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Original Research Article

Effect of storage time on the dimensional accuracy of 3D-printed dental casts fabricated by two commercially available 3D printers: An in vitro comparative study

Aishwarya Nigam[1], Siddhi Tripathi[1], Pankaj Datta[1]*, Sumiron Bose[2], Roopal Lal[1], Ravi Gulati[1]

[1]Dept. of Prosthodontics and Crown & Bridge, ITS CDSR, Muradnagar, Ghaziabad, Uttar Pradesh, India
[2]Dept. of Conservative and Endodontics, Saraswati Dental College, Lucknow, Uttar Pradesh, India

Abstract

Introduction: Dimensional accuracy is essential for the clinical success of 3D-printed dental models used in prosthodontic procedures. However, these models may undergo dimensional changes over time due to storage conditions and material properties. Such variations can compromise the fit and accuracy of dental restorations. Therefore, it is important to evaluate the effect of storage time on the dimensional stability of 3D-printed casts fabricated using different 3D printers.
Purpose: This study aimed to evaluate and compare the effect of storage time on the dimensional accuracy of 3D-printed dental casts fabricated using two commercially available printers: Shining 3D and Sonic Mighty.
Materials and Methods: A total of 22 samples were prepared using a typodont model of a dentulous mandible, which was scanned to generate a high-accuracy STL reference file. These samples were divided equally into two groups. Group 1 comprised casts fabricated using SLA technology with the Shining 3D printer and DM12 photopolymer resin, while Group 2 included casts fabricated using DLP technology with the Sonic Mighty printer and Aqua Gray photopolymer resin. The 3D printed casts were stored in an incubator set to a constant temperature of 37°C and 50% relative humidity to standardize environmental conditions. Dimensional accuracy was assessed at three specific time intervals—Day 1, Week 1, and Month 1. At each interval, the stored models were re-scanned using a desktop scanner to ensure consistency. The resulting scans were superimposed on the original STL reference model using Exocad software, and dimensional deviations were quantified using root mean square error (RMSE) values. The data collected were statistically analysed using SPSS software. Intragroup comparisons over time were evaluated using paired t-tests, while intergroup comparisons between the two printer groups were analysed with independent sample t-tests. A significance threshold of $p \leq 0.05$ was applied to interpret the results.
Results: The Shining 3D printer demonstrated superior dimensional accuracy across all time intervals compared to the Sonic Mighty printer. Statistically significant differences were observed between the two printer groups at each storage time ($p<0.001$, $p<0.001$, $p<0.001$). Both printers exhibited progressive dimensional changes over time, with the Sonic Mighty showing greater deviations.
Conclusion: Dimensional accuracy of 3D-printed dental models is significantly affected by storage time. The Shining 3D printer maintained better stability and precision, making it more suitable for clinical workflows requiring delayed use of models. In contrast, the Sonic Mighty printer displayed higher variability, limiting its applicability for precision-demanding procedures.

Keywords: 3D printer, Exocad, Photopolymer resin, STL file, Dimensional accuracy, Desktop scanner.

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1. Introduction

Three-dimensional (3D) printing, also known as additive manufacturing, has revolutionized dentistry over the past two decades. This technology allows for the fabrication of intricate dental models, surgical guides, and prosthetic frameworks by depositing material layer by layer based on computer-aided design (CAD) files. The workflow involves intraoral or desktop scanning to create a digital representation, followed by designing in CAD software and converting the STL file into a printable format. The advantages of this approach include enhanced precision,

*Corresponding author: Pankaj Datta
Email: dr.pankajdatta@its.edu.in

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reduced chairside time, greater customization, and improved communication between dentists, laboratories, and patients.[1]

In dentistry, stereolithography (SLA), digital light processing (DLP), and liquid crystal display (LCD) printers have gained prominence due to their ability to produce high-resolution dental models. Among these, SLA and DLP technologies are particularly valued for their fine detail reproduction and superior surface quality, making them ideal for prosthodontic and restorative applications.[2] Dimensional accuracy is a critical parameter in evaluating the clinical reliability of 3D-printed dental models, as even minor deviations can result in misfitting prostheses, occlusal interferences, or open margins. These inaccuracies can lead to complications such as poor retention, marginal leakage, recurrent caries, or restoration failure.[3]

