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The Influence of One-step Polishing Systems on the Surface Roughness and Microhardness of Nanocomposites

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Clinical Relevance

One-step polishing systems exhibited similar or better surface roughness values when compared to multi-step polishing systems. In all groups, mylar-strip created surfaces showed lower microhardness values than polished surfaces. Different polishing procedures did not effect the microhardness of nanocomposites. One-step polishing systems may be a good choice for polishing nanocomposites, resulting in reduced chair time.

SUMMARY

Objectives: This *in vitro* study evaluated the surface roughness and microhardness of nanocomposites that contain nanoparticles and a microhybrid composite finished and polished with two different one-step polishing systems and a conventional multi-step polishing system.

Methods and Materials: The materials evaluated were Filtek Supreme XT, Grandio, Ceram X, Aelite Aesthetic Enamel, Tetric EvoCeram and Filtek Z250. A total of 240 specimens (10-mm in diameter, 2 mm thick) were fabricated for both tests (n=120 each test) in a plexiglass mold covered with a Mylar strip. After polymerization, five specimens per group received no polishing treatment and served as the control for both tests. For each composite group (n=15), the specimens were randomly divided into three polishing systems: PoGo, OptraPol and Sof-Lex. All polishing systems were applied according to the manufacturers' instructions after being ground wet with 1200 grid silicon carbide paper. The surface roughness values were determined using a profilometer. The microhardness measurements were performed using a digital microhardness tester (load 500 g; dwell time 15 seconds). The data were analyzed using the one-way ANOVA test at a significance level of 0.05 for both tests.

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Multiple comparison was performed with the Duncan Multiple Range test.

Results: The smoothest surfaces were achieved under Mylar strips in all composite groups (*p*<0.05). There were no statistically significant differences between polishing systems in the Filtek Supreme XT, Ceram X, Aelite Aesthetic Enamel and Grandio groups for surface roughness (*p*>0.05). In the Tetric EvoCeram group, Sof-Lex exhibited the highest roughness values. No statistically significant differences were evaluated between polishing systems (*p*>0.05); whereas, the surfaces under Mylar Strip showed statistically significant lower values than the polished surfaces in terms of microhardness (*p*<0.05).

Conclusion: One-step polishing systems may be successfully used for polishing nanocomposites.

INTRODUCTION

The clinical use of resin composites has expanded considerably over the past few years, due to increased esthetic demands by patients, new developments in formulations and simplification of bonding procedures.[1] Novel resin composites have improved filler technology, modifications in organic matrixes and a greater degree of polymerization that improves their mechanical and physical properties.[2] One of the most significant advances in the last few years is resin composites containing nanoparticles.

Proper finishing and polishing of composites are important steps that enhance both the esthetics and longevity of restorations.[3-5] Restoration finish, surface roughness and surface integrity, and the physico-chemical properties of the material itself, can influence plaque retention, periodontal disease and recurrent caries, thus affecting the clinical performance of materials.[6-7] Unfortunately, polishing is complicated by the heterogeneous nature of the dental materials.[8]

The intrinsic characteristics of resin-based composite materials, such as hardness and strength, are crucial mechanical properties that provide clinical success of the restorative material.[9] Hardness may be explained as the resistance of solid structures to permanent indentation or penetration. Alterations 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.[10] In addition, hardness can show the depth of cure of the material.[9] Materials with a low surface hardness are more susceptible to scratching.[9] Surface scratches can compromise fatigue strength and provoke premature failure of a restoration.[11]

Finishing is defined as the gross contouring or reduction of a restoration to obtain ideal anatomy. Polishing refers to the reduction of roughness and stratches created by finishing instruments.[12] A variety of instruments, such as carbide and diamond burs, abrasive finish strips and polishing pastes, may frequently be used to finish tooth-colored restorative materials.[4,13-15] Today, many attempts have been made to develop composite finishing instruments that are suitable for all steps of the trimming procedure. A set of highly flexible polyurethane-based finishing and polishing discs coated with aluminum oxide particles are widely used.[6] A responsible diamond micropolisher disc, commercially named PoGo, has been developed as a one-step polishing system.[15] Recently, OptraPol, which is a special mixture of silicones, and the specific composition and distribution of an abrasive particle one-step polishing system for resin composites, has been introduced. This is known as a "one-step polishing system," because contouring, finishing and polishing procedures can be completed using a single instrument.

