglossus muscle advanced to outer cortex and (d) Divergent cuts allowing for retention of advanced segment.

2.2. Surgical technique

If simultaneous orthognathic surgery is performed, it is recommended to complete this portion of the procedure prior to genial tubercle advancement. Incision starts with sharp dissection in a mandibular vestibular approach through mucosa and mentalis. Subperiosteal dissection is carried to the inferior border of the mandible with visualization of the mental foramen bilaterally. Next, the final occlusal splint/cutting guide is fit into place. Stabilization of the cutting guide to the occlusal surface allows for a stable and reproducible anatomic reference point from which the osteotomy is safely performed (Fig. 4b). The midline is marked to ensure symmetry, and then a sagittal saw is used to complete all cuts in bicortical fashion.

The arms of the cutting guide are then removed to allow access for the completion of the inferior horizontal osteotomy. If significant chin asymmetry is to be addressed with virtual planning, indexing guides are utilized prior to the inferior horizontal osteotomy. A reciprocating saw is used to complete the inferior horizontal osteotomy. This extends laterally to the inferior border of the mandible, while maintaining a 5 mm vertical separation from the mental foramen.

Once the inferior osteotomy is complete, direct visualization is afforded to the surgeon to ensure the musculature is incorporated into the segment (Fig. 4c). The genial tubercle segment is freely advanced to overlay the facial cortex passively. No fixation is required as there is sufficient overlapping of bone in its superior and lateral aspects (Fig. 4d). The buccal cortex and cancellous bone of this segment are then removed with a reciprocating saw, leaving only the lingual cortex. With significant orthognathic advancements, this bone can be used as an autogenous interpositional bone graft.

If chin esthetics are satisfactory preoperatively, the segment is fixated to its previous anatomic position. If repositioning is planned, the inferior segment is placed according to the virtual plan with the aid of attachments. For advancements, fixation can be performed with prefabricated titanium genioplasty plates with monocortical screws. Closure is performed in layered fashion with resuspension of the mentalis followed by closure of oral mucosa.

3. Discussion

The treatment of obstructive sleep apnea has evolved over the years with advancements in diagnostics, imaging and surgical technique. In cases with severe OSAS and retrolingual obstruction, MMA with concurrent genial tubercle advancement can help

