Technical note

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Flexural Properties and Swelling after Storage in Water of Polyacid-modified Composite Resin (Compomer)

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The flexural properties, flexural strength, flexural modulus and modulus of resilience, of four commercially available compomers, and one resin-modified glass ionomer cement and one microfilled resin comosite (as controls) immediately after light-activation and after 1 week of water storage were tested to assess the mechanical properties. The water swelling after storage in water was also tested to assess the characteristics in water of compomers. The flexural test showed compomers to be statistically stronger and more resilient than the resin-modified glass ionomer cement or the microfilled composite, when tested immediately after light-activation and after 1 week of water storage. Water swelling of compomers was statistically less than the resin-modified glass ionomer cement after 1 week of water storage.

Key words : Polyacid-modified composite resin, Flexural property, Water swelling

INTRODUCTION

Resin-modified glass ionomer cements are marketed in powder-liquid form. To avoid the technique-sensitive mixing and handling properties, one manufacturer introduced a new one-paste restorative material as a compomer in the early 1990s. It contained a radiopaque fluoride-silicate glass in a matrix of acidic polymerizable monomers but in insufficuent amounts to promote an acid-base reaction[1]. Subsequently, McLean *et al.*[2] proposed that it be classified as a polyacid-modified composite resin. The material has good handling characteristics and color matching in clinical evaluation[3−5]. In vitro evaluations have shown high enamel and dentin bond strengths[6−8]. We also think that the physical properties of the first commercially available compomer are similar to those of resin composites because of the components, as described previously[9]. Now there are many commercially available compomers in the market. However, no published data are available on the effectiveness of the mechanical properties after storage in water of updated commercial compomers. A flexural test was used to assess the mechanical properties of compomers, because such testing has previously been carried out to evaluate the mechanical strength of brittle restorative materials[10−12].

The aim of this study was to evaluate the flexural properties and the water swelling after storage in water of updated commercially available compomers, compared with a resin-modified glass-ionomer cement and a microfilled composite.

MATERIALS AND METHODS

Four compomers, one resin-modified glass ionomer cement and one microfilled resin composite as controls were used in this study (Table 1).

The materials were tested for (1) flexural strength, (2) flexural modulus, (3) modulus of resilience, and (4) the change in weight and dimension. A resin-modified glass ionomer cement was mixed according to the manufacturer's instructions. The paste or mixed cement was then filled in a rectangular Teflon mold (25 × 2 × 2 mm), and the surface of material was covered with a clear matrix strip. The specimen was cured in three overlapping sections, each for 30 seconds. The material was exposed to a visible light source (New Light VL-Ⅱ, GC, Tokyo, Japan; irradiated diameter: 13 mm). This hardened specimen was used for the flexural test. The changes in dimension and weight were tested using the same specimens employed in the flexural test. Ten specimens were made from each material. The measurements were performed immediately after light-activation and also after storage in distilled water at 37℃ for 1 week. The flexural strength was measured using the 3-point bending method with a 20 mm-span and loading speed of 0.5 mm/min (Model 5565, Instron, Canton, USA) outlined in ISO 9917-2 (1996). The flexural strength, in MPa, and the flexural modulus E, in GPa, were calculated with a software program (Series Ⅸ, Instron, Canton, USA). The modulus of resilience R, in MJ/m^3, was then calculated using the equation $R=P^2/2E$, where P is the proportional limit. The dimension of a fixed point on each specimen was measured with an electric micrometer (Digimicro MU-1001B, Nikon, Tokyo, Japan) and the change in the specimen's dimensions during storage in water was observed[11]. Water sorption was examined by a balance (AJ100, Mettler, Greifensee, Switzerland) and the change in the specimen's weight during storage was observed[11].

Table 1 Materials used

Code	Material	Category	Batch No.	Powder/Liquid or type (Fluorosilisate glass content[7])
FL	Fuji Ⅱ LC Improved[1]	Resin-modified glass ionomer cement	P: 051261 L: 050861	3.2g/1.0g
DY	Dyract[2]	Compomer	9604204	Paste type (−− , 72wt%)
IF	Ionosit Fil[3]	Compomer	96220115	Paste type (69vol%, 82wt%)
CG	Compoglass[4]	Compomer	725004	Paste type (56vol%, 79wt%)
HA	Hytac Aplitip[5]	Compomer	003	Paste type (−− , 66wt%)
SP	Silux Plus[6]	Resin composite	6DG	Paste type (38vol%, 52wt%)[8]

[1] GC, Tokyo, Japan
[2] DeTrey/Dentsply, Konstanz, Germany
[3] DMG, Hamburg, Germany
[4] Vivadent, Schaan, Liechtenstein
[5] Espe, Seefeld, Germany
[6] 3M, St. Paul, USA
[7] Manufacturer's information
[8] Filler content

Except for the flexural test measurement, all of the procedures were conducted in an air-conditioned room, 22±0.5℃ and 50± 2 % R.H. The results were analyzed statistically by ANOVA and Duncan's Multiple-Range Test ($p<0.05$).

RESULTS

Table 2 shows the flexural strength values immediately after light-activation and after 1 week of water storage. All compomers were significantly stronger than FL and SP immediately after light-activation. All compomers except CG were significantly stronger than FL and SP after 1 week of water storage. All compomers except CG showed a significant increase in flexural strength after 1 week of water storage compared with immediately after light-activation.

