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Case report

Digital technology for fabrication of removable dental prosthesis with double crowns combining fiber-reinforced composite and zirconia

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Abstract

Patients: This clinical report describes the process for fabricating a double-crown-retained removable dental prosthesis combining a fiber-reinforced composite and zirconia using digital technology. An 83-year-old woman presented with gingival swelling around the maxillary right premolar. The swollen tooth was the abutment tooth of a cross-arch fixed partial denture. An intraoral scanner (IOS) and computer-aided design/manufacturing as digital technology were used to plan treatment with a double-crown-retained removable dental prosthesis. A metal-free prosthesis using zirconia for the primary crown and fiberglass-reinforced composite resin for the secondary crown was planned, and the patient consented to the treatment plan. After autotransplantation of a tooth as one of the abutments, the IOS was used to obtain digital scans of the prepared surface of the abutment teeth, opposing dentition, and occlusal relationships. First, primary crowns were milled using zirconia. Next, the intraoral scanner obtained a pick-up impression of the primary crowns, and secondary crowns were designed and milled from the fiber-reinforced composite. After delivery, the patient expressed satisfaction with the functionality, esthetics, and fit of the double-crown-retained removable dental prosthesis.
Discussion: Digital technology offers many advantages such as efficient fabrication of double crowns, reduced material costs, improved biocompatibility, and good aesthetics of metal-free materials.
Conclusions: This clinical report describes the application of digital technology for the fabrication of a double-crown-retained removable dental prosthesis combining a fiber-reinforced composite and zirconia, resulting in patient satisfaction.

Keywords: Intraoral scanner, CAD-CAM, Double crown, Zirconia, Fiber-reinforced composite

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1. Introduction

Double crowns are used as retainers for removable dental prostheses with partially edentulous dentition and they consist of a primary crown cemented to the abutment teeth and a secondary crown connected to the denture base[1]. In removable dental prostheses using double crowns, the primary crown is cemented to the abutment tooth, and the secondary crown is rigidly connected to the primary crown, whereas, the secondary crown is connected to the denture base without mobility, establishing rigid support[2]. In double crowns, abutment teeth with primary and secondary crowns have a circumferential relationship, which can transfer occlusal forces along the long axis of the abutment tooth[3]. Thus, functional loads applied to the denture base can be optimally distributed to the abutment teeth and residual ridge[4]. Oral hygiene for abutment teeth and repair when abutment teeth are lost are both easily performed in patients[5].

Conventionally, double crowns are fabricated by skilled dental technicians using the casting technique[1,3]. However, the fabrication of double crowns using computer-aided design (CAD)/computer-aided manufacturing (CAM) technology has become possible in recent years, and it is expected to markedly improve the efficiency of the fabrication process. In addition, since fabrication allows the use of a variety of materials, the fabrication of double crowns using non-metal materials is also being actively investigated[6–10]. Furthermore, an intraoral scanner (IOS) can be used to obtain a pickup impression of the primary crown, which is necessary for the fabrication of double crowns[11]. Therefore, the fabrication process has become increasingly digitalized in recent times.

However, clinical reports regarding the use of such digital technologies for non-metal, double-crown-retained removable dental prostheses are lacking[12]. The purpose of this clinical report was to describe the process of fabricating a double-crown-retained removable dental prosthesis combining a fiber-reinforced composite and zirconia using digital technologies, including IOS and CAD/CAM

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Fig. 1. Frontal view before prosthodontic treatment

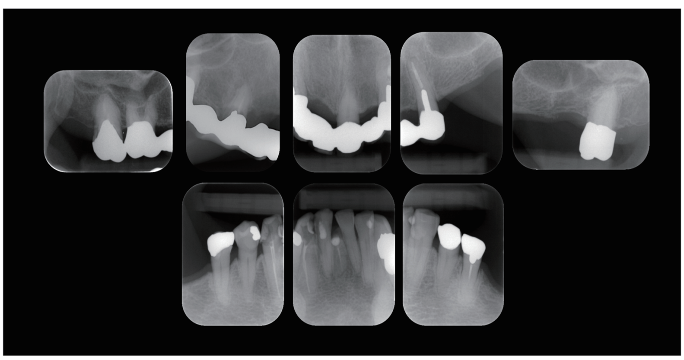

Fig. 2. X-ray images obtained at initial examination

technology.