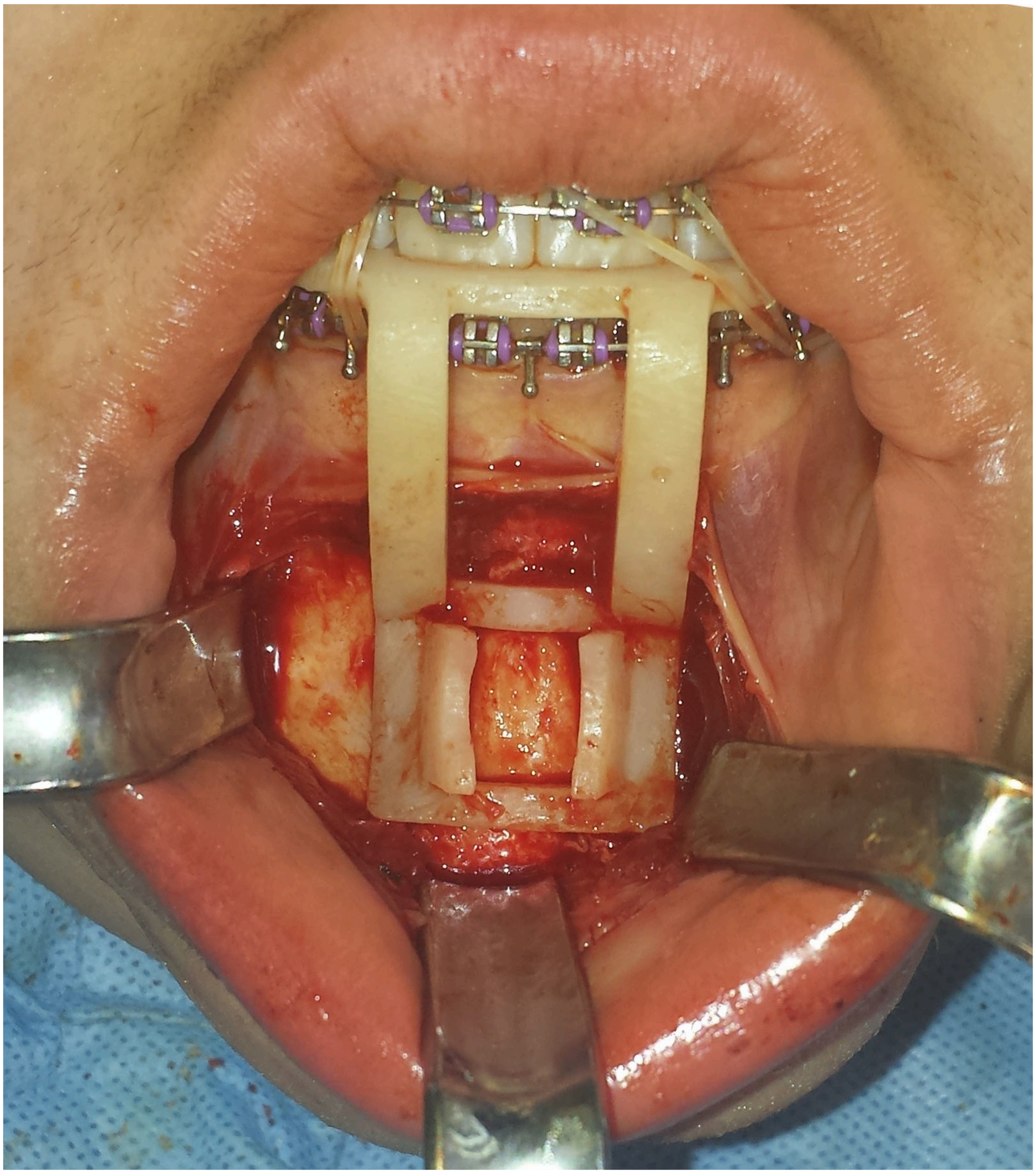

Fig. 4. (*continued*).

maximize the retrolingual space (Fig. 5a and b). More recently, VSP with MMA has been utilized with reliable outcomes in OSAS [41]. It has proven to be a valuable adjunct for oral maxillofacial and craniofacial surgeons. Advantages of VSP include 1) decreased preoperative workup time [40] 2) reliable repositioning of osteotomy segments [32,42] 3) reliable facial esthetics in MMA [41] and 4) highly accurate splints [43].

VSP can be performed with the osteotomy design tailored to the surgeon's preference. In this article, the authors chose to use the 2-piece trapezoidal osteotomy. This offers many advantages as outlined in Table 1. The divergent osteotomy design allows for a broader lingual osteotomy window. This ensures the full incorporation of the musculature that may insert laterally to the tubercles [14,19]. With predictable capturing of the musculature, less muscle tearing and bleeding complications should be encountered. Once the inferior osteotomy is complete, the muscle bellies can be fully visualized. This allows for a direct confirmation that the entire musculature is incorporated into the segment. Due to the nature of the design, the segment can be advanced with appropriate superior and lateral bony overlap with no segment rotation and minimal muscular torsion. The significant bony overlap encourages a broader surface area for osteosynthesis. The passive stabilization also allows for the elimination of any fixation screws adjacent to the root apices, thereby minimizing any potential damage to the dentition. The broader lingual window should allow for less lateral bony constriction on the advanced musculature as they diverge from the tubercle. The avoidance of any rotation on the segment should help minimize any unnecessary torsion on the musculature. This should theoretically decrease the risk of muscle detachment and subsequent relapse of the retrolingual obstruction [44]. Lastly, the inferior segment can be virtually and surgically repositioned in three

