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Digital Immediate Complete Denture for a Patient with Rhabdomyosarcoma: A Clinical Report

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Abstract

Fabricating an immediate complete denture can be very challenging in some clinical situations. This clinical report describes a digital workflow to fabricate a printed maxillary immediate complete denture for a patient with a severely compromised maxilla. Digital data obtained by using an intraoral scanner was utilized to reconstruct the three-dimensional (3D) image of the jaws at the desirable vertical dimension of occlusion. After performing the virtual teeth extraction and alveoloplasty, the denture base and teeth were designed. The resulting data were exported to a 3D printer for denture fabrication and the 3D printed (additively manufactured) denture was successfully inserted immediately after the surgery. After initial healing and confirmation of good retention and function, a new printed denture was fabricated by digitally duplicating the relined denture maintaining the same teeth positions but adjusting the base to a new intraoral scan of the healed ridge.

An immediate complete denture is defined as any fixed or removable prosthesis made to be installed immediately after the extraction of all remaining teeth.[1] This treatment can minimize the adverse social, psychological, and esthetic consequences of complete edentulism resulting from the extraction. The fabrication of a conventional removable immediate complete denture typically involves multiple clinical appointments and several laboratory procedures. There are a few challenges in the conventional method of fabricating immediate complete dentures. First, the whole process is lengthy and requires a considerable amount of time. Second, it is prone to human processing errors during multiple steps, which may result in increased clinical time to make necessary adjustments. Third, esthetic try-in is impossible if there are multiple remaining anterior teeth, which may compromise the esthetic result.

Since the 1990s, computer-aided design/computer-aided manufacturing (CAD/CAM) technology has been used to fabricate complete dentures.[2–4] The CAD/CAM technology allows the designing and manufacturing of removable dentures to be fully digitized, which leads to more effective communication between clinicians and technicians, simpler laboratory procedures, and fewer patient visits.[5–10] In addition, the digitally manufactured complete dentures can be conveniently archived and reproduced. The typical workflow to fabricate a digital complete denture consists of scanning the definitive impressions or casts and a maxillo-mandibular record, designing the denture base and arranging the artificial teeth by using a software program, and then manufacturing the denture by using either an additive (3D printing) or subtractive (milling) technique.[11–14] Currently 3D printing is mostly used to fabricate interim prosthesis (fixed or removable) and milling is more often used to fabricate final complete dentures because the materials for milling have superior material properties.[2] However, 3D printed complete dentures have the advantage of quick and cost-effective fabrication because of the wider availability and easier accessibility of 3D printers. In contrast, milling machines are very expensive and not practical for chairside dentistry.

The use of intraoral scans for complete denture fabrication may provide additional advantages by avoiding physical impressions, improving patient comfort, reducing chairside time, and simplifying laboratory procedures.[3] In addition to these

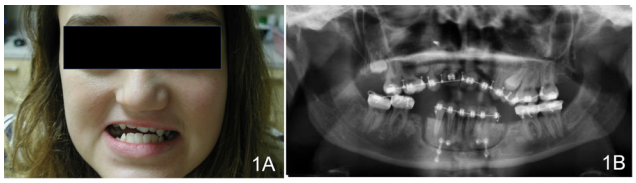

Figure 1 Initial examination of the patient: (A) clinical view; (B) panoramic radiograph after the surgery on the anterior mandible.

benefits, preliminary studies showed that intraoral scans have comparable accuracy for completely edentulous arches compared to conventional impressions.[15,16] A recent in vitro study also demonstrated a satisfactory accuracy of intraoral scans in partial and full dentate arches.[17]

Recent reports demonstrated different techniques to manufacture complete dentures with a hybrid approach combining digital and conventional procedures.[5,18–21] 3D printing technique is also being used to aid in the complete denture fabrication.[22,23] This report describes a fully digital workflow for fabricating a 3D printed immediate complete denture in a patient with a severely compromised maxilla.

Clinical report

A 16-year-old Caucasian woman presented for the treatment of malocclusion and partial edentulism. Clinical examination revealed complex oral conditions: the patient had an open bite of the anterior teeth, very short roots in the majority of the maxillary teeth, over-erupted left maxilla and anterior mandibular teeth, and missing mandibular premolars (Fig 1A). The patient was diagnosed with rhabdomyosarcoma of the right maxilla, a rare but highly aggressive malignant tumor, when she was 14-months-old. Subsequently, the patient was treated with surgery and adjuvant chemoradiation therapy. These treatments adversely affected the patient's craniofacial bone and teeth development, leading to compromised oral conditions. The patient desired to have a beautiful smile that would allow her to enjoy a normal social life.

