Digital capture, design, and manufacturing of a facial prosthesis: Clinical report on a pediatric patient

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Facial prosthesis fabrication for children can be a difficult and lengthy process. Conventional facial impression techniques often require that young children and infants undergo general anesthesia or are heavily sedated, resulting in multiple modifications in the fabrication and delivery of the prosthesis. A method that would require minimal contact from impression to delivery of a well-fitting prosthesis would be preferred.

Digital capture technology using photogrammetry techniques has proven to be an accurate alternative method for image capture for the digital design of facial prostheses.1,2 Digital capture systems are traditionally white light or laser scanning technologies, which can take several seconds, are sensitive to movement, and would be contraindicated for small children and infants. Advances in photogrammetry technology with digital cameras have made available commercial systems that allow for image capture in fractions of a second, eliminating the issue of scanning movement.3 The speed of camera-based digital capture is ideal for children and is used routinely to evaluate cranial deformities, soft tissue changes, and the results of surgical interventions.4-6

Once a digital image has been captured and 3-dimensional (3D) soft tissue geometry created, they can be used to digitally design the prosthesis and manufacture a mold, or directly print the prosthesis.1 Although directly printing the prosthesis would be the preferred method, the current additive manufacturing technologies in materials and coloring do have some limitations.7

Clinic report

A 4-year-old girl was referred for the fabrication of a nasal-facial prosthesis. As the result of an explosion, her left arm had been amputated below the elbow, she had severe facial trauma leading to bilateral enucleation of the eyes, and she had lost her entire nose. An examination of the patient revealed that she had a conformer in the right anophthalmic socket in preparation for an ocular prosthesis, a soft tissue flap to the midface, a missing nose, and a missing globe and palpebra in the left eye. She did not speak English, and all communications were through an interpreter. An adhesively retained, silicone nasal prosthesis was indicated, possibly with the help of eyeglasses to provide auxiliary retention. The eyeglasses could be heavily shaded or mirrored to camouflage the left eye, which cannot presently receive an ocular prosthesis. The patient was very cooperative during the initial consultation. She was excited to meet new people and

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was very friendly. However, because of the anticipated lack of cooperation for a moulage impression and the difficulties of communicating with such a young patient, a digital workflow was planned to fabricate the nasal-facial prosthesis.

A few days later, the patient was escorted to the Craniofacial Imaging department to obtain a full-head digital image captured with a stereophotogrammetry device (3dMDcranial system; 3dMD). This method of acquiring an impression was chosen because the image capture takes fractions of a second with minimal personal contact by the operator. The image was sent to the 3D Medical Applications Center at the Walter Reed National Military Medical Center for the design and fabrication of the prosthesis (Fig. 1). The library of templates did not include a model nose for a young girl; therefore, a digital image of a staff member’s 6-year-old daughter was acquired (Fig. 2). The 2 sets of 3-dimensional data were imported and manually registered in digital software (Fig. 3). The nasal and mid-face soft tissue geometry was then isolated from the staff member’s daughter (Magics; Materialise). The young patient and the model nose with surrounding soft tissue geometry was imported into software that allowed for the free-form manipulation of organically shaped objects with a haptic device (Freeform; Geomagic); the nose brim was reduced, and the prosthetic soft tissue borders were created (Fig. 4). After the replacement nose was finalized, a mold was designed, manufactured by using a binder jetting additive manufacturing technique (ProJet 460 plus; 3D Systems), infiltrated with cyanoacrylate resin (Apollo 5005 Cyanoacrylate; Cyberbond), and sealed with 2 coats of matte finish, clear acrylic resin sealer (Clear acrylic sealer; Plaid Enterprises, Inc).1,2

The patient was visited in the hospital a second time to select a silicone base shade. At this visit, a prototype silicone nose was brought to allow the patient to touch it and become familiarized with the feel of the material. She
was curious about it and was looking forward to having a prosthetic nose. The patient was happy to have visitors, and the visit was a positive experience for the child.

