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Effect of thermo-cycling on microhardness of CAD-CAM provisional materials

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Abstract

Purpose: Temporary restorations are an important stage of fixed prosthetic treatment in the period until the final restoration is made and the most appropriate provisional material with CAD-CAM technology used today should be researched. The aim of this study was to investigate the effect of thermo-cycling on micro hardness of CAD-CAM Provisional materials.

Materials and methods: Three types of provisional restorative materials produced for CAD-CAM systems were examined: Vita CAD Temp (Vita Zahnfabrik, Germany), Telio CAD (Ivoclar Vivadent, Liechtenstein) and Ceramill Temp (Amann Girrbach, Austria). A total of thirty disc specimens with 2 mm thick and 10 mm diameter were produced (n=10). Vickers hardness was measured under a load of 10g for 10s. All specimen groups were subjected to 5000 thermo cycles and hardness measurements repeated. One-way ANOVA and post hoc Tukey's test were used for statistical analysis.

Results: Hardness values (HV) of CAD-CAM provisional materials decreased after thermo-cycling, however, it was not statistically significant ($p>0.05$).

Conclusion: Thermo-cycling affects the hardness of CAD-CAM provisional materials tested. Thermo-cycling was directly related to the reduction of microhardness values for the CAD Temp and Ceramill Temp. These findings may support clinicians to advice patients who have to use temporary restorations for a long time to avoid thermal changes in the mouth.

Keywords: Thermo-cycling, microhardness, CAD-CAM, provisional material

1. Introduction

Provisional restorations are commonly used in dentistry to meet the patient's functional and aesthetic expectations until the final restorations are made [1]. They protect the prepared teeth from chemical and thermal factors, prevent the movement of the supporting teeth, as well as ensure the continuity of occlusal relations and occlusion [2, 3, 4]. Several types of acrylic resins such as polymethyl methacrylate (PMMA) resin, polyethyl methacrylate (PEMA) resin, polyvinyl methacrylate resin, bis-acryl composite resin, and visible light-cured urethane dimethacrylates are used for fabrication of provisional restorations. Since conventional temporary restorations are polymerized under non-standard conditions, they have an inhomogeneous, cracked and porous structure. Therefore, early coloration and long-term loss of stability and biocompatibility are observed in these prostheses [5]. There are two techniques in the construction of provisional restorations as direct and indirect method. The indirect method prevents the pulp and tissue surrounding the tooth from being damaged by heat and residual monomer and it can reduce polymerization shrinkage [6].

Today, the use of computer-aided design/computer-aided manufacturing (CAD/CAM) technology has become widespread in the construction of provisional restorations by indirect method. CAD/CAM systems allow the construction of long-lasting temporary restorations and reduce working time and labor. Many manufacturers offer high density polymers with high crosslinked polymethyl methacrylate (PMMA) resin content for CAD-CAM systems [7, 8]. These cross-linked materials have different mechanical properties depending on their chemical composition [9]. On the other hand, surface hardness is directly related to the quality of polymerization and cross-link density [4, 9]. The blocks and discs used for these systems have a stronger and more homogeneous structure as they were previously polymerized.

In addition, unlike the PMMA materials used in the conventional method, these blocks do not have an inhibition layer and do not undergo polymerization shrinkage since they are polymerized before milling [10].

Thermo-cycling is a popular method of artificially accelerated aging of dental materials, as it mimics the oral environment. This method involves standardized thermal conditions with baths ranging from 5 to 55 °C for several cycles. The thermo-cycling method can affect the long term success of the restoration. Because it can enable the simulation the behavior of the material in the oral environment [11].

This study aimed to investigate the effect of thermo-cycling on micro hardness of CAD-CAM Provisional materials. The null hypothesis for this study was that the microhardness values of different CAD CAM provisional materials used for interim restorations after thermo-cycling would be similar.

2. Materials and Methods

In this in-vitro study, three CAD-CAM provisional restorative materials were used for specimen fabrication. Thirty disc specimens of 2 mm thick and 10 mm diameter were obtained from Vita CAD Temp (Vita Zahnfabrik, Germany), Telio CAD (Ivoclar Vivadent, Liechtenstein) and Ceramill Temp (Amann Girrbach, Austria). Table 1 shows the materials evaluated in this study.

For the fabrication of specimens, a wax sample was produced. The sample was scanned in the CAD system and the images were transferred to digital media. In this study 1M2 for Vita CAD-Temp and for Telio CAD, light shade for Ceramill Temp was chosen for standardization. The samples were prepared by milling the discs using the CAM device.

Hardness measurements (VHN) were made with a Vickers microhardness indenter (Future Tech FM 800e, Future Tech Corp, Tokyo, Japan). Ten disc-shaped samples were obtained from the blocks for each group. The test specimens were wet ground using 800-, 1200-, and 2000- silicon carbide paper to remove surface irregularities. The indentations were made using a 10g load with a dwell time of 10 s. Three indentations were made on each specimen, and then the mean value was calculated. After the first measurements, thermo-cycling was applied in a specially designed device, which consists of 4 tanks with deionized water at standard temperatures. All specimens were thermocycled between 5-55 °C with 15 seconds dwell time for 5000 thermo cycles [12, 13].

