Evaluation of wear and surface roughness after brushing simulator of different CAD/CAM materials

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ABSTRACT

Aims: Chewing, toothbrushing, and parafunctional habits can increase the wear and surface roughness of restorative materials, directly affecting the longevity of restorations. This study aimed to evaluate the wear amount and surface roughness of CAD/CAM ceramics with different chemical compositions after a five-year toothbrushing simulation.

Methods: Feldspathic ceramic (Vita Mark II), zirconia-reinforced lithium silicate (Vita Suprinity), polymer-infiltrated hybrid ceramic (Vita Enamic), and resin nano-ceramic (Brilliant Crios) blocks were used. Specimens were sectioned into 2 mm thickness. Vita Mark II, Vita Suprinity, and Vita Enamic were glazed, while Brilliant Crios was polished according to the manufacturers' instructions. A computer-controlled toothbrushing simulator was applied with a 20 mm back-and-forth movement, 1.25 Hz frequency, and 3 N force. A total of 36.500 cycles simulated five years of brushing. Surface roughness was measured at the first, third, and fifth years using a 2D contact profilometer and a 3D optical profilometer, while wear was determined by precision balance.

Results: A statistically significant difference was found between Vita Suprinity and both Vita Enamic and Brilliant Crios in terms of wear (p<0.05). The order of wear, from lowest to highest, was: Vita Suprinity, Vita Mark II, Vita Enamic, and Brilliant Crios. The lowest wear occurred at the first year, and the highest at the fifth year. Surface roughness values ranked from lowest to highest as: Vita Suprinity, Vita Mark II, Vita Enamic, and Brilliant Crios. No significant difference was found between the first and fifth year roughness values (p>0.05), while significant differences were detected among other time points (p<0.05). The highest roughness was observed at first year, and the lowest at third year.

Conclusion: Glazed specimens exhibited an increase in surface roughness at first year, a decrease at third year, and an increase again at fifth years. Polished specimens showed a continuous increase in roughness over time. Surface wear was greater in glazed than in polished specimens. Vita Suprinity demonstrated the best performance in terms of both wear resistance and surface smoothness, while Brilliant Crios exhibited the highest wear and roughness.

Keywords: CAD/CAM ceramic, toothbrush abrasion, surface roughness, wear

INTRODUCTION

With the increasing aesthetic expectations of patients and the advancements in adhesive dentistry, interest in all-ceramic restorations has substantially grown.[1] The favorable properties of all-ceramics such as biocompatibility, high wear resistance, superior light transmittance, and color stability make them preferred options in restorative dentistry.[2] Nevertheless, their inherent disadvantages, including low tensile strength, difficulty in repair, and potential to cause wear on opposing natural dentition, have driven the development of alternative esthetic materials with modified compositions.[3] In recent years, the popularity of resin matrix ceramic blocks has increased with the advancement of computer-aided design and computer-aided manufacturing (CAD/CAM) technologies.[4] These hybrid ceramics, composed of both ceramic and resin matrices, present several clinical advantages: mechanical properties more comparable to natural dental tissues, ease of intraoral repair, and elimination of additional firing procedures for surface finishing. These features have expanded their application in esthetic dentistry.[5] Recent reviews further emphasize that novel CAD/CAM hybrids combine the advantages of ceramic strength with resin elasticity, offering improved machinability and repairability compared to conventional glass ceramics.[6]

Surface roughness, defined as the irregularities remaining on a material surface after final finishing, plays a crucial role in the clinical success of restorations.[7] Increased roughness can promote plaque accumulation, periodontal disease, secondary caries, loss of vertical dimension, staining, and

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compromised esthetics. Moreover, rougher surfaces exhibit greater bacterial adhesion due to lower free surface energy,[8] and they can also accelerate wear of the opposing dentition.[1] In addition, toothbrushing and the abrasiveness of dentifrices may further increase surface roughness, potentially reducing the long-term mechanical stability of restorations.[9] To minimize these risks, surface treatments such as glazing or mechanical polishing are often applied, thereby improving both mechanical integrity and esthetic stability over time.[10] Importantly, previous studies have suggested a biological threshold of approximately 0.2 μm for average surface roughness (Ra), above which bacterial adhesion and plaque accumulation significantly increase. Surfaces polished to values below this threshold are therefore considered clinically favorable, whereas rougher restorations may predispose patients to biofilm retention and secondary complications.[11]

