Effect of Finishing /Polishing Techniques and Time on Surface Roughness of Silorane and Methacrylate Based Restorative Materials

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Abstract

Aim: The study evaluated the efficiency of various finishing and polishing systems and the effect of finishing and polishing time by using various procedures on surface roughness and hardness of silorane based (FiltekP90) and methacrylate based (Z100) restorative materials.

Method: The surface roughness and surface hardness were measured using a profilometer and Vickers hardness tester respectively. Ten specimens of each composite resin were randomly subjected to one of the following finishing/polishing techniques: A - Diamond burs with soflex discs; B - Diamond burs with Astropol polishing brush; C – Tungsten Carbide burs with soflex discs; D - Tungsten Carbide burs with Astropol polishing brush. To assess the effect of time period, specimens were finished and polished immediately and another delayed by a week. Data were analyzed using repeated measures ANOVA and Tukey's test at a significant level of $p<0.05$.Results: Filtek P90 showed least Ra values with lower surface hardness than Z100. Delayed finishing/ polishing of materials was better than immediate polishing in both the tested materials. Among all the polishing system for silorane based composites (Filtek P90), Diamond bur- Astropol and Astrobursh combinations to be used. Whereas in methacrylate based composites (Z100) Tungsten carbide bur - Soflex disc used showed good surface finish.

Conclusion: Clinical significance of surface roughness and hardness is related to: i. Aesthetic appearance of restoration (discoloration and wear) ii. Biological consequences regarding periodontal health (gingivitis) iii.Development of secondary caries due to increased plaque accumulation. This study would be helpful to make some considerations about clinical indication and longevity of restorative materials studied.

Key Words: Composite resin, Silorane–based composite resin, Methacrylate based composite resin, Surface hardness, Surface roughness

Introduction

One of the desirable features for a satisfactory restoration is smooth surface finish [1,2]. High quality finishing and polishing of dental restorations are important aspects of critical clinical restorative procedures that enhance both esthetics and longevity of restored teeth [3-5].

Residual surface roughness associated with improper finishing and polishing of dental restorations can result in excessive plaque accumulation, gingival irritation, increased surface staining and poor esthetics of restored teeth that could potentially lead to demineralization of enamel, possible recurrent caries and periodontal problems [6-9]. Also, patient consciousness of restorations with possible irritations of tongue, lips and cheeks is matter of concern. A change of surface roughness in the order of 0.3µm can be detected by the tip of the patient's tongue [10]. Therefore, smoothness of restorations is of utmost importance for its success.

Among the wide variety of finishing and polishing devices that are available in the market to the clinician, silicone carbide-coated or aluminium oxide-coated abrasive discs, impregnated rubber or silicone discs, mutifluted tungsten carbide finishing burs, hard bonded-surface coated ceramic diamond rotary instruments are most commonly used to finish and polish dental restoratives [1,5,11,12]. Each of these instruments or devices leaves the surface of various restorative materials with varying degrees of surface roughness.

Over the years, Composite resins are the class of restorative materials that has been repeadtedly modified and improved to solve the problems faced in clinical practice. The composition of the composite resins affects the final finish and fineness of restorations. The varying degree of hardness, particle size and amount of filler as well as polishing medium and polishing technique affect the final finish [1,13-15]. In the past 30 years there have been no basic changes in the monomer systems since the introduction of methacrylate's, in the form of Bis-GMA. The most recent innovation in the monomer system has been the silorane based composites. A silorane based composite (Filtek P 90), comprises of ring-opening monomer, with siloxane and oxirane structural moieties. Changing the chemistry of setting and using a composite based on silorane chemistry, not only claims for low polymerization shrinkage (>1%) but also improved biocompatibility, wear resistance, optical properties, when compared with the methacrylate based composites [16-19].

The softer resin surface may retain the scratches created by the finishing procedures, which can affect the strength of restoration leading to premature failure [20]. Surface hardness is an important mechanical property that can predict the wear resistance and its ability to abrade or be abraded by opposing dental structures or materials [21]. The timing of polishing might affect the physical properties of the composite and

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might increase the risk of premature failures [22]. As the resin composite is a bad conductor of heat, it retains the heat produced by the polishing procedures in the outer layer of material and raises the temperature above the glass transition temperature, making the surface hard such that it can increase the mechanical properties of restoration such as microhardness and abrasion resistance [23].

