Bilateral Sagittal Split Osteotomy: Description of Surgical Technique to Complement the Procedural Cognition Simulation in the Craniofacial Interactive Virtual Assistant-Professional Edition

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Abstract: Operative experience for the contemporary trainee has become exceedingly more challenging in the setting of more stringent hospital regulations. Surgical training is thus shifting toward more self-directed, independent learning to maximize operative opportunities as they become available; yet, this can prove difficult for complex surgeries like craniofacial procedures. The intricate anatomy and fine reconstructive techniques employed cannot be readily depicted onto a two-dimensional page. To address this educational gap, the Craniofacial Interactive Virtual Assistant-Pro Edition (CIVA-Pro) was developed as a web-based surgical simulator to aid learners with conceptualizing the surgical principles utilized in these cases. The current work reviews the Bilateral Sagittal Split Osteotomy module of CIVA-Pro, providing detailed narratives for each chapter with expert commentary on broadened indications and future directions.

Key Words: Bilateral sagittal spit osteotomy, craniofacial surgery, plastic surgery education, virtual simulation

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The bilateral sagittal split osteotomy (BSSO) is an orthognathic procedure intended to improve a variety of mandibular deformities, including mandibular retrusion, protrusion, deficiency, or asymmetry.[1] Mandibular osteotomies date back to the late 19th century; however, it was Trauner and Obwegeser who first introduced the sagittal split of the ramus in 1957.[2] In their landmark publication, they improved previously described techniques using horizontal osteotomies of the ramus, which often resulted in relapse and open-bite. Dal Pont further refined their proposed technique by extending the buccal osteotomy toward the molar region, thereby including portions of the mandibular body and allowing for a larger surface area of bony contact to optimize healing.[3] In the past 60 years, improvements in technique and patient outcomes have been achieved by notable craniofacial and maxillofacial surgeons, each learning from their colleagues and building on each other's success.

This article is part of a larger initiative to disseminate operative experience and comprehensive instruction for craniofacial procedures.[4,5] The Craniofacial Interactive Virtual Assistant-Professional Edition (CIVA-Pro) is an online, multimedia simulator that was developed to aid trainee intellectualization of craniofacial surgeries. This interactive resource provides three-dimensional animation depicting complex anatomy integral to understanding disease pathology and surgical correction, as well as step-by-step illustration and audio description of surgical technique. Building on this foundation, the purpose of the present article is to provide a written companion to the CIVA-Pro BSSO module with more detailed descriptions of surgical technique, and provide a unique perspective on technical considerations and surgical preferences of an expert craniofacial surgeon independent of with simulator development.

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OPERATIVE TECHNIQUE

Chapter 1: Exposure and Soft Tissue Dissection

After nasoendotracheal intubation is achieved, appropriate measures are taken to protect the airway, globes, and nasal ala. The craniofacial area is prepped and draped in a routine fashion. Local anesthesia (typically 1% lidocaine with 1:100,000 epinephrine) is then applied to the oblique line of the ramus and the buccal face of the mandibular body and angle. A self-retaining retractor can be placed in the mouth to maintain open position. After appropriate intraoral exposure is achieved, a mucosal incision with a 15 blade is made along the anterior border of the ramus which continues inferiorly, along the sulcus of the mandible, preserving a 1 cm mucosal cuff. Bovie dissection is proceeded to maintain hemostasis until the bone is exposed and wide subperiosteal dissection is performed across the distal mandibular body, progressing proximally to the angle of the mandible, the oblique line, ramus, and sigmoid notch. A J-stripper is used to free the periosteal attachments from the inferior and posterior borders of the body and ramus, respectively. Muscular attachments, importantly the medial pterygoid on the lingual surface of the mandible, must be properly detached to achieve good bone exposure. The lingual face of the ramus is then exposed superior to the lingula.

Chapter 2: Corticotomies

After a sigmoid notch (Bauer) and mandibular (Lavesseur-Merrill) retractor is placed, drill holes are made to outline the path of the cortiocotomies to follow (Fig. 1A). Note the term corticotomy

