

# Evaluation of Mechanical Behavior of CAD/CAM Polymers for Long-term Interim Restoration Following Artificial Aging

## Keywords

Mechanical Properties  
Artificial Aging  
Interim Restoration

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## ABSTRACT

Mechanical properties are crucial parameters for the clinical performance of long-term CAD/CAM interim restorations. This study aimed to evaluate and compare fracture toughness (FT), flexural strength (FS), flexural modulus (FM), microhardness (H), and the brittle index (BI) of three different long-term interim restorative materials after simulated ageing. CAD-Temp; VCT, Everest C-Temp; CT, and PEEK; PK were the materials used. Specimens were divided into subgroup A (control group) with no thermocycling, and subgroup B subjected to 5000 thermocycles between 5 and 55 °C for 30 seconds. FS, FM, FT, H, microstructure, and the brittle index were evaluated. The data was examined using two-way ANOVA and Tukey's test for post-hoc comparisons. In the VCT group, FS, FT, and H were significantly reduced ( $p < 0.05$ ) after thermocycling. In the PK group, no statistically significant differences ( $p > 0.05$ ) were detected between the aged and non-aged groups. As for the CT group, the tested properties were significantly reduced ( $p < 0.05$ ) after simulated aging condition. The PK group recorded appropriate mechanical behavior both before and after simulating aging, in addition to its better machinability than other materials. The CT group had better mechanical properties before and after ageing, despite the significant reduction in mechanical properties after aging.

## INTRODUCTION

Interim restorations are an essential part of fixed prosthodontics and dental implantology because they provide aesthetics, mastication, and protection for soft and hard tissues for a period of time while the definitive prosthesis is being made. These restorations should be able to withstand masticatory stresses, be aesthetically acceptable, resist degradation, and provide enough marginal adaptation, in addition to wear resistance, color stability, rigidity, ease of production, and repairability.<sup>1</sup>

Interim prostheses are fabricated either by traditional or CAD CAM techniques. Because of its color stability and high mechanical properties, conventional polymethyl methacrylate (PMMA) was the most utilized polymer. However, due to heat generation during the polymerization, pulp damage and shrinkage may deform restoration. As a result, bis-acryl resin composites have overtaken PMMA. Recently, CAD/CAM highly cross-linked PMMA has gained popularity for fabricating interim restorations with high precision and reduced time.<sup>2-6</sup> These restorations are produced from high-density

Received: 20.12.2021  
Accepted: 25.03.2022

doi: 10.1922/EJPRD\_2392Soliman09

preprocessed resin polymer blocks which have been reported to have higher mechanical properties, marginal quality, and better color stability than the conventionally processed resin. In addition, it has been reported that the milled CAD/CAM PMMA was shown to have superior strength to the auto-polymerized PMMA and traditional bis-acrylic based materials.<sup>7-10</sup>

Long-term interim restorations are crucial issue in case of oral implantation treatment or when comprehensive occlusal reconstruction is required especially when subjected to prolonged functional stresses.<sup>11</sup> The type of materials,<sup>12-14</sup> ease of processing and bonding,<sup>15-17</sup> mechanical properties and oral environmental conditions<sup>18</sup> are necessary factors to be considered when selecting long-term interim restorative materials. While CAD/CAM PMMA restorations appear to be very promising materials, their long-term survival rate might be compromised in the oral environment. As a result, new materials such as fiberglass reinforced polymer, and Poly ether ether ketone have been released to address this problem, with claims of improved mechanical properties and durability.<sup>7,1,20</sup> However, there is little information on their long-term mechanical durability.

