Conventional vs Combination of Conventional and Digital Approaches to Prosthetic Rehabilitation of Orbital Defect: Case Report

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Abstract

Background: Presently, the digital impression and fabrication techniques for maxillofacial prostheses have been introduced. The efficient, easy and accessible one was created, selected, performed and compared with the conventional one.

Case Presentation: Prosthetic reconstructions were performed in a large and unfavorable facial defect, involving left orbital and intimately surrounding structures, with 2 different approaches: conventional approach vs combinational approach. One-month and 6-month follow-up visits were conducted. The results revealed that the combined technique overcame the conventional one in term of patients' comfort, risk of trauma, laboratory workload, mold accuracy and split mold fabrication, whereas, the inferior appearance of skin texture from the scan powder and the layer lines on the printed mold surface was noticeable.

Conclusions: Digital technique can be utilized to support, replace and even outperform conventional technique in certain steps of maxillofacial prosthesis fabrication which decreases workload and increases patient satisfaction.

Keywords: 3D printing, Orbital prosthesis, Split mold, Case report

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Introduction

Sinonasal squamous cell carcinoma is a rare form of head and neck malignancy, with an incidence of 3%,[1, 2] while squamous cell carcinoma (SCC) of the ethmoid sinus is even more infrequent. Since ethmoid cancer in the early stage of the disease is difficult to be recognized, most patients are diagnosed with locally advanced SCC of the ethmoid sinus. Ethmoid cancer extends into the surrounding anatomical structures with ease, including the skull base plate, intracranial organs, orbital content and facial skin. Surgery, radiotherapy or chemoradiotherapy are treatments of choice.[1] Relatively high incidences are reported in Asia and Africa, and in individuals who have been exposed to wood dust, nickel, industrial fumes, textile dust, asbestos and formaldehyde. Other suggested risk factors are chronic sinusitis, allergies, nasal polyposis and tobacco smoking.[3]

A facial defect as a consequence of the cancer treatments, results in multiple functional and psychosocial difficulties. The mid-face reconstruction or rehabilitation is easily perceived by an observer due to its location, especially for the orbital defect which with the normal adjacent one makes a comparison obvious. Despite advancement in surgical techniques, the restoration of orbital defects is considered as one of the most difficult procedures, in term of the risk of complications and the final aesthetic outcome.[4] Moreover, large and unfavorable facial defects present challenges for prosthetic reconstruction as a result of movable tissue margin, large heavy prostheses, lack of retention and reduced marginal adaptation of the prostheses.

The conventional workflow is performed by facial impression with impression material, fabrication of stone molds, sculpting wax patterns and silicone processing. The prosthetic outcomes can vary with patient, defect and healthcare professional factors. While a conventional workflow requires skill-dependent, artistically driven, time-consuming, and labor-intensive expertise,[5] as well as possible patient discomfort[6] and risk of trauma, this traditional technique has been used for a long time with the advantages of instrument and material availability and acceptable final outcomes.

The full digital workflow has the potential to provide an efficient, standardized and affordable treatment in the future. It starts by scanning the patient to obtain anatomic data with high speed, precision and safety. A design program then processes and modifies the scan data using a digital database[7] or mirror image of the contralateral side[8] to facilitate the generation of anatomic parts during the design process. Then, the 3D printing of silicone is the last step to fabricate maxillofacial prostheses.[9] Presently, several authors have introduced the digital impression and fabrication techniques including computerized tomography scanning and computer-aided design,[10] magnetic resonance imaging, laser, stereophotogrammetry,[11] monoscopic photogrammetry[12] and direct 3D printing of silicone.[13] There are advantages and disadvantages in each technique. Intraoral scanners are commonly available in dental clinics. They reduce the gag reflex, especially in maxillectomy patients and the risk of retention of the impression material in the defect.[14] Moreover, they can obtain enough detail to reproduce skin textures for maxillofacial prostheses.[15] However, accurate reproduction of large and flat topographical areas such as the face is limited because the sensor recognizes fewer reference points.[16] In addition, the direct 3D printing of silicone facial prosthesis has been reported to have inferior clinical outcome due to poor marginal adaptation and color match,[13] poor mechanical properties and untested biological responses.[17] Therefore, the combined technique[17, 18] of printed negative molds and the conventional silicone processing was chosen.

