Surface roughness of aesthetic restorative materials: An *in vitro* comparison

Keywords: Surface roughness, composites, compomers, glass ionomers

SUMMARY

The purpose of this study was to compare the surface roughness of three types of aesthetic restorative material. Six standard samples of two brands of each type of material were prepared namely: hybrid composites (Prodigy, Z100), compomers (Compoglass F, Hytac Aplitip) and glass ionomer cements (Photac-Fil, Vitremer) in a perspex mould (N = 36). Upper and lower surfaces were covered with Mylar strips which, in turn, were covered with glass slides and compressed to express excess material. After light curing, specimens were stored in distilled water for 14 days. Thereafter, one side of each specimen was polished sequentially with medium, fine and super fine Soflex discs (treatment). Untreated surfaces served as controls. All surfaces were examined with Talysurf and the surface roughness (R_a) of each specimen was recorded. Three measurements were made of each specimen. A 4-way ANOVA and Tukey's Studentised range test were used to analyse the data. Statistically significant effects were found for both type of material (P = 0.0001) and for treatment process (P = 0.0065). Among unpolished specimens: Compoglass F is significantly rougher than Vitremer, Z100, Prodigy and Hytac Aplitip, and compomers are significantly rougher than hybrids. Among polished specimens: Photac-Fil is significantly rougher than Z100 but does not differ from Compoglass F, Vitremer, Prodigy and Hytac Aplitip, and glass ionomers are also significantly rougher than hybrids. The smoothest surface is obtained when curing materials against a Mylar strip.

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OPSOMMING

Die doel van hierdie studie was om die oppervlak-grofheid van drie tipes estetiese herstelmateriale te vergelyk. Ses standaardmonsters van twee handelsmerke van elke tipe materiaal is voorberei, naamlik: hibriede komposiete (Prodigy, Z100), kompomere (Compoglass F, Hytac Aplitip) en glasionomeer sement (Photac-Fil, Vitrimer) in 'n perspeks gietvorm (N = 36). Boonste en onderste oppervlaktes is bedek met Mylar-strokies wat weer op hulle beurt bedek is met glasplaatjies en saamgepers is om van oortollige materiaal ontslae te raak. Na ligkuring is die monsters vir 14 dae in gedistilleerde water gestoor. Hierna is een kant van elke monster opeenvolgend met medium, fyn en superfyn Soflex poleerskyfies gepoleer. Onbehandelde oppervlaktes het as kontroles gedien. Alle oppervlaktes is met Talysurf ondersoek en die oppervlak-grofheid (R_a) van elke monster is aangeteken. Drie metings is van elke monster gedoen. 'n Vier-rigting ANOVA en Tukey se gestudentiseerde reekstoets is gebruik om data te analiseer. Statisties betekenisvolle uitslae is gevind vir beide die tipe materiaal (P = 0.0001) en vir die behandelingsprosedure (P = 0.0065). In die ongepoleerde monsters was Compoglass F betekenisvol growwer as Vitremer, Z100, Prodigy en Hytac Aplitip, en kompomere betekenisvol growwer as hibriedes. In gepoleerde monsters was Photac-Fil betekenisvol growwer as Z100 maar het nie verskil van Compoglass F, Vitremer, Prodigy en Hytac Aplitip nie. Glasionomere was ook betekenisvol growwer as hibriedes. Die gladste oppervlaktes is verkry wanneer materiale teenaan 'n Mylar-strokie gekuur is.

Introduction

The establishment of a smooth surface has always been a prime objective for composite resin restorations because of the biologic consequence of plaque accumulation (Berastegui *et al.*, 1992). Composite restorative surfaces appear to accumulate more plaque than enamel and plaque accumulation has been related to surface roughness (Larato, 1972). Therefore, a smooth composite restoration surface is necessary to promote a plaque-free environment (Shintani *et al.*, 1985) thereby improving the lifespan of the restoration (Chandler, Bowen and Paffenbarger, 1971; Heath and Wilson, 1976).

