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Original Research Article

Effect of different finishing and polishing systems on surface roughness and surface microhardness of microhybrid, nanohybrid and nanofilled composites- An in vitro study

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Abstract

Aim: The impact of different polishing and finishing techniques. (EVE Diacomp Plus Twist and Optrapol NG) on surface roughness and surface microhardness of various composites (Mani Micro, Endure Nano, Filtek Z350 XT).

Materials and Methods: A total of 96 discs of 3 different composites was prepared using standardized dimension custom made stainless steel cylindrical mold (diameter 10mm, thickness 2mm). The specimens were divided into three main groups with 32 specimens in each group according to the type of composites Group I (n=32) Mani Micro (MANI INC, Tochigi Japan), Group II (n=32) Endure Nano (SEPTODONT, saint Maur des Fosses France), Group III (n=32) Filtek Z350 XT (3M ESPE USA). Quantitative assessment of surface roughness was done using surface roughness profilometer SJ-201, MITUYOTO JAPAN. Vicker's hardness test was performed for assessment of surface micohardness. All the discs (n=16) from each group were subjected to finishing and polishing procedure using EVE Diacomp Plus Twist (Ivoclar Vivadent AG, Schaan, Liechtenstein) and Optrapol NG (Ivoclar Vivadent AG**,** Schaan, Liechtenstein according to the manufacturer's instructions.

Results: Filtek Z350xt universal (Nanofilled composite) exhibits lowest surface roughness and highest surface microhardness with both the polishing systems (EVE Diacomp Plus Twist and Optrapol NG).

Conclusion: Finishing and polishing techniques significantly effects the surface roughness and surface microhardness of composite restorations.

Keywords: Nanocomposites, Surface roughness, Surface microharness, Contact stylus profilometry, Finishing and polishing

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1. Introduction

Preparing the tooth for the insertion of restorative material is necessary to restore a tooth to its proper structure and function. Resin composites are now a popular alternative for restorative materials due to their special blend of aesthetics, bonding strength, availability of adaptable materials, and tooth structure preservation.[1]

Resin composites have been classified according to the filler particle sizes into three categories: Micro filled, Micro hybrid, and Nano composites. Micro hybrid composites have filler particle size ranging from 0.4-0.8 µm and filler content is 72-79% by wt. Because of the presence of high filler content, the micro hybrid composites have better physical properties and wear resistance than micro filled.[2]

Mani Micro (MANI INC, Tochigi Japan) is a micro hybrid composite with outstanding physical properties and high-quality polished surface achieved easily because of the smaller particle size of the filler.

Nanotechnology applications in dentistry have introduced nanocomposites in the field of esthetic dentistry. Nanohybrids and nano filled composites are the two primary categories of dental resin-based nanocomposites. A composite resin called nanofill is made up of both nanomer and nanocluster, whereas nanohybrid composite resin with nanofiller particle is a pre polymerized filler form. Particles in nanofills are all nanometric in diameters and are almost all of the same size. The filler particle sizes range from 0.005 to 0.04 µm in nano filled composites and filler content ranges from

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71-82 % by wt. Whereas nanohybrid composites have a particle size range from 0.5–1.5μm.

Endure Nano (Septodont, saint Maur des Fosses France) is nanohybrid universal composite with 80 wt % silanated 40nm ytterbium fluoride, silanated 500 nm barium glass and 10 nm silica.

Filtek Z350 XT (3M ESPE USA) is a nano filled composite in which filler particles are manufactured in a variety of sizes, allowing for a high filler loading of 78.8% weight.

Numerous elements, such as filler type, filler size, filler loading, resin content, and particle shape, affect the composite resin's surface quality. Plaque accumulation can be decreased by creating a smooth, polished restoration. This will lessen patient discomfort from gingival irritation, surface discoloration, and the emergence of secondary caries.

Therefore, to achieve high surface quality and maintain gloss overtime for a composite restoration can be done by adopting an acceptable finishing and polishing protocol.

EVE Diacomp Plus Twist (Ivoclar Vivadent AG, Schaan, Liechtenstein) is a two-step finishing and polishing system impregnated with diamond particles. The distinctive flexibility of EVE Diacomp Plus is a key feature. The spirals used for polishing may adjust to any kind of surface structure. As a result, one shape can be used to polish every tooth surface equally well.

