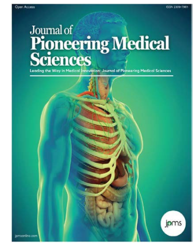

Journal of Pioneering Medical Sciences
Received: February 04, 2025 | Accepted: March 27, 2025 | Published: April 27, 2025
Volume 14, Issue S01, Pages 194-197

DOI https://doi.org/10.47310/jpms202514S0124

Wear Resistance and Surface Roughness of CAD-CAM Ceramics Versus 3D-Printed Resin Crowns: An *In vitro* Study

Adham Abdulmajeed Niyazi[1*]
[1]Department of Prosthodontics, General Dentistry Program, Batterjee Medical College, Jeddah, 21442, Makkah, Saudi Arabia

Author Designation: [1]Lecturer

*Corresponding author: Adham Abdulmajeed Niyazi (e-mail: adham.niyazi@bmc.edu.sa).

Abstract **Objectives:** Durability of dental restorations is influenced by their wear resistance and surface roughness. CAD-CAM ceramics and 3D-printed resin-based crowns are widely used in prosthodontics; however, comparative data on their wear behavior is limited. **Materials and Methods:** This *in vitro* study evaluated 40 crowns, equally divided into Group A (CAD-CAM lithium disilicate ceramic crowns) and Group B (3D-printed photopolymer resin crowns). All crowns underwent wear simulation using a dual-axis chewing simulator (50 N, 100,000 cycles). Surface roughness (Ra) was assessed pre- and post-wear using a non-contact profilometer. Statistical analysis included independent t-tests ($p<0.05$), effect size (Cohen's d), and 95% confidence intervals. **Results:** CAD-CAM ceramics exhibited significantly less wear (25±2 µm) compared to 3D-printed resin crowns (58±3 µm; $p<0.001$, d = 11.0). Initial surface roughness was lower for ceramics (0.21±0.03 µm) versus resin (0.35±0.05 µm). After simulation, roughness increased to 0.28±0.04 µm (ceramics) and 0.62±0.06 µm (resins) ($p<0.001$). **Conclusion:** CAD-CAM ceramic crowns demonstrated superior wear resistance and smoother surface characteristics compared to 3D-printed resin crowns. While 3D-printed crowns offer cost and customization benefits, their clinical use may be best suited for provisional or low-load applications. Further in vivo studies are warranted.

Key Words Wear resistance, surface roughness, CAD-CAM ceramics, 3D-printed resin, dental crowns, *in vitro* study

INTRODUCTION

Dental crowns survive through time when they combine high wear resistance with advantageous surface characteristics because these characteristics determine both functionality and patient safety as well as appearance. The dental prosthodontic field has adopted Computer-aided design and computer-aided manufacturing (CAD-CAM) ceramics together with three-dimensional (3D)-printed resin-based materials because their improved mechanical and esthetic properties [1,2]. The exceptional strength combined with remarkable wear resistance and smooth surface of CAD-CAM ceramics including lithium disilicate and zirconia renders them appropriate for durability-based restorations [3,4]. The availability of 3D-printed resins as an alternative material solution brings efficiency with cost-effectiveness and customizable features to market which suffers from surface property and wear resistance deficiencies [5,6].

Dental crowns need exceptional wear resistance features for protecting their structure along with preventing damage to teeth that bite against them [7]. The superior strength of ceramics surpasses resin-based materials because of their increased density and hardness qualities [8]. Superficial material irregularities in dental restoratives enable bacterial adhesion and plaque development as well as diminishes aesthetic outcomes which demonstrates the significance of surface texture analysis [9,10].

Research into the wear behavior and surface roughness of 3D-printed resins has grown slowly because very little data exists about these attributes when compared to CAD-CAM ceramics. This research examines the relationship between simulated chewing cycles and the wear resistance alongside surface roughness performance between CAD-CAM ceramic dental crowns and 3D-printed resin dental crowns. The obtained research results could help identify suitable materials for long-lasting dentist-recommended restorations. It was hypothesized that CAD-CAM ceramic crowns would demonstrate superior wear resistance and reduced surface roughness compared to 3D-printed resin crowns under simulated chewing conditions. This hypothesis formed the foundation of the current study, aiming to clarify the suitability of each material type for long-term clinical use.

MATERIALS AND METHODS

The researchers performed this *in vitro* study to evaluate the wear resistance together with surface roughness variation between CAD-CAM ceramic crowns and 3D-printed resin crowns. The research team generated 40 crowns that were divided into two groups of equal sizes (n = 20).

The research divided crowns into two distinct groups which included CAD-CAM ceramic crowns (lithium disilicate) in Group A. The second group contained crowns which were manufactured via 3D printing technology using photopolymer-based resin materials.

