Effect on bonding of curing through dentin

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The aim of this study was to investigate the effect of the thickness of dentin (1, 2, or 3 mm) placed between the light guide and the composite resin on the shear bond strength to dentin treated with a simplified Gluma system. The effects of the thickness of composite resin (2 or 3 mm), irradiation time (20, 40, or 60 sec), and shade (universal or brown) were also examined. The results showed that the thickness of dentin influenced bonding and interacted with the other three variables. It is suggested that dentin located between the light guide and composite resin may attenuate the light aimed at the bonding interface in the same manner as a layer of composite resin. □ *Composite resin; curing depth; dentin adhesive; operative dentistry; shear bond*

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Limited curing depth is one of the problems associated with light-cured restorations of composite resin. Several variables, including irradiation conditions and shade of composite resin, have been reported to affect curing depth (1–5). In our previous study on variables in bonding to dentin (6), it was argued that the thickness of the composite resin and the distance to the light guide have a greater influence on bonding than irradiation time and that bond strength may depend on the amount of light transmitted through the composite resin.

In some clinical situations the tooth structure prevents a direct access of light to the restoration. Swartz et al. (1) have demonstrated that enamel has high translucency and that the curing depth is not affected when the thickness of the enamel is 0.5 to 1.0 mm. Chan & Boyer (7) have shown that the attenuation of light by dentin has the same effect on the curing depth as layers of composite resin of similar opacity. This interfering effect of dentin is dependent on its thickness.

The purpose of this study was to investigate the effect of the thickness of dentin discs placed between the light guide and composite resin on the shear bond of dentin. The effects of the thickness of composite resin, irradiation time, and shade were also examined. In addition, the curing depth of two shades of the composite resin was measured.

Materials and methods

A simplified Gluma system (8), described in Table 1, and Pekafil (Bayer, Germany; universal, batch no. 7543T, or brown, batch no. 7544T) were used in the study.

Shear bond strength

Dentin discs (approximately 1, 2, or 3 mm thick) were made from the coronal dentin of noncarious extracted molars. The surface of each disc was flattened by wet-grinding with no. 1000 carborundum paper at the final stage; the discs were stored in distilled water when not in use. The final thickness of the dentin discs was 0.88, 2.00, or 2.95 mm, respectively. A specimen for measuring the shear bond to dentin was prepared as previously described (9). A flat surface of dentin was produced by wet-grinding with no. 1000 carborundum paper at the final stage. After the dentin surface had been primed with the Al_2Ox_3/Gly solution (Table 1) and treated

Table 1. The composition of a simplified Gluma system

Al_2Ox_3/Gly solution	
Aluminum nitrate	4.96 g
Oxalic acid	2.50 g
In 100 g H_2O	
pH adjusted to 1.25 with glycine	
Gluma resin	
Glutaraldehyde (25%)	10 g
HEMA	17 g
BISGMA	5 g
H_2O	17 g
Tetrahydrofuran	48 g
Acetic acid	3 g
Camphorquinone	0.1 g

with the Gluma resin (Table 1) as described in a previous paper (6), a split Teflon mold with a cylindrical hole (diameter, 3.5 mm; height, 2 or 3 mm) was clamped on the treated surface (9). One of the shades of Pekafil was filled into the hole with a syringe and its free surface covered with a transparent matrix (3M, USA). Thereafter, one of the dentin discs was placed in contact with the matrix. Irradiation for 20, 40, or 60 sec was carried out through the dentin disc by use of a light source (Luxor; ICI, U.K.) with close contact between light guide and dentin disc. After 24 h of storage in water at 37°C, the specimen was mounted in a testing machine (Instron; High Wycombe, U.K.), and the shear bond strength was measured at a cross-head speed of 1 mm/min as previously described (9). Six specimens were prepared for each set of conditions given in Tables 2 and 3.

Curing depth

A split Teflon mold with a cylindrical hole (diameter, 3.5 mm; height, 8 mm) was placed on a glass plate. Universal or brown paste was filled into the hole by use of a syringe, covered with a matrix band, and irradiated for 60 sec with close contact between the light guide and matrix. Immediately after curing, the specimen was immersed in 99.9% ethanol for 2 min. The softened part of resin was gently removed with a plastic spatula. The length of the cured, residual part was measured with a micrometer. Five specimens were prepared for each shade.

Statistical analyses

The shear bond strengths were subjected to Kruskal–Wallis one-way analysis of variance by ranks or Student's *t* test to estimate the effect of the variables. Curing depths of the two shades were analyzed with Student's *t* test.

Results

Shear bond strength

The results of the measurements are shown in Table 2 for the universal and Table

Table 2. Shear bond strength to dentin (MPa; mean ± SD) of the universal shade

Dentin disc (mm)	Irradiation time (sec)	Composite resin	
		Thickness, 2 mm	Thickness, 3 mm
1	20	16.7 ± 5.1	12.1 ± 2.2
	40	–	16.5 ± 1.5
	60	–	17.4 ± 4.4
2	20	16.5 ± 1.5	11.3 ± 5.1
	40	–	17.3 ± 3.3
	60	–	17.2 ± 4.4
3	20	16.0 ± 4.7	–
	40	19.0 ± 2.7	3.9 ± 3.5
	60	21.4 ± 3.6	11.8 ± 2.8

Table 3. Shear bond strength to dentin (MPa, mean ± SD) of the brown shade

Dentin disc (mm)	Irradiation time (sec)	Composite resin	
		Thickness, 2 mm	Thickness, 3 mm
1	20	8.0 ± 0.9	0.5 ± 0.2
	40	12.2 ± 1.5	11.3 ± 1.3
	60	16.0 ± 4.4	13.8 ± 2.4
2	20	3.5 ± 1.8	–
	40	16.8 ± 3.8	1.6 ± 0.5
	60	19.0 ± 3.5	8.7 ± 2.5
3	20	–	–
	40	1.9 ± 0.4	–
	60	11.2 ± 5.2	–

3 for the brown shade. For several conditions, indicated with a dash in the tables, no measurement was carried out by reason of predictable results.