The smoothest surface is obtained when curing composite against a Mylar strip [Chung, 1994; Saito, Lovadino and Kroll, 1999). Unfortunately most restora-

M Rosen, LDS, MSc (Dent)*
ES Grossman, PhD**
PE Cleaton-Jones, BDS, MB ChB, PhD, DSc (Dent)**
A Volchansky, BDS, PhD**
**Department of Restorative Dentistry, School of Oral Health Sciences*
***Dental Research Institute, Medical Research Council, University of the Witwatersrand, Johannesburg, PO Wits, 2050, South Africa.*
Address for correspondence: Prof M Rosen, Department of Restorative Dentistry, School of Oral Health Sciences, University of the Witwatersrand PO Wits 2050, South Africa, Tel: +27 11 803 3893, fax +27 11 803 4717, e-mail: **113mos@cosmos.wits.ac.za**

tions need to be finished and polished to ensure contour and marginal integrity. The quality of the polish depends on the ability of the abrasive to polish yet not damage the surface of the composite. Diamond finishing burs have been found to cause extensive damage to surface areas of enamel and composites finished with diamond burs appear rough and uneven [Quiroz and Lentz, 1985; Hoelscher *et al.*, 1998). Different types of restorative composite resin finished with Soflex discs had a smoother surface than those finished by other finishing methods (Van Dijken and Ruyter, 1987; Berastegui *et al.*, 1992; Wilson, Heath and Watts, 1990; Bouvier, Duprez and Lissac, 1997; Hoelscher *et al.*, 1998). Little advantage appeared to be gained by prior smoothing of the surface with stones or points (Wilson, *et al.*, 1990). This smooth surface may be due to the ability of the Soflex discs to cut or abrade filler particles and resin matrix equally (Kaplan, *et al.*, 1996). However, Soflex discs also seemed to cause cracks, caused by frictional heat on the polymer matrix (Kaplan, *et al.*, 1996), emphasising the need to prevent overheating of a restoration during polishing.

Many types of aesthetic restorative materials, each having unique physical properties, are available on the market. As surface roughness of composite restorative resins has been associated with failure and plaque retention and subsequent biological complications, the purpose of this study was to compare the surface roughness of different types and brands of aesthetic restorative material which have recently come on the market.

Materials and methods

The surface roughness of three types of aesthetic material was compared, using two brands of each, namely: hybrid composites, Prodigy and Z100; compomers, Compoglass F, and Hytac Aplitip; and resin modified glass ionomers, Photac-Fil and Vitremer. Details of the materials tested are given in Table 1.

Six discs (5 mm in diameter and 1.5 mm thick) of each brand were prepared in clear perspex moulds giving 6 test surfaces and 6 control surfaces per brand of material making a total of 36 specimens with 72 test surfaces. After placement of the material, upper and lower surfaces were covered with mylar strips[1] which in turn were cov-

1. Buffalo Dental Manufacturing. Co, Brooklyn, USA
2. Dentsply Caulk, Milford, USA
3. 3M, St Paul, USA
4. Taylor Hobson, Leicester, UK

Table I. **Details of materials tested**

Brand name and type	Manufacturers	Batch number	Composition
Glass ionomer			
Photac-Fil	ESPE, Norristown, PA	Liquid 035	Copolymers of maleic acid, camphoroquinone monomers, oligomers
		Powder 007	Na-Ca-Al-La fluorosilicate glass
Vitremer	3M, St Paul, MN	Liquid 3303L	Polyalkenoic acid
		Powder 3303A3	Fluoroaluminosilicate glass
Hybrid composite			
Prodigy	Kerr, Orange, CA 92867	CE0086	Filler: fumed silicon dioxide, zinc oxide, barium aluminiborosilicate, titanium dioxide Matrix: Bis GMA, TEGDMA, EDADM
Z100	3M, St Paul, MN	3022A2	Filler: zirconia-silica Matrix: Bis GMA, TEGDMA
Compomer			
Compoglass F	Vivadent, FL9494,	Schaan 909411	Filler: yttriumtrifluoride, Ba-Al-fluorosilicate glass & spheroidal mixed oxide Matrix: urethrane dimethacrylate, cycloaliphaticdicarboxylic acid dimethacrylate
Hytac Aplitip	ESPE, Norristown, PA	004	Filler: yttrium fluoride, Ca-Al-Zn fluoroglass Matrix: methacrylate & carboxyl groups

ered with glass microscope slides and compressed with finger pressure to express excess material. Each specimen was light cured for 40 seconds on each side, using a Dentsply QHL75 curing light[2] and then stored in distilled water for 14 days. Thereafter one side of each specimen was polished sequentially with medium, fine and super fine Soflex discs.[3] Each disc was used for 30 seconds in a slow handpiece and new discs were used for each specimen. Unpolished surfaces served as controls. Thereafter, the specimens were returned to distilled water for a further 7 days until surface profiles were recorded. Surface profiles were recorded using a Rank Taylor Hobson Ltd., Form Talysurf Series 2 instrument.[4] Three replicate R_a measurements (mean value for roughness) of the profiles were randomly noted for each specimen, providing a total of 18 recordings per brand of material.

