J Mater Sci: Mater Med (2007) 18:143–147
DOI 10.1007/s10856-006-0673-x

Comparative study of the wear behavior of composites for posterior restorations

Cecilia P. Turssi · Juliana J. Faraoni-Romano · Márcio de Menezes · Mônica C. Serra

Received: 4 May 2005 / Accepted: 24 October 2005

Abstract This investigation sought to compare the abrasive wear rates of resin composites designed for posterior applications. Seventy-five specimens were fabricated with conventional hybrid (Charisma and Filtek Z250) or packable composites (Filtek P60, Solitaire II and Tetric Ceram HB), according to a randomized complete block design ($n = 15$). Specimens were finished and polished metallographically and subjected to abrasive wear which was performed under a normal load of 13N at a frequency of 2 Hz using a pneumatic device (MSM/Elquip) in the presence of a mucin-containing artificial saliva. Wear was quantified profilometrically in five different locations of each specimen after 1,000, 5,000, 10,000, 50,000 and after every each 50,000 through 250,000 cycles. A split-plot ANOVA showed a significant difference between the wear resistance of composites ($\alpha = 0.05$). Tukey's test ascertained that while the composites Filtek Z250 and Charisma wore significantly less than any other of the materials tested, Tetric Ceram HB experienced the greatest wear rates. Filtek P60 and Solitaire II showed intermediate rates of material removal. The wear pattern of composites proved to be biphasic with the primary phase having the faster wear rate. In conclusion, packable resin composites may not have superior wear compared to conventional hybrid composites.

C. P. Turssi (✉)
Departamento de Odontologia Restauradora—FORP/USP Av. do Café, s/n, Ribeirão Preto, SP, Brazil
e-mail: cturssi@yahoo.com

J. J. Faraoni-Romano · M. de Menezes · M. C. Serra
Department of Restorative Dentistry, School of Dentistry of Ribeirão Preto, University of São Paulo (USP), Brazil

Introduction

In an effort to address concerns surrounding aesthetic direct posterior restorations, resin composites have been the focus of intensive research activity. Specifically, investigations have been directed toward the development and refinement of composites in pursuit of overcoming some of their clinical deficiences, such as polymerization shrinkage and its accompanying stresses, wear, insufficient proximal contact and contour, and fracture [1].

Despite the fact that it has no longer been cited as one of the major drawbacks of composites [2], wear is still considered as a factor that contributes to materials' failure because it is an inevitable consequence of cycling loading during normal occlusal and masticatory function [3]. Wear of composites is known to depend on filler particle-related features, particularly on the concentration and size of the filler reinforcement [4]. Finer particles for a fixed-volume-fraction of filler have been documented to result in decreased interparticle spacing and thereby reduced wear [5, 6]. In terms of filler content, some *in vitro* wear studies have revealed that increased loading may enhance the wear resistance of dental composites [7–9]. In this respect, there is a threshold filler volume near 80% above which wear resistance is decreased [10]. However, the enhancement of wear resistance can only be achieved if the particles are homogeneously dispersed and well-bonded to the resin matrix [9].

With their relatively higher filler volume fraction, packable composites have been launched on the market with high expectations. However, there is some disagreement in the literature on the comparative wear performance of such materials. While some studies suggested that packable composites show an increased wear resistance [11–13], other investigators reported their indistinguishable or relative worse performance as compared with nonpackable resins [14].

Presumably, this apparent disparity in the reported data for wear of packable composites arises in part from the type of the test apparatus and the testing conditions employed to evaluate wear.

Due to the uncertainties associated with estimating the performance of composites designed for posterior applications, this study was undertaken as a collaborative approach to assess whether packable composites have similar wear characteristics to conventional hybrid composites and how both types of composite perform over the period of testing.

Materials and methods

Experimental design

The design of this investigation was a randomized complete block with a split-plot factorial arrangement ($n = 15$). Factors examined comprised *composite* at five levels (Charisma, Filtek Z250, Filtek P60, Tetric Ceram HB and, Solitaire II, as listed in Table 1) and *number of cycles* at eight levels (1,000; 5,000; 10,000; 50,000; 100,000; 150,000; 200,000; 250,000). The response variable was wear depth, measured profilometrically (μm).

