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Large maxillomandibular advancements for obstructive sleep apnea: An operative technique evolved over 30 years

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A R T I C L E I N F O

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A B S T R A C T

Objective: Obstructive sleep apnea (OSA) can be a challenging disorder to treat. Maxillomandibular advancements (MMAs) generally have high success rates; however, larger advancements have higher success and cure rates. Our aim is to present and to describe the current technique used by the senior authors, which has been successful for performing large advancements, thereby improving post-operative outcomes.
Methods: The senior authors have developed and modified their maxillomandibular advancement operative techniques significantly over the past 30 years. The current version of the Riley–Powell MMA technique is described in a step-by-step fashion in this article.
Results: Initially, as part of the MMAs, patients underwent maxillomandibular fixation with wires, lag screws and harvested split calvarial bone grafts. The current technique utilizes plates, screws, Erich Arch Bars, and suspension wires which are left in place for 5–6 weeks. Guiding elastics are worn for the first week. The MMA technique described in this article has yielded a success rate over 90% for patients with a body mass index (BMI) <40 kg/m^2 and 81% for patients with a BMI ≥40 kg/m^2.
Conclusion: Large advancements during maxillomandibular advancement surgeries can help improve post-operative obstructive sleep apnea outcomes.

1. Introduction

Obstructive sleep apnea (OSA) is a common disorder which can be affected by soft tissues in the upper airway and the facial skeleton (Garcia Vega et al., 2014; Gerbino et al., 2014). There are several medical treatment options (Camacho et al., 2014, 2015a; Kumar et al., 2014) as well as surgical treatment options (Certal et al., 2014; Senchak et al., 2015). Given that a deficiency of the facial skeleton in the antero-posterior dimension is seen in OSA patients, advancing the facial skeleton with maxillomandibular advancements (MMAs) has been a successful surgical treatment modality (Costa and dos Santos Gil, 2013). MMAs are more successful when the maxilla is advanced 10 mm or more and the mandible is advanced over 11 mm (Riley et al., 1993; Holty and Guilleminault, 2010). The senior authors have modified their operative technique significantly over the past 30 years (Riley et al., 1984, 1986; Hester et al., 2002). Initially, as part of the MMAs, patients underwent maxillomandibular fixation utilizing wires, lag screws and harvested split calvarial bone grafts. Our aim is to describe the current technique.

2. Materials and methods

2.1. Intubation

A standard endotracheal tube is used. The plastic endotracheal tube connector is replaced with a metallic endotracheal tube

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connector which provides needed curvature and additional length, thereby decreasing pressure on the nares during surgery. A standard head wrap is then applied, with a nasogastric tube in the nares opposite to the endotracheal tube (Fig. 1). Erich Arch Bars are applied in the standard fashion. A throat pack is then placed.

2.2. LeFort 1 osteotomies

A maxillary gingivobuccal incision is created from first molar to first molar. The soft tissue and periosteum are elevated off the anterior maxilla (superiorly to the level of the infraorbital nerve) and supero-laterally to the root of the zygoma. The piriform aperture is identified and the dissection is carried medially to the nasal spine. A freer elevator is utilized to elevate the mucoperiosteum off of the floor of the nose. Half-inch cottonoid pledgets are then placed into the nasal cavity bilaterally, between the mucoperiosteum and the floor of the nose. A sagittal saw is used to create horizontal osteotomies from the nasal apertures to the pterygomaxillary fissures bilaterally, superiorly enough to avoid the teeth apices. Approximately 1–3 mm tapered segments of bone are then removed from the antero-lateral aspect of the maxilla (Fig. 2). The nasal septum is separated from the maxillary crest with an osteotome. The pterygoid plates are then separated from the tuberosities of the maxilla utilizing a curved osteotome, with one finger in the oropharynx at the level of the hamulus, creating bimanual tactile feedback. The osteotome is placed in the lower 1/3 of the pterygoid plates to decrease the possibility of injuring the pterygoid plexus (Fig. 2). The maxilla is mobilized and downfractured. The medial maxillary wall is partially removed in a piecemeal fashion. Posteriorly, the descending palatine arteries are identified and preserved. Next, a small section of the inferior aspect of the nasal septum is removed according to what is necessary for the planned maxillary advancement and impaction. The inferior turbinate sizes (Camacho et al., 2015b, 2015c) are assessed and if enlarged, then turbinoplasties are performed.

