Regional Variations of μTBS of Light- and Chemically-cured Resin Composite Restorations in Clinically Relevant Situations

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**Purpose:** To test whether the distance to the mass center of a buildup made of visible-light- or chemically curing composite resin bonded to dentin and cured in one increment has an influence on μTBS.

**Materials and Methods:** In the experimental groups, one-increment visible-light (Z250) or chemically-cured (TiCore) composite-resins buildups were bonded to flattened bovine dentin surfaces. In the control groups, the same materials were bonded as separate buildups on circumscribed areas to minimize the effect of shearing polymerization contraction. Compound composite/interface/dentin specimens were trimmed out of buildups and tested in tension until detachment; the distances to the mass centers of their respective buildups were recorded as the independent variable. The correlation between μTBS and distances was tested in each group. Slopes and intercepts of regression lines (μTBS to bonded area) were compared in the experimental groups.

**Results:** The correlation between μTBS and distances was negative and statistically significant for both experimental groups (p < 0.0001), but not for the two control groups (p > 0.34).

**Conclusion:** In clinical situations such as direct resin veneering or resin core construction, where a first layer of a light- or chemically cured resin composite is bonded and cured on a broad surface, the μTBS of the interface decreases proportionally to the distance to the mass center of the restoration.

**Keywords:** polymerization shrinkage, polymerization stress, resin composite, regional bond strength, microtensile testing.

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Stress within dental curing composite resins is not a material property, but a local physical state, derived from the combination of material properties, direction and intensity of curing light, spatial distribution of restoration and complementary bonded surfaces, and boundary conditions.3,15,17,38,69,71

It has been shown that the ultimate tensile bond strength of resin composites bonded to dental tissue changes with regions in the cavity walls50 due to polymerization shrinkage. In FEA studies, a triaxial distribution of polymerization contraction stresses has been shown. In cases of minimum compliance, the magnitude of intermediate stresses were calculated parallel to the bonded interface. Similar analyses calculated shear stresses, also distance-related,4,29,33,39 in the vicinity of bonded interfaces.54

Since its introduction in dental research,62 microtensile bond strength (μTBS) testing has become a routine method for assessing the bond strength of an interface.1 Some of its advantages are that it can be used to evaluate and compare different areas of same tooth, and that its results are closer to the real adhesive strength, because bonded area (BA) is minimized, hence minimizing the effect of defects in the interface.1

However, it has important limitations: results very much depend on the preparation protocol, either in the form of compound slabs or sticks,30,60 on the dimensions and shape of the BA,1,28,48,56 and on the method of fixation of specimens before submitting them to stress.23,70 In addition, although many readings are acquired from an individual specimen or tooth, they are interrelated and should not be statistically considered as independent measurements.21,44,59
One of the most commonly used methods to test μTBS consists in building up a simulated restoration, bonded to a ground or flattened dentin or enamel surface of an extracted human (or other animal) tooth. Such exposed surfaces can be very extensive, for instance, the frequently used transversal section of a molar at the level of the amelodentinal junction.

Afterwards, the bonded assembly is sectioned in one or two planes perpendicularly to the bonded interface, yielding up to 7 slabs per specimen or between 8 and 30 compound sticks or bars to be tested.

It has been experimentally shown that the interfacial μTBS of elongated composite resin buildups bonded to an enamel surface and cured in one increment correlates with the distance from the mass center of the restoration. It has been suggested that this correlation may be due to centripetal displacements of the restorative components of the interface (bonding agent, restorative material). This would happen while curing is incomplete and the flow towards the mass center of the restorative material is still possible, thus destabilizing the hybrid layer when it is still immature.

Such strain may be the source of the disk deflection that is detected with the deflecting disk method of polymerization contraction measurement. Stress of this nature has been experimentally shown and seems to contribute to marginal defect formation in some direct and indirect restorations.