Preparation of specimens

According to a randomized complete block design, a total of 15 rectangular-shaped samples (10 mm long × 6 mm wide and 2 mm thick) of each resin composites were made in a polytetrafluoroethylene mold with the upper and lower surfaces covered with Mylar matrix strips. They were light polymerized using an Optilux 401 curing unit (Demetron/Kerr, Danbury, CT, USA). The power density of the curing light was periodically monitored with a hand-held radiometer (Demetron/Kerr Corp, Danburry, USA) and ranged from to 520 to 580 mW/cm^2. The polymerized specimens were then removed and maintained for 24 h in a 100% relative humidity at 37° ± 1°C. The upper surface of the composite was metallographically ground and polished on 600- and 1200-grit Al_2O_3 papers. After polishing, samples were sonicated for 10 min in deionized water.

Wear testing and analyzing

Wear testing was performed using the MSM (ElQuip, São Carlos, SP, Brazil) electro-pneumatic wear simulator that has been characterized in detail elsewhere [15]. Briefly, a spherical antagonist made from stainless-steel under a 13 N load was applied to the specimens and moved across the surface over a 3 mm linear path, generating abrasive wear. Tests were carried out at 37° ± 0.5°C in five individual compartmens in the presence of a mucin-containing artificial saliva

Table 1 Characterization of resin composites investigated

Resin composite (manufacturer)	Classification	Basic composition*	Particle size (μm)*	Filler Loading	Batch #
Charisma (Heraus Kulzer)	Hybrid	Ba-Al-F glass; highly dispersive siliciumdioxide, Bis-GMA	0.02–2	64 vol% 75 wt%	030070
Filtek Z250 (3M Espe)	Hybrid	Zirconia, silica, Bis-GMA, UDMA, Bis-EMA	0.01–3.5	60 vol% 82 wt%	2UM
Filtek P60 (3M Espe)	Packable	Zirconia, silica, Bis-GMA, UDMA, Bis-EMA	0.19–3.3	61 vol% 83 wt%	4WC
Solitaire II (Heraus Kulzer)	Packable	Porous silica, Ba-Al-F-silicate, BisGA, PENTA, HPMA, ETMA	2–20	90 vol% 75 wt%	010250
Tetric Ceram HB (Ivoclar Vivadent)	Packable	Ba-glass, Ba-Al-F-silicate glass, ytterbium trifluoride, highly dispersed silicon dioxide, spheroid mixed oxide, Bis-GMA, UDMA, decandiol dimethacrylate	0.04–3	63 vol% 81 wt%	D66314

*As disclosed by the manufacturers
Bis-GMA = bisphenol glycidyl methacrylate; UDMA = urethane dimethacrylate; Bis-EMA = bisphenol A polyetheylene glycol diether dimethacrylate; BisGA = bisphenol acrylate; PENTA = pentaerythriol tetraacrylate; HPMA = hydroxypropyl methacrylate; ETMA = ethyl triglycol methacrylate.

Table 2 Original cumulative wear depth for each resin composite at each number of cycles

Resin Composite	Cycles ($\times 10^3$)							
	1	5	10	50	100	150	200	250
Charisma	0.95	1.34	1.44	1.85	2.20	2.82	3.66	4.09
	(0.40)	(0.60)	(0.66)	(0.64)	(0.57)	(1.19)	(0.93)	(1.43)
Filtek Z250	1.02	1.40	1.55	1.71	2.07	2.57	3.61	4.17
	(0.40)	(0.55)	(0.52)	(0.60)	(0.91)	(1.07)	(1.38)	(1.25)
Filtek P60	0.87	1.71	2.09	2.66	2.86	3.05	3.24	4.00
	(0.31)	(0.69)	(0.80)	(0.97)	(1.21)	(1.25)	(1.21)	(1.31)
Solitaire II	1.57	1.74	1.93	2.34	2.77	2.83	3.19	3.93
	(0.43)	(0.76)	(0.56)	(1.13)	(1.14)	(1.06)	(0.99)	(1.77)
Tetric Ceram HB	1.79	2.35	2.53	2.91	3.37	4.00	5.21	5.56
	(0.57)	(1.07)	(0.83)	(0.99)	(1.54)	(1.63)	(1.72)	(2.31)

Standard deviations are in parentheses.
Different superscripts denote significant difference between composites within each column ($\alpha = 0.05$).