In addition to initial accuracy, the effect of storage time on dimensional stability is of paramount importance. Dental models are often stored for varying durations before clinical use, during which environmental factors like temperature, humidity, and light exposure can induce changes in the material. Post-curing polymerization shrinkage, surface distortion, and warping are common issues that compromise the clinical acceptability of stored models.[4] This is particularly critical for applications such as surgical guides and prosthetic restorations, where deviations can significantly impact treatment outcomes.[5]

Previous studies have highlighted that SLA-printed models generally maintain higher dimensional accuracy over time compared to other technologies. However, variations in accuracy due to storage time remain a point of debate, with some studies suggesting that storage duration significantly affects the dimensional integrity of printed models, while others emphasize the role of printer type, resin properties, and storage conditions.[6]

Therefore, this study aims to evaluate and compare the effect of storage time on the dimensional accuracy of dental casts fabricated using two commercially available 3D printers, the SLA-based Shining 3D printer and the DLP-based Sonic Mighty printer.

2. Materials and Methods

This study was conducted in the Department of Prosthodontics and Crown & Bridge. A total of 22 samples were prepared using a typodont model of a dentulous mandible, which was scanned with a desktop scanner to generate a high-accuracy STL file that served as the reference model. The samples were equally divided into two groups: Group 1 consisted of 3D casts fabricated using SLA technology with the Shining 3D printer and DM12 photopolymer resin, while Group 2 consisted of casts fabricated using DLP technology with the Sonic Mighty printer and Aqua Gray photopolymer resin.

The 3D printing process adhered to the manufacturer's recommended settings for each printer. Following printing, the casts underwent post-processing, which included washing the models in isopropyl alcohol for 5 minutes to remove uncured resin, followed by UV curing for 10 minutes to ensure complete polymerization. After curing, the models were stored in an incubator set at 37°C and 50% relative humidity to standardize storage conditions. Storage duration was categorized into three intervals: Day 1 (24 hours post-fabrication), Week 1, and Month 1, allowing for the assessment of short-term and long-term dimensional changes.

At each storage interval, the casts were scanned again using the same desktop scanner to ensure uniformity in data acquisition. The scanned files were superimposed on the original STL reference model using Exocad software, which calculated dimensional deviations as root mean square error (RMSE) values. This provided a precise measure of the degree of deviation from the reference model over time.

The data collected from the scans were subjected to statistical analysis using SPSS software (version 16.0). Intragroup comparisons were performed using paired t-tests to evaluate changes in dimensional accuracy over time within the same group. Intergroup comparisons between the two printer groups were conducted using independent sample t-tests to determine statistically significant differences in dimensional accuracy at each storage interval. Additionally, the Kolmogorov–Smirnov test was applied to check for normality of the data distribution. A significance level of $p \leq 0.05p$ was adopted for all tests. Descriptive statistics, including mean, standard deviation, and standard error, were computed to summarize the dimensional accuracy at different time points.

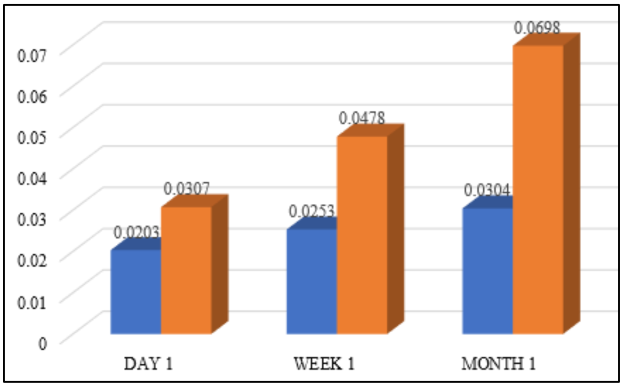
3. Results

The results of the study highlight critical insights into the effect of storage time on the dimensional accuracy of 3D-printed dental casts fabricated using two commercially available printers: the Shining 3D and Sonic Mighty 3D printers. Across all time intervals—Day 1, Week 1, and Month 1—the Shining 3D printer demonstrated superior dimensional stability and accuracy compared to the Sonic Mighty printer.

