

CLINICAL REPORT

Integration of digital technology in the workflow for an osseointegrated implant-retained nasal prosthesis: A clinical report



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Digital technology has been introduced into the treatment of patients with facial prostheses (Fig. 1). Imaging has been used to determine the most appropriate location for implant placement, particularly in patients whose quality or quantity of bone may be uncertain. Digitally designed surgical guides can be 3D printed to assist in the placement of implants.^{1,2} Computer-generated implant guides (CGIGs) provide intraoperative guidance for implant placement, thereby simplifying complex procedures, reducing surgical time, and potentially improving surgical outcomes. Surface scans of patient anatomy can be used to digitally design nasal prosthesis prototypes³⁻⁶, molds^{4,7-10} and customize retentive components^{4,9,11} that reduce treatment time and increase the anatomic accuracy of the prosthesis. Computerized color formulation of prosthetic silicone based on the patient's skin color from spectrophotometric scans has been demonstrated to accurately reproduce skin color and provides a tool in the management of metameric color mismatch.¹²⁻¹⁵ The integration of a digital technology workflow into the treatment process improves the predictability of treatment outcomes, allows for optimal management of the patient's anatomic deficit, and reduces the

ABSTRACT

This clinical report describes the integration of digital technology into the treatment of a patient with an osseointegrated implant-retained nasal prosthesis. The surgery was planned digitally to determine the optimal implant positions. Implant placement surgical guides were digitally designed and additively manufactured. Prosthetic components, including the nasal form and substructure, were simulated digitally. Based on this simulated prosthetic model, patient-specific abutments were digitally designed and copy-milled. Prototypes for the substructure and prosthesis were 3D printed. Spectrophotometry and computerized color formulation were used to generate the silicone base color of the prosthesis, and characterization was performed by eye. The integration of digital technology allowed for optimized prosthetic retention, predictable esthetic outcomes, and reduced patient appointment time. (J Prosthet Dent 2019;121:858-62)

time required for the patient to be present during treatment.

Midfacial defects may pose a significant facial prosthetic challenge because of the limitations of space in and around the defect. The anatomic accuracy of the prosthetic form may be sacrificed to accommodate retentive components, thereby compromising the esthetic result. The use of digital technology can assist in overcoming these challenges. Digital implant placement, simulation planning, and CGIG allow for optimal implant placement in limited bone volume. Custom-designed retentive components can address the limited space and convergent implant angles often associated with midfacial defects.¹⁶ Digitally designed prosthesis prototypes allow for the incorporation of retentive components without compromising the esthetic outcome of the midfacial prosthesis. Digitally designed patient-specific abutments also optimize the emergence profile and improve periaabutment hygiene.

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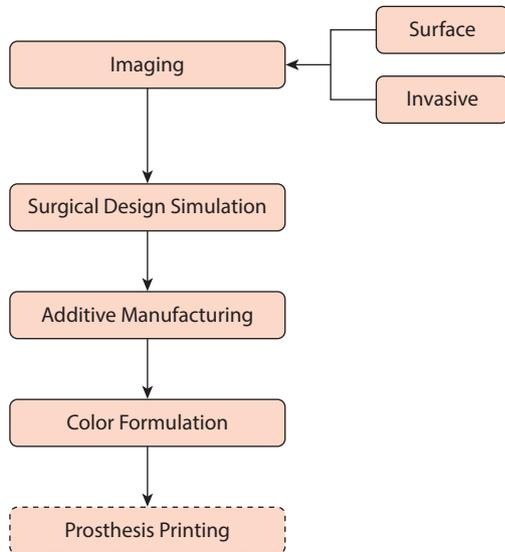


Figure 1. Integration of technology in facial prosthetic pathway.

CLINICAL REPORT

A 50-year-old white man presented to the Institute for Reconstructive Sciences in Medicine for facial prosthetic treatment after the surgical resection of his nose, anterior maxilla, and a portion of his upper lip because of recurrent squamous cell carcinoma. A radial forearm free flap was used to reconstruct the anterior palate. The patient underwent postoperative chemotherapy and radiation therapy. The potential for autogenous nasal reconstruction was limited, and the extent of the defect and patient preference contraindicated treatment with an adhesively retained prosthesis. Treatment with an osseointegrated implant-retained facial prosthesis was selected.