−3.5 g of porcine mucin, 2.0 g of xylitol, 100 mg of methylparaben, 50 mg of EDTA, 2.0 mg of benzalkonium chloride, and 0.42 mg of NAF in 100 mL of water solution, as described previously [16]. The test assembly operated at a frequency of 2 Hz.

Wear depth was analyzed at the end of 1,000, 5,000, 10,000 and 50,000 cycles and, after that, at the completion of each 50,000 through 250,000 cycles. Five scans, perpendicular to the wear facet, were performed on each specimen, after they had been rinsed with deionized water for 15 s, using a stylus profilometer (Surfcorder SE-1700, Kosaka, Tokyo, Japan). The reference plane was based on the nonabraded areas surrounding the wear facet.

Statistical analysis

The average of the five profilometric measurements obtained at each stage of the experiment for each specimen was calculated and used as the outcome value for that specimen at each specific number of cycles. Data were log transformed prior to the split-plot analysis of variance in order to meet the assumption of homoscedasticity. Tukey's test was run at each *number of cycles* level to ascertain differences in wear among composites. The cumulative wear of each composite was plotted against number of cycles. Statistical significance was assumed at $p \leq 0.05$ and tests were performed with the aid of SAS 6.11 (SAS Institute, Cary, NC, USA) and Statgraphics Plus (Manugistics, Rockville, MD, USA).

Results

The original mean values and standard deviations for abrasive wear are shown in Table 2. A split-plot ANOVA applied to the log-transformed data indicated significant effects for *composite* ($p < 0.0001$) and *number of cycles* ($p < 0.0001$) but no significant interaction between them ($p = 0.2849$). Tukey's test ascertained that the wear depth of Tetric Ceram HB was significantly greater than any of the other composites tested. Filtek P60 and Solitaire II were not significantly different and exhibited a significantly greater wear than Charisma and Filtek Z250. No significant difference was observed between these two hybrid composites.

Figure 1 depicts the change in wear with the number of cycles for all the resin composites. The wear pattern of composites showed two phases, the primary phase had a faster rate of wear than the secondary phase.

Discussion

The results suggested that the *in vitro* wear rates of composites designed for posterior applications were material-dependent and biphasic. The latter finding, which is of importance as it establishes the wear trend of composites, can be appreciated in Fig. 1. By examining the curves, it is clear an initial onset of wear as a result of the running-in process. During such a phase, in which the contact area between the triboelements (antagonist and composite) was established, it is likely that the yield stress of materials was exceeded, leading to an initially high wear. As abrasion continued and stresses became lower, only a slight increase in wear rates was observed. These results are consistent with previously reported wear-resistance data for composites [13, 17].

Confirming the expectation that as particle size is decreased so is the wear [6, 18], when comparing composites having identical composition (Filtek Z250 and P60) but different filler sizes, the composite consisting of smaller particles was found to wear less. In the conventional hybrid composite Z250 a comparatively greater number of particles was probably present on the surface. Consequently,