Once the base shade and notes of characterization had been established, the molds were prepared with a mold release spray (Silicone Spray; Dentsply Intl), and a small amount of Part A and B A-2000 silicone (Factor II, Inc) without pigment was mixed in a 1:1 volume ratio and de-aired in a vacuum chamber for 1 rise and fall evolution. A layer approximately 1-mm thick of the clear silicone was applied to the margin area of the future prosthesis on both the cope and drag (upper and lower parts of the mold) to help camouflage the margins (Fig. 5). The separate molds were placed in a polymerizing oven for 5 minutes at 49°C to increase the viscosity of the silicone, but without allowing it to completely polymerize. Additional silicone was mixed in an amount sufficient to pack the mold and allow for excess silicone to extrude from the junction of the cope and drag while pressing. Flocking and intrinsic pigments (Functional Intrinsic II; Factor II) were added to match the base skin tone and the silicone was de-aired for 1 rise and fall evolution. The colored silicone was transferred to a syringe and injected into the cope and drag, avoiding the clear silicone margins. Once the cope and drag had been filled to the desired amount, the colored silicone was carefully painted over the clear silicone to form a gradual transition from color to transparent. The cope was placed over the drag, and hand pressure was applied to create intimate contact on all sides. The invested molds were processed in a hydraulic heat press (Carver, Inc) under 345 psi, at 49°C for 40 minutes. The silicone nasal prosthesis was removed from the mold, and the margins were trimmed with scissors (Fig. 6).

The definitive characterization and delivery of the prosthesis were delayed for 2 weeks, because of the patient’s outpatient status. When she returned, she had been placed in foster care with a new caretaker and was

seen in the Maxillofacial Prosthetics Clinic to verify fit and esthetics. Extrinsic characterization was applied to the prosthesis with the patient present to better match skin tones. Once the color and characterization were acceptable, an outer layer of silicone (A-100 silicone; Factor II, Inc) was applied to seal extrinsic modifications, and the prosthesis was applied with adhesive (Daro; Factor II, Inc). The family was happy with the esthetics and fit of the prosthesis, and the patient eagerly participated in the positioning and adhesion of the prosthesis, insisting on holding it until it felt secure. The caretakers were given postoperative instructions on how to apply the prosthesis as well as homecare and maintenance (Fig. 7). In a follow-up email, the foster mother reported that the nose had given the child a lot of freedom, and for the first time they were able to go out without any
problems. She stated: “We were out all weekend for everything, shopping, restaurant, parks, and playing outdoors.”

**DISCUSSION**

Because of the age of the child, the recent trauma, and her limited communication skills, the use of digital imaging, digital design, and additive manufacturing of the prosthetic mold, with minimal direct patient contact, was chosen for the fabrication of the prosthesis. It was evident at the time of the initial evaluation that this patient would not have been able to tolerate a moulage impression technique without sedation. Digital imaging techniques provided the accurate capture of the soft tissue in a more normal patient position, reducing capture time and the subsequent modifications in fabrication and delivery that must be anticipated with conventional contact impression techniques. In order to approximate an age-appropriate prosthesis, the image of another child of similar age and size was used as a template to evaluate and design the prosthesis. Now that the design has been established, future prosthetic designs can be fabricated by resizing and reshaping to the new image of the child as she grows.

Although a 5-pod image capture system was used, any device that can capture the midface and provide a file format suitable for 3D design (.stl, .obj, .vrml, .amf, and so on) could be used, including the tissue surface of a computed tomography (CT) scan. Technology to fabricate the surface of the face of a patient is available in a variety of medical 3D software, and a facial cast can be manufactured in a number of materials, with a number of different additive manufacturing techniques. However, the registration of the images, development of the prosthesis, and design of the molds for fabrication do require more than 1 software package, in that a single software package does not provide everything needed to address the 3D files and the mold workflow.

The molds were fabricated from a bonded gypsum material. Although the surface roughness was ideal for reproducing the skin surfaces, when heat is used to polymerize the silicone under a press, after 2 uses, they begin to fracture and deteriorate. This may not be an issue if only a limited number of prostheses need to be fabricated; for long-term use, a different mold material may be more appropriate. However, the molds can be stored as digital files, reducing physical storage and allowing easy modification as required.

**SUMMARY**

A clinical report is presented on the application of digital technologies in the fabrication of a nasal-facial prosthesis for a child. The fabrication of a facial prosthesis is a difficult process for both the provider and the patient, regardless of age. It requires several visits involving potentially uncomfortable and stressful procedures that are even more demanding for a child with minimal communication skills. The procedure presented involved 3 sessions of brief physical interaction with the patient and resulted in a well-fitting, esthetic prosthesis. In addition, the process allows for the continued fabrication of prostheses as the child grows, requiring only a 3D digital image that can be used to resize the prosthesis, fabricate a new mold, and process a new prosthesis. Additive manufacturing technologies have advanced to include recent improvements in limited color printing of soft materials. This development may provide a way of directly printing a prosthesis in multiple materials that would closely match the color shades of the patient. These advances may eventually lead to the ideal workflow of digital image capture, digital design, and direct printing of prostheses.

**REFERENCES**


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