2. Outline of the case

An 83-year-old woman visited the Department of Prosthodontics at Suidoubashi Hospital, Tokyo Dental College, complaining of gingival swelling around the maxillary right first premolar (#14: FDI two-digit system). A cross-arch fixed partial denture (#16 to #23) with four abutment teeth (#14, 16, 21, and 23) was attached to the maxilla. Swollen #14 was the abutment tooth for the fixed partial denture. In the partially edentulous regions of the maxilla (#24-26) and mandible (#36-37, #46-47), unilateral removable partial dentures had been used for the lost molars (**Figs. 1 and 2**). The periodontal pocket was a maximum of 8 mm deep at #14 and less than 3 mm deep at other teeth, and no mobility of the remaining teeth was recorded. The right mandibular central incisor (#41), with a residual root, underwent linguoversion. The patient did not have any systemic disease.

For creation of the maxillary prosthetic, the use of an IOS and CAD/CAM as digital technologies was applied to the double-crown-retained removable dental prosthesis. Since #14 was diagnosed as unpreservable, extraction of that tooth would result in a reduced number of abutment teeth and an unfavorable support zone. As a result, the options of either supplemental, so-called strategic, implant, or autotransplantation of a tooth (#41) were presented to the patient. Notably, #17 was not included as an abutment tooth because of its

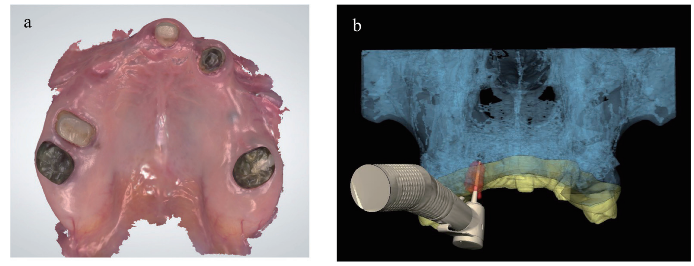

Fig. 3. Virtual 3-dimensional planning of donor tooth position. a: Intraoral scanning data before tooth autotransplantation. b: Virtual transplantation of donor tooth (#41) and virtual preparation of recipient area.

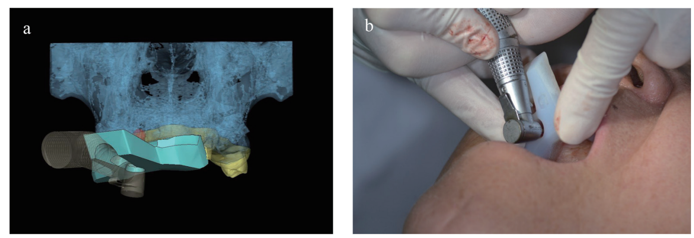

Fig. 4. Surgical guide template. a: Planning of the surgical guide template. b: Preparation of the recipient area using the surgical guide template.

poor prognosis based on the condition of the periodontal tissue on X-ray imaging. The patient underwent autotransplantation. Since the patient did not like the metal color of the primary crown when the removable prosthetic was removed, a metal-free prosthesis using zirconia for the primary crown and fiberglass-reinforced composite resin (FRC) for the secondary crown was planned accordingly. The patient consented to participate in the treatment plan.

Before autotransplantation of the tooth, the fixed partial denture in the maxilla was removed and #14 was extracted. The removed fixed partial denture was reused as a temporary prosthesis. Digital data (**Fig. 3a**) were obtained using IOS (Trios3; 3Shape, Copenhagen, Denmark) and cone beam computed tomography (3D Accuitomo F17; Morita, Kyoto, Japan). The contra-angle handpiece and round bar were scanned using an ATOS core200 (GOM, Braunschweig, Germany). The direction and depth of drilling were simulated from the resulting data using Mimics and Magics software (Materialize, Leuven, Belgium) (**Fig. 3b**). Based on this simulation, a surgical guide template was designed such that the tip of the round bar was guided to the same position in the mouth (**Fig. 4a**). The surgical guide template was formed on a 3D printer (Objet260 Connex; Stratasys, Eden Prairie, MN, USA) using a hard acrylic resin (Vero White RGD835; Stratasys). For tooth autotransplantation, a full-thickness flap was dissected from #11 to #16, and the bone was drilled using the template to the depth of the graft bed, which was formed with a round bar to fit the root form (**Fig. 4b**). After the formation of the graft bed, #41 was implanted and fixed with sutures (**Fig. 5**).