Table 1: Materials evaluated in this study

Material	Type	Manufacturer
CAD Temp	Bis-acryl composite resin	Vita Zahnfabrik, Germany
Telio CAD	Monometacrylate (PMMA)	Ivoclar Vivadent, Liechtenstein
Ceramill Temp	Monometacrylate (PMMA)	Amann Girrbach, Austria

Statistical analyses were performed with the software SPSS 19.0 (IBM Corporation, Armonk, USA). The variables were investigated using visual (histograms, probability plots) and analytical methods (Kolmogorov-Smirnov/ Shapiro-Wilk's test to determine whether or not they are normally distributed. Descriptive analyses were presented using means and standard deviations normally distributed variables. The one-way ANOVA was used to compare the micro-hardness values among there different CAD-CAM provisonal materials. Levene test was used to assess the homogeneity of variances. An overall p-value of less than 0.05 was considered to show a statistically significant result. When an overall significance

was observed pairwise post-hoc tests were performed using Tukey's test. In addition, t-test was used to evaluate the difference between the values obtained before and after thermo-cycling. p values < 0.05 were considered statistically significant.

3. Results

The results of the micro-hardness testing for three CAD-CAM provisional restorative materials using one-way ANOVA are shown in Table 2. Statistical analysis revealed no significant difference in hardness values (HV) of the materials tested after thermo-cycling. The results of this experimental study indicated that HV of CAD Temp and Ceramill Temp decreases after thermo-cycling. For HV of tested materials, Telio CAD specimens demonstrated the lowest mean values (22.22 ± 1.80), while CAD Temp exhibited the highest HV values (24.95 ± 1.46) before thermo-cycling. On the other hand, although there is a significant difference between the HV of Telio CAD and CAD Temp ($p < 0.05$), Ceramill Temp is no different from the others before thermo-cycling ($p > 0.05$). In addition, Telio CAD surface hardness increased after thermo-cycling. The results of the micro-hardness testing for three CAD-CAM provisional restorative materials before and after thermo-cycling using t-test are shown in Table 3. There were statistically significant differences between hardness values before and after thermo-cycling ($p < 0.001$).

Table 2: Vickers Hardness means (VHN) \pm standard deviations for the experimental groups.

	Telio CAD	CAD Temp	Ceramill Temp	p value
Before thermo-cycling	$22.22 \pm 1.80^{*a}$	$24.95 \pm 1.46^{*b}$	23.82 ± 1.29^{ab}	0.002
After thermo-cycling	22.34 ± 0.91	22.37 ± 0.79	21.86 ± 1.22	0.448

*: Statistically significant difference ($p < 0.05$)

Table 3: Comparison of micro-hardness values before and after thermo-cycling using t-test (n=30)

	Mean \pm SD	p value
Before thermo-cycling	23.66 ± 1.88	0.000*
After thermo-cycling	22.19 ± 0.99	

*: Statistically significant difference ($p < 0.001$)

4. Discussion

In the present study, microhardness of three CAD-CAM provisional restorative materials were investigated with respect to the effect of thermo-cycling procedure. The null hypothesis was accepted. This in-vitro study demonstrated that thermo-cycling decreased the hardness values of CAD-CAM provisional materials evaluated except for Telio CAD. After thermo-cycling, there was no statistically significant difference between the hardness values of the CAD-CAM provisional materials tested.

In fixed prosthetic treatment, provisional restorations meet the functional and aesthetic expectations of the patient until the final restoration, as well as protect pulpal tissue against physical, chemical and thermal injuries. In addition, they are necessary in ensuring occlusion, contour and health of gingival tissues. The oral environment is dynamic and a number of factors such as saliva, food components and the interaction of thermal changes cause wear and aging in provisional restorations. As temporary restoration material, several types of resins are used to fabricate provisional restorations. The development of CAD-CAM technology has enabled the construction of provisional restorations with the

indirect method. There are some studies investigating the mechanical properties of temporary restorations in the literature [14, 15, 16]. Studies on the hardness of CAD-CAM temporary restoration materials with thermo-cycling are limited. Therefore, in our study, we investigate the effect of thermo-cycling on hardness of CAD-CAM provisional restorative materials.

