Technical procedure

Denture flask fabrication using fused deposition modeling three-dimensional printing

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1. Introduction

There are two ways to digitize a complete denture: milling and printing [1]. Although many studies have reported the superiority of digitally fabricated dentures [2–4], they have also reported limitations of the materials used [5]. In particular, the material used for printing is weaker than the denture base resin or artificial tooth material used in the past [6]. Moreover, materials used in three-dimensional (3D) printing are more difficult to develop than those used for milling [7]. In addition, even if a good 3D printing material is developed, significant time and effort will be required before it is approved for clinical use. Therefore, it is currently necessary to use conventional materials to fabricate a satisfactory complete denture despite the use of these materials being difficult to integrate with digital methods.

To overcome this limitation, we have introduced herein a new technique for manufacturing a digitally fabricated denture. Most digitally fabricated dentures are produced by digitizing the dentures themselves [8–11]; however, in this procedure, digitization is applied to the flask used in the analog denture manufacturing process. Subsequently, the conventional process of creating a complete denture was followed. The digitized flask produced a predictable complete denture. The protocol, including the sequential processes involved in manufacturing the digitally fabricated denture, is described below.

2. Materials and methods

2.1. Design of 3D-printed denture flask

First, a digitally fabricated complete denture was designed using dental CAD software (exocad Dental-CAD; exocad GmbH, Darmstadt, Germany) according to the manufacturer’s instructions and extracted into a Standard Tessellation Language (STL) file. Universal development system software (Rhinoceros Version 5 SR11 64-bit [5.11.50203.14395, 2015-02-03]) was used to create the digital flask with the designed complete denture (Fig. 1). Artificial teeth and fused deposition modeling (FDM) printing of a digital flask involve production errors. In particular, the certification criteria for ready-made artificial teeth are specified to be within 5%
of the size suggested by the manufacturer. Therefore, an offset value was required for this novel denture production protocol. To perfectly combine the denture base with the artificial teeth using the conventional complete denture method, the offset value was set to 200 μm using the offset mesh command (Fig. 2). A denture base with no offset, teeth with 200-μm offset, and teeth/base STL files were used to design the 3D-printed flask. The denture file and a pre-designed conventional flask file were then superimposed. At this time, the flask was set with a column for fixing the upper and lower flasks and an injection port for inserting the autopolymerizing resin. The Boolean split function was used to remove the overlap between the denture and the flask to create an empty space for the denture base and the artificial teeth (Fig. 3). The output file was obtained using an FDM 3D printer (Cubicon Style-210D; Cubicon Inc., Seongnam, Korea) and filaments (100-μm stacking pitch, 1.75-mm thickness; 100ABS_A100; TLC Korea, Wonju, Korea), and the upper and lower flasks were checked to ensure their accuracy (Fig. 4).

2.2. Denture fabrication using 3D-printed denture flask

The procedure for fabricating the complete denture followed the conventional method. Since the flask was designed for a denture, the appropriate artificial teeth were selected and placed in their respective positions (Fig. 5). The upper and lower flasks were then combined, and the autopolymerizing resin (Castdon; Dreve Dentamid, Unna, Germany) was used; hence, there was no deformation by heat and pressure. This mixed resin was subsequently poured into a preset resin injection port according to the manufacturer’s instructions [12]. The denture fabrication procedure followed the manufacturer’s instructions; the material was allowed to flow at 45° for 15 min. The denture was finally removed from the 3D-printed flask using a heavy wire cutter to twist and pull it, and the denture was finished and polished (Figs. 6 and 7).

3. Difference from conventional methods

The 3D-printed flask described in this paper was created using a novel manufacturing method that differs from the method used for
a conventional flask made from a mold. While the conventional metal flask is simply a tool that blocks the gypsum and artificial resin teeth, this 3D-printed flask was digitized with a digitizer and converted into a customized flask. Therefore, the process of making the flask also almost completed the denture fabrication process.

The 3D-printed flask can also be freely adjusted in size, making it possible to produce a large-sized denture that conventional mold flasks cannot hold [13]. In addition, conventional mold flasks have a fixed size; depending on the denture, a large amount of gypsum may be required. However, the 3D-printed flask requires no gypsum because the space around the denture is completely filled with the printing material, saving both material and time. Furthermore, for similar reasons, resin, as the 3D printer material, is very economical and capable of rapid output; hence, it is now widely used in digital technology.

Digital flask fabrication can lead to considerably more uniform results than traditional flask fabrication methods that differ among techniques. Therefore, the process for producing a 3D-printed flask will be successful even if not performed by a skilled dental technician. Hence, the 3D-printed flask can be easily manufactured to fabricate dentures with consistent quality.

4. Effect or performance

Many dental prostheses are currently being manufactured using digital technology [14,15]. However, many dentists and technicians still fabricate prostheses using conventional analog methods because it takes time to introduce new technologies and the cost of introducing digital equipment is high [16,17]. In this transitional phase, combining existing and digital methods can be very useful.

From this perspective, here we described a method for 3D printing of the flask that is used in the conventional method. As reported in various publications, the main problem with using 3D printing is the development of biocompatible materials [18]. In contrast, the method described in this study involves the use of conventional resin material and artificial teeth that have been in use for a long time, making it possible for many dentists to create reliable dentures. In addition, the 3D-printed flask can be manufactured at a much lower cost than that involved in creating a conventional flask using a mold.

In this study, the flask was created using FDM-based 3D printing because it was more cost-effective than other printing methods. This is clinically sufficient time compared to the time required for the conventional method. In addition, the 3D-printed flask showed satisfactory results in terms of the completeness of the complete dentures. The denture manufactured using this protocol showed a root mean square value of about 200–300 μm compared with the original STL file (Fig. 8). In a previous study, compressive mucosal displacement due to the denture baseplate has been reported as 375–500 μm [19]. Therefore, it is considered that these protocols have satisfactory clinical results. In this protocol, we used a cost-effective printer; thus, it took about 7 h to make the 3D-printed flask. However, if a faster printer is developed, it would be possible to create complete dentures much more rapidly. This novel method can also be applied to new denture fabrication at any time. Therefore, this method is very efficient for creating complete denture prosthetics.
5. Conclusion

In this study, a flask was fabricated by FDM 3D printing for the preparation of complete dentures. With this method, we can use digital denture CAD design and existing denture materials. This method permits application of the advantages of the repeatable digital approach while discarding the doubtful materials used in digital production.

Conflict of interest

The authors have no financial conflicts of interest.

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