Interim restorative materials should be strong enough to prevent fracture, as repair will consequently demand an additional appointment. Furthermore, these materials are routinely exposed to oral circumstances such as rapid temperature changes and repetitive occlusal force. The thermal stresses could degrade the materials' surfaces and compromise their mechanical properties when hot and cold beverages are consumed in the oral cavity. As a result, the mechanical properties of long-term interim restorations are critical issues that may alter their durability when subjected to thermal and masticatory stresses.<sup>18</sup>

Understanding mechanical properties is crucial for validating manufacturers' claims, evaluating newer materials on the market, and comparing them to others to find the best material for long-term interim restorations. Hence, fracture toughness, flexural strength and hardness become extremely valuable mechanical properties, particularly in long span prostheses, in patients with parafunctional patterns, or when the patient must use the interim restoration for an extended period. Therefore, this study aimed to assess and compare fracture toughness, flexural strength, flexural modulus, microhardness, and the brittle index of three different types of CAD/CAM polymers used for long-term interim restorations following simulated aging. The null hypothesis proposed that these materials have similar mechanical properties and the simulated aging conditions would have no effect on these properties.

## MATERIAL AND METHODS

Three types of CAD/CAM polymer; Polyacrylate polymer (CAD-Temp; CT), fiber-glass-reinforced polymer (Everest C-Temp; ET), and Poly ether ether ketone PEEK (BioHPP; BH) were used in this study for fabrication of interim restorations (Table 1). According to the power analysis (size effect=2.34,  $\alpha$ -two tailed=.05), a sample size of twenty specimens in each group was required to obtain a 0.95 power using a 0.05 significance level.

## SPECIMEN PREPARATION AND GROUPING

Sixty bar-shaped specimens were cut from each CAD/CAM polymer block (n=20) with the desired dimensions for each test by an ISOMET (Techcut4, Allied, USA). The edges of the specimens were chamfered to prevent stress concentration. A digital caliper (Mitutoyo Corporation, Tokyo, Japan) was used to ensure uniform specimen dimensions. Different grit sizes (600-2000 grits) of silicone carbide papers were used to

**Table 1. Materials used in the study.**

Product	Composition/ Manufacturer	Indication	Lot. No.
CAD-Temp	-83–86 wt.% PMMA, 14 wt.% micro filler (silica), Pigments (<0.1%). - VITA Zahnfabrik	Multi-unit, fully or partially anatomical long-term temporary bridges with up to 2 pontics.	38590
Everest C-Temp	-Fiber glass-reinforced polymer. - High performance endless molecular Polymer chain plastic. - KaVo, Biberach, Germany	Long-term temporary restoration up to 6 units.	6946
Bre CAM Bio HPP	-Poly ether ether ketone, 20 wt% titanium dioxide ceramic filler and Aluminum oxide sand (50 $\mu$ m mean particle size) - Bredent GmbH &co., Senden, Germany	4-part posterior bridge up to two pontics.	56654456

finish specimens under copious water-cooling followed by a 3-minute ultrasonic cleaning in deionized water then polished by diamond paste (Buehler, Düsseldorf, Germany). Following that, the specimens were distributed into two subgroups (n=10). Subgroup A: specimens were evaluated at room temperature for 24 hours to serve as a control, while subgroup B: specimens were subjected to 5000 -times thermocycles (SD Mechatronic GmbH, Feldkirchen Westerham, Germany) at between 5 and 55 °C for 30 seconds.

## FLEXURAL STRENGTH TESTING

Twenty bar-shaped specimens (25 mm × 2 mm × 2 mm<sup>3</sup>) were produced from each material in accordance with ISO 10477:2020 (Dentistry-Polymer-Based Crown and Bridge Materials).<sup>21</sup> The universal testing machine is calibrated once a year. Specimens were put into a specimen holder apparatus with a support span of 20 mm on a universal testing machine. Following insertion, the load was applied to the specimens' middles at a crosshead speed of 1.0 mm/min. The following mathematical formulas were used for measurement: flexural strength  $\sigma_s$  (MPa) and flexural modulus  $E_f$  (GPa).<sup>21-23</sup>

$$\text{Flexural strength } (\sigma_s) = \frac{3PL}{2BD^2}$$

$$\text{Flexural modulus } (E_f) = \frac{PL^3}{4BD^3d}$$

where P (N) is the maximum load at fracture, L is the roller span (20 mm), B is the bar width, D is the bar height, and d is the deflexion corresponding to load P.

