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THREE-DIMENSIONAL PRINTING OF TEMPORARY CROWNS WITH POLYLACTIC ACID POLYMERS BY WELD MODELING

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Abstract
Thanks to the latest developments in digital dentistry, research into methods and materials for three-dimensional (3D) printing is actively underway. We report on the clinical application and results of 3D printing temporary crowns made of polylactic acid (PLA) using a fused deposition (FDM) printer. Five participants were recruited from among patients who were scheduled to undergo treatment using a single full-coverage crown at the University Medical Center's dental clinic from June to August 2022. As temporary crowns, we used 3D printed crowns made of PLA using an FDM printer. were evaluated for discomfort, fractures, and displacements. Temporary 3D printed crowns were preserved without fractures, displacement, or discomfort until the permanent prosthesis was ready. The average time it took to print temporary crowns was about 7 minutes. 3D printing temporary PLA crowns on an FDM printer is a convenient process for dentists. However, these crowns have some limitations, such as rough surface texture and transparency; therefore, the 3D printing process needs to be improved to produce better prosthetics.

Keywords: Digital dentistry, Polylactic acid, Temporary dental restoration, Three-dimensional printing.

Introduction

Temporary crowns are an important part of fixed prosthetic treatment because they protect prepared teeth, provide position stability, and support functions such as chewing and aesthetics. Temporary crowns can be made directly on the prepared tooth or indirectly on the model of the prepared tooth. The direct method is convenient, but has significant drawbacks, such as irritation of adjacent tissues and shrinkage of the polymer. In addition, the chemical odor produced during polymerization causes severe discomfort to patients. The traditional indirect fabrication method overcomes these drawbacks, but additional processes such as impression making and plaster modeling may be required. If the temporary crown is prepared arbitrarily before the tooth is prepared, its accuracy is reduced, leading to the same problems in the rebasing process as with the direct method. If the temporary crown is made indirectly after the tooth has been prepared, the time spent in the chair is increased due to the impression and model manufacturing processes.

However, with the recent development of digital dentistry, the indirect method of making temporary dentures using three-dimensional (3D) printing has been introduced, which is being actively developed to overcome the limitations of the conventional indirect method. To make 3D objects from digital 3D data, 3D printing is an additive manufacturing method. A 3D printed

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temporary crown is made through a digital process that involves 3D scanning the prepared tooth, digitizing it on a computer, transferring it to a 3D printer, and fabricating a 3D structure.

3D printing technologies commonly used for the preparation of dental polymers include stereolithography machine (SLA), digital light treatment (DLP), material blasting (MJT), and fused deposition modeling (FDM). SLA and DLP are the most popular technologies in dentistry at the moment. Both processes create 3D structures by photopolymerizing liquid photopolymer and can quickly create high-resolution restorations. MJT is a direct 3D printing process in which droplets of molten material are ejected onto a heated assembly platform and glued together; MJT is also accurate and fast, but it comes at a cost. In the FDM method, three-dimensional structures are fabricated in such a way that the solid filament material is melted in a nozzle, polymerized during extrusion, and laid layer by layer. The equipment and materials required for FDM are cheaper and easier to use than those required for SLA or DLP. However, while FDM 3D printed objects have corresponding physical properties, they are not popular in dentistry because they require long printing times and have low resolution.

Interest in 3D printing temporary crowns is growing, but limited research has evaluated the use of 3D printing technologies and materials used to make temporary dentures. Several studies on 3D printing temporary crowns have focused on SLA and DLP. However, FDM has advantages such as cost-effectiveness, convenience, and the ability to produce material with appropriate physical properties. If the disadvantages of the rough surface of the final product and the low speed of operation are eliminated, FDM can be successfully used in dental clinics.

Here we report on our experience with printing and clinical application of a relatively convenient filamentous polymer (polylactic acid [PLA]; QUVE Co. Ltd., Seoul, Korea), which has been developed and marketed as a temporary restoration material for use in FDM 3D printers (CUBICON Style Plus - A15D; CUBICON Co. Ltd., Seoul, Korea).

Potential participants were recruited from among patients who had visited the dental clinic. Five patients were included in the study, five teeth were scheduled for treatment using a single full-coverage restoration. The teeth were prepared by an experienced dentist, the temporary 3D printed crowns were fixed to the prepared teeth using Temp-Bond NE (Kerr Dental, Brea, California, USA) and maintained until the final denture was ready.