In many clinical situations, a relatively large amount of resin is bulk cured and bonded to an extensive dentin area. For example, this may be the case in cementation of resin is bulk cured and bonded to an extensive dentin area. For example, this may be the case in cementation of resin or to extensive dentin areas. Control groups were also examined, in which the phenomenon can be considered negligible, as small, randomly distributed resin-bonded buildups were cured to control for the influence of variations in the adhesive substrate.

### MATERIALS AND METHODS

Following the guidelines of the Animal Research Committee of Complutense University, 14 sound bovine incisors were collected and stored for up to 1 month after extraction.

#### Preparation of Teeth and Restorations (Fig 1)

Roots were removed ca 1 mm apical to the cementoenamel junction with a water-cooled diamond saw (3031 CP/N Exakt; Norderstedt, Germany). A flat dentin surface was produced on the labial surface of each incisor’s crown by wet grinding in a grinder-polisher (Struers Dap-7; Rodovre, Denmark) with 500-grit SiC paper to achieve a standardized bonding substrate.

Teeth were randomly assigned to one of four experimental groups (Table 1). In the experimental groups VLC1 (visible-light curing, Filtek Z250) and CC1 (chemically curing, Ti-Core), the two restorative composite resins were built up to a height of 2 mm and bonded. In VLC1, the buildup was evenly cured (Optilux 501, Demetron/Kerr; Orange, CA, USA, 800 mW/cm²) in one increment over the maximum available dentin surface. The curing tip was placed as close as possible to the material being cured but without contact. In CC1, the composite resin was allowed to cure also in one increment, once both components were adequately mixed.

In the control groups VLC2 and CC2, buildups of ca 2 x 2 x 2 mm were bonded as in the corresponding experimental groups, but restricted to randomly selected sites of exposed dentin (up to seven sites per restoration). All precautions were taken to avoid contact between the buildups. Such sites were selected from a mesh that was superimposed on the exposed dentin area.

In all groups, buildups were prepared at least 0.5 mm short of surrounding enamel, to guarantee that bonding was restricted to dentin. All restored teeth were stored for 24 h in a 100% humidity chamber until sectioning to allow completion of curing.

#### Specimen Preparation and μTBS Testing

The restored teeth of all groups were sectioned (3031 CP/N Exakt) perpendicularly to the bonded interface in two planes to produce rectangular compound composite resin-dentin specimens. Their bonded areas (BA) in mm² were measured with a digital caliper (Mitutoyo SPC, Mitutoyo; Tokyo, Japan) exact to 0.01 mm. Specimens were fixed (Super glue 3, Loctite; Madrid, Spain) to a rigid tensile testing device. Once affixed, glue was added to their lateral aspects. Then the adhesive joints were submitted to tension (Hounsfield HTI 500N; Croydon, UK) at a crosshead speed of 1 mm/min until failure.

Subsequently, the debonded areas were observed (40X) with a stereoscopic microscope (Leica MZ12, Leica Imaging Systems; Cambridge, UK) to determine the type of fracture (adhesive, cohesive, or mixed). Only adhesively debonded specimens were included in the analysis. μTBS (MPa) was calculated.
Fig 1 Preparation of teeth, restorations, sectioning, and testing of specimens. VLC: visible-light curing; CC: chemically curing.

Table 1 Materials used and group assignment

<table>
<thead>
<tr>
<th>Polymerization</th>
<th>Visible-light curing</th>
<th>Chemically curing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>VLC1 e</td>
<td>CC1 e</td>
</tr>
<tr>
<td>No. of teeth</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Restorative</td>
<td>Filtek Z250, 3M-ESPE; St Paul, MN, USA. Batch # 20030414</td>
<td>Ti-Core, Essential Dental Systems; Hackensack, NJ, USA. Batch # 071107</td>
</tr>
<tr>
<td>Adhesive</td>
<td>Adper Scotchbond 1 XT, 3M-ESPE. Batch # 174213 (Single Bond in USA)</td>
<td>Adper Scotchbond MP, 3M-ESPE. Activator Adper Scotchbond 1.5 batch # 20080627. Primer Adper Scotchbond 2. batch # 20080806. Adper Scotchbond 3 batch # 20080806 admixed with catalizer Adper Scotchbond 3,5 batch # 20080716.</td>
</tr>
</tbody>
</table>

