Digitally fabricated bulb obturator using virtual data and 3D printing

Dr Tariq Saadi, UAE

Introduction

Computer-assisted digital planning has become an important diagnostic and therapeutic tool in modern dentistry. Digital technologies related to imaging and manufacturing provide the clinician with a wide variety of treatment options. Additive manufacturing (3D printing) technology offers a simple and predictable means of fabricating dental prostheses.1

This case report presents the rehabilitation of a patient who had undergone a hemi-maxillectomy. This clinical case describes the digital workflow using an intra-oral digital impression, 3D facial scanning, and cone beam computed tomography (CBCT) volumetric data to create a digital (3D) virtual model of the dentition, defect area, and soft and hard tissue for this patient. 3D printing technology was used to manufacture a resin obturator prosthesis (a hollow bulb with a removable partial denture).2

Clinical case

Clinical history

A 65-year-old patient with squamous cell carcinoma of the maxillary left alveolar process presented to our clinic two months post-surgery. According to her medical report, she had undergone left hemi-maxillectomy, left neck dissection and a split-skin graft harvested from her left thigh for the lining of the maxillary defect (Fig. 1).

Fig. 1: Initial situation with missing maxillary left dentition. Fig. 2a: Mirrored intra-oral view revealing a surgically removed left maxilla, extending up to the nasal septum. Fig. 2b: Used medicated gauze and flat acrylic plate with metal clasps.

Intra-oral examination

There was a significant limitation in her mouth opening, owing to radiation and surgical scar contracture, a stiff oral aperture and difficulty in stretching of the lips. Intra-oral examination revealed the surgical removal of the entire upper left jaw, including the premaxilla, maxilla, and hard and soft palate. The dissection extended to the nasal septum, and there was communication between the oral cavity and nasal cavity (Fig. 2a). For two months after the surgery, the patient had worn a medicated gauze pack covering a flat acrylic plate retained by metal clasps (Fig. 2b).3

Chief complaint

The postsurgical maxillary defect had resulted in hyper-nasal speech, leakage of fluid into the nasal cavity and impaired masticatory function.4 Trismus, xerostomia, mucositis, tissue ulceration and gingival bleeding were
side effects of the patient’s postoperative chemoradiotherapy (adjunctive treatment).

**Dental assessment**
The absence of a dental prosthesis had resulted in both functional disability and cosmetic disfigurement.², ⁴ The fabrication of a dental prosthesis like a bulb obturator and denture is essential for oral functions such as speech, swallowing and mastication, and for esthetics.⁵

Limited mouth opening (microstomia)³ commonly leads to difficulties in taking conventional impressions even when using custom-fabricated trays. The reduced mouth opening hinders conventional dental treatment, and so alternative procedures have to be considered in order to overcome these challenges when managing the case.

Digital technology creates opportunities for enhancing the fabrication and delivery of a maxillofacial prosthesis.⁵ Digitised data of any object can be obtained from various sources, such as CBCT, 3D facial and 3D intra-oral scans (digital impressions).

**Data collection phase**
Digitising this patient was initiated with an intra-oral digital impression (TRIOS 3, 3Shape). Utilising the intra-oral scanner allowed for successful capture of the right maxilla and remaining dentition, even with the limited mouth opening (Fig. 3a).⁶ ⁷ A facial scanner (Bellus3D) was then utilised to digitise the patient’s face (Fig. 3b).⁸

A CBCT unit (GiANO HR, NewTom) was capable of producing high-quality 3D diagnostic images in submillimetre resolution with a short scanning time, low radiation exposure, and minimal distortion, capturing the maxillofacial hard and soft tissue accurately (Fig. 3c).⁹ ¹⁰

**Data integration phase**
The representation of a 3D virtual patient requires the successful superimposition of the data collected on the 3D structures: (1) the DICOM format derived from the CBCT scan; (2) the STL and PLY formats derived from the intra-oral scan; and (3) the OBJ format derived from the facial scan showing colour and texture information.¹¹ The key to linking the different files was to identify common reference points as constant landmarks within the same software in all three data acquisitions, to allow for predictable superimposition, in order to create a 3D virtual patient (Fig. 4a).¹¹ In this case, all the data was integrated using the Dental System software (3Shape; Fig. 4b). The superimposition of data from the CBCT, intra-oral and facial scans and the creation of the virtual patient allow for better diagnosis, treatment planning and communication with the patient, the laboratory and other professionals involved in the treatment.¹¹

**Treatment plan**
The goal of treatment for this patient was to restore a barrier between the oral cavity and the structures above it.¹² Owing to the complexity of this case and the difficulty in inserting and removing the obturator, the decision was made to fabricate¹³ a detachable obturator to overcome this problem.¹⁴ The plan
was to fabricate a hollow bulb and a removable partial denture as a transitional solution for this patient, until the surgical site had healed completely and patient was prepared, physically and emotionally, for any further surgical and restorative care that might be necessary.15

Prosthetic phase

*Digital denture fabrication*

Digitalisation of intra-oral data enables design and fabrication of dentures without trays or conventional impressions.16 A digital workflow using design software and a 3D printer was simplified to produce a partial denture quickly, easily and cost-effectively:

1. Denture fabrication began by importing the patient’s digital data (CBCT, intra-oral and facial scan data) into Dental System to create a 3D virtual patient (Figs. 4a & b).