Dental hard tissues undergo wear during mastication and toothbrushing.[12] Similarly, restorative materials are susceptible to wear, which may compromise their longevity and necessitate replacement.[13] Ideally, restorative materials should display wear characteristics comparable to those of natural teeth.[14] However, studies indicate that while all-ceramics may induce significant wear of opposing dentition, resin matrix ceramics tend to exhibit higher wear when opposed by natural teeth.[15] Recent investigations further show that zirconia-reinforced lithium silicate ceramics and polymer-infiltrated ceramics display promising wear behavior, but long-term brushing simulation data remain scarce.[16,17]

Although multiple in-vitro studies have examined the effects of toothbrushing on surface roughness and wear of restorative materials, investigations focusing on recently developed CAD/CAM ceramics remain limited. Therefore, the aim of this study was to compare novel monolithic CAD/CAM materials including zirconia-reinforced lithium silicate, resin nanoceramics, and polymer-infiltrated glass ceramics in terms of wear and surface roughness after simulated toothbrushing.

The null hypothesis of this study was that no significant differences would be detected in wear and surface roughness among the tested CAD/CAM blocks, suggesting that all materials could maintain similar long-term surface integrity under simulated oral hygiene conditions.

METHODS

Ethics

This study is an in-vitro laboratory investigation that did not involve human participants, patient data, or animal subjects.

Therefore, in accordance with national and international ethical guidelines, approval from an ethics committee was not required. The study was carried out in full compliance with research and publication ethics.

Specimen Preparation

The sample size of the study was calculated using G*power software (version 3.1.9.7, Universität Düsseldorf, Germany) through an a priori power analysis. The parameters were set as a significance level of α=0.05, statistical power (1–β)=0.95, and effect size f=0.885, resulting in a 95% confidence level. Under these conditions, a total of 48 specimens were required to achieve adequate statistical power.[18]

The monolithic CAD/CAM ceramic block materials compared in this study are presented in detail in **Table 1**. CAD/CAM blocks with dimensions of 12×14×18 mm were sectioned under water cooling using a precision cutting machine (Isomet 1000; Buehler, USA) equipped with a diamond wafering blade (Diamond Wafering Blade Series 15 LC; Buehler, USA) to obtain twelve specimens from each group, each measuring 2 mm in thickness. In total, forty-eight specimens with dimensions of 12×14×2 mm were prepared. To standardize the cut surfaces, the specimens were sequentially ground using 600, 800, 1000, and 1200 grit silicon carbide abrasive papers (Mirca Galaxy; Mirka, Turkiye) under water irrigation.[19] Mechanical cleaning was performed in an ultrasonic cleaner (Whaledent Biosonic; Coltène/Whaledent, Switzerland) with distilled water. For the Vita Mark II group, glazing was performed according to the manufacturer's instructions using the Programat EP 3000 furnace (Ivoclar Vivadent, Liechtenstein) and Vita Akzent Glaze Paste (Vita Zahnfabrik, Germany). The glazing cycle included a heating rate of 80°C/min until reaching 850°C, a holding time of 1 min at the peak temperature, and controlled cooling inside the furnace. In the Vita Suprinity group, sintering and crystallization were performed in the Programat EP 300 furnace, with a peak temperature of 840 °C and holding time of 8 min, followed by glazing with Vita Akzent Glaze Paste under the same conditions described above. For the VITA Enamic group, glazing was performed using VITA Akzent LC light-curing glaze (VITA Zahnfabrik, Bad Säckingen, Germany); the glaze was applied and light-cured for 90 s in a laboratory polymerization unit in accordance with the manufacturer's instructions. In the Brilliant Crios group, surface finishing was achieved using Dia Polisher (GC Corporation, Tokyo, Japan) polishing paste applied with a soft brush, as recommended by the manufacturer. Additionally, a two-step polishing protocol was followed: a medium-grit rubber polisher at 10.000 rpm for 30 s, followed by a fine-grit