Calculation of the Dependent Variable PTens

The specimens were not manipulated further after sectioning and there were no additional refinements of BA. They were rectangular in shape, directly obtained by trimming, with a BA mean (SD) of 0.78 (0.29) mm². Such fluctuations made it advisable to adjust each μTBS value to the specific BA on which it was based to exclude bias due to BA differences.

For this, a μTBS (in MPa) to BA (in mm²) regression curve of results of all valid specimens (pooled experimental and control groups) was calculated using the LSD (least squares differences) method (IBM SPSS Statistics v.19, SPSS; Chicago, IL, USA). This was based on the idea that if the μTBS results of all specimens had been determined by BA alone (with no influence of their individual distances to the mass center of its tooth), all of them would then have been exactly aligned on this regression line. However, the present data did not behave in this manner. The difference between the actual μTBS values and the regression line of the μTBS (“residuals”, in MPa) were considered to be caused by factor(s) other than BA. In this study, such residuals are considered the outcome, as they were hypothetically related to the distance of specimens to the mass center of the restoration whence they originated.

Additionally, it is possible that μTBS evaluation of the bovine teeth used in this research resulted in consistently higher (or lower) values because of some unidentified, individual characteristic of the dentin, such as its (micro)structure, calcification, or age of the animal. Because this study deals with variations in residuals within each bonded surface caused by the independent variable (distance to the center of the mass of the restoration), only increases or decreases of bond strength relative to same bonded surface are considered.
Therefore, residuals were transformed into fractional ranks (in %) – the dependent variable, termed PTens – within each restored tooth by the formula PTens = 100 x R/MaxR, where R is the residual for that case, and MaxR the maximum residual for that case.

**Calculation of the Independent Variable PDist**

In VLC1 and CC1 experimental groups, the distance of each specimen to the mass center of its restoration was directly recorded from the trimmed restorations as the horizontal distance of the center of each specimen along its major axis to the mass center of its restoration.

In VLC2 and CC2 control groups, specimens were trimmed out from separate composite resin build-ups, prepared at randomly selected positions: there was no real mass center. The distances of specimens were defined as the distance of their centers to a mean theoretical mass center of restorations in these groups, as if all restorations had the same extension and profile as the mean extension and profile of those in experimental groups.

Exposed dentin areas of all teeth had different sizes. For this reason, resin buildups in experimental groups and theoretical restorations in control groups had diverse sizes and resulted in a different number of specimens when sectioned.

The hypothesized effect is assumed to be distance-related; therefore, in all groups, distances of each specimen to the mass center (or theoretical mass center, in control groups) of its restoration were transformed into fractional ranks (in %) – the independent variable PDist – with the formula: PDist = 100 x D/MaxD, where D is distance of the center of the specimen to the mass center of the restoration, and MaxD the maximum distance of the corresponding restoration.

**Evaluation and Comparison Between Groups**

To determine whether there was a correlation between PDist and PTens, Pearson’s correlation test (r, coefficient of correlation) and its 95% confidence interval (CI) was calculated for each group.

To compare the levels of the effect between VLC1 and CC1 groups by polymerization mode (VLC1, visible-light curing; CC1, chemically curing), a comparison of intercepts and slopes of the regression lines was done (Statgraphis+ 5.0, Statistical Graphics; Warrenton, VA, USA).

To compare the levels of the effect between experimental and control groups at the outermost margins of restorations, a nonparametric Mann-Whitney U-test of was performed between PTens values of the 10% highest PDist of each group.