To address the patient's concern, a multidisciplinary treatment team was formed, including an oral and maxillofacial surgeon, an orthodontist, and a prosthodontist. The long-term plan was to restore the patient with an implant-supported prostheses. Before the implant therapy in the final phase, two earlier phases of treatment were determined to be necessary. In the first phase of treatment, the orthodontist and surgeon made an initial correction of the mandibular occlusal plane. Because of the severe overeruption of mandibular anterior teeth, the surgeon had to lower them with a segmental mandibular osteotomy (Fig 1B). This significantly improved the patient's occlusal plane and created a reference by which the maxillary dentition could be planned. In the second phase of treatment, a maxillary immediate complete denture was required due to the full extraction of remaining maxillary teeth and alveoloplasty of the left maxilla. The immediate complete denture not only provided immediate esthetic and functional needs but also functioned as a reference for the orthodontist to fine-tune the tooth alignment and provided a reference for future implant placement. The demands for an immediate prosthesis were especially acute given her young age and social concerns.

An intraoral scanner (TRIOS 3; 3Shape, Denmark) was used to acquire 3D intraoral data for both arches (Fig 2A, 2B). The existing occlusal vertical dimension was maintained by scanning the buccal surfaces of maxillary and mandibular teeth in occlusion. The intraoral scanner software allows the virtual alignment of the scanned maxilla and mandible using the virtual occlusal record as a reference (Fig 2C). STL files of the scanned arches were exported for subsequent use.

After the above steps, the virtual extraction of all remaining teeth and alveoloplasty of over erupted left maxilla were performed using CAD/CAM software (Meshmixer; Autodesk, San Rafael, CA) (Fig. 3A, 3B). The files of the mandibular arch, maxilla arch with existing teeth, and the new maxilla with virtual extractions and alveoloplasty were then imported to a dental CAD/CAM software (3Shape Dental Systems; 3Shape, Denmark) to design a digital complete denture. Alternatively, virtual extractions and alveoloplasty could be performed on 3Shape dental CAD/CAM software but the file would still need to be exported from one order and entered in another separate order to design the complete denture. Using her existing anterior teeth as landmarks, the software allows for aligning a patient's photograph at smiling with a 3D file to define the lip position in relationship to the 3D reconstructed maxilla (Fig 4A, 4B, and left image in 4C), which enable us to properly design the anterior teeth and evaluate the esthetic outcome in a simulated environment (Fig 4C, right image). In addition to the lip position, the opposing teeth also served as a reference to determine the occlusal plane and design the digital complete denture (Fig 5A, 5B). The designed complete denture was exported as a single STL file and processed for 3D printing using a desktop 3D printer (Form2; FormLabs, Somerville, MA) following the manufacturer settings and parameters for the chosen materials. The complete denture was printed with denture teeth resin (Denture teeth A2; FormLabs) (Fig 6A) at a 50 μm layer thickness according to manufacturer's instructions. Before post-curing, the buccal flange of the 3D printed complete denture was characterized with pink composite resin (Gradia gum shades; GC Corp, Japan). In brief, composite primer (Gradia System; GC Corp, Japan) was applied to the buccal flange, followed by layering pink composite resin. In this case, Gum Opaque GO12 followed by Gum G23 shade was used according to manufacturer instructions. After characterization, the finalized complete denture was post-cured in the ultra-violet curing chamber (FormCure; FormLabs) (Fig 6B) as recommended by the manufacturer. Then the complete denture was finished and polished using adjusting, finishing and polishing burs (Ultra Denture System; Brasseler, Savannah, GA).

Immediately following surgery, the 3D printed complete denture was tried in and the slightly overextended buccal flanges were reduced. Then, the complete denture was inserted after the relining with tissue conditioning material (Coesoft; GC America Inc, Alsip, IL). Satisfactory retention was achieved, and no occlusal adjustment was needed. The relining procedure for the 3D printed complete denture is similar to conventionally fabricated denture. After 24 hours, the patient could comfortably wear the denture and speak, and

