Wear of Posterior Composite Resins

Yoshiaki TANI, Hideaki GOTO and Kazuo IDA

Department of Dental Materials, Research Center for Medical Polymers and Biomaterials, Kyoto University Sakyo-ku, Kyoto 606, Japan

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In vitro wear of sixteen posterior composite resins was determined by the glass beads abrasion test. The wear was remarkably greater with the thick slurry than with the thin slurry. Microfilled posterior composites were higher wear-resistant than highly loaded and blended posterior composites. There is little difference in wear between submicrofilled resins and microfilled resins with the thick slurry. This suggests that the filler particle size is relatively important to wear resistance of the posterior composite material. There was a close parallel between the results of the glass beads abrasion test and clinical observations. There is no consistency among the wear measurements in the toothbrushing abrasion test.

Key words: Posterior Composite, Abrasion Resistance, Wear Test

INTRODUCTION

Wear resistance and marginal fracture toughness are the two most important properties of the composite restorative materials for posterior teeth. The test method to evaluate these properties, moreover, must be reflected in clinical evaluation.

The results of our glass beads abrasion test¹⁾ showed a close parallel to clinical findings in the composite restoration. The composite resin developed originally as the anterior restorative material has been progressively improved in its mechanical and physical properties enough to endure various stresses. The recently developed posterior composite tends to be more highly loaded, and it blended fillers with a wide range of distribution in particle size.

The purpose of the present investigation was to determine the wear of sixteen commercially available posterior composites by the glass beads abrasion test reported previously.

MATERIALS AND METHODS

Materials evaluated for abrasion resistance in this study consisted of five chemical-cured posterior composites and eleven visible light-cured posterior composites. Batch numbers and manufacturers for all materials tested are given in Table 1. Isomolar, Heliomolar and Heliomolar Radiopaque are microfilled composites. Palfique and Palfique Light are submicrofilled composites which are filled with about 70 wt. % of spherical silica particles of the filler 0.2–0.3 μm in diameter of uniform size²⁾. Palfique has sufficient strength for restoration of posterior teeth and excellent esthetic appearance for anterior teeth³⁾. Bell Firm P is filled ground silicon nitride (Si_3N_4) and α -quartz in the amount of 80 wt. % in matrix resin (tetramethylol methane trimethacrylate and tetramethylol methane tetramethacrylate)⁴⁾. Sinter Fil is filled with microfillers and with agglomerated microfiller

Table 1 Materials tested

Material	Batch Number	Manufacturer
Chemical-cured		
Clearfil Posterior	PU2216, PC2116	Kuraray
Bell Feel	17E48	Kanebo
P-10	A : 5B1, B : 5D2	3 M
Palfique	U743, C300	Tokuyama Soda
Isomolar	3182.01, 3134. 03	Vivadent
Light-cured		
Estilux Posterior	167	Kulzer
Ful-fil	1016854	Caulk-Dentsply
P-30	6P1	3 M
Occlusin	LH06	ICI
Lite Fil P	068561	Shofu
Photo Clearfil A	HAS-1007	Kuraray
Pyrofil Light Bond	169-005S	Sankin
Palfique Light	LU213	Tokuyama Soda
Sinter Fil	41071	Teledyne Getz
Heliomolar	317702	Vivadent
Heliomolar Radiopaque	337601	Vivadent

complexes prepared by sintering the microfillers. The other nine materials may generically be called highly loaded composites.

Five specimens ($10 \times 10 \times 1.5$ mm) of each material were prepared after mixing according to the manufacturers' instructions. Specimens of light-cured posterior composites were

Fig. 1 Schematic drawing of specimen and positions of visible light exposure.

exposed to light emitted by Optilux* with five 10-second exposures on both the upper and lower sides of the specimen through a plastic sheet (Fig. 1).

All specimens were polished with a 1200-grit silicon carbide paper to wear away 200 μm in thickness from the surface and then cleaned with an ultrasonic cleaner** for 10 min. After these specimens were kept in a desiccator until they attained a constant weight, specific gravity of each material was measured with a specific gravity meter for solid material***, prior to one week storage in 37°C water.