**Relationship Between Distance and Pre-test Failures**

If the hypothesized effect was present, a relationship between the number of pre-test failures (PTFs) produced during trimming or preparation of specimens and PDist could be expected. If the μTBS of specimens were reduced in any way by high levels the hypothesized effect (at the outer limits of restorations) PTFs could be expected in higher proportions than specimens exposed to lower levels of the effect (ie, those located near the mass center of the restoration).

To examine this, only PTFs were included with a known reason for failure which could be logically attributed to a decreased interfacial TBS. These were only PTFs produced during trimming or preparation.

To determine whether there is an association between PTF proportions and PDist, the Mantel-Haenszel test for linear-by-linear association between proportions was used. Due to requirements of the test, PDist as the independent variable was classified into 5 categories (0% to 20%, 21% to 40%, 41% to 60%, 61% to 80%, 81% to 100%). PTen proportions in each category were compared.

**RESULTS**

**μTBS and Distances**

The mean BA was 0.78 mm² (SD = 0.29). The relationship of μTBS test results of all valid specimens (all groups pooled) to their BA values was found to be logarithmic (Fig 2), according to the equation 
μTBS = 21.8 – 16.3·Ln(BA),
with the μTBS in MPa and BA in mm². ANOVA showed the relationship to be significant, with p < 0.0001 (r² = 0.26).

In total, 775 specimens were produced (Table 2). The distance on the y-axis of the actual specimens’ μTBS values to the common regression line (regression’s residuals, in MPa) were transformed into fractional ranks (in %) – the dependent variable PTens – within each restored tooth. The distance of each valid specimen to the mass center (or theoretical mass center) of its restoration was transformed into a fractional rank (in %) – the independent variable PDist – as mentioned in the previous section. The distributions of PTens to PDist by group are shown in Fig 3.

**Assessment of the Effect and Comparison Between Groups**

Pearson’s correlation test (r, coefficient of correlation; 95% CI) results are shown in Table 3. The correlation between PTens and PDist was statistically significant in the experimental groups (VLC1 and CC1, p < 0.0001 in both). This correlation was negative: the higher the PDist value, the lower the PTens, thus confirming the test hypothesis (Fig 3). In the control groups (VLC2 and CC2), this correlation was also negative but not statistically significant (p = 0.99 and 0.34 respectively, Table 3). Significance is also shown through Pearson’s r and 95% CI intervals: in VLC1 and CC1 groups they do not overlap zero values, but in VLC2 and CC2 groups they do.

The comparison of intercepts and slopes of the regression lines (Table 3 and Fig 3) between VLC1 and CC1 groups was not significant (for the intercepts, p = 0.48 and for the slopes, p = 0.44): between experimental groups, variations of PTens values were not statistically significant at the centers of restorations, where PDist = 0 (intercepts). For these groups, the decline of PTens values exhibited the same slopes when distances to the mass centers of restorations increased.
Regression of μTBS (MPa) test results to BA (mm²) of all pooled valid specimens. Logarithmic regression formula: μTBS = 21.8 – 16.3·Ln(BA).

Fig 2

Fractional ranks of residuals to regression line in Fig 2 (PTens dependent variable, in %) plotted against distances of each specimen to the mass center (or theoretical mass center) of its specimen, transformed to fractional ranks within their restoration (PDist independent variable, in %) per group.

Fig 3

Table 2

<table>
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<tr>
<th>Group</th>
<th>Valid</th>
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</tr>
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The results comparing PTens values of the 10% highest PDist of each material group were significantly different, with p = 0.004 for the visible-light curing material and p = 0.012 for the chemically curing material (Mann-Whitney U-test). Decreases in PTens values were significant for both light-curing and chemically curing materials if the restorations were placed and cured in one increment (experimental groups), compared to the situation where the hypothesized effect was not present (control groups) for the same manner of polymerization.

