

Mechanical properties of flowable composites

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الخصائص الميكانيكية للكمبوزيت الإنسيابي (ملخص بحث) هدفت الدراسة لتقييم الخصائص الميكانيكية (مقاومة الانضغاط والالتواء وصلابة السطح) للعديد من أنواع الكمبوزيت الإنسيابي المتوفرة حالياً. وتم استخدام مادة (Z-100) كمجموعة إيجابية للمقارنة. تم تحضير خمس عينات من كل مادة تم تخزينها في ماء مقطر لمدة أربع وعشرين ساعة في درجة حرارة 37 درجة مئوية، وأحسري بعد ذلك اختبار مقاومة الانضغاط والالتواء باستخدام جهاز السنرون أما اختبار صلابة السطح فتم بواسطة جهاز فيكر. دلت نتائج التحليل الإحصائي على وجود اختلاف واضح بين المواد المختبرة ومساعدة للقراراة بالنسبة لاختبار مقاومة الانضغاط وصلابة السطح. لكن لم يلاحظ أي اختلاف فيما يتعلق بمقاومة الالتواء. يمكن الاستنتاج على أن الكمبوزيت الإنسيابي (بومافلو) هو الأفضل من حيث خصائص مقاومة الانضغاط وصلابة السطح. أما الخصائص الميكانيكية للكمبوزيت الإنسيابي فكانت أدنى من الكمبوزيت المحسن، ومنزل كد الدراسات السريرية للنتائج المخبرية.

The aim of this study was to evaluate the mechanical properties (compressive strength, flexural strength, and surface hardness) of five currently available flowable composites (Revolution, Aeliteflo, Composan LCM flow, Permaflo, and UltraSeal XT plus). Z-100 composite resin was used as a positive control. Five specimens of each material were prepared and stored in distilled water for 24 hours at 37°C. Compressive and flexural strength were tested on an Instron machine. A Vickers indenter (VH) was used to measure surface hardness. The statistical analysis (ANOVA and Tukey's Post hoc test) showed significant differences among the flowable composite materials and the positive control group for both compressive strength and surface hardness, but there was no significant difference noted regarding flexural strength for all tested materials. It was concluded that one of the five composites (Pemaflor) showed better results than the other tested flowable composite materials regarding compressive strength and surface hardness. Based upon the conditions of this study, the mechanical properties of flowable composites are inferior to the hybrid composite mechanical properties. Clinical studies are needed to confirm these *in vitro* results.

Introduction

Since the introduction of composite resins to dentistry in the 1960s, numerous refinements have been made to the traditional composites over the past decade.¹ The current term "flowable" was applied in 1996 to a reduced viscosity hybrid composite that could be delivered with disposable syringe tips.² These flowable composites were created by retaining the same small particle sizes of microfill, hybrid and micro hybrid universal composites and by reducing the filler content the viscosity of the mixture was reduced.^{1,3,4} Flowability is regarded as a desirable handling property since it allows the material to be injected through small gauge dispensers thus simplifying the placement procedure and amplifying the range of applications suggested by manufacturers of flowable composite.^{5,6} Since the trend toward conservative treatment allows new preparation and placement techniques to be developed for use in conjunction with restorative materials, this may be the greatest opportunity for the utilization of flowable composite in different clinical situations.^{2,3,6,7}

Little is known of the properties of flowable composites.¹ The purpose of this study was to evaluate the mechanical properties (compressive,

flexural strength, and surface hardness) of several flowable composites. One hybrid composite resin material was included as a positive control group for comparison.

Materials and Methods

Six restorative materials were tested in the study (Table 1). These materials included five flowable composites (Revolution, Aeliteflo, Composan LCM flow, Permaflo, and UltraSeal XT plus) and one hybrid composite resin Z-100 (as a positive control). A total of 30 specimens were prepared. Five specimens of each material were made for each test.

