Title: Resistance to fatigue and to fracture of 3D-printed and CAD-CAM hybrid resin restorations fabricated on different preparation designs with digital impressions

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Background

The term "stereolithography" was introduced for the first time in 1986 by Charles W. Hull, who defined it as a method for manufacturing solid objects by subsequently printing thin layers of an ultraviolet curable material one on top of the other.

A concentrated beam of ultraviolet light is focused on the surface of a vat filled with liquid photopolymer and, while the light beam draws the object onto the surface of the liquid, each time a resin layer is cured or cross-linked. The object is constructed layer by layer, to create a solid object.

The production process follows the following scheme:
- A 3D model of the object is generated with a CAD program.
- A software divides the CAD model into many thin layers, which can be from 5 to 20 layers per millimeter. A higher number of layers improves resolution.
- The laser scans the liquid resin in the tank and sets itself, thus creating the first layer.
- The platform descends into the tank a fraction of a millimeter (or less) and the laser scans the next layer.
- This process continues layer by layer until the model is complete.
- Once the process is completed, the objects are rinsed with a solvent to remove the uncured resin and then placed in an ultraviolet ray oven that completely polymerizes the resin.

This process is slow and, depending on the size and number of objects being created, the laser might take a minute or two for each layer.

One of the first applications of additive manufacturing technologies was the production of physical models of the human anatomy based on CT data using SLA. SLA models started to be used in medicine and dentistry for the planning of surgical procedures. SLA is now routinely used to produce surgical guides for the placement of dental implants. Its use is gradually being extended to include the manufacture of temporary crowns and bridges and resin models for loss wax casting.

The accessibility of 3D printers for both industrial and general public use has grown dramatically in the past decade. Global sales that include the devices, materials and services for industrial-scale to consumer-based printers have grown by an annual average of more than 33% over the last three years to a total of $4.1 billion in 2014. These machines and the various polymeric materials are suitable for creating a wide array of surgical guides and other tools as well as for the production of medical model implants, abutments, crowns, bridges and CT-imaged tissue replicas.

While preformed polymeric materials in powder, filament and sheet form are used in 3D printing, several additive manufacturing also utilize the active polymerization of photo-sensitive resins. Since dentistry was an early adopter of photo-curing and remains heavily reliant on photo-polymerization, it is natural that UV or visible light-based approaches to 3D printing will be utilized.
as dentistry takes advantage of this quickly developing technology. In fact, the photocuring as a methodology for 3D printing is particularly attractive for several reasons: high levels of build resolution, smooth part surfaces that do not typically require finishing processes, good z axis strength due to chemical bonding between layers, fast builds possible, and the ability to print clear objects.

Between each layer, the platform is lowered by 50 μm or less in higher resolution applications and 200 μm or more for parts with standard or lower resolution demands. When the part is complete, the excess resin is drained and can be reused. The formed parts are washed to remove excess resin and the support structures are physically removed. Depending on the resin material, a UV flood post-curing step may be included to raise conversion of the photopolymer. 4

3D printable provisional restorative material allows for sufficient mechanical properties for intraoral use but the accuracy is related to the type of 3D printer used.5

Future work utilizing 3D printing systems that allow for optimization of printing parameters as a function of resin of choice should be performed to improve the accuracy of 3D printed dental materials.

Among the advantages of this technology should be mentioned: (1) Finer detail reproduction (undercuts, better anatomy), (2) more economic than milling, (3) more mass production (greater numbers of units), (4) larger objects produced (facial prosthesis), (5) better than passive production (6) can reproduce complex shapes without requiring special tools, (7) unlimited geometry options, (7) faster than milling, and (9) print exactly as designed without waste.6

In the literature, also a study on 3D-printed zirconia dental implant is reported. The authors concluded that the implant showed a flexure strength that was similar to those of conventionally produced ceramics but they emphasized that the optimization of the 3D-printing process is still needed to improve the microstructure of the printed product.7

Silva et al.8 showed that the tolerance of the fabricated workpiece is less than 25μm and stated that this value is acceptable for intraoral application.

New continuous rather than layered printing approaches allow structures of significant size to be printed in minutes and certain biocompatible-grade polymeric materials are approved for in-mouth placement. However, a great amount of work to do still remains before 3D printed polymer-based materials are more widely implemented in dental practice.

Aims

To evaluate the influence of fabrication method (CAD-CAM or 3D-printing) and preparation design on resistance to fatigue and to fracture of hybrid resin restorations.

The final aim of the research is to improve the current knowledge in the field of prosthetic materials produced with 3D printers in order to evaluate a possible clinical application since, currently, the use is limited to orthodontic splints, surgical guides and master dental models.
Research activity of the research fellow

The research activity will be carried out following the present scheme:

1) Choice of the 3D printer model and type of technology based on production costs and analysis of the literature (e.g: DFAB (DWS)).

2) Choice of materials to test with 3D printer among those currently available on the market (e.g: Temporis, Polymer considered a Class IIa long-term invasive medical device (DWS); NextDent, 3D Printing Dental Material (C&B Vertex Dental); Freeprint Temp, Light-curing, biocompatible 3D resin (Detax)).

3) Choice of materials to test with CAD CAM technology (e.g: Polycon, PMMA-based acrylate resin (Straumann); Telio CAD, cross-linked PMMA (Ivoclar Vivadent); VITA CAD-Temp, acrylate polymer material (Vita)).

4) Digital impression (True Definition (3M), Trios (3Shape)) of resin teeth before preparation.

4) Preparation of resin teeth on Frasaco model with different finish line designs (knife-edge (KE), chamfer (C), rounded-shoulder (RS)).

5) Digital impression of prepared teeth and digital design of restorations with a laboratory software.

6) Production of composite/resin restorations with CAD-CAM materials.

7) Production of hybrid resin restorations with 3D printer.

8) Production of epoxy resin replicas of prepared teeth.

9) Application of the cyclic fatigue test (performing 1,200,000 chewing cycles, corresponding to 5 years of clinical service) on restorations.

10) Fracture test of restorations using an Instron universal testing machine.

11) Evaluation of results and dissemination.
REFERENCES


4 Stansbury JW, Idacavage MJ 3D printing with polymers: Challenges among expanding options and opportunities. Dental materials 2016;32:54–64