Relationship Between Distances and PTF Proportions

The numbers of PTFs and valid specimens are shown in Table 2. The Mantel-Haenszel linear-by-linear test showed that the proportions of PTF specimens linearly increased with PDist category in experimental groups (Table 3). This increase was statistically significant (p < 0.0001 for both groups). In control groups, proportions did not change significantly: in VLC2, p = 0.67; in CC2, p = 0.3.

DISCUSSION

A hypothesized centripetal shearing effect of polymerization contraction of composite resins was tested in this study. This effect would hypothetically cause a decrease of μTBS ranging from a minimum at the specimen’s center to a maximum at the outer limits of the restoration.

Bovine incisors were used because their dentin has proven similar to human for microtensile
testing. It has been widely used for the analysis of polymerization contraction stresses and μTBS testing. In addition, larger areas of exposed dentin, such as the ones obtained from these teeth, allowed for an augmentation of the hypothesized effect.

Experimental groups contained five teeth each, as opposed to control groups, where fifteen teeth each were used. These differences were intentional: in control groups, fewer specimens were obtained per tooth (between four and seven), as they were trimmed from separate builds. In order to compare possible effects due to polymerization mode, two different resin composites were used, one visible-light (VLC1 and VLC2) and one chemically curing (CC1 and CC2), corresponding to two common clinical situations.

A relationship has been described between μTBS and polymerization contraction shrinkage and between the modulus of elasticity of a material and polymerization shrinkage. Despite the important differences in the modulus of elasticity of materials used in this study (11.5 GPa for Z250, 6.1 GPa for TiCore), neither differences in intercept nor in slopes of their regression curves were statistically significant. In this study, the hypothesized effect was present, but the modulus of elasticity of the materials apparently did not produce noticeable differences.

An FEA study on polymerization contraction stresses in resin composite restorations predicted shearing stresses appearing in the bottom of a rectangular cavity, increasing in importance as the distance to the center of the cavity increased. Although differences between configurations in that study (rectangular cavity with a C-factor of 3.8, and bonded lateral walls) and in the current report (resin builds with an approximate C-factor of 0.53) must be considered, the presence and characteristics of the mentioned shearing stresses could explain the distance-related effect found in our study. Similar stresses have been described by other authors, although the configuration factors there were also different from that of this study.

The two materials were bonded using different bonding systems (Scotchbond 1 XT for VLC1 and VLC2, Adper Scotchbond MP for CC1 and CC2, Table 1). In the former, a visible-light curing material was needed, and in the latter a chemically cured one. To test whether this caused differences in μTBS between chemically and visible-light curing materials, PTens ranks were compared between VLC1 and CC1 materials placed in central positions (PDist equal to or lower than 50%, to select specimens placed in similar dentin). With these restrictions, the mean (SD) for VLC1 was 69.6 (23.2) MPa, and for CC1 73.1 (22.4) MPa, with 100 and 78 specimens, respectively; thus, the ranks were not statistically significantly different (p = 0.29). Apparently, differences in adhesives did not cause statistically significant differences between PTens of the materials in the experimental groups.

One of the advantages of the microtensile test is that it minimizes and allows a certain measure of control over the influence of the BA size on the results. It has been shown that BA variations produce differences in μTBS results. The interrelationship between BA and μTBS has been described as following logarithmic, linear, inverse, or exponential distributions. BA differences among specimens in this study were not refined or in any way modified after trimming. To prevent the bias that such differences would have produced, μTBS results (in MPa) were transformed to residuals to the BA/μTBS regression line. Later, the PTens dependent variable was calculated by means of a percentage rank transformation. In this way, all specimens (of all BAs) of all teeth (of all extents of bonded dentin) were comparable.

However, this method of balancing the influence of BA on μTBS has undesirable consequences: direct clinical interpretation of μTBS results by themselves becomes very difficult. However, the interpretation of its relationship to PDist is straightforward: the higher the distance to the center of the restoration, the lower the μTBS value.