This *in vitro* study evaluated the surface roughness and microhardness of nanocomposites that contain nanoparticles and a microhybrid composite finished and polished with two different one-step polishing systems and a conventional multi-step polishing system.

METHODS AND MATERIALS

Five nanocomposites and a microhybrid composite were used in this study. The resin composites that were evaluated include Filtek Supreme XT, Ceram X, Aelite Aesthetic Enamel, Tetric EvoCeram, Grandio and Filtek Z250. The properties of these materials are shown in Table 1. The finishing and polishing systems evaluated were PoGo, OptraPol and Sof-Lex Pop-On discs. Table 2 shows the composition and manufacturers of the polishing systems tested.

A total 240 specimens (40 specimens of each restorative material) were fabricated using a plexiglass well (10 mm in diameter and 2 mm thick) covered by a Mylar strip (SS White Co, Philadelphia, PA, USA) and pressed flat with a microscopic glass slide using six different composite materials. All the restorative materials were cured according to the manufacturers' instructions with a halogen curing light (Optilux 501, Kerr, Corporation, Orange, CA, USA). The curing light was placed perpendicular to the specimen's surface at or less than a distance of 1.0 mm. The curing light intensity was measured at 620 mW/cm^2 and monitored with a light meter.

To reduce variability, all specimen preparation, finishing and polishing procedures were performed by the same operator. The specimens were examined for obvious voids, labeled on the bottom and randomly separated into four treatment groups (n=10). The mylar strip groups were selected and others were wet ground with 1200 grit silicon carbide paper on a metallurgical finishing wheel to provide a baseline before using the polishing systems.

Table 1: *Characteristics of Resin Composites Tested*

Restorative Materials	Material Category	Shade	Filler Volume (%)	Filler Weight (%)	Average Filler Size (µm)	Filler Type	Manufacturer
Filtek Supreme XT	nanocomposite	A2	59.5	78.5	0.6-1.4	zirconia/silica cluster	3M ESPE, St Paul, MN, USA
Ceram X	nano-ceramic restorative	A2	57	76	1.1-1.5	barium aluminum borosilicate glass	Dentsply, DeTrey, Konstanz, Germany
Aelite Aesthetic Enamel	reinforced nanofill composite	A2	54	70-75	0.04	glass frit amorphous silica	BISCO, Inc, Schaumburg, IL, USA
Tetric EvoCeram	nanohybrid	A2	68	82.5	0.5	barium glass, ytterbium-trifluoride, mixed oxide, prepolymer	Ivoclar-Vivadent, Schaan, Liechtenstein
Grandio	nanohybrid	A2	71.4	87	0.02-0.06	glass-ceramic	Voco, Cuxhaven, Germany
Filtek Z250	microhybrid	A2	60	66	0.01-3.5	zirconia/ silica	3M ESPE, St Paul, MN, USA

Table 2: *The Composition and Manufacturer of the Polishing Systems Investigated*

Polishing Systems	Composition	Manufacturers
PoGo (One-Step)	Diamond coated mico-polisher	Dentsply/Caulk, Milford, DE, USA
OptraPol (One-Step)	Mixture of silicones	Ivoclar-Vivadent, Schaan, Liechtenstein
Sof-Lex Pop-On Discs (Multi-Step)	Medium aluminum oxide disc (40 µm) Fine aluminum oxide disc (24 µm) Ultra-fine aluminum oxide disc (8 µm)	3M ESPE, St Paul, MN, USA

Group I (control): Mylar strip (no application).

Group II (PoGo): Flat, broad surface of the PoGo diamond micropolisher disc, first application with light hand pressure using a planar motion for 30 seconds at 15,000 rpm using a slow speed handpiece.

Group III (OptraPol): The same procedures as in Group 2 were performed to the OptraPol group.

Group IV (Sof-Lex): Sof-Lex Pop-On Discs at medium, fine and super-fine grits were used for 30 seconds each on the composite samples. After each polishing step, all the specimens were thoroughly rinsed with water and air dried before the next step, until final polishing.

Each disc and diamond or silicon polisher was discarded after use. Following polishing, the specimens were stored in deionized water for 24 hours. All the specimens were equally subdivided for the surface roughness and microhardness tests.

Surface Roughness Test

The surface roughness test was performed with a profilometer (Perthometer M1 Mahr, Göttingen, Germany). Three successive measurements in different directions were recorded for all the specimens in each group. Average surface roughness (Ra) values were obtained.