The maxilla is then advanced by 10 mm or more (without using an intermediate splint). The position of the maxilla is oriented by the surgeon standing at the head of the bed, ensuring that the position of the central incisors is midline and is properly oriented with respect to the mandibular teeth. Once the maxilla is in the proper position, it is held in place firmly while four 24-guage stainless steel wires (two per side) and four 4-hole titanium plates (two per side) are secured with 2.0 × 5 mm mono-cortical screws.

2.3. Suspension wires

Next, bilateral maxillary drill holes are placed 4 mm away from the edge of the nasal aperture and 24-guage wire is fixated from the holes to the Erich Arch Bars, providing suspensory forces to the arch bars. The anterior nasal spine is then removed. A nasal alar synching stitch is then placed to reposition the nasal alas medially, to avoid having the nostrils become flattened and widened. The wound is closed with 3-0 chromic sutures.

2.4. Genioglossus advancement

Next, the genioglossus advancement is sometimes performed in patients with a retrodisplaced base of tongue. The procedure could also be performed during Phase 1 surgery (Riley et al., 1993). A gingivobuccal sulcus incision is made, approximately 3 cm in length over the anterior mandible. The periosteum is then reflected to the inferior border. The lateral cephalogram and panorex imaging studies are re-examined at this time and the genial tubercle is palpated manually to further confirm the location for the osteotomy. Beginning at least 5 mm below the apices of the teeth, parallel horizontal cuts are made approximately 20 mm in length. Two parallel, vertical cuts approximately 10 mm in length are created laterally (ensuring that the cuts are at least 8–10 mm away from the inferior border). Prior to completing the osteotomy, a 10 mm titanium screw is placed in the outer cortex of this small segment of bone to allow for grasping. The last horizontal cut completes the rectangular osteotomy. The fragment is then grasped by the screw and is re-positioned into the floor of the mouth. Any bleeding from the mandible is controlled with electrocautery; additionally, Gelfoam® (Pharmacia & Upjohn Company LLC, Kalamazoo, MI, USA) can be placed into the oozing segment of bone. The bone fragment is then pulled out of the mandible and is held by the inner cortex with a Kocher clamp, then it is rotated between 30 and 90° over the anterior aspect of the mandible. There must be enough bone to place a screw in the fragment and fixate it to the lower border of the mandible. The outer cortex and cancellous bone are then removed, leaving the inner cortex intact. A 2 mm drill bit is

Fig. 1. Nasal intubation with a standard endotracheal tube and metallic endotracheal tube connector (gray arrow). The additional length and curvature of the connector provide improved angulation, thus decreased pressure on the nares during surgery.

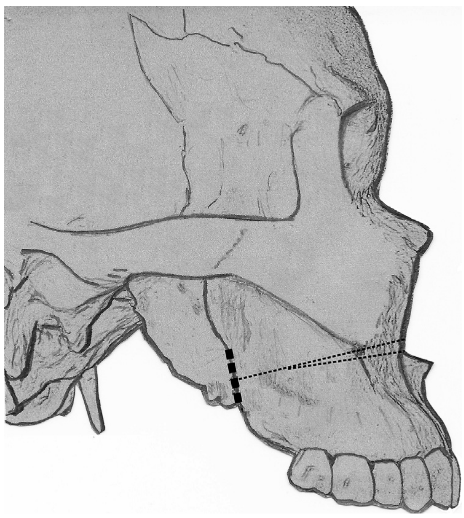

Fig. 2. Maxillary osteotomies. Note the low osteotomies (thick dashed lines) between pterygoid plates and the tuberosities of the maxilla to help decrease the chance of damaging the pterygoid plexus. Also, a 1–3 mm tapered segment of bone (thin dashed lines) is typically removed from the antero-lateral aspects of the maxilla.