After the preparation of the tooth, an intraoral scan of the prepared tooth was performed using a 3D scanner (Medit i500; MEDIT Corp., Seoul, Korea) (Figure 1). The digital data was then transferred to the NexWay platform (QUVE Co. Ltd.) as an STL file, and the temporary crown was designed by an experienced dental technician using computer-aided design and computer-aided manufacturing (CAD/CAM) software (Exocad GmbH, Darmstadt, Germany) (Rice. 2). Finally, the design was transferred to an FDM (CUBICON Style Plus - A15D) 3D printer installed in the dental clinic and printed into a 3D structure using PLA resin (Rice. 3).

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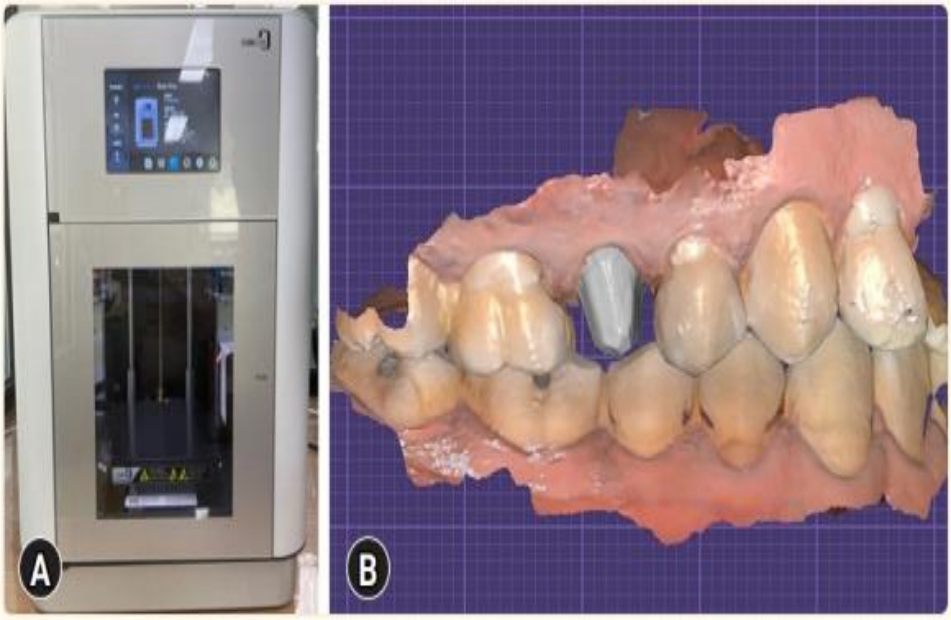
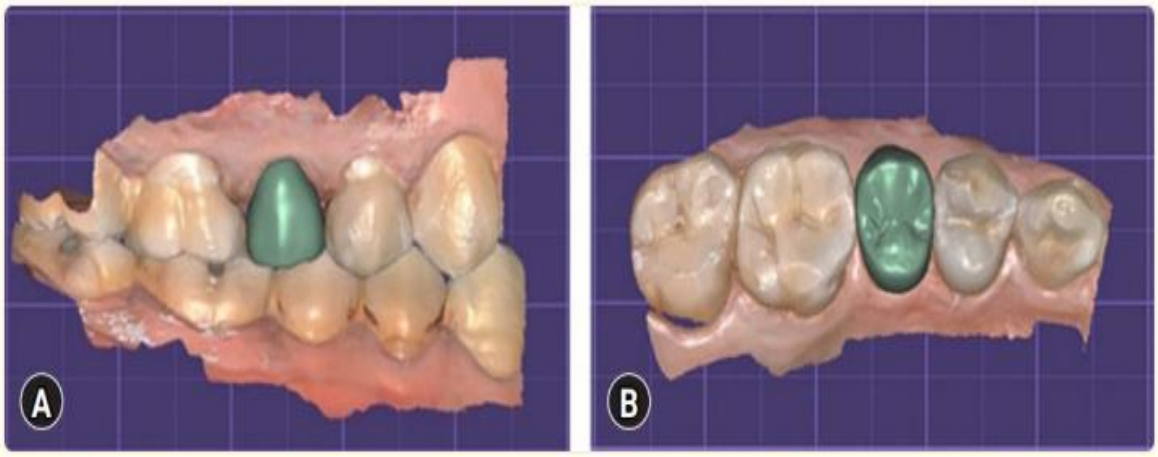
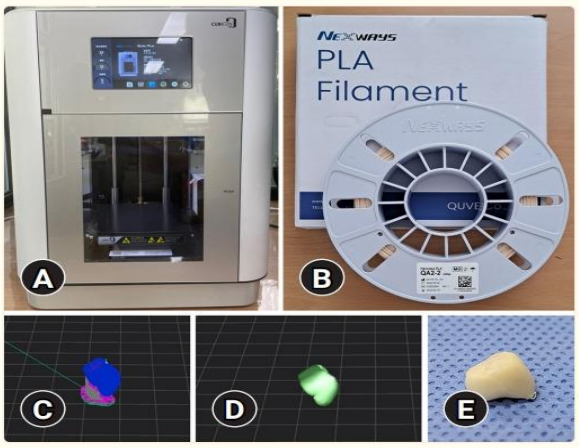