Table 1. CAD/CAM blocks and their compositions			
Material	**Type of ceramic/hybrid**	**Composition (wt%)**	**Manufacturer**
Vita Mark II	Feldspathic ceramic	SiO_2 56-64%, Al_2O_3 20-23%, Na_2O 6-9%, K_2O 6-8%, CaO 0.2-0.6%, TiO_2 0.0-0.1%	Vita Zahnfabrik, Germany
Vita Suprinity	Zirconia-reinforced lithium silicate	SiO_2 6-64%, Li_2O 15-21%, ZrO_2 8-12%, CaO 6-8%	Vita Zahnfabrik, Germany
Vita Enamic	Polymer-infiltrated hybrid ceramic	SiO_2 58-63%, Al_2O_3 20-23%, Na_2O 9-11%, K_2O 4-6%, B_2O_3 0.5-2%	Vita Zahnfabrik, Germany
Brillant Crios	Resin-based hybrid nanoceramic	Cross-linked methacrylate (Bis-GMA, BIS-EMA, TEGDMA), 71 wt% barium glass and silica particles	Coltene/Whaledent, Switzerland
SiO_2: Silicon dioxide, Al_2O_3: Aluminum oxide, Na_2O: Sodium oxide, K_2O: Potassium oxide, CaO: Calcium oxide, TiO_2: Titanium dioxide, Li_2O: Lithium oxide, ZrO_2: Zirconium dioxide, B_2O_3: Boron trioxide, Bis-GMA: Bisphenol A diglycidyl methacrylate, Bis-EMA: Bisphenol A ethoxylated dimethacrylate, TEGDMA: Triethylene glycol dimethacrylate			

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polisher at 12.000 rpm for 30 s, under constant water irrigation. All polishing procedures were performed by the same operator to ensure standardization. The prepared specimens were embedded in silicone impression material (Zetaplus C; Zhermack, Italy) within polyester molds (25 mm in diameter and 40 mm in height), leaving a 1 mm margin from the glazed or polished surfaces. The embedded specimens were mounted in a toothbrushing simulator (Esetron MF-100; MOD Dental, Ankara, Turkiye). Medium-hard toothbrushes (Compact; Banat, Turkiye) were positioned parallel to the long axis of the specimens to cover the entire surface. A dentifrice with a high relative dentin abrasivity (RDA) value (White Now; Signal, United Kingdom) was diluted 1:1 with distilled water and placed into the toothpaste reservoir.

The simulator was set to operate in a reciprocating motion with a 20 mm stroke length, a cycle frequency of 1.25 Hz, and a brushing force of 3 N. Each specimen was subjected to 36.500 brushing strokes, simulating five years of clinical toothbrushing, corresponding to 20 strokes per day on a restoration surface. The toothpaste slurry was replenished after every 100 strokes, and the toothbrushes were replaced with new ones after every 3.650 strokes, representing six months of brushing.[11]

Surface Roughness and Wear Analysis

Following toothbrushing simulation, the surface roughness and wear of the specimens were evaluated at baseline 0 year, and after simulated 1, 3, and 5 years, using a two-dimensional contact profilometer (Sj-301; Mitutoyo, Japan) and a three-dimensional optical profilometer (Bruker Contour GT, Bruker Nano Surfaces Division, USA). In addition, material weight loss of the specimens was measured with a precision balance (Weightlab WSA-224; Weithlab Instruments, İstanbul, Turkiye).

Statistical Analysis

The obtained data were analyzed using statistical software (SPSS v23.0; IBM, USA) at a significance level of $\alpha=0.05$. The normality of distribution for continuous numerical variables was assessed using the Shapiro–Wilk test, while homogeneity of variances was evaluated with Levene's test. Differences between groups and brushing periods were examined using two-way analysis of variance (ANOVA), and multiple comparisons were performed with the Bonferroni test.

RESULTS

Wear Results

The wear values varied according to the ceramic specimens and brushing periods ($p<0.001$). The mean wear amounts and standard deviations of the experimental groups, expressed in milligrams, are presented in **Table 2** and **Figure 1**. The standard error values were consistent among all groups, indicating uniform data distribution across specimens. The mean wear value was 0.124 mg for Brilliant Crios, 0.112 mg for Vita Enamic, 0.089 mg for Vita Mark II, and 0.054 mg for Vita Suprinity. Statistically significant differences were found among the ceramic specimens ($p<0.001$). Regarding brushing periods, the wear values were 0.106 mg at 1 year, 0.123 mg at 3 years, and 0.155 mg at 5 years. No statistically significant difference was found between the 1-year and 3-year periods or between the 3-year and 5-year periods ($p>0.05$); however, significant differences were observed among the other comparisons ($p<0.001$). The lowest wear was recorded at the end of the 1-year period (0.106 ± 0.077 mg), while the highest wear was observed at the end of the 5-year period (0.155 ± 0.097 mg).
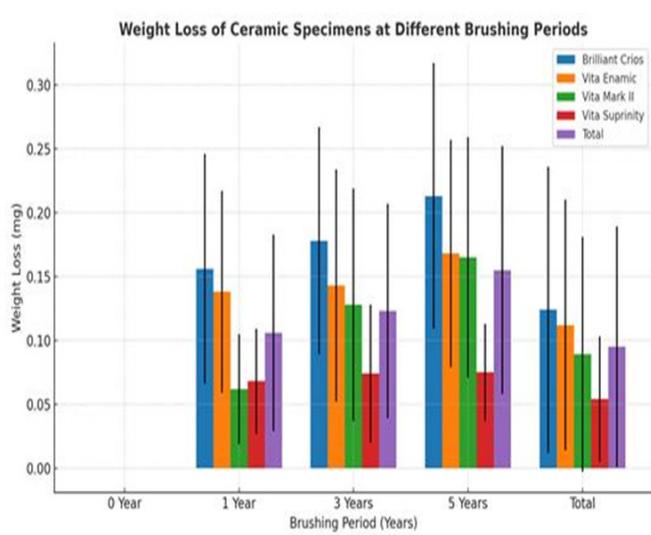
Figure 1. Graph of mean and standard deviation of wear amounts according to ceramic specimens and toothbrushing periods