As finishing and polishing procedures are generally done immediately post polymerization it would make the restorative material more susceptible to effects of heat generation. Delaying the time of finishing and polishing may make the restorative material less susceptible to negative effects of heat generation [22,24,25]. It is thus critical to determine the finishing and polishing system used and time of finishing and polishing which would offer best results for silorane based and methacrylate based restorative materials. The present study evaluated the efficiency of various finishing and polishing systems and the effect of finishing and polishing time by using various procedures on surface roughness and hardness of silorane based and methacrylate based restorative materials

Methodology

A silorane based composite (Filtek P 90- Microhybrid Composite) and methacrylate based composite (Z100- Hybrid Composite) were selected as test materials in this study.

Specimen preparation

Specimen preparation was done by a single operator, in order to reduce variability. Specimens were prepared using Brass molds (10 mm diameter x 2 mm thickness). The mold was sandwiched between transparent matrix strips. The uncured composites were inserted into the mold and intentionally overfilled. Light pressure was applied to expel excess material from the mold. Each specimen was light cured through the top and bottom for the duration recommended by the manufacturers. The intensity of the light-curing unit was checked before each sample run using a radiometer. The set cylindrical specimens were separated from the mold. The specimens were stored at 100% relative humidity at 37°C for 24hrs *(Figure 1)*.

Forty specimens of each restorative material were fabricated (n=10). The matrix strip formed surface was used as a baseline for all tests. Forty specimens were finished and polished immediately using four finishing and polishing procedures and the remaining forty specimens were finished and polished after a week. Specimens were examined for obvious voids, labeled on the bottom and randomly separated into four treatment groups.

Finishing and polishing procedures

Method I: Extra fine finishing diamond bur followed by Soflex discs (Al2O2-coated, abrasive disc system, fine grit, and extra-fine grit) was employed with a high-speed turbine with water-spray-coolant, and an air-dried slow hand-piece, respectively.

Method II: Extra fine finishing diamond bur followed by the Astropol and Astrobrush polishing system (silicon-based abrasive polisher point and polisher brush) was employed with a high-speed turbine with water-spray coolant, and a low-speed hand-piece with water spray, respectively.

Method III: Thirty-fluted tungsten carbide bur followed by the Soflex discs (Al2O2-coated, abrasive disc system, fine grit and extra fine grit) was employed with a high-speed turbine with water-spray coolant, and an air-dried slow hand-piece, respectively.

Method IV: Thirty-fluted tungsten carbide bur followed by the Astropol and Astrobrush polishing system was employed with a high-speed turbine with water-spray coolant, and a low-speed hand-piece with water spray, respectively.

Each step of the finishing–polishing was applied for 30 s. Each bur was applied using light pressure in multiple directions. The Soflex discs was changed after the polishing of each sample and each silicon-based polisher point was discarded after use, while the diamond burs and carbide burs was changed every three samples.

Measurement of surface roughness

The surface roughness was evaluated using Taylor/Hobson Precision, Surtronic 3+ (Taylor Hobson Limited, England) coupled to a computer with Talyprofile software surface analyzer with a cut off length of 0.80 mm and a crosshead speed of 0.25mm per second to obtain average surface roughness (Ra, µm) and a surface profile tracing. Each sample was rotated 120°, relative to the center, for each of three readings and averaged to generate average roughness value (Ra).

