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Expedited Digital-Analog Hybrid Method to Fabricate a 3D-Printed Implant Overdenture

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Dr. Michael Scherer is the Chief Clinical Advisor; Implants and Prosthetics for Zest Dental Solutions.

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Abstract

The present case report describes a technique to convert an interim mandibular complete dental prosthesis into a digitally designed and additively manufactured implant overdenture prosthesis. A patient had two dental implants placed, an interim complete denture, and a soft reline procedure completed. After implant osseointegration, existing healing abutments were removed, a functionally generated reline impression with polyvinyl siloxane impression material was made. Using an intraoral scanner, a 360-degree optical scan was obtained of the relined interim prosthesis. A new prosthesis was digitally designed using the optical scan, additively manufactured, and housings picked-up intraorally to create an implant-retained overdenture.

A complete prosthesis with dental implants and attachments aiding in retention of the prosthesis is considered a predictable and efficient treatment with a high degree of patient satisfaction.[1–3] Patients interested in implant stabilization of mandibular complete prostheses are historically treated with placement of two dental implants in the interforaminal region, followed by a clinical reline using a soft-reline material. After a period of implant osseointegration, the retentive abutments are placed, and an elastomeric impression made within the intaglio surface of the prosthesis using a functionally generated (aka "closed-mouth") reline technique.[4–5] In analog workflows, after the conventional impression procedure is made within the prosthesis, a laboratory reline or rebase using acrylic resin is completed, producing a complete dental prosthesis that is adapted to the soft tissue surface and also matches the existing occlusion scheme and occlusal vertical dimension without needing a replica of the opposing arch.[6] During the clinical delivery of the prosthesis, a clinician may request the retentive element to be attached at the laboratory or the clinician may use a chairside processing technique to attach the retentive element of the attachment system.[7]

Digital fabrication methods of fabricating complete prostheses with dental implants result in reduced laboratory and clinical costs, less frequent appointments of the patient to the clinician, expedited treatment, creating a virtual digital database of prosthetics for future treatment needs, and a lower overall burden on edentulous patients.[8] Additive manufacturing (AM) technology, such as utilized with 3D printing, has numerous applications for use within clinical practice, ranging from diagnostic casts, prototyping of restorations, surgical implant guides, prosthetics for occlusal dysfunction, and prosthetics.[9] Although directly fabricating prosthetics with polymer 3D printers is a relatively new modality, it can be used to produce a complete dental prosthesis comparable to that of analog methods.[10]

The combination of digital technologies, such as intraoral scanners (IOSs), cone-beam computed tomography units, and polymer 3D printers, can reliably produce implant-retained complete prosthetics. Dental literature has described various techniques to produce an implant-retained complete prosthesis using optical scans of the tissue surface,[11] impressions made in duplicate 3D printed prosthetics,[12,13] and using a combination of optical scanners and analog processing methods.[14] Although these hybrid methods have been successfully employed, they may require multiple clinical visits and a delayed treatment time for patients. This case report describes the process for fabricating an implant-retained AM implant-retained overdenture prosthesis in a single clinical appointment using a hybrid

Figure 1 Patient presented with an existing interim complete dental prosthesis and healing abutments on implants. Locator abutments sized and placed.

Figure 2 Denture housings placed onto each abutment and the prosthesis adjusted until passively seating onto edentulous ridge.

Figure 3 Physiologic border molding performed on existing interim complete dental prosthesis using a mouth-temperature wax.

digital-analog approach that combines a functionally generated impression technique, optical scanning, digital design, and 3D printing.

Clinical report

A 70-year-old patient with an existing interim mandibular complete dental prosthesis requested conversion of his existing prosthesis into an implant-retained prosthesis. The patient had two dental implants with overdenture-retained abutments (LOCATOR Overdenture Implant System; Zest Dental Solutions, Carlsbad, CA, USA) placed in the anterior mandible 3 months prior. The intaglio of the interim mandibular complete denture had a soft tissue conditioner placed the day of surgical procedures. The patient was successfully wearing the interim prosthesis during the implant osseointegration time period. The patient returned to the practice where he indicated that he was interested in converting his interim prosthesis into an implant-retained definitive prosthesis. Upon further discussion with the patient, he indicated that he was moving out of the area and wished to complete the procedure as soon as possible.

