Materials Research. 2010; 13(3): 409-415

Surface Roughness and Hardness of a Composite Resin: Influence of Finishing and Polishing and Immersion Methods

Ana Luísa Botta Martins de Oliveira[a,*], Patrícia Petromilli Nordi Sasso Garcia[b], Patrícia Aleixo dos Santos[c], Juliana Álvares Duarte Bonini Campos[b]

[a]*Department of Children's Dentistry, Araraquara School of Dentistry, São Paulo State University, Rua Orlando Damiano, 2281, CEP 13560-450, São Carlos, SP, Brazil*
[b]*Department of Social Dentistry, Araraquara School of Dentistry, São Paulo State University, Rua Humaitá, 1680, CEP 14801-903, Araraquara, SP, Brazil*
[c]*Departament of Dentistry, University Center of Araraquara – UNIARA, Rua Carlos Gomes, 1338, CEP 14801-340, Araraquara, SP, Brazil*

Received: April 19, 2010; Revised: June 14, 2010

This study evaluated the finishing and polishing effect on the surface roughness and hardness of the Filtek Supreme XT, in fluoride solutions. Specimens were prepared (n = 140) with half of the samples finished and polished with Super-Snap® disks. The experimental groups were divided according to the presence or absence of finishing and polishing and immersion solutions (artificial saliva, sodium fluoride solution at 0.05% - manipulated, Fluordent Reach, Oral B, Fluorgard). The specimens remained immersed in artificial saliva for 24 hours and were then subjected to initial analysis (baseline) of surface roughness and Vickers microhardness. Next, they were immersed in different fluoride solutions for 1 min/day, for 60 days. Afterwards, a new surface roughness and microhardness reading was conducted. The data were submitted to a two-way ANOVA and Tukey's test (5% significance level). For the comparison of mean roughness and hardness at baseline and after 60 days, the paired Student t test was used. The results showed that the surface roughness and microhardness of the Filtek Supreme XT were influenced by the finishing and polishing procedure, independently of the immersion methods.

Keywords: *dental polishing, fluorine, composite resins*

1. Introduction

Achieving a restoration's surface smoothness is vital for its success[1,2], given that the rough surfaces contribute to the deposition of dental plaque, residues and coloring, resulting in damage to the soft tissue and periodontal, decrease of the restoration brightness and increasing its susceptibility to discoloration and/or surface damage[1,3-6]. In addition to interfering with the optical properties of the material, surface roughness also affects their mechanical properties by decreasing its resistance and accelerating its abrasion[7].

Within this context, the procedures for finishing and polishing have been indicated to improve aesthetics and the longevity of direct composite resin restorations[8,9]. These procedures are used for the removal of coarse restoration excesses[1] and to revert to the anatomical form[10]. Moreover, this approach assists to obtain surface smoothness with light reflection similar to dental enamel, revert to physiologically acceptable shape for tissue support and improved marginal fit, preventing infiltration and relapse of dental caries[7].

According to Lutz et al.[1], Heath et al.[4] and Joniot et al.[11], removing the most superficial layer of the restoration, which is composed mainly of organic matrix, by means of finishing and polishing instruments, results in a more resistant and stable surface in terms of aesthetic.

Another important mechanical property of a restorative material is its surface hardness, which measures the material's strength to its surface plastic deformation. A material's hardness is the result of interaction of the properties such as strength, ductility, malleability, resistance to cutting and abrasion. A decrease in the microhardness value may indicate a superficial degradation, and therefore a change in its roughness, which collaborates with the accumulation of plaque and consequently the deposition of lactic acid, hence jeopardizing the restoration's longevity[12-15]. There are several methods to measure this property and the Vickers microhardness test is one of them.

Both the surface roughness as well as the hardness of the composite resin may also be associated to its characteristics, such as the type of organic matrix, size, composition and distribution of loading particulates[2,3], including the material's exposure to low pH food, drinks and mouth rinse solutions[12,16,17].

Studies have been conducted to observe the influence of finishing and polishing procedures[2,3,5,6,8,11,13,18-22], characteristic of the composite resin[8,21,23] and agents in the patient's diet[6,12] on the surface texture and hardness of the composite resin. However, the influence of fluoride solutions on the surface roughness and hardness of the restoration has not yet been investigated.

Therefore, the purpose of the present study was to evaluate the effects of finishing and polishing procedures on the surface roughness and hardness of a composite resin subjected to various fluorided solutions.