Table 3 shows the flexural modulus values. IF and HA had significantly greater values than the other products immediately after light-activation. All compomers ex-

Table 2 Flexural strength

Code	Mean±S.D. (MPa)		Statistical difference between two results
	Immediately after light-activation	Storage in water for 1 week	
FL	32.9± 2.3 A	63.9±11.8 E	S
DY	74.3± 8.1 B	108.5±17.9 F	S
IF	76.1± 6.4 B C	127.9±13.9 G	S
CG	63.2±11.9 D	59.1± 8.4 E	NS
HA	71.7±10.3 B	126.9±17.5 G	S
SP	59.3± 4.1 D	56.8± 7.4 E	NS

Number of specimens: 10
Means connected with the same letters are not significantly different by Duncan's multiple-range test ($p>0.05$).
S: Significantly different by t-Test ($p<0.05$)
NS: Not significantly different by t-Test ($p>0.05$)

Table 3 Flexural modulus

Code	Mean±S.D. (GPa)		Statistical difference between two results
	Immediately after light-activation	Storage in water for 1 week	
FL	3.6±0.3 A B	8.8±1.3 E	S
DY	3.4±0.2 A	11.5±0.7 F	S
IF	6.3±0.5 C	12.3±0.7 F	S
CG	3.4±0.4 A	8.5±0.7 E	S
HA	5.8±0.4 D	13.6±0.9 G	S
SP	3.8±0.1 B	5.3±0.5 H	S

Number of specimens: 10
Means connected with the same letters are not significantly different by Duncan's multiple-range test ($p>0.05$).
S: Significantly different by t-Test ($p<0.05$)

Table 4 Modulus of resilience

Code	Mean±S.D. (MJ/m^3)		Statistical difference between two results
	Immediately after light-activation	Storage in water for 1 week	
FL	0.15±0.02 A	0.24±0.07 E F	S
DY	0.31±0.12 B	0.53±0.18 G	S
IF	0.47±0.08 C	0.67±0.15 H	S
CG	0.62±0.26 D	0.21±0.06 E F	S
HA	0.45±0.13 C	0.60±0.16 G H	S
SP	0.47±0.06 C	0.31±0.07 E	NS

Number of specimens: 10
Means connected with the same letters are not significantly different by Duncan's multiple-range test ($p>0.05$).
S: Significantly different by t-Test ($p<0.05$)
NS: Not significantly different by t-Test ($p>0.05$)

Table 5 Change after storage in water for 1 week

Code	Mean±S.D.(%)[1]	
	Weight	Dimension
FL	7.86±1.04 A	2.14±0.43 D
DY	0.91±0.07 B	0.32±0.23 E F
IF	0.69±0.10 B	0.27±0.09 F
CG	0.90±0.08 B	0.42±0.16 E F
HA	0.62±0.11 B	0.53±0.20 E
SP	1.74±0.11 C	0.44±0.16 E F

Number of specimens: 10
[1] The value immediately after light-activation is zero (baseline).
Means connected with the same letters are not significantly different by Duncan's multiple-range test ($p>0.05$).

cept CG had significantly greater values than FL and SP after 1 week of water storage. All materials showed a significant increase value in flexural modulus after 1 week of water storage compared with that immediately after light-activation.

The result of the modulus of resilience measurements is shown in Table 4. All compomer values were significantly greater compared with that of FL immediately after light-activation. All compomers except CG had significantly greater values than FL and SP after 1 week of water storage. All materials except HA showed a significant increase in value after 1 week of water storage compared with immediately after light-activation.

Table 5 shows the change of percentage weight and dimension after 1 week of water storage, the value immediately after light-activation representing zero or the baseline. All compomers were significantly less changed than FL and SP. There were no significant differences among the compomers. The results of dimension measurement after 1 week of water storage were similar to those in weight.

DISCUSSION

Statistical analysis revealed significantly higher flexural strengths, greater flexural moduli, and greater moduli of resilience for compomers compared with those of a resin-modified glass ionomer cement and a microfilled composite when tested immediately after light-activation and after 1 week of water storage. This may be attributed to differences in composition, especially inorganic filler contents, and in the polymerization system of the matrix structure. The novel acid monomer of the compomer contains two acidic carboxylate groups and two polymerizable methacrylate groups enabling free radical polymerization by light curing and acid-base reaction if water is present[1]. Compomers' hardened structures contained more inorganic filler compared with SP (see Table 1, SP is a microfilled type). Attin *et al.*[9] reported physical properties for the compomer to be similar to those of resin composites. The result may be an enhancement of the binding energy of the matrix structure, and adhesion between the matrix polymer and the inorganic fillers compared with resin-modified glass ionomer cement[11,13]. This would improve the setting process, as it continues to advance during storage in water. The acid-base reaction also improves during storage in water[1].

The values for flexural strength and modulus of resilience of CG and SP were not significantly different before and after storage. This is probably due to the lower durability in water. Statistical analysis revealed significantly lower water swelling in compomers compared with the resin-modified glass ionomer cement when tested after 1 week of water storage. This may be attributed to differences in matrix structure or composition. The matrix of a resin modified-glass ionomer cement is complex because it contains Poly-HEMA, chemically linked to the polyacrylate matrix[14].

The improvement in flexural properties, especially the greater modulus of resilience, may not only be significant for fracture energy (because compomers are brittle materials) but also clinically significant for wear resistance[10]. However, the flexural properties were only evaluated after 1 week of aging. The stability of the increases in flexural properties must be evaluated over a longer time period to determine if compomers have significant long-term benefits. Further work is in progress to characterize these properties.

CONCLUSION

Flexural testing of compomers showed them to be statistically stronger and more resilient compared with a resin-modified glass ionomer cement and a microfilled composite, when tested immediately after light-activation and after 1 week of water storage. Water swelling of compomers was statistically less compared with that of a resin-modified glass ionomer cement after 1 week of water storage.

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