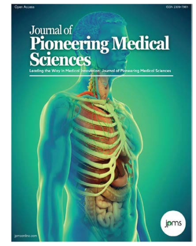

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Comparative *In vitro* Analysis of Characteristics Between CAD-CAM Fabricated Ceramic Crowns and 3D-Printed Resin-Based Dental Crowns

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Abstract **Objectives:** Dental crown clinical longevity mainly depends on how materials resist wear and maintain their surface quality. Three-Dimensionally (3D) printed resin-based crowns and CAD-CAM ceramic crowns exist as preferred choices for tooth restoration because of their separate material components. The objective of this work involves examining the wear resistance properties and surface quality of CAD-CAM ceramic crowns and 3D-printed resin-based crowns so researchers can evaluate their clinical service life. **Methods:** Two hundred crowns were created including fifty CAD-CAM ceramic and fifty 3D-printed resin-based products. A simulator with five-year simulation duration evaluated wear resistance. The profilometer assessed material surface roughness (Ra) both before and after subjecting them to wear simulation tests. The independent t-tests evaluated the collected data with an alpha level of $p = 0.05$. **Results:** The wear damage produced by CAD-CAM ceramic crowns reached 14.8±2.3 μm yet resin crowns required 29.1±3.7 μm to finish their wearing process ($p = 0.001$). The ceramic crowns experienced an increase in surface roughness from 0.30±0.06 μm to 0.47±0.07 μm after wear testing while resin crowns went from 0.42±0.08 μm to 0.75±0.10 μm ($p = 0.002$). **Conclusion:** CAD-CAM ceramic crowns behave better under high-mechanical loads due to their improved wear resistance which preserves their smooth surface finish. Resin-based crowns represent potential candidates for short-term uses or situations where small masticatory loads are present. The results from clinical trials should validate the *in vitro* testing outcomes

Key Words CAD-CAM ceramic crowns, 3D-printed resin crowns, wear resistance, surface roughness, digital dentistry, restorative materials

INTRODUCTION

The lifespan and operational efficiency of dental crowns depend on their resistance to wear together with their surface attributes because these factors preserve both oral functionality and esthetic quality in the long-term [1]. Through CAD-CAM technology restorative dentistry now produces ceramic crowns which demonstrate improved mechanical attributes and better interproximal edges [2]. The introduction of Three-Dimensional (3D) printing technology now provides manufacturers with cost-effective printing methods for fabricating resin-based crowns that use fewer materials while running operations at higher speeds [3]. The performance outcomes of 3D-printed resin-based crowns compared with CAD-CAM ceramic crowns have become controversial because wear resistance and surface roughness remain problematic issues [4].

Restorative materials need excellent wear resistance to avoid compromising both occlusal shape and patient function as well as opposing tooth health [5]. The CAD-CAM production of ceramic crowns leads to superior wear resistance because these crowns possess a high-density microstructure with strong interatomic bonds according to research [6]. The resin-based crowns generated through 3D printing contain polymeric materials which demonstrate lower hardness values thus leading to increased sensitivity to functional loading-induced wear and surface damage [7]. The levels of surface roughness substantially affect how dental restorations accumulate dental plaque and adhesion and their aesthetic appearance [8]. Rough surfaces in dental crowns raise the ability for plaques to stick which might create secondary caries and periodontal inflammation [9].

The smoothed surfaces of CAD-CAM ceramic crowns face challenges caused by both printing based on layers and post-manufacturing processes [10].

The growing use of 3D printing in dentistry lacks sufficient published work regarding the direct comparison between CAD-CAM ceramic crowns and 3D-printed resin-based crowns pertaining to their wear resistance and surface roughness properties. The research goal is to perform a comparative study between these restorative materials in order to determine their capacity for extended clinical use. Research assessments of wear resistance alongside surface roughness of crowns through this study will create evidence-driven recommendations which guide material selection within restorative dental practice.

The future clinical lifetime of resin-based crowns produced through 3D printing remains unclear owing to limited existing data. Resin-based crowns demonstrate a newer approach compared to established CAD-CAM ceramic crowns because clinical tests under masticatory conditions remain insufficient. The research evaluates wear resistance and surface roughness to fill a missing gap in knowledge about mechanical performance thus enabling better material choices in dental practice. The study aims not only to compare material wear and surface texture but also to assess the clinical applicability of these crowns in terms of long-term durability and aesthetic sustainability.