Figure 1.Intraoral scanning after tooth preparation. (A) Three-dimensional scanner (Medit i500; MEDIT Corp., Seoul, Korea). (B) Intraoral image scanning.



Rice. 2. Crown design using computer-aided design/computer-aided manufacturing (CAD/CAM) software (Exocad GmbH, Darmstadt, Germany). (A) Side view. (B) Occlusal view.



Rice. 3.

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Fabrication of a three-dimensional (3D) printed temporary crown using fused deposition modeling (FDM) and polylactic acid polymer (PLA). (A) FDM 3D printer (CUBICON Style Plus - A15D; CUBICON Co. Ltd., Seoul, Korea). (B) Nexway PLA (QUVE Co. Ltd., Seoul, Korea). (C, D) Making a single temporary crown using PLA. (E) A single temporary crown made of PLA.

Case 1

A 59-year-old man complained of pain coming from tooth No. 15 when chewing. Based on clinical and radiological data, the patient was diagnosed with: cracked tooth No. 15; Therefore, he underwent root canal treatment and stump augmentation. It was planned that the treated tooth would be covered with a metal-porcelain (PFM) crown, which was prepared in accordance with the requirements for the preparation of PFM crowns. The temporary crown was made of PLA using the FDM method.

Case 2

A 45-year-old woman came to our clinic about the displacement of the old crown on tooth No. 36. Secondary caries was present in tooth No. 36, and infection was found in the previously treated root canal system. After repeated root canal treatments, a gold crown restoration was planned. The temporary crown was made of PLA using the FDM method.

Case 3

A 34-year-old man presented with the main complaint of spontaneous pain emanating from tooth No. 37. Clinical and X-ray examination revealed irreversible pulpitis of tooth No. 37. After the root canal treatment, a gold crown restoration was planned. The temporary crown was made of PLA using the FDM method.

Case 4

A 54-year-old woman came to our clinic for prosthetics of tooth No. 46 after root canal treatment. A restoration with a gold crown was planned, and a temporary crown for the tooth was made of PLA using the FDM method.

Case 5

An 80-year-old man complained of pain coming from tooth No. 14 when biting, difficulty chewing along the entire dentition. On the right first premolar of the upper jaw, irreversible pulpitis was diagnosed. He had long-term abnormal occlusion due to missing teeth Nos. 15, 16, 17, 45, 46, and 47; Therefore, the remaining front teeth had pronounced pathological abrasion, and there was no room for a prosthesis in the lower jaw. Root canal treatment of tooth No. 14 was planned, which was subsequently covered with a crown so that it could be used as an abutment for removable partial dentures. Due to the short clinical length of the crown and low aesthetic expectations, a gold crown was planned, and a temporary crown was made of PLA using the FDM method.

The process of printing each crown took approximately 7 minutes. The workplace was free of noise and dust and kept clean. During the temporary restoration period, which took an average of 7 days, no failures due to fracture or displacement of the temporary crown were recorded, and there were no complaints of discomfort, poor aesthetics or surface roughness (Table 1). Occlusal correction was performed using a prosthesis bur, as is done with a temporary traditional straight polymer crown. However, these cases with single temporary crowns required little to no occlusal correction because there were few protruding points or guide interference.

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Таблица 1.

Характеристики пациентов и трехмерная печать временных коронок

Дело №.	Пол/возраст (год)	Номер зуба.	Время работы (мин:сек)	Неудача временной реставрации
1	Мужчина/59	#15	7:02	Нет события
2	Женский/45	#36	7:12	Нет события
3	Мужчина/34	#37	7:10	Нет события
4	Женский/54	#46	7:08	Нет события
5	Мужчина/80	#14	6:58	Нет события

Открыть в отдельном окне

Рабочее время соответствовало времени, необходимому для изготовления временной коронки.

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