To make results comparable to other reports, μTBS values are given (Table 4) for those specimens placed in central positions (PDist lower or equal to 50%), with BAs between 0.9 and 1.1 mm². A comparable value was reported for one of the adhesives used, Adper ScotchBond 1 XT, 35.6 (4.2) MPa, using a BA range from 0.73 to 0.78 mm². A review of μTBS results using different test methods reported 36.1 (10.4) MPa, but no information is given on BA size used. Other studies reported 40.11 (15.68) MPa using 0.42 mm² BA and 48.4 (8) MPa or 49.6 (13.9) MPa using BA of 0.8 mm². For the other

### Table 3 Results of statistical analyses

<table>
<thead>
<tr>
<th>Group</th>
<th>Correlation PTens to PDist</th>
<th>Regression PTens to PDist</th>
<th>Significance (p) of PTF proportions according to Mantel-Haenszel test</th>
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<tr>
<td></td>
<td>Pearson’s r</td>
<td>Significance of correlation (p)</td>
<td>Intercept</td>
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<tr>
<td>VLC1</td>
<td>-0.59</td>
<td>&lt; 0.0001*</td>
<td>92.9</td>
</tr>
<tr>
<td>CC1</td>
<td>-0.66</td>
<td>&lt; 0.0001*</td>
<td>98.5</td>
</tr>
<tr>
<td>VLC2</td>
<td>-0.001</td>
<td>0.99</td>
<td>-</td>
</tr>
<tr>
<td>CC2</td>
<td>-0.09</td>
<td>0.34</td>
<td>-</td>
</tr>
</tbody>
</table>

* Statistically significant.
adhesive used – Adper ScothBond MP – μTBS values of 3.9 (1.3) MPa using a BA = 25 mm², 36.01 (8.4) MPa using a BA of 1.08 mm², or 20.01 MPa using a BA of 1.1 mm² or a median μTBS result of 52.7 MPa using a BA of 2.25 mm² have been reported by Betarmar et al,5 Burrow et al,9 and Bortolotto et al,7 respectively.

Pearson’s regression coefficient of μTBS results to BA of all pooled, valid, specimens was significant (p < 0.0001), although the relationship was weak (r² = 0.26) (Fig 2). Reasons for this low value could be intrinsic variability, or because the two variables – namely, BA and the independent variable PDist – are mixed in the analysis, and PDist acts as a confounding factor, as the regression was calculated only for BA. As an example, regression was calculated for each group separately, and Pearson’s r² coefficients were different (VLC1 = 0.09, CC1 = 0.1, VLC2 = 0.4, CC2 = 0.3). It can be seen that if adjustment of μTBS for BA is performed independently for control groups, in which the hypothesized effect is not present (VLC1 and CC1, in which it is supposed to be present), the coefficients are at least three times higher than in the experimental groups (VLC1 and CC1, in which it is supposed to be present).

Yet another consequence of this transformation is a relative augmentation of variation in results. The relationship between PTens and PDist shows considerable dispersion of PTens data according to material (Fig 3). Such variability is probably increased by the transformation of μTBS values to the PTens variable. This transformation into percentages causes the maximum μTBS value of each tooth to transform into 100% PTens and the other μTBS values to vary accordingly. As a result, high dispersion of PTens values is observed. However, the correlation is strong enough in experimental groups to be statistically significant.

In addition, transformation of the distance of specimens to the mass center of their restorations to PDist was required. Distances of the center of specimens to the mass center of the restoration were transformed into fractional ranks and given in percentages, producing the independent variable PDist. Exposed dentin surfaces were dissimilar in size, thus allowing for the construction of buildups having different total bonded areas. All efforts were made to produce 2-mm-high buildups in all cases. For this reason, two theoretical specimens having the same absolute distances to mass centers of their restorations would have been considered identical, but the extent of the hypothesized effect would have been different. It would depend not only on the distance to the mass center (the same for both), but also on the amount of material located between each specimen and the external margins of corresponding restorations measured along both lines passing through mass centers and specimens’ centers, which may have exerted an opposing effect.