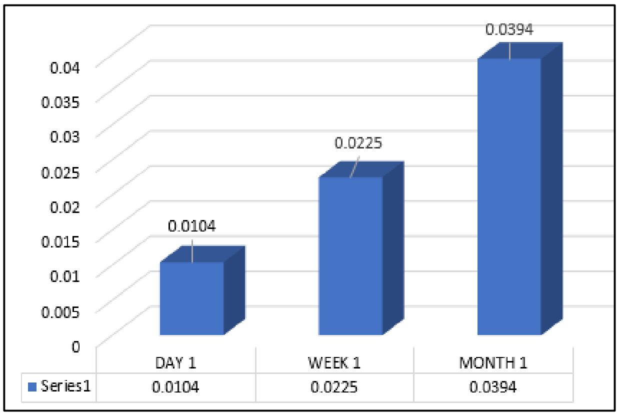
For the Shining 3D printer (Group 1), dimensional deviations were minimal and increased gradually over time. The mean deviation was recorded at 0.0203 mm on Day 1, which slightly increased to 0.0253 mm at Week 1, and further to 0.0304 mm at Month 1.(**Graph 1**) These findings indicate that the SLA (Stereolithography) technology used by the Shining 3D printer provides better consistency and reliability over extended storage periods. This aligns with prior research emphasizing the advantages of SLA technology, such as higher resolution and reduced layer thickness, which contribute to enhanced dimensional accuracy.

In contrast, the Sonic Mighty printer (Group 2), which utilizes DLP (Digital Light Processing) technology, exhibited more significant dimensional changes over time. The mean deviation started at 0.0307 mm on Day 1, increased substantially to 0.0478 mm at Week 1, and reached 0.0698 mm by Month 1. This pronounced deviation suggests that DLP technology is more susceptible to dimensional instability, potentially due to post-curing polymerization shrinkage and environmental factors such as temperature and humidity.

The differences between the two groups were statistically significant at all-time points, with p values <0.001 consistently below 0.001.(**Graph 3**) This establishes that the Shining 3D printer maintains superior accuracy compared to the Sonic Mighty printer, regardless of the storage duration. The intergroup analysis also revealed that the Shining 3D printer outperformed the Sonic Mighty printer by a margin of 0.0104 mm on Day 1, 0.0225 mm at Week 1, and 0.0394 mm at Month 1. These differences were further reinforced by confidence intervals that did not overlap, ensuring the reliability of the findings.

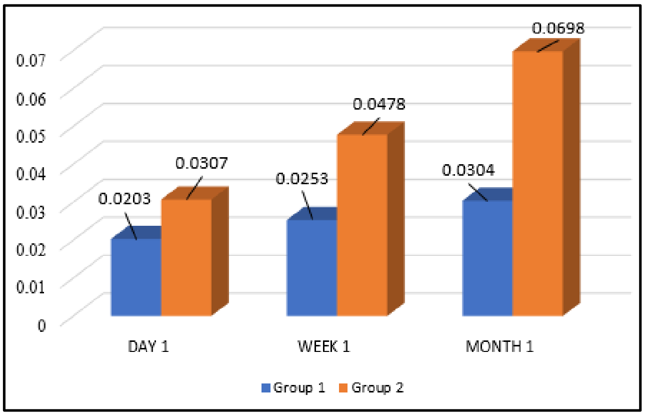


Graph 1: Dimensional accuracy at different time intervals



Graph 2: Intragroup comparison of Dimensional accuracy at different time intervals

Intragroup comparisons showed that both groups experienced progressive dimensional changes over time, but the magnitude was significantly lower for the Shining 3D printer.(**Graph 2**) This highlights the importance of selecting appropriate printer technologies for clinical workflows where the models may need to be stored for extended periods before use. For instance, models fabricated using the Sonic Mighty printer may be less suitable for precision-critical applications, such as the creation of surgical guides or full-arch prostheses, where even small dimensional changes can compromise treatment outcomes.