The detailed procedures for the glass beads abrasion test were demonstrated in a previous paper¹⁾. A schematic diagram of the glass beads abrasion test apparatus is shown in Fig. 2.

Fig. 2 Schematic diagram of the glass beads abrasion test apparatus.

Two types of slurry were prepared. One (standard slurry) was mixed with 140 g of glass beads # to 100 ml water, and the other was mixed with 280 g of the same glass beads to 100 ml water. The intermediate particle size of the glass beads is 18 with a particle size distribution ranging from several μm to about 30 μm . The slurry was spread over the PMMA plate stage. The specimen, fixed in the horizontal drive arm, was reciprocated with a 400 g load of glass beads at a velocity of 60 strokes per minute for 10,000 times, which is equivalent to traveling 1,000 m. The degree of wear was measured by weight loss, later converted to volume loss with specific gravity.

The conventional toothbrushing abrasion test was also carried out for comparison. In preparing the abrasive slurry, 150 g of tooth paste ## was added to water to make a total volume of 500 ml. The specimen was reciprocated with a 250 g load on a hard tooth brush which was connected to five other tooth brushes ### in series with the slurry.

RESULTS AND DISCUSSION

The results obtained for the wear caused by the glass beads abrasion test are shown for all materials in Table 2 and Fig. 3 and 4.

* Demetron Research Corporation, Danbury, Conn., U. S. A.

** Transister / Ultrasonic T-9, L and R Mfg., Co., New Jersey, U. S. A.

*** S-280, Shimadzu Corporation, Kyoto, Japan.

EGB-731, Toshiba-Ballotini Co., Ltd., Tokyo, Japan.

Lark Sunstar, Sunstar Inc., Takatsuki, Japan.

Perio-II-H, Sunstar Inc., Takatsuki, Japan.

Table 2 Wear of posterior composites after glass beads abrasion test in the different rate of water, to glass beads

Material	Ratio of water to glass beads		Specific gravity
	100 ml/140 g	100 ml/280 g	
Clearfil Posterior	2.67 (0.14)	26.36 (3.01)	2.094
Bell Feel	4.27 (2.03)	31.04 (1.56)	2.365
P-10	10.69 (2.36)	35.53 (0.14)	2.198
Palfique	4.15 (0.40)	13.38 (1.67)	1.734
Isomolar	0.75 (0.38)	10.88 (1.56)	1.600
Estilux Posterior	7.56 (0.69)	34.00 (4.03)	2.062
Ful-fil	5.81 (1.23)	28.63 (4.22)	2.204
P-30	6.83 (0.84)	33.23 (9.87)	2.269
Occlusin	11.28 (3.12)	38.51 (9.95)	2.428
Lite Fil P	10.14 (0.59)	28.46 (4.17)	1.992
Photo Clearfil A	3.63 (0.47)	24.99 (3.09)	2.201
Pyrofil Light Bond	2.19 (0.27)	35.90 (6.96)	2.184
Palfique Light	3.12 (1.36)	18.29 (8.06)	1.761
Sinter Fil	4.45 (0.75)	32.04 (4.80)	1.729
Heliomolar	0.31 (0.10)	5.37 (0.12)	1.621
Heliomolar Radiopaque	0.43 (0.37)	8.73 (2.94)	1.868

Wear is expressed in volume loss ($\text{cm}^3 \times 10^{-3}$).
 Parentheses indicate standard deviation.

Fig. 3 Wear of posterior composites after glass beads abrasion test in the ratio of 100 ml water to 140 g glass beads.

Fig. 4 Wear of posterior composites after glass beads abrasion test in the ratio of 100 ml water to 280 g glass beads.

The wear under the standard test condition (in the rate of 100 ml water to 140 g glass beads) was minimal with Heliomolar, Heliomolar Radiopaque and Isomolar, and followed in increasing order by Pyrofil Light Bond, Clearfil Posterior, Palfique Light, Photo Clearfil A, Palfique. Occlusin, P-10 and Lite Fil P showed the greatest wear. The wear was remarkably greater with the thick slurry than with the standard slurry. The wear was minimal with Heliomolar, Heliomolar Radiopaque, Isomolar and Palfique, nevertheless, Occlusin, P-10 showed the greatest wear. It is noteworthy that much greater wear was shown with Pyrofil Light Bond and Clearfil Posterior, which showed considerable little wear in thin glass beads slurry.