The sample size (n = 20 per group) was determined based on similar previous *in vitro* wear studies and was considered adequate to detect statistically significant differences ($\alpha = 0.05$, power = 80%). Simple randomization was used to assign crowns into each group to minimize selection bias.

The manufacturing process involved software design followed by proper implementation of manufacturers' guidelines. Mattling of ceramic crowns happened through a CAD-CAM milling unit yet resin crowns originated from digital light processing (DLP) 3D printer fabrication. When fabrication ended ceramic crowns received sintering treatment and glazing process but resin crowns needed standard post-curing procedures followed by polishing.

Research scientists used a two-axis chewing device to test the crown resistance to wear. The applied load of 50 N for 100,000 cycles was selected to simulate approximately one year of clinical masticatory forces, based on literature standards for laboratory wear testing. While oral environmental factors like humidity, pH, and temperature fluctuations were not replicated in this setup. The wear depth (µm) measurements occurred before and after testing with a non-contact 3D surface profilometer at different locations.

The profilometer served to measure surface roughness before-wear simulation and after-wear simulation. The profilometry device obtained three surface roughness measurements from each crown at various positions to determine the mean Ra value (in µm). Calibration of the chewing simulator and profilometer was performed prior to testing using manufacturer-recommended protocols to ensure measurement reliability. All measurements were conducted under standardized laboratory conditions (temperature: 22°C±1°C; relative humidity: 50%±5%).

The analysis of data utilized SPSS software version 26. Both measurements obtained mean and standard deviation values for wear resistance and surface roughness. An independent t-test with a p value set at $p<0.05$ performed intergroup comparisons. In addition to independent t-tests, Cohen's d was calculated to assess effect size. Confidence intervals (95%) were reported to improve interpretation of the results.

RESULTS

The test revealed CAD-CAM ceramic crowns achieved an average material loss of 25±2 µm yet 3D-printed resin crowns revealed considerably higher results at 58±3 µm. The groups exhibited a statistically meaningful variance ($p<0.001$) between their results. Wear tests demonstrated that CAD-CAM ceramics detected greater resistances to wear than 3D-printed resin crowns through this data (Table 1). The difference in wear loss between the two groups was statistically significant ($p<0.001$), with a large effect size (Cohen's d = 11.0; 95% CI for mean difference: 31.7 µm to 35.3 µm).

Both CAD-CAM ceramic crowns and 3D-printed resin crowns started with a surface roughness (Ra) of 0.21±0.03 µm and 0.35±0.05 µm before wear simulation. The surface roughness measurement demonstrated an elevation in the wear results for each group where CAD-CAM ceramics increased to 0.28±0.04 µm and 3D-printed resin crowns augmentation reached 0.62±0.06 µm. The analysis determined the difference between these groups proved significant at the $p<0.001$ level (Table 2). Surface roughness increase was significant in both groups ($p<0.001$). Effect size for final roughness difference between groups was also large (Cohen's d = 6.6; 95% CI for difference: 0.30 µm to 0.36 µm).

Table 1: Wear Resistance of CAD-CAM Ceramic and 3D-Printed Resin Crowns

Group	Sample Size (n)	Mean Wear Loss (µm)±SD	p-value
CAD-CAM Ceramic Crowns	20	25±2	<0.001
3D-Printed Resin Crowns	20	58±3	<0.001

Table 2: Surface Roughness (Ra) Before and After Wear Simulation

Group	Sample Size (n)	Roughness (µm)±SD		p-value
		Initial	Final	
CAD-CAM Ceramic Crowns	20	0.21±0.03	0.28±0.04	<0.001
3D-Printed Resin Crowns	20	0.35±0.05	0.62±0.06	<0.001

These results suggest that CAD-CAM ceramic crowns have better wear resistance and maintain a smoother surface compared to 3D-printed resin crowns (Tables 1 and 2, Figure 1 and 2).

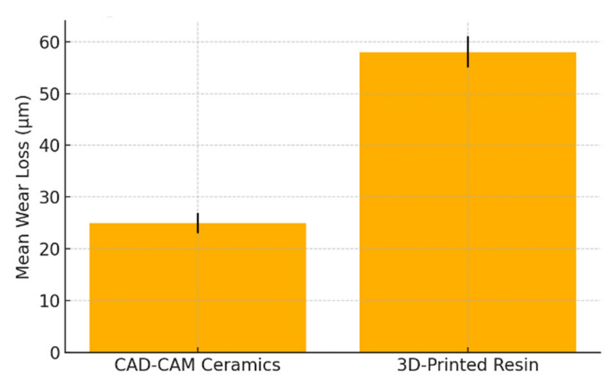

Figure 1: Mean wear loss (µm) between CAD-CAM ceramic and 3D-printed resin crowns, showing significantly lower wear for CAD-CAM ceramics.