Statistical analysis

The results were subjected to a 4-way analysis of variance (ANOVA) (SAS Institute Inc., 1989), with roughness as the dependent variable and type and brand of material (6), treatment (2), replication (3) and specimen (6) as the independent variables. Where the ANOVA showed any statistically significant effects Tukey's
Studentized range test was used to establish where these differences lay. The critical level of statistical significance was set at $P = <0.05$.

Results

The ANOVA showed statistically significant effects on surface roughness of the independent variables, namely, materials (df = 5, F = 7.23, P = 0.0001) and treatments (df = 1, F = 7.56, P = 0.0065) but not replication and specimen. Unpolished surfaces were significantly smoother than polished surfaces as indicated by the lower R_a measurements listed in Table II.

The absence of statistically significant effects of replication and specimen indicate a consistency in the production of the specimens and laboratory procedures employed to record the Talysurf profiles.

In Table III mean surface roughness values of unpolished material are arranged in descending order. Compoglass F has the roughest surface and does not significantly differ from Photac-Fil but is significantly rougher than all the other materials, of which Prodigy is the smoothest. Examples of the surface tracings of Compoglass F and Prodigy are shown in Fig. 1. A comparison within each type of material indicates that Compoglass F is significantly 7.5 times rougher than Hytac Aplitip but there are no significant differences within the hybrids and glass ionomers.

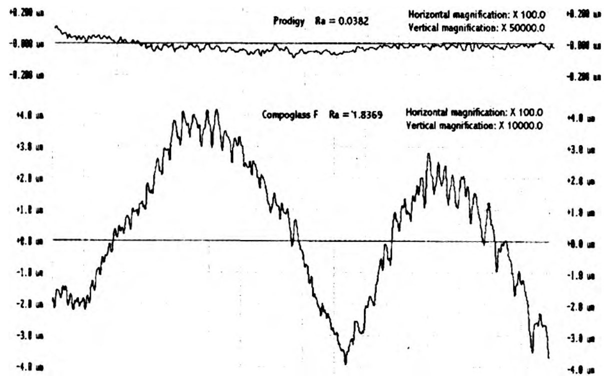

Fig. 1. Tracings of unpolished materials comparing the surface roughness profiles of Prodigy (R_a0.0382) and Compoglass F (R_a1.8369). Note that the magnification differs for the two tracings.

In Table IV mean surface roughness values of polished material are arranged in descending order. The only significant difference observed is between Photac-Fil and Z100, where Photac-Fil is rougher by a factor of 4.2. The difference between these two materials is illustrated graphically in Fig. 2. No significant differences were observed between the brands within each type of material.

***Table II.* Mean values of surface roughness R_a (micrometers) for unpolished and polished surfaces (N = 36 per type)**

Material	Unpolished	95% CI	Polished	95% CI
Hybrid				
Z100	0,21	0,04-0,39	0,36	0,17-0,55
Prodigy	0,15	0,10-0,20	0,47	0,30-0,64
Group mean	0,18	0,10-0,27	0,41	0,29-0,54
Compomer				
Compoglass F	1,15	0,42-1,89	1,34	0,36-2,32
Hytac Aplitip	0,15	0,05-0,25	0,61	0,05-1,17
Group mean	0,65	0,26-1,04	0,97	0,42-1,52
Glass ionomer				
Photac-Fil	0,72	0,20-0,30	1,52	0,79-2,24
Vitremer	0,43	0,30-0,55	0,66	0,41-0,90
Group mean	0,57	0,36-0,79	1,09	0,69-1,48

Comparison between material types

The surface roughness between types of material for unpolished specimens was compared. The ANOVA for the 108 records is similar to previous results shown on page 319 and indicates statistically significant effects on surface

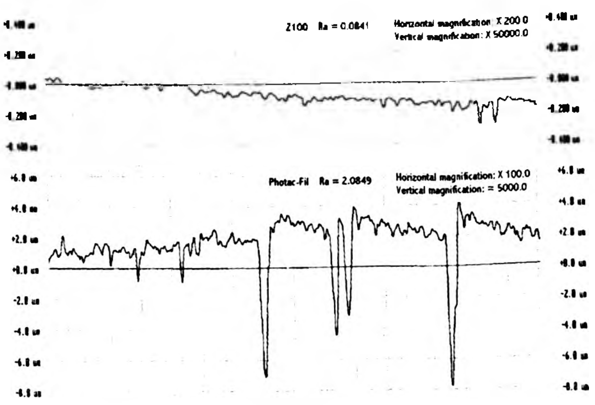

Fig. 2. Tracings of polished materials comparing the surface roughness profiles of Z100 (R_a0.0841) and Photac-Fil (R_a2.0849). Note that the magnification differs for the two tracings.

