PEEK Maxillary Obturator Prosthesis Fabrication Using Intraoral Scanning, 3D Printing, and CAD/CAM

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Computer-aided design/computer-assisted manufacturing (CAD/CAM) was introduced in the dental field in 1980. In recent years, CAD/CAM technology combined with modern materials and imaging techniques has enriched the treatment possibilities for patients and clinicians. With the combination of these materials and technologies, chair time is reduced for the clinician, resulting in less patient inconvenience and discomfort.1 Patients who have undergone resection of all or part of their maxilla tend to have increased sensitivity to gagging.2,3 Digital impressions result in significantly less stimulation of the gag reflex in comparison to analog impressions.4

Much of the digital dentistry workflow and available literature are related to fixed dental prostheses (FDPs) and/or implant restorations.5 Articles that discuss three-dimensional (3D) printing of removable dental prosthesis (RDP) framework patterns are also available. The printed framework pattern is conventionally invested and cast in the traditional manner.6,7 The combined digital/analog workflow allowed the authors to fabricate a predictable framework pattern that may be modified prior to casting.7

Maxillary obturator prostheses are usually fabricated from polymethyl methacrylate (PMMA) if the patient is completely edentulous, or from PMMA and a cast framework if partially edentulous. As the size of the surgical resection increases, the weight of the prosthesis also increases. Traditionally, the weight of the prosthesis has been minimized through the use of hollow bulb obturators. Polyether ether ketone (PEEK)
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in combination with digital impressions and design software, can be used in the fabrication of maxillofacial prostheses. To date, no report of a fully digital protocol for maxillofacial restorations has been described. The purpose of this clinical report was to describe the combination of a CBCT scan, digital impression, and 3D printing in order to fabricate a two-piece definitive maxillary obturator RDP.

Clinical Report

A 47-year-old woman presented for the replacement of her existing definitive maxillary obturator prosthesis. She had been previously diagnosed with adenoid cystic carcinoma (T4N1M0) of the right maxillary sinus. She underwent unilateral maxillectomy and postoperative radiation therapy. Her oncologic treatment resulted in a 5.5 × 4–cm palatal defect (Figs 1a and 1b). The definitive obturator prosthesis had been used by the patient for 5 years (Figs 1c and 1d). Her chief concerns related to the prosthesis included nasal regurgitation of liquids, hypernasal speech, difficult deglutition, and diminished masticatory ability. As a result of her radiation treatment, she suffered from xerostomia, trismus, and orofacial pain. Her remaining teeth were in good repair with no carious lesions noted and excellent periodontal status. In order to address the patient’s chief complaints, a treatment plan was created to include fabrication of a new definitive maxillary obturator RDP.

Cone beam computed tomography (CBCT) and multi-slice spiral computed tomography (MSCT) are used as diagnostic tools during treatment planning. Digital technology has enabled the transfer of oral and facial information, thus decreasing the need for conventional impression-making techniques. Volumetric data from CBCT scans can be accurately converted into rapid prototyping information. The resultant high-resolution images, material has been successfully used for the fabrication of the bulb portion of a maxillary obturator. PEEK is a lightweight material with excellent biocompatibility. It has been shown to be successful when used as the major connector and as retentive clasps in an RDP. The retention between acrylic resin and PEEK is mechanical in nature, and therefore design considerations must be taken into account.

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Figs 1a and 1b Initial condition. (a) Occlusal and (b) frontal views.

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tissues at the area of interest were segmented. DICOM files were converted into a relevant standard tessellation language (STL) file of the maxillary defect. After segmentation, the STL file was modified through Meshmixer software for advanced processing and editing of 3D triangular meshes (Meshmixer, Autodesk). During this modification, the internal borders of the lateral side of the right nasal cavity and the wall of the cranial orbit were extruded by 2 mm, avoiding any changes of the external palatal borders of the defect. The final resulting STL file was printed in resin (V1, Formlabs) at a resolution of 25 μm using a 3D printer (Form 2, Formlabs) (Fig 2b). This 3D-printed resin model was used for the fabrication of the silicone hollow bulb obturator (female).

**Laboratory Fabrication of Hollow Bulb Obturator**

**Female.** A wax pattern (Anutex Modelling Wax, Kemdent) of the hollow bulb of the obturator was fabricated on the 3D-printed model, incorporating an undercut in the intaglio surface (female) for the retention of the second obturator piece (male) (Fig 3a).

This 3D-printed model including the wax pattern hollow bulb was mounted on a three-post reline jig (ReFlex Reline Jig, Lang Dental) using Type IV dental die stone (Fujirock EP, GC Europe), and a laboratory condensation vulcanizing modeling silicone index (Laborsil 90, Dreve Dentamid), was used to duplicate the intaglio surface and the borders of the female portion of the hollow bulb obturator (Fig 3b). Following duplication, the jig was opened, the wax was boiled out, a separating agent was applied, and long-term room-temperature vulcanizing silicone denture soft lining material (bredent Multisil) was injected into the stereolithographic model, followed by jig repositioning (Fig 3c) and insertion in a pressure pot under 4-bar pressure. After polymerization, the resulting silicone hollow bulb obturator (female) (Fig 3d) was polished using silicone trimming wheels (UltraTrimm, Dreve Dentamid), tried in, and successfully inserted into the patient’s mouth.