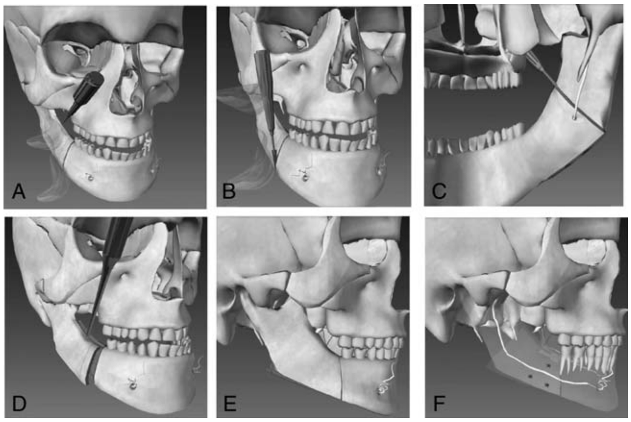

FIGURE 1. Snaphot of the CIVAPro simulator demonstrating (A) drill hole placement, with corticotomy design outlined in blue; (B) buccal corticotomy with a reciprocating saw; (C) lingual corticotomy from the intraoral view, and its proximity to the infra-alveolar nerve; (D) final split of the lingual and buccal segments of the mandible using a thin osteotome; (E) retrograde mandibular positioning and achievement of adequate occlusion with the maxillary teeth; (F) intraoral fixation with bicortical screws placed above and below the infa-alveolar nerve.

is used as the cut is limited only to the cortex of bone. Alignment of these drill holes should carefully consider a sufficiently thick segment of bone on the buccal side to avoid a thin, fragile piece that can break during splitting. A corticotomy is made using a reciprocating air-driven saw along the oblique line of the ramus and superior aspect of the mandibular body. The corticotomy continues mesially as a vertical corticotomy along buccal surface of the mandibular body, to the inferior border of the mandible at the midpoint where the buccal and lingual aspects meet (Fig. 1B). Careful preoperative evaluation of the course of the infra-alveolar nerve is paramount to avoid damage during this corticotomy (Fig. 1C). A channel retractor can be hooked beneath the inferior border of the mandible for protection of soft tissue. In cases where a large mandibular advancement is planned, this vertical corticotomy can be placed more mesially as advocated by Dal Pont. Importantly, the goal is to optimize degree of bony contact, and so if the vertical split is positioned too far mesially, the angle from the ramus to body may push the tooth-bearing region out laterally. The distal aspect of the oblique line corticotomy extends horizontally, along the lingual surface of the mandibular ramus, superior to the lingula. The horizontal location of the lingula can be sighted by identifying the antilingula on the buccal surface of the ramus.

Chapter 3: Mobilization of the Mandible

An osteotomy is carefully made through the cancellous bone of the mandible. Thin osteotomes (Dautrey or Freihofer) are placed through the corticotomy on the superior aspect of the body, directed inferiorly toward the lower border of the mandible. The osteotome can be rotated toward the lingual bone segment, as it is the stronger bony base, to begin separation of bone segments (Fig. 1D). The osteotomies also extend posteriorly through the ramus to the posterior border and to the horizontal corticotomy on the lingual surface of the ramus. Bone spreaders are used to confirm completion of the osteotomy. Identification of the infra-alveolar nerve at this point will allow complete dissection from the buccal cortex and positioned toward the lingual side. There can be residual bony attachments at the inferior border of the body and at the posterior area of the angle, which should be separated. Once the mandible is freed of all bony attachments bilaterally, it can be translated and rotated into a new position.

Chapter 4: Mandibular Positioning

Before application of rigid fixation, the mobile mandibular segment is placed in class I occlusion with the maxillary dentition (Fig. 1E). The condyles are seated in the glenoid fossa. This may require direct manipulation of the buccal cortex of the ramus. With occlusion established and condyles seated, maxilla-mandibular fixation is applied.

Chapter 5: Mandibular Fixation

After maxillomandibular fixation is achieved, rigid fixation is applied with screws alone or a combination of plates and screws. Bicortical screws can be applied percutaneously. A depth gauge can be useful in ensuring that screw fixation incorporates both the lingual and buccal surfaces of the mandible. Two screws should be placed along the lower border of the mandible and 2 screws can be placed closer to the superior border, avoiding damage to the infra-alveolar nerve (Fig. 1F). Once rigid fixation is applied, maxillo-mandibular fixation is released and proper occlusion is confirmed by opening and closing the jaw. If occlusion is inappropriate, then plates and screws should be removed, the occlusion should be re-established, and the condyles seated, once again in the glenoid fossa. If fixation is unstable, then more screws can be applied or maxillomandibular fixation is left intact. Incision lines then are closed with interrupted, absorbable sutures.

ADDITIONAL CONSIDERATIONS

Computerized Surgical Planning

The invited surgeon's (EDR) general approach to the BSSO is similar to what has been previously described, as well as what is illustrated in the CIVA-Pro simulator. A notable supplement he employs is the occasional utilization of computerized surgical planning (CSP), which guides intraoperative jaw manipulation and aids in achieving optimal postoperative maxillary–mandibular occlusion. Computerized surgical planning has positively impacted the way craniofacial surgeons can evaluate patient-specific pathology and prepare individualized strategies for challenging procedures, including orthognathic surgeries.[6,7] Three-dimensional computed tomography offers surgeons the opportunities to simulate various surgical plans in a virtual environment until an ideal plan is reached that can accurately predict surgical results[8] (Fig. 2).