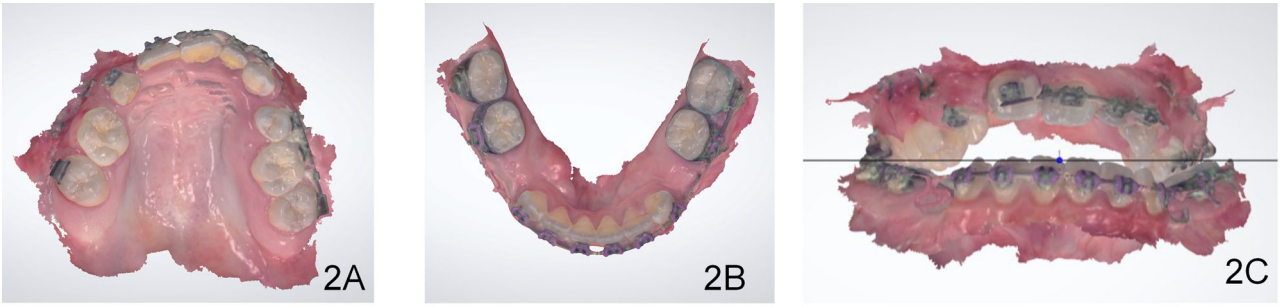

Figure 2 Intraorally scanned images: (A) maxilla; (B) mandible; (C) aligned maxilla and mandible using virtual bite registration.

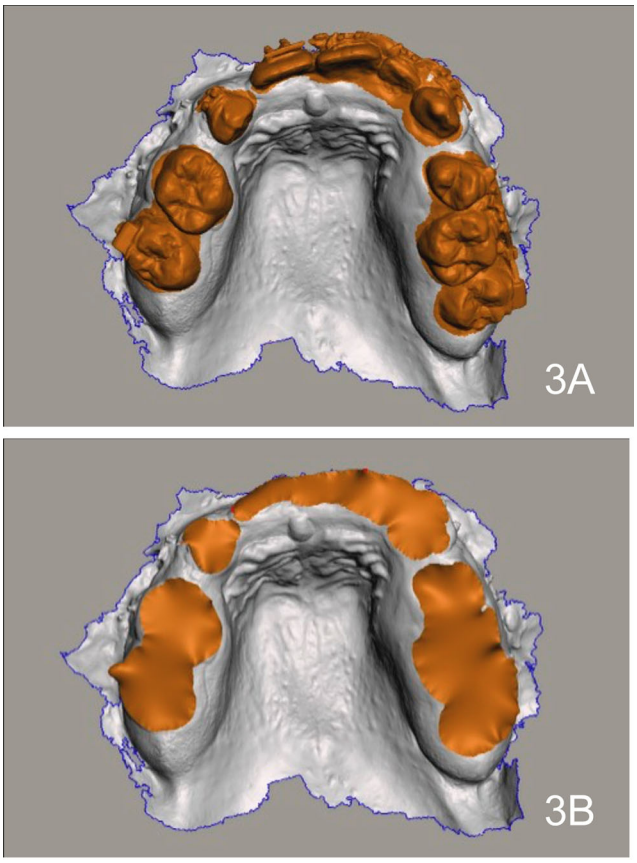

Figure 3 Scanned maxillary arch: (A) before and (B) after performing the virtual extraction and alveoloplasty.