The interaction between ceramic type and brushing time also significantly affected wear values ($p=0.015$). Brushing time had a greater effect on wear than the type of ceramic specimen (partial $\eta^2=0.439$). Together, brushing duration and ceramic material type explained 51.7% of the variance in wear.
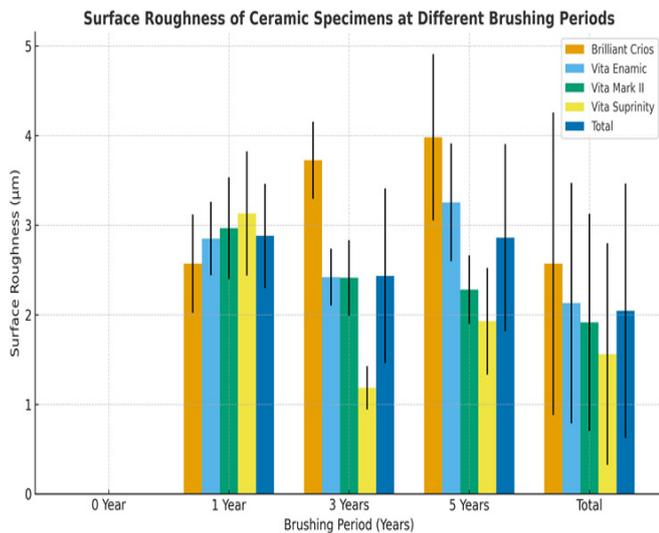
Surface Roughness Results

Surface roughness values varied according to the ceramic specimens and brushing periods ($p<0.001$). The mean surface roughness values and standard deviations of the experimental groups, expressed in micrometers (μm), are presented in **Table 3** and **Figure 2**. The standard error was similar across all groups, suggesting consistent measurement reliability. In addition, three-dimensional optical profilometer images of the brushed surfaces

Table 2. Descriptive statistical values of weight loss according to ceramic specimens and brushing periods						
		Brillant Crios	Vita Enamic	Vita Mark II	Vita Suprinity	Total
Wear amount (mg)	0 year	0±0	0±0	0±0	0±0	0±0[a]
	1 year	0.156±0.09	0.138±0.079	0.062±0.043	0.068±0.041	0.106±0.077[bc]
	3 year	0.178±0.089	0.143±0.091	0.128±0.091	0.074±0.054	0.123±0.084[c]
	5 year	0.213±0.104	0.168±0.089	0.165±0.094	0.075±0.038	0.155±0.097[dc]
	Total	0.124±0.112[a]	0.112±0.098[a]	0.089±0.092[ab]	0.054±0.049[b]	0.095±0.094

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Table 3. Descriptive statistical values of surface roughness in the experimental groups						
		Brillant Crios	**Vita Enamic**	**Vita Mark II**	**Vita Suprinity**	**Total**
Surface roughness	0 year	0±0	0±0	0±0	0±0	0±0[a]
	1 year	2.57±0.55	2.849±0.41	2.965±0.568	3.129±0.692	2.878±0.583[b]
	3 year	3.723±0.43	2.418±0.317	2.411±0.422	1.183±0.242	2.434±0.973[c]
	5 year	3.979±0.928	3.253±0.656	2.279±0.381	1.926±0.595	2.859±1.043[b]
	Total	2.568 ±1.688[a]	2.13±1.341[b]	1.914 ±1.211[c]	1.559±1.237[d]	2.043±1.419

