디지털 정보의 통합과 하악 움직임 트래킹을 이용한 고정성 전악보철 회복 증례

Application of multi-source digital information integration and Jaw motion tracking for complete arch implant-supported prosthesis: a case report

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This case report details the diagnostic design process for a 72-year-old woman with an edentulous mandible, which was achieved by creating a virtual patient. The 3D data files, which included facial, dental, and cone beam computed tomography (CBCT) scans, were then aligned using dental computer-aided design (CAD) software. A provisional restoration was fabricated using milling and 3D printing technologies to reflect the ideal diagnostic design. Following this, four implants were placed in the mandible, and an intraoral scan method was used to fabricate fixed provisional implant restorations. Finally, definitive full fixed-type prostheses were fabricated using the double scan technique and jaw motion tracking. (J Korean Acad Prosthodont 2025;63:246-53)

Keywords
CAD-CAM; Digital workflow; Double scan technique; Facial scan; Jaw motion tracking

Introduction

Conventionally, diagnostic wax-ups have been important in treatment planning for patients requiring full-mouth rehabilitation. It allows clinicians to control and predict function, shape, and appearance.[1,2] Advances in digital technology now allow the creation of diagnostic wax-ups using dental computer-aided design (CAD) software.[1] The term "diagnostic design" will be used instead of "wax-up" in

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the following text. A diagnostic design can be developed by integrating digital data, such as radiographs and facial and intraoral scans, within CAD software.[3-5] Milling and 3D printing technology have been developed as tools to transfer a diagnostic design from the dental CAD software to the patient's mouth.[6-8]

Efforts to replicate mandibular movements for definitive prosthesis design have shifted from traditional articulators to virtual articulators. However, semi-adjustable articulators cannot accurately replicate patient-specific mandibular movements. The ultrasonic jaw motion analyzer can be used to reproduce the actual mandibular motion data of a patient with dental CAD software.

This case report describes the use of a digital workflow for the diagnosis and treatment of a patient with an edentulous mandible. After the placement of four implants in the mandible and fixed provisional prostheses, the full mouth was rehabilitated using the double scan technique and jaw motion tracking.

Case Report

A 72-year-old woman presented to the Department of Prosthodontics at the University Dental Hospital, complaining of swelling and pain in the left maxillary canine region. The patient's medical history was reviewed, revealing no contraindications for prosthetic or periodontal treatment. In addition, she was unable to chew with her existing denture. The patient received multiple maxillary fixed prostheses and a mandibular Kennedy class I removable partial denture 20 years ago but had not visited a dentist since. An intraoral examination identified a retained root in the maxillary left canine, secondary caries under the existing prostheses, and localized periodontitis in the maxillary right second molar. The prosthetic teeth of the mandibular denture were abraded, and the maxillary molars showed supra-eruption. A lateral cephalometric analysis showed an excessive anterior horizontal overlap of approximately 7 mm, indicating skeletal class II malocclusion. The old prostheses were removed, and after evaluation, the maxillary right lateral incisor, canine, and second premolar, as well as the left incisors and premolars, were deemed hopeless and were extracted (Fig. 1). The vertical dimension was restored using the existing denture, freeway space, and facial profile as references. A facebow (Arcus Evo; KaVo, Biberach, Germany) was used to mount the casts on a semi-adjustable articulator (Protar Evo 7; KaVo, Biberach, Germany). Facial three-dimensional (3D) scans were obtained while resting and smiling using a facial scanner (SNAP scanner; DOF, Seoul, Korea).

A diagnostic design was developed using the collected data and dental CAD software (Exocad; Exocad GmbH, Darmstadt, Germany). First, while mounted, the diagnostic casts were scanned using a tabletop scanner (T500; Medit, Seoul, Korea) in virtual articulator mode. Then, facial scan data were aligned by matching them to the position of the maxillary teeth. The teeth were arranged in