Microhardness Test

The Vickers hardness number (VHN) was determined using a microhardness test machine (Buehler, Lake Bluff, IL, USA). Indentations were made with a 500-g load applied for 15 seconds. Three indentations were recorded at different points on each specimen, and the microhardness value was obtained as the average of these findings.

Statistical Analysis

The data were analyzed using the one-way ANOVA test at a significance level of 0.05 for both the surface roughness and microhardness tests. A multiple comparison was performed with the Duncan Multiple Range test

RESULTS

The average surface roughness values and standard deviation produced by the Mylar strips, Sof-Lex discs, PoGo and OptraPol on six resin-based composites are listed in Table 3 and Figure 1.

Table 3: *Mean Values and Standard Deviations of Groups for Surface Roughness (Ra)*

Groups	Finishing System	n	Mean Values and Standard Deviations (±)
Filtek Supreme XT	Mylar Strip	5	0.03 ± 0.01
	PoGo	5	0.12 ± 0.06
	OptraPol	5	0.12 ± 0.05
	Sof-Lex	5	0.09 ± 0.03
Ceram X	Mylar Strip	5	0.07 ± 0.00
	PoGo	5	0.12 ± 0.02
	OptraPol	5	0.12 ± 0.05
	Sof-Lex	5	0.14 ± 0.01
Aelite Aesthetic Enamel	Mylar Strip	5	0.06 ± 0.01
	PoGo	5	0.13 ± 0.03
	OptraPol	5	0.14 ± 0.04
	Sof-Lex	5	0.14 ± 0.02
Tetric EvoCeram	Mylar Strip	5	0.08 ± 0.01
	PoGo	5	0.38 ± 0.04
	OptraPol	5	0.36 ± 0.11
	Sof-Lex	5	0.54 ± 0.12
Grandio	Mylar Strip	5	0.07 ± 0.02
	PoGo	5	0.55 ± 0.21
	OptraPol	5	0.44 ± 0.17
	Sof-Lex	5	0.43 ± 0.15
Filtek Z250	Mylar Strip	5	0.05 ± 0.00
	PoGo	5	0.20 ± 0.02
	OptraPol	5	0.16 ± 0.03
	Sof-Lex	5	0.17 ± 0.02

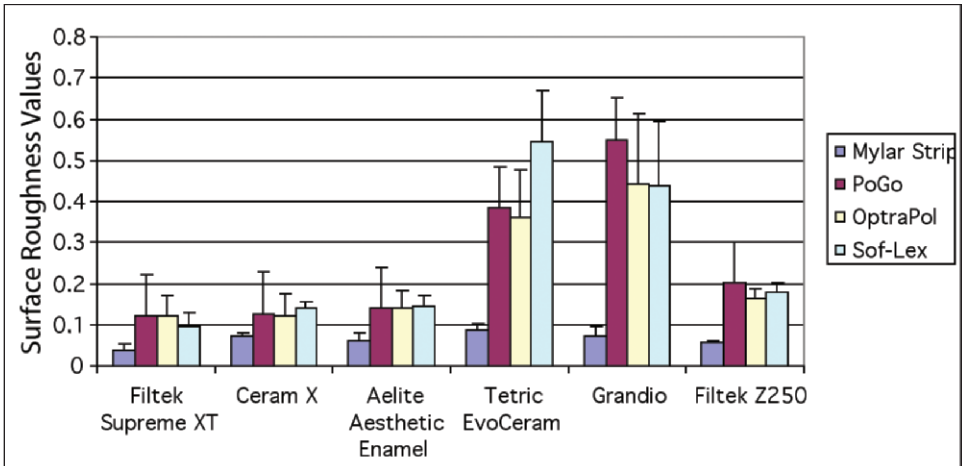

Figure 1. *Mean surface roughness values for the resin composites tested.*

The mylar strip exhibited significantly lower roughness values (smoothest surface) than the polishing systems ($p<0.05$). There were no statistically significant differences between PoGo, OptraPol and Sof-Lex for the Filtek Supreme XT, Ceram X, Aelite Aesthetic Enamel and Grandio groups ($p>0.05$). In the Tetric EvoCeram group, Sof-Lex showed significantly higher roughness values than other polishing systems ($p<0.05$). On the other hand, in the Filtek Z250 group, PoGo exhibited significantly higher roughness values than OptraPol ($p<0.05$), but it was not significantly different from Sof-Lex ($p>0.05$).