Figure 2. Graph of mean and standard deviation of surface roughness according to ceramic specimens and toothbrushing periods

are presented in **Figure 3**. The images revealed that the Brilliant Crios group exhibited the most irregular surface topography, whereas Vita Suprinity showed a comparatively smoother surface texture after brushing.
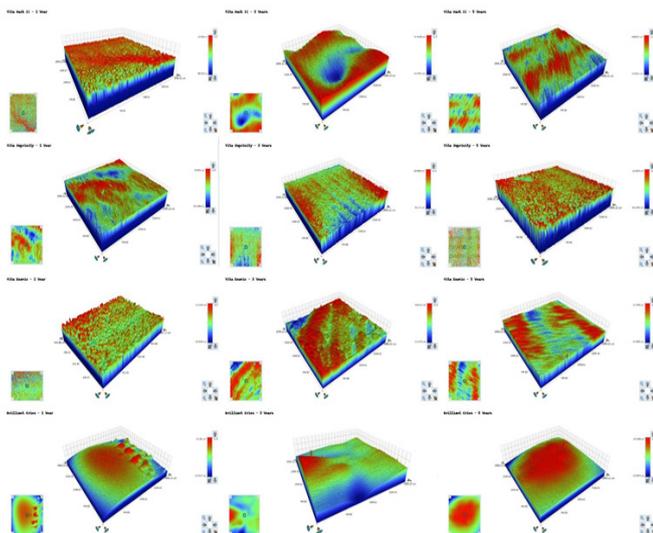
Figure 3. Three-dimensional optical profilometer images of the brushed surfaces of the experimental groups

The mean roughness value was 2.568 µm for Brilliant Crios, 2.13 µm for Vita Enamic, 1.914 µm for Vita Mark II, and 1.559 µm for Vita Suprinity. While no statistically significant difference was found between Vita Enamic and Vita Mark

II, significant differences were observed among the other ceramic specimens (p<0.001).

Regarding brushing periods, the roughness values were 2.878 µm at 1 year, 2.434 µm at 3 years, and 2.859 µm at 5 years. No statistically significant difference was observed between the 1-year and 5-year periods, whereas significant differences were found among the other comparisons (p<0.001). The highest roughness was observed at the end of the 1-year period (2.878±0.583 µm), while the lowest roughness was obtained at the end of the 3-year period (2.434±0.973 µm).

The interaction between ceramic type and brushing time significantly affected roughness values (p<0.001). Brushing time had a greater effect on roughness than the type of ceramic specimen (partial η^2=0.874). Together, brushing duration and ceramic material type explained 89.7% of the variance in surface roughness.

DISCUSSION

Aging of CAD/CAM ceramic materials with different compositions under simulated toothbrushing conditions resulted in statistically significant alterations in both surface roughness and wear. Accordingly, the null hypothesis of this study was completely rejected. The highest roughness and wear values were recorded after the 5-year simulation period. Among the tested materials, Brilliant Crios demonstrated the greatest surface degradation, whereas Vita Suprinity exhibited the lowest values for both parameters.

The preservation of surface characteristics is crucial for the long-term success of restorative materials. Smooth surfaces prevent biofilm accumulation, support periodontal health, and ensure the long-term maintenance of esthetic outcomes.[20] They also reduce the likelihood of patients experiencing a foreign body sensation from the restorations.[21] For this reason, all specimens in the present study underwent glazing or mechanical polishing according to the manufacturers' instructions.

The effect of toothbrushing force on restorative materials has been extensively discussed in the literature.[22] In a study by Ganss et al.,[23] the mean toothbrushing force of individuals was reported as 2.3±0.7 N . In the present study, a 3 N force representing the maximum force that can occur during manual brushing was applied. This allowed simulation of the highest possible mechanical stress under realistic conditions.

Although different methods can be used to measure wear, the present study employed precision weighing to obtain more reliable results.[24] While Zhi et al.[26] calculated wear by height

loss, Dahl et al.[25] measured weight changes. In this study, weight-loss-based evaluation was deemed appropriate, as it enables the accurate detection of wear at the micron level in in-vitro conditions, where moisture control is challenging.[27]