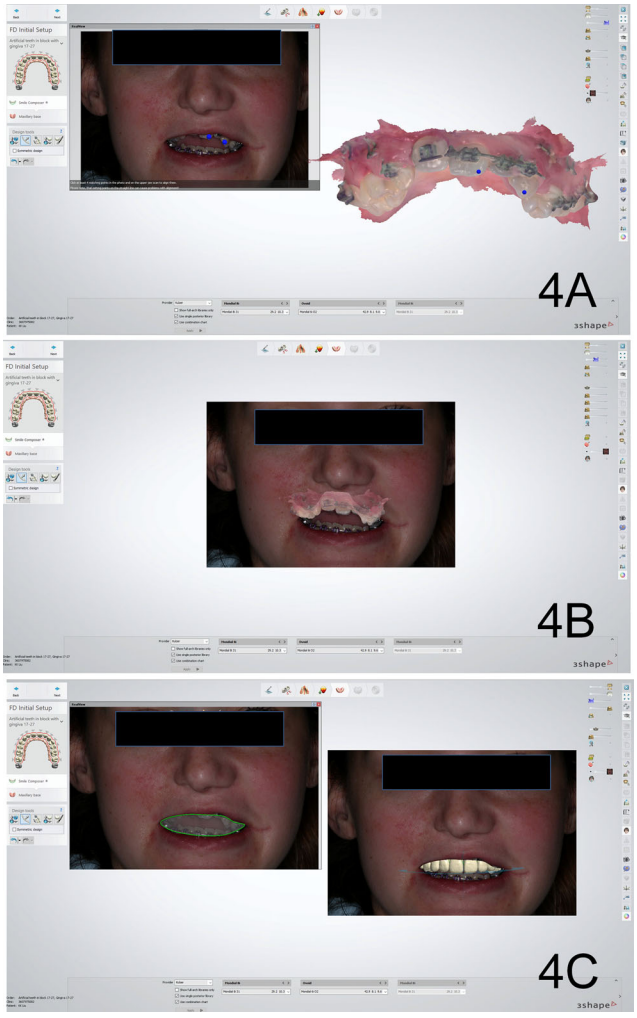

Figure 4 Virtual design of anterior teeth: (A) selecting the aligning points (blue dots) on the anterior teeth of photo and the digital model; (B) superimposing image of smile photo and digital model; (C) digitally setting up anterior teeth using the drawing of the lip line as reference.

she was very satisfied with the outcome (Fig 6C). The patient wore the immediate complete denture while the orthodontist continued to fine-tune the mandibular occlusal plane. After the initial healing at two months post-surgery, the immediate complete denture was relined again with new tissue conditioning material to ensure an adequate fit post healing of the extraction sites. The freshly relined complete denture, the mandible, and healed maxilla were scanned with an intraoral scanner (TRIOS 3; 3Shape, Denmark). The new STL files were exported to 3Shape Dental Systems software (3Shape, Denmark) and the mandible, existing denture and edentulous maxilla were aligned to maintain the occlusal vertical dimension for the new denture (Fig 7A). The design of second complete denture was exported as two separate STL files for 3D printing. One file was used to print the teeth with denture teeth resin

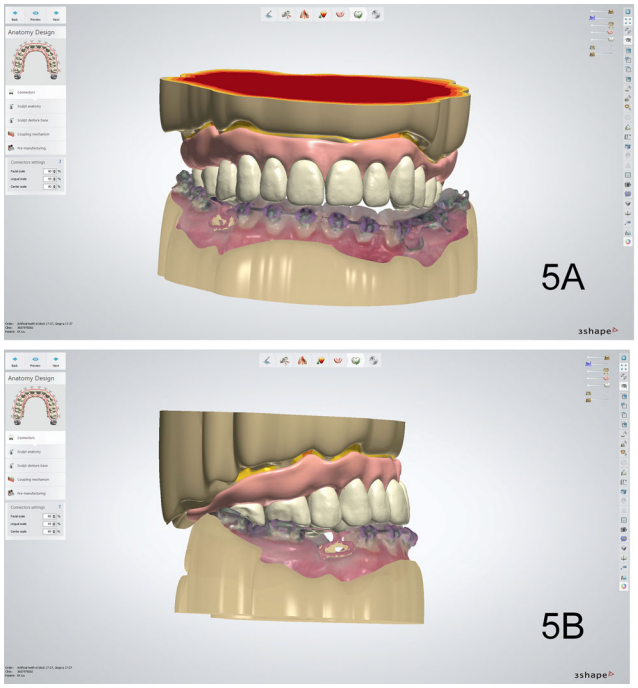

Figure 5 Virtual design of complete denture base and teeth: (A) frontal view; (B) lateral view.

(Denture teeth A2; FormLabs, Somerville, Massachusetts), and the other file was used to print the denture base with denture base resin (Denture base light pink; FormLabs), both at a 50 μm layer thickness. After printing, the complete denture base and denture teeth were luted together with a thin layer of the same denture base resin. The combined complete denture base and teeth was then post-polymerized in the UV curing chamber (FormCure), according to the manufacturer's instructions and subsequently polished and finished. The finished new 3D printed complete denture (Fig 7B) was then inserted in the patient's mouth (Fig 7C).

Discussion

In recent years, the development of intraoral scanners, 3D printers, and milling machines with superior performances, and the introduction of improved materials, is shifting the paradigm of complete denture fabrication towards a digital workflow. This article describes a fully digital workflow to fabricate a 3D printed immediate complete denture with superior fabrication efficiency and accuracy.