## FRACTURE TOUGHNESS TESTING

The fracture toughness ( $K_{Ic}$ ) was determined using the single-edge notch-three-point bending (SENB) test. Twenty bar-shaped specimens (25 mm × 5 mm × 2 mm) were prepared from each material. To produce the notch, specimens were placed in a customized flat holder. The holder is fitted into a precision cutting machine. A V-shaped notch perpendicular to the specimen's long axis was made in the specimen's middle with a diamond cutting disc (0.3 mm thick) as a beginning notch 0.5 mm deep. To achieve a controlled and smooth notch, the created notches were filled with diamond polishing paste, finished using a razor blade attached to a custom machine with uniform back-and-forth movements, after which it was ultrasonically cleaned for 5 minutes. The blade was replaced after every four specimens. The notch depth ranged from 0.8 to 1.2 mm.<sup>24-26</sup> An optical stereomicroscope with a magnification of 40x (Olympus SZ61, Tokyo, Japan) was used to measure the depth of the notch and evaluate the specimens for defects. A defective specimen was replaced with a new one. The specimens were loaded into a three-point bending in a universal testing machine (AGS-1000A; Shimadzu CO., Kyoto, Japan) with a crosshead speed of 1.0 mm/min, at room temperature, and the notch was positioned centrally beneath the crosshead contact, according to ISO 13586:2018.<sup>27</sup> The distance between the two supports was 20 mm.

Using the following equation,<sup>27</sup> the fracture toughness,  $K_{Ic}$  (MPa m<sup>0.5</sup>) was calculated as follows:

$$K_{Ic} = g \left[ \frac{P_{max} S_0}{BM^{3/2}} \right] \left[ \frac{3(a/W)^{1/2}}{2(1-a/W)^{3/2}} \right]$$

Where

$$g = g\left(\frac{a}{W}\right) = \frac{1.99 - [a/W][1 - a/W][2.15 - 3.99[a/W] + 2.7[a/W]^2]}{1 + 2[a/W]}$$

Where  $K_{Ic}$  is the fracture toughness, while g is a function of the ratio a/W, Pmax is the maximum load to failure (N), S0 is the distance between the center of the rollers (20 mm), W is the specimen width, B is the specimen thickness, and a is the depth of the notch.

## MICROHARDNESS TESTING

Twenty bar-shaped specimens of each material were produced with (14 mm × 4 mm × 4 mm) dimensions. A digital microhardness tester (Buehler Micro Met II, Buehler Ltd., Lake Bluff, IL, USA) was used to determine the surface microhardness. A diamond indenter was used to make five indents in each specimen for 20 seconds under a 9.8 N force, in the center of the specimen and at least 0.5 mm apart. The major diameters of the Vicker's indent (d1 and d2) were measured with an optical micrometer.<sup>25,28</sup> The following equation was used to calculate the Vickers hardness for each specimen:<sup>25,29</sup>

$$H = 1.8544 \frac{P}{d^2}$$

where H is the hardness (MPa), P is the applied load (kg) and d is the mean indentations diagonal length (mm).

## BRITTLE INDEX (BI) TESTING

The following equation was used to calculate the brittleness index (B) for each specimen:<sup>30-32</sup>  $\frac{H}{K_{Ic}}$  where H is the hardness (GPa) and  $K_{Ic}$  is the fracture toughness.

