Marginal leakage in occlusally loaded, etched, class-II composite resin restorations

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Lundin S-Å, Norén JG. Marginal leakage in occlusally loaded, etched, class-II composite resin restorations. Acta Odontol Scand 1991;49:247–254. Oslo. 0001-6357.

Microleakage was studied in class-II cavities restored with a calcium hydroxide liner and an adhesive system combined with two different posterior composite resins. The restorations were exposed to repeated loading when immersed in dye solution. The teeth were cut, and microleakage along the cavity walls and into dentin was evaluated by light microscopy. Dye penetration at the interface between the cavity and the restoration was recorded in 61% of the loaded and in 30% of the unloaded teeth. The difference between loaded and unloaded was greater for the teeth lined with Life® than with Gluma® dentin bonding. □ *Adhesive system; calcium hydroxide liner; dye penetration; in vitro study; operative dentistry*

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As has been pointed out by several authors, marginal leakage is one of the major drawbacks of composite restorations (1–6). Therefore, efforts have been made to investigate methods of minimizing the leakage. One way is to produce good adaptation and adhesion between the restoration material and the cavity by using bonding material (7, 8). The Gluma® system has been shown in several studies to have good properties in this respect (9–11). Another factor involves the shrinking properties of composites. Composites that are highly loaded with filler particles have less polymerization shrinkage than microfilled composites (12). However, the microfilled composites have better properties with regard to compensations for polymerization shrinkage from the 'free' surface of the restoration (6, 13). Furthermore, loading can be expected to cause bending of the restoration, thus stressing the adhesion at the cervical margin, which can result in increased leakage (14). Therefore the combination of adhesion, minimal shrinkage, and resistance against loading are important properties of resin-based restorative material.

The purpose of this paper was to study the microleakage, in an in vitro test, after repeated loading of class-II restorations, with one liner and one adhesive system in combination with two different class-II composite resin types.

Materials and methods

Restorative process

Forty-eight premolars, extracted for orthodontic reasons, were used in this study. After extraction the teeth were stored in 0.1% isotonic chlorhexidine solution for 1–2 months before restorative treatment. On each tooth a modified MO or DO preparation was prepared (Fig. 1), using a diamond bur in a high-speed handpiece with air–water spray. The depth, height, and width were all approximately 2 mm. All the cavity margins were in enamel and were not beveled. After cavity preparation the teeth were randomly divided into two groups. A base lining and a dentin bonding agent were applied in each group of cavities. Half of the cavities in each group were then restored with one of two composite resins, Occlusin® (ICI, Macclesfield, Cheshire, U.K.) and Heliomolar® (Vivadent Dental GmbH, Ellwangen, Germany). The composition and

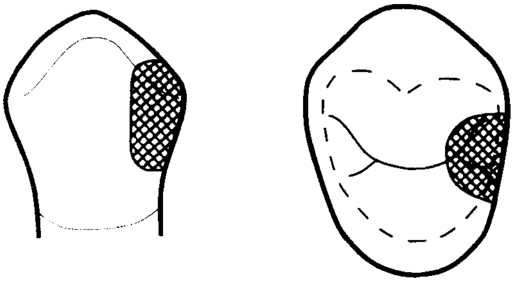

Fig. 1. Premolar with a modified proximal class-II preparation.

flexural and compressive strengths of these materials are outlined in Table 1.

In the first group the cavity walls were actively cleaned with a cotton pellet soaked in Tubulicid® (Dental Therapeutics AB, Apoteksbolaget, Sweden) for 30 sec, rinsed with water for 10–30 sec, and dried with air. A steel matrix band was adapted to the tooth. A thin layer of calcium hydroxide base, Life® (Kerr Europe, Basel, Switzerland), was placed on all dentin surfaces and was left to harden for 3 min. The enamel margins were etched for 30 sec with 37% orthophosphoric acid solution, rinsed with water for 10–20 sec, and dried with air. The intermediate resin for the composite system was applied to the cavity walls with a small burnisher, spread with a gentle air stream, and polymerized with light for 20 sec, using a high-intensity fiberoptic light (Luxor, ICI, Macclesfield, Cheshire, U.K.). The cavity was then filled with a posterior composite material, Occlusin or Heliomolar, in two layers. The first layer was adapted to the cervical, buccal, and lingual cavity walls and polymerized with light for 40 sec. Then the rest of the cavity was filled with a second layer and polymerized for 40 sec. Thereafter, finishing was performed with Soflex® discs (Dental Products 3M, St. Paul, Minn., USA). During the entire restoration process the teeth were kept humid and were then stored in 0.1% chlorhexidine solution for 4–6 weeks until the loading tests were carried out.