Digital Imaging and Communications in Medicine (DICOM) data from a cone beam computed tomography (CBCT) scan of the patient's head were imported into a 3D image-processing software program (Mimics; Materialise). Thresholding was used to create masks of the hard and soft tissues, and 3D models were generated from these masks.

Implant placement surgery was simulated with computer-aided design cylinders of the same dimensions as implants positioned in the virtual osseous structures to determine optimal implant positions (Fig. 2). The virtual osseous structures and simulated implant placement were exported as standard tessellation language (STL) files. A digital modeling software program (Geomagic Freeform Plus; 3D Systems, Inc) was used to digitally design a bone fitting, drilling CGIG based on the simulated surgical design (Fig. 3). The CGIG was printed (Fortus 400mc; Stratasys, Ltd) using a biocompatible thermoplastic material (PC-ISO; Stratasys, Ltd). A model of the skull was also printed (Dimension 1200es; Stratasys, Ltd) using a thermoplastic material (ABSplus-P430;

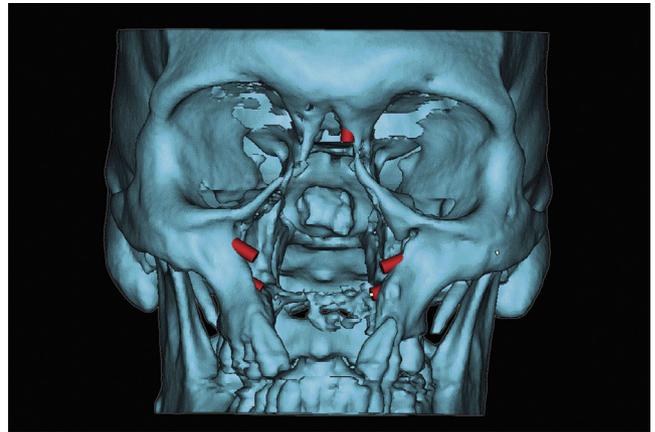


Figure 2. Implant installation simulation with computer-aided design cylinders simulating implants placed in virtual osseous structures.

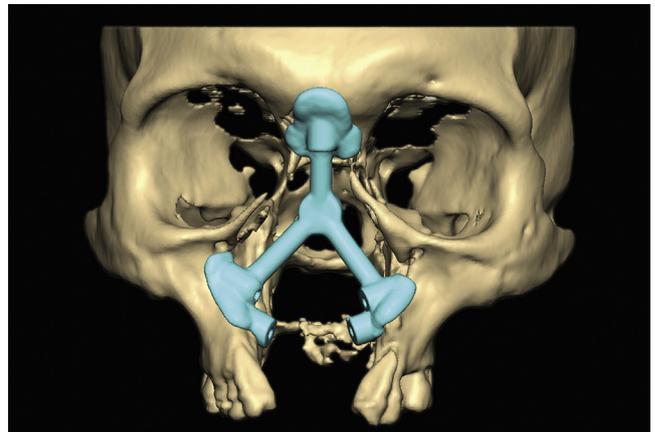


Figure 3. Digital design of bone fitting computer-generated implant guides and model skull.

Stratasys, Ltd). Based on the surgical simulation, possible implant dimensions were identified.

As the patient had undergone radiation therapy, implant installation surgery was performed in two stages 6 months apart. The resection of the anterior maxilla left limited available bone for implant installation and necessitated the installation of implants in the right and left zygomas (Zygoma TiUnite, 30 mm, Branemark Systems; Nobel Biocare). Implants were also installed laterally into the right and left maxilla (TRI-NEX 3.5 mm × Ø 13 mm length implants; Southern Implants, Ltd). One implant was installed in the glabellar region (IBN 3.5 mm Ø × 13 mm length implant; Southern Implants, Ltd).