Table III. Results of Tukey's Studentised range test for R_a (micrometers) for unpolished material (N = 18 per brand)

Material	**Type**	**Mean R_a**	**Tukey's grouping**
Compoglass F	Compomer	1,15	│
Photac Fil	GIC	0,72	│ │
Vitremer	GIC	0,43	│
Z100	Hybrid	0,21	│
Hytac Aplitip	Compomer	0,15	│
Prodigy	Hybrid	0,15	│

Means on the same vertical line are not significant

roughness of the independent variable material (df = 2, F = 3.87, P = 0.0241). No significant differences were found between replication and specimen. The results of Tukey's Studentised range test, where N = 36 per group of two brands, indicate that compomer (R_a0.6531) is significantly rougher than hybrid (R_a0.1807) but not significantly different from glass ionomer (R_a0.5719); glass ionomer does not differ significantly from hybrid.

Similarly, the surface roughness between types of material for polished specimens was analysed. The ANOVA for the 108 records indicates statistically significant effects

Table IV. Results of Tukey's Studentised range test for R_a (micrometers) for polished material (N = 18 per brand)

Material	**Type**	**Mean R_a**	**Tukey's grouping**
Photac-Fil	GIC	1,52	│ │
Compoglass F	Compomer	1,34	│ │
Vitremer	GIC	0,66	│ │
Hytac Aplitip	Compomer	0,61	│ │
Prodigy	Hybrid	0,47	│ │
Z100	Hybrid	0,36	│

Means on the same vertical line are not significant

on surface roughness of the independent variable material (df = 2, F = 3.43, P = 0.0364). No significant differences were found between replication and specimen. The results of Tukey's Studentized range test, where N = 36 per group of two brands, indicate that when the materials are polished glass ionomer (R_a1.0864) is significantly rougher than hybrid (R_a0.4145) but not significantly different from compomer (R_a0.9720); compomer does not differ significantly from hybrid.

Discussion

A summary of the comparison of the surface roughness of the different types and brands shows that there is a trend for compomers and glass ionomer cements to have a rougher surface than hybrid composites. The restorative material cured against a mylar strip gives the smoothest surface. Unfortunately required finishing of the restoration destroys this surface. Differences in surface roughness between the unpolished materials could be due to differences in the composition of the materials, method of polymerisation and the curing instrument (Youssef *et al.*, 1998). However, in the polished state, differences previously apparent disappear. This is seen in the current study where, in the unpolished state, Compoglass F was significantly rougher than Vitremer, Z100, Hytac Aplitip and Prodigy. However, when these materials were polished there were no significant differences in surface roughness between the above mentioned materials. A possible explanation is that the surface roughness is now dictated by the coarseness of the abrasive used and not by the composition of the material. Evidence suggests that there is no connection between different types of matrix and polishing behaviour and no correlation between filler content and surface roughness (Behr *et al.*, 1998).

Results from the current study cannot be directly compared to other studies because of the paucity of comparable information. Most research in this field has concentrated on comparing polishing techniques on surface roughness and not on the polishability of materials. However, in the broader context of comparing types rather than brands some comparisons can be made. We found that unpolished compomer was rougher than hybrid composite and no different to glass ionomer, whereas polished glass ionomer became rougher than composite but remained as smooth as compomer. Gladys *et al.* (1997) showed that polished composite and compomer were smoother than resin modified glass ionomer and Tate and Powers (1996) found that polished composite was smoother than hybrid glass ionomer (Vitremer included). Bouvier *et al.* (1997) found both unpolished composite and compomer of similar smoothness and smoother than glass ionomer. However, when polished, composite was found to be smoother than both compomer and glass ionomer.

The results of this study show that when finished against a Mylar strip there is no significant difference in the surface roughness of Prodigy, Vitremer and Photac-Fil. However, St. Germain and Meiers (1995) found that Vitremer was significantly rougher than Photac-Fil while Dörter *et al.* (1998) found Prodigy was statistically smoother than Vitremer. The current study found no significant differences between the composites Z100 and Prodigy in either the unpolished and polished states, while both materials became significantly rougher when polished. These results were confirmed by the findings of Youssef *et al.*, (1998).