From the data presented in this study, microfilled posterior composites were much higher wear-resistant than highly loaded and blended posterior composites, which are popularly known as the hybrid composites. There is little difference in wear between submicrofilled resins and microfilled resins with the thick slurry. This suggests that the filler particle size is relatively important to wear resistance of the posterior composite material.

Figure 5 shows the SEM photograph of the surfaces of specimens after the glass beads abrasion test. On the left in the photograph is Heliomolar which showed the least wear and on the right is Occlusin which showed the greatest wear. Fig. 6 shows a SEM photograph of a lower second molar restored with a highly loaded blend-type composite resin (Occlusin). Fig. 7 shows a SEM photograph of two second molars restored with the only submicrofilled composite resin (Palfique).

Our results in this study, that the wear level of the microfilled composite was smaller

Fig. 5 Comparative wear of surfaces of Heliomolar Radiopaque (left) and Occlusin (right) after glass beads abrasion test with thin slurry. (Orig. mag. $\times 1000$).

Fig. 6 Scanning electron photomicrographs of a lower second molar restored with Occlusin after 14 months (left) and baseline (right).

Fig. 7 Scanning electron photomicrographs of two cases of Palfique restorations in molar teeth.

than the other composite, agreed with other reports⁵⁻⁷). Sinter Fil is filled with microfillers and with agglomerated microfiller complexes prepared by sintering the microfillers. It was confidently expected that Sinter Fil would show favorable wear resistance due to tight bonding by the infiltration of organic matrixes and by wealth in the retention sites. The wear of Sinter Fil after the glass beads abrasion test, contrary to expectation, was much the same as the highly loaded blend-type posterior composites. It is possible that the sintering of microfillers lost characteristic as a microfiller and exposed its characteristic as a coarse filler. A Sinter Fil restoration exhibiting severe localized deterioration after 2 years is illustrated

Fig. 8 Stone dies of two cases of Sinter Fil restorations in molar teeth.

Table 3 Wear of posterior composites after toothbrushing abrasion test

Material	Volume loss ($\text{cm}^3 \times 10^{-3}$)
Clearfil Posterior	0.110 (0.091)
Bell Feel	0.085 (0.042)
P-10	0.150 (0.055)
Palfique	0.173 (0.115)
Isomolar	0.331 (0.181)
Estilux Posterior	0.131 (0.056)
Ful-fil	0.045 (0.045)
P-30	0.339 (0.066)
Occlusin	0.111 (0.049)
Lite Fil P	0.186 (0.029)
Photo Clearfil A	0.123 (0.055)
Pyrofil Light Bond	0.060 (0.027)
Palfique Light	0.114 (0.057)
Sinter Fil	0.463 (0.058)
Helimolar	0.105 (0.142)

Parentheses indicate standard deviation.

Table 4 Wear of several restorative materials after brushing abrasion test

Type of restoratives	Type of water suspension*	
	Water	Water + 10% Glycerin
Unfilled MMA resin (Sevriton)	0.37 (0.10)	0.28 (0.40)
Microfilled resin (Silar)	1.49 (0.26)	2.14 (1.89)
Submicrofilled resin (Palfique)	0.17 (0.05)	0.32 (0.23)
Conventional composite (Clearfil F II)	0.34 (0.04)	0.53 (0.02)
Highly-loaded composite (Clearfil Posterior)	0.10 (0.04)	0.51 (0.02)
High copper amalgam (Spherical D)	0.03 (0.03)	0.04 (0.02)

Wear is expressed in volume loss ($\text{cm}^3 \times 10^{-3}$).

Parentheses indicate standard deviation.

* For preparing the abrasive slurry, 150 g of toothpaste was added water suspension to make a total volume of 500 ml.

in Fig. 8. This is similar to the finding of a microfilled composite of agglomerated silica demonstrated by Heymann *et al.*⁸⁾.

The present study amply demonstrated that the results obtained by the glass beads abrasion test were in accord with clinical findings for occlusal wear.