This case report details the medical history of the patient and the procedures of maxillofacial prosthetic fabrication in one unfavorable orbital defect with 2 approaches. The results were compared and discussed regarding the patient, clinician and lab technician perspectives.

Case Presentation

A 57-year-old female patient with left orbital defect was referred to the Dental Division for prosthetic reconstruction. She presented with a chief complaint of limitation of the existing orbital prosthesis in term of difficulty in retention and a desire for prosthetic improvement of appearance. Due to her history of allergy to medical adhesive which created reactions including the redness and scaly skin, she had used transparent film dressings to hold the prosthesis in place (Figure 1) which made difficulty in insertion, ruined the prosthesis and looked unnatural.

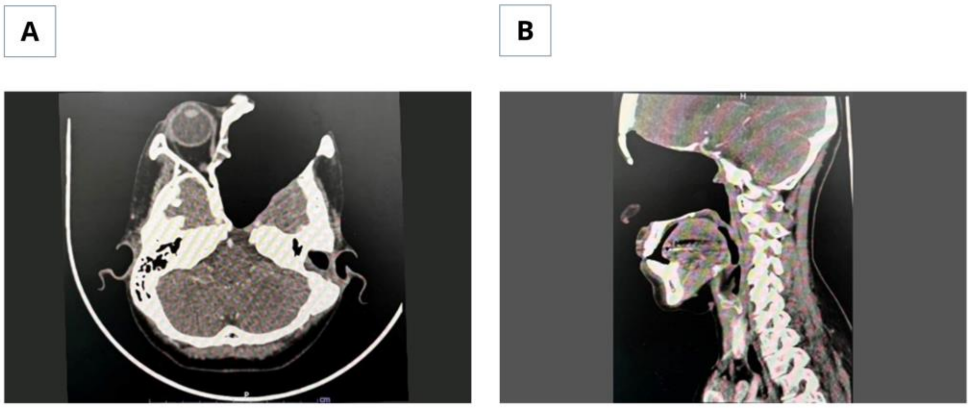
The patient reported a history of keratinizing squamous cell carcinoma ($T_4N_0M_0$) at her left ethmoid sinus status post recurrences and multiple resections including wide excision, left orbital exenteration and craniotomy, along with chemotherapy and radiotherapy. The residual tumor her at temporal lobe and brain edema had been followed up annually since then. The classification of orbital exenteration was type III, which are cases with penetration of the skull base, which imply a pterional craniotomy as a surgical approach to the affected brain structures.[19] The clinical examination revealed a defect that extended vertically from the left eyebrow to nearly the inferior rim of the nose, horizontally from ipsilateral margin of the nose to left lateral canthus and the posterior border to cranial floor. The surrounding tissue was movable when she lifted her eyebrows or smiled. There was moderate deformity of nose and left nasolabial fold.

The radiographic examination (Figure 2) demonstrated the evidence of left temporal craniotomy, left orbital exenteration and left mastoidectomy with resection of the posterior-inferior wall of the left external auditory canal, abutting the superficial left parotid lobe and the posterior aspect of the left temporomandibular joint, without new discrete enhancing lesion to suggest local tumor recurrence. The surrounding bone was insufficient for craniofacial implant. The existing orbital prosthesis was made 14 years ago with the problems of discoloration and retention due to the change in shape of the defect and the prosthesis, along with the adhesive allergy issue. After discussion, the patient desired a new orbital prosthesis with better appearance and stability without using adhesive nor craniofacial implant.

