Evaluation of Marginal and internal adaptation of adhesive class II restorations, in vitro fatigue tests
Dietschi, D.L.

Citation for published version (APA):

General rights
It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

Disclaimer/Complaints regulations
If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please Ask the Library: http://uba.uva.nl/en/contact, or a letter to: Library of the University of Amsterdam, Secretariat, Singel 425, 1012 WP Amsterdam, The Netherlands. You will be contacted as soon as possible.
Chapter 4:

Adaptation of Stratified Compomer-Composite Class II Restorations
Aim of the study

As previously mentioned, the reduction of polymerisation shrinkage, and improvement of several composite physical properties, was achieved through an increase in filler content (Willems et al, 1993). The potentially negative consequence of elevating most of composite physical properties, including the elasticity modulus, is a reduction of their ability to flow and an increase of stresses generated at the adhesive interface during polymerization (Feilzer, 1989; Feilzer et al, 1990). Kemp-Scholte and Davidson (1990) therefore early emphasized on the importance of incorporating an "elastic" layer at the restoration base, to act as a stress absorber and then to reduce internal tensions induced by polymerization of further composite layers or function. This role can be assumed by the hybrid layer (Van Meerbeck et al, 1993), the bonding resin (Kemp-Scholte and Davidson 1990; Eliades, 1994) or a soft base-liner (Davidson, 1994; Roulet and Lösche, 1994; Friedl et al, 1997). Actually, the resin-modified glass ionomers and compomers can advantageously be combined to composite resins to form a resistant but less rigid base which could preserve adhesion, due to a lower and slower development of polymerization stresses (Wilson, 1990; Friedl et al, 1997; Suh, 1997). For some brands, this interesting property seems related to a specific resinous matrix composition and structural network showing only little cross-linkage after light-activation, providing a higher initial material elasticity (Suh, 1997). The material however attains later superior mechanical strength, after progression of the acid-base reaction and the development of an ionic substructure (Wilson, 1990).

The bond strength to dentin of resin-modified glass ionomers and composites proved comparable (Triana et al, 1994; van der Vyver et al, 1995; Fritz et al, 1996) because they both rely on modern adhesive concepts, through the formation of a hybrid layer. As an effective bond can be achieved between resin-modified glass-ionomers and composites (Tate et al, 1996; Friedl et al, 1997), the concept of stratified compomer-composite adhesive restorations appears a feasible and advantageous restorative option. However, it remains to be determined in which configuration the best restoration quality is achieved.

The present study tested the hypothesis that the marginal and internal adaptation of direct class II restorations, after mechanical loading, could be influenced by the presence and configuration of a low elasticity modulus compomer base.

Specific Methods and Materials

Sample preparation

Box-shaped Class II cavities (MOD) with parallel walls and beveled enamel margins were prepared, with proximal margins located 1.0 mm below (mesially) and above (distally) the cementum-enamel junction, such as described in chapter 2 (Fig. 2.5A). The 24 prepared teeth
were randomly assigned to one of the 3 experimental groups, corresponding to the different restorative options: direct composite filling (CP), direct composite filling with a compomer lining (closed "sandwich" configuration) (LD) and direct composite filling with a compomer base (opened "sandwich" configuration, with base material covering gingival margins) (BD) (Fig.4.1).

Restorative procedures

The same restorative composite material, a fine hybrid brand (TPH Spectrum, Dentsply DeTrey; Kontsanz, D-78467, Germany), and the same multi-functional adhesive (Prime & Bond 2.1, Dentsply DeTrey) were used in all groups. The characteristics of these materials are summarised in Table I.