The conventional approach to fabricating an immediate complete denture is a lengthy process that takes multiple clinical and laboratory steps. It may not be able to meet a patient's needs in demanding clinical scenarios. However, a digital approach can offer an efficient alternative solution. For this patient, at the time of starting the fabrication of the immediate complete denture, she was about to attend college and surgery was scheduled on a date that could accommodate her needs. As a result, a limited window of time to fabricate the immediate complete denture was available. The conventional complete denture fabrication approach could not meet the treatment needs due to the time demand; therefore, a fully digital approach was utilized. With this approach, it took less than 2 hours from the start of intraoral scanning to the finish of the complete denture design. The subsequent complete denture printing and modification took 2 to 3 hours, and printing time could be as little as 30 minutes with more advanced printers. Surgery was performed and the immediate complete denture was inserted one week before her matriculation, and this patient's need was successfully met. Using this described ap-

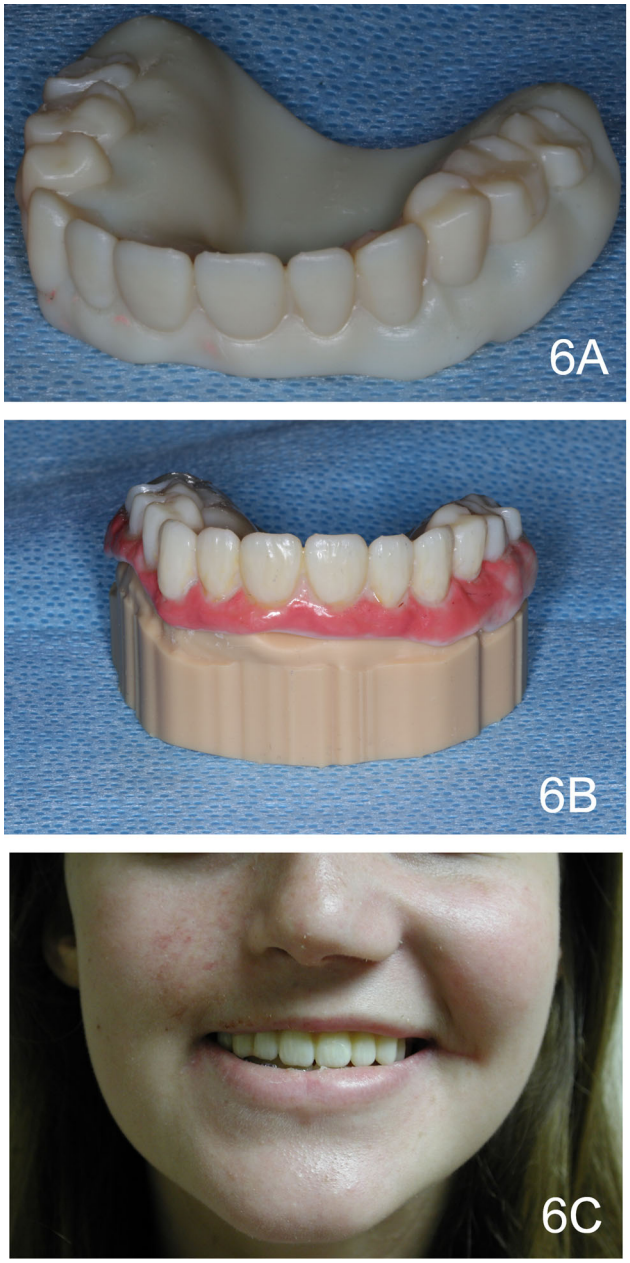

Figure 6 Printed complete denture: (A) printed complete denture with monocolor; (B) printed complete denture after the characterization with pink composite on the buccal flange; (C) printed complete denture in place.

