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Intraoperative Three-dimensional Virtual Reality and Computed Tomographic Guidance in Temporomandibular Joint Arthroplasty of Syndromic Craniofacial Dysostoses

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Summary: Bony ankylosis of the temporomandibular joints (TMJ) occurs in up to 28% of patients with syndromic mandibular dysostoses. Release of complete osseous ankylosis is particularly challenging due to the lack of tissue planes separating the mandible from the skull base and the presence of congenital skeletal abnormalities. One recent advance in surgical imaging technology is three-dimensional virtual reality (3D VR), now in common use in neurosurgical resections. In this study, we describe the usage of 3D VR in TMJ arthroplasty and compare 3D VR to traditional computed tomographic (CT) guidance. Pediatric patients with syndromic mandibular micrognathia including Treacher Collins, Nager, and cerebrocostomandibular syndrome were retrospectively evaluated between 2008 and 2016. Patient characteristics, complications, inpatient times, and operative times were recorded. Of the 29 children with syndromic mandibular micrognathia treated between 2008 and 2016, 7 were diagnosed with TMJ ankyloses. Four consecutive pediatric patients (mean 8.7 years) undergoing interpositional TMJ arthroplasty with Matthews device placement were retrospectively evaluated. Two patients underwent traditional CT-guided versus 3D VR-guided temporomandibular joint arthroplasty (TMJA). No statistically significant differences were found among the age, complications, or inpatient hospitalization times. The average operative time in the traditional CT guidance group was 300 minute versus 134 minutes in the 3D VR group. Three-dimensional VR is a useful preoperative planning and intraoperative guidance tool. The major difference between VR and older technologies is the improved imaging in 3 dimensions for guidance, thereby potentially decreasing operative times. *(Plast Reconstr Surg Glob Open 2019;7:e2388; doi: 10.1097/GOX.0000000000002388; Published online 10 September 2019.)*

INTRODUCTION

Bony ankylosis of the temporomandibular joints (TMJ) occurs in up to 28% of patients with syndromic mandibular dysostoses.[1] Reconstruction of complete osseous TMJ ankylosis is challenging in syndromic patients as the mandible is completely continuous with the skull base, thus preventing the ability to visually identify the junction between mandibular versus calvarial bone. One recent advance in surgical imaging technology is the use of three-dimensional virtual reality (3D VR) in combination with standard computed tomographic (CT)–aided navigation. Commonly used in neu-

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rosurgical resections, the 3D VR system allows surgeons to preoperatively visualize and conceptualize abnormal anatomy in all 3 dimensions and coordinate with intraoperative guidance to easily visualize complex regions at an increased speed in real time.[2–4] In this study, we describe the usage of 3D VR in TMJ arthroplasty and compare 3D VR with CT guidance to traditional CT guidance.

METHODS

Surgical Technique

Before surgery, preoperative VR was used to visualize the abnormal TMJ from both the buccal and lingual aspect of the mandible (Surgical Theater, Los Angeles, Calif.) (**See** Video, [online], which displays a 3D display of CT guidance in temporomandibular joint Arthroplasty.) Data from the CT scan were loaded onto the image guidance platform (Brainlab Cranial, Brainlab, Munich, Germany, and SNAP, Surgical Theater, Cleveland, Ohio) before surgery. Registrations were performed according to manufacturer's directions. After preauricular incision and blunt dissection down to the ankylosed TMJ, the stereotactic wand was used to identify the junction of cranial base and the mandible. The skull was visualized on the imaging platform in two 3D views simultaneously. The ankylosed section was resected with a pineapple burr. Navigation using the stereotactic wand was utilized with hiding of posterior or anterior tissues of the 3D reconstructed skull (Fig. 1). Following the completion of the gap arthroplasty, either a vascularized temporoparietal fascial flap or acellular dermal matrix was used as an interpositional material. Finally, placement of a Matthews device for distraction of soft tissues was performed for ankylosis rehabilitation (KLS Martin, Jacksonville, Fla.). Postoperatively, all patients were distracted 1 turn twice a day and were given a regimen of jaw opening and closing exercises (20 rounds) performed 6 times a day by their parents or caretakers.