There are contradictions in the literature regarding the use of hardness tests. Although the Vickers hardness test is less sensitive to surface conditions, there is a literature that recommends its use because it is more sensitive to measurement errors [14]. In this study, the Vickers hardness test was chosen as it is suitable for determining the hardness of small areas and applying it for very hard materials [17]. The Vickers hardness test method consists of a diamond indenter in the form of a right pyramid with a square base and an angle of 136 degrees between opposite faces. During the Vickers hardness test, a load between 1 and 100 Kgf is applied to the surface for 10 to 15 seconds. After removal of the load, diagonals of the indentation were measured using a microscope and the area of the sloping surface of the indentation is calculated [17, 18]. In this study, 10 gr load was applied for 10 seconds. There are also studies in which different loads are applied in different time periods in the literature [19, 20]. On the other hand, the hardness value is related to the applied load. Higher results may occur at higher indentation loads. Chuenarrom *et al.* in their study investigating the effect of indentation load and time on the micro hardness of enamel and dentin, reported that while the difference in indentation time did not affect the hardness values of enamel and dentin for the same indentation loads, the change in indentation loads affected the hardness values [18]. The clinical performance of a dental material is determined with its mechanical properties. Good mechanical properties are necessary for the clinical success of temporary restorations. Hardness which is one of these properties of a dental material, is defined as the resistance to permanent indentation or penetration and the greatest changes in the hardness values of resin composites occur within the first 7 days [21]. Hardness of provisional restorations gain importance, especially in cases where the patient has to use pro-visional restoration for a long time, parafunctional habits are present, and a long-span prosthesis is planned [22]. In this experimental study, although the hardness measurements of 3 different CAD-CAM provisional restorative materials before thermo-cycling were different, there was no statistical difference between the hardness values after thermo-cycling. This difference prior to thermo-cycling may arise from the type, composition of the resin matrix and the filler particles. Because, it is known that as with the other composite structures, these parameters affect the mechanical properties of the material [22].

Surface hardness of provisional materials may be influenced by saliva, food components, beverages and interactions among these materials. Changes occur in the structure of the material due to its exposure to different temperatures with long-term use. Thermo-cycling is a good process that simulates changes in the oral environment, causing aging of the material (19). A total of 10,000 cycles represent one year on clinical usage [23]. The number of cycles varied in different studies [23, 24, 25]. In the present study, the samples were subjected to 5000 cycles between 5°C and 55°C. Studies such as Oliveiraa *et al.* [4] and Ghavami-Lahiji *et al.* [24] investigated the effect of thermo-cycling on micro-hardness and reported that thermo-cycling significantly decreased the hardness.

These results are consistent with our study.

In this in-vitro study, three CAD-CAM provisional restoration materials were used. Vita CAD Temp (Vita Zahnfabrik, Germany) is bis-acryl composite resin, Telio CAD (Ivoclar Vivadent, Liechtenstein) and Ceramill Temp (Amann Girrbach, Austria) are monometacrylates. (PMMA). Bis-acryl composite resins have a high hardness due to the presence of a high amount of nanoparticulate filler in their composition. Because of functional methacrylate esters the number of crosslinks between monomers is increased [26]. However, Cad-Temp in bis-acryl composite resin structure showed the highest hardness values in hardness measurements before thermo-cycling in the present study. In addition, Reepomaha *et al.* [27] reported that provisional restorations manufactured using the CAD / CAM process and conventionally manufactured bis-acryl resins have higher fracture resistance. Although mono-metacrylate was mechanically inferior to bis-acryl, PMMA restoration manufactured with CAD / CAM technology exhibits significantly higher fracture strength than conventionally produced PMMA.

In the literature, the number of studies investigating the effect of thermo-cycling on the microhardness of CAD-CAM provisional materials is very limited. Digholkar *et al.* [28] evaluated and compared the flexural strength and microhardness of provisional restorative materials fabricated utilizing rapid prototyping (RP), CAD-CAM and conventional method and reported a hardness value of 25.6 KHN (knoop hardness number) for CAD-CAM resin group. Verma *et al.* [29] investigated the effect of water temperature and duration of immersion, on the marginal adaptation and microhardness of four different commercially available provisional restorative materials and concluded that the bis-acryl composite materials exhibit superior surface microhardness. Diaz-Arnold *et al.* [30] stated that bis-acryl composite resin materials exhibited superior microhardness over the traditional methyl methacrylate resins. Similar to the studies mentioned above, according to the findings of this in-vitro study, the CAD Temp in bis-acryl composite resin structure showed the highest micro hardness values of 24.95 HV and 22.37 HV before and after thermo-cycling.

Today, CAD / CAM technology is preferred because of its easy and accessible nature. In addition, CAD / CAM manufacturing processes allow for faster production of temporary restorations. Whether it is produced by conventional methods or with CAD-CAM technology, thermo-cycling reduces the hardness of restorations and causes them to fail more easily in oral cavity. Nevertheless, the use of cad cam technology can be supported for the long-term clinical success of provisional restorations.

5. Conclusion

Within the limitations of this study, it may be concluded that hardness of CAD-CAM provisional restorative materials are statistically affected by thermo-cycling in-vitro ($p < 0.05$) Thermo-cycling was directly related to the reduction of micro-hardness values for the CAD Temp and Ceramill Temp. These findings may support clinicians to advise their patients who have to use temporary restorations for a long time to avoid thermal changes in the mouth.

6. References

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