악안면 결손 환자에서 3D printing을 이용한 보철 수복 증례

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Application of 3D printing technology for rehabilitating maxillary defects

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The use of an obturator prosthesis for patients with maxillary defects is a common treatment method to improve their oral function and achieve esthetic satisfaction. However, due to various difficulties and complexities, conventional methods for fabricating dental obturators continue to pose a challenge for dentists and patients, as well as laboratory technicians. CAD-CAM technologies may make it simple to fabricate maxillofacial prostheses including hollow obturators, which could improve comfort for clinicians by reducing burdensome manipulations. In addition, patients without a specialist in their vicinity will be able to be treated via cooperation between a nearby general practitioner and a distant prosthodontist. The aim of this clinical report is to investigate the possibility of using digitally fabricated maxillofacial prostheses that can be designed in one location, and manufactured in another in clinical situations. (*J Korean Acad Prosthodont* 2020;58:349-55)

Keywords: 3D printing; Obturator prosthesis; Remote dental service

Introduction

Cancer, trauma, and certain congenital factors may result in maxillofacial defects, which may lead to physical dysfunctions and esthetic complications. In case involving damage to the maxillofacial region, an obturator prosthesis is required to restore masticatory function, improve pronunciation, and prevent inhalation of food.¹⁻³

CAD-CAM technology for dentistry has advanced over the past 20 years and such technology has been widely researched and applied in clinical practice across the entire field of dentistry. Computer aided technologies allow for more accurate and effective processes that

could reduce the burdensome steps of both chairside and laboratory work, and save working time.^{4,5} The application of these technologies continues to increase in implant, fixed prosthodontics and is expanding to removable, maxillofacial prosthodontics.⁶⁻⁸

Fabricating maxillofacial prostheses using conventional methods is a complex and stressful process for both clinicians and patients. The fabrication of a well-adjusted, light weight prosthesis is also a challenging and time-consuming process for laboratory technicians. Therefore, maxillofacial prosthetic treatment is regarded as a specialized field of prosthodontics. CAD-CAM technology may provide an innovative approach to overcome the inherent drawbacks of

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conventional fabrication of maxillofacial prostheses. Manufacturing processes may become easy and simple by the use of computer-aided procedures that can reduce the complex manipulation such as wax-up, flasking and capping. The potential for duplicating an existing obturator or repairing a fractured prosthesis without multiple clinical steps and visits provides additional advantages. Moreover, it might be possible for patients without a prosthodontist in their vicinity to be treated in cooperation between a general practitioner and a distant prosthodontist.

In the following cases, patients with ill-fitting obturators covering maxillary defects visited the department of prosthodontics, Ewha Womans University Mokdong Hospital in Korea. These patients' data which were obtained in Korea were sent to the department of removable prosthodontics in Tsurumi University, Japan where they were used for new obturator designs. Design data were sent back to Korea to fabricate obturators, which were delivered to the patients. The purpose of this study is to explore the application of CAD-CAM technology in maxillofacial prosthetic treatment and to identify the possibilities of providing remote dental service via cooperation among distant clinicians.

Clinical reports

Patient 1

A 90-year-old Korean woman with an ill-fitting maxillary obturator was referred to the Department of Prosthodontics in Ewha Womans University Mokdong Hospital. The patient presented with a history of squamous cell carcinoma on the left maxilla for which she had undergone a hemimaxillectomy approximately 10 years ago (Fig. 1). She asked for a new obturator with better stability and comfort. Since she had no problems with her existing mandibular complete denture, it was decided that this denture would be kept.

Preliminary impression was made with irreversible hydrocolloid impression material using the existing obturator (Fig. 2A). An individual tray was made, and maxillary final impression was obtained using polysulfide (Permlastic; Kerr, Orange, CA, USA) (Figs 2B and 2C). The patient's jaw relationship and occlusal vertical dimension were registered using an occlusal wax rim. The maxillary master cast and the opposing complete denture, as well as the interocclusal record of the occlusal rim, were scanned using a desktop scanner

Fig. 1. Initial clinical and radiographic view of patient 1. (A) Maxillary occlusal view, (B) Panoramic radiograph.

Fig. 2. Impression procedure of Patient 1. (A, B) Individual tray was made from patient's existing obturator, (C) The maxillary impression was obtained using polysulfide.

(Identica Blue, Medit Corp, Seoul, Korea).

The patient's computed tomography images (DICOM file) and model scan data (stereolithography, STL) obtained in Korea were sent to Tsurumi University in Japan. A maxillary obturator was designed in Japan using digital design systems that included modeling software (ZBrush, Pixologic, Los Angeles, CA, USA) and measuring software (SpaceClaim, SpaceClaim Corp, Concord, MA, USA). The bulb portion of the virtual obturator base was hollowed leaving a 5mm wall thickness all around. The finalized designed data were sent back to Korea (Fig. 3).