## SCANNING ELECTRON MICROSCOPY EVALUATION

Three additional representative specimens from each material (10 mm × 10 mm × 1 mm) were produced and cleansed with 96% ethanol in an ultrasonic bath for two minutes, then air-dried. For the qualitative investigation of each material, specimens were mounted on metallic stubs, gold sputter-coated, and then examined under a SEM (Jeol-JSM-6510, Tokyo, Japan) with an original magnification of 100 and 500 x.<sup>33,34</sup>

## STATISTICAL ANALYSIS

The normality and equal variance assumptions were fulfilled according to the Shapiro-Wilk test and Levene's test. Subsequently, statistical analyses (SPSS 22.0; IBM statistics) of the flexural strength, flexural modulus, fracture toughness, and hardness were analyzed using two-way ANOVA to determine statistically significant differences. A One-way ANOVA was conducted for the BI values of the three different materials. Tukey's significant difference test was used for *post-hoc* comparisons. A two-way ANOVA was

also applied to detect the interaction between the two independent variables (material type and aging). For all statistical tests, the level of significance was set at 5%. Additionally, FS data was entered into a Weibull analysis to calculate Weibull modulus ( $m$ ), characteristic flexural strength ( $\sigma_0$ ).

## RESULTS

Table 2 shows the means and standard deviations of flexural strength, flexural modulus, fracture toughness, and hardness before (control) and after simulated ageing. The two-way ANOVA showed statistically significant differences in FS, FM, FT, and H among the three different materials (VCT, CT, PK) either before (control) or after simulated aging ( $p < .05$ ). Regarding the VCT group, FS, FT, and H were significantly reduced ( $p < .05$ ) after aging conditions, while there was no significant difference between FM values either before or after aging ( $p = .23$ ). Regarding the PK group, no statistically significant differences were detected in the values of FS ( $p = .16$ ), FM ( $p = .98$ ), FT ( $p = .41$ ), and H ( $p = .44$ ) between the aged and non-aged groups. As for CT group, the tested properties were significantly reduced ( $p < .05$ ) after simulated aging condition. One-way ANOVA indicated a statistically significant difference in the BI values of the three different materials. Independent variables (material type, and aging) and their interactions were significantly affecting ( $p < .001$ ) the tested properties values as shown by the two-way ANOVA table (Table 3).

The surfaces of CAD-Temp (VCT), C-Temp (CT), and PEEK (PK) under SEM showed variations in the surface microstructures (Figure 1). VCT showed spherical areas of widely varying extensions that well obviously embedded in the resin matrix material (Figures 1a and b). While CT group showed irregular shaped long fibers intervening between them spherical shaped fillers particles with homogenous distribution with

in the materials (Figures 1 c and d). As for the PK group, it showed homogenous topography without voids or morphological defects (Figures 1 e and f).

## DISCUSSION

Long-term interim prostheses are commonly used in implant-supported treatments, periodontal therapy that necessitates ongoing monitoring, and maxillofacial rehabilitation where the prostheses are subjected to functional stresses. Furthermore, they may provide new treatment choices in the case of complex comprehensive treatments and immediate loading protocols due to their excellent mechanical properties.<sup>7,1,35</sup> While mechanical properties are one of the most important parameters for the clinical success and longevity of long-term CAD/CAM interim restorations,<sup>11,23</sup> independent studies on these parameters are scarce. As a result, the aim of the current was to evaluate and compare flexural strength, flexural modulus, fracture toughness, and microhardness of three different types of CAD/CAM polymers used for long-term interim restorations after simulated aging. Furthermore, the brittle index of these materials was determined to better understand the mechanical behavior of these CAD/CAM materials.

While no single property can anticipate a material's clinical performance, measurements such as flexural strength (FS), flexural modulus (FM), fracture toughness (FT), and hardness (H) can provide insight into these materials' behavior when subjected to simulated environmental thermal stresses. The findings of a three-point flexural test can be used to calculate FS, FM, and FT.<sup>36,37</sup> The flexural strength of a material can be used to determine its resistance to bending failure. The flexural modulus can be used to measure the stiffness of a material that can elastically store energy.<sup>37</sup>

**Table 2.** Mean (standard deviation) values of flexural strength (FS), flexural Modulus (FM), fracture toughness (FT), hardness (H), and brittle index (BI) of VCT, CT, and PK interim restoration.