For conventional approach, a facial moulage was obtained by using light bodied polysulfide (Permlastic, Kerr), gauze strips and plaster (Snow white plaster No. 2, Kerr) (Figure 3A). Gypsum type V (Velmix, Rocky) was poured to fabricate the facial cast. The ocular prosthesis was fabricated and set the gaze. The wax-up (Figure 4A), showed acceptable marginal adaptation, and was refined until satisfied by the patient. On the stone mold, posterior side, the wax-up margin was elongated to create more surface into tissue undercut, whereas, on the anterior side, the margin was shortened due to no need for adhesive space. Conventional technique for silicone processing was performed by mixing 2-part silicones (Platinum Silicone Elastomer VST-50, Factor II) in ratio 10:1 by weight, according to the manufacturer's instructions. The intrinsic color (Functional Intrinsic, Factor II) and additional materials like flock were added to match the patient's skin tone in different areas such as upper eyelid, lower eyelid, nasofacial sulcus, cheek and forehead. Thixotopic agent was combined to thicken the silicone. The mixed and pigmented silicone was gradually smeared on the facial side of the mold to mimic the color of the patient's skin in each area. The remaining silicone was put into a plastic syringe and injected in all areas

Figure 1. Existing Orbital Prosthesis was Retained by Transparent Tape

Figure 2. Preoperative Computerized Tomography Scan



A, Axial view.

B, Sagittal view.

of the mold. The mold was closed and kept under hydraulic press of 500 kg for more than 8 hours to cure at room temperature. Demolding and trimming were carefully performed. After the prosthesis was completed, extrinsic color (Functional Extrinsic, Factor II) was added chair side to imitate the non-defect side.

For digital assisted conventional approach, the patient was scanned with the 3D scanner (Artec Space Spider, Artec3D) (Figure 3B). The mold was designed with 3D design software (Materialise 3-matic, Materialise) and printed with a fused deposition modeling (FDM) 3D printer (Flashforge Guider IIs, Zhejiang Flashforge 3D Technology) in polylactic acid material (PLA). The PLA printing parameters were layer height 0.2 mm, nozzle diameter 0.4 mm, extrusion temperature 210 °C, build-plate temperature 50 °C, infill percentage 15% and print speed 60 mm per second. Postprocessing was removal of support structures and smoothing those areas. The sculpted wax pattern was performed on the printed mold as analog method (Figure 4B). After completed wax try-in on the patient, the sculpted wax on the printed mold was sprayed with scanner spray and then scanned from the front and the back. From the scan data, operating with the same 3D design software, 3D printer and 3D printing material as the former printed mold, design modification was created for the indexed 6-piece negative mold which was then deployed to the mold in PLA (Figure 5). After that the silicone prosthesis was fabricated from the printed split mold and then extrinsic painting was performed in the same way as the conventional approach.

On delivery, both facial prostheses were tried-in and delivered to the patient (Figure 6). Instructions were given to the patient regarding application, removal and care of the prostheses. Both prostheses showed acceptable marginal adaptation. Also, the retention from tissue undercut was sufficient to maintain each prosthesis in place without using silicone adhesive or transparent film dressing as before. However, the surface texture of the one from the combined technique was scantly inferior in appearance. After wearing a 2-week rotation on each piece, irritation or sore area was not detected on the patient's soft tissue. The patient had no complaint on esthetics and comfort. The retentions from both prostheses were sufficient that she felt confident with no concern about prosthesis dislodgement during the day.

