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Technical Note
Pre-Implant Surgery

Patient-specific sub-periosteal zygoma implant for prosthetic rehabilitation of large maxillary defects after oncological resection

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Abstract. A 74-year-old woman needed a subtotal bilateral maxillectomy due to squamous cell carcinoma of the palate. Immediate and secondary reconstruction of the defect was not feasible, so the defect was closed with an obturator prosthesis wired to the zygoma complex. To improve the patient's severely impaired speech and swallowing, a patient-specific sub-periosteal implant (psSPI) was designed that matched the remnants of the zygoma complex. First, the patient's post-surgical anatomy was visualized through segmentation of the pre- and post-maxillectomy computed tomography data. Next, based on the data, a customized zygoma-supported framework was designed to support the obturator prosthesis. Surgical guides for intraoperative navigation were designed and three-dimensionally printed, along with an obturator prosthesis to fit the planned outcome situation. The preoperatively manufactured psSPI and obturator prosthesis matched the intraoperative conditions. The postoperative results were favourable; within a week after surgery the patient could speak and swallow normally without nasal leakage. No problems occurred during follow-up. These results indicate that a psSPI-retained prosthesis can be considered for the restoration of speech and oral functioning in cases with a largely compromised maxillary bone anatomy, accompanied by impaired oral functioning and no feasible conventional reconstruction options.

Key words: zygomatic implant; sub-periosteal; maxillary obturator; maxillectomy; computer-aided design; three-dimensional.

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The rehabilitation of large maxillary defects resulting from ablative tumour surgery is a reconstructive challenge. To restore oral function and preserve psychological well-being, reconstruction can be achieved through conventional approaches, such as closure of the maxillary defect by microvascular free flap surgery or prosthetic obturation[1,2]. In both

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treatment options, osseointegrated implants can enhance the stability and retention of the prosthesis. Occasionally, zygoma implants cannot provide satisfactory implant anchorage due to insufficient bone volume, but these patients still need an adequate implant-retained obturator prosthesis. Otherwise, oral functions like mastication, swallowing, and speech remain severely impaired.

Recently, Mommaerts introduced an innovative concept for an additive-manufactured sub-periosteal jaw implant that uses modern computer-aided design and manufacturing (CAD/CAM) technology[3]. His approach offers an alternative implant option for patients with extreme jaw bone atrophy. He also suggested that this technique could be used for the rehabilitation of extended post-resection defects. However, tissue conditions after oncological resection and postoperative radiotherapy require a specific design due to the lack of sufficient bone to support even a sub-periosteal implant.

Case presentation

A 74-year-old female patient was treated with a subtotal bilateral maxillectomy due to squamous cell carcinoma of the palate. Seven years before, the patient had received primary radiotherapy (cumulative dose 60 Gy) for squamous cell carcinoma of the floor of the mouth. To restore speech and swallowing, the resulting maxillary defect was obturated perioperatively with an obturator prosthesis. The obturator was fixed bilaterally with wires around the zygomatic arches. However, the patient developed postoperative swallowing and speech problems due to loosening of the prosthesis. Moreover, the patient experienced increasing problems with cleaning the prosthesis, which resulted in halitosis and a severe negative impact on quality of life. Surgical restoration of the maxillary defect was not feasible due to the patient's poor medical condition, in particular compromised vascularization. As insufficient bone support was present for placement of dental or zygomatic implants to support a prosthesis, a patient-specific sub-periosteal zygoma implant (psSPI) was developed. This psSPI was provided with an implant-supported obturator prosthesis, which was retained to the framework with anchor attachments (the Swiss Dalbo-System) (Fig. 1).

Materials and methods

Design

Prior to ablative oncological surgery, the patient's functional prosthesis was digitized through three-dimensional (3D) optical surface scanning. This virtual prosthesis model was matched to 3D models of the patient's anatomy – the starting point for the psSPI design. The planned position of the prosthetic dental arch was determinative for the location of the four anchor attachments. On these attachments, a U-shaped framework was designed to support the obturator prosthesis. After designing the basal structure of the psSPI using CAD techniques, two connectors were designed to fix the psSPI to the zygomatic bone. As part of the design, the preferred screw and retention positions were taken into consideration, thereby circumventing the irradiated areas of the remaining maxillary and zygomatic bone. Only the extensions of the two connectors on which the U-shaped framework was situated penetrated the oral mucosa, making it easier to clean the psSPI. Materialise 3-matic version 11.0 (Materialise, Leuven, Belgium) and SolidWorks Professional 2017 (Dassault Systèmes, SolidWorks Corp., Waltham, MA, USA) software was used to design the psSPI. In addition, a patient-specific surgical drill guide was designed to translate the 3D plan to the surgical procedure. Furthermore, based on the 3D design, a temporary obturator prosthesis with four Dalbo attachments was manufactured prior to the surgical procedure. The psSPI was manufactured by Witec (Witec Fijnmechanische Techniek BV, Ter Apel, the Netherlands) from medical-grade titanium alloy (Ti–6Al–4V). Threads matching 2.0-mm locking screws (KLS Martin, Tuttlingen, Germany) were added to the screw holes.