Three months after autotransplantation, the grafted tooth was built with a fiber post. The following three conditions were set for the preparation of the abutment teeth: a minimum clearance of 3 mm from the opposing teeth, a convergence angle of 6°, and a deep-chamfer with a finish line 0.5 mm below the gingival margin[13]. The breakdown of clearances was as follows: nonmetallic double crowns

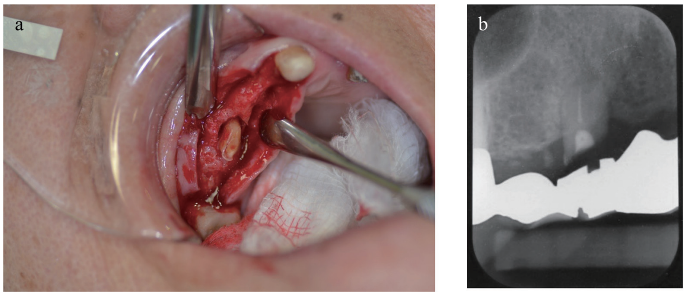

Fig. 5. Autotransplantation of tooth. a: Immediate autotransplantation of the right central incisor in the recipient area. b: Postsurgical intraoral radiograph with autotransplanted tooth.

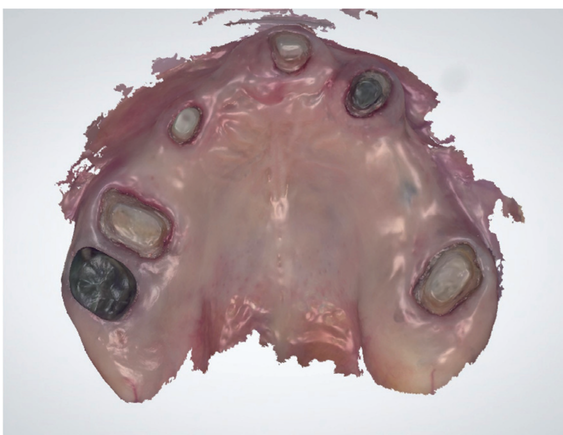

Fig. 6. Digital wax-up of secondary crowns

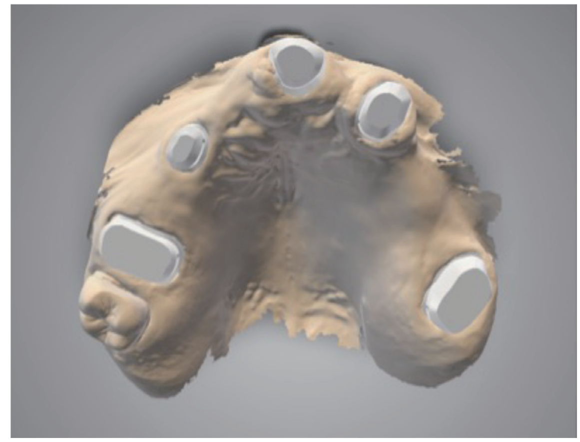

Fig. 7. Digital wax-up of primary crown

Fig. 8. Occlusal view of primary crown

each required a thickness of at least 1 mm for the zirconia primary crown[14], FRC secondary crown, and veneering material. The thicknesses of the secondary crown and veneering material were considered acceptable according to the manufacturer's instructions[15]. The IOS was used to obtain digital impression data of the prepared surface of the abutment teeth, opposing dentition, and occlusal relationships (**Fig. 6**). Parallel-sided cylindrical primary crowns were designed using dental CAD software (CARES Visual 2021; Straumann AG, Basel, Switzerland) (**Fig. 7**)[16]. The primary crowns were milled from a zirconia disk using CAD data (Luxen Zirconia HT: GeoMedi, Fukuoka, Japan). The primary crown was placed on a 3D-printed dental model (MED690; Stratasys), ground, and polished using a parallel milling machine (Fraesgeraet-F1; Degussa, Frankfurt, Germany). The fit of the margin and inner surface of the primary crowns was evaluated intraorally using a silicone-based fitting check material (Fit Checker Advanced; GC, Tokyo, Japan) and a dental explorer. A small amount of temporary cement (HY-Bond Temporary Cement Hard, Shofu, Kyoto, Japan) was used to fix the primary crown to the abutment tooth (**Fig. 8**). The crown surface was coated with a scanning spray (CEREC OptiSpray; Sirona Dental Systems GmbH, Bensheim, Germany), and pick-up impressions of the primary crown were obtained using the IOS (**Fig. 9**). Dental CAD software (Dental System; 3 shape) was used to design the secondary crown framework. To provide space for resin veneering, cutback was performed on the occlusal and labial/buccal surfaces. Data were sent to a milling center (Shofu S-wave CAD/CAM Center, Kyoto, Japan) after all the crowns had been joined (**Fig. 10**). The secondary crowns were then milled from fiber-reinforced composite resin discs (Trinia, Shofu). After adjusting and polishing the intaglio surface of the secondary crowns with diamond paste (Zircon-Brite; Dental Ventures, Corona, CA, USA), the primary crown was removed using a retentive force of approximately 8–10 N (**Fig. 11**). The intraoral fit of the secondary crowns was checked. The secondary crowns were then veneered with a composite resin (Twiny; YAMAKIN, Tokyo, Japan) (**Fig. 12**).