2. Materials and Methods

2.1. Experimental design

This research uses a double-blind experimental study design. The surface roughness and hardness are the dependent variables and the

*e-mail: analuisabotta@hotmail.com

independent variables are the two-level finishing and polishing (with and without finishing and polishing) and the five-level immersion method (artificial saliva, sodium fluoride at 0.05% manipulated, sodium fluoride at 0.05% Fluordent Reach, sodium fluoride at 0.05% Fluorgard, sodium fluoride at 0.05% Oral-B). Ten experimental groups were obtained from the association between variables. The number of specimens used for each experimental condition (n = 14) was calculated after the pilot study according to the recommendations by Cochran[24], totaling 140 test specimens.

To evenly distribute possible errors, the specimens were randomly distributed into the experimental groups, using a table of random numbers.

Figure 1 shows the methodology outline, from the making of the specimens until the completion of the readings.

2.2. Preparing the sample specimens

The nano-composite resin Filtek Supreme XT (3M ESPE, St. Paul, MN) (Table 1), color B1E, was used in the preparation of the specimens from a stainless steel bipartite matrix, with four 10 mm diameter and 2 mm thick circular holes. The material was embedded into the matrix in a single increment and covered by a 10 mm wide polyester strip (K-Dent – Quimidrol, Com. Ind. Importação Ltda, Joinville, SC, Brazil) and a glass plate. A 1 kg stainless steel weight was applied for 30 seconds for excess outflow and for a smooth and standardized surface[12]. Next, the weight and plate glass were removed and the photopolymerization was carried out for 40 seconds, with the Curing Light XL 3000 halogen light device (3M Dental Products Division, St. Paul, MN, USA) with irradiance of 530 mW/cm², constantly monitored by a radiometer (Curing Radiometer Model 100 - Demetron Research Corp., Danbury, CT, USA).