Compressive strength testing

The specimens were prepared utilizing cylindrical Teflon split molds, (8 mm diameter x 4 mm) lubricated with silicone.^{1,8} With the mold placed on a transparent matrix strip and a glass microscopic slide, the material was injected directly into the mold until it was intentionally overfilled. The material was covered with another matrix strip and a glass microscopic slide. Light pressure was applied to expel excess material from the mold. Each specimen was light-cured through the top and bottom glass slides for the duration

Received 3 Sept. 2000, Revised 18 Sept. and 11 October 2000
Accepted 22 October 2000
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Table 1. Materials tested.

Material	Manu- facturer	Filler Information	Lot Number	Shade
Revolution	Kerr U.S.A.	Type: Barium glass **Average: 1.0 *Weight %:55	8-1335	A2
Aeliteflo	Bisco U.S.A.	Type: Barium glass Average: 0.7 Weight %: 60	089287	A2
Composan LCM flow	Promedica Germany	Type: Silica, Barium Strontium, Borosi- licate Average: 0.7 Weight %: 64	99706	A2
Permaflo	Ultradent U.S.A.	Type: Zirconium Average: 1.0 Weight %: 68	3KWH	A2
Ultrasal	Ultradent U.S.A.	Type: Glass ionomer glasses Average: 1.0-1.5 Weight %: 60	3C89	A2
Z-100	3M U.S.A.	Type: Zirconia/ Silica Average: 0.6 Weight %: 85	7Kp	A2

Average: Average diameter of filler particles, in micrometer *
Weight %: Percentage of filler by weight

Table 2. Mean values for compressive strength, surface hardness and flexural strength of tested materials.

Tested Materials*	N	Mean Deviation	Std.		
Compressive strength (MPa)	Ultrasal XT plus	5	112.79	21.08	a*
	Composan LCM flow	5	126.59	26.18	ab
	Revolution	5	183.92	45.55	abc
	Aeliteflo	5	202.03	38.65	bc
	Permaflo	5	208.17	24.23	c
	Z-100	5	299.31	69.78	d
Flexural strength (MPa)	Revolution	5	0.37	0.08	a*
	Permaflo	5	0.43	0.06	a
	Aeliteflo	5	0.47	0.07	a
	Z-100	5	0.50	0.14	a
	Ultrasal XT plus	5	0.52	0.12	a
	Composan LCM flow	5	0.54	0.07	a
Vickers hardness (Kg/mm ²)	Aeliteflo	5	25.04	1.18	a*
	Revolution	5	29.98	3.36	ab
	Composan LCM flow	5	32.65	1.42	b
	Ultrasal XT plus	5	33.92	1.31	b
	Permaflo	5	40.50	3.50	c
	Z-100	5	114.04	3.87	d

* The materials are organized in an ascending order

* Identical superscript letters indicate mean values with no significant differences

recommended by the respective manufacturers. The set cylindrical specimen was separated from the mold. Flash was removed with a scalpel blade. The middle part of the specimen was light-cured again for the same duration. All specimens were stored in distilled water at 37°C for 24 hours. After drying the specimens, a Universal Testing Machine (Instron, Model 8500, Digital control) was used for testing. Each specimen was loaded between two steel platens with a crosshead speed of 0.5 mm/min.

Flexural strength testing

The specimens were prepared utilizing silicone lubricated Teflon mold (14 mm diameter x 2 mm). With the mold placed on a transparent matrix strip and a glass microscope slide, the material was injected directly into the mold until it was intentionally overfilled. The material was covered with another matrix strip and a glass microscope slide. Light pressure was applied to expel excess material from the mold. The material was light-cured in four quadrants. Each quadrant of the circular disc was cured for the duration recommended by the manufacturer, and from the two opposing surfaces to ensure complete polymerization of the material.