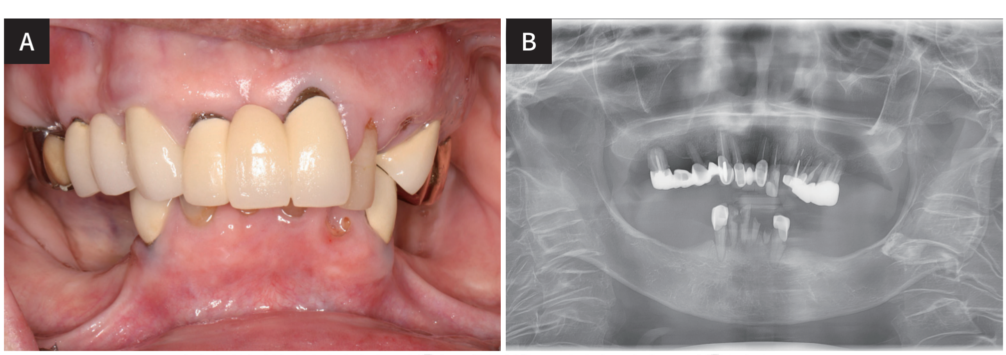

Fig. 1. Pretreatment. (A) Intraoral photograph: frontal view, (B) Panoramic radiograph.

harmony with the interpupillary line, Camper's line, the position of the mandibular premolars, and the exposure of the anterior teeth on the facial scan (Fig. 2).[5] A properly curved mandibular occlusal plane was designed with the frame library (Calotte; KaVo, Biberach, Germany) (Fig. 3D).[9] The virtual analysis on dental CAD software indicated that forward placement of the mandibular incisors would offer minimal esthetic benefits, as the lower lip already contributed sufficiently to the patient's speech.

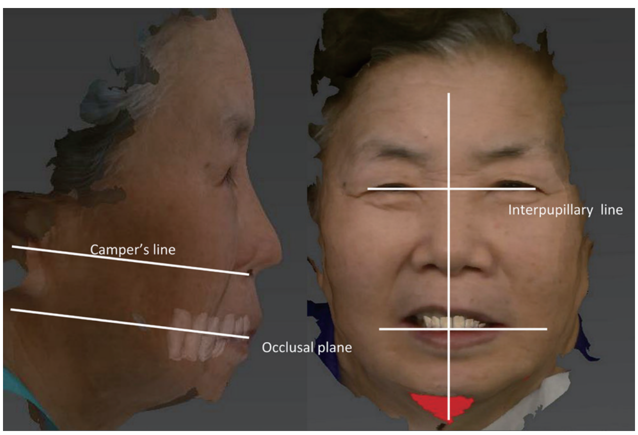

Fig. 2. Three-dimensional facial scan and reference plane.

Therefore, the anteroposterior position of the mandibular incisors remained unchanged. Finally, the design was prepared on the virtual articulator to achieve group function during lateral movement (Figs. 3A, C, and E).

The treatment plan, based on the final diagnostic design (Fig. 3B), involved restoring the maxilla and mandible with fixed prostheses. Four implants were planned for the bilateral mandibular canines and first premolars, and a full arch implant-supported prosthesis was fabricated for the mandible. Implant placement in the second premolar area would have required extensive bone grafting. Since the patient declined extensive bone grafting, implant placement in the second premolar area was excluded from the plan. This plan was based on the concept of a shortened dental arch, where the maxillary first and mandibular second premolars were intended to be in occlusal contact due to the skeletal class II relationship. On this basis, egg-shell provisional restorations of the maxillary teeth were prepared by milling (Bx5; Megagen, Daegu, Korea) a polymethyl methacrylate (PMMA) block (VIPI Block Monocolor; VIPI, São Paulo, Brazil). Mandibular provisional dentures were completed by 3D printing