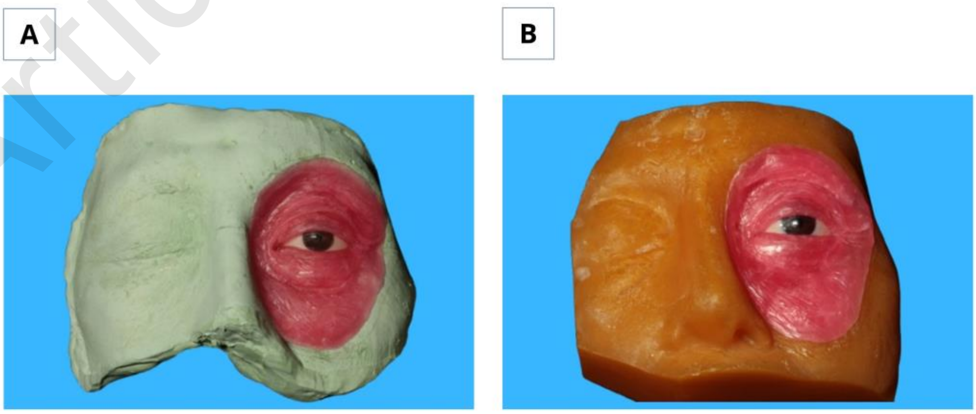
At 6-month follow-up, marginal adaptation, retention and color stability remained adequate for both prostheses over time. Although the conventional prosthesis created insignificant pressure on medial soft tissue and was slightly difficult to insert and remove, the patient reported comfortable daily usage of both prostheses.

Figure 3. Conventional Facial Impression Created Patient Discomfort and Minor Distortion While Patient Digital Image Revealed Those Disadvantages Less in This Large Extension of Orbital Defect

A, Conventional facial impression.

B, Patient digital image.

Figure 4. Both Wax Patterns on Conventional Stone Mold and Printed Mold Showed Acceptable Marginal Adaptation on Patient Tissue



A, Conventional stone mold.

B, Printed mold.

Figure 5. 3D Printed Indexed 6-Piece Negative Mold for Fabricating Silicone Orbital Prosthesis

Figure 6. Final Prostheses on Delivery Visit From Conventional and Combination Techniques

A, Conventional technique.

B, Combination technique.

Discussion

The thrust in cancer care is not simply on survival but on rehabilitation, which aims to improve multiple impairments and quality of life, enhancing patient's comfort and psychological morale.[6]

The sheer size of the facial prosthesis presented retention, weight, fabrication and patients' comfort challenges, as did maintaining closed margins abutting movable tissues. A variety of retentive methods for facial prostheses have been suggested such as retained by adhesive, attachment to osseous integrated implants, teeth,[20] magnets,[21, 22] eyeglasses,[23] denture[24] or even existing bone-anchored reconstruction plates.[25] However, the survival rate of implants in irradiated patients is lower than in nonirradiated patients.[26] In this case report, not only compromised quality, but also insufficient quantity of the surrounding bone contradicted the craniofacial implant option. Moreover, the patient had a history of medical adhesive allergy. Therefore, the undercut of encircling soft tissue was selected for the retentive method.

Due to the considerable size and extensive border of the orbital defect in this case, a large amount of impression material was used in the conventional method. This created patient discomfort and potential tissue trauma if there was a lack of proper defect preparation. Also, its heaviness can create tissue displacement resulted in minor distortion as the patient reported slight pressure on soft tissue only with the conventional one. Digital impression is more accurate, nonintrusive and design processes can be saved for future reproduction.[15] Nevertheless, in this case, a minor limitation was the sensor tip which was quite large which created difficulty in accessing to the undercut area of the defect.

Implementing a 3D printing service in a hospital requires establishing facilities, legal and medical documentation, and funding/billing. The difficulty in setting up and high initial investment on equipment and materials are worthwhile in terms of advancement of healthcare, more resiliency to clinical operation and also cost-effectiveness.[27] In this case, the setting was also in a hospital and centralizing the 3D printing operations can offer advantages in various applications for education, treatment and research.[27, 28]

Furthermore, from this report, the digital approach also aided in fabrication of the split mold, which is impossible to obtain from the conventional technique. The split mold made it easier and eliminated the risk of prosthesis tear, while removing the silicone prosthesis out of the mold especially in this case which utilized soft tissue undercut for retention.