The primary crowns were definitively cemented (RelyX Adhesive Resin Cement; 3M ESPE, St. Paul, MN, USA) and the fit between the primary and secondary crowns was checked using discolored media (Occlude; Henry Schein, Melville, NY, USA). The strong contact area of the secondary crown was adjusted under a dental laboratory microscope and a removable dental prosthesis was inserted accordingly. Follow-up appointments were scheduled at 1 d, 1 week, 1 month, and 6 months after delivery of the prosthesis. After delivery, the patient expressed satisfaction with functionality, esthetics, and fit (**Figs. 13a, 13b, 14**).

3. Discussion

In this report, we describe the fabrication of a double-crown-retained removable dental prosthesis combining a fiber-reinforced composite and zirconia using digital technologies.

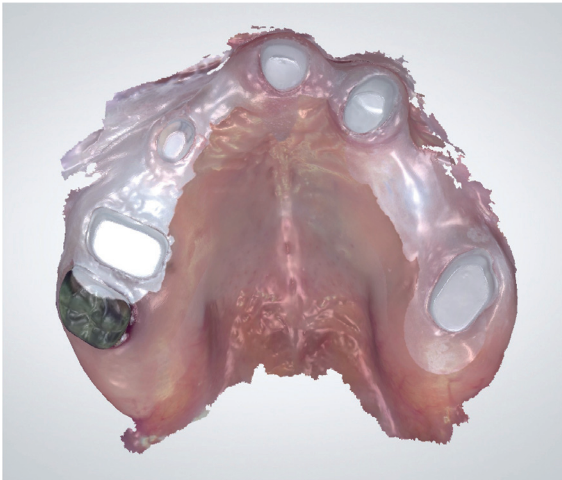

Fig. 9. Pick-up impression of primary crown made using an intraoral scanner

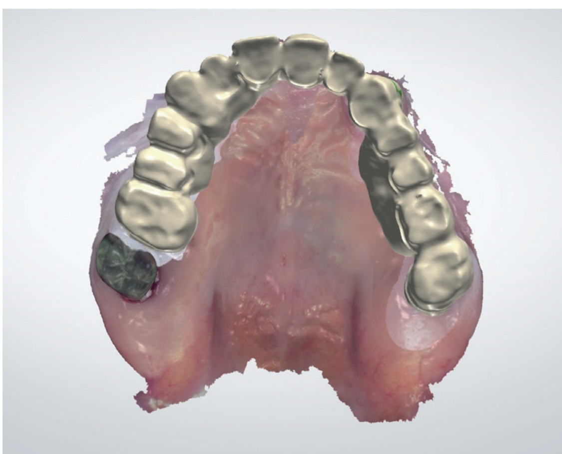

Fig. 10. Digital wax-up of secondary crown

Fig. 11. Fitting between primary and secondary crowns

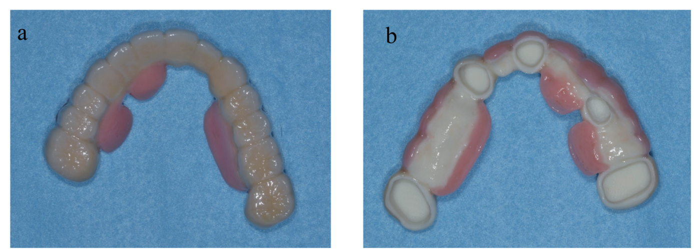

Fig. 12. Completed secondary crown. a: Occlusal view. b: Intaglio surface view.