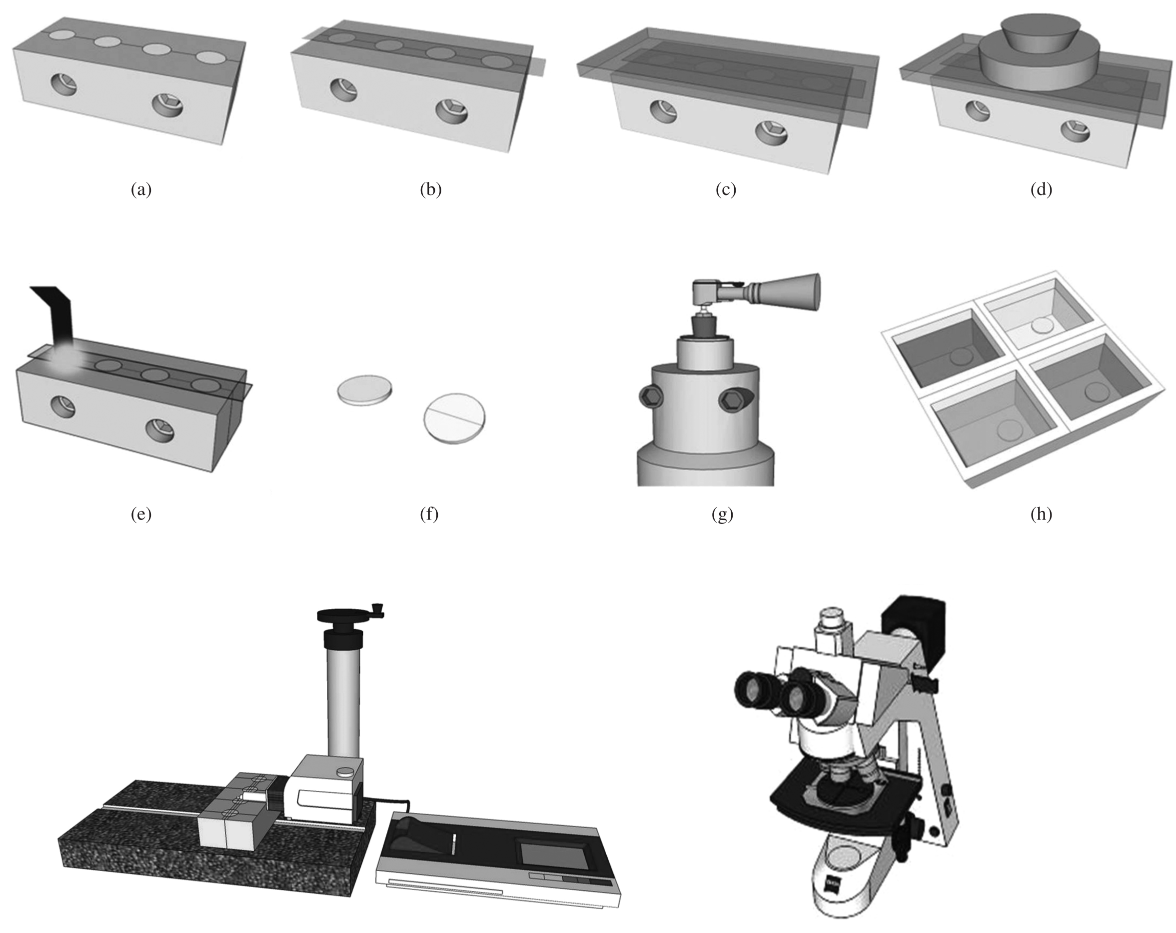

Figure 1. Methodology outline: a) insertion of composite resin into the bipartite matrix in a single increment; b) positioning of the polyester matrix; c) placing the glass plate; d) application of the 1-kg weight for 30 seconds; e) removal of all plaque-weight and photopolymerization through the polyester matrix, f) demarcated test specimens on the back due to the furrow on the bipartite matrix; g) finishing and polishing procedure in the matrix with central height adjustment; h) immersion procedures; i) reading of the surface roughness; and j) of the Vickers microhardness.

Table 1. Characteristics of the restorative material.

Brand	Manufacturer	Type	Resin matrix	Filler composition	Shade
Filtek Supreme XT	3M ESPE, St. Paul, MN, EUA	Nanofilled	Bis-GMA Bis-EMA UDMA TEGDMA	Nanoagglomerated nano silica filler (20 nm), Agglomerated Zirconia/silica nanocluster (0.6-1.4µm)	B1E

2.3. Finishing and polishing procedures

Half of the specimens were subjected to finishing and polishing procedures with Super-Snap® aluminum oxide discs (Shofu Dental Corp. Kyoto, Japan), 12 mm in diameter, in a decreasing granulation sequence(13), coupled to a counter-angle, at low speed, with 18,000 revolutions per minute. Each disc was used on the damp surface for a 15-second period[25]. The other half of the specimens were unpolished.

For the finishing and polishing procedures, the specimens were positioned in a bipartite stainless steel matrix with central height adjustment[26], which prevented the contact of the finishing and polishing instruments with the surface of the matrix, hence facilitating implementation.

During construction, all the specimens were demarcated in the back by the fitting groove of the bipartite matrix, which served as a guide for the finishing and polishing procedures that were performed perpendicular to this demarcation[5], with a standardized pressure of 2 kg.

Between every other grain, the specimens were washed with air-water jets for 5 seconds and at the end of the process, were taken to ultrasound (Ultrasonic Cleaner Plus 1440; Odontobrás - Comércio de Eq. Médicos-Odontológicos LTDA, Ribeirão Preto, SP, Brazil) containing water, for 30 minutes, to remove the impurities deposited on the surface.

The specimens were immersed in artificial saliva and stored in a bacteriological oven (EBC1-Odontobras - Comércio de Eq. Médicos-Odontológicos LTDA, Ribeirão Preto, SP, Brazil) and maintained at a temperature of 37 ± 1 °C for 24 hours.

2.4. Immersion procedure

The specimens were immersed in 2 mL of each solution: artificial saliva, solution of sodium fluoride at 0.05% - manipulated, Fluordent Reach by Johnson & Johnson mint flavor, Gillette's Oral B mint flavor, Colgate Fluorgard cherry flavor (Table 2), for a minute, daily, for 60 days.

After immersion, they were washed in running water and kept in artificial saliva at a temperature of 37 ± 1 °C.

For the artificial saliva group, the specimens were maintained at 37 ± 1 °C with daily artificial saliva change, and these procedures were repeated for 60 days.

2.5. Evaluation of surface roughness

The reading of the surface roughness was obtained by a properly calibrated researcher (ρ = 0,94), using the 5 μm radius diamond tip of the portable surface roughness tester (Surftest Mitutoyo SJ-401, Mitutoyo Corporation, Japan) of 1 mm length, at a speed of 1 mm/s, with accuracy of 0.01 μm. This procedure was performed in three different places, creating three values[8,12,21] that resulted in an average final Ra, which was calculated for each test specimen. For the standardization of the readings a matrix similar to the preparation of the specimens was used, with two lines drawn parallel to the matrix splitting line (one 2 mm below and another 2 mm above), and right angles. The intersection of the lines marked in the matrix resulted in three points that guided the positioning of the diamond tip of the surface roughness tester to obtain the three reading points (Figure 2).

After 24 hours immersed in artificial saliva a reading of the initial roughness was performed (baseline reading) and final roughness reading was performed after 60 days of the immersion procedures.