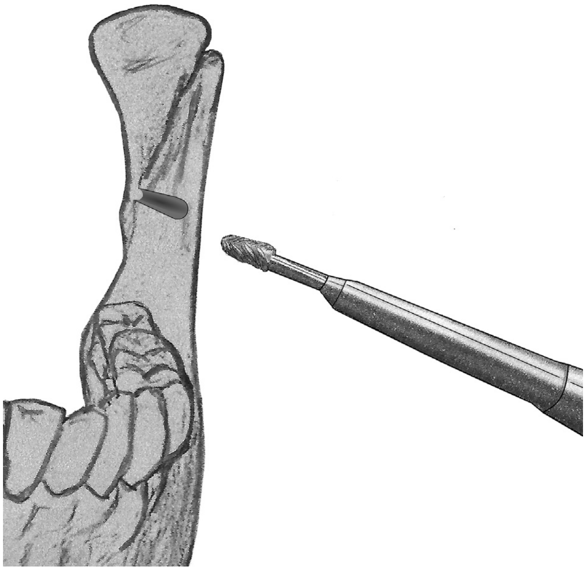

Fig. 3. A pineapple shaped burr is used to make a trough in the mandible, above the lingula. The saw can then be placed in the trough, and the vertical osteotomy can be created more easily.

used for drilling a hole in the small bone segment, and a 1.5 mm drill bit is used for the mandible. The fragment is then fixated inferiorly with one 2.0 × 10 mm titanium screw. The fragment is then recontoured by using a pineapple shaped burr to remove excess bone that is projecting; however, great care must be taken not to thin the segment too much and risk fracturing or weakening it.

2.5. Bilateral split sagittal osteotomies

The mandibular skeletal fixation wires are placed. These consists of two (one per side), 2.0 × 12 mm screws which are positioned in the mandibular alveolus between the lateral incisors and canines. 24-guage stainless steel wires are then placed between the 2.0 screws and the Erich Arch Bars.

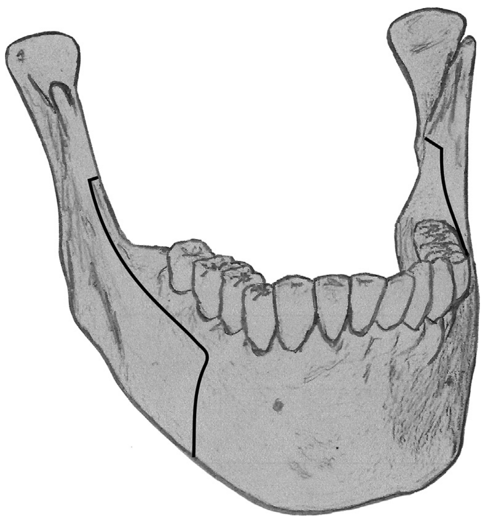

Fig. 4. Mandibular bilateral split sagittal osteotomies demonstrated by the dark black lines. The vertical osteotomies are near the junction of the second premolar and first molar.

Fig. 5. Final splint. Note the open anterior segment, which would allow for mouth breathing if the splint were to need to be wired into position.

An incision is made in the mandibular gingivobuccal sulcus near the retromolar area. The periosteum is reflected off the lateral aspect of the mandible, the anterior ramus and the medial ramus above the inferior alveolar nerve. The lingula is then identified with a nerve hook. The Hunsack modification of the Obwegeser and Dal Pont bilateral split sagittal osteotomy technique is utilized. A horizontal cut with the pineapple shaped burr is made above the lingula, on the medial ramus to a level approximately half way through the thickness of the bone, parallel to the occlusal plane (Fig. 3). The osteotomy is then continued inferiorly with a sagittal saw blade along the anterior border of the ascending ramus to the level of the first molar (remaining ≥5 mm lateral to the teeth). The lateral osteotomy is then performed from the buccal cortex, in a vertical direction near the junction of the second premolar and first molar, and is extended down to the inferior border (Fig. 4). The osteotomy at the inferior border must be complete (including both inner and outer cortices), extending superiorly ≥5 mm, otherwise there is a higher risk of obtaining a bad split. Osteotomes are first utilized to trace the osteotomy site throughout the entire length of the cuts, followed by careful wedging to complete the splits. The inferior alveolar nerve must be identified and if it is in the lateral segment, then it is meticulously dissected free and placed against the medial segment.