For the Mylar strip groups, Filtek Supreme XT showed the lowest surface roughness values compared to the other composites but not a significant difference from Filtek Z250. Tetric EvoCeram showed the highest surface roughness values compared to the other composites but not a significant difference from Ceram X and Grandio.

For the PoGo groups, the ranking for surface roughness values from least to most were as follows: Filtek Supreme XT = Ceram X = Aelite Aesthetic Enamel = Filtek Z250 < Tetric EvoCeram < Grandio ($p<0.05$).

For the OptraPol polishing systems, the ranking for surface roughness values from least to most were as follows: Filtek Supreme XT = Ceram X = Aelite Aesthetic Enamel = Filtek Z250 < Tetric EvoCeram = Grandio ($p<0.05$).

For the Sof-Lex groups, the ranking for surface roughness values from least to most were: Filtek Supreme XT = Ceram X = Aelite Aesthetic Enamel = Filtek Z250 < Grandio = Tetric EvoCeram ($p<0.05$).

The average microhardness values and standard deviations produced by Mylar strips, Sof-Lex discs, PoGo and OptraPol on six resin-based composites are listed in Table 4 and Figure 2. According to the microhardness values, no statistically significant differences were observed between the polishing systems (PoGo, OptraPol and Sof-Lex) for all composite groups ($p>0.05$). However, the Mylar strip created surfaces that exhibited statistically significant lower microhardness values compared with all the polishing systems for the six resin composites tested ($p<0.05$).

For the Mylar strip group, the ranking for microhardness values from least to most were: Ceram X < Tetric EvoCeram = Aelite Aesthetic Enamel < Filtek Supreme XT < Filtek Z250 < Grandio ($p<0.05$).

For the PoGo and OptraPol groups, the ranking for microhardness values from least to most were: Tetric

Table 4: *Mean Values and Standard Deviations of Groups for Microhardness (VHN)*

Groups	Finishing System	n	Mean Values and Standard Deviations (±)
Filtek Supreme XT	Mylar Strip	5	65.14 ± 0.40
	PoGo	5	77.12 ± 3.81
	OptraPol	5	77.31 ± 3.63
	Sof-Lex	5	76.67 ± 2.98
Ceram X	Mylar Strip	5	49.45 ± 2.01
	PoGo	5	68.36 ± 1.15
	OptraPol	5	68.51 ± 2.03
	Sof-Lex	5	69.39 ± 1.11
Aelite Aesthetic Enamel	Mylar Strip	5	56.86 ± 2.77
	PoGo	5	69.63 ± 2.70
	OptraPol	5	68.83 ± 0.57
	Sof-Lex	5	68.12 ± 1.19
Tetric EvoCeram	Mylar Strip	5	55.85 ± 1.56
	PoGo	5	67.86 ± 3.33
	OptraPol	5	66.20 ± 3.13
	Sof-Lex	5	67.54 ± 1.51
Grandio	Mylar Strip	5	97.59 ± 0.65
	PoGo	5	106.34 ± 5.32
	OptraPol	5	107.86 ± 5.07
	Sof-Lex	5	109.96 ± 1.78
Filtek Z 250	Mylar Strip	5	78.76 ± 0.65
	PoGo	5	89.73 ± 4.74
	OptraPol	5	89.01 ± 1.94
	Sof-Lex	5	87.24 ± 4.35