In Korea, the base of the maxillary obturator and artificial teeth were 3D printed with printable PMMA (NextDent Base, NextDent C&B, NextDent, Soesterberg, Netherlands) using a DLP (digital light processing)-based 3D printer (Bio3D W11, Bio3D Inc., Seoul, Korea) (Fig. 4A). Each artificial tooth was printed separately. The supports of the obturator base and the artificial teeth were removed, and the 3D prints were cleaned in alcohol solution for 10 minutes to remove the excess uncured resin. Each tooth had indentation made with round bur, and it was bonded into the socket with a liquid pink colored resin (Dentca denture base, Dentca Inc., Torrance, CA, USA), and light-cured for 30 seconds. The assembled obturator was then placed in the post curing machine (LC 3DPrint Box, NextDent, Soesterberg, Netherlands) for final curing

The completed new obturator adjusted was delivered, patient's comfort and esthetics as well as speech were evaluated (Figs 4B and 4C). The patient felt that her new lightweight hollow obturator was comfortable, but slight occlusal adjustment was required. Speech and language assessment was conducted in the Speech and Phonetic Evaluation Center of Ewha Womans University Mokdong Hospital by U-TAP (Urimal test of articulation and phonation) method.⁹ The patient was asked to read 30 Korean words with and without the obturator, and the accuracy of the individual phonemes of each word was evaluated for consonants and vowels. This evaluation showed that the accuracy of consonants was 67.44% without the obturator but 100% with the obturator (Table 1). In addition, the obturator enhanced the resonance of the oral and nasal cavities when the patient was evaluated with a nasometer. (Nasometer II 6450®, KayPENTAX, Lincoln Park, NJ, USA).

Table 1. Speech and language assessment of patient 1

	Without obturator (%)	With obturator (%)	Threshold (%)
Nasal sound			
Continuous /e/ vowel	80	67	32.0
Oral sound sentence	39	14	11.4
Accuracy of consonants	67.44	100

Fig. 3. Hollow obturator designed in Japan. (A) Denture base, (B) Denture teeth, (C) Obturator designed with hollow bulb.

Fig. 4. 3D printing of the obturator in Korea. (A) Printing of the obturator base, (B, C) Definitive maxillary hollow obturator.

Patient 2

A 26-year-old Korean woman with an uncomfortable maxillary obturator visited Ewha Womans University Mokdong Hospital. The patient presented with a history of mucoepidermoid carcinoma on the right maxilla for which she had undergone a hemimaxillectomy approximately 5 years ago. Her palatal defect had decreased over time, leading her to feel uncomfortable with her old obturator. With the exception of the defect area, she had complete dentitions (Fig. 5).

Similarly to the first case, a CT was performed and a stone model was created using conventional methods. The master casts and the patient's interocclusal records were scanned using a desk top scanner (Identica Blue, Medit Corp., Seoul, Korea). The patient's CT data (.dcm) and all the scan data (.stl) were sent to Japan for the design of a new obturator.

The scanned model was virtually surveyed, and an obturator was designed using the same systems (Z-brush, SpaceClaim) utilized for the first patient. The virtually designed obturator consisted of a metal framework, bases, and artificial teeth (Fig. 6). As the surveyed crowns were already existed on the left second premolar and the first molar, the rest and the clasp were designed on these teeth. After the design was confirmed by clinicians from both countries, the finalized designed data (.stl) were transferred to Korea.

The metal framework was built with cobalt-chrome (Co-Cr) powder (EOS CobaltChrome, EOS GmbH, Krailling, Germany) using an additive manufacturing machine (MetalSys 250, WinforSys, Yongin, Korea) (Fig. 7A). Support structures were removed and finishing and polishing accomplished in the same manner as conventionally manufactured frameworks. Using a DLP-based printer (Bio 3D W11, NextDent, Soesterberg, Netherlands), the bases of the obturator (tis-

Fig. 5. Initial clinical and radiographic view of patient 2. (A) Maxillary occlusal view, (B) Panoramic radiograph.

Fig. 6. Obturator was designed in Japan. (A) Metal framework, (B) Resin base on polishing part, (C) Obturator design with teeth, (D) Resin base on tissue side.

Fig. 7. 3D printing of the obturator in Korea. (A) Printing of the metal framework, (B) Printing of the obturator base, (C) Printing of the obturator teeth.

Fig. 8. Definitive prosthesis of patient 2. (A) Polished surface of the obturator, (B) Tissue surface of the obturator, (C) Maxillary occlusal view of patient 2 after obturator delivery.

sue part and polishing part) and artificial teeth were printed with 3D printable PMMA (NextDent Base, NextDent C&B, NextDent, Soesterberg, Netherlands) (Figs 7B, 7C, and 7D). They were cleaned in alcohol solution for 10 minutes.

The obturator bases (tissue part and polishing part) and metal framework were seated over the master cast for bonding. The metal primer was applied to the mesh part of metal framework and it was bonded with obturator bases with liquid pink resin (Dentca denture base, Dentca Inc., Torrance, CA, USA). As in the first case, the artificial teeth were bonded to the obturator base with pink resin. In this case, with the help of metal printing, the entire fabrication process was performed using CAD-CAM.

The new obturator was delivered and evaluated (Fig. 8). The occlusal rest and the posterior palatal area fitted well, but premature contact occurred in the molar areas, therefore, occlusal adjustment in the patient's mouth was required.