In the second group the cavities were cleaned, rinsed, and dried, and a matrix band applied as with the first group. The enamel margins were etched for 30 sec with 37% orthophosphoric acid solution, rinsed with water for 30 sec, and dried with air. Thereafter the dentin walls were additionally cleaned with a cleanser, Gluma® (Bayer Dental, Leverkusen, Germany) system, for 30 sec, rinsed with water for 10–20 sec, and dried. A dentin-bonding agent, Gluma Primer, was applied and allowed to dry for 30 sec. The intermediate resin for the composite system was applied to the cavity with a small burnisher, gently spread with air, and polymerized with light for 20 sec. The cavities were restored, polymerized, and finished using Occlusin or Heliomolar (Table 1), as in the first group, and then stored in 0.1% chlorhexidine solution for 4–6 weeks.

The restored teeth within each group were randomly divided into test and control restorations.

Table 1. Composition and strength properties* of the resin-based composite materials used

Material	Resin system	Filler	Percentage filler volume	Flexural strength, MPa	Compressive strength, MPa
Occlusin® Batch no., lot no. 71B; color, Universal	Urethane-dimeth-acrylate TEGDMA	Barium-aluminum silicate	71	113	270
Heliomolar® Batch no., 435102; color, DY	UEDMA BIS-GMA	Amorphous silica	45	67	267

* Data from Öysaed & Ruyter (15) and Ruyter & Öysaed (16).

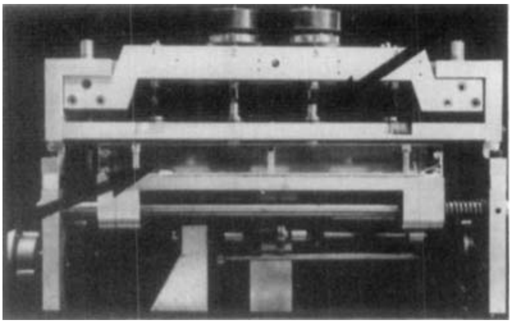

Fig. 2. Loading machine with pistons (arrow) and Plexiglas tub (arrow) for the dye solution.

Loading experiments

To simulate a clinical occlusal loading of posterior restorations during chewing, a special loading machine was used (Fig. 2). All teeth were cut approximately 2 mm apically to the cervix and placed in holders for the loading machine. The apical end of the tooth was fastened to the holder with a composite resin polymerized with light, thus also sealing the root canal. The control teeth were sealed at the cut apex in the same manner but were not mounted in holders.

Each restoration was loaded with a piston with a steel ball, 1.5 mm diameter, at the end. The piston was loaded with a weight of 350 g. The loading was carried out over 100 min with 82 loadings per minute. For each load the steel ball was initially balanced on the approximal ridge of each test restoration. By a controlled movement of the tub with the fastened test teeth, the steel ball moved 1.5 mm along the occlusal surface of the restoration (Fig. 3). During the experiment the tub was filled with dye solution (Nigrosin Fluka 0.5% + sodium dodecyl sulfate 1% + water at room temperature) (4). The controls were placed in the solution in the tub during the loading experiments. Thereby both the test and control test were immersed in dye solution for the same 100 min.

After the loading, the teeth were examined under an Olympus (Olympus, Japan) stereomicroscope. Fractures of the restoration, presence of unpolymerized resin, overfills, air voids, pooled resin, and gap formations were recorded for each tooth (Fig. 4). After 1 h all teeth were cut in the mesial–distal direction with a Leitz (Wetzlar, Germany) low-speed saw microtome (17). Both halves were examined under the microscope, and dye penetration, air voids in the material, air voids or gaps at the material/cavity interface, and cracks in the base material were registered (Fig. 5). All examinations of the proximal surface and the mesial/distal cut surfaces were photographically documented under the microscope.

The dye penetration depths were registered in four grades (Fig. 6): 0 = no penetration; 1 = penetration into the enamel/composite interface, without reaching the

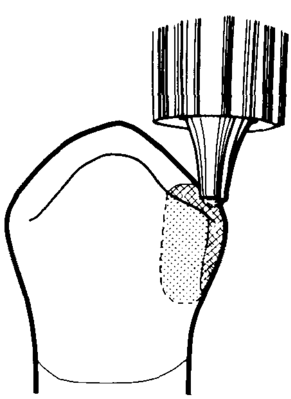

Fig. 3. Restored premolar with piston balanced on the approximal ridge.