The results for wear, caused by the toothbrushing abrasion test, are shown in Table 3. There is no particular tendency in wear among the posterior composites. Table 4 compares the wear of several different restorative materials after toothbrushing abrasion test. Amalgam showed the least wear, and microfilled resin showed the most. The conventional composite was better than the microfilled resin. The results were not consistent with the clinical results.

CONCLUSION

Wear resistance of sixteen posterior composites was evaluated by the glass beads abrasion test. From the data presented in this study, microfilled and submicrofilled posterior composites were more superior in wear resistance than the highly loaded posterior composites. This suggests that the filler particle size is relatively important to wear resistance of the posterior composite material. There was a close parallel between the results of the glass beads abrasion test and clinical observations. Moreover, SEM studies supported the results described above.

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臼歯用コンポジットレジンの耐摩耗性

谷 嘉明, 後藤秀明, 井田一夫

京都大学医用高分子研究センター歯科材料応用研究部門

臼歯用修復材としての諸物性のうち、耐摩耗性および marginal fracture toughness は臨床的にきわめて重要である。しかも、それらの評価法は臨床結果を反映し、予測できるものでなければならない。筆者らの考案したグラスビーズ摩耗試験が臨床の結果と比較的良好な一致性を示すことを確認したが、今回、本試験法を用いて、市販の 16 種類の臼歯用コンポジットレジンの耐摩耗性を評価した。

その結果、超微粒子フィラー配合型が、もっともすぐ

れた耐摩耗性を示し、次いでサブミクロンフィラー配合型が良好で、高密度充填型はおおむね摩耗が大きいことがわかった。このことから、超微粒子フィラーと粒径数 μm の fine fillers とが混合された高密度充填型でも含有しているフィラーのサイズが大きければ、摩耗が大きいことが示唆され、そのことは臨床症例の所見によっても確かめられた。今回、同時に行ったハブラシ摩耗試験の結果には、一定の整合性がなく、そのデータにはとくに意味を見出せなかった。

多孔性 Zr-Ti インプラントの空孔の形状と機械的性質

奥野 攻, 柴田直幸, 三浦維四

東京医科歯科大学医用器材研究所

多孔材の空孔には骨が成長侵入し、強固な結合が得られるが、このような多孔材の強度は一般に低いのが問題であった。そこでジルコニウムとチタンの球形粒子を良く混合し、焼結して得られる高強度の多孔材を開発した。粒径を変えて多孔性 60 wt%Zr-40 wt%Ti 合金を作製し、空孔の形状寸法、多孔率と機械的性質を調べ、歯科用インプラントとしての可能性を検討した。空孔径や多孔率から 200~250 μm の粒子の多孔体でも骨組織の成長が可能と考えられた。圧縮強さは曲げ強さの約 2 倍で、

小粒子径による多孔体の方が高い強さを示した。圧縮強さや曲げ強さは骨よりかなり高かった。弾性率も同様に小粒子による多孔体ほど高かった。弾性率は皮質骨と同じ範囲であり、骨と力学的にも適合性の良いことが分かった。圧縮疲労強度は 420~510 μm の粒径の多孔体で 60 MPa、250~300 μm の粒径の多孔体で 100 MPa で、臼歯用インプラントとして十分な疲労強さと考えられた。

多孔性 Zr-Ti インプラントへの骨の成長侵入と軟組織の反応

柴田直幸, 奥野 攻

東京医科歯科大学医用器材研究所

多孔性 Zr-Ti 合金がインプラント材として十分な機械的性質をもつことを先に報告した。ここでは 3 種の粒子径の多孔材 (250-300 μm , 350-420 μm , 500-590 μm) を家兎の大腿骨に埋入し骨の成長侵入について検討した。埋入後、2 週、4 週、8 週、12 週で屠殺し試料を含む大腿骨を摘出し押出し試験および組織観察を行った。

骨の成長侵入は 2 週から、4 週にかけてかなり上昇し、4 週以降緩やかな上昇がみられた。押出し強さも同様な傾向が見られた。粒子径の大きなもののほど押出し強さは高く、27 MPa ぐらいの高い値を示した (4 週以降)。Zr-Ti 多孔材と骨は大部分直接接しており生体親和性はきわめて良好であると思われた。