More recently, the manufacturers introduced different types of abrasives particles in one system and called them "one-step" polishing and finishing techniques.

By using this kind of finishing and polishing technique, fillings can be made to have a high degree of shine and contouring while requiring less time in the clinic to complete the restoration.[3]

Optrapol NG (Ivoclar Vivadent AG, Schaan, Liechtenstein) is single step finishing and polishing system. Up to 72% of the silicone polishers that work well are heavily packed with micro-fine diamond crystallites. The benefit is quick, one-step high-gloss polishing.[4]

Surface roughness can be measured quantitatively or qualitatively, and it serves as a gauge for the effectiveness of finishing and polishing. In addition to being unsightly, rough surfaces cause wear on neighboring teeth, secondary caries development, plaque buildup, gingival inflammation, and restoration discolouration.

Surface micro-hardness of composite resin is another important property related degree of polymerization of materials, which affects the resistance of composites to wear as well as the wear of opposite teeth or restorations.[5] There is scarcity of literature on the effect of various finishing and polishing systems on surface roughness and surface microhardness of different resin composites which play an important role in clinical outcome of restorative procedure.

Therefore, this research assessed the impact of different polishing and finishing techniques. (EVE Diacomp Plus Twist and Optrapol NG) on surface roughness and surface microhardness of various composites (Mani Micro, Endure Nano, Filtek Z350 XT).

2. Materials and Methods

A total of 96 discs of 3 different composites was prepared using standardized dimension custom made stainless steel cylindrical mold (diameter 10mm, thickness 2mm). The specimens were divided into three main groups with 32 specimens in each group according to the type of composites.

Group I (n=32) Mani Micro (MANI INC, Tochigi Japan)
Group II (n=32) Endure Nano (SEPTODONT, saint Maur des Fosses France)
Group III (n=32) Filtek Z350 XT (3M ESPE USA)

In all the groups the composite disc was prepared by placing the stainless-steel mold on the mylar strip which was supported by the glass slide of 1mm thickness. The restorative material was placed in one increment directly into the mold using composite placing instrument. After complete loading of the mold, the material was covered with another transparent mylar strip on the top of the filled mold. To remove extra material from the mold, a glass slide was lightly pressed up against the translucent mylar strip's top surface.

The specimens were polymerized through the 1mm thick glass slide using a light curing unit (BLUEPHASE-N Polywave LED) with a spectrum of 515 nm at 650 mW/cm².The curing time was set as 40 sec. Every specimen had light curing on both the top and bottom surfaces. Composite discs from each group were removed from the mold and kept for 24 hours at 37°C and 100% relative humidity in a container.

2.1. Evaluation of baseline surface roughness

Half of the specimens form each group (i.e. n=16) were subjected to quantitative assessment of surface roughness test using surface roughness profilometer SJ-201, MITUYOTO JAPAN. The average surface roughness Ra (mm) was measured at three different positions of each sample and the mean of these scores obtained was tabulated as baseline surface roughness.

2.2. Evaluation of baseline surface microhardness

Another half of the specimens from each group (n=16) were subjected to vicker's hardness test using a vicker's hardness tester. Vickers micro hardness tester is equipped with a diamond indenter. A standardized load of 200gms or 0.2N was applied to the surface for dwell time of 10 seconds. 3 indentations equally spaced over a circle were made on the each specimen's surface and the mean of these scores obtained were tabulated as baseline surface micro hardness.

2.3. Subgrouping of samples

Three groups were further subdivided into two subgroups according to the finishing and polishing systems used Subgroup A (n=16) - (EVE Diacomp Plus Twist, Ivoclar Vivadent AG, Schaan, Liechtenstein) Subgroup B (n=16) - (Optrapol NG Ivoclar Vivadent AG, Schaan, Liechtenstein)

All the discs (n=16) from each group were subjected to finishing and polishing procedure using EVE Diacomp Plus Twist (Ivoclar Vivadent AG, Schaan, Liechtenstein) and Optrapol NG (Ivoclar Vivadent AG, Schaan, Liechtenstein according to the manufacturer's instructions.

