



Effect of Thermocycling on Microhardness of Three CAD/CAM Provisional Materials

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Abstract

Purpose: This study aimed to evaluate and compare the surface Microhardness of three CAD/CAM provisional restorative materials before and after Thermocycling.

Materials and Methods: In this in-vitro study, ten rectangular specimens (12 × 13 × 1.5 mm) were prepared from each of the following CAD/CAM provisional materials: Structur CAD (VOCO GmbH, Germany), Telio CAD (Ivoclar Vivadent, Liechtenstein), and Vita CAD Temp Monocolor (Vita Zahnfabrik, Germany). Surface Microhardness was measured using the Vickers test (20 g load for 10 seconds). All specimens underwent 5,000 thermal cycles between 5°C and 55°C to simulate six months of clinical service. Post-cycling Microhardness was measured, and results were statistically analyzed using Repeated Measures ANOVA.

Results: Before Thermocycling, Telio CAD exhibited significantly higher Microhardness compared to Structur CAD and Vita CAD Temp ($p < 0.05$). After Thermocycling, differences among the three groups were not statistically significant ($p > 0.05$). Telio CAD and Structur CAD showed a significant decrease in surface Microhardness post-Thermocycling, while Vita CAD Temp did not show a statistically significant change.

Conclusion: Thermocycling affected the surface Microhardness of CAD/CAM provisional materials differently. While initial hardness varied among the materials, all showed comparable performance after simulated clinical aging. For temporary restorations lasting up to 6 months, none of the tested materials demonstrated a clinically superior advantage in terms of surface microhardness.

Keywords: Thermocycling; Surface Microhardness; CAD/CAM; Provisional Restoration; Vickers Test

Introduction

Mechanical deficiencies in temporary restorations, particularly in properties such as surface microhardness, can compromise the clinical success of fixed prosthodontic treatments. A reduction in surface microhardness can lead to increased surface roughness, which promotes plaque accumulation and may result in periodontal complications. Therefore, temporary restorations must possess adequate mechanical and biological properties to fulfill their critical functions. These include pulpal protection, prevention of supra-eruption or tooth tipping, maintenance of interproximal and occlusal stability, and serving as a prototype for the final prosthesis [1,2].

In recent years, the use of computer-aided design and computer-aided

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manufacturing (CAD/CAM) systems for fabricating provisional restorations has gained popularity. These systems offer advantages such as faster production and improved physical properties due to the use of pre-polymerized blocks and discs with a more homogeneous and durable internal structure [3]. Several studies have compared the mechanical behavior of CAD/CAM-based provisional materials to that of conventionally fabricated materials. CAD/CAM materials have generally shown better performance in terms of mechanical strength, surface hardness, and marginal adaptation [3-5].

Given the dynamic nature of the oral environment, temporary restorations must retain their mechanical integrity over time. To simulate clinical aging, thermocycling is commonly used in laboratory settings. This process mimics thermal stresses encountered in the oral cavity, enabling evaluation of material behavior under fluctuating temperatures [6]. However, not all studies assessing mechanical properties of provisional restorations have included thermocycling, despite evidence suggesting it may significantly influence results [7].

Some studies have reported increased surface roughness after thermocycling without affecting microhardness [8], while others have shown that thermocycling can either decrease or increase surface microhardness, depending on the material. These inconsistencies, along with the limited number of comparative studies focused on CAD/CAM provisional materials, highlight the need for further investigation.

Thus, the aim of this study was to evaluate and compare the surface microhardness of three commercially available CAD/CAM provisional restorative materials before and after thermocycling. The materials were selected based on availability and clinical use at the Islamic Azad University Dental Branch.

Materials and Methods

This in vitro experimental study evaluated the surface microhardness of three commercially available CAD/CAM provisional restorative materials: Structur CAD (VOCO GmbH, Germany), Telio CAD (Ivoclar Vivadent, Liechtenstein), and Vita CAD Temp Monocolor (VITA Zahnfabrik, Germany). Ten rectangular specimens were prepared from each material, measuring 12 mm × 13 mm × 1.5 mm in thickness (n = 10 per group) (Figure 1).