	FS		FM		FT		H		BI
	Non-Aged	Aged	Non-Aged	Aged	Non-Aged	Aged	Non-Aged	Aged	Non-Aged
VCT	96.47 <sup>c1</sup> (± 2.38)	77.39 <sup>c2</sup> (± 3.48)	4.01 <sup>c1</sup> (± .15)	3.71 <sup>c1</sup> (± .04)	1.14 <sup>c1</sup> (± .10)	0.89 <sup>c2</sup> (± .07)	26.13 <sup>c1</sup> (± 2.19)	21.43 <sup>c2</sup> (± 1.85)	.22 <sup>b</sup> (± .02)
CT	319.16 <sup>a3</sup> (± 6.92)	264.71 <sup>a4</sup> (± 5.91)	17.30 <sup>a2</sup> (± .97)	13.77 <sup>a3</sup> (± .95)	2.36 <sup>a3</sup> (± .06)	1.85 <sup>a4</sup> (± .04)	68.67 <sup>a3</sup> (± 2.09)	56.45 <sup>a4</sup> (± 2.04)	.29 <sup>a</sup> (± .01)
PK	201.48 <sup>b5</sup> (± 5.00)	204.46 <sup>b5</sup> (± 2.31)	4.45 <sup>b4</sup> (± .14)	4.45 <sup>b4</sup> (± .13)	1.58 <sup>b5</sup> (± .10)	1.55 <sup>b5</sup> (± .07)	28.98 <sup>b5</sup> (± 1.35)	27.25 <sup>b5</sup> (± 1.78)	.17 <sup>c</sup> (± .09)

Mean values represented with different superscript lowercase letters (column) for each type of material is significantly different ( $P < .05$ )  
Mean values represented with different superscript numbers (row) for each property is significantly different tests ( $P < .05$ )

**Table 3. Two-way ANOVA for the dependent variables**

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
<b>Material</b>	Flexural Strength	422721.70	2	211360.85	9684.07	$p < .001$
	Flexural Modulus	1727.22	2	863.61	2707.61	$p < .001$
	Fracture Toughness	11.91	2	5.95	873.18	$p < .001$
	Hardness	18479.75	2	9239.87	2741.27	$p < .001$
<b>AGING</b>	Flexural Strength	8295.03	1	8295.03	380.06	$p < .001$
	Flexural Modulus	24.52	1	24.52	76.89	$p < .001$
	Fracture Toughness	1.06	1	1.06	155.49	$p < .001$
	Hardness	710.70	1	710.70	210.85	$p < .001$
<b>Material * AGING</b>	Flexural Strength	8390.44	2	4195.22	192.21	$p < .001$
	Flexural Modulus	38.52	2	19.26	60.39	$p < .001$
	Fracture Toughness	.58	2	.29	42.82	$p < .001$
	Hardness	216.00	2	108.00	32.04	$p < .001$
<b>Total</b>	Flexural Strength	2697457.79	60			
	Flexural Modulus	5603.46	60			
	Fracture Toughness	159.81	60			
	Hardness	105403.56	60			

The three-point bonding test was carried out in accordance with ISO 10477:2020 (Dentistry-Polymer-Based Crown and Bridge Materials),<sup>21</sup> as it is a typical test for determining flexural strength properties. Fracture toughness is characterized as the resistance of a material to crack propagation. It is frequently used to describe the fracture resistance of brittle materials. The single-edge notch-three-point bending test was used because it is a commonly used method for testing fracture toughness, imposing a tensile force on the notch and causing fracture through the thickness of the material.<sup>24,27</sup> According to ISO 10477:2020 and ISO 13586:2018, the dimension of the bar-shaped specimens was (25 mm x 2 mm x 2 mm<sup>3</sup>) because the loading span should be 10x greater than the thickness of the specimen.<sup>21,27</sup> When comparing restorative materials, hardness is regarded as an important property. The surface hardness of a material is a relative measure of its resistance to an external indentation force. The hardness testing can predict a material's wear resistance and ability to abrade the opposing structure.<sup>13,20,38</sup>

Two-way ANOVA (Table 3) revealed a significant effect ( $p < .001$ ) of the two independent variables (material type, and Aging) and their interactions on the tested mechanical properties. Consequently, the two null hypotheses were rejected.