Success in BSSO relies heavily on final placement of the tooth-bearing mandibular segment in relation to the maxillary dentition. This permits adequate occlusion, which becomes difficult to assess intraoperatively, especially when double-jaw surgery is performed.

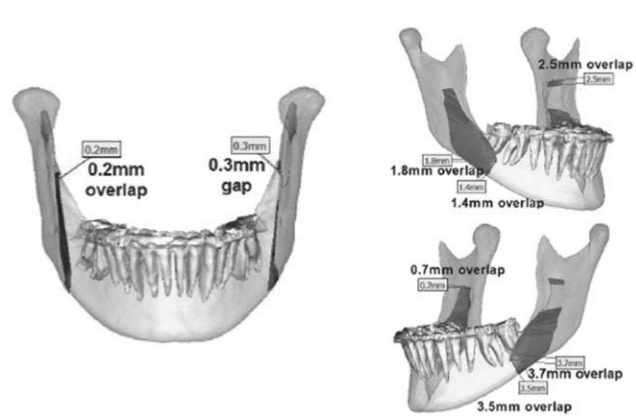

FIGURE 2. Computerized surgical plan for a conventional bilateral sagittal split osteotomy with detailed measurements of simulated outcome.

When both jaw segments are being repositioned, the LeFort I maxillary advancement typically precedes posterior displacement of the mandible, and can therefore serve as a stable reference point. Knowing final placement of the maxilla, CSP can calculate the necessary distance of mandibular movement and final inset. Custom-designed cutting guides can be three-dimensionally printed for a snap fit on the mandible, providing the surgeon with near-exact guidance of where the planned corticotomies should lie. Similarly, a personalized occlusal splint can be fabricated according to the operative plan so that once the mandibular segment is pushed back to the calculated degree, and intermaxillary fixation is released, the mandibular teeth can passively fit into proper occlusion. This final splint confirms the ultimate position of the mandible and increases perioperative confidence regarding the maxillary–mandibular relationship.

Notably, one of the greatest benefits of CSP is that the anatomic trajectory of the inferior alveolar nerve can be traced, and corticotomies are planned accordingly to avoid this critical structure. Neurosensory dysfunction of the chin and lower lip is reported as one of the most common complications following BSSO,[9] and is largely the result of technical error. Computerized surgical planning does not eliminate the possibility of injuring the nerve, as careful identification and manipulation are still necessary; nevertheless, it is a tool that can facilitate the identification of the nerve path inside the mandible, reducing risk of injury. Without this insight, the surgeon is largely blinded to the course of the nerve and great care must be taken, likely increasing the duration of the procedure.

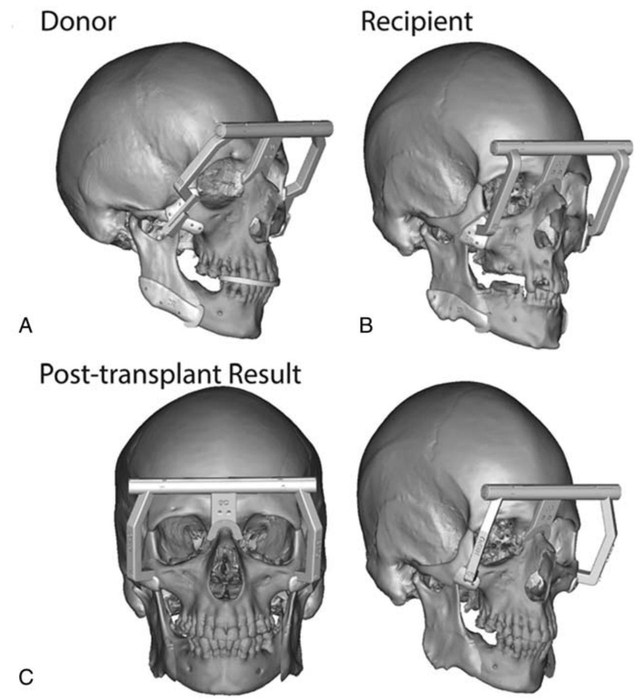

FIGURE 3. Computerized surgical plan for double jaw transplantation illustrating donor-specific (A) and recipient-specific (B) cutting guides, and bone segments for transplantation depicted in green and blue, respectively. Posttransplant three-dimensional renderings are illustrated (C).

Evolution of Bilateral Sagittal Split Osteotomy Indications

As the surgical patterns of mandibular osteotomies have evolved, so too have the indications for these procedures. Mandibular re-positioning can be tailored to meet patient-specific needs, and together with the advancing technology of CSP, a new indication for the BSSO has emerged: facial transplantation. Cases where the facial allograft is designed to incorporate maxillary and mandibular components present a new challenge, particularly during allograft inset and attempting optimal occlusion.[10] With the maxilla and accompanying midface structures stabilized to recipient structures, a BSSO is feasible and can be substantially simplified with the aid of CSP (Fig. 3).

