Rapid Prototyping Use in Prosthodontics

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ABSTRACT

Rapid prototyping (RP) methods have been applied by dentists in the modeling of oral and maxillofacial surgery and implantology. This method is becoming increasingly appealing in the fabrication of dental prostheses as new research on molding materials and the forming process of RP techniques emerges; yet, few researchers have published material on the RP technology of prosthesis pattern production. This article examines and explores the use of RP techniques in prosthodontics, including (1) the creation of wax patterns for dental prostheses, (2) the creation of dental (facial) prosthesis molds, (3) the creation of dental metal prostheses, and (4) the creation of zirconia prostheses. Through a variety of dental prosthesis production methods, a large number of people could profit from this innovative technology. In the near future, RP approaches may also alter current prosthodontic procedures.

Keywords: Rapid prototyping; prosthodontics.

INTRODUCTION

Since the 1990s, rapid prototyping (RP) techniques—also known as solid freeform fabrication (SFF) or layered manufacturing—have been used in medicine to create intricate 3D models. [1-4] The fundamental benefit of RP techniques is the ability to produce medical models with undercuts, voids, and intricate interior geometries like sinuses or neurovascular canals. [5] The RP model is now primarily utilized for a better, more economical medical diagnosis and precise surgical planning, which speeds up the procedure and greatly lowers patient risk. [6,7]

The molding material and the forming process have seen remarkable advancements in RP method research in recent years. This technique can now be utilized to create actual functional parts rather than just prototypes. As a result, RP is drawing increased interest for dental applications. Dental prostheses like copings, crowns, and fixed partial dentures can be designed, developed, and produced using RP processes (FPDs).

Numerous studies have concentrated on data collection using various 3D scanning tools and computer-aided design (CAD) elaboration for the design of the prosthesis; nevertheless, publications on the use of RP technology for prosthesis pattern production are still uncommon. In this article, we examine the prosthodontic applications of RP procedures. We concentrate mainly on the creation of metal prostheses (including FPDs and framework for removal partial dentures [RPDs]), all-ceramic crowns, wax patterns for prostheses, and casts for prostheses.

Dental prosthesis wax pattern fabrication

Making the wax pattern is traditionally the most difficult and important phase in creating porcelain-fused-to-metal crowns, pressed ceramic crowns, and RPD frameworks. The quality of the wax-up in this time-consuming task depends on the individual's competent labor.

Application of RP has four benefits. The first benefit is a high rate of output. The dental laboratory can readily produce more than 150 units per hour using RP procedures. The second benefit is the wax copings' quality control, which produces a highly precise fit and constant wall thickness. Reduced spruing time is the third benefit. The reduced amount of finishing required on cast copings is the final benefit. Inconsistencies in wax coping thickness can be avoided because they often need more work to finish the metal after casting. [8,9]

After RP fabricates the wax pattern, the conventional lost-wax procedure is still required. The procedure is less expensive than direct manufacturing methods like laser melting or sintering, which are still out of most dental laboratories' price ranges.

Rapid prototyping of dental (facial) prosthesis mold (shell)

Mold (shell) for metal casting

In contrast to traditional casting production techniques (which include building tooling and pouring a casting), ceramic molds for metal parts can be made immediately from CAD models. On a computer screen, these molds are made utilizing RP procedures.

Curodeau et al. cast functional orthopedic implants made of a high-resistance cobalt-chrome alloy using ceramic molds with incorporated surface macrotextures created using 3DP. [10] Most of the labor- and time-intensive steps of the conventional investment casting process are eliminated by RP methods. Additionally, they avoid the requirement for wax and core tool design and production, wax and core molding, wax and core assembly, shell dipping and drying, and wax removal.

Mold for facial prosthesis

A facial prosthesis has been successfully created using RP techniques over the previous ten years. [11-16] Although conventional flasking and investing techniques were still required to create the actual prosthesis, pattern manufacturing by RP has been successful. It has been suggested to use cutting-edge CAD and RP techniques to create the facial prosthesis' negative mold, which will be used to cast the prosthesis directly in silicon. After the design and fitting phases, a CAD model of a mold is produced using the prosthesis computer model as a reference rather than producing a positive RP pattern of the prosthesis.