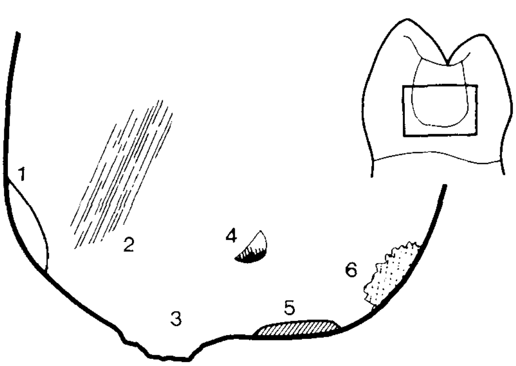

Fig. 4. Overview of the approximal restored cavity surface. Examination under a stereomicroscope shows 1 = fracture, 2 = unpolymerized resin, 3 = overfill, 4 = air void, 5 = pooled resin, and 6 = gap formation.

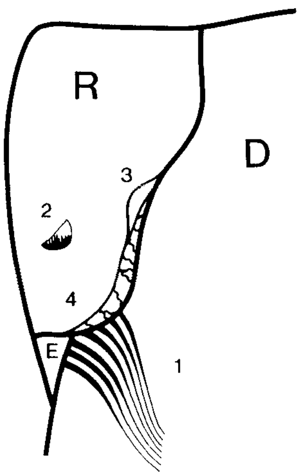

Fig. 5. Mesiodistal cut surface of a tooth with a composite restoration. D = dentin, E = enamel, R = restoration, 1 = dye penetration, 2 = air void, 3 = gap formation, and 4 = cracked base material.

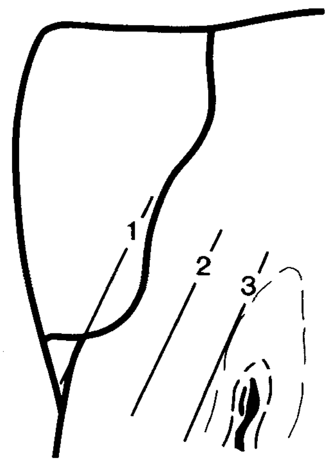

Fig. 6. Dye penetration depths: 1 = penetration into the enamel, without reaching the dentin; 2 = penetration into the dentin, without reaching the pulp; and 3 = penetration to the pulp.

dentin/composite interface; 2 = penetration through the enamel/composite interface into the dentin/composite interface or into the dentin, without reaching the pulp; and 3 = penetration as in point 2, through the dentin to the pulp.

Multiple linear analysis and the Mantel–Haenszel chi-square test were used for the statistical analysis.

Results

Results were obtained for 46 of the original 48 teeth. Two teeth, both restored with Occlusin, were lost owing to failure of pulp sealing, thus enabling the dye to penetrate into the pulp and the dentin.

The results are summarized in Tables 2 and 3. Many of the restorations had a slight

Table 2. Faults of class-II restorations

	Occlusin®, n = 22				Heliomolar®, n = 24			
	Life®, n = 11		Gluma®, n = 11		Life®, n = 12		Gluma®, n = 12	
Material	Load, n = 6	Control, n = 5	Load, n = 5	Control, n = 6	Load, n = 6	Control, n = 6	Load, n = 6	Control, n = 6
Overfill	5	3	4	4	5	4	5	6
Air void	0	2	1	3	4	4	0	4
Gap formation	2	1	2	2	5	4	3	6
Fracture	1	0	0	0	1	2	0	0
Unpolymerized resin	0	3	0	1	0	0	0	0
Pooled resin	1	1	0	0	3	1	3	3
Air void*	4	1	3	3	5	3	4	3
Gap formation*	0	1	0	0	0	2	1	0
Crack of base*	4	0			0	0		

* Examination of cut tooth.

