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A Comparative in Invitro Investigation of Aging Effects on Colour Stability and Fracture Toughness of 3D Printed Interim Restorations

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ABSTRACT

Advancements in digital dentistry have revolutionized the fabrication of interim restorations, with 3D printing technologies offering enhanced precision, efficiency, and customization. This study compares two prominent 3D printing methods—stereolithography (SLA) and digital light processing (DLP)—to evaluate their dimensional accuracy and color stability in the production of provisional dental restorations. Thirty samples were digitally designed using Exocad and printed using SLA and DLP technologies. Dimensional accuracy was assessed through high-resolution 3D scanning and best-fit alignment in Geomagic Control X software, while color stability was tested by immersing the restorations in turmeric and coffee solutions for seven days, followed by spectrophotometric analysis. Results indicated that both SLA and DLP produced restorations with comparable dimensional fidelity and color resistance, with no statistically significant differences. These findings suggest that both printing technologies are clinically reliable and can be chosen based on workflow needs without compromising restoration quality.

Keywords: *D printing, Interim restorations, Stereolithography (SLA), Digital light processing (DLP), Dimensional accuracy, Color stability, Additive manufacturing, Digital dentistry, CAD/CAM, Provisional restorations*

INTRODUCTION

The way dental restorations are designed and made has changed dramatically in recent years because of developments in digital dentistry. Among these developments, 3D printed interim restorations have drawn a lot of interest due to their potential to improve dental procedures' accuracy and efficiency.

In the past, chairside milling or laboratory-based procedures were used to produce interim restorations. These methods frequently involved several patient visits and took a significant amount of time. Nevertheless, the development of 3D printing technology has brought about a paradigm change in the restorations' manufacturing process, providing a more efficient, precise, and adaptable option. Dental practitioners may now create high-quality interim restorations with better fit and aesthetics in a fraction of the time by utilizing digital scanning, computer-aided design (CAD), and additive manufacturing techniques.

By cutting down on waiting times and appointment schedules, the use of 3D printing in interim restorations improves patient satisfaction while also providing exact control over the form, size, and color of the restoration. This creative method lays the groundwork for a new benchmark in restorative dentistry by bridging the gap between current dental practices and totally digital workflows of the future. The significance of 3D printed interim restorations in contemporary dental practices is highlighted by the growing evidence of their potential to enhance patient satisfaction and outcomes.

Two sophisticated 3D printing methods, noted for their extreme precision and capacity to create minute features, are stereolithography (SLA) and digital light processing (DLP). These methods employ light to convert liquid resin into solid structures. SLA creates the required shape by tracing the cross-section of each layer on the resin surface and curing the resin selectively with the help of a laser beam. Because of its high level of accuracy, this technique is perfect for projects like jewelry, dental models, and delicate prototypes that call for minute details and flawless surface finishes. By using a digital light projector to flash a complete layer's picture at once, DLP, on the other hand, cures the resin all at once. This method enables DLP to achieve great resolution and detail at a faster rate than SLA, especially for bigger or multiple prints. In domains where accuracy and speed are crucial, such as dentistry, medical, and engineering, both SLA and DLP are extensively employed. They are well-liked options in the field of additive manufacturing because of their capacity to create intricate, high-quality parts.

Various studies have investigated and compared 3D printed interim restorations with either milled or chairside material, but not enough data comparing the two methods of printing itself. Therefore, this study aims to compare aging effects on colour stability and fracture toughness of SLA and DLP 3D printed interim restorations.

MATERIALS AND METHODS

This study aimed to evaluate the dimensional accuracy and color stability of provisional restorations fabricated using two different 3D printing technologies: stereolithography (SLA) and digital light processing (DLP). A total of 30 samples were divided into two groups of 15 each, with one group produced using SLA technology and the other using DLP. The designs of the provisional restorations were created using Exocad software, ensuring uniformity in design parameters such as dimensions, contours, and occlusal morphology. This Exocad design served as the control reference for subsequent dimensional accuracy evaluations.

After finalizing the designs, the provisional restorations were printed using SLA and DLP 3D printers under manufacturer-recommended settings. The printed restorations underwent standard post-processing procedures, including cleaning to remove residual resin, curing to enhance material properties, and polishing to refine surface finish. Each sample was carefully handled to ensure consistency in preparation.