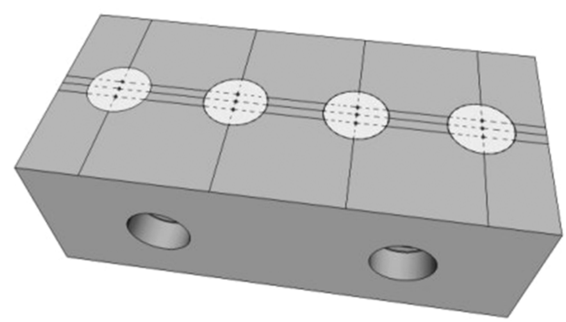

Figure 2. Matrix for standardization of the surface roughness reading.

Table 2. Characteristics of solutions.

Solution (Brand)	Composition	Manufacturer
Artificial saliva	KH_2PO_4, K_2HPO_4, KCl, NaCl, $MgCl_2.6H_2O$, $CaCl_2.2H_2O$, NaF, Sorbitol, Nipagin, Nipasol, Carboxymethyl Cellulose (CMC), Water.	Laboratory of Biochemistry of FCFRP-USP
Manipulated sodium fluoride solution	0.05% of Sodium Fluoride solution	Santa Paula Pharmacy
Fluordent Reach	Water, Glycerin, Alcohol, Poloxamer 407, Methylparaben, Mint Flavor, Na_2HPO_4, Sucralose, NaH_2PO_4, Cetylpyridinium Chloride, 0,05% Sodium Fluoride (226ppm of fluoride), Propylparaben, Yellow Pigment, FD&C Blue nº. 1	Johnson & Johnson
Fluorgard	Water, Sorbitol, Polysorbate 20, Potassium Sorbate, Sodium Biphosphate, Phosphoric Acid, 0,05% sodium Fluoride (226ppm of fluoride), Red Pigment, Flavor	Colgate
Oral B	Water, Glycerin, PEG-40 Hydrogenated Castor Oil, Methylparaben, Flavor, 0,053% Monohydrated Cetylpyridinium Chloride, 0,05% Sodium Fluoride (226ppm of fluoride), Sodium Saccharin, Sodium Benzoate, Propylparaben, FD&C Blue nº. 1	Gillette

2.6. Evaluation of the Vickers microhardness

The Vickers microhardness reading (VHN) was obtained by a properly calibrated researcher (ρ = 0,75), using a pyramid-shape diamond of a digital microdurometer (Buehler, Lake Bluff, Illinois, USA), applying a 50 gf load for 30 seconds over the surface of the specimen[13]. This procedure was performed in three different places, creating three values, which resulted in a final average that was calculated for each specimen[13]. A device was created to standardize the positioning of the specimens and the reading in the microdurometer. The specimens were positioned in the device so that the central groove on its back was coincident with the center line drawn on the device (Figure 3). Specific coordinates were set to the north-south and east-west axis of the microdurometer to obtain the readings at three points of the previously standardized specimens.

After 24 hours immersed in artificial saliva the reading of the initial hardness baseline was performed, with the final reading performed after 60 days of the immersion procedures.

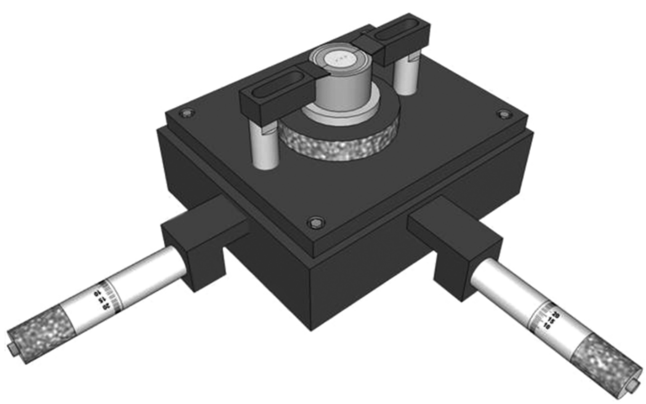

Figure 3. Matrix for standardization of the hardness reading.

2.7. Statistical analysis of data

The average of the surface roughness and hardness of the different groups at the baseline time and after 60 days was calculated for the specimens with and without finishing and polishing.

After the normality assumptions and homoscedasticity were tested and met, the two-way analysis of variance (ANOVA) ("finishing and polishing" factor and "means of immersion" factor) were carried out for the study of surface roughness and hardness of the specimens after 60 days. The Tukey test was used for multiple comparisons. To compare the mean roughness and hardness at the baseline and after 60 days, the paired Student's t-test was used. The significance level was 5%.