The patient's existing interim prosthesis was evaluated to ensure that it was acceptable to the patient and to reported criteria previously established by Sato et al.[15] Upon evaluation, the existing prosthesis occlusal vertical dimension, centric, tooth position, and esthetic were deemed acceptable. After discussing the benefits and risks of a digitally produced implant-retained complete dental prosthesis, the patient requested an AM implant-overdenture prosthesis using the following protocol:

1. Using a marker, a dot was placed onto the nose and the chin of the patient's face and a measurement from the nose to the chin was obtained and recorded using a ruler. The mandibular interim prosthesis was removed from the mouth followed by the removal of the existing soft tissue conditioner by using an acrylic bur. Relief was placed within the intaglio surface of the interim complete denture to create space for impression material.
2. Healing abutments were removed. Measurements made from the platform of the implant to the gingival margin of the soft tissues were completed. Stud-style overdenture abutments (LOCATOR; Zest Dental Solutions) were placed with tissue heights corresponding to the tissue measurement (Fig 1). A panoramic radiograph was obtained and the implant abutments were torqued according to manufacturer's recommendations. Housings with processing elements were placed on top of each implant abutment (Fig 2).
3. The relieved interim prosthesis was air-dried and bordering molding material (Adaptol; Jelenko, Armonk, NY, USA) was applied. The prosthesis was placed onto the ridge and physiologic border molding procedures[16] were completed using the patient's cheeks, tongue, and oral tissues to assist molding the material (Fig 3).
4. Polyvinyl siloxane adhesive (PVS Tray Adhesive; Coletene, Altstätten, Switzerland) was placed onto the intaglio of the prosthesis. Medium viscosity polyvinyl

Figure 4 A functionally generated ("closed-mouth") impression made with elastomeric impression material and physiologic border molding performed ensuring the patient closed into centric and at the pretreatment occlusal vertical dimension.

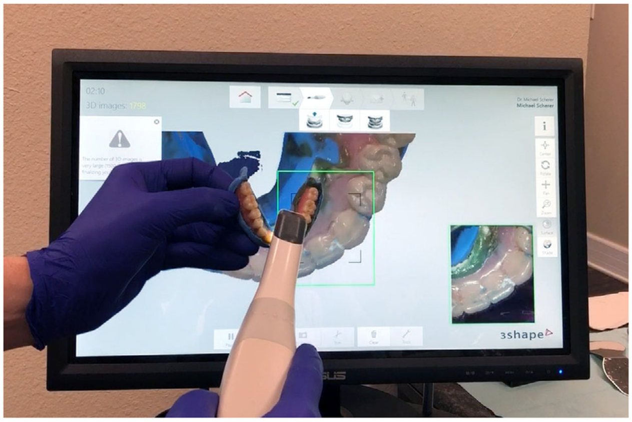

Figure 5 The prosthesis was removed and inspected. An optical scan was made using an intraoral scanner, capturing the intaglio and cameo surfaces and dentition in a single scan.

siloxane impression material (Examix Monophase; GC America, Alsip, IL, USA) was placed into the intaglio surface of the interim prosthesis and then placed onto the edentulous ridge. Physiologic border molding procedures[16] were completed and the patient was asked to close into the centric position. Measurements made up of the nose and chin marks were compared to the ones made previously, ensuring alteration of the occlusal vertical dimension did not occur during impression procedures (Fig 4).

5. After complete polymerization of the impression material, the interim prosthesis was removed and inspected for completeness. The prosthesis was digitized by using an IOS (TRIOS 3; 3Shape A/G, Copenhagen, Denmark) beginning on the intaglio of the interim complete denture and rotating buccal and lingually until an impression was made up of the tissue surface. Once the tissue surface scan was completed, the procedure was continued until the prosthesis was optically scanned completely around the prosthesis including the tissue and teeth in a single scan to assist in controlling peripheral ambient light sources while performing optical scanning procedures (Fig 5).[17]
6. The optical scan case was sent from the IOS software program to a design computer where it was imported into an open-architecture nondental software program (Meshmixer; Autodesk, Mill Valley, CA) for segmentation and extraction of the tissue surface into two layers. The teeth were selected using selection tools and separated into a second layer within the software program. The remaining portion of the scan was inverted to create a physical model of the edentulous ridge with the housing in place. The two layers were exported as two separate scans: (1) a digital representation of the tissue surface with housings and (2) a digital representation of the tooth positions in the complete prosthesis.
7. The two separate optical files were imported into a dental-specific software for digital design (Dental System 2020; 3Shape A/G). The software used the inverted scan of the impression as a digital "definitive cast" and the scan of the denture tooth positions as a "wax rim." Virtual prosthetic teeth were arranged within the software, using the scan of the existing denture teeth "wax rim" scan to guide placement of the teeth. Similar to using an analog laboratory jig-reline, virtual denture teeth were guided by index marks of the existing denture teeth in the optical scan of the patient's prosthesis (Fig 6). The prosthesis design was completed and two standard tessellation language (STL) files were exported in the forms of a tooth arch and a separate denture base.
8. The denture base was AM on a desktop-industrial 3D polymer printer (NextDent 5100; 3D Systems, Santa Clarita, CA) using a pink base resin (Denture 3D+; NextDent B.V., Soesterberg, the Netherlands). The prosthetic tooth arch was produced via AM on the same printer using a tooth shaded resin (Nexdent C&B MFH; 3D Systems) that corresponded to the shade of the patient's existing interim prosthesis (Fig 7).
9. The AM objects were rinsed in a series of alcohol baths (Isopropyl alcohol 91%; Cumberland Swan, Smyrna, TN, USA) for 3 minutes and subsequently in a second bath with clean alcohol for 2 minutes.[18] The objects were placed in a UV-polymerization machine (LC-3DPrint Box; 3D Sytstems) with full-spectrum UV-light exposure for 30 minutes following the manufacturer's recommendations.
10. Supports were removed and the prosthetic arch and base were lightly polished. Light-polymerized resin (Optiglaze; GC America, Alsip, IL, USA) was placed onto the prosthetic tooth arch and UV cured to characterize the teeth (Fig 8).
11. The tooth arch was bonded into the prosthetic base using light-polymerizing resin (Nexdent Denture 3D+; 3D Systems) and UV cured. Pumice and water were used to polish the final prosthesis.
12. The housings on each implant were removed and cleaned with air and water and replaced on each