Graph 3: Intergroup comparison of dimensional accuracy at different time intervals group 1 and Group 2

4. Discussion

The null hypothesis stated that storage time does not significantly affect the dimensional accuracy of 3D-printed casts fabricated using two commercially available printers, was conclusively rejected. The study demonstrated statistically significant differences in dimensional accuracy between the Shining 3D and Sonic Mighty printers across all tested time intervals, with the Shining 3D printer consistently exhibiting superior stability. These findings are consistent with existing literature, such as the studies by Joda et al.[15] and Lin et al.[3] which reported that SLA-based printers maintain better dimensional accuracy over time due to their higher resolution and reduced layer thickness. Similarly, Groth et al.[7] highlighted SLA's superior trueness and precision, while Emir et al.[30] emphasized its consistency in accuracy along the Z-axis, making SLA technology more reliable for precision-demanding applications.

Contradictory evidence in the literature, however, suggests that external factors such as resin composition, storage environment, and post-curing protocols can significantly influence the dimensional stability of 3D-printed models, occasionally mitigating the inherent advantages of SLA systems. For instance, Park et al.[10] demonstrated that DLP models stored under controlled conditions, such as minimal light exposure and regulated humidity, could achieve dimensional stability comparable to SLA models. KIm et al.[12] also found that vacuum-sealed storage could effectively minimize polymerization shrinkage and warping in DLP-printed models. These studies underscore the critical role of optimizing storage conditions and post-processing protocols alongside printer technology.

Dimensional discrepancies of approximately ≤0.1 mm (100 µm) are generally considered acceptable for most clinical applications such as diagnostic casts, removable prostheses, and even certain fixed prosthodontic procedures. The findings of this study have direct clinical implications, particularly in precision-critical workflows such as prosthetic restorations, implant-supported frameworks, and surgical guides. The Shining 3D printer's superior stability over time makes it more suitable for workflows where models are stored for later use. Conversely, the Sonic Mighty printer displayed significant dimensional changes over time, which could result in misfits in crowns, inaccurate surgical guide angulations, or compromised treatment outcomes. This study also contributes valuable insights for clinicians and laboratories operating within budget constraints, demonstrating that mid-range SLA printers can deliver clinically acceptable results with appropriate workflow optimization.

Despite its contributions, this study has certain limitations. Only two printer models and one resin formulation per printer were evaluated, which restricts the generalizability of the findings. Furthermore, the focus was limited to linear dimensional deviations without assessing volumetric changes or internal stress distributions that might occur during storage. While the study was conducted under controlled storage conditions, it did not account for variations often encountered in clinical environments, such as fluctuating humidity, exposure to varying light intensities, or temperature changes. These factors could further impact the dimensional stability of printed models and merit exploration in future research. Future studies should broaden the scope to include a diverse range of 3D printers, resins, and environmental conditions to provide a comprehensive understanding of factors influencing dimensional stability. Advanced analyses incorporating volumetric changes and internal stress assessments could yield deeper insights. Additionally, investigating the effects of extended storage durations and evaluating emerging technologies such as CLIP and MJP would enhance the clinical relevance of 3D printing. Research focusing on optimizing post-processing techniques, including UV curing protocols and storage solutions, could establish standardized guidelines for achieving consistent and reliable outcomes in dental workflows.

5. Conclusion

Within the limitations of this in vitro study, the following conclusions can be drawn:

1. Storage time has a significant impact on the dimensional accuracy of 3D printed dental casts fabricated from Shinning 3D printer at different time intervals. There was decrease in dimensional accuracy when cast were stored for 1 Day, 1 week, 1 month and the results were statistically significant ($p < 0.001$).
2. Storage time has a significant impact on the dimensional accuracy of 3D printed dental casts fabricated from Sonic Mighty 3D printer at different time intervals. There was decrease in dimensional accuracy when cast were stored for 1 Day, 1 week, 1 month and the results were statistically significant ($p < 0.001$).
3. Shining 3D printer has significantly better dimensional accuracy as compared to Sonic Mighty 3D printer at different time intervals ($p < 0.001$).

6. Source of Funding

None.

7. Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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