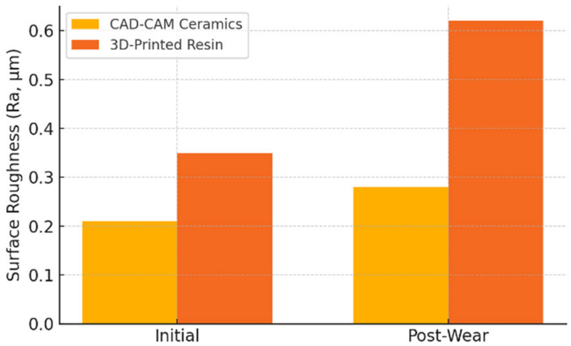

Figure 2: Surface roughness (Ra) before and after wear simulation for both materials, highlighting the increase in roughness and the superior smoothness of CAD-CAM ceramics

DISCUSSION

Both the durability against wear along with surface roughness levels were evaluated between CAD-CAM ceramic crowns compared to 3D-printed resin crowns within this research. The experimental data showed CAD-CAM ceramic material outperformed 3D-printed resin crowns regarding wear resistance abilities and surface roughness levels which leads to better clinical performance.

Research results verify that CAD-CAM ceramics achieve greater density and hardness which leads to enhanced wear resistance compared to dental resin materials. CAD-CAM ceramics perform better due to their precise glazing during fabrication combined with their smooth surface finish that results from exact milling.

Wear performance acts as a crucial determinant for dental restorations since it directly controls their structural integrity alongside opposing teeth protection. Results from the current research show CAD-CAM ceramic crowns demonstrated superior wear performance than 3D-printed resin crowns because ceramic materials benefit from their higher density together with greater hardness according to earlier reports [1,2]. The combination of lithium disilicate and zirconia-based CAD-CAM ceramics stands out because they demonstrate exceptional durability and small volumetric loss under oral stress [3,4]. The polymeric composition of resin-based materials leads to increased wear since they demonstrate diminished surface stability under functional application [5,6].

Wear loss increased in 3D-printed resin crowns because these restorations contain less fillers while their polymerization procedures impact their mechanical response [7]. The mechanical strength of 3D-printed dental materials increased with new developments in additive manufacturing but these materials demonstrate worse wear performance compared to ceramic materials according to [8,9]. Research has already demonstrated that CAD-CAM ceramics demonstrate excellent structural preservation throughout dental restoration use which makes them excellent material options for full-coverage dental work [10].

Surface roughness maintains essential importance for plaque accumulation along with bacterial adhesion plus it determines overall restoration aesthetics and appearance. The current research showed that CAD-CAM ceramic crowns demonstrated reduced initial and post-wear surface roughness measurements than 3D-printed resin crowns. Research from past studies confirms that the precise milling and proficient glazing processes create smooth surface characteristics in CAD-CAM ceramics [11,12].

The testing conditions led to enhanced surface roughness in both groups yet 3D-printed resin crowns displayed a substantially elevated level of roughness. The materials present distinctions at the microstructural level that lead to this difference. CAD-CAM ceramics endure heat-related processing with sintering followed by glazing to produce a smooth and enduring surface [13]. 3D-printed resins need additional post-curing along with polishing processes that cannot match the surface quality CAD-CAM ceramics offer [14]. The increased resin-based material surface roughness promotes plaque retention along with staining potential which damages both dental appearance and oral health [15].

The wear properties and long-term durability of CAD-CAM ceramic crowns surpass those of 3D-printed resin crowns according to clinical observations. The high wear loss combined with increased surface roughness of 3D-printed resin crowns makes them suitable for specific low-stress dental applications while their cost savings and quick fabrication abilities stand as major benefits. Future improvements in 3D printing techniques that involve material enhancement along with post-processing methods could enhance these materials for future applications.

The absolute laboratory environment used for this research do not precisely represent the complete nature of the oral cavity. External factors from the oral cavity especially temperature shifts and pH changes and mechanical stresses would impact both wear patterns and surface texture of these materials. Additional validity in these results would come from in vivo testing as well as extended observation periods. The evaluation of different finishing and polishing methods applied to 3D-printed resin materials represents a necessary research field to enhance their clinical outcomes. The experimental setup involved *in vitro* testing but failed to reproduce the dynamic characteristics of oral conditions like fluid flow, enzymatic activities and acid-base changes and bacterial communities. The study's sample size needs justification because it decreases the ability to generalize research findings to other settings. Operational methods used by the operator potentially affected the consistency of results through standardized procedures. Research into better resin materials and enhanced photopolymerization approaches needs attention since both elements can boost material wear properties. Future research needs to evaluate alternative finishing methods and polishing techniques to determine their effects on 3D-printed resin surface roughness. Longitudinal in vivo studies with focused outcomes from patient participants will provide extra validation to the results obtained from laboratory testing.