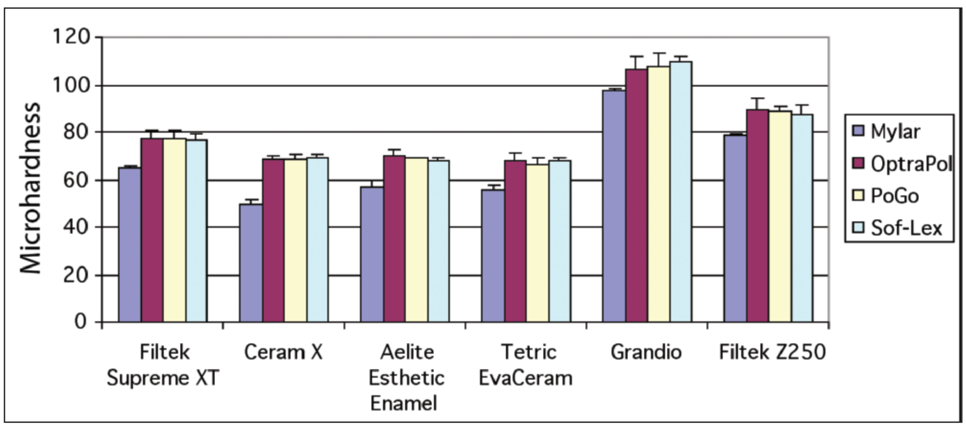

Figure 2. *Mean microhardness values for the resin composites tested.*

EvoCeram = Ceram X = Aelite Aesthetic Enamel < Filtek Supreme XT < Filtek Z250 < Grandio ($p<0.05$).

For the Sof-Lex group, the ranking for microhardness values from least to most were: Tetric EvoCeram = Aelite Aesthetic Enamel = Ceram X < Filtek Supreme XT < Filtek Z250 < Grandio ($p<0.05$).

DISCUSSION

In esthetic dentistry, the restorative material should duplicate the appearance of the natural tooth. It is clinically important to determine the finishing technique that will result in the smoothest surface using minimum time and instruments.[16]

Composite surface roughness is basically dictated by the size, hardness and amount of filler, all of which influence the mechanical properties of the resin composites, and by the flexibility of the finishing material, hardness of the abrasive and grit size.[17-18]

Fruits and others[19] have reported that three types of motion may be equally critical to the development of optimal surface smoothness: A rotary motion (circular), a planar motion and a reciprocating motion. In the current study, a planar motion, which is a rotational movement with the axis of rotation of the abrasive device perpendicular to the surface being smoothed (abrasive discs), was used for all polishing systems.

In this and other studies,[12,20-22] mylar strips formed the smoothest surface in all the composite groups tested. Although the surface obtained with a mylar strip is perfectly smooth, it is rich in resin organic binder. Therefore, removal of the outermost resin by finishing-polishing procedures would tend to produce a harder, more wear resistant and, hence, a more esthetically stable surface.[23] In this study, a Mylar strip-created surface exhibited statistically lower microhardness values than all polishing systems.

In dentistry, surface roughness measurements are usually carried out with the help of a profilometer.[24-27] In the current study, the profilometer was used to determine surface roughness. Arithmetical roughness average is the most commonly used parameter in the assessment of surface roughness.[7,28-29]

Clinically, some functional adjustment is necessary in almost all restorations. In this study, finishing was carried out with 1200 grid silicon carbide paper under running water to simulate diamond bur texture and produce specimens without undulations.

Numerous studies have shown the ability of abrasive discs to produce smooth composite surfaces.[6-7,30] On the other hand, aluminum oxide discs have limitations, due to geometry. When using the discs, it is often difficult to efficiently create, finish and anatomically polish contoured surfaces, especially in the posterior regions of the mouth.[16]

Weitman and Eames and Shintani and others[31-32] have reported no appreciable difference in plaque accumulation between surfaces polished by different methods, which resulted in Ra values within the 0.7-1.4 µm range. The highest mean Ra value for all composite materials tested in the current study was 0.55 µm. All nanocomposites and microhybrid composites produced acceptable Ra values for all the tested polishing systems.

It has been reported that, because of the variations in filler particles and types of resin, it is important to pair a resin composite with a matching polishing system. Other factors affecting polishing results may include the amount of pressure used, orientation of the abrading surface and the amount of time spent with each abrasive material.[23] In the current study, Sof-Lex showed significantly higher roughness values than other polishing systems in the Tetric EvoCeram group. This can be attributed to the fact that products from different companies may not be compatible with each other.

The finishing procedure, as performed in a clinical setting, can also affect the physical properties of resin composites.[33-34] Examination of the removed composite restorations suggest that physio-chemical stresses resulted in the formation of microcracks, microvoids or interfacial gaps at the interface between the filler and matrix.[35-36] It is important to note that these observations were not made on the effects of finishing procedures on surfaces with Mylar finishing; instead, they were observed on composite surfaces with the resin-rich layer removed.

It has been suggested that the degree of polymerization of resin composites effects the hardness of the resin matrix. The greater the conversion rate of carbon double bonds, the higher the hardness value.[37-38] In the current study, in order to obtain adequate polymerization, all samples were polymerized according to the manufacturers' instructions using a halogen curing light.