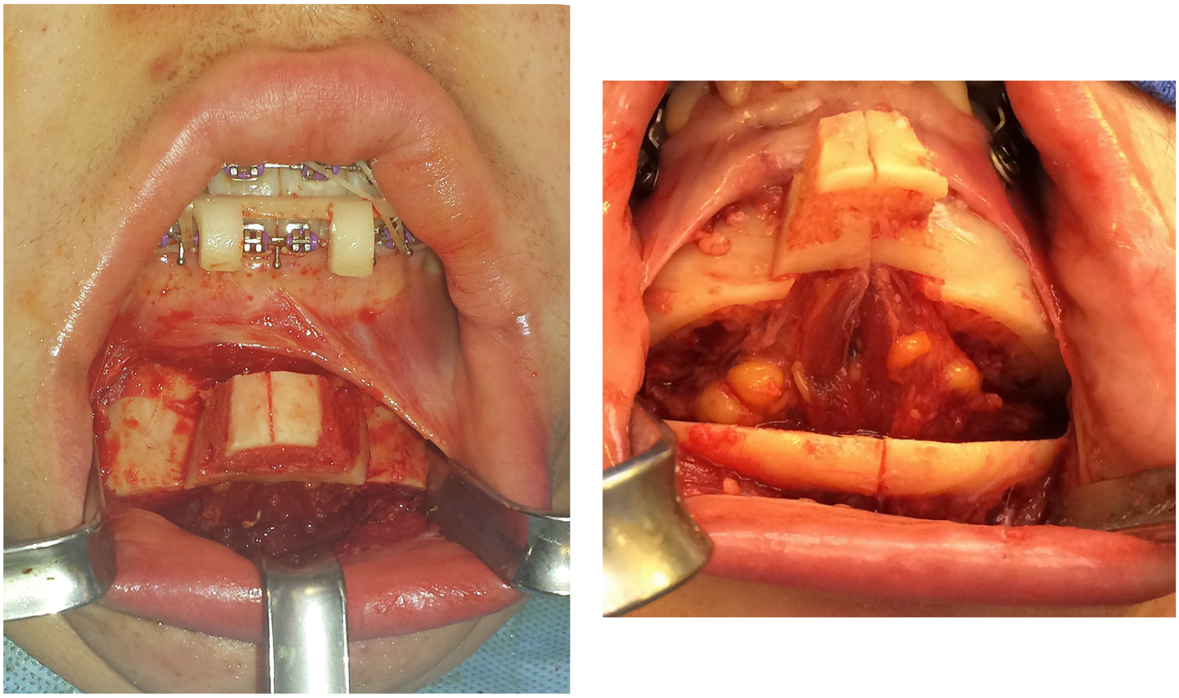

Fig. 4. (*continued*).

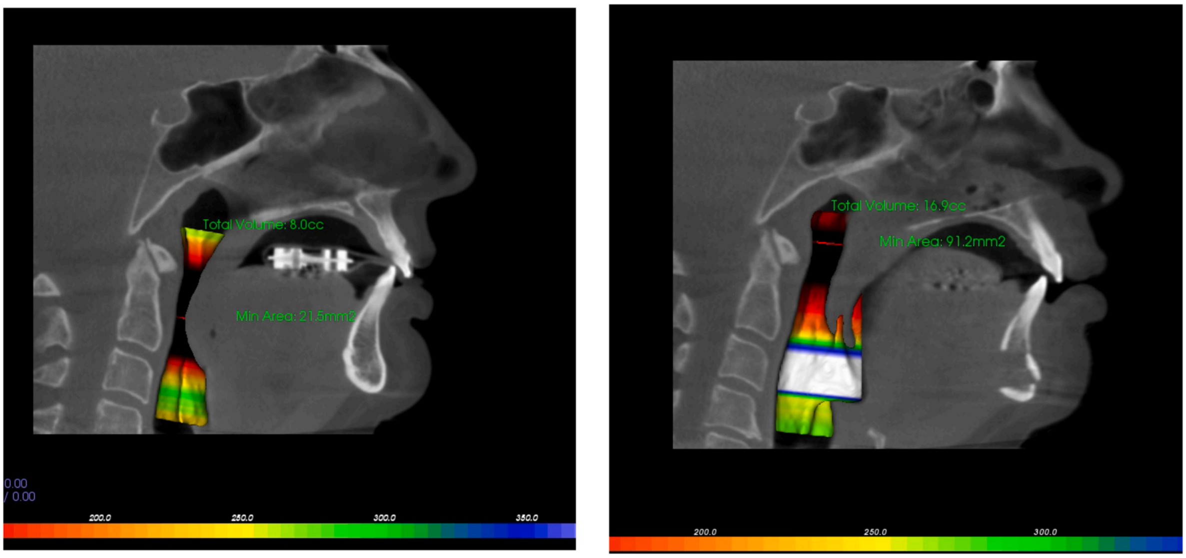

Fig. 5. (a) Pre-op airway volumetric analysis and (b) Post-op airway volumetric analysis.

Table 1
Advantages of 2-piece trapezoidal osteotomy in genial tubercle advancement.

- Improved incorporation of the musculature
- Direct confirmation of the incorporated musculature
- Avoidance of any torsion on the advanced musculature
- Passive stabilization of the advanced segment with increased bony overlap
- Decreased fixation requirements
- Ability to reposition the chin in three dimension

dimensions to correct any craniofacial deformities and optimize facial esthetics.

Disadvantages include nerve paresthesia and mandibular fracture, however there is no greater risk of mandibular fracture than the mortised genioplasty originally designed by Riley. Multiple studies have shown the mortised genioplasty to be a safe procedure with minimal risk of mandibular fracture [25,26]. Additionally these patients are maintained on a soft food diet throughout their healing course.

4. Conclusion

VSP has been proven to be a useful tool for craniofacial, oral maxillofacial and sleep apnea surgeons. The preoperative planning process continues to become simplified and streamlined, allowing for improved versatility and time efficiency compared to conventional approaches. We hope this technique will serve as a useful adjunct for surgeons to confidently and safely advance the genial tubercle, maximally expand the oropharyngeal airway, correct underlying craniofacial deformities and optimize facial esthetics.

Proof of consent

As this is a demonstration of a technique article, no consent is needed.

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