After completion of the preparation, enamel was selectively etched for 30s prior to a 15s full cavity etching with a 37 % H₃PO₄ acid gel (Ultraetch; Ultradent; South Jordan, UT 84095-3942, U.S.A). The cavity was thoroughly rinsed for 30 s and gently air dried (3s air spray with low pressure) so that conditioned dentin was kept slightly moist. Then, the adhesive was placed in two layers, according to manufacturer’s instructions, and light-cured for 40s. For the full composite fillings (group CP), the 3-sited light curing technique (Lutz et al, 1986a and b) and the oblique layering technique (Weaver et al, 1988; Tjan et al., 1992) were used for respectively restoring the proximal and occlusal portions. Each increment was individually cured from gingivally (1st layer) and laterally (all subsequent layers) for 40s, with a final 40s occlusal illumination, using a halogen light-curing unit (Optilux 500, Kerr-Demetron; Orange, CA 92867, U.S.A), the power density of which is about 500 mW/cm². The compomer lining (Dyract, Dentsply DeTrey) (group LD) was applied uniformly (1.5mm thickness approximately) on the bottom of the cavity, maintaining the gingival margins free for composite application. The compomer base (Dyract, Dentsply DeTrey) (group BD) was applied uniformly over the proximal boxes and the occlusal preparation ground (1.5mm thickness approximately). Compomer lining and base, were light cured for 40s using the same halogen curing device. The remaining volume of both based and lined cavities was filled similarly to those of group CP, with exception of the first gingival layer which wasn’t applied in samples with a base (group BD). Finally, each restoration was covered with a glycerin gel and light-cured for a final 20s irradiation on each surface. Flame and pear-shape fine diamonds burs (Intensiv No 4205L; 4255; 5205L and 5255) and polishing discs (Pop On XT, 3M; St-Paul, MN 55144-1000, USA) were used for immediate restoration finishing and polishing.

Restorative procedures are summarized in Table II.

Mechanical loading was applied such as described in chapter 2 (Figs. 2.1-2.4). The standardized preparation of specimen for SEM evaluation, detailed in chapter 2; Figs. 2.6-2.10), was applied to all samples for the marginal and internal adaptation evaluation.
Statistics

All results were submitted to a non-parametric statistical analysis. The Kruskall Wallis and Nemenyi tests (Sachs, 1974) served for comparing the restorative methods. The Friedman and Wilcoxon-Wilcoxon tests (Sachs, 1974) served for evaluating the influence of the number of cycles on the marginal adaptation. All tests were carried out at a 5% level of significance.

Results

Marginal adaptation

The results of the marginal adaptation evaluation (in percentage of continuity) are presented in Fig.4.3 and table 4.III, together with statistical analysis.

The proximal adaptation of the restorations in enamel proved satisfactory for the 3 groups on both mesial and distal sides, with percentages of "continuity" between 94.6% (LD) and 100% (BD), after 1 million cycles. The only type of defect observed at the enamel margins was the "marginal tooth fracture", which extent was usually strictly limited.

In dentin, the adaptation was judged excellent, with proportions of "continuity" between 95.2% (CP) and 98.0% (BD), before mechanical loading. Loading produced only a slight degradation of margins for the full composite restoration (CP) ("continuity" values varied from 90.3% to 75.3%, between 250'000 and 1 million cycles), while it remained stable for the restorations with the compomer lining (LD) ("continuity" values varied from 89.5% to 88.4%, between 250'000 and 1 million cycles). The degradation at the dentin margins was severe for the restorations with the compomer base (BD) ("continuity" values dropped from 67.5% to 10.6%, between 250'000 and 1 million cycles).

Internal adaptation

The results of the internal adaptation evaluation (in percentage of continuity) are presented in Fig. 4.4 and table 4.IV, together with statistical analysis.

The evaluation of internal adhesive interfaces showed higher proportions of "continuity" at the gingival enamel (95.4% for CP to 98.4% for BD), when compared to dentin segments (40.4% for BD, gingivally, to 80.8% for LD, occlusally). The difference proved however significant only between gingival dentin and gingival enamel portions. The application of a compomer lining allowed to reduce significantly the occurrence of gaps in dentin at the gingival level, as compared to the base configuration or composite filling without base-lining.

Micromorphology of internal interfaces

The most common observation was, in case of adhesive failure, that the separation was predominantly located at the top of an acid resistant layer, which seemingly corresponds to the
"hybrid layer" (Figs. 4.5 and 4.6). In enamel, failures appeared to be of cohesive nature (Fig. 4.6). The presumed hybrid layer generally appeared to be 5 to 10 μm thick. Only insignificant proportions of the defective interfaces showed evidence of another failure mechanism such as cohesive fractures in dentin or within the hybrid layer (Fig. 4.7). Adhesive failures resulting from a detachment at the hybrid layer base was in fact not detected.