The relative importance of a microhardness test shows the fact that it gives information as to the mechanical properties of the material.[39] A positive correlation has been determined between the hardness and inorganic filler content of composites.[40] Increased organic filler levels result in increased hardness values.[41] In this study, the nanohybrid composite Grandio, which had the highest filler content (87% by weight), showed significantly higher microhardness than the other materials. No other significant difference in hardness was observed among the different polishing systems tested in all the composite groups. Composites with harder filler particles exhibited higher surface roughness; however, the bond of filler particles to the polymer matrix affects their hardness values.[11]

The results of this *in vitro* study correlate to clinical situations where there are accessible and relatively flat surfaces. Future laboratory studies should be conducted to establish the efficiency of one-step polishing systems on concave and convex surfaces.

CONCLUSIONS

Under the conditions of this *in vitro* study, the smoothest surfaces were produced with Mylar strips in all the restorative materials tested. There were no statistically significant differences between one- and multi-step polishing systems in the Filtek Supreme XT, Ceram X, Aelite Aesthetic Enamel and Grandio groups for surface roughness. Sof-Lex exhibited higher roughness values than one-step polishing systems in the Tetric EvoCeram group.

Mylar strip-created surfaces showed statistically significant lower microhardness values than polished surfaces. There were no statistical differences between one- and multi-step polishing systems in terms of microhardness. The nanohybrid composite Grandio exhibited the highest microhardness values compared to the other composites for all polishing systems tested.

Considering the reduced steps, application time and the elimination of cross-infection risks, one-step polishing systems may be preferred for polishing nanocomposite materials.

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References

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

2. Bayne SC, Heymann HO & Swift EJ Jr (1994) Update on dental composite restorations *Journal of the American Dental Association* **125(6)** 687-701.

3. Venturini D, Cenci MS, Demarco FF, Camacho GB & Powers JM (2006) Effect of polishing techniques and time on surface roughness, hardness and microleakage of resin composite restorations *Operative Dentistry* **31(1)** 11-17.

4. Jefferies SR (1998) The art and science of abrasive finishing and polishing in restorative dentistry *The Dental Clinics of North America* **42(4)** 613-627.

5. Goldstein GR & Waknine S (1989) Surface roughness evaluation of composite resin polishing techniques *Quintessence International* **20(3)** 199-204.

6. Roeder LB, Tate WH & Powers JM (2000) Effect of finishing and polishing procedures on the surface roughness of packable composites *Operative Dentistry* **25(6)** 534-543.

7. Setcos JC, Tarim B & Suzuki S (1999) Surface finish produced on resin composites by new polishing systems *Quintessence International* **30(3)** 169-173.

8. Strassler HE & Bauman G (1993) Current concepts in polishing composite resins *Practical Periodontics and Aesthetic Dentistry* **5(3 Supplement 1)** 12-17.

9. Gordan VV, Patel SB, Barrett AA & Shen C (2003) Effect of surface finishing and storage media on bi-axial flexure strength and microhardness of resin-based composite *Operative Dentistry* **28(5)** 560-567.

10. Yap AU, Wong ML & Lim AC (2000) The effect of polishing systems on microleakage of tooth-coloured restoratives. Part 2: Composite and polyacid-modified composite resins *Journal of Oral Rehabilitation* **27(3)** 205-210.

11. Craig RG (1997) *Restorative Dental Materials* Mosby-Year Book Inc, St Louis.

12. Yap AU, Lye KW & Sau CW (1997) Surface characteristics of tooth-colored restoratives polished utilizing different polishing systems *Operative Dentistry* **22(6)** 260-265.

13. Uctasli MB, Bala O & Gullu A (2004) Surface roughness of flowable and packable composite resin materials after finishing with abrasive discs *Journal of Oral Rehabilitation* **31(12)** 1197-1202.

14. Attar N (2007) The effect of finishing and polishing procedures on the surface roughness of composite resin materials *Journal of Contemporary Dental Practice* **8(1)** 27-35.

15. Turkun LS (2004) Effect of re-use of a disposable micro-polisher on the surface of a microhybrid resin composite *American Journal of Dentistry* **17(4)** 279-282.

16. Turkun LS & Turkun M (2004) The effect of one-step polishing system on the surface roughness of three esthetic resin composite materials *Operative Dentistry* **29(2)** 203-211.

17. Pratten DH & Johnson GH (1988) An evaluation of finishing instruments for an anterior and a posterior composite resin *Journal of Prosthetic Dentistry* **60(2)** 154–158.