3. Results

Table 3 shows the averages and standard deviations of surface roughness (Ra) in μm of the specimens, according to the finishing and polishing procedures and immersion methods at baseline time and after 60 days, as well as the results of the Student's t test, and Analysis of Variance.

Comparing the average of surface roughness in the studied groups at the baseline and 60 days after immersion in the solutions, it can be observed through the analysis of Table 3 that only the group that received finishing and polishing and immersed in artificial saliva showed a statistically significant difference in the studied periods.

When assessing the influence of the "finishing and polishing" and "means of immersion" factors in the surface roughness of the specimens in 60 days time, it was observed that the "finishing and polishing" factor showed significant variability (F = 15.977; p = 0.001), independently of the studied solution. When the means of immersion were analyzed there was no significant variability (F = 1.688; p = 0.156) with a non-significant interaction between the factors (F = 0.619; p = 0.649).

Table 4 shows the averages and standard deviations of the specimens' microhardness, according to the finishing and polishing procedures and immersion methods.

Table 3. Surface roughness average - Ra (μm) and standard deviation according to polishing and finishing and means of immersion. FOAr - UNESP, 2008.

Procedures and immersion	Baseline	60 days of immersion*	t	p
With finishing and polishing				
Artificial saliva	0.28 ± 0.16	0.56 ± 0.53	–2.625	0.021
Sodium fluoride 0.05% manipulated	0.27 ± 0.11	0.3 ± 0.16	–2.003	0.066
Sodium fluoride 0.05% Oral B	0.34 ± 0.23	0.42 ± 0.31	–1.131	0.278
Sodium fluoride 0.05% Fluordent Reach	0.37 ± 0.20	0.32 ± 0.19	0.661	0.520
Sodium fluoride 0.05% Fluorgard	0.31 ± 0.22	0.46 ± 0.29	–1.595	0.135
W/out finishing and polishing				
Artificial saliva	0.65 ± 0.48	0.76 ± 0.58	–0.584	0.569
Sodium fluoride 0.05% manipulated	0.43 ± 0.36	0.54 ± 0.39	–1.096	0.293
Sodium fluoride 0.05% Oral B	0.93 ± 0.79	0.97 ± 0.75	–0.186	0.856
Sodium fluoride 0.05% Fluordent Reach	0.51 ± 0.43	0.63 ± 0.57	–0.869	0.401
Sodium fluoride 0.05% Fluorgard	0.69 ± 0.85	0.73 ± 0.63	–0.459	0.654

*Finishing and polishing: gl = 1; F = 15.977; p = 0.001; Means of immersion: gl = 4; F = 1.688; p = 0.156; Interaction: gl = 4; F = 0.19; p = 0.649.

Table 4. Mean and standard deviation Vickers hardness values according to polishing and finishing and immersion methods. FOAr - UNESP, 2008.

Procedures and immersion	Baseline	60 days of immersion*	t	p
With finishing and polishing				
Artificial saliva	63.77 ± 5.27	72.30 ± 11.22	2.1209	0.0536
Sodium fluoride 0.05% manipulated	64.10 ± 8.71	73.88 ± 7.71	– 3.7080	0.0026*
Sodium fluoride 0.05% Oral B	66.15 ± 8.56	68.07 ± 7.71	–0.6496	0.0527
Sodium fluoride 0.05% Fluordent Reach	65.73 ± 8.99	72.89 ± 8.49	–2.5440	0.0244*
Sodium fluoride 0.05% Fluorgard	65.73 ± 7.15	77.82 ± 9.60	–3.1307	0.0079*
W/out finishing and polishing				
Artificial saliva	61.02 ± 9.00	61.67 ± 4.65	–0.2432	0.8116
Sodium fluoride 0.05% manipulated	59.29 ± 4.85	61.50 ± 3.76	–1.3818	0.1902
Sodium fluoride 0.05% Oral B	57.19 ± 6.57	65.14 ± 5.43	–3.2205	0.0067*
Sodium fluoride 0.05% Fluordent Reach	56.72 ± 7.03	67.30 ± 6.43	–49766	0.0001*
Sodium fluoride 0.05% Fluorgard	58.64 ± 6.92	65.58 ± 7.31	–2.3725	0.0337*

* Finishing and polishing: gl = 1; F = 47.143; p = 0.001; Means of immersion: gl = 4; F = 2.369; p = 0.056; Interaction: gl = 4; F 2.238; p = 0.068.