Discussion

Marginal adaptation

The quality of the restoration marginal adaptation at the level of enamel margins remained nearly unaffected by mechanical loading, in all the three groups. This again proves the superior efficiency and predictability of adhesion to acid etched enamel and the value of bevel in maintaining restoration margin integrity (Munechika et al., 1984; Carvahlo et al., 2000). Actually, the incidence of marginal tooth fracture was negligible and without any significant difference between the different groups. Enamel micro-cracks are typical of in vitro tests with mechanical loading when butt preparations are realized (Krejci and Lutz, 1993; Dietschi and Moor, 1999), while such defects are significantly reduced with beveled preparations (Dietschi and Herzfeld, 1998). This observation likely reflects the influence of prism orientation in bonding efficiency to acid-etched enamel (Munechika et al., 1984; Carvalho et al., 2000). Therefore, beveling cavity margins appears definitely as the ideal finishing design for direct composite restorations, in any area providing proper access and anatomy.

Unlike to enamel margins, the restoration adaptation to gingival dentin was significantly affected by mechanical loading for the full composite restorations and, as well, for those with a compomer base, which presented almost fully opened margins at the end of the test. The application of a more elastic layer underneath an adhesive restoration proved to help absorbing polymerization shrinkage and functional stresses (Kemp-Scholte and Davidson, 1990; Van Meerbeck et al., 1993; Eliades, 1994). It remained however to determine which base-lining configuration is best suitable. In the present experimental conditions, the restorations with a base (the compomer assumes the gingival closure of the cavity) behaved similarly to the other configurations before the fatigue test, but proved inadequate to resist mechanical loading. This presumably reflects the influence of some specific physical properties of the tested material. The higher flexibility and more important volume of the base likely amplified deformations under simulated occlusal loading. In gingival dentin, where the adhesion is the most critical, this resulted in an excessive proportion of opened margins. Krejci et al (1988) made similar observations after testing different base-liners under class II restorations, although at this time, non-adhesive cements were used. A restorative material, such as a composite resin, exhibiting
physical properties and in particular an elasticity modulus close to natural dentin, seems necessary for covering the margins and maintaining the peripheral seal.

The best results were obtained with the lining configuration, suggesting that a rather thin layer of Dyract (1mm) was adequate to reduce stress but did not result in excessive deformation under load. Actually, because of its low initial elasticity modulus (Suh, 1997) this specific material shows a good potential in this application.

In the 3 groups, the restoration adaptation to dentin appeared inferior to that of enamel. This confirms that the numerous laboratory measurements of dentin bonding shear or tensile strength, presenting adhesion values identical if not superior to those obtained on acid-etched enamel (Hasegawa et al, 1995; May et al, 1997; Wakefield et al, 1998; Wilder et al, 1998; Tanumiharja et al, 2000) are poorly relevant for predicting their performance in a clinical configuration.

Internal adaptation

Regarding the influence of the restorative technique and the superior efficiency of adhesion to enamel, the results of the internal and marginal adaptation proved to be in good correlation. The gingival portions presented more gaps than axial or occlusal areas, although this appeared to be only a trend. Therefore, even in the absence of any statistical evidence, this observation substantiates the concept that the variation in tubule density and orientation within the different cavity areas can affect dentin bonding efficiency (Watanabe et al, 1996; Ciucchi et al., 1995) (Fig. 4.8). In superficial dentin, the surface occupied by tubules is minimal and, with exception of the occlusal floor, their orientation is not perpendicular to the cavity base, thus reducing their contribution to dentin bonding and lowering the overall adhesion efficiency (Cagidiaco and Ferrari, 1995; Cagidiaco et al, 1997). Although it appears logical, this hypothesis remains controversial (Yoshiyama et al, 1996). The proportion of adhesive failures was higher internally than externally. This observation proves again that adhesion to dentin is perfectible and that marginal adaptation does not fully reflect the integrity of the internal adhesive interface.