Obtaining a smooth surface has been held to be important when finishing composite restorations and an association between failure and surface roughness has been established (Smales and Webster, 1993). However, a degree of roughness appears to be tolerable as R_a values of less than 10 µm are clinically undetectable, and hence any system that delivered a surface roughness of less than 10 µm would be acceptable (Kaplan *et al.*, 1996). In this study significant differences were found between the roughnesses of the materials tested. The clinical significance of these discrepancies may not be important. According to Kaplan *et al.*, 1996, they would be clinically acceptable as all R_a values recorded in this study were less than 10 µm. However, there is a need to define unsatisfactory restorations more clearly in terms of actual adverse effects on oral health, rather than merely in terms of restoration deterioration (Smales and Webster, 1993).

Conclusion

It is concluded that the smoothest surface is obtained when curing materials against a Mylar strip. Unpolished specimens: Compoglass F is significantly rougher than Vitremer, Z100, Prodigy and Hytac Aplitip; compomer is significantly rougher than hybrid composite. Polished specimens: Photac-Fil is significantly rougher than Z100 but does not differ from Compoglass F, Vitremer, Prodigy and Hytac Aplitip; glass ionomer cement is significantly rougher than hybrid composite.

REFERENCES

Behr, M, Rosentritt, M, Leibrock, A, Schneider-Feyrer, S & Handel, G (1998) Composite, compomere and ceromer materials. Comparison of results of thermogravimetric analysis and polishing properties. *Journal of Dental Research*, **77**: Special Issue B, 686.

Berastegui, E, Canalda, C, Brau, E & Miquel, C (1992) Surface roughness of finished composite resins. *Journal of Prosthetic Dentistry*, **68**: 742-750.

Bouvier, D, Duprez, JP & Lissac, M (1997) Comparative evaluation of polishing systems on the surface of three aesthetic materials. *Journal of Oral Rehabilitation*, **24**: 888-94.

Chandler, HH, Bowen, RL & Paffenbarger, GC (1971) Method for finishing composite restorative materials. *Journal of the American Dental Association*, **83**: 344-48.

Chung, KH (1994) Effects of finishing and polishing procedures on the surface texture of resin composites. *Dental Materials*, 10, 325-30.

Dorter C, Gömec Y, Efes BG & Yildiz, E (1998) Effect of polishing procedures on surface characteristics of tooth colored restoratives. *Journal of Dental Research*, **77**: Special Issue B, 948.

Gladys, S, Van Meerbeek, B, Braem, M, Lambrechets, P & Vanherle G (1997) Comparative physico-chemical characterisation of new hybrid restorative materials with conventional glass ionomer and resin composite restorative materials. *Journal of Dental Research*, **76**: 883-94

Heath, RJ & Wilson, HJ (1976) Surface roughness of restorations. *British Dental Journal*, **140**: 131-37.

Hoelscher, DC, Neme, AM, Pink, FE & Hughes, PJ (1998) The effect of three finishing systems on four esthetic restorative materials. *Operative Dentistry*, **23**: 36-42.

Kaplan, BA, Goldstein, GR, Vijayaraghavan, TV & Nelson, IK (1996) The effect of three polishing systems on surface roughness of four hybrid composites: a profilometric and scanning electron microscopy study. *Journal of Prosthetic Dentistry*, **76**: 34-8.

Larato, DC (1972) Influence of a composite resin restoration on the gingiva. *Journal of Prosthetic Dentistry*, **28**: 402-04.

Quiroz, L & Lentz, DL (1985) The effect of polishing procedures on light cured composite restorations. *Compendium of Continuing Dental Education*, **6**: 437-39.

Saito, SK, Lovadino, JR & Kroll, LB (1999) Surface roughness of glass ionomer cements x finishing and polishing. *Journal of Dental Research*, **78**: Divisional Abstracts, 961.

SAS Institute Inc. (1989) SAS/STAT(r) User's Guide, Version 6, Fourth edition, Volume 1, Cary, NY:SAS Institute Inc., 209-243.

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**: 225-27.

Smales, RJ & Webster, DA (1993) Restoration deterioration related to later failure. *Operative Dentistry*, **18**: 130-37.

St Germain, HA & Meiers, JC (1995) Roughness of hybrid glass ionomer cement restoratives after finishing. *Journal of Dental Research*, **74**: Special Issue, 18.

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

Van Dijken, JW & Ruyter, IE (1987) Surface characteristics of posterior composites after polishing and toothbrushing. *Acta Odontologica Scandinavica*, **45**: 337-46.

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

Youssef, MN, Moldes, VL, Fossen, AM & Cassoni A (1998) Surface roughness: study in vitro of two hybrid resin after polishing. *Journal of Dental Research*, **77**: Divisional Abstracts, 1144.