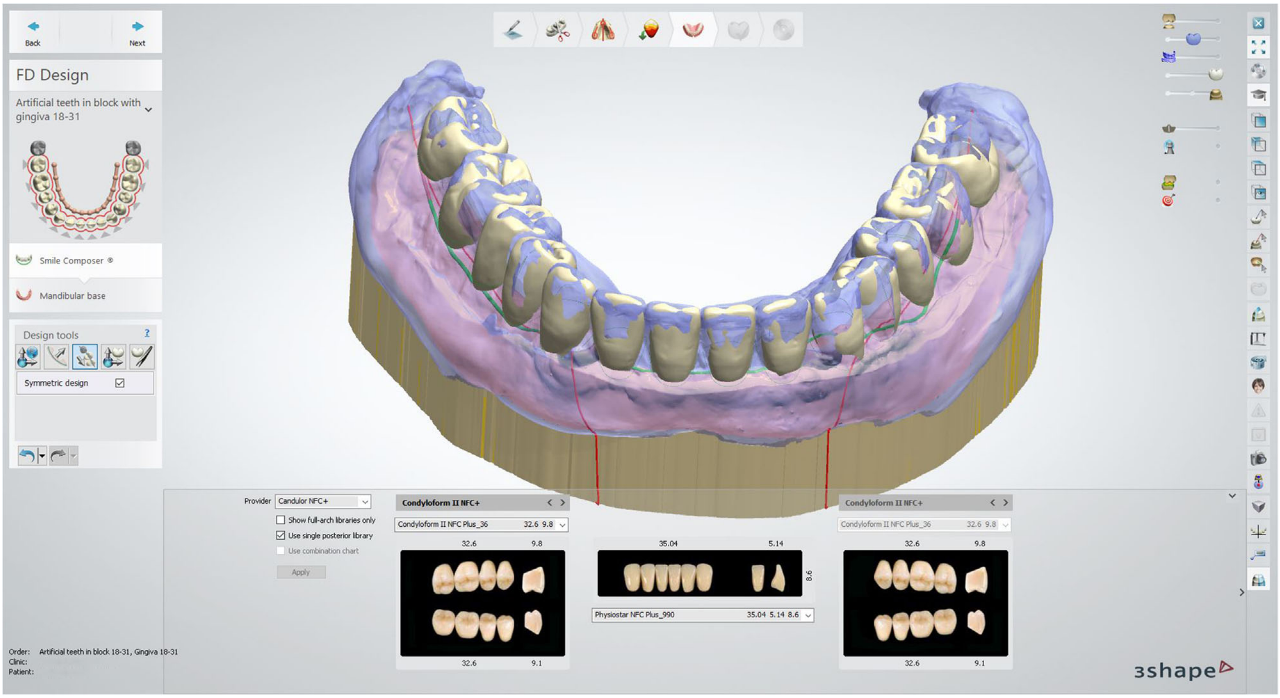

Figure 6 The optical scan files were imported into software and virtual prosthetic teeth (white outlines) were placed in positions matching the existing prosthetic teeth in the interim complete denture (purple outline). The prosthesis design was completed and was designed to separate the planned tooth arch and prosthetic base.