In line with the findings of De Andrade et al.,[28] which reported increased roughness in resin-based materials such as Vita Enamic, Cerasmart, and Lava Ultimate after brushing, our study also demonstrated significant increases in surface roughness values of Brilliant Crios and Vita Enamic at the end of 5 years. Similarly previously studies have reported that polymer-infiltrated and resin-based composites undergo selective matrix loss and filler debonding under prolonged brushing. The greater roughness of Brilliant Crios in the present study may be linked to the absence of a glassy phase and the predominance of organic matrix, which accelerates micro-abrasion.[9,16] The higher roughness observed in Brilliant Crios may be attributed to the faster wear of mechanically polished surfaces compared to glazed layers. The glaze layer of Vita Enamic contains low-viscosity methyl methacrylate, which may also have contributed to its greater susceptibility to wear. These findings highlight the clinical importance of surface treatment techniques for long-term success. Similarly, Muhlemann et al.[11] reported that roughness initially decreased after glazing and later increased again. A comparable pattern was observed in the present study: surface roughness of Vita Enamic, Vita Mark II, and Vita Suprinity temporarily decreased at the end of 3 years but increased again at the 5-year period. This may be related to the gradual wear of the glaze layer, exposing the restoration surface to brushing forces.

Bollen et al.[29] reported that for biological compatibility, the surface roughness of restorative materials should remain below 0.2 µm. However, in the present study, all tested materials exhibited values above this threshold. This may be explained by the use of a toothpaste with a high RDA value. According to ISO standards, RDA should not exceed 250; the toothpaste used in this study had an RDA value of 160.[30] High RDA values are known to exert a significant abrasive effect on the surface quality of restorative materials.

In a study by Ludovichetti et al.,[31] Vita Suprinity and Vita Enamic caused greater wear on bovine enamel antagonists. In contrast, the present study found the greatest wear in Brilliant Crios and the least in Vita Suprinity. This discrepancy can be explained by differences in inorganic content and hardness of the materials. Specifically, the higher polymer content of Brilliant Crios likely contributed to its greater wear, whereas the zirconia-reinforced structure of Vita Suprinity provided superior resistance. Dal Piva et al.[14] reported that Vita Enamic showed the highest wear values after long-term toothbrushing simulation, while no significant difference was observed between Vita Suprinity and Vita Mark II. Our results are consistent with these findings. The low wear of Vita Suprinity may be attributed to its high inorganic filler content and hardness. Moreover, the incorporation of zirconia into the glass-ceramic matrix enhances wear resistance.

Therefore, the clinical success of CAD/CAM materials depends not only on their initial mechanical properties but also on their long-term surface stability. Thus, restorative material selection should consider composition, hardness, surface treatment, and resistance to brushing-induced wear. Based on the present findings, Vita Suprinity, which demonstrated the lowest wear and surface roughness, appears to be the most suitable option for anterior or high-esthetic restorations requiring long-term gloss retention. Vita Mark II may also be indicated for anterior crowns and veneers due to its favorable surface integrity. In contrast, Brilliant Crios and Vita Enamic, which exhibited higher wear and roughness values, may be more appropriate for posterior restorations under lower occlusal loads or as interim restorations. Additionally, patient-specific factors such as brushing habits, toothpaste abrasivity, and dietary patterns should be considered to ensure individualized and long-lasting clinical outcomes.

Limitations

The main limitation of this study is that it was conducted under in-vitro conditions. Intraoral factors such as saliva, pH changes, temperature fluctuations, and biological influences could not be fully simulated. Furthermore, only toothbrushing simulation was performed, and additional aging methods such as thermal cycling were not included. Therefore, caution is advised when generalizing the present findings directly to clinical settings.

CONCLUSION

The surface properties of CAD/CAM materials are influenced by their composition, hardness, surface treatment, and exposure to long-term environmental factors. In this study, the effects of simulated toothbrushing on surface roughness and wear were evaluated for four CAD/CAM materials. Among them, Vita Suprinity exhibited the lowest wear and surface roughness values, indicating superior resistance to brushing abrasion, while Brilliant Crios showed the highest wear and roughness, suggesting reduced surface stability. Materials with higher inorganic content generally demonstrated greater wear resistance. Although all groups exhibited increased roughness after brushing, the values exceeded the biological threshold of 0.2 µm. Clinically, material selection should consider not only esthetics but also long-term durability and biological compatibility. Future studies should explore the effects of intraoral repolishing and the influence of toothpastes with different RDA values on wear and surface characteristics.

ETHICAL DECLARATIONS

Ethics Committee Approval

This study is an in vitro laboratory research that does not involve human participants, patient data, or animal subjects. Therefore, in accordance with national and international ethical guidelines, approval from an ethics committee was not required.

Informed Consent

Informed consent was not required for this study as it did not involve human subjects.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Financial Disclosure

Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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