18. Strassler HE (1992) Polishing composite resins *Journal of Esthetic Dentistry* **4(5)** 177–179.

19. Fruits TJ, Miranda FJ & Coury TL (1996) Effects of equivalent abrasive grit sizes utilizing differing polishing motions on selected restorative materials *Quintessence International* **27(4)** 279-285.

20. Woolford MJ (1988) Finishing glass polyalkenoate (glass-ionomer) cements *British Dental Journal* **165(11)** 395-399.

21. Wilson F, Heath JR & Watts DC (1990) Finishing composite restorative materials *Journal of Oral Rehabilitation* **17(1)** 79-87.

22. Tate WH & Powers JM (1996) Surface roughness of composites and hybrid ionomers *Operative Dentistry* **21(2)** 53-58.

23. Stoddard JW & Johnson GH (1991) An evaluation of polishing agents for composite resin *Journal of Prosthetic Dentistry* **65(4)** 491-495.

24. Baseren M (2004) Surface roughness of nanofill and nanohybrid composite resin and ormocer-based tooth-colored restorative materials after several finishing and polishing procedures *Journal of Biomaterials Applications* **19(2)** 121-134.

25. Drummond JL, Jung H, Savers EE, Novickas D & Toepke TR (1992) Surface roughness of polished amalgams *Operative Dentistry* **17(4)** 129-134.

26. Jagger DC & Harrison A (1994) An *in vitro* investigation into the wear effects of unglazed, glazed, and polished porcelain on human enamel *Journal of Prosthetic Dentistry* **72(3)** 320-323.

27. Scurria MS & Powers JM (1994) Surface roughness of two polished ceramic materials *Journal of Prosthetic Dentistry* **71(2)** 174-177.

28. Pedrini D, Candido MS & Rodriques AL (2003) Analysis of surface roughness of glass-ionomer cements and compomer *Journal of Oral Rehabilitation* **30(7)** 714-719.

29. Wilder AD Jr, Swift EJ Jr, May KN Jr, Thompson JY & McDougal RA (2000) Effect of finishing technique on the microleakage and surface texture of resin-modified glass ionomer restorative materials *Journal of Dentistry* **28(5)** 367-373.

30. St Germain HA Jr & Meiers JC (1996) Surface roughness of light activated glass-ionomer cement restorative materials after finishing *Operative Dentistry* **21(3)** 103-109.

31. Weitman RT & Eames WB (1975) Plaque accumulation on composite surfaces after various finishing procedures *Journal of the American Dental Association* **91(1)** 101-106.

32. Shintani H, Satou J, Satou N, Hayashihara H & Inoue T (1985) Effects of various finishing methods on staining and accumulation of Streptococcus mutans HS-6 on composite resins *Dental Materials* **1(6)** 225-227.

33. Wu W, Toth EE, Moffa JF & Ellison JA (1984) Subsurface damage layer of *in vivo* worn dental composite restorations *Journal of Dental Research* **63(5)** 675-680.

34. Leinfelder KF, Wilder AD Jr & Teixeira LC (1986) Wear rates of posterior composite resins *Journal of the American Dental Association* **112(6)** 829-833.

35. Mair LH (1989) Surface permeability and degradation of dental composites resulting from oral temperature changes *Dental Materials* **5(4)** 247-255.

36. Mair LH (1991) Staining of *in vivo* subsurface degradation in dental composites with silver nitrate *Journal of Dental Research* **70(3)** 215-220.

37. Asmussen E (1982) Restorative resins: Hardness and strength vs quantity of remaining double bonds *Scandinavian Journal of Dental Research* **90(6)** 484-489.

38. Ferracane JL & Greener EH (1986) The effect of resin formulation on the degree of conversion and mechanical properties of dental restorative resins *Journal of Biomedical Materials Research* **20(1)** 121-131.

39. Braem M, Finger W, Van Doren VE, Lambrechts P & Vanherle G (1989) Mechanical properties and filler fraction of dental composites *Dental Materials* **5(5)** 346-348.

40. Boyer DB, Chalkley Y & Chan KC (1982) Correlation between strength of bonding to enamel and mechanical properties of dental composites *Journal of Biomedical Materials Research* **16(6)** 775-783.

41. Chung KH (1990) The relationship between composition and properties of posterior resin composites *Journal of Dental Research* **69(3)** 852-856.