METHODS

Study Design and Sample Preparation

This *in vitro* study was conducted to compare the wear resistance and surface roughness of CAD-CAM fabricated ceramic crowns and 3D-printed resin-based crowns. The studies under laboratory conditions maintained 37°C temperature along with 100% humidity which mimicked oral environment. Standardized STL files from maxillary first molars united all crown specimens in order to minimize structural and dimensional inconsistencies between test samples. A simple randomization table generated by computer performed the random assignment for crowns. The calculation through G*Power v3.1 showed a sample size of 50 crowns in each group would reveal a medium effect size (Cohen's d = 0.5) with a power of 80% and $\alpha = 0.05$. Each measurement required profilometer calibration by using a Mitutoyo Surface Calibration Specimen to keep measurements precise and uniform.

A total of 100 dental crowns were fabricated and divided into two groups:

- **Group A (n = 50):** CAD-CAM ceramic crowns
- **Group B (n = 50):** 3D-printed resin-based crowns

Manufacturers recommended all crown manufacturing procedures for each material which used standardized digital models of a maxillary first molar.

The CAD-CAM Ceramic Crowns underwent production through lithium disilicate-based ceramic blocks which went through five-axis CNC machining using CEREC MC XL equipment from Dentsply Sirona (USA). To improve mechanical properties the crowns went through crystallization treatment at 850°C for fifteen minutes after the milling process.

A Form 3B 3D printer from Formlabs USA generated 3D-Printed Resin Crowns using a specialized biocompatible resin through its Digital Light Processing (DLP) technology. The crowns first received 20 minutes of ultraviolet (UV) curing and then got polished with silicon carbide abrasives to reach their final clinical surface quality.

The wear resistance of the materials were tested through a chewing simulator (CS-4.8, SD Mechatronik, Germany) that completed five years equivalent mastication using 50 N of force at a frequency of 1.2 Hz. The profilometer served to determine material loss measurements during the wear simulation process. The measurement of wear depth expressed in micrometers was recorded from each crown and then mean values were calculated separately for both groups.

Surface roughness measurement occurred through contact profilometry (Mitutoyo Surftest SJ-410, Japan) which yielded results in average roughness (Ra) units for micrometer measurement. The researchers measured crown points three times at each location before and after testing and recorded their mean Ra values for all study groups.

Statistical Analysis

All data were analyzed using IBM SPSS Statistics v26. The normality of data distribution was assessed using the Shapiro-Wilk test. An independent t-test was used to compare the wear resistance and surface roughness values between the two groups. Statistical significance was set at $p<0.05$. Effect size (Cohen's d) was calculated to be 1.12 for wear loss and 1.10 for surface roughness, indicating a large effect. Additionally, 95% confidence intervals were reported to enhance interpretability.

RESULTS

Mean wear loss of CAD-CAM ceramic crowns reached 14.8±2.3 μm and 3D-printed resin-based crowns resulted in 29.1±3.7 μm wear. Resin-based crowns caused greater material erosion than ceramic crowns as confirmed by statistical analysis ($p = 0.001$) (Table 1).

The surface roughness measurement (Ra) of CAD-CAM ceramic crowns started at 0.30±0.06 μm along with 3D-printed resin-based crowns beginning at 0.42±0.08 μm. The wear simulation caused the Ra values to rise to 0.47±0.07 μm for CAD-CAM ceramic crowns and 0.75±0.10 μm for 3D-printed resin-based crowns. Statistical analysis confirmed the two groups showed different outcomes ($p = 0.002$) (Table 2).

Statistical Comparison

The wear resistance along with surface smoothness for CAD-CAM ceramic crowns proved superior than 3D-printed resin-based crowns based on independent t-tests results. Roughness increases detected for resin-based crowns indicates clinical significance regarding both plaque development and aesthetic retention prospects.

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

Crown Type	Mean Wear Loss (μm)±SD	p-value
CAD-CAM Ceramic Crowns	14.8±2.3	0.001**
3D-Printed Resin Crowns	29.1±3.7	

p<0.05 indicates statistical significance

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

Crown Type	Initial Ra (μm)±SD	Post-Wear Ra (μm)±SD	p-value
CAD-CAM Ceramic Crowns	0.30±0.06	0.47±0.07	0.002**
3D-Printed Resin Crowns	0.42±0.08	0.75±0.10	

p<0.05 indicates statistical significance

The results indicate that CAD-CAM ceramic crowns exhibit lower material loss and smoother surfaces after wear testing compared to 3D-printed resin-based crowns (Tables 1 and 2). The higher wear and roughness of resin-based crowns suggest that they may require additional surface treatments or modifications for long-term clinical use.