Universal shade (Table 2). There was no difference between shear bond strengths obtained by various thicknesses of composite or irradiation time when the dentin disc was 1 or 2 mm thick ($p > 0.05$). Even when the disc was 3 mm thick, irradiation time had no influence on bond strength with 2 mm thickness of the composite resin ($p > 0.2$). However, 3 mm thickness of composite cured through 3-mm-thick dentin gave a significantly lower bond strength even after being irradiated for 60 sec, compared with 2 mm thickness of composite ($p < 0.001$) or 3 mm thickness of composite cured through 2-mm-thick dentin disc ($p < 0.05$).

Brown shade (Table 3). Irradiation for 20 sec produced low strength under any conditions, compared with longer irradiation times ($p < 0.001$). When the dentin disc was 1 mm thick, irradiation for 40 or 60 sec conveyed the same strength at both 2 and 3 mm thickness of composite ($p > 0.1$). When the dentin disc was 2 mm thick, there was also no difference between the bond strengths of 2-mm-thick composite resin irradiated for 40 or 60 sec ($p > 0.5$). A composite resin of 3 mm thickness, however, gave lower strength even after being irradiated for 60 sec than 2 mm thickness of composite ($p < 0.001$) or 3 mm thickness of composite cured through 1-mm-thick dentin disc ($p < 0.01$). A dentin disc with 3 mm thickness produced a lower strength of 2-mm-thick composite resin irradiated for 60 sec than did a 2-mm-thick dentin disc ($p < 0.02$).

Table 4. Curing depth of the universal and the brown shade (mm; mean ± SD)

Universal	6.06 ± 0.10
Brown	4.92 ± 0.09

Universal versus brown shade. Strengths of universal and brown shade irradiated for 60 sec were compared at two irradiation conditions in which the thickness of composite resin and dentin disc was 2 and 3 mm or 3 and 2 mm, respectively. Under both conditions the universal shade showed higher values than the brown ($p < 0.01$).

Curing depth

The curing depths obtained in the study were 6.06 ± 0.10 mm for the universal and 4.92 ± 0.09 mm for the brown shade (Table 4). Student's *t* test showed a difference at the 0.1% level of significance between two values.

Discussion

In this study the effect of the thickness of dentin discs placed between the light guide and composite resin on the shear bond to dentin was investigated. In addition, the thickness of composite resin, irradiation

time, and shade were selected as variables in bonding to dentin.

The results showed that the effect of the thickness of the dentin disc interacted with the thickness and shade of composite resin. With the universal shade the thickness of the dentin disc had no influence on the shear bond when the composite resin was 2 mm thick. However, a thicker dentin disc reduced the bond strength in case of 3 mm thickness of composite resin. It has been stated that the shear bond strength to dentin depends on the light intensity transmitted through the composite resin (6). In their study on the transmission coefficient of light, Chan & Boyer (10) indicated that the light intensity transmitted through a layer of porcelain placed between the light guide and composite resin decreases exponentially with the increase in thickness of the porcelain. Therefore, not only the composite resin but also the dentin disc will attenuate the light reaching the bonding interface, thus reducing the shear bond strength in the study. Comparing two bond strengths obtained under conditions in which the thickness of the dentin disc and composite resin were 3 and 2 or 2 and 3 mm, respectively, the attenuation of light by dentin has almost the same effect on shear bond to dentin as a layer of universal paste. This is concordant with the result of Chan & Boyer (7). With the brown shade, the effect of the dentin disc was more severe than with the universal. Even a long irradiation time through 3-mm-thick dentin did not give acceptable strength. It has been reported that the curing depth of composite resins depends on their translucency (5). In the present study the curing depth of the brown shade was approximately 81% of that of the universal shade. This shows that the brown shade is inferior to universal in translucency. The light intensity was reduced during transmission through dentin and then much weakened by the light absorption of the brown shade. As a result of this process, a greater effect of the thickness of the dentin disc was found with the brown shade than with the universal shade.

The effect of irradiation time in the study was relatively small compared with the other factors. This is in accordance with the result of our previous study (6). The surface hardness of a composite resin under a layer of porcelain has been reported to be predicted from the product of the exposure time and the square root of the light intensity when the composite is irradiated through the porcelain (10). With regard to bonding to dentin, the light intensity may be a greater factor than the irradiation time.

To conclude, dentin located between the light guide and composite resin has an interfering effect on light not less than that of a corresponding layer of composite resin and thus lowers the bond strength to dentin. In clinical situations in which irradiation is to be done through dentin, composite resins should be applied by an incremental technique even in shallow cavities.

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