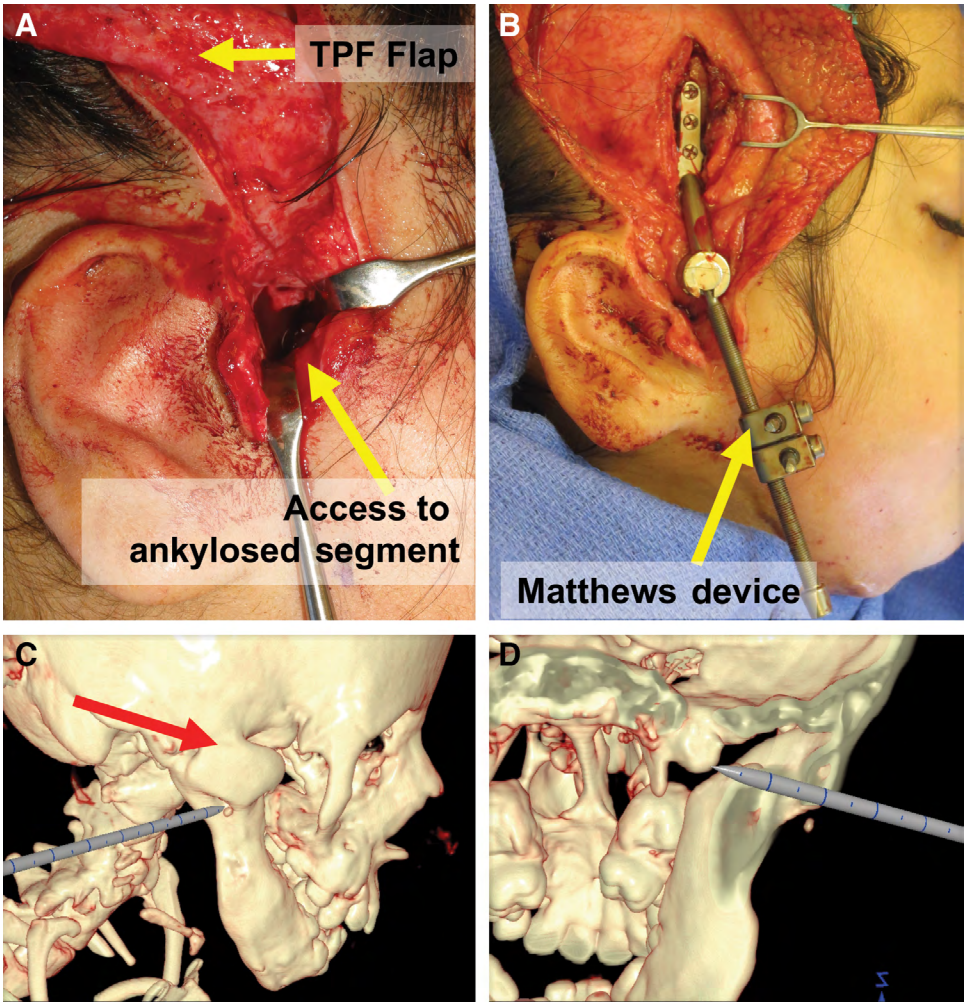

Fig. 1. Combined intraoperative virtual reality and computed tomographic guidance. Intraoperative view of access to the ankylosed segment and elevated temporoparietal fascia flap (A). Lateral (C) and posterior cutaway (D) views of combination of virtual reality and computed tomographic guidance with stereotactic wand shown in gray. Red arrow denotes the temporomandibular joint ankylosis with complete effacement of the glenoid fossa. Intraoperative view following completion of interpositional arthroplasty with Matthews device placement (B).