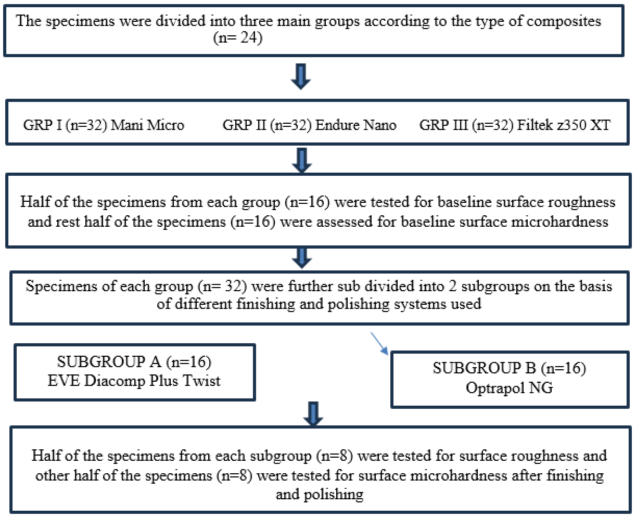

Figure 1: Flow chart of sample distribution

All the discs (n=16) - from each group were subjected to finishing and polishing procedure using EVE Diacomp Plus Twist (Ivoclar Vivadent AG, Schaan, Liechtenstein) and Optrapol NG (Ivoclar Vivadent AG, Schaan, Liechtenstein according to the manufacturer's instructions.

2.4. Evaluation of surface roughness and surface microhardness after finishing and polishing

Half of the specimens of each subgroup (n=8) were subjected to surface roughness test using a surface roughness profilometer SJ-201, Mituyoto Japan. Another Half of the specimens of each subgroup (n=8) were subjected to surface hardness test using vicker's hardness tester.

The values of surface roughness and surface microhardness after finishing and polishing were compared with base line surface roughness and baseline surface microhardness of all the groups (Mani Micro, Endure Nano, Filtek Z350 XT).

The results were tabulated and were statistically analysed.

3. Results

Table 1 represents the mean and standard deviation (SD) of microhardness and roughness values of the groups belonging to microhybrid, nanohybrid and nanofilled composite resins. There was a significant difference among the microhardness of three groups at baseline. Curing distance (P<0.001), whereas there was no significant difference in the values of baseline surface roughness of three composite groups.

Table 2 represents the mean and standard deviation (SD) of microhardness values of all the subgroups. There was a significant increase in the microhardness after finishing and polishing with EVE Diacomp Plus Twist and Optrapol NG in all 3 group.

Table 3 represents the mean and standard deviation (SD) of surface roughness values of all the subgroups. In group I and in group II there was a significant increase in the surface roughness after finishing and polishing with EVE Diacomp Plus. Whereas there was no significant difference in surface roughness after finishing and polishing with Optrapol NG in both groups. In group III (Filtek Z350XT), there was no significant difference in surface roughness before and after finishing and polishing with EVE Diacomp Plus and Optrapol NG.

3.1. Statistical analysis

SPSS (statistical package for social sciences) Version 22.0 (IBM Corp 2013, New York, USA) was the program used for statistical analysis. The normality of data was tested by Shapiro Wilk test and data was found to be normal. For comparison of surface roughness and microhardness before and after finishing and polishing, the one-way ANOVA test was used and for intragroup comparison independent t test and paired t test was used. There was a 5% threshold of significance and a 95% confidence interval, respectively.