Discussion

An increasing number of reports that compare conventional and digitally fabricated prostheses are being published.^{7,10,11} However, there are still only a small number of such studies, with even fewer investigations addressing the use of additive manufacturing for removable and maxillofacial prostheses. The possibility of complete denture fabrication using additive manufacturing has been reported, but technological advancement is still required.^{12,13} Additive manufacturing offers various advantages over the conventional or milling methods. It offers reduced labor and speed when compare to conventional method, and material waste can be reduced compared to milling method. However, the high cost associated with 3D printers could be hindrance to smaller dental laboratories. Moreover, these systems require adequate operator training, as well as prior knowledge of traditional fabricating methods.¹⁴ Alharbi also stated that

although additive manufacturing offers new possibilities in prosthodontics, its application remains limited, and its accuracy and effectiveness should be verified.¹⁵

The current article describes the digital fabrication of obturators by an additive manufacturing method involving digital light processing (DLP) and selective laser melting (SLM). A previous *in vitro* study reported that a denture base produced using DLP showed better tissue surface adaptation than those generated using a milling method or the conventional pack- and- press method.¹⁶ In the present case report, tissue adaptation of the palatal area including the defect was also fair and patients were satisfied with their new obturators, which exhibited improved sealing. Particularly in the first case, the hollow obturator was fabricated relatively simply and easily using the additive manufacturing, such simplicity and ease would not have been possible with the milling method. Additive technology permits manufacturing of an object regardless of its dimensional complexity and quantity.^{15,17}

In the second case, the metal framework was printed using SLM, which is one type of PBF (powder bed fusion) technique.¹⁴ Although SLM has the advantage of allowing the printing of complex designs, it also has drawbacks, for instance, pores, cracks, and incomplete fusion may be observed if the designed thickness is too thin.¹⁸ The initial framework design of the second patient had to be revised since the framework's minor connector and clasps were designed to be overly thin, which led to incomplete printing. Trial and error involving several attempts indicated that a thickness of at least 0.4 mm was required for the metal framework to be successfully printed. Since direct bonding of metal framework and the resin base is difficult, we expected the adhesion of the two resin bases, the polishing and the tissue side, and the mesh part of metal framework was between these two. Premature contact occurred in molar areas in the second case, therefore, occlusal adjustment in the patient's mouth was required. A technical error was thought to have occurred when using pink resin

to bond each artificial tooth to the resin base and the resin base to the metal framework. The possibility of error increases as the number of steps of manual laboratory work increases.

The patients were observed during the clinical check periods at 1 and 4 weeks and informed to return for checkups at 6-months intervals. For both patients, the obturators worked well through 6 month of follow-up, but long-term follow-up is needed to confirm these results.

The whole process did not yet appear to be much better than the conventional method, and the overall fit of the obturators showed room for improvement. Due to the limitations on intraoral scanning of maxillary defect areas, in each case, a definitive impression was obtained in a conventional manner to make a stone cast. Laboratory work such as adjusting and polishing the metal framework and bonding the printed teeth to the base was inevitable. Further development is expected to overcome these limitations, possibly allowing all steps, including digital surveying, prosthesis design and prosthesis manufacture, to be accomplished using only intraoral scanned data, without requiring a stone model. If these were to be realized, true remote dental service would be possible.

Conclusion

In this clinical report, both patients' maxillary defects were successfully restored with 3D printed obturators that were designed in Japan and fabricated in Korea. The obturators were fabricated successfully using a CAD-CAM process that can reduce the time-consuming and complex procedures and relatively simple manipulations. These cases display the potential of treatment via cooperation among distant dentists and suggest the promise of advancement in the field of maxillofacial prostheses with the help of CAD-CAM technology.

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악안면 결손 환자에서 3D printing을 이용한 보철 수복 증례

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외상, 구강암, 선천적 요인 등에 의한 구강 결손시 음식물의 섭취, 흡입성 폐렴 방지, 안모 지지를 위하여 치과용 obturator가 제작된다. 그러나 기존의 전통적인 인상 채득 방법을 이용한 obturator제작 시, 제작 과정에서 술자와 환자, 기공사 모두 번거로운 과정을 거쳐야 하며, 환자는 악안면 보철 치료가 가능한 치과 보철 전문의가 있는 병원을 찾아 방문해야 하는 어려움이 있다. 그러나, 3D printing을 포함한 CAD-CAM 기술을 이용하면 비교적 간단하게 hollow obturator를 제작할 수 있고, 보철 전문의가 없는 지역에서도, 지역 치과의사와 멀리 떨어져 있는 보철 전문의 간의 협진을 통해 수월한 치료가 가능할 수 있다. 본 연구에서는 한국의 상악 구개 결손 환자들의 치료를 위해, 일본에서 obturator를 디자인하고 한국에서 3D printing하여 성공적으로 obturator를 제작하였고, 더불어 원격 치료의 가능성을 확인하였기에 보고하는 바이다. (대한치과보철학회지 2020;58:349-55)

주요단어: 3D 프린팅; 폐색장치; 원격 치료

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