International Journal Dental and Medical Sciences Research
Volume 5, Issue 4, July-Aug 2023 pp 92-95 www.ijdmsrjournal.com ISSN: 2582-6018

3D - Printed vs. Heat - Cured Denture Base Materials – Composition and Properties – A Review

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Date of Submission: 05-07-2023 Date of Acceptance: 15-07-2023

ABSTRACT: This research aims to conduct a literature review on comparative studies of heat-cured resins and three-dimensionally printed biomaterials for denture bases in terms of composition, and physical and mechanical properties. As digital dentistry advances, it is becoming increasingly vital to use 3D-printed resin materials for the fabrication of removable dentures. However, more research on existing and developing materials is required to enable advancement and extend their applicability in removable prosthodontics. The articles chosen for inclusion were authored in English and published between 2010 and 2023 on 3D-printed and heat-cured dental resins for removable dentures. A search approach was used, criteria were defined, and 15 studies were chosen to summarize the results. Heat-cured PMMA outperformed 3D printed materials for removable dentures in terms of flexural, bond, and impact strength. 3D printed resins were shown to have superior surface roughness and lower hardness values than conventional materials.

KEYWORDS: 3D Printing, CAD/CAM, Heat-Cured Resins, Removable Dentures, Denture Base Materials

I. INTRODUCTION

The polymer polymethyl methacrylate (PMMA) has been the most extensively utilized material for manufacturing conventional removable dentures. The material offers various advantages, including ease of manufacturing and repair, biocompatibility, good esthetic qualities, and a low cost[1]. As a result, patients' acceptability has increased. Despite this, PMMA has a number of drawbacks, including significant polymerization shrinkage, imbibition, dimensional and color changes over time, and allergy reactions caused by monomer leaching [2]. Additive manufacturing (AM), often known as three-dimensional (3D) printing or rapid prototyping (RP), refers to processes for layer-by-layer fabrication of items. Despite its recent arrival, 3D printing has shown promise in a variety of sectors, including engineering and medicine, notably dental medicine [3]. Resins, composites, metals, ceramics, biomaterials, and food ingredients are among the 3D printing materials available[4].

Since its inception in the 1980s, digital dentistry has transformed the practice of dentistry in many areas [5,6]. The first attempt was to create a computer-aideddesign/computer-aided manufacturing (CAD/CAM) system capable of producing fully detachable prostheses. CAD/CAM technology has recently been used to construct several types of prosthetic restorations, including implants and full dentures [7].

This study aims to conduct a literature review on comparing heat-cured resins and three-dimensional printed biomaterials for denture bases in terms of composition, characteristics, fabrication procedures, and clinical performance.

Acrylic resins absorb water and steadily expand over time. This equivalent extension, which is stated in three dimensions, is critical. According to ISO standard (ISO 20795-1: 2013), the expansion of acrylic resin is proportional to the time spent immersed in water until equilibrium is established [8]. The mean equilibrium water content (saturated water content) must not, however, exceed 32 g/mm3. Water absorption can also release intrinsic tensions that have developed during the production of acrylic plastic, primarily heat-curing, and a change in the shape of the prosthesis is possible. Constant wetting and drying of the detachable plastic prosthesis should be avoided because it causes material aging and can result in prosthetic structural deformation [7].

II. MATERIALS AND METHODS

The methodology included using a search strategy, identifying relevant research, and forming information to summarize the results. "Denture", "Removable Dental Prostheses", "Removable Denture", "Complete Denture", "Three-dimensional printed", "CAD/CAM", "CAD-CAM", "Computer Aided Design and Computer Aided Manufacturing", "Milled", "3D Printed" OR "Printed" and "Digital Denture" were the search terms utilized.

This review's search technique included three stages: examining titles, abstracts, and the final selection of publications for full-text analysis. Articles chosen from the database search were individually sorted by four reviewers, and any variations in selection were discussed until a consensus was established.

III. RESULTS

Denture base materials must have a variety of properties, including mechanical strength, chemical inertness, high biocompatibility, and good aesthetic characteristics. Many improvements have been made to PMMA acrylics' physical qualities, durability, technological modes of operation, and processing time[9].

The most common resins for 3D printing are acrylonitrile butadiene styrene (ABS), polycarbonates (PC), polylactic acid (PLA), and polyetherimide (PEI). Polycaprolactone (PCL) is a semi-crystalline thermoplastic resin with about 45% crystallinity[10]. PCLs have mechanical characteristics similar tomedium-density polyolefins[11]. Their elongation at break and elasticity modulus are typical, and their softness and tensile strength are comparable to nylon[12]. PCL has a milky white hue, a medium density, and a waxy texture, comparable to polyethylene. The PCL has a glass transition temperature of around 60 °C and a melting point of approximately 63 °C[13].