Table 1: Microhardness and surface roughness at baseline

Variable	Group	Mean	SD	p value
Microhardness	Group I	75.11	7.00	<0.001*
	Group II	84.94	7.62	
	Group III	93.22	11.23	
Surface roughness	Group I	0.07	0.03	0.987
	Group II	0.07	0.03	
	Group III	0.06	0.03	

One-way ANOVA test; * indicates significant difference at p≤0.05

Table 2: Comparison of baseline microhardness with post polishing microhardness

Group				p value				p value
		Mean	SD			Mean	SD	
Group I	Baseline	76.49	8.29	0.005*	Baseline	73.74	5.66	0.011*
	Subgroup A	93.04	11.70		Subgroup B	88.85	8.94	
Group II	Baseline	87.99	2.53	0.049*	Baseline	81.39	5.07	0.002*
	Subgroup A	95.06	9.37		Subgroup B	89.11	4.17	
Group III	Baseline	94.55	4.21	0.035*	Baseline	85.51	3.15	0.048*
	Subgroup A	101.11	8.09		Subgroup B	96.12	11.30	

Paired t test; * indicates significant difference at p≤0.05

Table 3: Comparison of baseline surface roughness with post polishing roughness

Group		Baseline		p value		Subgroup A		p value
		Mean	SD			Mean	SD	
Group I	Baseline	0.06	0.03	0.038*	Baseline	0.07	0.04	0.052
	Subgroup A	0.13	0.06		Subgroup B	0.11	0.04	
Group II	Baseline	0.06	0.03	0.005*	Baseline	0.08	0.03	0.076
	Subgroup A	0.14	0.05		Subgroup B	0.10	0.05	
Group III	Baseline	0.06	0.03	0.079	Baseline	0.07	0.04	0.108
	Subgroup A	0.10	0.05		Subgroup B	0.09	0.02	

Paired t test; * indicates significant difference at p≤0.05

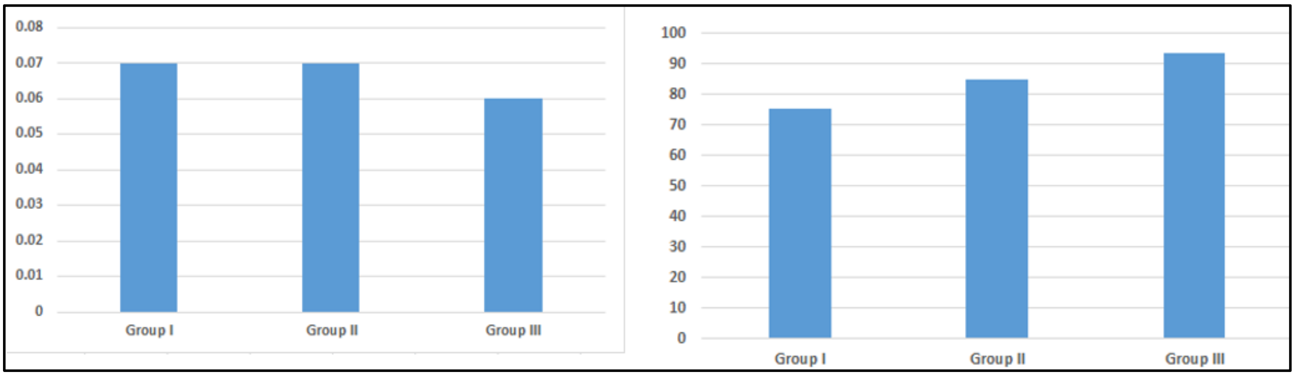

Figure 2: Microharness and roughness of each group

4. Discussion

The aim of providing esthetic restoration is to obtain the finest surface which will minimize the accumulation of dental biofilm, reducing stains and can easily be maintained. Thus, adequate finishing and polishing of dental restorations are critical clinical procedures and are crucial for maintaining the long-term success. The surface characteristics mainly depends on composition of the resin composite system such as filler content, filler particle size and resin content. Larger fillers may lose the ability to hold onto the resin matrix during the polishing process, which might be microscopically thought of as a grinding process. This could lead to the fillers falling off and leaving additional dents and pits on the surfaces. As a result, achieving ideal surface smoothness would be difficult. This problem is fully resolved by the addition of nanoscale filler particles, which can be eliminated in an equal manner with the resin matrix.[2] To achieve highly polished surfaces on resin composite restorations, a variety of polishing systems have been developed. These systems vary from single-step polishing systems featuring cups embedded with diamond and aluminum oxide particles to multi-step systems that utilize fine and superfine diamond burs, abrasive disks, and soft rubber cups infused with diamond and silicon. The obvious benefit of a one-step polishing method is its efficiency and ease in creating an extremely even surface without requiring the need to wash and dry in between steps to guarantee that the bigger abrasives from the previous stage are removed, or to convert to a finer polish.[4]

Finishing and polishing also affects the mechanical properties of restoration such as surface roughness and microhardness.[5]

The crucial threshold value of surface roughness (Ra) for clinical relevance has been reported to be 0.2µm.[6] Surface roughness above this threshold raises the risk of caries, periodontal inflammation, and plaque buildup.