The flexural properties of the three CAD/CAM materials are consistent with ISO 10477:2020 standard, which states that, the flexural strength should be at least 50 MPa. According to the findings of this current study, the flexural properties of the tested materials were ranked from highest to lowest as follows: CT > PK > VCT. This could be justified due to the different composition of the tested materials (Figure 1). CT is a high performance, endless molecular polymer chain plastic with a long glass fiber content.<sup>19</sup> The glass fiber-reinforced composite resins have been reported to have superior mechanical properties.<sup>26</sup> on the other hand, VCT is an acrylate polymer with vinyl groups, which are two carbon atoms that are double linked to each other and attached to carbonyl carbon. Because acrylates' double bonds are relatively reactive and have low strength, they quickly form polymers.<sup>8</sup>

The resin matrix, the geometry, and the quantity of reinforced fillers or fibers are all factors that could influence FT property. The CT group showed the highest FT values. It has been reported that the fracture toughness of long glass fiber reinforced composites can achieve better results.<sup>26,39</sup> Additionally, the FS, FM, FT, and H values of poly ether-ether ketone (PEEK) was significantly higher than those of VITA CAD-Temp. This could be attributed to the differences in polymer chemistry

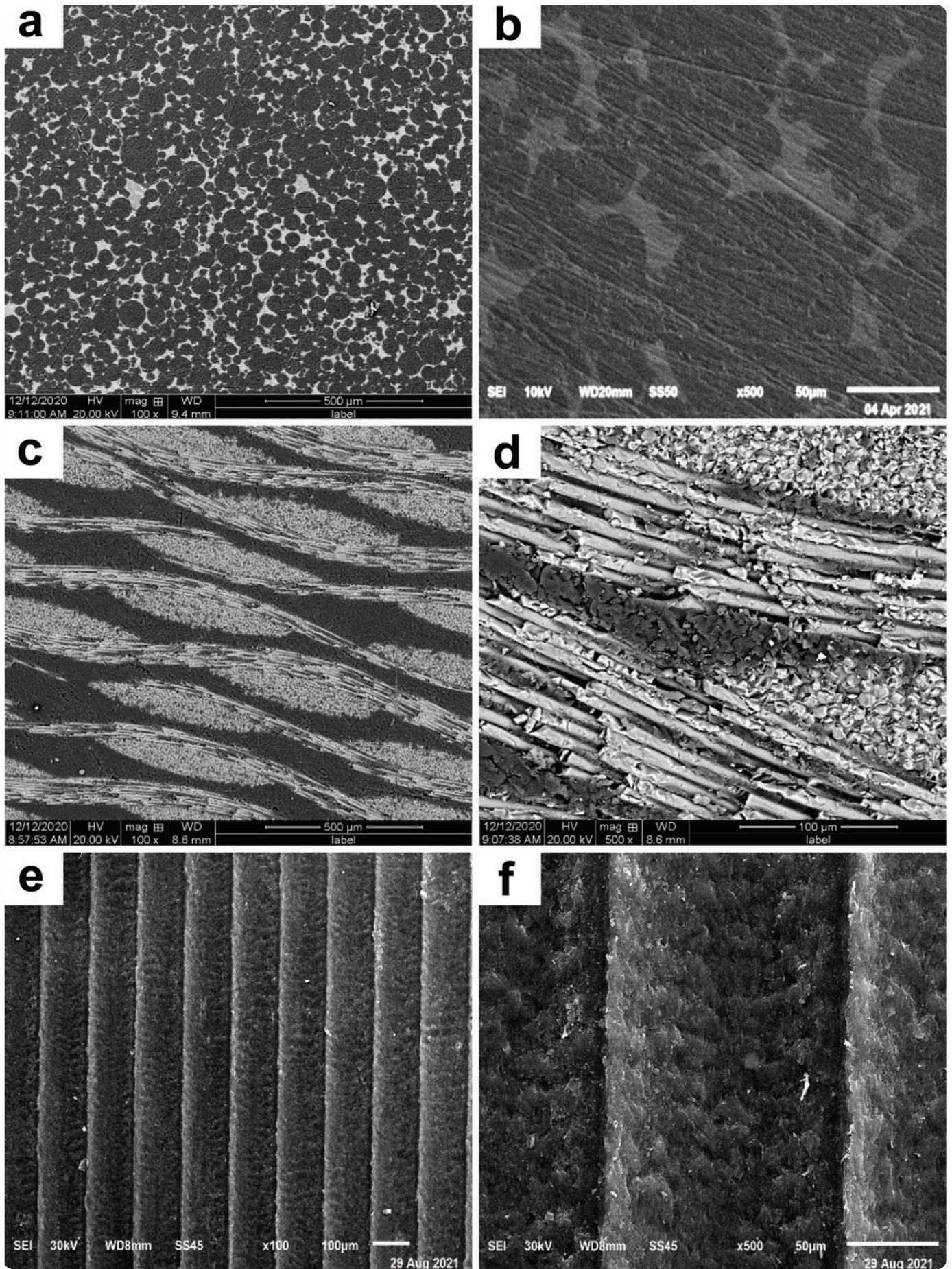


Figure 1: SEM micrographs (100 and 500 X) of CAD-Temp (a-b) C-Temp (c-d) and PEEK (e-f)

and degree of crosslinking, and the presence of another inorganic phase. It is a highly cross-linked polymer with 20% ceramic filler (with a grain size of 0.3–0.5  $\mu\text{m}$ ) that can penetrate and seal the area between the PEEK polymer's chains, limiting chain mobility and minimizing water penetration.<sup>40,41</sup> Furthermore, PEEK's semi-crystalline structure (30–35% crystalline) could improve the rigidity over VITA CAD-Temp, which lacks the inorganic ceramic filler phase.<sup>40</sup>