Material of choice for the printed molds in this report was PLA because it is a widely used plastic filament material in FDM 3D printing. Nonetheless, PLA has a relatively low heat resistance,[29] and then it is unable to be cleaned up with steam cleaner to get rid of the residual wax, which consequently creates a risk of contamination in a silicone setting. In this case, gauze soaked in isopropyl alcohol (IPA) was scrubbed on the mold surface as cleaning method because IPA does not dissolve or significantly damage cured PLA, even with prolonged soaking. Alternatively, different printing materials can be selected such as heat resistant PLA,[29] polyetheretherketones, fluorinated polymers, polyurethanes, and polyacrylates[30] which have higher heat resistance and can be cleaned with steam cleaner.

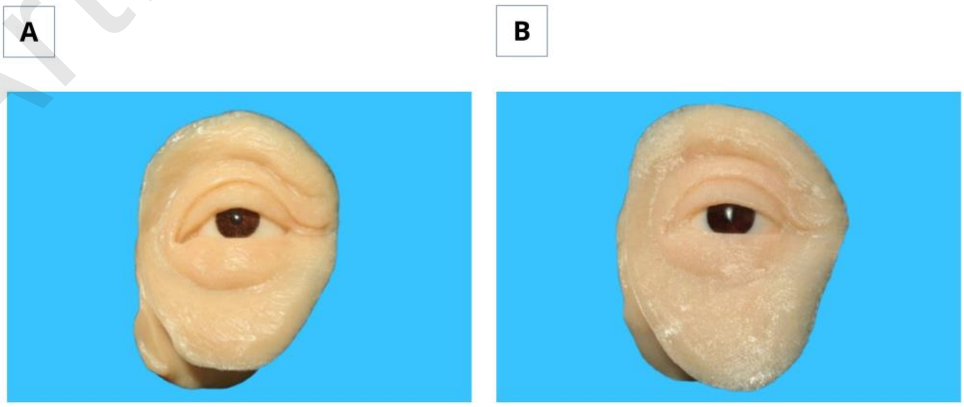
Scanner powder or spray are used to coat reflective, shiny or dark objects to create matte surfaces that allow the 3D scanner's light to be detected more easily and uniformly. Spray systems produce thinner layering and create superior marginal adaptation of final restorations than powder systems.[31] In this case, the sculpted wax was unable to be scanned without the coating because of its reflection, so the scanner spray was used (Figure 7). However, the loss of skin texture detail on the sculpted wax pattern, which resulted from scanner spray coating was found. This shortcoming might be caused by the thickness of scanner spray and the unfavorable coating technique. Similarly, some studies have reported that the homogeneity and thickness of coatings were influenced by the clinician's experience[31] and poor-quality coatings have been related with defective marginal adaptation of the restorations.[32] Also, the thicknesses (10 to 30 mm) of various coatings exhibit considerable variability.[33] Besides, the modelling material which was wax may be replaced with modelling clay (sculptor's clay), plaster or plastolene.[34]

Moreover, for the appearance aspect, the step effect, which is the visible layered appearance of the printed objects, (Figure 8) was noticeable. Also, these unnatural stripes from the 3D printing complicated extrinsic coloring.

From patient perspectives, she preferred scan to analog impression, because of shorter period of time, absence of substantial matters on her face, absence of unpleasant odor from impression material and lesser emotional impact. For the final prostheses, although slight irritation during insertion and removal was found with the conventional one, the patient was satisfied with retention, appearance and ease-of-use of both prostheses.

Figure 7. Scan Powder Eliminated Skin Texture Detail on Sculpted Wax Pattern Resulting in Loss of Natural Appearance in Final Prosthesis

Figure 8. Definitive Prostheses from Conventional and Combination of Conventional and Digital. Notice Skin Texture was Impaired on the One from Combination Technique



A, Conventional technique.

B, Combination technique.

Conclusions

In conclusion, the combined technique overcame the conventional one in term of patients' comfort, risk of trauma, laboratory workload, mold accuracy, split mold fabrication, and reproducibility, whereas, the inferior appearance of skin texture from the scanner spray and the layer lines on the printed mold surface were presented. Although digital techniques presented some limitations in this case report, the advancement of this technology will make it replace and even surpass the analog technique in the future of the maxillofacial prosthodontic field.

Additional Information

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