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The Effect of Polishing and Thermocycling on the Surface Roughness of Two Nanohybrid Composites

Research Article

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Abstract

Objective: This study aimed to investigate the effect of polishing and thermocycling on the surface roughness of two nanohybrid composites.
Materials and Methods: Two nanofilled composites were used. The surface roughness (Ra) was initially measured in a profilometer using a cut-off of 0.25 mm, after 1000 thermal cycles. Data were subjected to Paired Samples t-test and Independent Samples t-test (a = 0.05).
Results: Overall, 1000 thermal cycles slightly increased the surface roughness values for both the materials used. It was found that there existed a statistically significant difference between the individual groups before and after thermocycling ($p<0.05$) and there was no statistically significant difference between the groups after thermocycling ($p>0.05$).
Conclusion: Thermocycling increased surface roughness of both the composites. When the post thermocycling surface roughness values of Filtek Z350XT and Polofil NHT were compared, no significant differences were observed.

Keywords: Roughness; Composite Resin; Degradation.

Introduction

Composite resin has been available as an aesthetic material for restorative procedures since the early 1960s [1]. A resin matrix and filler particles are chemically connected by silane coupling agents in a composite material. For direct dental restorations, a variety of composite materials are available, including microhybrid, microfilled, and nanofilled composites [2]. These varied filler forms of resin composite materials affect both their handling characteristics and physical properties. The final surface polish has an important effect on the final aesthetics of these tooth-colored restoratives. Mechanical degradation can vary depending on the monomer system, filler composition, and matrix-filler coupling agent of composite resins. Damage to composites has been identified as a result of matrix degradation, which may reduce the likelihood of polymer restorations surviving in vivo. The surface smoothness of composite resins is directly affected by the composition of the resin matrix, coupling agent, and filler particle characteristics [3]. The most important factors are the form of inorganic particles, their size, and the extent of filler filling. Plaque accumulation, staining susceptibility, and wear have all been shown to be influenced by the surface roughness of restorative materials [4, 5]. Dental plaque accumulation may increase the risk of both caries and periodontal inflammation if the restoration has a surface roughness of 0.2 mm (Ra) or more [6]. During the restorative process, successful finishing and polishing procedures can increase surface smoothness and compensate for surface roughness caused by wear mechanisms on restorations [7]. Proper finishing and polishing of dental restoratives enhance the esthetics and longevity of restorations [8].

Hydrolytic degradation can affect the mechanical properties of composite resin [9]. Long-term water storage and thermal cycling are considered important conditions to assess the stability of res-

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in bonds in in vitro studies [10]. Furthermore, the roughness of certain resin-based products may be altered by the toothbrushing and thermocycling processes, which can affect the composite restoration's durability [11]. In this way, the analysis of surface roughness of resin-based materials, as well as the impact of degradation on this property, is critical for aesthetic restorations to last. As a result, the surface roughness of two nanofilled composite resins subjected to thermocycling procedures after polishing was investigated in this study. Previously our team had a rich experience in working on various research projects across multiple disciplines [12-26]. Now the growing trend in this area motivated us to pursue this project. The research hypothesis is that the thermocycling process could affect the roughness of two different materials due to differences in structure between composites, such as filler form and resinous matrix.

Materials and Methods

The materials used in this study are two nanohybrid composites, Polofil® NHT (VOCO) which has nano scaled particles with glass ceramic fillers with particle size of 0.01-0.1 µm and filler fraction of 83/68 Wt. %, Vol. %. and Filtek™ Z350 XT Universal Restorative (3M) in which the resin contains bis-GMA, UDMA, TEGDMA, and bis-EMA resins, PEGDMA and Non-agglomerated/non-aggregated 20 nm silica filler, non-agglomerated/non-aggregated 4 to 11 nm zirconia filler, and aggregated zirconia/silica cluster filler are among the fillers (comprised of 20 nm silica and 4 to 11 nm zirconia particles). A metal mold (2 mm in thickness and 6.2 mm in diameter) was used to produce ten samples of each resin-based composite, for a total of 20 composite disk samples. On the top and bottom of the molds, a mylar strip was placed, and the cavity was fully filled with composite resin. A thin glass plate was placed over the composite, and using a variable intensity light curing unit (Bluephase NM), the samples were light-cured for 60 seconds. All samples were then finished and polished using Shofu Super Snap Rainbow Technique Kit Ca using a low-speed handpiece (11,000 rpm).

The surface roughness value (Ra) was measured in a profilometer SJ-310, (Mitutoyo Corp., Tokyo, Japan). The Ra value was chosen because it reflects the arithmetical mean of surface roughness and is the most commonly used parameter for this reason. Each measurement was taken after rotating the sample 120 degrees and taking three measurements with a 0.25 mm cut-off. The samples were then held at 37 degrees Celsius in distilled water until the thermal cycling process began. Thermal cycling (alternate immersion of samples in distilled water with a temperature of 5 and 55 degree celsius, 5 min each and a transfer interval of 5 s) was carried out in a thermal cycler Chewing Simulator CS-4 thermal cycling machine (SD Mechatronik). Roughness measurements were collected after 3000 thermal cycles. The paired samples t-test was used to compare the surface roughness values before and after the thermocycling procedure between individual groups and independent samples t-test to compare the surface roughness values after the thermocycling procedure between Filtek Z350 XT and Polofil NHT.

Results & Discussion

While the two composites were compared individually before and after thermocycling procedure there existed a statistically significant difference ($P<0.05$).