Comparing the average hardness of the studied groups at baseline and 60 days after immersion in the solutions, it can be observed by the analysis of Table 4 that the groups that received finishing and polishing immersed in sodium fluoride 0.05 % manipulated, Fluordent Reach and Fluorgard and the ones that did not receive finishing and polishing immersed in Oral B, Fluordent Reach and Fluorgard showed statistically significant difference in the studied periods.

Observing the "finishing and polishing" factor with respect to microhardness, it showed significant variability (p: 0.001), independently of the studied solution.

When the means of immersion (solutions) were analyzed, no significant variability was noted (p: 0.056), and the interaction between the factors was non-significant (p: 0.068).

4. Discussion

The surface roughness and hardness of a restoration can be associated to, among other factors, the restorative material[2,8,9,22], to the finishing and polishing instruments used[2,3,27] and the means of immersion to which they are subjected[12]. This study sought to investigate the influence of finishing and polishing procedures on the surface roughness and hardness of the nanoparticled composite resin Filtek Supreme XT in different means of immersion. It was found that only the "finishing and polishing" factor showed significant variability, and the groups that received this type of surface treatment had lower surface roughness values than those that did not receive this treatment, including higher hardness values, independently of the studied solution. This reinforces the importance of finishing and polishing procedures to maintain the surface smoothness and microhardness of the studied composite resin.

The results presented in this work concerning the microhardness increase by the specimens that received finishing and polishing, confirms the studies by Chinelatto et al.[13] in 2006 and Park et al.[28] in 2000.

With respect to these procedures, some authors[5,8,20,27] declared that these are essential to obtain surface smoothness, given that they remove restoration excesses and possible surface irregularities. According to Berastegui et al.[3], Heath et al.[4], Lutz et al.[1], Reis etal.[8], Sarac et al.[21], Wilder Jr et al.[5], Yap et al.[6], these procedures prevent critical problems related to the quality of restoration, such as staining, bacterial plaque retention, gingival irritation and recurrent caries. Moreover, removing the most superficial layer of composite resin, which is more vulnerable to abrasion and wear, by means of the finishing and polishing procedures, collaborates by showing the hardest surface of the restoration, making it more resistant to degradation by extrinsic factors such as the acids from the bacterial plaque and diet[13].

There are various odontological instruments in the market that can be used for finishing and polishing, as carbide cutters[1,3,4,8,11,19], diamond tips[1-3,8,11,19,27] rubbers[9,11], strips, stones[1,29], pastes and abrasive disks[1-4,8,11,27,30]. The flexibility of the reinforcement material in which the abrasive is impregnated, the abrasive hardness and its size influence the final surface roughness of the restoration[21,23]. Besides the characteristics of the material used for the restoration's surface treatment, factors such as size, hardness and quantity of the composite resin particles may also influence their mechanical properties[21,23].

Therefore, for the finishing and polishing to be effective, the abrasive particle must be harder than the composite resin, because, otherwise, only the matrix resin will be removed, resulting in protruding particles on the surface[8,21].

In this study the finishing and polishing process was performed with aluminum oxide discs Super Snap®, which have a greater hardness than the majority of particles found in the formulation of composite resins. As a result, resins with a large quantity of small particles, such as Filtek Supreme XT, investigated in this study, show greater smoothness, once the reduction in size of the particles enables a better distribution in the resinous matrix. This assumption is reinforced by Reis et al.[8], Nagem Filho et al.[2], Turkun, Turkun[22], that emphasize that the composite resins with a higher percentage of loading and better distributed particles in the resinous matrix have greater surface smoothness.

Although there are works in literature that state that a greater surface smoothness is obtained by the polyester matrix[1,2,4,18,21,30-33], this study showed that the groups that did not receive finishing and polishing, in other words, whose surface smoothness was obtained only by means of the polyester matrix, were the ones that showed the highest surface roughness as well as lower microhardness values.

In spite of much effort in standardizing the methodology in this study, it is possible that the surface of the specimens prepared with the polyester matrix was not free of imperfections due to the nature of the resinous matrix[9] and the possible irregularities in the polyester matrix[9,22,26]. This fact may have resulted in greater surface roughness for the groups without finishing and polishing.

As to the influence of the immersion methods in the surface roughness of the composite resins, it was observed in this study that there was no statistically significant difference among them.

Although there is little material in the literature regarding this aspect, especially with regard to immersion in fluorided mouth rinse solutions, Badra et al.[12] in 2005, found a surface roughness change of composite resins for conservation in beverages such as coffee and Coca-Cola®, while Yap et al.[6] in 2000, studying other solutions, such as citric, lactic and ethanol acid used to simulate the intake of drinks, vegetables and fruits, found no influence on the surface roughness.