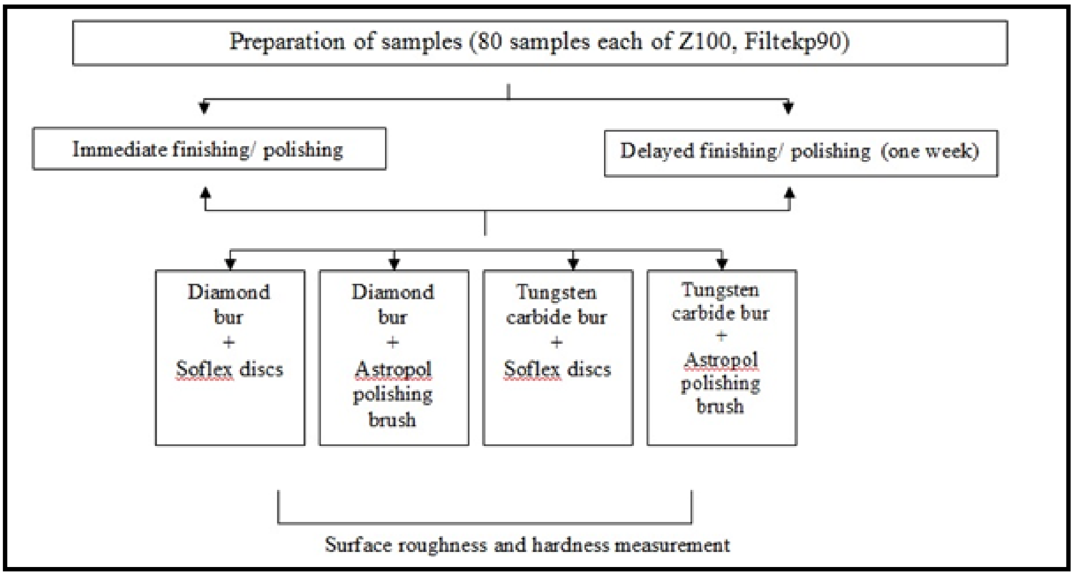


***Figure 1**. Experimental design.*

Measurement of surface hardness

The surface hardness was evaluated using Matzusawa Micro Vickers hardness Tester (Model MMT X 7A, Matsuzawa Co Ltd, Japan). Prior to testing, all specimens were sonically cleaned for 10 min to remove any influence of precipitate on surface hardness. Specimens were placed on platform with the surface under testing facing the diamond indenter. Load applied was 300g for 15s. Three indentations were made no closer than 1 mm to the adjacent indentations on the surface of each specimen. Average of three readings were taken as mean value. The hardness was measured by using formula:

VHN= 0.1854 x P/d2 (N/ mm2), where P= load in N, d= average length of diagonal of indentation in mm.

Results

The data was expressed as mean ± SD. p values<0.05 was considered as significant.

Surface roughness measurement *(Figure 2)*

Two way repeated measures ANOVA followed by tukey test was used. There was significant difference in surface roughness in materials as well as finishing system used (p>0.05). Surface roughness however did not vary over time significantly (p=0.759). Filtek P90 showed significantly smoother (p=0.004) surface when compared to Z100. Diamond bur produced smoother finish in Filtek P90 (<0.001) when compared to Z100, whereas tungsten carbide was found to be better for Z100 (p<0.001). Further diamond astropol and diamond soflex gives lower Ra values in silorane based P90 whereas tungsten carbide –soflex and tungsten carbide astropol was better for methacrylate Z100 (p= 0.047). Polishing systems, diamond –astropol and diamond soflex combinations were better with lower Ra values, showing better surface finish and polish in Filtek P90. The order of smoothness was Diamond astropol> diamond soflex> tungsten carbide soflex> tungsten carbide astropol. In Z100 tungsten carbide soflex and tungsten carbide astropol show least Ra values. Tungsten carbide soflex was the smoothest finishing agent followed by tungsten astropol, diamond astropol, diamondsoflex. Delayed polishing is better and suggested. Delayed polishing was better in all combinations except in diamond soflex and tungsten carbide soflex for Filtek P90.

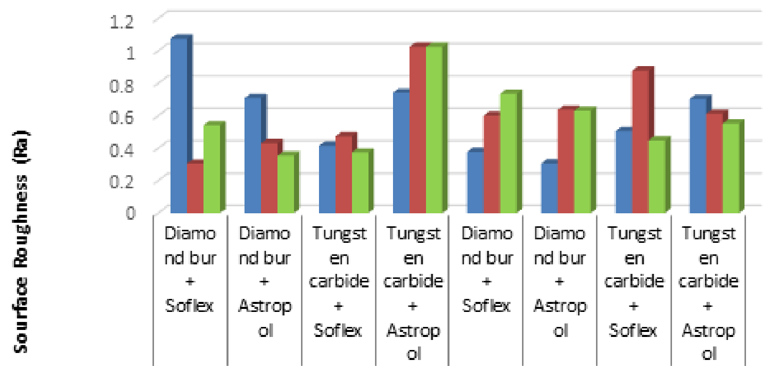
Surface hardness measurement *(Figure 3)*

Two way repeated measures ANOVA followed by tukey was used. Composite Z100 showed significant higher values (p<0.001) of hardness in all combinations of polishing system when compared to FiltekP90. There was significant difference seen over time, materials, and finishing system. Among the polishing system, Tungsten astropol and diamond astropol are the best for FiltekP90. Irrespective of the material, Z100 showed equal amount of hardness achieved with no significant difference (p>0.05) in hardness values. Delayed polishing is better in both materials (p=0.002) except in FiltekP90 for soflex combinations immediate was better.