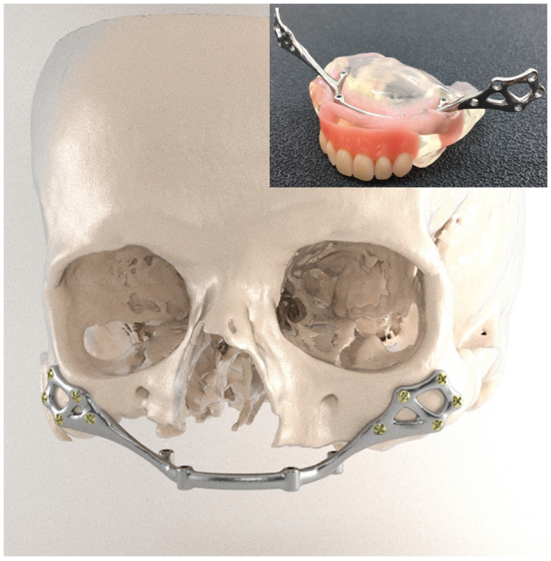

Fig. 1. The additive manufactured patient-specific sub-periosteal implant (psSPI). Rendered three-dimensional model of the patient showing the implant matching the anatomical geometry of the zygoma remnants. Only the extensions of the two connectors on which the U-shaped framework is situated penetrate the oral mucosa, which makes cleaning the psSPI easier. Note the insert showing the additive manufactured psSPI with the implant-retained obturator prosthesis in place.

Surgical procedure

Under general anaesthesia, a full-thickness flap was raised to expose the remnants of the zygomatic bone. The stability and fit of the bone-supported surgical template was then verified. Guided by the surgical template, the holes for the locking screws were drilled. To align the implant to the drilled holes, the implant was positioned using stainless steel (316L) pins prior to screw insertion. This approach resulted in precise alignment of the psSPI with the underlying zygomatic bone. The psSPI was fixed with the locking screws. Next, the fit of the obturator prosthesis on the U-shaped part of the psSPI was checked, and the mucoperiosteal flap was repositioned and sutured (Vicryl 3–0; Johnson & Johnson, Brunswick, NJ, USA). Finally, the implant-retained obturator prosthesis was placed by the prosthodontist. Only minor adjustments had to be made to the base of the prosthesis to obtain optimal obturation of the defect.

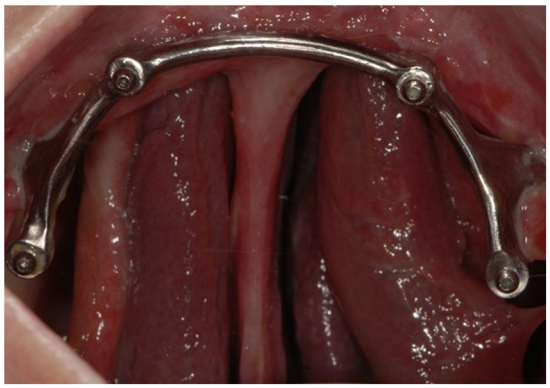

Fig. 2. Clinical view of the patient-specific sub-periosteal implant (psSPI). Intraoral view 6 months after surgery showing the large oronasal defect, the psSPI, and healthy peri-implant tissues.

Results

Recovery from the procedure was uneventful. Obturation of the defect was satisfactory. Within 1 week, speech performance was favourable and there was no nasal leakage during swallowing. Two weeks after surgery, the sutures were removed. Oral inspection showed no signs of inflammation or dehiscent bone, and an uncomplicated adaptation of the soft tissues around the arms of the psSPI was apparent. During the next 6 months (final follow-up), the soft tissue remained in a good condition (Fig. 2) and the obturator prosthesis functioned well. The patient felt confident with wearing the prosthesis and was very satisfied. She spontaneously reported recovery of her social life as a major achievement.

Discussion

This customized, prosthesis-driven implant design offers an alternative approach for the rehabilitation of large maxillary defects in cases where immediate or delayed surgical reconstruction is not feasible and oral functioning and oral cleaning are impaired. The easily removed obturator prosthesis is a major benefit. This allows examination of the tissues and enables patients to maintain and clean the prosthesis and peri-implant tissues themselves.

Although sub-periosteal implants have fallen into disuse due to severe inflammation and inappropriate or non-rigid fixation[4], the design used here enabled us to provide a solution for a patient without other treatment options, resolving her poor oral functioning and impaired oral health-related quality of life. Furthermore, titanium is more tissue-friendly than the chrome–cobalt alloys that were used in the previous sub-periosteal implants.

As it had to be determined beforehand whether the psSPI would be able to withstand chewing forces, a finite elements analysis was performed to assess implant strength and fatigue resistance (data not shown). This analysis revealed that the psSPI could easily bear occlusal loading. We therefore recommend the digitally planned psSPI to provide effective support for obturation of large maxillary defects in patients for whom a direct or delayed restoration of the defect is not feasible.

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Patient consent. Written patient consent was obtained.

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