Micromorphology of the internal adhesive interface

The presence of an acid resistant layer on the top of dentin with clearly visible resin tags (Figs. 4.5 to 4.8) was rather consistently observed underneath the restoration, which likely represents the hybrid layer. The absence of this layer at the restoration interface with enamel confirms this assumption. The morphological characteristics of the hybrid layer obtained with the Prime & bond 2.1 appeared consistent with the observations made by Perdigao et al (1996) and Tay et al, (1996a and b). An indirect observation on replicas, such as applied in the present study, precluded a precise distinction of all components of the adhesive interface but, whenever present, it allowed a localization of debonding, relative to the hybrid layer.
The adhesive failures were predominantly located over the acid resistant layer, which suggest a week link between the hybrid layer top surface and the restoration. This observation confirms previous findings (Jacobsen and Finger, 1993; Dietschi et al, 1995; Perdigao et al, 1996). Tay and co-workers (1996 a and b) described the "over-wet" phenomenon related to the interaction between residual water and primer/adhesives containing acetone as the main solvent. Actually, by applying the concept of "wet-bonding" (Gwinett, 1992; Kanka, 1992) the displaced water causes the formation of blisters-like spaces and also inhomogeneous phases within the adhesive interface, which could act as stress raisers on top of the hybrid layer. The problem of dealing with the excess of water remains critical for some current adhesive systems. Actually, even when drying etched dentin moderately, there is a risk to affect the bond strength due to a collapse of the collagen structure and incomplete infiltration of the resinous components within the demineralized dentin (Pashley et al, 1993; Tay et al, 1996a and b). A last potential explanation for the existence of this week link between the hybrid layer and restoration is an insufficient polymerization in the rather thin resin layer left after adhesive placement and solvent evaporation (only a few microns) (VanMerbeek et al, 1992; VanMeerbeeck et al, 1993; Prati et al, 1999). Actually, the inhibitory effect of oxygen is known to affect resin polymerization to a depth of 100μm or more and to create a totally uncured layer of about 15μm (Rueggeberg and Margeson, 1990). As a consequence, the collagen network might be disturbed during composite placement, in case only a thin resin layer was produced over treated dentin. It is actually known that a stabilization of the hybrid layer by proper curing of the bonding resin is critical to optimise bond strength and marginal adaptation of indirect and direct class II restorations (Frankenberger et al, 1999).

Conclusions

An in vitro fatigue test simulating 4 years of occlusal function was applied to direct full composite and stratified compomer-composite class II restorations in order to evaluate the influence of a compomer base or lining on marginal and internal adaptation. In the present experimental conditions, it appeared that:
- mechanical loading had a detrimental effect on restoration adaptation to dentin while it did not influence adaptation to enamel. Although laboratory bond strength values of Prime & Bond 2.01 to dentin and enamel proved identical, this adhesive remains less effective on dentin than on acid-etched enamel, when evaluated in a clinical configuration.
- the incidence of adhesive failures in dentin increased with the number of mechanical loading cycles. This reduction in the proportion of continuous margins appeared significant for the restorations with a Dyract base or no base-lining (full composite).
- the compomer Dyract applied as a base, extending up to the restoration margins, proved inadequate for preserving margin integrity in dentin, while it improved the restoration quality in the lining configuration. The use of a low elasticity modulus layer under the restorative material seems advantageous, providing its volume and configuration is well determined.
- adhesive failures occurred predominantly at the hybrid layer top surface.
Table 4.1: Composition and elasticity module of the products under investigation (manufacturer's data)