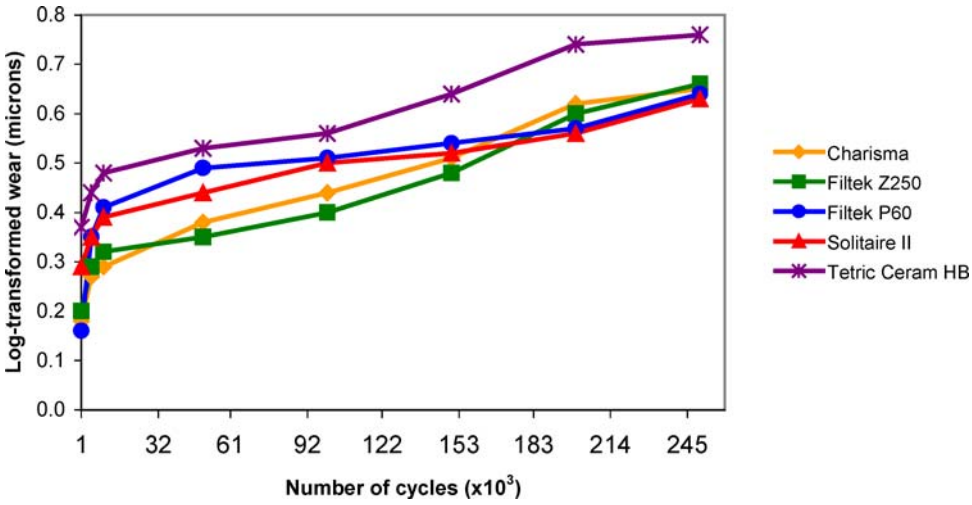

Fig. 1 Plot of cumulative log-transformed wear depth against number of abrasive cycles for each resin composite investigated. Each point represents the log-transformed mean depth of fifteen specimens of each material.

a larger contact area may have been established between the fillers and the counterpart, resulting in improved wear resistance.

Despite having fillers ranging larger in size than Tetric Ceram, Solitaire II HB showed lower wear. This is not surprising in view of the differences in their filler types. Solitaire II is combined with porous filler particles that are claimed to be penetrated by resin matrix. Consequently, it is assumed that a mechanical interlocking mechanism is created and, under such a circumstance, a better resistance to filler plucking-out may be achieved and thereby an improved wear resistance. This aspect coupled with the dissimilar filler content and monomeric constituents may substantiate the differences between both composites. In effect, in previous studies, wear resistance was shown to be dependent on the degree of conversion of monomers [7]. Therefore, composites having different monomers are likely to demonstrate dissimilar rates of monomer conversion which ultimately affect their wear resistance.

Despite the fact that the superiority of Solitaire II over Tetric Ceram HB could mainly have been attributed to the high filler content of the former, its filler loading of 90 vol% has been unconfirmed. There is a report documenting that the filler content by volume of Solitaire II is rather of 58% [19]. This may partly explain the lack of difference between Solitaire II and P60. It can be speculated that the advantages claimed for the porous fillers blended to Solitaire II may be offset by the mechanical properties of P60. Evidence for this is the fact that mechanical properties of P60 was found to be superior in comparison to that measured for Solitaire II [20, 21].

Although the interaction between the main factors (*composite* and *number of cycles*) was not statistically significant, from Fig. 1 it can be noted that there was a trend toward all composites, except for Tetric Ceram HB, worn similarly as the number of cycles increased. In fact, a previous short-term report on the clinical performance of packable and unpackable composites have show their indistinguishable wear scores [22]. However, because packable composites are quite different in mechanical and physical properties the suitability of such materials for posterior restorations has still been considered questionable [23].

Based upon the observation that lubrication was shown to modulate *in vitro* wear rates of composites, a mucin-containing artificial saliva was interposed between the tribolelements (specimen and antagonist). A previous investigation supported by studies on the lubricity ability of such an artificial saliva, suggested that this mucin-containing preparation is considered as a potential lubricant for *in vitro* wear test purposes [15].

Several wear-testing machines have been reported in the literature for simulating abrasion. A previous paper focused on the comparison between different equipments revealed that when ranks of restoratives were investigated, the results varied substantially between the methods [24]. This may explain the controversial literature findings with regard to the ranking of packable composites relative to conventional hybrid counterparts [11–14]. The current study was designed to simulate a two-body abrasive wear condition, which may occur during direct occlusal or proximal tooth or restoration contact. However, despite the fact that the present findings may be integrated into the overall understanding of the performance of packable composites, two-body abrasion represents only one of the conditions governing the wear process *in vivo* [10].