Case Series

Four consecutive pediatric patients undergoing interpositional TMJ arthroplasty with Matthews device placement were retrospectively evaluated. Statistical analyses were performed using SPSS Version 24 (Chicago, Ill.) with independent sample Student's *t* tests.

RESULTS

Four consecutive syndromic craniofacial patients with bilateral, complete, osseous TMJ ankylosis underwent interpositional arthroplasty at an average age of 8.7 years (range 6.8–11.3 years). The patients were diagnosed with Nager (n = 2), Treacher Collins (n = 1), and cerebrocostomandibular syndrome (n = 1). Before development of TMJ ankylosis, all patients underwent multiple rounds of internal mandibular distraction for micrognathia and upper airway obstruction. Two patients were treated with standard CT guidance and required an average of 300 minutes for completion. The latter 2 patients were treated with a combination of 3D VR and CT guidance and required an average of 134 minutes for completion ($P = 0.03$). Postoperative follow-up averaged 4.0 ± 2.4 years. No intraoperative or postoperative complications occurred in any of the patients; however, ankylosis recurred overtime in all of the patients requiring revision surgery, such as rib grafting in 2 patients.

DISCUSSION

TMJ ankylosis in the setting of congenital skeletal abnormalities presents a reconstructive challenge due to undefined tissue planes and anatomic landmarks. However, this could potentially be overcome using intraoperative navigation systems for image-guided reconstruction. These techniques have successfully aided in the reconstruction of aesthetic and functional deformities, including auricular, orbital, and rhinectomy defects.[5] In addition to acquired defects, integration of 3D VR with CT-guided navigation in the operative setting has been applied to complex pediatric craniofacial surgery. Wood et al[6] demonstrated that applying Brainlab technology to Le Fort III advancement enabled them to establish precise osteotomy lines and trajectories. In doing so, they avoided extensive operative blood loss and reduced operative times.

In our case series, we demonstrated a significant reduction in operative time when applying real-time image guidance to TMJ arthroplasty. Multidimensional visualization of anatomical structures of interest related to preloaded CT images allowed for greater precision with surgical dissection and increased surgical confidence. Specifically, using Brainlab imaging, we were able track the extent of bilateral TMJ and condylar ankylosis, minimizing the risk of damage to surrounding anatomy and encroachment upon the skull base. Minimizing trial and error maneuvering during the operation in turn reduces the risk of blood loss and infection.[7] However, we did not find any relationship between using the technology to overall outcomes as both groups demonstrated reankylosis and all patients have either undergone revision surgery or have been recommended revision surgery, a common scenario for syndromic TMJ bony ankyloses.

This study is limited by its design and number of patients. However, the goal of this study is not to report outcome measures but rather to highlight novel principles in operative technique when reconstructing challenging craniofacial defects such as TMJ ankylosis. Although the intraoperative imaging guidance can provide real-time anatomical topography to optimize surgical outcomes, the practicing surgeon must ultimately rely on his or her understanding of the anatomy rather than depending solely on the technology. Our preliminary data may benefit from prospective studies of increased power that could provide more insight into advantages and disadvantages of incorporating 3D VR into intraoperative navigation systems for image-guided reconstruction.

CONCLUSIONS

With the increased risk associated with surgical approaches to craniofacial reconstructions that closely border skull base and orbital floors, it is critical to advance both preoperative training and intraoperative navigation to minimize complications and improve surgical outcome. The trend of using image guidance has advanced neurosurgery with improved operative time and patient safety.[8,9] Three-dimensional VR simulation technology further enhances preoperative comprehension of abnormal anatomy and provides an additional modality to guide operative decision-making.[4,10] We demonstrate that the combined use of 3D VR and standard image guidance resulted in additional improvement in operative efficiency, enhanced real-time visualization of important anatomy, and minimized surgical complications.

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