All sites are copiously irrigated and the throat pack is removed. The final splint (Fig. 5) is brought in and the distal mandibular fragment is repositioned so it fits appropriately into the splint. The patient is then placed into maxillomandibular fixation with intermaxillary wires. The mandibular fragments are fixated through intraoral and percutaneous approaches with two, 2.4 × 12 mm (or 14 mm) bi-cortical screws. Next, a six-hole titanium plate is placed and is secured with four, 2.4 × 6 mm mono-cortical screws. This is repeated for the opposite side. Then the intermaxillary wires are removed. The mandible is mobilized and returned to the splint to ensure the dental occlusion is appropriate and that the mandibular movement is unrestricted. In larger advancements, there should be a posterior open bite which is planned at the level of the second molars, and is approximately 1–2 mm. The wounds are then closed with 3-0 chromic and 3-0 Vicryl. Six or eight ounce elastic bands are then placed. The final product is similar to Fig. 6. A head dressing is then applied.

2.6. Post-operative care

Patients are placed in the intensive care unit (ICU) overnight. Post-operative medications include intra-venous kefzol, or

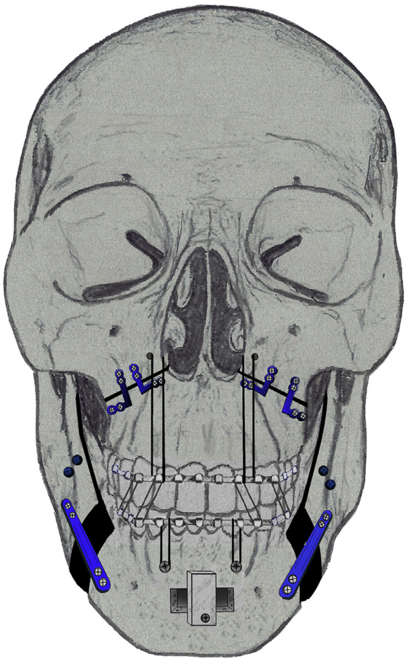

Fig. 6. Maxillomandibular fixation with plates, screws, suspension wires and elastics placed between the Erich Arch Bars. In this example, a genioglossus advancement was also performed.

clindamycin in the penicillin allergic patient. Patients are placed on a clear liquid diet. Decadron at 10 milligrams (mg) is given every 8 h for a total of 3 doses. There is a low threshold for performing flexible fiberoptic laryngoscopy if patients have breathing complaints. Once out of the ICU, the patients are transferred to a ward bed. They are then transitioned to oral antibiotics for 5–7 days, placed on chlorhexidine oral rinses, liquid oral narcotics and a stool softener. For nausea, the medications of choice are metoclopramide at 10 mg, famotidine at 20 mg, and ondansetron at 4 mg. Nutrition is consulted to review dietary modifications with the patients prior to their departure from the hospital. Typical diet advancement consists of a clear liquid diet for the first 24 h, then a full liquid diet

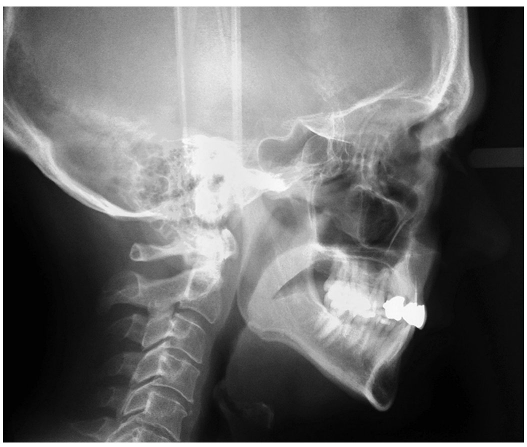

Fig. 7. A pre-operative lateral cephalogram of a patient presenting with significant airway narrowing at the level of the tongue base during awake flexible nasopharyngoscopy despite only demonstrating moderate retroglossal airway narrowing on the lateral cephalogram.