Table 3. Leakage of class-II restorations

Material	Occlusin®, $n = 22$				Heliomolar®, $n = 24$			
	Life®, $n = 11$		Gluma®, $n = 11$		Life®, $n = 12$		Gluma®, $n = 12$	
	Load, $n = 6$	Control, $n = 5$	Load, $n = 5$	Control, $n = 6$	Load, $n = 6$	Control, $n = 6$	Load, $n = 6$	Control, $n = 6$
Dye penetration, grade 1	0	0	0	0	0	1	0	0
Dye penetration, grade 2	2	2	3	2	2	0	2	1
Dye penetration, grade 3	3	0	0	0	1	0	1	1

overfill. Air void and gap formation (Fig. 7) at the proximal surface were more frequent for Heliomolar than for Occlusin. Pooled resin (Fig. 7) along the cervical cavosurface margin was noted more often with Heliomolar than with Occlusin.

No differences were found between the tested restoratives or dentin-covering materials with regard to air void formation at the mesially–distally cut surfaces in the material or at the material–cavity interface. Cracks in the base lining were found in connection with Occlusin only when the restorations were loaded.

Dye penetration could be detected in almost half of the teeth (Fig. 8). A greater tendency for leakage was found with Occlusin than with Heliomolar. A significant difference in penetration of dye was found when the loaded restorations were compared with the unloaded, 61% and 30%, respectively ($p < 0.05$). Further, a significantly higher frequency of dye penetration was found for loaded than for unloaded restorations lined with Life ($p < 0.05$). The corresponding difference in dye penetration after using the Gluma bonding system was less and not statistically significant. Among the variables evaluated—penetration of dye, loading, restorative material, and liner—only loading and penetration of dye showed a significant correlation ($p < 0.05$).

Discussion

The technical performance of composite resin restoration has been the subject of several investigations. The clinical recommendations on how to prepare the restorations are, however, highly diverse (11, 18–24). The restorations in this in vitro study followed normal clinical procedures as closely as possible; that is, the cavity outline was

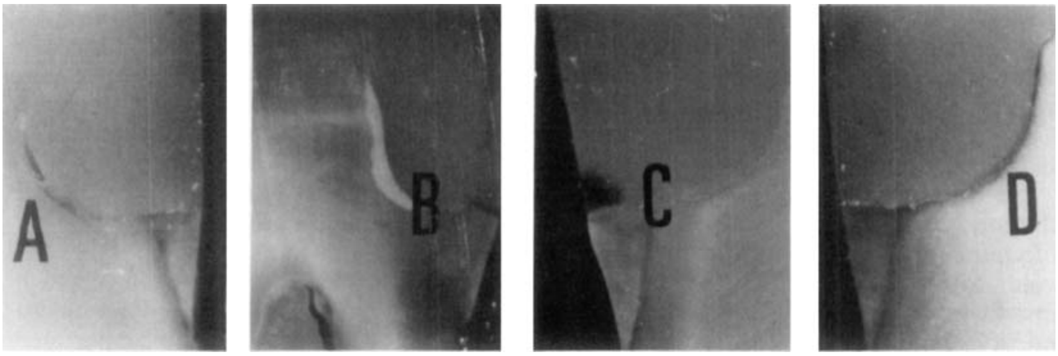

Fig. 7. Macrophotographs of a surface cut in a mesial–distal direction of a restored premolar. A = air void between restoration and cavity surface, B = gap formation in the marginal area, C = pooled resin in the cervical area of the restoration, and D = dye penetration.

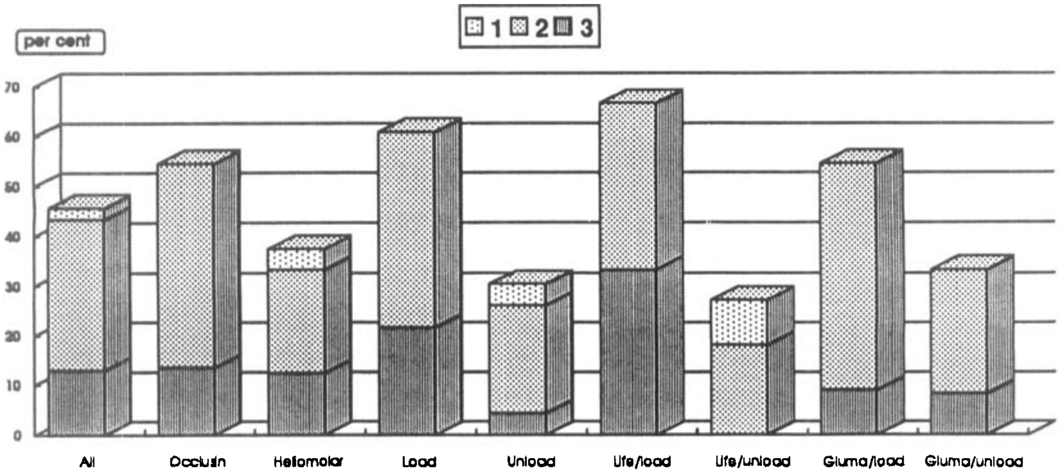

Fig. 8. Histogram of marginal leakage in occlusally loaded, etched, class-II composite resin restorations in accordance with dye penetration depths. 1 = penetration into the enamel, without reaching the dentin; 2 = penetration into the dentin, without reaching the pulp; and 3 = penetration to the pulp.