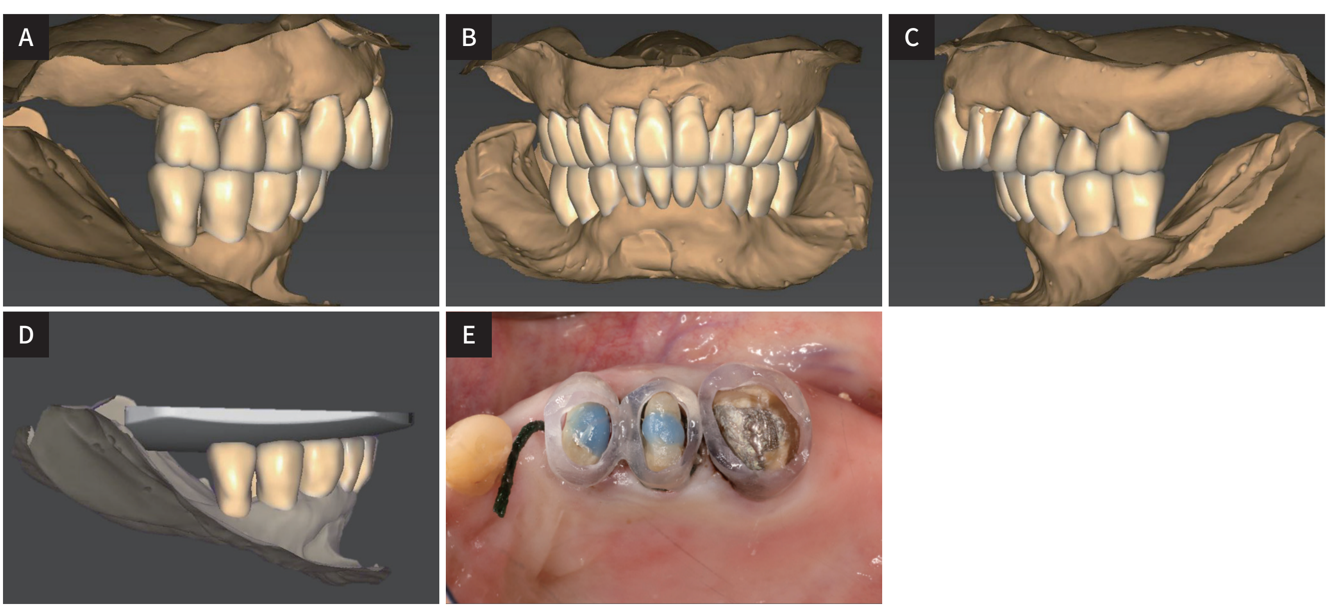

Fig. 3. Diagnostic design. (A) Right lateral view, (B) Frontal view, (C) Left lateral view, (D) Setting of the occlusal plane with Calotte device, (E) Preparation jig.

(C&B; Nextdent, Soesterberg, Netherland) by adding a gingival design to the completed dentition. Occlusal adjustments were performed in the oral cavity using the preparation jig fabricated on dental CAD software (Fig. 3E).

Cone beam computed tomography (CBCT) data were acquired with a radiographic template made by duplicating the mandibular provisional denture. A surgical template was prepared with an implant planning software (Implant Studio; 3shape, Copenhagen, Denmark), and implants (Superline II; Dentium, Seoul, Korea) were placed in the right maxillary first molar, mandibular first premolars, and canine regions (Fig. 4). Three months later, secondary surgery was performed. Tissue impressions (Aquasil Ultra; Dentsply Sirona, Charlotte, NC, USA) using a replica of the existing provisional denture and intraoral scans (Trios3; 3shape, Copenhagen, Denmark) were aligned to create a fixed-type provisional implant prosthesis that reflected the tooth morphology and occlusion of the existing denture (Fig. 5). After one month of using fixed-type provisional restorations, occlusal adjustment was performed, and anterior and lateral guidance with a group function, as planned in the virtual patient, was achieved. The gingiva was stable, and the oral hygiene maintenance was good; the fabrication of the definitive restorations was then planned.

Digital impressions of the provisional restorations were acquired. Precise impressions of the abutments and implants were made with polyether (Impregum Penta; 3M, Maplewood, MN, USA) in individual trays prepared by the traditional method. Using universal CAD software (Meshmixer; Autodesk, San Francisco, CA, USA), the two sets of scan data were aligned. This alignment transferred the silhouette of the provisional restoration to the abutment model using the double scan technique. The maxilla was matched based on the palate and attached gingiva, while the mandible relied solely on the attached gingiva. Mandibular movements were recorded using an ultrasonic mandibular movement tracking device (JMA; Zebris Medical GmbH, Isny, Germany). A patient-specific jig was manufactured to accurately fix the tracking device to the mandible. The patient was instructed to perform the opening, protrusive, and lateral movements to record the mandibular border movement (Fig. 6). The record-

