Case Report

Complex, Computer Assisted Skull Reconstruction Using Patient Specific Implants after Resection of an Intraosseous Meningioma — A Case Report

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Abstract

Background: Resection defects of the skull have long been reconstructed using autogenously and alloplastic materials [1]. Complex reconstructions of the orbit have been reported to benefit from patient specific implants [2]. Due to new algorithms planning procedures for these implants have recently improved significantly. Rapid production methods such as selective laser melting and rapid prototyping have now been introduced into the clinical routine [3].

Case Report: We report a case of a 49-year old woman presenting with a recurrence of a previously surgically resected meningioma. The lesion had grown from the lateral sphenoidal bone towards the orbit and compromised her appearance and vision. The surgical procedure included resection and alloplastic reconstruction using a patient specific implant (PSI) planned by our department and manufactured by selective laser melting (SLM). We focus on the process of implant planning and its interaction with the production process.

Conclusion: Patient specific implants provide the treating surgeons with a superior method of anatomically correct, alloplastic skull reconstruction, which is able to contribute to an improved clinical outcome.

ABBREVIATIONS

PSI: Patient Specific Implant; CAS: Computer Assisted Surgery; CT: Computed Tomography; MRI: Magnetic Resonance Imaging; CAD: Computer Aided Design; SLM: Selective Laser Melting

CASE PRESENTATION

A 49-year old woman reported to our ambulance with severe exophthalmos limited to the left eye, ciliary injection and painful eye motion. MRI scans suggested a recurrence of a previously resected meningioma extending from the sphenoidal bone to the lateral orbital wall. Fervious treatment included a subtotal resection of a partially intraosseous meningioma with in the left sphenofrontal area 5 years ago. Computed tomography revealed compression of the lateral rectus muscle, as well as on the eye globe. Ophthalmologic exams showed no significant vision impairment or increased intraocular tension.

As a first step a maxillary occlusal splint containing 4 Synthesis screws was manufactured according to patients dental plaster models. Using this splint CT data suitable for navigation can be acquired without invasive procedures [4]. This data was then transferred into Brain lab CMF iPlan 3.0.5 (Brainlab®, Feldkirchen, Germany) for further analysis and operation planning. Algorithms for several other standard cases have been described [3]. As a first step the tumor to be resected was segmented using the Smart brush algorithm, which consists of automated region of interest determination between two predefined points. After defining the tumor borders in axial slice orientation, this step is carried out again in sagittal slice orientation. Using intelligent 3D interpolation, the space-occupying lesion is automatically segmented. After this step different parts of the skull were segmented by a combination of threshold and atlas based algorithms. Hardly any structures needed to be outlined manually. Due to the initial severe skull and
orbit deformity in this case, the opposite site was automatically mirrored and carefully aligned to adjacent structures such as the zygomatic arch and the temporal bone (Figure 1) by that the ideal postoperative situation was determined and used for further planning. As well as the original set of data, the desired surgical result was exported as STL mesh data (Geomagic®, Rock Hill, USA) and consecutively transferred into the digital modeling CAD system Geomagic freeform plus. Using a haptic feedback device both sets of data can be further investigated and analyzed. After discussing and simulating several possible surgical procedures[5-7], borders for resection templates were outlined on the preoperative model. A curve, defining the later to be manufactures titanium implants borders was digitally drawn onto the postoperative model according to the prior defined resection margins. By selective laser melting (SLM), two highly accurate patients specific implants were manufactured (Figure 2)[2]. The surgical procedure was carried out through a coronal and transconjunctival approach. To prevent peripheral nerve damage a piezoelectric instrument was used for resection in this case [8]. Through a hemicoronal, blepharoplastics and transconjunctival approach the pre described space occupying lesion could be resected. Using a pre-manufactured polyamide cutting guide, desired resection borders were easily recognizable. Following resection the first implant was inserted via transconjunctival approach to replace the anterior part of the orbital floor. Exact implant position was ensured by optical navigation comparing predefined trajectories on each implant with those planned in CMF iPlan3.0.5. The implant was then fixated onto the infraorbital rim by 1,5mm x 4mmself cutting screws. Through an extended hemicoronal approach another patient specific implant replacing parts of the zygoma and temporal bone was inserted. Both implants were then fixated using 1,5mm screws of different lengths. Due to the large temporal resection area, the temporal muscle needed to be subtotally detached from its origin. To prevent “temporal hollowing” [9] a second, non pre-manufactured “camouflage” mesh was implanted on top for cosmetic reasons and fixated onto the zygomatic arch and temporal bone. After wound closure the patient was transferred to a neurosurgical ICU for 3 days. Following surgery, the resected tissue was sent to the department of pathology for further analysis. The pathologic report revealed a fully resected, WHO grade I, partially intraosseous, transitional type meningioma. Immuno histochemically the probes presented to be partially EMA positive. As expected for a low-grade meningioma, the Ki 67 positive rate was low (2%) [10,11]. Several weeks after surgery the patient presented with a nearly physiological shape of her face, wounds continued healing well. Bulb position was nearly physiological. Unrestricted eye movement could not be fully achieved; the inferior rectus muscles function only recovered slowly. Postoperative swelling reduced quickly and the patient did not suffer from pain. One month after the procedure the implants were still in place and there was no indication of infection or implant loosening.

**DISCUSSION**

Meningiomas are rarely located within the skull bone [5], and recurrence rates are moderate [13]. In cases of recurrence of this benign tumor, adequate surgery may leave the patient...
with large resection defects in soft and hard tissue. Procedures as the previously described remain reserved for experienced CMF and neurosurgeons, as challenging situations during surgery and postoperative care may occur. As well as the complicated resection, the cranioplasty is a critical step. Determining the patients’ postoperative regeneration and appearance, it should be carried out as carefully as the lesion resection itself. Replacing resected parts of the skull can be considered a standard procedure and manually, instantly formed implants from polymers are still used frequently. Main disadvantages include a lack of precision and changeability as soon as the polymerization process is completed. The material used should carefully be taken into consideration. Other commonly used replacement methods include, but are not limited to cranioplasty using polymer, ceramics, solid titanium or titanium mesh implantation [14,15]. As reactions of SLM manufactured implants to high therapeutic radiation doses are not sufficiently studied, they are more frequently used in replacement of benign lesions or after trauma. It has been shown, that they are very well tolerated [12]. In CMF surgery, patient specific implants manufactured by selective laser melting have proven to be useful in orbital surgery [2], mandible and maxillary reconstruction. This process leaves the surgeon with a variety of possibilities, as the implants form can be designed without limitations to its shape. A biologically adequate implant shape can therefore be transferred from preoperative planning into a patient specific implant. Positions for drilling and fixation and screw angulation and size can be chosen freely. Encoding information such as resection margins, the localization of critical structures and pre defined fixation screw lengths are further advantages of this system. As manufacturing times are currently decreasing immensely, planning and production become more efficient. Apart from production technological advances, new algorithms using intelligent 3D interpolation like the smart brush algorithm facilitate the planning process immensely. As lesions do not have to be outlined manually anymore, segmenting times could be reduced drastically [16]. Two to three weeks can be considered an average time for the complete process of planning and production in our department. The time until surgery is usually not significantly increased in cases involving patient specific implants. The presented case clearly shows that patient specific implants provide the treating surgeons with a superior method of alloplastic skull reconstruction which is able to contribute to a good surgical outcome and can planned and manufactured within a short period of time.

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REFERENCES