The main advantage of the BSSO over a horizontal osteotomy at the body of the mandible during transplantation is the resulting increase in bone-to-bone contact surface.[11] Mirroring the initial observations that propagated the shift toward sagittal splitting, the benefit of maximizing bony contact underscores the indication for this technique when transplanting mandibular bone. The additional hurdle of overcoming expected wound healing complications due to immunosuppression requirements further supports a conservative approach that promotes osseous healing. The application for CSP in this setting is readily apparent, not only for intraoperative ease during a high-stakes, complicated procedure, but also in reducing allograft ischemia time and guiding ideal positioning for allograft inset. Computerized surgical planning can inform the surgical team of potential anatomic aberrations and donor-recipient mismatches, thus eliminating the element of intraoperative surprise. In addition, CSP proves useful when preserving the inferior alveolar nerve in both the donor and recipient for coaptation, if desired.

Corticotomies and Sagittal Split Design

Some of the most debated aspects of the BSSO procedure lie in corticotomy design and in ways to achieve the most desired splitting possible. Although no one technique is superior to others, each surgeon has their preferences, beginning with instrumentation. The advantage of the reciprocating saw is that it is thin, precise, and easy to manually manipulate. The initial corticotomy over the oblique line of the ramus can be performed with a saw and does not need to extend fully to the posterior border of the mandible, which can result in a possible condylectomy. Limiting the corticotomy just to the posterior aspect of the inferior alveolar foramen can initiate a greenstick fracture that will trace down to the inferior border of the ramus, and set an adequate plane for splitting. A medial border retractor can be placed right above the entrance of the inferior alveolar nerve into its foramen (which can vary from patient to patient), thus protecting it from injury.

Next, the corticotomy along the buccal aspect of the mandibular body can be approached from an oblique angle instead of perpendicularly. This is done so that when placing a thin, metal osteotome to further divide the buccal and lingual segments, it can rest in line with the splitting plane, and avoid the need for a sharp 90-degree turn. Furthermore, this approach prevents an unfavorable split or consequential fracture of the buccal plate, which then leaves no stable point for fixation. In addition, extending this corticotomy just a few millimeters along the inferior border of the mandible can significantly facilitate the splitting of the buccal and lingual segments. Although not essential, this short and simple cut along the inferior border can help the surgeon gain better control over the designed split. When the nerve is identified, it should be carefully freed with an elevator and pushed lingually before the remainder of the inferior border is split.

It is important to note that stability of the condyle is sometimes compromised, and some degree of condylar sag may be expected. In an effort to not affect centric relation, the proximal segment of the split mandible is pushed posteriorly and superiorly in the glenoid fossa, before the setback of the mobile tooth-bearing segment of the mandible. This can be achieved by using a Dingman retractor and

Kocher clamp, and will assist in accommodation of the tooth-bearing segment without disruption of the temporomandibular joint.

Intraoral Fixation

Stability of the repositioned mandible into optimal occlusion depends on the degree of fixation provided. Monocortical plates and screws across the external oblique ridges will provide reliable bony fixation while also allowing for postoperative manipulation through orthodontic care. In cases where the optimal occlusion could not be achieved despite strict preoperative planning and careful intraoperative execution, the early postoperative period can be leveraged by orthodontists to wield dental relationships and arrive at the occlusion intended. Whenever possible, a facial incision should be avoided to prevent thermal damage to the skin from contact with the reciprocating saw. A right angle drill bit and screwdriver can be utilized to preserve the integrity of the overlying skin and avoid any intra- and extraoral communication.

Oftentimes, upon fixation, there remains a prominence of the external oblique ridge, and contouring of this proximal segment can be achieved with a pineapple burr. Burring at this point can be done liberally to ensure that no sharp bony segments protrude, which can potentially damage the sensory nerve. These final contouring maneuvers may also be performed before completing fixation.

Soft Tissue Considerations

With regard to soft tissue elevation, conservative stripping of the lateral muscles and more aggressive disinsertion of medial attachments is advocated, to maintain as much blood supply to the mandible as possible. Preservation of the masticatory muscles and not disrupting the proximal portion of the lateral periosteum can sufficiently perfuse the mandible and prevent malunion or resorption of mobilized bone. Medial attachments, specifically the medial pterygoid muscle, must be dissected for proper visualization and to accommodate for the posterior displacement of the tooth-bearing segment of the mandible. The medial soft tissue, however, can still serve as a reliable tissue envelope surrounding the overlapping bone segments in the posterior mandible and assist in perfusion.

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