kept small, the cavity margins were not beveled, an intermediate resin layer was used, the cavity was filled in layers, and the restoration was finished immediately after polymerization.

The results clearly show the inherent difficulties in making restorations without defects. Many of the restorations had a slight overfill even though the restorations were performed in vitro. The differences found between Occlusin and Heliomolar in the frequency of air voids, gap formation, and pooled resin were not statistically significant. Thus, no conclusions can be drawn concerning possible differences between these two restorative materials. However, this study shows the risk of pooling the intermediate resin layer, which might cause problems in the radiographic diagnosis of secondary caries.

No differences could be found between the conventional lining with Life and the use of Gluma dentin bonding with regard to air void formation at the material cavity interface, which is not in agreement with previous reports (9, 11, 25–27), which found better adaptation when Gluma was used. It seems that loss of adaptation somewhere along the material/cavity interface is inevitable. This lack of adhesion could have technical reasons or may be due to polymerization shrinkage.

The finding of cracks in the Life base lining material has to our knowledge not been reported earlier. They were found in connection with Occlusin when the restorations were loaded but not in connection with Heliomolar. A possible explanation could be transferral of the loading force enhanced by the high flexural strength of Occlusin, whereas the more resilient material Heliomolar absorbed some of the energy in the loading force. The clinical relevance of this difference is difficult to assess. However, it indicates a risk that the sealing of the dentinal tubules by the calcium hydroxide base could be damaged.

Dye penetration could be detected in almost half of the loaded teeth, which is lower than seen in previous studies, which report that almost all dental restorations have some degree of microleakage (1–6, 28). An explanation could be that the teeth in this study were only examined for microleakage in one plane. Further, the test teeth were not thermocycled, which has been reported to have a major deteriorating effect, causing increased microleakage (3, 29). Another explanation could be that the test teeth were loaded with 350 g in the present study, which is a small load compared with the static loading of a tooth in the in vivo situation (30).

The load and slide combination have to our knowledge not been used earlier on test restorations in teeth and was chosen to simulate the clinical situation. However, although the analysis of dye penetration was performed in only one plane, the test and control teeth were not thermocycled, and small loading forces were applied, a significant difference with regard to microleakage was noted for the loaded test teeth compared with the unloaded. The difference between loaded and unloaded was greater for the teeth lined with Life than with Gluma dentin bonding. A possible explanation could be that the sliding movement (1.5 mm) during the loading contributed to the noted difference. It must, therefore, be stated that even a low level of loading seems to involve a risk of inducing leakage in modified class-II restorations if the lining material Life is used.

In addition, it must be noted that the use of Tubulicid before the Gluma bonding system in this study may have affected the bond strength negatively, which underlines the difference between the use of Gluma bonding system and conventional lining with Life base material. The advantages and disadvantages of different lining materials and dentin bonding systems in combination with different composite resin materials must be subjected to further investigation. It is also important to study further the chewing effect on the development of marginal leakage.

It can be concluded that repeated loading under movement of posterior composite resin restorations considerably increases the risk of marginal leakage and cracking of base material. Thus, until further knowledge is obtained, composite restorations in the posterior regions, which are exposed to heavy occlusal loading, should be limited, especially if a base material is used.

Acknowledgement.—This study was supported by a research grant, project 983/86, from Örebro County Council Research Committee, Örebro, Sweden.