Each block was sectioned using a precision cutting machine (Presi T210, France) operating at 3200 rpm with a feed rate of 0.2 mm/s. The specimens were polished using a polishing unit (Malek Teb, Iran) at 250 rpm with successive silicon carbide abrasive papers of 1200, 2000, and 3000 grit, each applied for 60 seconds. Surface debris was removed using an air syringe. Specimens were then ultrasonically cleaned in distilled water at 37 ± 1°C for 10 minutes (Euronda Eurosanic

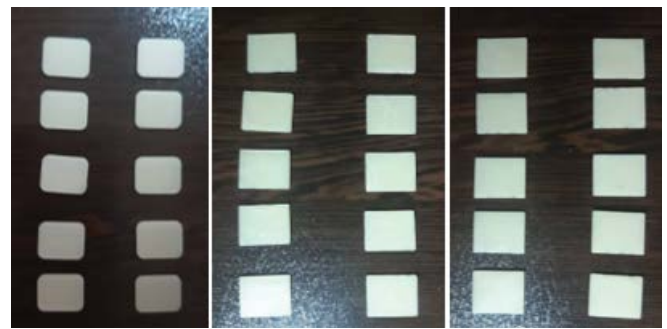


Figure 1: Prepared samples.

4D, Italy) under 100% humidity. Dimensional accuracy was verified using a digital caliper (MAX150, Netherlands).

Surface microhardness was measured using a Vickers microhardness tester (Baresiss, Germany) equipped with a square-based pyramidal diamond indenter. An initial load of 10 g was found insufficient to produce clear indentations; therefore, a load of 20 g was applied for 10 seconds. Three indentations were made per specimen (figure 2), and the diagonal lengths of each square indentation were recorded. The Vickers hardness number (VHN) was calculated using the standard formula:

$$HV = 1.854 \times F / d^2$$

where F is the applied force (kg) and d^2 is the average of the squared diagonals of the indentation (mm^2).

After baseline measurements, all specimens underwent thermocycling using a laboratory thermocycler (Vafaei TC300, Iran). The process involved 5,000 cycles between water baths at 5°C and 55°C, with a dwell time of 30 seconds in each bath and a transfer interval of 10 seconds.



Figure 2: Effect of indenter on samples.

This protocol simulates approximately six months of clinical intraoral thermal exposure.

Post-thermocycling microhardness was reassessed using the same protocol. The collected data were analyzed using repeated measures analysis of variance (ANOVA) to evaluate changes in microhardness within and between material groups. The level of statistical significance was set at $\alpha = 0.05$.

Results

A total of 30 specimens were prepared and evaluated, comprising three groups of CAD/CAM provisional restorative materials ($n = 10$ per group). The mean and standard deviation of surface microhardness values (Vickers hardness number, VHN) before and after thermocycling are presented in Table 1 Prior to thermocycling, Telio CAD exhibited significantly higher surface microhardness compared to Structur CAD and Vita CAD Temp ($p < 0.05$). No significant difference was observed between Structur CAD and Vita CAD Temp.

After thermocycling, no statistically significant differences

in microhardness were found among the three groups ($p > 0.05$) (Table 2, Figure 3). However, within-group analysis revealed a statistically significant decrease in surface microhardness in both the Telio CAD and Structur CAD groups ($p < 0.05$). In contrast, the change in surface microhardness in the Vita CAD Temp group was not statistically significant (Figure 3).

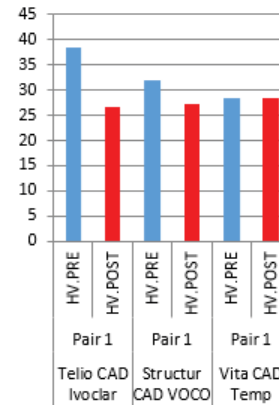


Figure 3: Comparison of Mean Vickers Hardness (HV) before and after Thermocycling in each group.

Table 1: Mean and standard deviation of surface Microhardness of the studied groups before and after Thermocycling.

Timepoint	Material	n	Mean	SD	SE	95% CI (Lower)	95% CI (Upper)	Min - Max
Before thermocycling	Telio CAD (Ivoclar)	10	38.55	5.9	1.87	34.33	42.77	29.60 - 50.20
	Structur CAD (VOCO)	10	31.92	4.39	1.39	28.78	35.06	25.40 - 37.40
	Vita CAD (VITA)	10	28.43	1.74	0.55	27.18	29.68	26.10 - 31.50
	Total	30	32.97	6	1.09	30.73	35.21	25.40 - 50.20
After thermocycling	Telio CAD (Ivoclar)	10	26.68	2.22	0.7	25.09	28.27	23.60 - 30.90
	Structur CAD (VOCO)	10	27.17	1.89	0.6	25.82	28.52	24.30 - 29.90
	Vita CAD (VITA)	10	28.31	2.21	0.7	26.73	29.89	25.00 - 31.00
	Total	30	27.39	2.15	0.39	26.58	28.19	23.60 - 31.00

SD: Standard Deviation; SE: Standard Error; CI: Confidence Interval; VHN: Vickers Hardness Number.