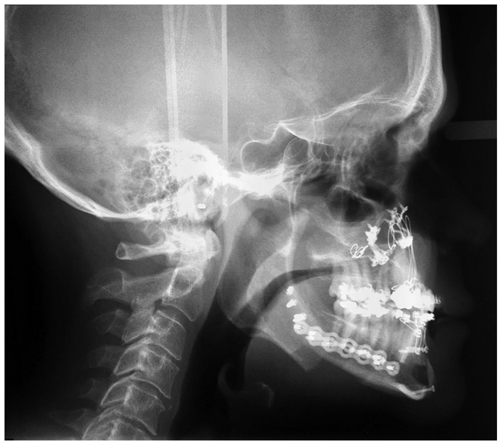

Fig. 8. A lateral cephalogram for the same patient from Fig. 7 post-maxillomandibular advancement with genioglossus advancement, note the dramatic improvement in size of the upper airway in totality, after an 18 mm advancement at the level of the mandible.

is initiated for 1 week, followed by a no chew diet (soups, noodles, yogurt, ice cream, etc.) for 5–6 weeks.

3. Results

The senior authors have performed over 2000 maxillomandibular advancements for obstructive sleep apnea. Together, the combination of Phase 1 and 2 surgeries have yielded over 90% success in patients with a body mass index <40 kg/m^2 and 81% for patients with a BMI ≥ 40 kg/m^2 in reducing the AHI to under 20 events/hr with at least a 50% reduction of the AHI from pre-operative values (Riley et al., 1993; Li et al., 2000). Fig. 7 demonstrates the pre-operative lateral cephalogram of a patient presenting with significant airway narrowing at the level of the tongue base during awake flexible nasopharyngoscopy despite only demonstrating moderate retroglossal airway narrowing on the lateral cephalogram. Fig. 8 demonstrates the lateral cephalogram for the same patient from Fig. 7 after undergoing a maxillomandibular advancement combined with genioglossus advancement (the figure demonstrates a dramatic improvement in the size of the upper airway in totality, with an 18 mm advancement at the level of the mandible). Over the past five years the senior authors have performed a genioglossus advancement in approximately 10% of patients at the time of other soft tissue sleep surgeries and approximately 15% of patients at the time of maxillomandibular advancements.