For the bi-axial flexure strength, the disc shaped specimen was placed in the Instron Universal testing machine and was supported on three ball bearings equally spaced around the periphery with the distance of approximately 10 mm between them. The load was applied to the center of the specimen with a steel piston of 1 mm diameter at a crosshead speed of 0.2 mm per minute. The relevant Instron software was used to calculate the bi-axial flexure strength applying the equations used by Wachtman et al.⁹

Surface hardness testing

The mold used for the specimens prepared for flexural strength testing was also used for this test. The top surfaces of the specimens were ground flat using 600-grit silicone carbide abrasive paper, till smooth surface was obtained. Then, it was polished with 0.05 micrometer polishing compound and polishing cloth. After storage in distilled water at 37°C for 24 hours, the Vickers microhardness of the specimens was measured utilizing Beuhler Micromet indenter according to the well established, standard procedure.

Five equally spaced indentations were made on

the disc surface for this purpose.

Mean values and standard deviations were computed for the data of the three tests. All data were analyzed statistically by utilizing one-way analysis of variance (ANOVA) and Tukey's Post hoc test to determine significant differences between the test materials.

Results

Compressive strength

Mean values are shown in Table 2 and Fig. 1 respectively. All flowable composites showed compressive strength values that were significantly lower than that for Z-100 (299.31 + 69.78 MPa), UltraSeal XT plus (112.80 + 21.08 MPa) was significantly different from other composites except Composan LCM flow (126.59 + 26.18 MPa) and Revolution (183.92 + 45.55 MPa). Composan LCM flow was insignificantly different from Revolution and Aeliteflo (202.03 + 38.55 MPa). Revolution, Aeliteflo, and Permaflo (208.17 + 24.23 MPa) were statistically similar among the flowable composites. A ranking of materials, according to decreasing compressive strength was as follows: Z-100>Permaflo, Aeliteflo>Revolution>Composan LCM flow > UltraSeal XT plus.

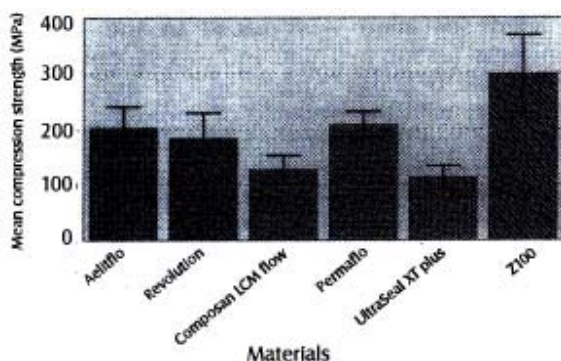


Fig. 1. Mean compressive strength of the tested materials (MPa).

Flexural strength

Mean flexural strength values presented in Table 2 and Fig. 2 showed no significant differences among all the tested composites.

Surface hardness

Mean values are shown in Table 2 and Fig. 3. The hardness value for Z-100 (114.04 + 3.99 MPa) was

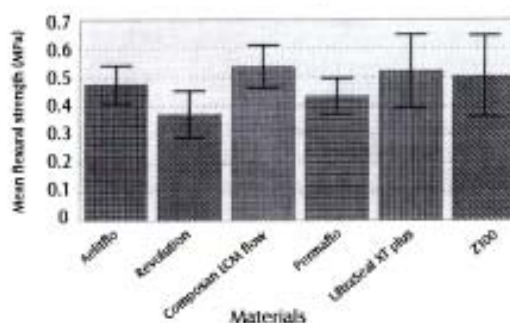


Fig. 2. Mean flexural strength of the tested materials (MPa).

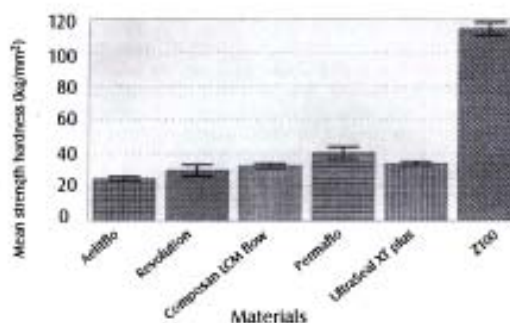


Fig. 3. Mean surface hardness of the tested materials (kg/mm²).

significantly greater than the values for any of the tested flowable composites. Aeliteflo (25.04 ± 1.18 MPa) was significantly different from the other tested materials except Revolution (29.96 ± 3.36 MPa). Revolution, Composan LCM flow (32.65 ± 1.42 MPa) and UltraSeal XT plus (33.92 ± 1.32 MPa) were statistically equivalent. Permaflo was significantly harder (40.50 ± 3.50 MPa) than any of the tested flowable composites. The materials were ranked in decreasing value as follows: Z-100 > Permaflo > UltraSeal XT plus > Composan LCM flow > Revolution > Aeliteflo.