Discussion

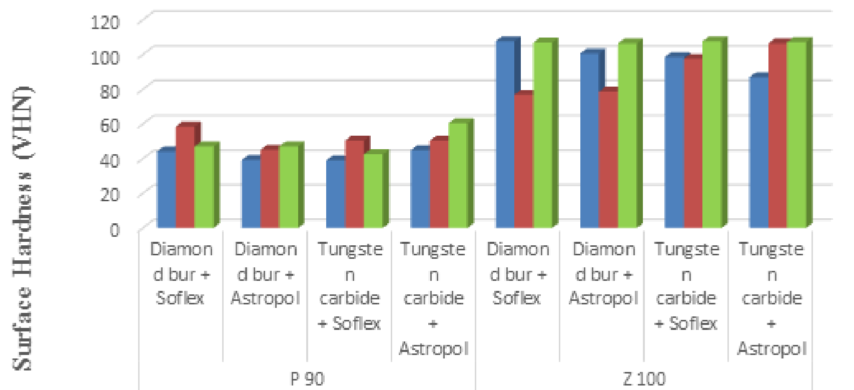
Finishing and polishing of composite resins are important clinical steps in restorative procedures that determine the quality of restorations. Evaluating the suitability of various finishing and polishing methods for the tested materials requires assessment of their surface roughness and hardness. The techniques employed during finishing and polishing of the tooth-colored dental restorative materials not only improves its longevity and aesthetic appearance of the material, but also minimizes plaque accumulation, gingival irritation and secondary caries [6-9]. It is practically impossible to achieve a highly polished surface because of the heterogeneous nature of the composition, i.e., hard filler particles embedded in a relatively soft matrix, which do not abrade at same degree due to their different hardness [26,27]. Literature shows that the use of polyester strip or matrix produces the smoothest surface to the restorative materials, but further contouring and finishing to remove excess material may spoil the finish [1,28,29]. Insufficient polymerization in the outer surfaces results in a reduction in hardness or produce surface discoloration. The removal of the outermost composite by finishing and polishing procedures is thus warranted to produce a wear-resistant, harder, and color stabilized restoration [1,30,31].

Surface roughness is a function of the microstructure created by a series of physical processes used to modify the surface, and also related to the scale of measurement. When the same polishing system for different composites is used, differences between material compositions should be



	P 90 Diamond bur + Soflex	P 90 Diamond bur + Astropol	P 90 Tungsten carbide + Soflex	P 90 Tungsten carbide + Astropol	Z 100 Diamond bur + Soflex	Z 100 Diamond bur + Astropol	Z 100 Tungsten carbide + Soflex	Z 100 Tungsten carbide + Astropol
SURFACE ROUGHNESS BASELINE	1.0764	0.7084	0.415	0.7424	0.3768	0.3064	0.5054	0.7038
SURFACE ROUGHNESS IMMEDIATE	0.3052	0.4304	0.4736	1.0256	0.6005	0.6372	0.8776	0.612
SURFACE ROUGHNESS DELAYED	0.5416	0.3544	0.374	1.0248	0.736	0.6316	0.448	0.552

Figure 2.*Comparison of surface roughness with time, materials and polishing techniques.*



	P 90				Z 100			
	Diamond bur + Soflex	Diamond bur + Astropol	Tungsten carbide + Soflex	Tungsten carbide + Astropol	Diamond bur + Soflex	Diamond bur + Astropol	Tungsten carbide + Soflex	Tungsten carbide + Astropol
HARDNESS BASELINE	44.09	39.24	39.05	44.94	107.7	100.66	98.56	87.06
HARDNESS IMMEDIATE	58.54	45.02	50.53	50.37	76.87	78.68	97.59	106.46
HARDNESS DELAYED	46.98	47.14	42.58	60.38	106.89	106.44	107.71	107.23

Figure 3. *Comparison of surface hardness with time, materials and polishing techniques.*