After adequate healing, an impression using impression copings was recorded to capture the position of the implants and the patient's surrounding tissues. The definitive dental stone cast was poured. Healing abutments (Southern Implants, Ltd) were connected to each implant analog (Southern Implants, Ltd), and the definitive cast was laser scanned (ShapeGrabber Ai310;

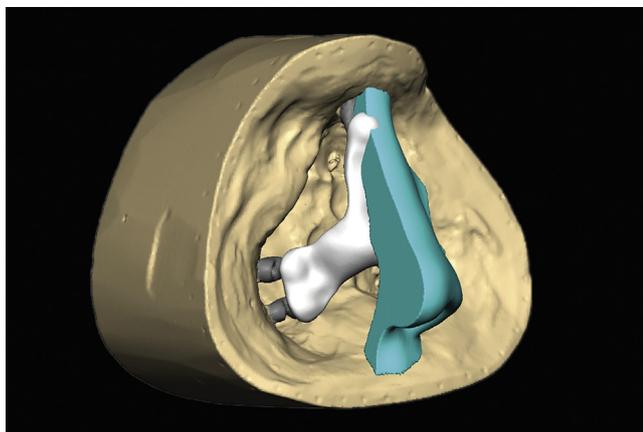


Figure 4. Digital prosthesis configuration with laser scan of definitive cast, scanned abutments, and digitally designed substructure and nasal prototypes.



Figure 5. Printed abutment prototypes attached to interim abutments, refined with wax.

ShapeGrabber, Inc) to obtain a digital record of the patient's cast. A surface scan (3dMD Flex; 3dMD) of the patient's head was captured, and a prototype for the nasal prosthesis was digitally designed (ZBrush; Pixologic, Inc) based on presurgical photographs provided by the patient. The scan of the definitive cast, surface scan of the patient's head, and digital nose prototype was registered (Geomagic Freeform Plus; 3D Systems, Inc). Patient-specific abutments were digitally designed based on the simulated prosthesis prototype as was a substructure to house the magnetic components of the prosthesis (Fig. 4).¹⁶

The digital abutment prototypes were 3D printed (Objet260 Connex3; Stratasys, Ltd) using a photopolymer material (Objet VeroWhitePlus; Stratasys, Ltd). The 3D-printed abutment prototypes were attached and polymerized to the corresponding interim abutments. Conventional fixed prosthodontic techniques were used to wax over and refine the printed abutment prototypes before copy milling the definitive implant abutments in titanium (Panthera Dental) (Fig. 5).

Minor adjustments were made to the design of the nasal prototype and substructure based on the definitive implant abutments, and both were 3D printed (Objet260 Connex3; Stratasys, Ltd) using photopolymer material (Objet VeroWhitePlus; Stratasys, Ltd). The substructure prototype was duplicated in acrylic resin (ProBase Cold; Ivoclar Vivadent AG). Patient-specific definitive abutments were connected to the patient, and keepers (B-MC1-S; Technovent, Ltd) were connected to the patient-specific definitive abutment (Fig. 6). Magnets (ML1-S; Technovent, Ltd) were connected to each keeper and polymerized to the substructure in situ.

The printed prosthesis prototype was duplicated in wax (Fig. 7). The substructure was integrated into the wax form, and the remaining stages of prosthesis sculpting and mold creation were completed using traditional



Figure 6. Patient-specific abutments connected.

techniques. Three-dimensional printing for mold construction is increasing in use and has been reported in other publications.^{9,10,17}



Figure 7. Printed prototypes of digitally designed substructure and prosthesis prototype and duplicated polymethyl methacrylate substructure and wax nasal form.

A spectrophotometer (CM-2300d; Konica Minolta Sensing America, Inc) was used to measure the patient skin color, and a computerized color formulation software program (Spectromatch Pro; Spectromatch, Ltd) was used to formulate a silicone base color for the nasal prosthesis. Additional intrinsic colors were mixed by eye, and the mold was packed chairside in the presence of the patient. Subsequent finishing of the prosthesis was completed (Fig. 8).

Prosthesis seating and retention were excellent, and the patient could easily insert and remove the prosthesis. The patient reported satisfaction with the fit and appearance of the prosthesis at delivery and at the 4-month follow-up. The emergence profile of the patient-specific definitive abutments allowed for a high level of hygiene control. The patient presented at follow-up visits with no adverse skin responses.