<table>
<thead>
<tr>
<th>Materials</th>
<th>Product name</th>
<th>Composition</th>
<th>Elasticity module</th>
<th>Batch numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>tissue conditioner</td>
<td>Ultraetch</td>
<td>H3PO4 37% gel</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(Ultradent; Salt-lake City, USA)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>adhesive</td>
<td>Prime &amp; Bond 2.1</td>
<td>Dymethacrylate resins, PENTA, photoinitiators, stabilizers, cetylamine hydrofluoride, acetone</td>
<td>1.60 Gpa*</td>
<td>960820</td>
</tr>
<tr>
<td></td>
<td>(Dentsply De Trey; Konstanz, Germany)</td>
<td></td>
<td>1.20 Gpa**</td>
<td></td>
</tr>
<tr>
<td>base-liner</td>
<td>Dyract</td>
<td>UDMA resin, TCB resin</td>
<td>7.4 GPa*</td>
<td>961016</td>
</tr>
<tr>
<td></td>
<td>(Dentsply De Trey; Konstanz, Germany)</td>
<td></td>
<td>6.1 GPa***</td>
<td></td>
</tr>
<tr>
<td>restorative material</td>
<td>TPH spectrum</td>
<td>mod. BisGMA, BisEMA, TEGDMA</td>
<td>10.6 GPa*</td>
<td>961016</td>
</tr>
<tr>
<td></td>
<td>(Dentsply De Trey; Konstanz, Germany)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dentin enamel</td>
<td></td>
<td></td>
<td>12 GPa*</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>50 GPa+</td>
<td></td>
</tr>
</tbody>
</table>

* measured at 24 h; ** measured at 30 days; *** measured at 90 days; + Verluis et al, 1996
Table 4.11: Summary of restorative procedures

<table>
<thead>
<tr>
<th>Groups</th>
<th>Restorative materials applied</th>
<th>Restorative procedures</th>
<th>Closure at gingival margins by</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP</td>
<td>adhesive</td>
<td>prox.: 3 site-layering *</td>
<td>adhesive/composite</td>
</tr>
<tr>
<td></td>
<td>composite</td>
<td>occl.: oblique layering</td>
<td></td>
</tr>
<tr>
<td>LD</td>
<td>adhesive</td>
<td>prox.: 3 site-layering *</td>
<td>adhesive/composite</td>
</tr>
<tr>
<td></td>
<td>compomer</td>
<td>occl.: oblique layering</td>
<td></td>
</tr>
<tr>
<td></td>
<td>composite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BD</td>
<td>adhesive</td>
<td>prox.: 2 site-layering **</td>
<td>adhesive/compomer</td>
</tr>
<tr>
<td></td>
<td>compomer</td>
<td>occl.: oblique layering</td>
<td></td>
</tr>
<tr>
<td></td>
<td>composite</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Lutz et al, 1986
** only layers 2 and 3 of the the 3-sited-light curing technique
Table 4.III: Results of the marginal adaptation evaluation at the different proximal locations, according to the number of mechanical loading cycles (percentages of continuity +/- SD)

<table>
<thead>
<tr>
<th>Nb of cycles</th>
<th>location</th>
<th>CP</th>
<th>LD</th>
<th>BD</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Enamel (distal)</td>
<td>100 (-)</td>
<td>97.3 (5.6)</td>
<td>97.6 (6.7)</td>
</tr>
<tr>
<td>250'000</td>
<td></td>
<td>99.5 (1.4)</td>
<td>97.6 (6.7)</td>
<td>98.6 (3.8)</td>
</tr>
<tr>
<td>500'000</td>
<td></td>
<td>100 (-)</td>
<td>95.5 (7.0)</td>
<td>100 (-)</td>
</tr>
<tr>
<td>1'000'000</td>
<td></td>
<td>100 (-)</td>
<td>94.6 (5.6)</td>
<td>100 (-)</td>
</tr>
<tr>
<td>0</td>
<td>Enamel (mesial)</td>
<td>100 (-)</td>
<td>97.9 (3.4)</td>
<td>98.8 (3.1)</td>
</tr>
<tr>
<td>250'000</td>
<td></td>
<td>100 (-)</td>
<td>98.0 (3.8)</td>
<td>98.8 (3.1)</td>
</tr>
<tr>
<td>500'000</td>
<td></td>
<td>100 (-)</td>
<td>97.9 (3.8)</td>
<td>99.3 (1.7)</td>
</tr>
<tr>
<td>1'000'000</td>
<td></td>
<td>100 (-)</td>
<td>97.6 (4.2)</td>
<td>99.3 (1.7)</td>
</tr>
<tr>
<td>0</td>
<td>Dentin</td>
<td>95.2 (8.9) a, A</td>
<td>96.3 (5.6) a, A, B</td>
<td>98.0 (3.3) a, A</td>
</tr>
<tr>
<td>250'000</td>
<td></td>
<td>90.3 (13.7) a, A, B</td>
<td>89.5 (11.8) a, b, C</td>
<td>67.5 (14.9) b, B</td>
</tr>
<tr>
<td>500'000</td>
<td></td>
<td>86.3 (13.7) a, A, B,C</td>
<td>90.7 (11.4) a, B, C</td>
<td>53.7 (21.7) b, B</td>
</tr>
<tr>
<td>1'000'000</td>
<td></td>
<td>75.3 (13.7) a, b, C</td>
<td>88.4 (11.6) a, C</td>
<td>10.6 (8.9) b, C</td>
</tr>
</tbody>
</table>