responsible for different Ra values [28]. However, the system used for finishing and polishing also should be taken into consideration. Finishing procedures are performed with rigid rotary instruments, such as super-fine-grit diamond burs or multi-fluted tungsten carbide finishing burs. These have been used to contour anatomically structured and concave surfaces such as the lingual of anterior teeth or the occlusal of posterior tooth surfaces [32]. Finishing diamonds were best suited for gross removal and contouring because of their high cutting efficiency of composite surfaces, while carbide finishing burs would be best suited for smoothing and finishing as a result of their low cutting efficiency [20,29]. Most investigators agree that for final polish, flexible aluminum- oxide discs and/or silicone-based points are the best instruments for providing low roughness on composite surfaces [32-34]. The capability of aluminum oxide discs to produce a smooth surface was not only related to the planar motion of the disc, but also to their ability to cut the filler particle and matrix equally [33,34]. As in most studies it is reported that diamond burs (of various degrees of fineness) produced visibly rough surface [35,36] with loss of shininess and numerous scratches, but the use of aluminum oxide as secondary finishing agents affected in increased smoothness, as the abrasion created by diamond bur would be reduced and contributed to removal of scratches. Though there are other studies proving the polishing effect of astropol was equivalent to the well-established soflex discs or worse than soflex but still better than that of other polishing systems [10]. Our results agreed with the finding of literature that for silorane based composite (FiltekP90) diamond soflex combinations and for methacrylate based composite (Z100) tungsten carbide and soflex combinations produced smoother surface finish. With hybrid composites, finishing diamonds have shown to produce rough, throughlike surfaces compared to carbide burs. Jung M 2002 [29] suggested that finishing diamonds were best suited for gross removal and countouring because of their high cutting efficiency while carbide finishing burs would be best suited for smoothing and finishing as a result of their low cutting efficiency, which was in agreement with the hybrid composite Z100 used in our study.

In our study extra fine diamond burs and 30-fluted tungsten carbide burs were used to finish the surface of the restorations and following these procedures Soflex discs(in Groups I and III) and Astropol and Astrobursh (in Groups II and IV) were used to polish the restorations. When different polishing systems were used, the surface roughness (Ra) values varied in either materials. In silorane based FiltekP90, Diamond bur- Astropol and Astrobursh showed least Ra values followed by Diamond bur- Soflex disc, Tungsten carbide bur - Soflex disc and Tungsten carbide bur-Astropol and Astrobursh, with higher Ra values, suggesting for the polishing of silorane based composites, Diamond bur- Astropol and Astrobursh combinations to be used. Whereas in methacrylate based composites (Z100) Tungsten carbide bur - Soflex disc showed least Ra values followed by Tungsten carbide bur-Astropol and Astrobursh, Diamond bur- Astropol and Astrobursh whereas Diamond bur- Soflex disc showed highest Ra values. The roughness produced may be attributed to distinct patterns of particle size and their arrangement within the resin matrix. For a finishing system to be rendered effective the cutting particles must be harder than the filler particles; otherwise the abrasive medium may abrade the softer matrix only. This may result in higher surface roughness. Therefore, the effectiveness of finishing and polishing procedures on restorative material surface may be more critical.

Another variable responsible for the different results is the polishing time. In clinical situations, resin composites are usually polished and exposed to the oral environment immediately after restoration. The main controversy regarding composite polishing probably is when to initiate polishing. Polishing time and materials employed [35,37], polishing method and instruments, [38] showed a significant effect on the surface roughness and surface hardness of composite restorations. While some authors claim that finishing and polishing should be done after removal of the matrix or five minutes later [24,39,40], several authors have suggested that if these procedures were delayed 24 hours, better marginal sealing could be obtained [25,41]. Changes in hardness may reflect the state of the setting reaction of a material and the presence of an ongoing reaction or maturity of the restorative material [25,42]. Immediate finishing and polishing could cause plastic deformation (flow) of resin which is cured 75% after 10 min due to the thermal insults of polishing as the composite polymerization reaction would not be complete prior to 24 hours [25]. It is also proposed to delay any finishing procedures until after hygroscopic expansion occurs because of the risk of fracture of the unsupported enamel surrounding the marginal gap [40,41].