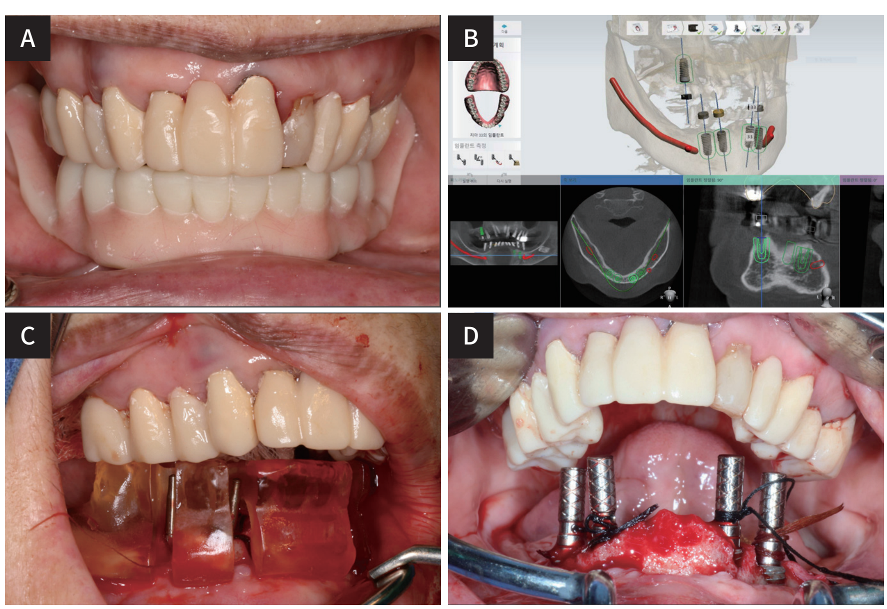

Fig. 4. (A) Provisional restorations on maxillary teeth and provisional denture on mandible, (B) Implant planning, (C) Surgical template, (D) Implant surgery.

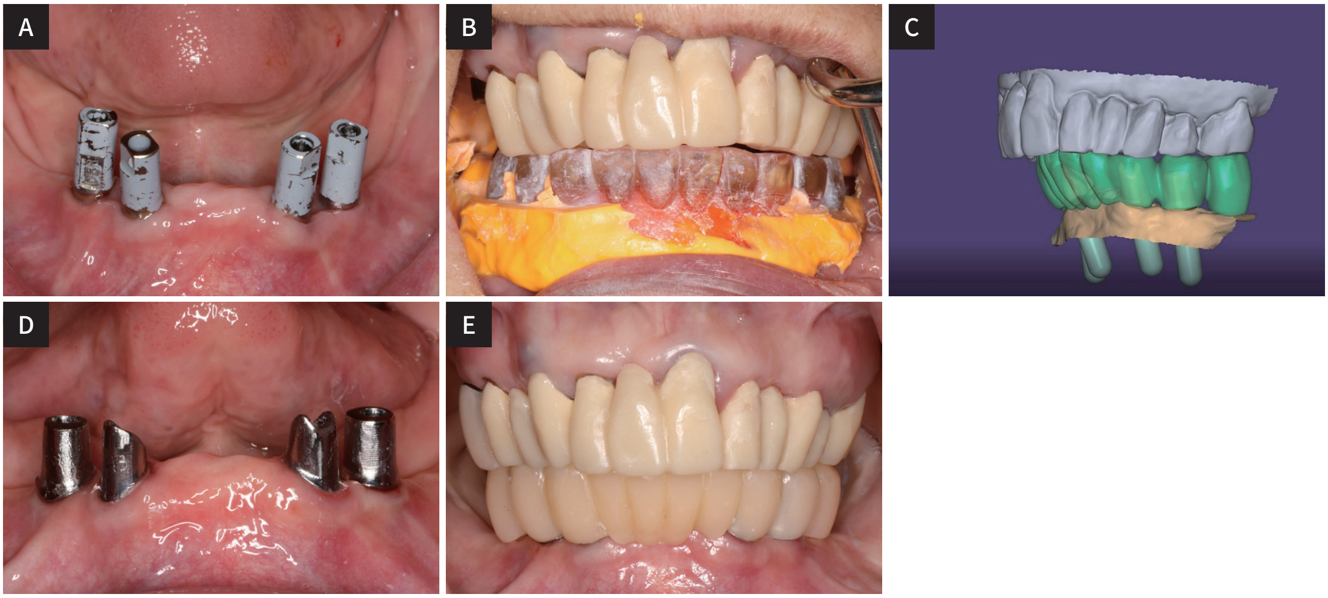

Fig. 5. (A) Intraoral scanning with scan bodies, (B) Intaglio surface impression and interocclusal record, (C) Fabrication of fixed-type implant-supported provisional restoration on computer-assisted design software, (D) Custom abutments, (E) Mandibular implant-supported fixed provisional prosthesis.