No significant difference was found for enamel margins. For comparison between groups (rows), means with same lower case letter are not statistically different at p=0.05 using the Kruskal-Wallis and Nemenyi tests. For comparison between the number of cycles (columns), means with same capital letter are not statistically different at p=0.05 using the Friedman and Wilcoxon-Wilcox tests.
Table 4.1V: Results of the internal adaptation evaluation, according to the different interface segments and the whole dentin interface (total) (percentages of continuity +/- SD)

<table>
<thead>
<tr>
<th>Groups</th>
<th>GE</th>
<th>GD</th>
<th>AD</th>
<th>OD</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP</td>
<td>95.4 a, A</td>
<td>43.8 a, B</td>
<td>66.5 a, A, B</td>
<td>58.3 a, A, B</td>
<td>64.8a (17.8)</td>
</tr>
<tr>
<td></td>
<td>(11.1)</td>
<td>(21.5)</td>
<td>(15.0)</td>
<td>(30.0)</td>
<td></td>
</tr>
<tr>
<td>LD</td>
<td>92.6 a, A</td>
<td>68.1 b, B</td>
<td>65.0 a, A, B</td>
<td>80.8 a, A, B</td>
<td>75.6a (6.8)</td>
</tr>
<tr>
<td></td>
<td>(17.5)</td>
<td>(7.9)</td>
<td>(17.6)</td>
<td>(13.2)</td>
<td></td>
</tr>
<tr>
<td>BD</td>
<td>98.4 a, A</td>
<td>40.4 a, B</td>
<td>51.2 a, A, B</td>
<td>65.3 a, A, B</td>
<td>62.5a (8.2)</td>
</tr>
<tr>
<td></td>
<td>(2.2)</td>
<td>(19.2)</td>
<td>(17.4)</td>
<td>(15.4)</td>
<td></td>
</tr>
</tbody>
</table>

For comparison between products (columns), means with same lower case letter are not statistically different at p=0.05 using the Kruskall Wallis and Nemenyi tests. For comparison between locations (rows), means with same capital letter are not statistically different at p=0.05 using the Kruskall Wallis and Nemenyi tests.
Figure 4.1: Horizontal layering technique (1-3 represent the 3 subsequent increments).

Figure 4.2: Diagrammatic representation of the LD (compomer lining) and BD (compomer base) groups (left) and the CP (compomer lining) group (right)
Number of cycles

- 0
- 250'000
- 500'000
- 1'000'000

Figure 4.3: Results of the marginal adaptation in dentin (% of continuity ±SD)

Figure 4.4: Results of internal adaptation (% continuity ±SD)
Figure 4.5: SEM microphotograph of a CP sample section (composite filling) showing the adhesive interface with its different constituents, as revealed by the observation method: the resin tags (RT), the hybrid layer (HL) and the bonding resin together the composite restoration (CP)

Figure 4.6: SEM microphotograph of a CP sample section (composite filling) demonstrating the two typical failure types: cohesive micro-fractures in superficial enamel (MF) and debonding on the top of the hybrid layer (GAP) in dentin
Figure 4.7: SEM microphotograph of a CP sample section (composite filling) showing a rather rare type of failure: cohesive debonding within the hybrid layer (HL). As well, cohesive dentine fractures were virtually absent in this study (D = dentin)

Figure 4.8: SEM microphotograph of a LD sample section (compomer lining) showing a rather large gap close to the cavity margin, which progressively closes toward the pulpal wall. Note the inclination and reduced opening of tubules on the proximo-gingival border (GD = outer gingival dentin; IGD = inner gingival dentin)