2. A digital artificial substructure for the left maxilla was required to allow for setting up of the virtual teeth (Fig. 5a). The upper right jaw intra-oral scan data was inserted into Meshmixer software (Autodesk), and the copy and mirror tools were used to create a digital upper left jaw in the mirror image of the acquired data of the right side of the jaw (Fig. 5b).17

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**Fig. 5a:** First step in fabrication of the removable partial denture. **Fig. 5b:** Digital maxillary left dentition acquired by mirroring the data gathered from the right maxilla. **Fig. 5c:** Complete digital maxillary dentition. **Fig. 5d:** Digital maxillary left teeth virtually extracted. **Fig. 5e:** Digital maxillary dentition with artificial left alveolar ridge. **Fig. 5f:** Digital maxillary dentition with denture borders. **Fig. 5g:** Digital maxillary dentition with designed maxillary left teeth. **Fig. 5h:** Digital maxillary dentition with an artificial left alveolar ridge and left teeth. **Fig. 5i:** Final removable partial denture design for printing.

**Fig. 6a:** Milled teeth (milled using the CORITEC 140i, imes-icore). **Fig. 6b:** Printed denture. **Fig. 7a:** 3D image from CBCT data. **Fig. 7b:** Segmented hard and soft tissue using 3D Slicer software.
3. A complete maxillary digital arch was obtained by joining both sides together.
4. The new data was imported into Dental System (Fig. 5c), and virtual teeth extractions were done to remove the teeth from the mirrored left side (Fig. 5d).
5. An artificial alveolar ridge was created to allow for setting of the new virtual teeth (Fig. 5e).
6. The design process continued by creating a denture border, denture base and retentive clasps (Figs. 5f–i).
7. The final design was printed on a 3D printer (NextDent 5100, 3D Systems) using a denture resin material, and the acrylic teeth were milled (CORiTEC 140i, imes-icore; Figs. 6a & b).

Digital hollow bulb fabrication

The conventional fabrication of an obturator is a complex task that requires multiple scheduled appointments and involves a maxillofacial surgeon, prosthodontist and dental laboratory technician.\(^5\), \(^13\), \(^18\), \(^19\), \(^20\) Modern digital technology, including CBCT and 3D printing, opens up the possibility of manufacturing maxillofacial prostheses more efficiently and cost-effectively:\(^21\), \(^22\)

1. A 3D image of the maxillary defect and the remaining maxilla was compiled from the CBCT scan (Fig. 7a).\(^23\)
2. The images were imported into 3D Slicer software for 3D processing of the DICOM images and building of an anatomical virtual model.
3. 3D Slicer software was utilised for hard and soft tissue segmentation and preparation of an STL file (Fig. 7b).
4. The data obtained from 3D Slicer was processed and then uploaded to Meshmixer (Fig. 8). Meshmixer was utilised to design the digital obturator to fit within the defect borders and extensions (Figs. 9a & b).\(^24\) The weight of the obturator was minimised by reducing the thickness of the walls and hollowing its internal aspect (Fig. 10).
5. The digital bulb obturator was 3D-printed (NextDent S1000 and NextDent Denture 3D+ resin material, 3D Systems; Figs. 11a & b).

Prosthesis delivery

The two-piece maxillary detachable obturator required a retentive element to facilitate the easy insertion and removal of the prosthesis (Figs. 12a & b).\(^13\) Magnets were added to retain the prosthesis and assist in easy orientation and placement of the denture.\(^24\) The obturator bulb housed one part of the magnet using autopolymerising acrylic resin. The other magnet was embedded into the inner surface of maxillary denture in the proper position to the opposite magnetic pole in the bulb during the try-in session.\(^25\) A soft denture relining material (Bisico Softbase, Bisico Bielefelder Dentsilicone) was used on both components to achieve a more intimate fit to the soft tissue and to ensure the magnets would re-
main completely isolated from the oral environment when the bulb and denture of the obturator were in place.

The patient was educated on how to insert and remove the prosthesis and instructed on oral hygiene and self-maintenance. Follow-up visits every two weeks for further assessment and a new reline were indicated owing to rapid soft tissue changes that occur during the wound healing process.15, 25

Future steps

Based on 3D digital data, patient-specific reconstructions (custom-made implants) can be produced as a definitive solution.26 In close collaboration with the maxillofacial surgeon and prosthodontist, the design can be modified, customised and fabricated utilising 3D printing material to achieve better aesthetics and function to enhance patient satisfaction (Figs. 13a & b).27

Conclusion

Dentistry has entered a new era where 3D virtual treatment planning, design and fabrication are common and affordable. The thought process on how to treat our patients has changed. We can now predictably have a prosthesis fabricated using CAD/CAM technology without the need for conventional impressions and fabrication techniques.

The digital revolution is changing dentistry, and the impact of new 3D image acquisition devices such as CBCT devices, intra-oral scanners and facial scanners is already influencing the dental field.28 At the same time, CAD/CAM software and innovative fabrication procedures, including 3D printing and milling, are transforming the way we treat our patients, making those previously difficult manual tasks easier, faster, cheaper and more predictable.11 Nowadays, digital design, including 3D virtual planning, and fabrication of a provisional or definitive prosthesis can be accomplished with a concise workflow with predictable aesthetic and functional outcomes.1, 29

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Declaration of patient consent

The author certified that all appropriate patient consent forms were obtained.

Conflicts of interest

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about

Dr Tariq Saadi is a medical director and general dental practitioner in a dental facility in the UAE. Dr Saadi focuses on the digital workflow in cosmetic and implant dentistry. His vision is that digital technologies will dramatically change the world of dentistry; therefore, he decided in 2015 to transform his work completely from analogue to digital. He invested in digital intra-oral scanners, 3D facial scanners, 3D printing, CAD/CAM software, milling machines and CBCT. He believes that digitally driven dentistry is what we need today to fulfil patients’ expectations of dental treatments.

contact

Dr Tariq Saadi
Phone: +971 50 293 9550
E-mail: dr.tariqsaadi@hotmail.com
Instagram: dr_tariqsaadi