In this study, another factor to be discussed is that only the finishing and polishing group immersed in artificial saliva showed a statistically significant difference with respect to its surface roughness during the study period. This finding may be explained by the deposition of minerals on the surface of the specimens immersed in saliva, resulting in the formation of a film probably composed of calcium[34].

Regarding the influence of the immersion methods in the microhardness of the composite resins, this study showed that there was no statistically significant difference among them. Some studies using restorative materials such as conventional glass-ionomer cements, modified by resin[14], and composite resin[12] indicate influences of mouth rinse solutions, fluorided varnish and diet in the microhardness of these materials, which is related to characteristics such as pH, as well as the temperature of the solutions. According to Walls et. al.[35] and Diaz-Arnold et al.[14], the acid pH can cause dissolution or surface erosion of the restorative material and the high temperature[12] can interfere in their properties.

In the present study, we can assume that a significant change of the microhardness values was not found, since the fluoridated mouthwash solutions used did not have a low pH and the administration was conducted at room temperature.

From the findings of this study, we can assume that the prescription of any of the fluorided mouth rinse solutions, important allies in the prevention of dental caries, may be performed by the Surgeon-Dentist without having to worry that they may affect the surface roughness and microhardness of the composite resin. It should also be noted that the finishing and polishing procedures, usually required for excess removal and restoration reshaping[32], is a crucial step to obtain surface smoothness and should be considered by professionals during a restoration preparation.

5. Conclusion

Based on the applied methodology and the obtained results, it may be concluded that the surface roughness and hardness of the composite resin Filtek Supreme XT were influenced by the finishing and polishing process, independently of the studied fluoride solutions.

References

1. Lutz F, Setcos JC and Phillips RW. New finishing instruments for composite resins. *The Journal of the American Dental* Association. 1983; 107(4):575-580.
2. Nagem Filho H, D'Azevedo MTFS, Nagem HD and Marsola FP. Surface roughness of composite resins after finishing and polishing. *Brazilian Dental Journal*. 2003; 14(1):37-41.
3. Berastegui E, Canalda C, Brau E and Miguel C. Surface roughness of finished composite resins. *The Journal of Prosthetic Dentistry.* 1992; 68(5):742-749.
4. Heath JR, Jordan JH and Watts DC. The effect of time of trimming on the surface finish of anterior composite resins. *Journal of Oral Rehabilitation.* 1993; 20(1):45-52.
5. Wilder Jr AD, Swift Jr EJ, May Jr KN, Thompson JY and McDougal RA. Effect of finishing technique on the microleakage and surface texture of resin-modified glass ionomer restorative materials. *Journal of Dentistry.* 2000; 28(5):367-373.
6. Yap AUJ, Low JS and Ong LFKL. Effect of food-simulating liquids on surface characteristics of composite and polyacid-modified composite restoratives. *Operative Dentistry.* 2000; 25(3):170-176.
7. Bolanho A, Anauate Netto C, Youssef MN, Do Carmo ARP and Mandelli A. Estudo in vitro da rugosidade superficial de resinas para dentes posteriores submetidas a diversos tratamentos de superfície. *Jornal Brasileiro de Dentística & Estética.* 2003; 2(5):51-57.
8. Reis AF, Giannini M, Lovadino JR and Dias CTS. The effect of six polishing systems on the surface roughness of two packable resin-based composites. *American Journal of Dentistry.* 2002; 15(3):193-197.
9. Yap AUJ, Sau CW and Lye KW. Effects of finishing/polishing time on surface characteristics of tooth-coloured restoratives. *Journal of Oral Rehabilitation*. 1998; 25(6):456-461.
10. Miyazaki SS, Silva RCSP and Araújo MAM. Estudo clínico comparativo entre dois procedimentos de acabamento de restaurações estéticas diretas em resina composta e cimento de ionômero de vidro fotopolimerizáveis. *Revista de Odontologia da UNESP.* 1999; 28(2):475-489.
11. Joniot SB, Gregoire GL, Auther AM and Roques YM. Three-dimensional opticall profilometry analysis of surface states obtained after finishing sequences for three composite resins. *Operative Dentistry.* 2000; 25(4):311-315.
12. Badra VV, Faraoni JJ, Ramos RP and Palma-Dibb RG. Influence of different beverages on the microhardness and surface roughness of resin composites. *Operative Dentistry.* 2005; 30(2):213-219.
13. Chinelatti MA, Chimello DT, Ranos RP and Palma-Dibb RG. Avaliação da dureza superficial de resinas compostas antes e após o polimento em diferentes tempos. *Journal of Applied Oral Science.* 2006; 14(3):188-192.
14. Díaz-Arnold AMD, Wistrom W and Swift Jr EJ. Topical fluoride and glass ionomer microhardness. *American Journal of Dentistry.* 1995; 8(3):134-136.
15. Samuel SMW and Rubinstein C. Microhardness of enamel restored with fluoride and non-fluoride releasing dental materials. *Brazilian Dental Journal*. 2001; 12(1):35-38.
16. Gürgan S, Onen A and Köprülü H. In vitro effects of alcohol-containing and alcohol-free mouthrinses on microhardness of some restorative materials. *Journal of Oral Rehabilitation.* 1997; 24(3):244-246.
17. Sarrett DC, Coletti DP and Peluso AR. The effects of alcoholic beverages on composite wear. *Dental Materials.* 2000; 16(1):62-67.
18. Choi MS, Lee YK, Lim BS, Rhee SH and Yang HC. Changes in surface characteristics of dental resin composites after polishing. *Journal of materials science. Materials in medicine.* 2005; 16(4):347-353.
19. Ferracane JL, Condon JR and Mitchem JC. Evaluation of subsurface defects created during the finishing of composites. *Journal of dental research.* 1992; 71(9):1628-1632.
20. Reis AF, Giannini M, Lovadino JR and Ambrosano GM. Effects of various finishing systems on the surface roughness and staining susceptibility of packable composite resins. *Dental Materials*. 2003; 19(1):12-18.
21. Sarac D, Sarac YS, Kulunk S, Ural C and Kulunk T. The effect of polishing techniques on the surface roughness and color change of composite resins. *The Journal of Prosthetic Dentistry*. 2006; 96(1):33-40.
22. Turkun LS and Turkun M. The effect of one-step polishing system on the surface roughness of three esthetic resin composite materials. *Operative Dentistry*. 2004; 29(2):203-211.
23. Hachiya Y, Iwaku M, Hosoda H and Fusayama T. Relation of finish to discoloration of composite resins. *The Journal of Prosthetic Dentistry.* 1984; 52(6):811-814.
24. Cochran WG. *Sampling Techniques*. 3th ed. New York: John Wiley; 1977.
25. Guler AU, Kurt S and Kulunk T. Effects of various finishing procedures on the staining of provisional restorative materials. *The Journal of Prosthetic Dentistry.* 2005; 93(5):453-458.