Discussion

Z-100 was used as a positive control group in this study because it is popular and routinely used, its properties are fairly well known, and it represents a standard for hybrid composite resins.

The compressive strength value of Z-100 was higher than any of the flowable composites tested. The strength was close to other reported values tested in the same way.¹

Z-100 is a minifilled composite resin,¹¹ its inorganic filler is 85% by weight (Table 1). Generally, the high filler content and properly

spaced filler particles would improve the mechanical properties.¹⁻¹⁰ The compressive strength values of Permaflo and Aeliteflo were the highest among the flowable composites. The filler content of Permaflo and Aeliteflo are 68% and 60%, respectively (Table 1). Their high compressive strength values were consistent with the fact that higher filler level results in increased hardness, compressive strength, and other mechanical properties.^{1-10,12} The filler content may be considered a factor; however the filler type may have a stronger effect on the mechanical properties than the percentage of the filler because, Composan LCM flow which had a high filler content 64% (Table 1) was not as strong as Permaflo or Aeliteflo. The compressive strength values of Aeliteflo and Revolution were 216.72 MPa and 146.29 MPa in another study,¹¹ with which this study compared favorably (Table 2).

A Vickers hardness test was used to measure surface hardness. The relative importance of Vickers hardness lies in the fact that, in general, it predicts other mechanical properties of the materials investigated.¹⁰ A high Vickers hardness value combined with a relatively low surface roughness value would be an ideal characteristic of posterior composites.

Z-100 is among the composites which display adequate Vickers hardness (114.03 kg/mm²) in comparison to human dentin (60 kg/mm²).¹⁰ Accordingly, it has been classified as a composite that can support occlusal stresses for restoring posterior cavities.¹⁰ The surface hardness value of Z-100 obtained in this study was close to the value reported by others,¹⁰ because of similar testing methods.

Among the flowable composites, the surface hardness value of Permaflo was the highest. It was close to microfilled composite values when classified according to Willems et al.¹⁰ The hardness values for flowable composites were significantly lower than those for human enamel (408 kg/mm²) or dentin (60 kg/mm²) denoting that the materials were not appropriate for use in relatively high stress areas. This conclusion is in agreement with other reports.¹ Aeliteflo was surprising because its hardness value was low, although its compressive strength value was high. The explanation of this behavior needs further study.

It was reported that flowable composites have reasonably high flexural strengths.¹ Our results support this fact because no statistical differences were noted between the flowable composites and Z-100.

The mechanical properties of the tested flowable composites demonstrated acceptable results for some materials. For example, Permaflo showed relatively high compressive strength and adequate surface hardness. However, they may not be an adequate substitute for more highly filled composites that are recommended for use in high-stress areas. Therefore, it is suggested that all the flowable composites would be acceptable as filling materials in low-stress applications.^{1,13} It is believed that the flowable composites can be used in conjunction with packable and hybrid composite resins to achieve significant adaptability and reduced microleakage.¹⁴

Studying the mechanical properties of a composite can help in determining whether the properties of the newer materials are equal to or perhaps superior to traditional materials before costly clinical trials are undertaken.¹ The future success of flowable composites would depend on the long-term clinical assessment to confirm their in vitro performance.¹

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Acknowledgment

Special thanks to Dr. Abed S. Al Jabab for his cooperation, support and advise. Moreover, the author wishes to express her sincere appreciation to Dr. Abdullah R. Al Shammery and Dr. Nazeer Khan for their advise and assistance with the manuscript.