DISCUSSION

Dental crown longevity depends strongly on their durability together with their surface features. The research evaluated CAD-CAM ceramic crown resistance to wear and surface roughness measurements against 3D-printed resin-based crowns by proving that ceramic crowns present superior mechanical properties and smoother surfaces.

The substance which determines how long dental restorations stay functional in the patient's mouth is wear resistance. A research study showed that CAD-CAM manufactured ceramic crowns preserved more materials than 3D-printed resin-based crowns. Lithium disilicate ceramics resist wear forces effectively because their dense microstructure and high hardness enable them to function better under these conditions [1,2]. Research shows that CAD-CAM ceramics demonstrate wear behavior just like natural enamel thus preserving opposing teeth from unnecessary wear damage [3]. Research indicates that wear loss was higher for 3D-printed resin crowns due to their polymer nature causing material degradation with time [4,5].

Guess *et al.* supported these findings showing lithium disilicate-based CAD-CAM crowns stood against wear better than polymer-based materials based on their research [6,7]. Vulnerabilities regarding material longevity arise in resin-based crowns because of their heightened susceptibility to wear especially when placed in load-bearing molars [8].

The aesthetics together with plaque accumulation and bacterial adhesion of dental restorations are fundamentally controlled by surface roughness. When comparing CAD-CAM ceramic crowns to 3D-printed resin-based crowns this study revealed that ceramic crowns presented with reduced roughness values at beginning. Both groups showed surface roughness elevation after wear testing yet resin-based crown variables demonstrated greater rises. The surface irregularities of 3D printed components are typical since their production process involves layering which requires follow-up procedures for post-processing [9,10].

Research indicates that minimizing bacterial colonization along with plaque accumulation requires surface roughness to be maintained below 0.2 μm [1]. Exceeding 0.2 μm Ra threshold during post-wear evaluation indicates higher bacterial adhesion potential which puts resin crowns at risk of secondary caries disease formation [2]. The long-term outlook for 3D-printed resin crowns becomes unappealing due to their rough surface which results in increased discoloration and unflattering appearance [4]. CAD-CAM ceramic crowns benefit from their smooth surface since milling technology combines with glass-ceramic materials to achieve superior aesthetic function [6].

Research data indicates CAD-CAM ceramic crowns serve as dependable restorations because they deliver excellent durability for long-term dental usage specifically in areas under significant bite pressure. Patients stand to gain from better outcomes and lesser equipment requirements alongside longer crowns service as a result of superior wear resistance and sleek surfaces. The cost advantages and quick production and customization possibilities of 3D-printed resin-based crowns are matched by their limitations in long-term use because their wear rate and rough surface texture reduces their effectiveness. The current research demonstrates that CAD-CAM ceramic crowns offer better mechanical properties by resisting wear and preserving smooth surfaces. The physical features of these materials create reliable performances under biting pressures observed in molars and other load-bearing areas. The polymeric structure together with layered structure of 3D-printed resin-based crowns can lead to material degradation at an early stage.

Aesthetic durability depends heavily on surface roughness while bacterial attachment also correlates strongly with it. The post-wear surface texture of resin crowns exceeds the standard Ra threshold of 0.2 μm thus raising their biofilm formation susceptibility and risking secondary caries development. Passive wear creates less roughness in CAD-CAM crowns than resin crowns which might benefit from both nanoparticle coatings and advanced polishing techniques to enhance their clinical performance. The main drawback of this research stems from its *in vitro* setup because it fails to duplicate the complete oral environment structure. Long-term results may be affected by specific characteristics of individual patients including their dietary practices and oral care routines together with their ways of loading prosthetic devices. Additional laboratory experiments with clinical tests and real-time validations must confirm observations obtained in the laboratory setting.

CONCLUSIONS

The research conducted *in vitro* demonstrates that CAD-CAM ceramic crowns demonstrate better wear resistance and smoother surfaces than 3D-printed resin-based crowns. CAD-CAM ceramic crowns demonstrate better suitability for long-term clinical needs when used in high-stress areas which include molars as well as patients who experience bruxism. The use of 3D-printed resin-based crowns is appropriate when used as temporary options or when placed in non-load-bearing locations of the front teeth. Research should focus on how nanoparticle reinforcement and optimized polymerization techniques and surface polishing methods will improve the clinical performance of resin-based crowns.

Ethical Statement

This *in vitro* study did not involve human or animal subjects and was therefore exempt from ethical review. All experimental materials were handled and disposed of according to institutional biosafety and environmental safety protocols, including recycling of unused resin where applicable.

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