The actual prosthesis is cast in polyurethane, medical-grade elastomer, or elastic materials using the created mold. In order to create a fresh STL file for the mold design, Ciocca et al. created a negative volume (of a designed.STL file) of the external ear. The real prosthesis' silicon mold was subsequently created via three-dimensional printing. [17]

Mold for complete denture

The field of designing and manufacturing a complete denture with a computer has only produced ten publications (published in the previous 20 years). Because there aren't many studies in this area, it's clear that sophisticated manufacturing technology hasn't been successfully used there. [18-20] A unique CAD and RP technology was created by Peking University researchers to create customized flasks (molds) for a complete denture.

Five entire dentures have been successfully designed and made by this method, despite the fact that it is still in the experimental setup phase. The dentures had a good fit and were in a central, balanced occlusion on the edentulous plaster models. To further enhance the system, laboratory quantitative testing and clinical studies should be carried out.

Direct dental metal prosthesis fabrication

In a dental prosthesis clinic, metal prostheses are frequently employed. The conventional procedure for creating a metal prosthesis is called lost-wax casting. The fabrication, embedding and burning out of the wax pattern, metal casting, and post-processing are some of the several manual procedures that make up this method's lengthy and labor-intensive process. A metal prosthesis can now be milled (in accordance with the CAD design) thanks to the development of CAD/CAM milling systems; nevertheless, this milling procedure is time-consuming and exposes the milling tools to significant wear. Additionally, the majority of the material is wasted, and creation of intricate forms like the RPD's framework is constrained by space constraints. [21,22]

Researchers have recently paid close attention to RP technology, particularly selective laser melting (SLM) and selective laser sintering (SLS) technology, for its quick manufacture of high-precision metal parts with various materials and geometries. [23] Due to their intricate geometry and the ease with which they may be altered without requiring time-consuming manual pre- or postprocessing, dental prostheses are excellent candidates for processing with SLS/SLM.

This proposed CAD/RP technology offers an effective and quick way to digitally design and manufacture biocompatible metal frameworks for complicated dental prostheses, even if optimization research of the processing parameters and clinical applications is still required.

All-ceramic restoration fabrication

Commercial dental CAD/CAM milling systems have recently been released with success for specialized industries like all-ceramic restorations. Zirconia ceramics were able to be used as a standard material for dental prosthetic restorations thanks to these milling systems; however, the drawback of this system is the significant amount of raw material waste because the leftovers from the monoblocks after milling must be thrown away and recycling the extra ceramic material is not practical.

The so-called generative manufacturing processes used in RP show promise for addressing the aforementioned shortcomings. [24-26] It has been suggested to use direct inkjet fabrication to create green zirconia all-ceramic dental restorations using a slurry microextrusion method. [27] The printing of a suspension with a high solid content of zirconia powder and drop-on-demand inkjet printheads is possible with the direct inkjet system. The appropriate solids loading, pH level, and drying rate of the slurries after delivery determine their ideal pseudoplastic and extrusion behavior.

The slurry can be extruded at low extrusion pressure and with good shape-keeping capabilities thanks to this control. The extrusion parameters, such as the nozzle size, extrusion rate, nozzle traveling speed, and distance between the nozzle head and the substrate or the previously delivered layer, also have an impact on the restoration's dimensional correctness. [28-30]

It remains to be researched and developed how to create unique zirconia powder slurries with proper rheological behavior and extrusion conditions, as well as how to optimize the drying process and create a customized multiple-stage sintering method.

Conclusion

Although RP procedures have been widely used in dentistry, prosthodontic applications of RP are still rather uncommon. The use of RP techniques in prosthodontics was covered in this article. Dental prostheses can be quickly and easily manufactured layer by layer from a computer model using a variety of RP processes without the need for part-specific tools or manual labor. This method completely alters how dental prostheses are made. It is feasible to produce various dental prosthesis for various applications by developing and researching the diversity of RP systems and the suitably constructed materials. The dental prosthesis wax pattern, dental (facial) prosthesis mold (shell), dental metal prosthesis, and ziconia prostheses are a few examples of these applications. In our opinion, RP methods are becoming more significant in the field of prosthodontics and will soon be one of the key technologies used in the digital manufacturing of dental prostheses.

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