Thermocycling is an *in vitro* simulation of the oral environment that has a negative impact on the mechanical properties of restorative materials.<sup>18</sup> For standardization, two subgroups according to the aging conditions were evaluated in this study. One group was evaluated after sample preparation within 24 h at room temperature as a control group. The other group was subjected to 5000 thermal cycles to simulate 6 months of clinical service.<sup>18</sup>

In the current study, flexural strength, fracture toughness and hardness of the VCT group was significantly reduced after thermocycling. This could be explained by its high polymeric content (83–86 wt.% PMMA) which liable to penetration of water between polymer chains' gaps and separating them from one another, resulting in water absorption and consequently cause resin matrix softening which have a negative impact on mechanical properties.<sup>42</sup> The results of the current study are in line with Yao *et al.*<sup>8</sup> and Neim *et al.*<sup>43</sup>, they found that 5000 thermocycles had significantly reduced the flexural strength and flexural modulus of CAD-Temp. On the other hand, the thermocycling process had no effect on the FM. This result is so far difficult to explain as this material revealed water uptake and solubility that complies with EN ISO 10477 Polymer based crown and bridge material according to manufacturer's specification. This might be explained by its ability to retain its original capacity to dissipate energy elastically.<sup>43</sup> Furthermore, it has been reported that a small moisture content ( $\leq 0.69$  wt%) has been reported to cause a stiffening effect on the polymer network, as evidenced by a distinct shift in the  $\beta$ -relaxation peak at higher temperatures.<sup>44</sup>