26. Botta AC, Duarte Jr S, Paulin Filho PI and Gheno SM. Effect of dental finishing instruments on the surface roughness of composite resins as elucidated by atomic force microscopy. *Microscopy and microanalysis*. 2008; 14(5):380-386.

27. Lopes GC, Franke MF and Maia HP. Effect of finishing time and techniques on marginal sealing ability of two composite restorative materials. *The Journal of* Prosthetic *Dentistry.* 2002; 88(1):32-36.

28. Park S, Krejci I and Lutz F. Hardness of celluloid strip-finished or polished composite surfaces with time. *The Journal of Prosthetic Dentistry.* 2000; 83(6):660-663.

29. Bagheri R, Burrow MF and Tyas M. Influence of food-simulating solutions and surface finish on susceptibility to staining of aesthetic restorative materials. *Journal of Dentistry.* 2005; 33(5):389-398.

30. Roeder LB and Powers JM. Surface roughness of resin composite prepared by single-use and multi-use diamonds. *American Journal of Dentistry.* 2004; 17(2):109-112.

31. Barbosa SL, Zanata RL, Navarro MFL and Nunes OB. Effect of different finishing and polishing techniques on the surface roughness of microfilled, hybrid and packable composite resins. *Brazilian Dental Journal.* 2005; 16(1):39-44.

32. Yap AU and Mok BY. Surface finish of a new hybrid aesthetic restorative material. *Operative Dentistry.* 2002; 27(2):161-166.

33. Yap AU, Yap SH, Teo CK and Ng JJ. Finishing/polishing of composite and compomer restoratives: effectiveness of one-step systems. *Operative Dentistry.* 2004; 29(3):275-279.

34. Santos PA, Garcia PPNS, Oliveira ALBM and Palma-Dibb RG. Chemical and morphological features of dental composite resin: influence of light curing units and immersion media. *Microscopy Research and Technique*. 2010; 73(3):176-181.

35. Walls AWG, McCabe JF and Murray JJ. The effect of the variation in pH of the eroding solution upon the erosion resistance of glass polyalkenoate (ionomer) cements. *Brazilian Dental Journal.* 1988; 164(5):141-144.