While the surface roughness values were compared after thermocycling procedure between Filtek Z350 XT and Polofil NHT, it was found that there was no statistically significant difference between the groups after thermocycling ($P>0.05$)

Table 1 shows the surface roughness of the two nanohybrid composites before and after 1000 thermal cycles. After 1000 thermal

Table 1: Surface roughness (Ra, µmm) means (SD) of the resin-based composites before and after thermal cycling.

Material	Initial	After 1000 cycles
Filtek Z350 XT	0.0051	0.0054
Polofil NHT	0.0047	0.0049

Table 2: represents paired samples T-test which compared the surface roughness values before and after thermocycling procedure between individual groups. It was found that there existed a statistically significant difference between the individual groups before and after thermocycling ($p<0.05$).

	Mean	Std. Deviation	t	df	Sig. (2-tailed)
Filtek Z350 XT Before and after Thermocycling	-0.0021	0.00074	-9.000	9	.000
VOCO Polofil NHT Before and after Thermocycling	-0.0019	0.00074	-8.143	9	.000

Table 3 : represents an independent T-test which compared the surface roughness values after the thermocycling procedure between Filtek Z350 XT and Polofil NHT. It was found that there was no statistically significant difference between the groups after thermocycling ($p>0.05$).

Surface degradation of two nanohybrid composites after thermocycling	df	Sig. (2-tailed)
	18	0.552
	18	0.552

cycles there was a slight increase in surface roughness of both the materials. VOCO Polofil showed lesser values of surface roughness compared to Filtek Z350 XT but there was no statistically significant difference after thermocycling (P>0.05).

Thermocycling had a critical impact on surface roughness of composite resins, regardless of the filler composition, according to the results of this in vitro study. Both the resin-based materials showed an increase in roughness values after polishing and 1000 thermal cycles. Previous studies also showed that thermal cycling significantly affected the surface texture of composites with dislodgement of filler particles [27, 28]. Restorations should be finished properly not only for aesthetic reasons, but also for oral health reasons. Finishing's main objective is to develop a restoration with good contour, occlusion, natural embrasure forms, and a smooth surface. Bacterial adhesion to the surface of composite resins and other dental restorative materials is a key factor in secondary caries growth [29, 30]. Hardness of material is defined as its resistance to permanent surface indentation or penetration, and this property is related to material strength, ductility, elastic stiffness, plasticity, strain, toughness, viscoelasticity, and viscosity [30, 31]. The surface quality of composite resins can also be affected by the composition, degree of conversion, finishing, and polishing procedures. As a result, the microstructure of composite resins, as well as the finishing and polishing processes used to modify their surface, have an effect on their surface finish [32]. There was no noticeable difference in plaque accumulation between surfaces polished using different methods that resulted in standard surface Ra values in the range of 0.7–1.4 m, according to the literature. Using a surface profilometer, the Ra value was mostly determined in each sample after the finishing and polishing procedures were completed according to the manufacturer's instructions [33, 34].

The number of cycles, different temperatures, dwell time, and intervals between baths used in the studies is associated in thermocycling makes clinical durability of dental composites compared, difficult.

Temperature changes have been applied to thermocycled samples, causing thermal stresses and microcracks in the matrix or failure at the filler/matrix interface [35]. Furthermore, exposure to water can result in hydrolytic degradation of the filler's silane coating or matrix swelling. After thermal cycling, differences in filler exposure are most probably related to matrix degradation, which exposes underlying filler particles and increases roughness. Composites with hydrophilic matrix components, such as TEGDMA, may be more prone to matrix degradation as they allow water to penetrate more easily due to its hydrophobicity [36]. This might be related to the higher surface roughness after thermocycling of Filtek Z350XT composite material which contains hydrophilic component TEGDMA. The surface roughness of a composite is determined by the size, hardness, and amount of filler used, which improves the mechanical properties of resin-based composites [37, 38]. According to a study, the depth of composite wear decreased uniformly as the filler level was increased. Since microfill composites have less particle fillers in their structure, they are more likely to be affected by increased thermal cycles [39]. The material composition, including the type of organic matrix, can influence the preservation of roughness over time [40]. Two nanohybrid composites have been used in the study with 83% filler for VOCO Polofil and 78.5% filler loading for Z350XT. This difference in the filler loading and higher filler loading in VOCO Polofil compared to Z350XT might be the reason for lesser surface roughness values of Polofil composite material. The 83% of fillers in composition of this Polofil including agglomerated and non-agglomerated nanofillers could account for this result.

The arithmetic average value of the deviation from profile from centerline is represented by the surface roughness parameter (Ra) [11, 40]. Both the nanohybrid composites used in the study showed roughness under the limit proposed by the literature (0.2 mm). The increase in roughness after thermocycling procedures could result in a variety of problems, including surface staining, dental plaque accumulation, and occluding tooth wear. Furthermore, organic matrices in composites may have absorbed some water, causing hygroscopic expansion in the resinous matrix and filler process, resulting in matrix–filler interface weakening [4, 11]. Also the use of polishing systems could be limited to the real accessibility and uniformity of the surfaces to be finished. Further research is needed to assess the most effective finishing procedure in clinical practice to achieve the best possible clinical outcomes. Our institution is passionate about high quality evidence based research and has excelled in various fields ([16], [41-50]).

Conclusion

Within the limits of this in-vitro study it can be concluded that polishing and thermocycling increased the roughness values for both the nanohybrid composites and the composition of the material, including the form of organic matrix, particle fillers influences in maintaining roughness over time.

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