3.1. Complications

Overall, serious complication rates are low. Prior to surgery, the decision is made as to whether or not the dental occlusion is going to be changed; in most patients, however, the sleep apnea and associated issues (sleepiness, tiredness, cardiovascular co-morbidities) are a priority and the patients often select to keep their dental occlusion the same. Of patients who selected to leave the occlusion the same, approximately 5% of patients developed new malocclusion post-operatively, which was corrected with orthodontics. Three patients, however, had malocclusion that could not be corrected with orthodontics, thus required revision surgeries to repeat the osteotomies and to re-fixate their mandibles. Two of these patients started regular diets early after surgery which caused malocclusion, secondary to mandibular shifting. Serious bleeding is rare, but possible, especially during the down-fracturing of the maxilla. Post-operative bleeding requiring a return to the operating room has not occurred. Two patients developed osteomyelitis approximately 4–6 weeks after their surgeries and had to have peripherally inserted central catheters (PICC lines) placed, and the antibiotics subsequently resolved the infections. Three patients developed non-union of the LeFort 1 osteotomies and had to return to the operating room for harvesting of calvarial bone with placement of the grafts over the osteotomy sites, subsequently, all non-unions resolved in these patients. After MMAs there is often temporary inferior alveolar nerve hypoesthesia for a few to several months along the dermatome of the 3rd branch of the trigeminal nerve. Over the past five years, the complications from genioglossus advancement are consistent with our groups' previously reported rates (Li et al., 2001) to include wound dehiscence (~3% of patients), the genioglossus advancement osteotomy only included one of the two attachments of the genioglossus muscles to the genial tubercles (~5% of patients) or the osteotomy only included a portion of both genioglossus muscle attachments to the genial tubercles (~13% of patients). We have found that the lack of complete incorporation of both genioglossus muscle attachments is due to either asymmetrical osteotomies or the lack of extending the osteotomies laterally enough, however, the lateral extent is limited by the canine roots being either medially angulated or elongated and/or is limited by the presence of crowding of the mandibular incisors (Li et al., 2001). Careful patient selection guided by physical examination with manual palpation, cephalometry and direct visualization intraoperatively in our patients has led to no significant damage to the mandibular teeth requiring a root canal or dental extraction; however, because of the location of the osteotomies hypoesthesia after a genioglossus advancement is almost universal, and gradually improves after a few weeks (Li et al., 2001). Significant or life threatening events after MMA are rare demonstrated by no deaths, strokes or myocardial infarctions in our patients within 6 months of surgery.

4. Discussion

Large advancements can increase maxillomandibular advancement success and cure rates when it is selected as treatment for obstructive sleep apnea (Holty and Guilleminault, 2010; Pirklbauer et al., 2011). The Riley–Powell MMA technique is specifically designed to allow for larger advancements. The technique is a single-splint technique, therefore, it is not really known exactly how much the entire complex will be advanced until the surgery is actually performed. The technique is a maxillary driven procedure, and when done correctly, it is expected that the maxilla advances by 10 mm or more, while the mandible advances by more than 11 mm to match the dental occlusion. An important concept with the Riley–Powell MMA technique is the single splint technique, where only a final splint is used for the occlusion. No model surgery is done with an intermediate splint for maxillomandibular movements. This may initially be a difficult concept for surgeons who are used to performing orthognathic surgery. Since the goal of the MMA performed in OSA patients is to maximize soft tissue tension, an intermediate splint limits the surgeon's ability to maximize advancement. Furthermore, since counterclockwise rotation is frequently necessary to create adequate pharyngeal tension, the ability to alter maxillary position intraoperatively is important.

Adjunct procedures are also performed. It has been demonstrated that changing from an upright to a supine position decreases the cross sectional area of the upper airway by 32% at the tongue base and 50% at the level of the retro-lingual airway (Camacho et al., 2014, 2015a). Therefore, procedures to address this problem have been developed to include tongue suspension procedures, tongue reduction procedures (i.e. radiofrequency ablation, submucosal intra-lingual excision, tongue base coblation, etc.), and genioglossus advancement. The senior authors prefer radiofrequency ablation of the tongue for patients treated in the office and genioglossus advancement in patients who are treated in the operating room. Proper patient selection for genioglossus advancement performed simultaneously with an MMA is key since the genial tubercle is already advanced as part of the MMA; therefore, the procedure is generally reserved for patients who have either a significantly retrodisplaced tongue base on awake flexible nasopharyngoscopy, a large tongue in general, or have a significant mandibular deficiency.

Over the past five years, hyoid suspensions have only been used in rare occasions because maxillomandibular advancements (with or without genioglossus advancements) have yielded good results. Overall, MMA complication rates are low. With careful preoperative planning, counseling of patients, meticulous attention to detail intraoperatively and regular follow-up, patients will have improved outcomes. MMAs have been successful even in morbidly obese patients (Camacho et al., 2015b, 2015c).

5. Conclusion

Obstructive sleep apnea treated with large maxillomandibular advancements be challenging cases, thus this article seeks to describe a technique which has been successful.

Disclaimer

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Conflicts of interest

No author has a potential or actual conflicts of interest.

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