DISCUSSION

The use of a digital technology workflow in the patient's care provided a treatment outcome that would not have been readily possible with traditional prosthetic techniques. Surgical design simulation with the resultant printed cast and CGIC assisted in the successful installation of implants despite the challenging anatomy. The digital workflow ensured that implants were located optimally for prosthetic design. Digitally planning and designing the configuration of the definitive abutments and the prosthesis allowed for many of the challenges associated with implant-retained nasal prostheses to be recognized early in the treatment process and avoided. Digitally designing the abutments and prosthetic components ensured that adequate space for the retentive

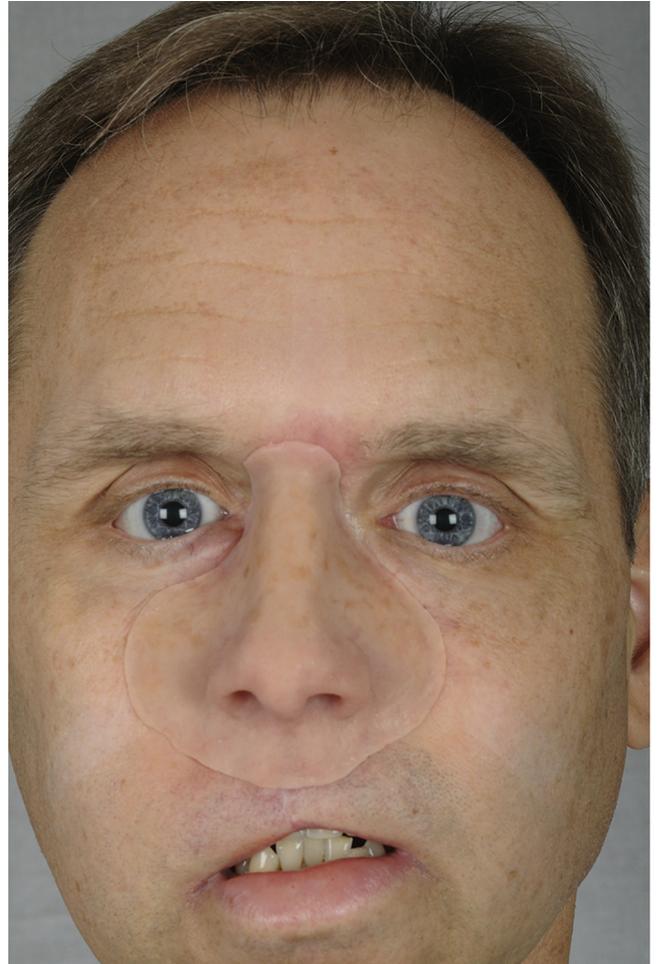


Figure 8. Patient with midfacial prosthesis connected.

components was created without compromising the treatment outcomes. Patient-specific digital abutment design and fabrication is an important step forward and allowed the abutment to be contoured for optimal hygiene and limiting adverse skin responses. The digitally designed prosthesis configuration was able to accommodate the retentive components without the sacrifice of anatomic form.

The present patient treatment illustrates how digital technology may improve the predictability and efficiency of treatment workflow when integrated into the various stages of prosthetic care. Future innovations in technologies such as the printing of silicone will doubtless have a major influence on the process of prosthesis fabrication. Printing directly in a material appropriate for long-term prosthetic use will eliminate the need for prototypes and molds. This is a critical next step in the digital workflow for facial prosthetic care.

SUMMARY

The integration of digital technology into the prosthetic treatment of the patient allowed for clinical outcomes

that exceeded what would have been achieved with traditional methods. The integration of digital design into a prosthetic workflow can reduce the amount of patient chair time by several hours as most of the prosthetic design process is completed without the patient being present. The digital workflow described is seen as having considerable benefit for enhanced patient care and is now in routine use at the Institute for Reconstructive Sciences in Medicine. The integration of digital technology into the workflow does not necessarily reduce costs as initial investments in computer programs and manufacturing equipment can be costly. The successful installation of digitally planned osseointegrated implants using a CGIG together with the design of biomechanically appropriate retention, ease of insertion and removal, peri-abutment hygiene, and the appearance of the prosthesis are all enhanced. With the evolution of the digital technology workflow for facial prosthetic treatment, the development of 3D printing in silicone elastomer in color is the critical next step.

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