Aging condition significantly decreased flexural properties and fracture toughness in CT group. This could be justified as follow, since the glass fiber reinforcing effect is to transfer stresses from polymer matrix to the fibers, the aqueous environment can cause a corrosion effect on the surface of a glass fiber due to penetration of water through the polymer matrix, resulting in a reduction in the mechanical properties.<sup>45</sup> Furthermore, Suzaki *et al.*<sup>46</sup> reported that the flexural properties of CAD/CAM fiber reinforced composite resin significantly decreased after one week immersion. It is worth to be mentioned that comparing fracture toughness values from different studies are difficult according to ADM guidance article 42 as there is variability in  $K_{Ic}$  values for the same material in the literature.<sup>39</sup>

On the other hand, aging had no statistically significant effect on PEEK properties in terms of FS, FM, FT, and H values. This might be attributed to their low water sorption ability value for the PK group. According to the manufacturer's claims, the

water sorption values for the PK group are ( $\leq 6,5 \mu\text{g}/\text{mm}^3$ ), for VCT ( $\leq 40 \mu\text{g}/\text{mm}^3$ ), while for the CT group is ( $9,6 \mu\text{g}/\text{mm}^3$ ).<sup>19,47</sup> Libermann *et al.*<sup>20</sup> assessed the effects of different aging solutions up to 180 days on water sorption of different CAD/CAM polymers. They concluded that storage media had no statistically significant effect on water sorption of PEEK. Furthermore, PEEK showed the lowest water sorption rates. Additionally, Neim *et al.*<sup>43</sup> investigated the effect of 5000 thermocycling cycles on the flexural strength and flexural modulus of several CAD/CAM restorative materials and discovered that thermocycling has no significant reduction effect on PEEK. Additionally, Schwitalla *et al.*<sup>40</sup> found no significant reduction in the flexural strength of PEEK polymer after up to 84 days of water storage.

The smoother margins of CAD/CAM polymers when milled have been related to the reduced brittleness of polymer-containing materials, which in turn results in less chipping at the margins.<sup>4,15,32</sup> The Brittle index is a criterion for estimating material machinability that is calculated by dividing hardness to fracture toughness. It can demonstrate how prone these materials to premature edge chipping. The lower the brittleness index, the higher the machinability.<sup>32</sup> In the current study, although the brittleness index of all tested materials was less than the required value<sup>32</sup> ( $4.3 \mu\text{m}^{0.5}$ ) for adequate machinability, PEEK demonstrated the lowest brittleness index when compared to other materials. The brittleness index has been shown to have a high positive association with the hardness attribute. It is one of the most crucial characteristics to consider when choosing a restorative CAD/CAM material. Furthermore, the relationship between hardness and fracture toughness may influence the brittleness index.<sup>30</sup>

Dentists will need to be able to use chair-side CAD/CAM technologies to improve their expertise and ability to perform digital restorations. The mechanical properties are particularly important as they may affect the longevity of CAD/CAM interim restorations, especially when exposed to environmental conditions.<sup>18</sup> In addition, understanding these properties necessitates clinician knowledge and familiarity to evaluate newer materials on the market and compare them to others to find the best material for long-term interim restorations. One of the limitations of this study is that the ageing conditions only simulate six months of clinical service. More studies are needed to investigate more clinical service times as well as different ageing conditions. Moreover, more research is needed to assess their adhesion to tooth structure and dental cement. Similarly, clinical performance is required to provide dental practitioners with reliable recommendations.

## CONCLUSIONS

Within the limitations of the current study, The PK group recorded appropriate mechanical behavior both before and after simulating aging, in addition to its better machinability than other materials. The CT group had better mechanical properties before and after ageing, despite the significant reduction their mechanical properties after aging.

## COMPETING INTERESTS

The authors declare that they have no conflict of interest in this research. The authors are not affiliated or receive benefits from the companies mentioned in this research

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