In our study, the effects of time period on the roughness and hardness, was evaluated at immediate polishing (after one day) and delayed polishing (after one week). Our results showed delaying the finishing and polishing procedure created a smoother and harder surface than immediate polishing. These findings agreed with that of Yap et al. [24] and Rai et al. [43] who concluded that the delayed finishing and polishing of polyacid-modified resins resulted in smoother surface. The authors attributed this result to the maturity of resin at the time of finishing and polishing. Several other authors also have proposed a 24-hour delay before the completion of finishing procedures [41,44], which supports the result obtained in this study. But during immediate polishing, the fact that hygroscopic expansion will improve marginal adaptation by closing the gap formed by polymerization shrinkage and finishing and polishing procedures should not be neglected [24]. Therefore, most dentists prefer to do the finishing and polishing step immediately after the light curing of the resin restoration, which is more acceptable and cost effective for the patient as proposed by Ceni et al. [45] who recommended immediate polishing since this procedure reduces the number of clinical sessions. Venturini et al. [25] found that immediate polishing did not produce a negative influence on the surface roughness, hardness and microleakage of a microfilled (Filtek A110) and a hybrid (Filtek Z250) resin composite compared to delayed polishing. In our study, use of diamond soflex and tungsten carbide soflex immediately on Filtek P90 showed higher surface hardness values. The increase of hardness in delayed finishing was not significant in microhybrid composite (FiltekP90), but it was significant in hybrid composite (Z100). Due to large differences between filler and matrix hardness immediately after post-cure, immediate finishing and polishing would result in a preferential loss of matrix phase, leaving the filler particles in positive relief. This explains the higher Ra values with immediate finishing and polishing. With time, the matrix phase matures and hardens, decreasing the difference in hardness and the preferential loss of matrix during the finishing and polishing resulting in lower Ra values. These results are in coincidence with the study of Chinelatti MA et al. [46] who found that the increase in hardness in delayed finishing and polishing generally results in surface similar to or even harder than that obtained with immediate finishing and polishing. On the other hand, another investigation by Cenci et al. [45] proved that loss of surface properties after polymerization using a delayed polishing procedure. Based on the results of our study, the effects of polishing system on surface roughness and roughness was time dependent and shows that the composite surface post curing properties was better with delayed polishing procedures.

In our study, the microhybrid composite (FiltekP90) exhibited lower hardness but with smoother surface finish than the hybrid composite (Z100). These findings can be explained by compositional differences between the two composites, their differences in residual polymerization or an increase in the resilience of the silorane polymer compared to methacrylate. Filler particle should be situated as close as possible in order to protect the resin matrix from abrasives. Reduced interparticle spacing in resin composites is achieved by decreasing the size and increasing the volume fraction of fillers [47]. Harder filler particles are left protruding from the surface during polishing as the softer resin matrix is preferentially removed. Resin composites with larger filler particles are expected to have higher Ra values after polishing. Since the resin composites used in this study were highly filled hybrid composites (Z100) with relatively large filler particles, this explains the roughness caused by Z100. Contradicting the results in our study Buchgrabera et al. showed higher Ra values in silorane based composites [48]. Micro filled or microhybrid composites have less inorganic content with smaller filler particle size and arrangement than hybrid and packable composites, therefore they can be finished to a smoother surface than packable and hybrid composite. The average size of filler particles in a microhybrid contains particles ranging in size between 0.01- 2mm which allows them to be polished to a smoother surface than compared to the particle size of hybrid which is 0.6-1.4 micron [15,13]. Our results were similar to previous studies where silorane based composite exhibited lowest VHN than methacrylates[49-53]. Measurement of degree of conversion is also an indirect measure for hardness. It was found in literature that in silorane based composites; the degree of conversion (DC) was lower than methacrylate based composites. [53-55]. The DC of the methacrylate based composites is measured as a function of the number of C=C double bonds that form during polymerization. However, the chemistry of the silorane composite monomers does not contain C= C aliphatic groups. Therefore, the polymerization of free radical species and cationic species are different [56]. Also, it can be related to tetrafunctionality of silorane molecules, as the molecule is trapped in the network under formation the mobility of other functionalities decreases. This may explain the low DC values of P90, but not necessarily result on reduction of mechanical properties [57].

In methacrylate based composites as they are richer in highly reactive and more flexible monomers (such as TEGDMA) they are expected to present higher conversion [55].

However the limitations with respect certain variables like rotation speed of the handpiece, press on force during application, should not be neglected and warrants extensive research in this area. The results from this invitro study only correlate to the clinical situations where there are accessible and relatively flat surfaces. When finishing complex surfaces with limited access, the effectiveness of the finishing sequences may be different and further laboratory studies should attempt to simulate concave and convex surfaces.

Conclusion

Under the limitations of this in vitro study, it might be concluded thatFiltek P90 showed least Ra values with lower surface hardness than Z100.Delayed finishing/ polishing of materials is better than immediate polishing in both the tested materials.Among all the polishing system for silorane based composites (Filtek P90), Diamond bur- Astropol and Astrobursh combinations to be used. Whereas in methacrylate based composites (Z100) Tungsten carbide bur - Soflex disc used showed good surface finish.

Clinical significance of surface roughness and hardness is related to: i. Aesthetic appearance of restoration (discoloration and wear) ii. Biological consequences regarding periodontal health (gingivitis) iii.Development of secondary caries due to increased plaque accumulation. This study would be helpful to make some considerations about clinical indication and longevity of restorative materials studied

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