This is the first study comparing the surface roughness and surface microhardness of micro hybrid, nanohybrid and nano filled composites before and after finishing and polishing withsingle and multistep polishing systems.

In methodology, Surface profilometer is used in this study for assessment of the roughness because the mechanical profilometer have been preferred for many years as they require no preparation on samples to measure surface roughness and they enable repeated measurements.[7] Vickers hardness test was applied as VHN is the most widely accepted and convenient method to measure the surface micro hardness according to literature.

According to the result, the mean of baseline roughness values was similar for Group I (0.07), Group II (0.07) and Group III (0.06). Surfaces against matrix strip exhibited lowest roughness values in all the groups. According to a study done by Bassiouny MA et al 1980 and Erdemir U et al 2012 which states that as their unpolished state contains more polymer matrix than fillers, surfaces against matrix are smoother than polished surfaces.[8,9]

After finishing and polishing, the average roughness values increased for all the groups. According to research conducted by Goncalves et al 2008, Final finishing and polishing eliminate the matrix surrounding the filler particles, which causes the filler particles to protrude from the composite surface and subsequently heighten the surface roughness.[10] The difference was not significant in surface roughness of Filtek Z350XT irrespective of the polishing system applied. The results showed that nano-filled composites (Group I Filtek Z350XT) had smoother surface under all conditions of finishing and polishing. These findings align with the study of Rai and Gupta et al 2013 which states that nano-filled composites have better surface finish than hybrid composites.[11]

It may be because of the combination of nanosized particles and the nanocluster formulations for nano-filled composites.

Smooth finish is achieved through abrasion because the main particles (nanomer sized) may be worn away instead of being pulled out.

Results showed that the difference was not significant in surface roughness of Filtek Z350XT irrespective of the polishing system applied. However, there was a significant increase in roughness of Mani Micro and Endure Nano) composites after finishing and polishing with subgroup A (EVE DIACOMP PLUS TWIST), whereas there was no significant increase in roughness value with subgroup B (Optrapol NG).

Current one-step solutions appear to be just as successful as multiple-step systems for polishing dental composites.[12]

According to the results of microhardness evaluation, Filtek Z350XT possess better Vickers microhardness (mean value 93.2) followed by Endure nano (mean VHN 84.93) and Mani micro (mean VHN 75.1). The high filler loading of about 78.5% along with the incorporation of nano sized silica and zirconia filler particles organized into nanoclusters enhance mechanical properties of nano-filled composites. This combination of the complex network of matrix and smaller filler particles results in a hard structure.

The mean values for average microhardness significantly increased after finishing and polishing irrespective of the polishing system used. The results of this study showed that polishing greatly increased the hardness values of the tested composite resins. The findings of a study carried out by Joniot SB et al. 2000 corroborate this, stating that while polymerization can produce a smooth surface, the superficial layer is primarily made up of organic matrix and is hence less thick than the underlying layer. Therefore, cleaning techniques that remove this layer increase surface resistance.[13] This is also in alignment with results of a study conducted by Kaminedi et al. 2014 which states that all the finished protocols in nano composites groups recorded a higher surface microhardness mean value than the initial hardness values.[14] Nasoohi et al. also concluded that temperature elevation caused by polishing increases the amount of cross-linking and thus improves the mechanical properties.[15]

5. Conclusion

Within the constraints of this research, Finishing and polishing techniques significantly effects the surface roughness and surface microhardness of composite restorations.

Filtesk Z350xt universal (Nanofilled composite) exhibits lowest surface roughness and highest surface microhardness with both the polishng systems (EVE Diacomp Plus Twist and Optrapol NG).

6. Source of Funding

None.

7. Conflict of Interest

None.

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