Table 2: Pairwise comparisons of surface microhardness (VHN) between groups before and after thermocycling.

Timepoint	Comparison	Mean Diff.	Std. Error	p-value	95% CI (Lower)	95% CI (Upper)
Before	Telio vs Structur	6.63*	1.95	0.006	1.79	11.47
Before	Telio vs Vita	10.12*	1.95	0	5.28	14.96
Before	Structur vs Telio	-6.63*	1.95	0.006	-11.47	-1.79
Before	Structur vs Vita	3.49	1.95	0.192	-1.35	8.33
Before	Vita vs Telio	-10.12*	1.95	0	-14.96	-5.28
Before	Vita vs Structur	-3.49	1.95	0.192	-8.33	1.35
After	Telio vs Structur	-0.49	0.94	0.863	-2.83	1.85
After	Telio vs Vita	-1.63	0.94	0.213	-3.97	0.71
After	Structur vs Telio	0.49	0.94	0.863	-1.85	2.83
After	Structur vs Vita	-1.14	0.94	0.459	-3.48	1.2
After	Vita vs Telio	1.63	0.94	0.213	-0.71	3.97
After	Vita vs Structur	1.14	0.94	0.459	-1.2	3.48

Statistically significant differences are marked with an asterisk (). CI: Confidence Interval

Discussion

This study evaluated the effect of thermocycling on the surface microhardness of three CAD/CAM provisional restorative materials. Among the groups, Telio CAD exhibited the highest baseline microhardness, which was significantly greater than that of Vita CAD Temp and Structur CAD. However, after thermocycling, no significant differences were observed among the groups, suggesting a convergence of their mechanical performance under thermal stress. Notably, Telio CAD and Structur CAD demonstrated a statistically significant reduction in surface hardness, whereas Vita CAD Temp maintained its microhardness.

Provisional restorations are essential for maintaining biological, functional, and esthetic stability during the interim phase of treatment. Surface microhardness is a critical factor that influences wear resistance, surface smoothness, and plaque accumulation, all of which are important for long-term success—especially in patients with parafunctional habits or those requiring extended temporization periods [3,8,17–19].

The Vickers microhardness test is a commonly used, non-destructive method for evaluating surface hardness in dental materials. Despite its simplicity and reproducibility, it is sensitive to variables such as indenter load and dwell time, which can affect measurement accuracy [3,10,13–15]. In the present study, a 10 g load was initially used, but insufficient indentation clarity led to the adoption of a 20 g load, consistent with findings from previous studies [3,8].

Our results are in agreement with those of Basak et al. and Atai et al., who reported significant decreases in the microhardness of CAD/CAM temporaries following thermocycling [3,24]. Similar findings were observed by Diaz-Arnold et al., who reported hardness reduction after immersion in artificial saliva [25]. In contrast, Oliveira et al. and Swabi et al. found no significant changes in surface microhardness following thermal or aqueous aging [8,26]. These conflicting findings may stem from differences in material composition, testing parameters, or sample preparation methods.

The mechanical behavior of provisional materials is highly influenced by their chemical structure. PMMA-based materials, such as Telio CAD, typically exhibit low filler content and high water absorption, leading to decreased mechanical stability over time. This may explain the significant reduction in microhardness observed in this group post-thermocycling [24]. On the other hand, materials like Vita CAD Temp, which are composed of highly cross-linked dimethacrylate (DMA) resins with microfillers, are known for their superior dimensional stability and resistance to hydrolytic degradation [17,19].

These differences underscore the importance of filler content and resin matrix composition in determining the long-term performance of provisional materials. Previous studies

have also suggested that higher filler loading is positively correlated with greater surface hardness [17].

While thermocycling provides valuable insight into the thermal aging of materials, it does not replicate all oral conditions. Clinical aging is influenced by mechanical loading, pH fluctuations, salivary enzymes, and dietary acids. Therefore, future studies should incorporate these additional factors to better predict the intraoral performance of provisional restorations.

Conclusion

Within the limitations of this in vitro study, it was found that the initial surface microhardness of the evaluated CAD/CAM provisional restorative materials differed significantly. However, after 5,000 thermal cycles simulating six months of intraoral thermal stress, no statistically significant differences remained among the materials. These results suggest that, despite initial variability, all tested materials demonstrated comparable performance following thermal aging.

The main limitation of this study is its in vitro design, which does not fully replicate the complex oral environment, including mechanical forces, salivary enzymes, and pH variations. Additionally, the selection of materials was restricted due to local availability and import regulations. Further clinical studies are warranted to validate these findings under real-world conditions.

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