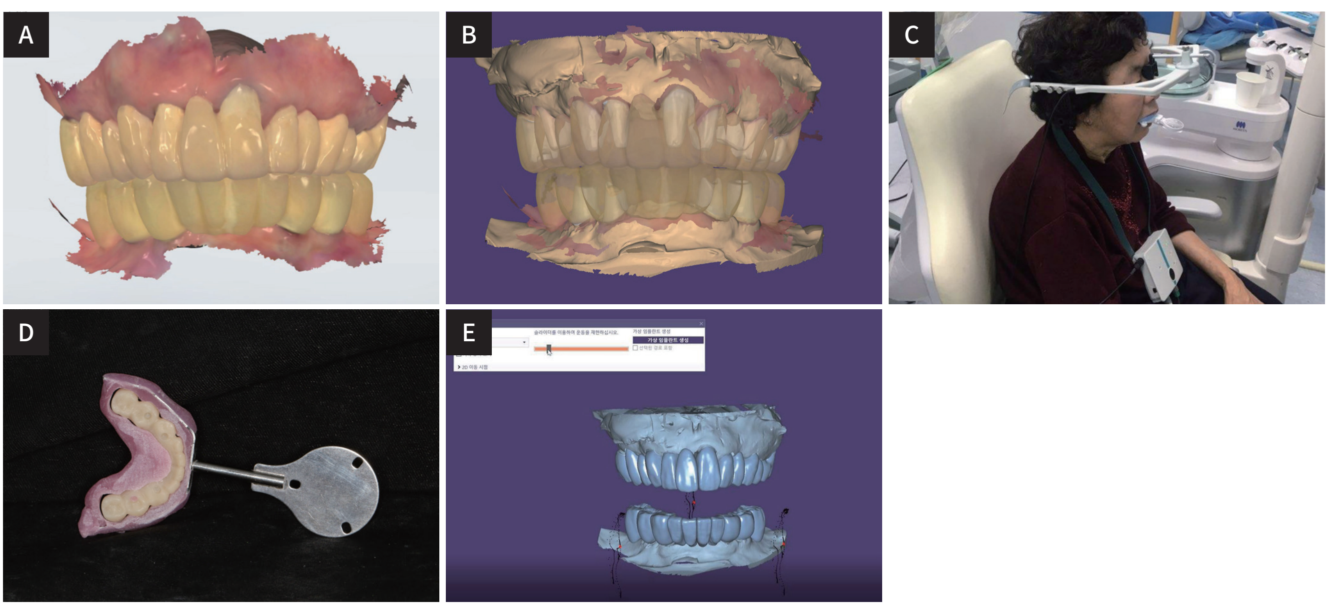

Fig. 6. (A) Intraoral scanning of provisional restoration, (B) Digital cast cross mounting, (C) Jaw tracking device on patient, (D) Mandibular jig for jaw motion analyzer, (E) Jaw motion tracking on computer-assisted design software.

ed mandibular motion data were imported as .xml files (Fig. 6E). Hence, the shape of the provisional restoration adapted in the oral cavity was duplicated, and the actual mandibular movement of the patient was incorporated in the design using jaw motion tracking data. Tracking the patient's actual jaw movements allowed us to design a prosthesis that minimized interference in fully adjustable functions, surpassing the limitations of virtual articulators reliant only on sagittal overbite and incisal guidance angles. Integrating jaw movement tracking with CAD software enabled us to identify and correct mismatches between the patient's actual mandibular movements and the virtual design. This process resulted in a prosthesis that better matched the patient's functional mechanics.

The definitive prosthesis for maxillary natural teeth was manufactured by milling (DWX-520; Roland, CA, USA) zirconia blocks (STML Katana; Kuraray, Tokyo, Japan). The maxillary implant prosthesis was wax milled and cast into a metal porcelain-fused crown, which is covered by national insurance. The PMMA prototype was milled and checked in the oral cavity to confirm and correct the misalignment error. A definitive zirconia prosthesis of the mandible was fabricated. The passive fit of the four abutments of the mandible and the maxillary zirconia fixed prosthesis was confirmed in the oral cavity. Little occlusal adjustment was required. The patient had become accustomed to the provisional restoration and therefore did not complain of any discomfort after placement of the final restoration (Fig. 7). The importance of oral hygiene was emphasized at the time of the final fitting and regular check-ups were scheduled to ensure maintenance. Maintenance of the occlusion, teeth, and periodontal health was good at the one-year visit.