CONCLUSIONS

This *in vitro* study demonstrated that CAD-CAM ceramic crowns exhibit significantly better wear resistance and smoother surface profiles compared to 3D-printed resin crowns. These properties make CAD-CAM ceramics more suitable for high-stress restorative applications. In contrast, the economic efficiency and ease of fabrication of 3D-printed resins make them useful for provisional restorations or low-load clinical scenarios. To optimize the long-term utility of 3D-printed crowns, further material and process innovations, coupled with in vivo validation, are recommended.

Conflicts of Interest

The authors declare no conflicts of interest related to this study.

Ethical Statement

As this study was conducted entirely *in vitro* using dental materials, ethical approval was not required.

REFERENCES

[1] Khoramian E. MS., *et al.* "Effect of Polishing Versus Glazing of CAD-CAM Ceramics on Wear and Surface Roughness of Opposing Composite Resin." *Dental Research Journal*, vol. 21, 2024. https://pubmed.ncbi.nlm.nih.gov/38476712/.

[2] Park, J.H., *et al.* "Wear of 3D printed and CAD/CAM milled interim resin materials after simulated mastication." *Scientific Reports*, vol. 11, no. 1, 2021.

[3] Al-Dulaijan, Y.A., *et al.* "Comparative physical and mechanical properties of a 3D printed denture base resin with conventional and milled resins." *Saudi Dental Journal,* vol. 35, no. 1, 2023, pp. 1-9.

[4] Park, Ji Man, *et al.* "Wear resistance of 3d printing resin material opposing zirconia and metal antagonists." *Materials,* vol. 11, no. 6, June 2018. http://dx.doi.org/10.3390/ma11061043.

[5] Temizci, Tuğba, and Hatice Nalan Bozoğulları. "Effect of thermocycling on the mechanical properties of permanent composite-based cad-cam restorative materials produced by additive and subtractive manufacturing techniques." *BMC Oral Health,* vol. 24, no. 1, March 2024. http://dx.doi.org/10.1186/s12903-024-04016-z.

[6] Fouda, Shaimaa M., *et al.* "Flexural properties and hardness of cad-cam denture base materials." *Journal of Prosthodontics,* vol. 32, no. 4, May 2022, pp. 318-324. http://dx.doi.org/10.1111/jopr.13535.

[7] Alzaid, Maryam, *et al.* "The effect of salivary pH on the flexural strength and surface properties of cad/cam denture base materials." *European Journal of Dentistry,* vol. 17, no. 01, July 2022, pp. 234-241. http://dx.doi.org/10.1055/s-0042-1749160.

[8] Revilla-león, Marta, and Mutlu Özcan. "Additive manufacturing technologies used for processing polymers: Current status and potential application in prosthetic dentistry." *Journal of Prosthodontics,* vol. 28, no. 2, April 2018, pp. 146-158. http://dx.doi.org/10.1111/jopr.12801.

[9] Alharbi, Nawal, *et al.* "Additive manufacturing techniques in prosthodontics: Where do we currently stand? a critical review." *The International Journal of Prosthodontics,* vol. 30, no. 5, September 2017, pp. 474-484. http://dx.doi.org/10.11607/ijp.5079.

[10] Ramakrishnaiah R., *et al.* "Applications of Raman spectroscopy in dentistry: analysis of tooth structure and dental materials." *Journal of Raman Spectroscopy*, vol. 46, no. 7, 2015, pp. 662-72.

[11] Stawarczyk, Bogna, *et al.* "Discoloration of manually fabricated resins and industrially fabricated cad/cam blocks <i>versus</i> glass-ceramic: Effect of storage media, duration, and subsequent polishing." *Dental Materials Journal,* vol. 31, no. 3, 2012, pp. 377-383. http://dx.doi.org/10.4012/dmj.2011-238.

[12] Matos, A.O., *et al.* "Surface roughness of CAD-CAM materials after different finishing and polishing protocols." *Journal of Prosthetic Dentistry*, vol. 121, no. 2, 2019, pp. 1-8.

[13] Juntavee ,N., *et al.* "Wear resistance of different occlusal splint materials: an *in vitro* study." *Journal of Prosthodontics*, vol. 27, no. 6, 2018, pp. 572-9.

[14] Kim, H.K., *et al.* "Optical and mechanical properties of CAD-CAM ceramic materials for esthetic restorations." *Journal of Prosthetic Dental*, vol. 120, no. 1, 2018, pp. 132-9.

[15] Papadiochou, Sofia, and Argirios L. Pissiotis. "Marginal adaptation and cad-cam technology: A systematic review of restorative material and fabrication techniques." *The Journal of Prosthetic Dentistry,* vol. 119, no. 4, April 2018, pp. 545-551. http://dx.doi.org/10.1016/j.prosdent.2017.07.001.