To assess dimensional accuracy, the post-processed restorations were scanned using a high-resolution 3D scanner to generate STL files for each sample. These STL files were then imported into Geomagic Control X software, alongside the original Exocad design file, which served as the control. In the software, the STL files of the printed restorations were superimposed onto the Exocad design using a best-fit alignment algorithm. This process allowed for a detailed comparison of the printed restorations to the control design. Parameters such as deviations in surface contours, volume, and overall alignment were recorded and analyzed to quantify the dimensional accuracy of the SLA and DLP technologies.

For the evaluation of color stability, the provisional restorations were subjected to immersion tests in two staining solutions: turmeric water and coffee water. The turmeric solution was prepared by dissolving a standard amount of turmeric powder in distilled water, and the coffee solution was made by dissolving instant coffee granules in distilled water, ensuring equal concentrations. Samples were evenly divided into two subgroups and immersed in either turmeric or coffee solutions. The immersion period was set at seven days, with the solutions maintained at a constant temperature of 37°C to simulate oral conditions.

Baseline color measurements for each restoration were obtained prior to immersion using a spectrophotometer, following the CIE Lab color space system to determine initial color values. After the immersion period, the restorations were removed, rinsed with distilled water, and dried before post-immersion color measurements were taken. The change in color (ΔE) was calculated by comparing the pre- and post-immersion measurements, providing a quantitative assessment of staining.

The data obtained from dimensional accuracy and color stability evaluations were statistically analyzed to compare the performance of SLA and DLP technologies, offering insights into their clinical reliability and suitability for fabricating provisional restorations.

DISCUSSION

The results of this study provide valuable insights into the performance of stereolithography (SLA) and digital light processing (DLP) 3D printing technologies for fabricating provisional dental restorations. Both methods demonstrated high levels of precision and comparable color stability, highlighting their clinical viability. Although DLP restorations showed slightly lower angular deviations when superimposed onto the Exocad control design, the difference was not statistically significant. Similarly, the immersion tests for color stability revealed no substantial difference between SLA and DLP restorations after exposure to staining solutions, further emphasizing the comparable performance of the two techniques.

Dimensional Accuracy

The slight advantage of DLP in achieving lower angular deviations aligns with findings from previous research that suggest its faster curing process and uniform layer-by-layer projection contribute to improved precision in specific applications. However, the lack of statistically significant differences between SLA and DLP indicates that both methods provide sufficient accuracy for clinical use. This result supports earlier studies, such as those by Alharbi et al. (2016), which found both SLA and DLP capable of producing dental restorations with acceptable precision. The precise alignment of the restorations with the control design in this study reinforces their reliability for provisional applications, offering clinicians flexibility in choosing a printing technology based on factors like speed and cost without compromising quality.

Color Stability

The immersion tests in turmeric and coffee solutions provided a practical assessment of color stability under simulated oral conditions. Both SLA and DLP restorations exhibited noticeable staining, but the ΔE values remained comparable between the two groups. This finding concurs with research by Tahayeri et al. (2018), which demonstrated that the color stability of 3D-printed dental materials is more dependent on the resin composition and finishing protocols than the printing technology itself. The results underline the importance of post-processing and material selection in mitigating staining, especially when restorations are exposed to chromogenic agents in the oral environment.

Clinical Implications

The comparable performance of SLA and DLP technologies in terms of dimensional accuracy and color stability suggests that both are suitable for fabricating interim restorations. Clinicians can make informed decisions based on other factors, such as workflow integration, material availability, or printer capabilities, without compromising the clinical outcome. Additionally, the study reinforces the broader utility of 3D printing in dentistry, offering significant advantages in terms of efficiency and patient satisfaction compared to traditional manufacturing methods.

LIMITATIONS AND FUTURE DIRECTIONS

While this study provides a comprehensive comparison of SLA and DLP technologies, its scope is limited to interim restorations and specific staining agents. Future research should explore long-term clinical outcomes, the effects of varied resin compositions, and the performance of these technologies under diverse oral conditions. Additionally, incorporating patient-reported outcomes could provide a more holistic evaluation of these techniques.

CONCLUSION

SLA and DLP 3D printing technologies both represent reliable options for fabricating provisional restorations, with minimal differences in accuracy and color stability. These findings support the continued adoption of 3D printing in restorative dentistry as a means of enhancing efficiency and patient outcomes.

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