References

1. Bergenholtz G, Cox CF, Loeshe WJ, Syed SA. Bacterial leakage around dental restorations: its effect on the dental pulp. J Oral Pathol 1982;11:439–50.
2. Davila JM, Gwinnet AJ, Robles JC. Marginal adaptation of composite resins and dental bonding agents [Abstract 623]. J Dent Res 1986;65.
3. Eakle WS. Effect of thermal cycling on fracture strength and microleakage in teeth restored with a bonded composite resin. Dent Mater 1986;2:114–7.
4. Forsten L, Kuusisto E, Ruokolainen R, Udd B. Marginal leakage in vitro of composite fillings in posterior human teeth. Proc Finn Dent Soc 1982; 78:155–8.
5. Leinfelder KF, O'Neal SJ, Mueninghoff LA. Use of $Ca(OH)_2$ for measuring microleakage. Dent Mater 1986;2:121–4.
6. Torstenson B, Brännström M. Composite resin contraction gaps measured with a fluorescent resin technique. Dent Mater 1988;4:238–42.
7. Fusayama T. Factors and prevention of pulp irritation by adhesive composite resin restorations. Quintessence Int 1987;18:633–41.
8. Gordon M, Plasschaert AJM, Saiku JM, Pelzner RB. Microleakage of posterior composite resin material and an experimental urethane restorative material, tested in vitro above and below the cementoenamel junction. Quintessence Int 1986;17:11–5.
9. Munksgaard EC, Hansen EK, Asmussen E. Effect of five adhesives on adaptation of resin in dentin cavities. Scand J Dent Res 1984;92:544–8.
10. Munksgaard EC, Irie M, Asmussen E. Dentin-polymer bond promoted by Gluma and various resins. J Dent Res 1985;64:1409–11.
11. Munksgaard EC, Irie M. Dentin-polymer bond established by Gluma and tested by thermal stress. Scand J Dent Res 1987;2:185–90.
12. Munksgaard EC, Hansen EK, Kato H. Wall-to-wall polymerization contraction of composite resins versus filler content. Scand J Dent Res 1987;95:526–31.
13. Hansen EK. Contraction pattern of composite resins in dentin cavities. Scand J Dent Res 1982; 90:480–3.
14. Qvist V. The effect of mastication on marginal adaptation of composite restorations in vivo. J Dent Res 1983;62:904–6.
15. Öysaed H, Ruyter IE. Composites for use in posterior teeth: mechanical properties tested under dry and wet conditions. J Biomed Mater Res 1986; 20:261–71.
16. Ruyter IE, Öysaed H. Composites for use in posterior teeth: composition and conversion. J Biomed Mater Res 1987;21:11–23.
17. Norén JG, Engström C. Cutting of mineralized hard tissues with the Leitz 1600 low-speed saw microtome. Leitz Mitteilungen 1987;9:49–52.
18. Crim GA. Effect of placement techniques on microleakage of dentin-bonded composite resin. Quintessence Int 1986;17:21–4.
19. Eick JD, Welch FH. Polymerization shrinkage of posterior composite resins and its possible influence

on posterior sensitivity. Quintessence Int 1986;17: 103–11.
20. Forsten L. Marginal leakage and consistency of the composite resin material in etched cavities. Acta Odontol Scand 1977;36:11–3.
21. Hansen EK. Effect of three dentin adhesives on marginal adaptation of two light-cured composites. Scand J Dent Res 1986;94:82–6.
22. Hansen EK, Asmussen E. Effect of postponed polishing on marginal adaptation of resin used with dentin-bonding agent. Scand J Dent Res 1988; 96:260–4.
23. Hansen KE, Qvist V. Applicering af plast. Tandlaegebl 1987;91:546–9.
24. Welch FH, Eick DJ. A method to reduce or prevent postoperative sensitivity with posterior composite resin restorations. Quintesscence Int 1986;17:667–76.
25. Eliades GC, Caputo AA, Vougiouklakis GJ. Composition, wetting properties and bond strength with dentin of 6 new dentin adhesives. Dent Mater 1985;1:170–6.
26. Hörstedt-Bindslev P. Monkey pulp reactions to cavities treated with Gluma dentin bond and restored with microfilled composite. Scand J Dent Res 1987;95:347–55.
27. Odén A, Öilo G. Tensile bond strength of dental adhesives. Dent Mater 1986;2:207–13.
28. Darbyshire PA, Messer LB, Douglas WH. Microleakage in class II composite restorations bonded to dentin using thermal and load cycling. J Dent Res 1988;67:585–7.
29. Blunck U, Roulet JF. In vitro marginal quality of dentin-bonded composite resins in class V cavities. Quintessence Int 1989;20:407–12.
30. Phillips RWP. Skinner's science of dental materials. 8th ed. Philadelphia: Saunders, 1982.

Received for publication 5 October 1990