**Male.** The surgical defect was classified as Aramany Class II, and the maxillary RDP obturator framework was designed according to the conventional Kennedy Class II RDP design. Both dental arches, including hard and soft tissue morphologies of the defect, teeth, and occlusion, were scanned digitally using an intraoral scanner (Trios, 3Shape) (Figs 4a and 4b).

STL files were imported into CAD software (3Shape Dental System) for processing and cast manufacturing. Digital casts were created, and a virtual RDP framework was designed by a commercial dental laboratory (Fig 4c).
Once the RDP digital design was approved, both maxillary and mandibular resin casts were 3D printed using an SLA desktop 3D printer (Form 2). The digital framework was milled from modified PEEK (BioHPP, bredent) using a computer numerical control (CNC) milling machine (D43, Yenadent) (Fig 4d). Interocclusal bite registration was accomplished using wax rims on the PEEK framework in the conventional manner. The 3D-printed
casts were articulated, and prosthetic teeth selection and arrangement were performed by hand (Figs 5a to 5c). Following prosthetic teeth try-in, heat-polymerized acrylic resin was used for the processing of the male portion of the obturator bulb and the RDP cameo surface (ProBase Hot, Ivoclar Vivadent) (Fig 5d).

The definitive two-piece maxillary obturator RDP was delivered to the patient (Fig 6a). After delivery, the patient was seen monthly for a 6-month period for evaluation and adjustment of the prosthesis. The patient was recalled yearly thereafter (Fig 6b).

DISCUSSION

Fabrication of an obturator RDP can be challenging. An accurate impression is crucial to the clinical success of the prosthesis. The use of conventional impression materials is often uncomfortable for the patient. The technique described here avoids the discomfort by utilizing a medical CT to capture the internal structures of the surgical site (soft tissue) and a routine digital dental scan to capture the remaining dentition (hard tissue). CBCT is very accurate on soft tissue, whereas intraoral scanners are more accurate on hard tissue. The 3D-printed cast produced from the segmentation procedure was used to fabricate the hollow bulb obturator. The cast printed from the intraoral scan was used for the fabrication of the PEEK framework. In addition to improved patient comfort, the use of a digital scan prevents the possibility of impression material being locked into undercuts in the surgical site.

The use of a digital design protocol to create the framework has several advantages. The first is the ease in which the necessary undercuts and paths of insertion can be completed with digital surveying. The ability to digitally design an RPD framework significantly decreases the amount of time necessary to fabricate the prosthesis. Additionally, since the impressions and design are digital, a replica prosthesis can be prepared with minimum effort if necessary.

**Fig 4** Intraoral scanning and digital prosthesis framework design. (a) Maxillary and (b) mandibular digital models. (c) Digital framework design. (d) Milled PEEK RDP framework.
A major issue with the conventional maxillary obturator prosthesis pertains to weight. The larger the defect, the heavier the prosthesis. Eventually, as the defect increases in size, the force of gravity prevails over the capacity of the substructures, either teeth or bone, to retain the prosthesis, resulting in loss of retention of the prosthesis or loosening of the abutment teeth. A solution to this problem is to create hollow obturator bulbs. This allows the prosthesis to maintain weight within acceptable values. Hollow bulb obturators are available in many iterations; the one described here is a two-piece hollow bulb. The advantage of a two-piece hollow bulb lies in the ability to overcome multiple divergent undercuts and create an acceptable and predictable path of insertion for the RDP framework.

PEEK was successfully used to fabricate the RDP framework. PEEK has been shown to have high biocompatibility, good mechanical properties, and resistance to cracking. Additionally, PEEK is significantly lighter in weight than cast alloys suitable for RDP frameworks. One of the main disadvantages of PEEK is the inability to adjust the RDP clasps to repair the framework if necessary.

CAD/CAM technologies can be successfully applied in the field of partial RDP framework design and fabrication, offering potential advantages such as automated determination of the proper path of insertion, elimination of unfavorable undercuts by digital surveying, rapid identification and utilization of guide planes, and reduction of fabrication time. Additionally, CAD/CAM and rapid prototyping procedures have been reported in maxillofacial prosthodontics. Concerns regarding scanning accuracy of edentulous areas or nonkeratinized tissues have been raised. The manufacturers of the latest intraoral scanners suggest that accuracy depends primarily on the scanning strategy and technique. A rapid scan with smooth transitions between quadrants and avoidance of instability while
scanning are recommended. This results in collection of the maximum amount of data without overlap and thus the greatest accuracy.

As with all techniques, certain drawbacks exist. An intraoral scan of the patient’s existing dentition may not be possible depending on the patient’s interincisal opening. The clinician must have some familiarity with digital dental technology or be in contact with a laboratory that is well versed in digital techniques.

**CONCLUSIONS**

Intraoral scanning, 3D printing, and CAD/CAM were successfully used for the fabrication of a PEEK maxillary two-piece obturator RDP. The resilience and long-term functionality of the PEEK clasps, as well as the biologic and structural stability of the two-piece obturator (male-female coupling) parts, have yet to be determined.
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REFERENCES