Discussion

A facial scan was performed during the diagnostic process, and accurate alignment of the scan with the maxillary teeth was crucial.[3] Then, the occlusal plane was designed along the three dimensions using the facial landmarks, and the exposure of the anterior teeth while smiling was recorded. This method allowed for the preparation of the diagnostic design by examining the face scan from multiple angles, offering advantages over the traditional use of a facebow or a two-dimensional photograph.

The definitive prosthesis was fabricated using the double scan technique. Conventional methods use a customized incisal guide table to replicate the anterior and lateral guidance of the provisional restoration. In contrast, the double scan technique replicates the exact form of the provisional restoration, enabling the fabrication of a final restoration precisely adapted to the patient's oral cavity.

There is still a lack of cases and studies applying jaw motion tracking technology. In this case, the alignment between the oral space and CAD space was confirmed by tracking jaw motion with CAD software. Fine occlusal adjustments were performed using fully adjustable functions while observing the mandibular movement path. Hong *et al*.[9] described using mandibular movement information to analyze a patient's chewing pattern. Occlusal interference is absent when the mandibular movement trajectory is smooth and consistent. In the future, jaw motion tracking technology is expected to have diverse applications in dentistry, emphasizing the need for further research into its accuracy and utility.

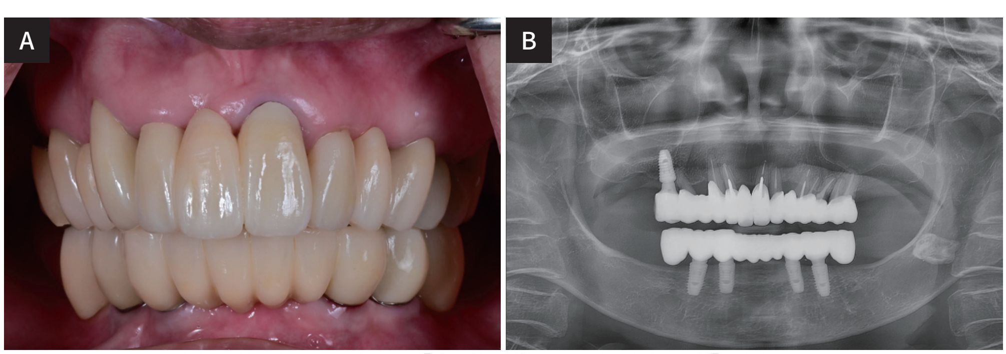

Fig. 7. Definitive prostheses. (A) Intraoral photograph: frontal view, (B) Panoramic radiograph.

Conclusion

This case report detailed the diagnostic design for a patient with an edentulous maxilla, integrating multisource digital information with dental CAD software. Four implants were placed in the mandible, a complete fixed provisional restoration was fabricated using intraoral scan data, and the definitive prostheses were installed with the double scan technique to account for mandibular movement.

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디지털 정보의 통합과 하악 움직임 트래킹을 이용한 고정성 전악보철 회복 증례

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하악 무치악을 가진 72세 여성에서 안면, 치아 및 콘빔 컴퓨터 단층촬영의 3D 데이터 파일을 치과용 캐드 프로그램에 정렬하여 가상 환자를 생성하여 치료한 증례이다. 이상적인 진단 디자인을 반영하기 위해 밀링 및 3D 프린팅 기술을 사용하여 임시 수복물을 제작했다. 이어서 하악골에 4개의 임플란트를 식립하고 구강 내 스캔 방법을 사용하여 고정성 임플란트 잠정 수복물을 제작했다. 마지막으로 더블 스캔 기법과 하악 움직임 트래킹을 사용하여 고정성 전악보철을 완성하였다. (대한치과보철학회지 2025;63:246-53)

주요단어

캐드캠; 디지털 워크플로우; 더블 스캔 기법; 안면 스캔; 하악 움직임 트래킹

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