Flexural strength, elastic modulus, and fracture toughness are all lower in 3D-printed polymers for denture bases [14]. This can be explained by the combination of 3D-printing resin monomer reactivity and curing conditions, which resulted in a reduced degree of double-bond conversion as compared to standard acrylic resins[15]. A weak interlayer bonding between consecutive printed layers could also account for the reduced mechanical properties[16]. However, the 3D-printed denture base material met ISO flexural strength criteria (65 MPa). As a result, 3D-printed materials can be considered while making denture bases [17].

Because of their transparency and ability to be easily colored to replicate the tissues that they replace, PMMA resins offer outstanding aesthetic attributes. The material must be transparent enough to resemble the look of the tissues it replaces. The plastic must be colorless and able to be tinted or pigmented, and the color or appearance of the material must not alter after manufacture [18].

Denture base materials developed using CAD/CAM technology and 3D printing now have comparable mechanical qualities and dimensional stability to other types of resins and are increasingly applied [19].

This material must also be resistant to volumetric changes under all conditions and not vary in size over time. Acrylic polymers have good volumetric stability if a proper polymerization technique is followed [20]. The volume of the solid polymer of the same type will be 21% less than the original (21% shrinkage) after polymerization of the liquid methyl methacrylate monomer, which is practically unacceptable because there will be a large discrepancy between the volume of the model and the actual size of the future prosthesis. As a result, in practice, a polymer-monomer mixture is used, which has a substantially reduced polymerization shrinkage [21]. Acrylic resins change volume more than injection-molded resins during the polymerization process.

IV. DISCUSSION

In the current paper, a number of articles were investigated, in terms of comparing the composition and properties of 3D-printed and heat-cured PMMA dental resins for removable dentures.

Gad et al. [22] investigated the flexural strength, impact strength, hardness, and surface roughness of 3D-printed denture base resin subjected to heat-cured resins for a removable prosthesis in an in vitro study; 120 specimens were fabricated and divided into two groups: heat-polymerized (Major.Base.20) as the control group and 3D-printed (NextDent) as the experimental group. A universal testing machine, Charpy's impact tester, Vickers hardness tester, and profilometer were used to assess flexural strength

(MPa), impact strength (KJ/m2), hardness (VHN), and surface roughness (m).

The study of Choi et al. [23], investigated the fracture toughness and flexural bond strength of three types of denture-base resins, heat cure, CAD-milled, and 3D printed, as well as four different types of commercial denture teeth (Unfilled PMMA, double cross-linked PMMA, PMMA with nanofillers, and 3D printed resin teeth). All specimens were surface treated, bonded, and processed as directed by the manufacturer. The chevron-notched beam approach was used to accomplish a 4-point bend test. According to the findings, teeth attached to heat-cured denture-base resins produced the best fracture toughness.

According to other authors [24], the color stability of CAD/CAM blocks and 3D-printing resins was studied for discoloration based on material type, colorant type, and colorant immersion length. The authors determined that color variations above the AT (E > 2.25) were observed in all test groups after immersion for 7 days or longer. The authors also discovered that 3D-printed resin had higher water sorption after heat cycling than prefabricated PMMA.

However, the authors demonstrated in the same study that each study material exhibited distinct features, even when employing the same 3D-printing technology [25]. As a result, it was clear that other variables, such as material qualities and output parameters, might influence the water sorption rate of 3D-printing resin.

Due to the limited number of research on the attributes of 3D-printed resins, such as water sorption, surface roughness, and hardness, prior to their inclusion in routine clinical practice, there was no significant comparison of the current findings with earlier data.

V. CONCLUSION

Three-dimensional printing has begun to enter and play a significant role in esthetic dentistry because the technique is used for manufacturing prosthetic restorations made from various materials and the production time is significantly reduced compared to the traditional heat-cured polymerization process. Poor esthetics and retention, inability to balance occlusion, and limited printer resolution are all limitations of 3D printed materials. Heat-cured PMMA outperformed 3D printed materials for removable dentures in terms of flexural, bond, and impact strength. 3D printed resins were shown to have superior surface roughness and lower hardness values than conventional materials.

Funding
This research was funded by Medical University of Plovdiv, Bulgaria.
Institutional Review Board Statement
Not applicable.
Data Availability Statement
Not applicable.

Acknowledgments
We are grateful for the support of Medical University of Plovdiv and the CAD/CAM Center of Dental Medicine, Research Institute, Department of Prosthetic Dental Medicine, Faculty of Dental Medicine, Medical University of Plovdiv, Bulgaria.

Conflicts of Interest
The authors declare no conflict of interest.

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