Figure 7 Prosthetic teeth and base were printed using a desktop-industrial 3D printer in tooth shaded and pink shaded resins.

Figure 8 The printed prosthetic teeth arch was stained and glazed using light-cured resin and bonded to the prosthetic base using 3D printer base resin and a UV cure oven.

abutment. The AM prosthesis was placed onto the edentulous ridge, ensuring passive fit and complete tissue adaptation over the housings. The patient was instructed to close into centric position, ensuring even occlusal contacts with no change in occlusal vertical dimension by measuring the reference from the nose–chin measurement.

13. The prosthesis was removed and air-dried. Light-polymerizing composite resin material (Chairside Attachment Processing Material; Zest Dental Solutions) was placed into each prepared recess, filling to approximately 2/3 of the way full (Fig 9).
14. The prosthesis was seated onto the edentulous ridge and lightly held into place, ensuring complete tissue adaptation during polymerization. After complete polymerization, the prosthesis was removed, and processing inserts were changed to definitive retentive inserts (Extra Light Retention Male; Zest Dental Solutions) (Fig 10).

Figure 9 The 3D printed denture was placed onto the edentulous ridge confirming passive fit around the metal housings. Composite resin was placed into the prepared recesses on the intaglio surface of the prosthesis and seated onto the ridge.

Figure 10 After complete polymerization, the prosthesis was removed and inspected. Processing inserts were changed to definitive inserts and the prosthesis was placed.

15. The prosthesis was placed onto the edentulous ridge and attachments engaged. The retention and stability of the prosthesis was evaluated, ensuring little to no movement occurred during physiologic movements. The patient's phonetics, centric, and esthetics were confirmed. The patient was satisfied with the result; home care and maintenance protocols were reviewed with the patient prior to dismissal.

Discussion

Although traditional methods of implant overdenture manufacturing are effective and have been utilized for years, these analog methods can be cumbersome and may be difficult to perform within a clinical environment.[19] Conventional techniques to perform a laboratory hard reline or rebase procedure require a considerable amount of time to mix and pour gypsum stone, fabricate a reline jig, strip out existing impression material, mix/cure acrylic resin, and polish excess resin upon completion. In addition, conventional acrylic resin processing techniques may result in substantial shrinkage of heat-processed acrylic resin.[20] The complexity of working with existing materials and analog workflows while ensuring proper clinical outcome remains a challenge.

Digital production of complete dental prostheses is widely seen as progress and the future of prosthetic production; however, the technology still has some limitations. Challenges exist on the wide-spread adoption due to seemingly more difficult scanning techniques, material compatibilities, software workflows, resin availability, strength of printed resins, surface water absorption, and printer choice.[21] Additionally, AM implant-retained complete dental prostheses are not extensively studied in the literature and there is limited evaluation of how well they perform long term in vivo. While these are limitations of the digital materials, many feel that the benefits outweigh the negatives including the ability to streamline procedures, speed and efficiency of clinical techniques, limited material shrinkage, customization of teeth and prosthetic bases beyond what can be achieved with premanufactured teeth, and a digital record of the patient's prosthesis that permits simple reproduction in the case where the patient loses or breaks their prosthesis.[22]

In this case report, the patient was an older patient with limited mobility and difficulty visiting the dental office. The patient was given the option of making multiple visits to fabricate a traditional implant-retained overdenture prosthesis or to have a single, extended duration visit at the dental practice to fabricate a digitally produced implant-retained overdenture prosthesis. The patient preferred the digital option and was able to receive an implant-retained prosthesis within a few hours. Digital methods permitted the author to perform clinical procedures with little disruption to the initial clinical technique as the reline impression technique is the same for analog or digital production methods. After the impression was made, the prosthesis was scanned, designed, printed, and finished in approximately 1-2 hours with the assistance of a dental technician in the practice. In addition, the patient was pleased to know that if he were to ever lose his prosthesis or break it, a copy could be readily produced and delivered in one shorter appointment rather than multiple visits.

While the digital methods required for AM dentures can often be viewed as being more complex than analog methods by some, others rapidly embrace the digital workflows. Limitations exist and there are concerns regarding strength, esthetics, and potentially greater complexity; however, as the younger generation of clinicians enroll in dental education programs, more and more are learning from and embracing digital methods of dental production and evaluation.[23] Many of these younger students have been raised on digital technology from youth; as they graduate and go into clinical practice, digital production methods will likely be viewed as a natural progression of clinical practice and techniques.

Summary

This case report describes an approach to perform a hybrid digital-analog clinical method to produce a 3D printed implant-retained complete dental prosthesis. Furthermore, this report illustrates benefits and limitations of using digital versus analog methods to produce an implant-retained overdenture.

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