Tooth autotransplantation was performed as a preprosthetic treatment using digital technology. Tooth autotransplantation using a surgical guide template created from 3D data allows for accurate treatment planning and surgery[17,18]. Autotransplantation of teeth with complete root formation has shown high survival rates[19]; however, data regarding its application as an abutment for double crowns is still lacking. Double crowns may be effective for the longevity of #41 since the crown-root ratio of the abutment tooth can be improved, and secondary splinting can be expected in patients[5]. Conversely, a weakened tooth such as #41 in this case potentially represents the weakness of the prosthesis, however the patient wanted to make the best use of her own tissues. If an autotransplanted tooth is to be extracted in the future, the patient will consider placing an additional implant.

Digital impression data were acquired using an IOS to fabricate the prosthesis. The accuracy of IOSs is reportedly comparable to that of conventional impressions if the unevenness of the residual ridges is sufficient in height and width and is covered with attached mucosa, as in the present case[20]. However, an IOS cannot be used to make pressure impressions of the mucosa on the residual ridge. In this case, pressure impressions were not necessary since autotransplantation of the tooth increased the number of abutment teeth, improved the support area, and provided support for the prosthesis. An IOS was used to pick up the impression of the primary crown. Careful attention was paid to the amount of scan spray covering the abutment teeth, as too much scan spray over the abutment teeth reportedly reduces the retentive force of the double crown. When using an IOS to make a pick-up impression of the primary crown, prior practice is required to provide a thin, homogeneous coating with a scan spray.

In this case, a double crown consisting of a primary crown made of zirconia and a secondary crown made of fiber-reinforced composite resin was used as the retainer. Primary zirconia crowns are known to be effective in terms of esthetics, biocompatibility, and oral hygiene[8]. Some concerns have been raised regarding the decrease in the retentive force of the secondary crown due to wear with long-term use. Tasaka *et al*. reported that the change in retentive force was affected by milling parameters during the fabrication of the secondary crown and the polishing method of the inner surface of the secondary crown[16]. In the present study, the offset parameter of the inner surface of the secondary crown was set to -10 μm, which should have stabilized the retentive force for a relatively long period of time. Diamond paste was used for polishing the inner surface. Even if the retentive force decreases, improvements can easily be obtained by adding resin to the inner surface of the secondary crown. However, whether FRC is applicable to conical crowns remains unclear. Coni-

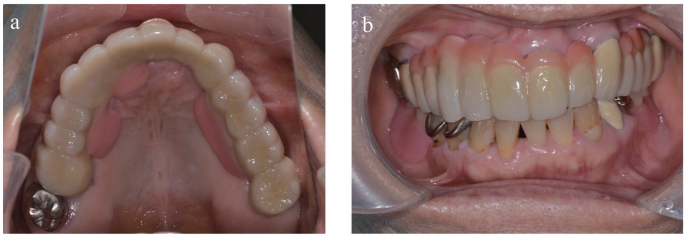

Fig. 13. Computer-aided design/computer-aided manufacturing double-crown-retained removable dental prosthesis after treatment. a: Occlusal view of secondary crown. b: Frontal view of secondary crowns.

cal crowns are double crowns with tapered sidewalls. Retention is achieved by a cone or press fit, depending on factors such as material parameters, cone angle, and joining force[21].

4. Conclusions

In this case, the use of digital technologies provided many advantages, including 1) efficient fabrication of double crowns during prosthesis fabrication, 2) reduced material costs, 3) increased biocompatibility, and 4) improved aesthetics due to the use of metal-free materials.

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Conflicts of interest

The authors declare no conflict of interest.

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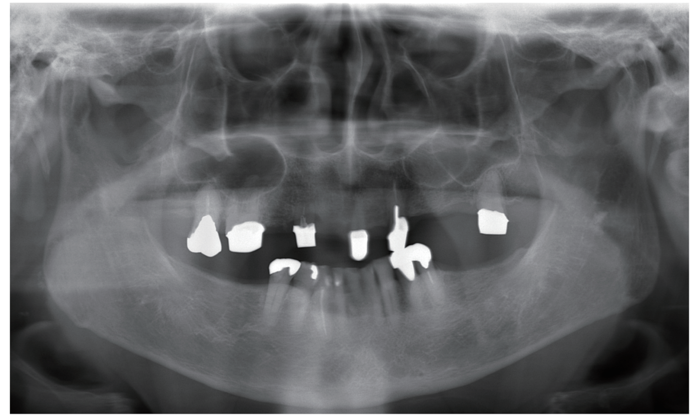

Fig. 14. Panoramic radiography obtained after treatment

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