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Clinical Paper
TMJ Disorders

Navigation-guided gap arthroplasty in the treatment of temporomandibular joint ankylosis☆

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Abstract. Gap arthroplasty, used in the treatment of temporomandibular joint (TMJ) ankylosis, is challenging, requiring resecting of massive abnormal bone formation at the skull base with complex and distorted anatomy. This study evaluated the application of image-guided navigation to gap arthroplasty. Four gap arthroplasties were performed on patients with unilateral TMJ ankylosis under computer-assisted navigation guidance. After preoperative planning and 3-dimensional simulation, the normal anatomic structures of the TMJ were created by superimposing and comparing the unaffected and affected sides. The amount and range of ankylotic bone to be resected was determined and displayed. Registration achieved an accurate match between the intra-operative anatomy and the CT virtual images. Anatomic structures and the position of surgical instruments were shown real time on the screen. In all cases the accuracy of the system measured by the computer did not exceed 1 mm. No complications occurred and the mean minimal thickness of the skull base between middle cranial fossa and reconstructed glenoid fossa was 1.97 mm. Using image-guided navigation resulted in safe surgical excision of the bony ankylosis from the skull base. Navigation-guided resection of the ankylotic bone in the TMJ gap arthroplasty was a valuable and safe technique in this potentially complicated procedure.

Keywords: computer assisted navigation; surgical simulation; gap arthroplasty; temporomandibular joint ankylosis.

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Temporomandibular joint (TMJ) ankylosis involves fusion of the mandibular condyle to the base of skull, which can cause speech impairment, difficulty with mastication, facial disfigurement, airway compromise or psychological stress[1,12,16]. Rehabilitating the mandibular movement and function, preventing reankylosis and promoting mandibular growth are the main treatment objectives. Treatment for TMJ ankylosis includes interpositional arthroplasty, gap arthroplasty and reconstruction of the joint using autogenous or artificial materials[11,15,21]. Wide bone resection of the ankylosis is important to avoid relapses[3].

In patients with TMJ ankylosis, the irregular ankylotic bone has no clear margin with normal anatomic structures. Resecting massive bone formation at the skull base, which includes vital anatomic

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structures, is difficult, especially with distorted anatomy. There is a high risk of hemorrhage resulting from damage of the internal maxillofacial artery, dura mater exposure, nerve injuries and cerebrospinal fluid leak[13,20].

Image-guided navigation for surgery is useful in areas of complex anatomy where precision is required. In oral and maxillofacial surgery, navigation technology has been introduced for foreign body removal, tumor resection, deformity correction, craniomaxillofacial reconstruction and oral implants[6,7,14,17,19]. Schmelzeisen et al. tried to resect severe ankylosis of the mandibular condyle in two patients with TMJ ankylosis using navigation guidance, and found that navigation can promote safety and reduce complications in skull base surgery[18]. Using surgical navigation, Malis et al. achieved 1-stage reconstruction of ankylosed TMJ[13]. Navigation technology is useful in gap arthroplasty for the real-time positioning of instruments and the identification of anatomy.

The purpose of this paper is to report the authors' experience using image-guided navigation in gap arthroplasty for the treatment of TMJ ankylosis based on various clinical cases.

Fig. 1. Five positioning screws implanted in the maxillary alveolar bone as navigation markers.

Material and methods

Preoperative planning and simulation

Five positioning screws were implanted in the maxillary alveolar bone of 4 patients as navigation markers. Preoperative thin-cut (0.625 mm), computed tomography (CT) (light speed 16, GE, Gloucestershire, UN) data were obtained in all patients (Fig. 1, Table 1). These data were recorded in a generic DICOM (digital imaging and communications in medicine) format from the CT scanner. Data were transferred via a compact disc (CD) to a Windows-based computer workstation with MIMICS software (Edition 8.11, Materialise, Leuven, Belgium). The MIMICS software converted DICOM data into a sterolithography (STL) format, compiled the 2-dimensional axial images and presented the data in axial, coronal, sagittal and 3-dimensional (3D) reconstructions.

Table 1. Clinical features and aetiology.

Case No.	Age (years)	Sex	Affected side	Aetiology
1	11	F	L	Falls
2	14	M	L	Traffic accident
3	15	F	L	Traffic accident
4	17	M	R	Falls

F: female. M: male. L: left. R: right.

The patients' individual anatomy was assessed in multiplanar (axial, coronal, sagittal) and 3D views. With the mirroring tool, and using the median sagittal plane as a reference plane, the normal anatomic structures of the target area were created by superimposing and comparing the unaffected and the affected sides. The normal contour of the affected skull base and glenoid fossa was ascertained (Fig. 2). In side to side comparison, the amount of ankylotic bone to be resected was determined and displayed in a different color. Special attention was given to the safe distance to the dura mater and the preservation of an approximately 1-mm thickness of bony auditory canal. When the simulation was completed, the data from the original and simulated 3D craniomaxillofacial models were imported into the TBNavis navigation system (Multifunctional Surgical Navigation System, Shanghai, China).

Intraoperative navigation

With infrared cameras tracking the navigation pointer and fiducials, intraoperative navigation was carried out by frameless stereotaxy. The positions of the patient and the instruments were identified with the digital reference frame (DRF) which was fixed rigidly to the patient's forehead and the surgical instruments. The reflective balls of the DRF reflect infrared light emitted by the cameras that allow the system to track their position. The patient and the virtual image at the workstation were matched by individual registration with the five positioning screws, which were implanted in the maxillary alveolar bone preoperatively allowing a safe interval to avoid tooth root injury and reducing possible artefact zones. An accurate match between the intra-operative anatomy and the virtual images was achieved (Fig. 3). The tracking information was processed by the attached workstation and merged with the 3D images, to show the surgeons continuous 3D positioning of their instruments. The accuracy of registration was checked visually in every case by repeatedly pinpointing the anatomic landmarks (e.g. maxillary incisor point, dental cusp). By viewing the display on screen, surgeons were able to know the physical location of the surgical instruments and their relation with surrounding anatomic structures.

Under general anesthesia, all patients underwent gap arthroplasty under the guidance of the navigation system. The ankylosed TMJ was exposed via a standard preauricular approach with temporal extension. The dissection was carried out and the superficial temporal fascia was reflected anteriorly. The ankylotic mass was exposed after the incision of the periosteum over the zygomatic arch. The margins of the ankylotic bone to be resected were ascertained by a navigated drill and can be positioned real time on the screen. According to the preoperative plan and the different colors displayed on the scope, the ankylotic bone was resected and the dura mater, bony auditory canal and internal maxillary artery were preserved. The ankylotic joints were removed for at least 15–20 mm vertically, and the free ends of the mandibular ramus were shaped to form a round surface. The temporalis myofascial flap was turned outward and downward over the zygomatic arch and placed into the glenoid fossa to complete the temporalis myofascial flap. It was then sutured medially and posteriorly to adjacent tissues. The coronoid process was ablated if encroachment occurred.

Results

Preoperative planning and intraoperative navigation were used to perform gap arthroplasty. In every case the accuracy