Furthermore, it is worthwhile to note that many factors besides wear can affect the lifespan of posterior restorations. However, it can be assumed that materials with better wear resistance should do better under cycling loading during normal occlusal and masticatory function. Therefore, despite the supposedly advantages of easy handling and placemement, in terms of wear resistance, packable composites may not be favored over conventional hybrid resins for posterior applications.

Acknowledgments This study was supported by the State of São Paulo Research Foundation (FAPESP) under research grant #01/12333-7. The authors are indebted to Patrícia Marchi for her technical assistance.

References

1. J. MANHART, H. CHEN, G. HAMM and R. HICKEL, *Oper. Dent*. **29** (2004) 481.
2. K. H.-K. YIP, R. J. SMALES and J. A. KAIDONIS, *Int. J. Prosthodont.* **17** (2004) 350.
3. M. BRAEM, P. LAMBRECHTS, V. VAN DOREN and G. VANHERLE, *Dent. Mater.* **2** (1986) 106.
4. C. P. TURSSI, B. DE MORAES PURQUERIO and M. C. SERRA. *J. Biomed. Mater. Res.* **65B** (2003) 280.
5. K.-J. SÖDERHOLM and N. D. RICHARDS, *Gen. Dent.* **46** (1998) 256.
6. C. P. TURSSI, J. L. FERRACANE and K. VOGEL, *Biomaterials* **26** (2005) 4932.
7. J. R. CONDON and J. L. FERRACANE, *J. Dent. Res.* **76** (1997) 1405.
8. Y. TORII, K. ITOU, T. ITOTA, K. HAMA, N. KONISHI, M. NAGAMINE and K. INOUE, *Dent. Mater. J.* **18** (1999) 453.
9. B.-S. LIM, J. L. FERRACANE, J. R. CONDON and J. D. ADEY, *Dent. Mater.* **18** (2002) 1.
10. X. HU, P. M. MARQUIS and A. C. SHORTALL, *J. Oral Rehabil*. **30** (2003) 729.
11. N. L. CLELLAND, S. C. VILLARROEL, L. A. KNOBLOCH and R. R. SEGHI, *Oper. Dent*. **28** (2003) 830.
12. S. SUZUKI, *J. Esthet. Rest. Dent.* **16** (2004) 355.
13. C. ZANTNER, A. M. KIELBASSA, P. MARTUS and K.-H. KUNZELMANN, *Dent. Mater.* **20** (2004) 277.
14. L. J. FERRACANE, K. K. CHOI and J. R. CONDON, *Compend. Contin. Educ. Dent*. **25** (1999) S60.
15. C. P. TURSSI, J. J. FARAONI, M. DE MENEZES and M. C. SERRA, *Dent. Mater*. **22** (2006) 77.
16. C. E. CHRISTERSSON, L. LINDH and T. ARNEBRANT, *Eur. J. Oral Sci.* **108** (2000) 418.
17. J. A. KAIDONIS, L. C. RICHARDS, G. C. TOWNSEND and G. D. TANSLEY, *J. Dent. Res.* **77** (1998) 1983.
18. S. SUZUKI, K. L. LEINFELDER, K. KAWAY and Y. TSUCHITANI, *Am. J. Dent.* **8** (1995) 173.
19. U. LOHBAUER, T. VON DER HORST, R. FRANKENBERGER, N. KRÄMER and A. PETSCHELT, *Dent. Mater.* **19** (2003) 435.
20. Y. ABE, P. LAMBRECHTS, S. INOUE, M. J. A. BRAEM, M. TAKEUCHI, G. VANHERLE and B. VAN MEERBEEK, *Dent. Mater.* **17** (2001) 520.
21. G. L. ADABO, C. A. S. CRUZ, R. G. FONSECA and L. G. VAZ, *J. Dent.* **31** (2003) 353.
22. F. B. DE SOUZA, R. P. GUIMARÃES and C. H. V. SILVA, *Quintessence Int.* **36** (2005) 41.
23. J. MANHART, H. Y. CHEN and R. HICKEL, *J. Am. Dent. Assoc.* **132** (2001) 639.
24. S. D. HEINTZE, G. ZAPINNI and V. ROUSSON, *Dent. Mater.* **21** (2005) 304.