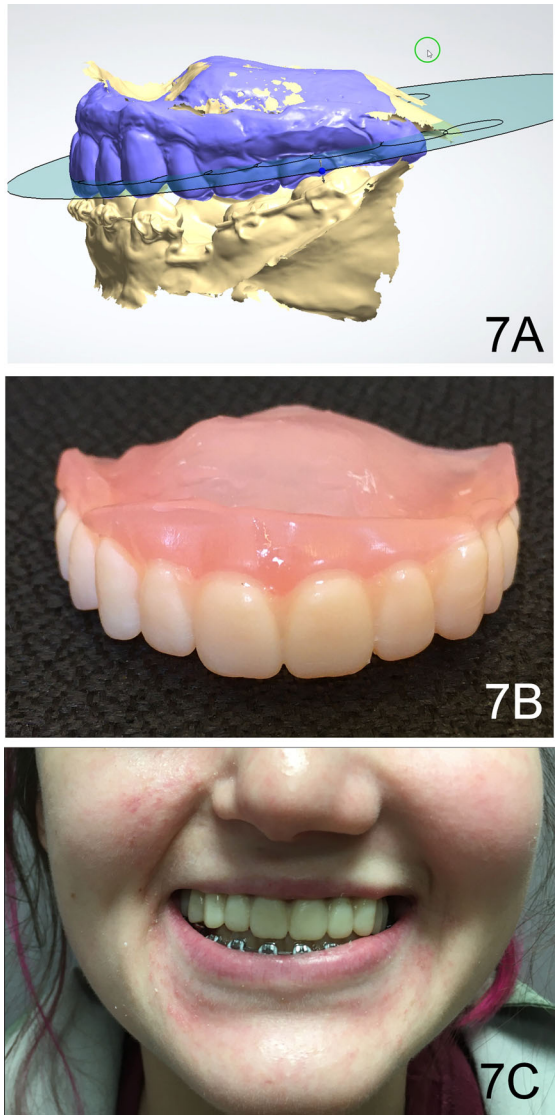

Figure 7 Fabrication of second printed complete denture after initial healing: (A) alignment of scanned relined complete denture (blue) with opposing arch and healed edentulous ridge (yellow); (B) printed complete denture after the luting of complete denture base and teeth; (C) printed complete denture in place.

proach, it is possible to finish both the clinical and laboratory steps of complete denture fabrication within one day if needed.

Another potential advantage of a digital approach is accuracy. A few factors contribute to this advantage. First is the elimination of multiple intrinsic error-prone laboratory steps presented in conventional immediate complete denture fabrication. Second is the virtual wax-up tools for adjusting teeth shape, size, and positions that allow the customized teeth to match perfectly with opposing teeth. Third is the virtual bite registration that avoids manual mounting. Of note, the virtual bite registration can be verified by comparing the location of contact points registered intraorally with articulating paper and those that the 3Shape software provides virtually, which may offer additional accuracy. In this patient's treatment, no occlusal adjustment was needed at the time of complete denture insertion, a testimony to the superior accuracy of printed digital complete dentures. A recent systematic review of in vitro studies assessed the accuracy of digitally fabricated complete dentures, showing they have similar or better adaptation than conventionally fabricated complete dentures. The greatest misfit of the intaglio surface was reported in the posterior palatal seal area and border seal area.[24] In this treatment, areas of misfit were identified in the buccal border areas. This is expected due to the limitation of the direct intraoral scan of the vestibular area. However, this limitation was easily overcome by using tissue conditioner to reline the immediate complete denture in the area of extraction, alveoloplasty, and the border area at the time of insertion. Lastly, in the digital complete denture design for this patient, the photo of the patient smiling was used to conveniently aid in the design of the anterior denture teeth. The esthetic try-in would not be possible for this patient if a conventional approach was used. Thus, this virtual try-in step contributed to a more predictable and esthetic outcome.

The printed complete denture has limitations. One limitation is that there is no proven long term reline material. To solve this problem, clinicians can simply scan the relined complete denture and then print out a new set. In this report, a modified approach was adopted to fabricate the second printed complete denture. The relined complete denture and the healed maxilla were scanned, and both sources of information were used to fabricate the new complete denture, aiming to yield a more accurate fit. It is also very important to follow manufacturer's recommendations for the chosen materials that have been validated for the compatible 3D printers to ensure accuracy. Additionally, current 3D printed resins may have inferior mechanical properties,[3,25] and their the longevity and color stability of the resins used for printed complete dentures need further clinical study.[26] However, it is very convenient to fabricate a second printed complete denture whenever needed. If a printed complete denture serves as an interim prosthesis, as in this case report, this limitation will not be a major concern. In the foreseeable future, with the improvement of printing materials, the longevity of printed complete dentures will undoubtedly increase.

In this report, a digital workflow was successfully utilized to efficiently fabricate the provisional complete denture and met the clinical need. Although the patient was very satisfied with the outcome, the occlusal plane was slightly tilted at the time of complete denture fabrication. This was mainly contributed to the slightly tilted mandibular teeth. After the provisional complete denture insertion, the orthodontist continued to improve the occlusal plane and prepare for the final treatment. In this treatment, a fully digital workflow was used. Alternatively, a conventional impression could have been obtained and digitized the working cast using a laboratory scanner. However, the patient still had braces at the time of making the impression. The fully digital flow simplified the treatment.

Summary

This article describes a fully digital workflow to fabricate a 3D printed maxillary immediate complete denture. The reported approach can significantly improve treatment efficiency.

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