It must also be considered that peripheral specimens, not having a rectangular BA shape when trimmed, were discarded. In this way, specimens accounted as extremes were really not placed in the outermost positions in their restorations, which would contribute to increased dispersion.

Each restoration produced several specimens. The interrelationship of various measurements from one sample (tooth) is a concern21,44,59 only if they are considered independent. In this study, this is not the case, as the effect that a specimen’s distance to its mass center may have on its μTBS results was assessed. This effect is particularized for each specimen, since dependent and independent variables (PTens and PDist) are transformed to percentage values within their restorations.

An analysis of the relationship between PDist and the PTF proportions of specimens has been reported previously,27 and yields supporting evidence of correlation. If the Mantel-Haenszel test shows statistical significance, as is the case for experimental groups, its interpretation is that increases in one variable (PTF proportions) are associated with constant increases in the other (PDist category) greater than would be expected by chance. PTF proportions with respect to valid specimens significantly increase when approaching to restoration boundaries in experimental groups (Fig 4, Table 2).

Table 4 μTBS values (MPa) for specimens in central positions (PDist lower or equal to 50%), with BA between 0.9 and 1.1 mm²

<table>
<thead>
<tr>
<th>Adhesive</th>
<th>Group</th>
<th>n</th>
<th>m</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adper SB 1 XT</td>
<td>VLC1</td>
<td>4</td>
<td>31.7</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td>VCL2</td>
<td>17</td>
<td>21.5</td>
<td>1.7</td>
</tr>
<tr>
<td>Adper Scotchbond MP</td>
<td>CC1</td>
<td>24</td>
<td>25.2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>CC2</td>
<td>13</td>
<td>26</td>
<td>1.4</td>
</tr>
</tbody>
</table>

n: number of specimens, m: mean, SD: standard deviation.
This could also be an effect of differences in substrate. In the center of the restorations, higher µTBS is to be expected, because the exposed dentin’s physical characteristics at those locations is more favorable for adhesion. Hence, a decrease of µTBS is obtained in the outer part of exposed dentin surfaces. However, our results showed that the correlation of PTens and PDist is negative but not significant in control groups: Pearson’s r in VLC2 group is -0.001 (p = 0.99), and in CC2 group is -0.09 (p = 0.34). Both experimental groups (VLC1 and CC1) showed also a negative, but significant correlation (Pearson’s coefficients were 0.59 and 0.66, both having p < 0.0001).

The behavior of PTF was similar (Fig 4). The Mantel-Haenszel test results showed that for the experimental groups, the proportion of PTF significantly (for both, p < 0.0001) increased with PDist. This did not happen for control groups (p = 0.67 and 0.3, respectively) (Table 3). This also supports the idea that centripetal stresses due to polymerization contraction of composite resins are a probable cause of defects at the margins of large direct resin-bonded restorations.

Pre-test failures were not included in the statistical analysis of µTBS. From our hypothesis, shearing stresses towards mass centers disrupted the immature interface, causing PTFs in proportions that increased toward the outer limits of the bonded area. We excluded them because assigning them a zero value would have been unrealistic: most likely, specimens debonded because their resistance was very low, but not zero, and because including such extremely low values would imply that they were expected values, which would also have been also inaccurate.

As mentioned above, some studies have reported differences in µTBS between central and peripheral measurements, when measured on extensive dentin areas, but the results are inconclusive. Possible reasons for this, other than local differences in dentin, can be that BAs were not controlled in these reports, that an enamel band at the periphery of the dentin bonding area was allowed, which would produce a counteracting effect, that few specimens were produced, and probably most important, that the relationship between distance and µTBS has not yet been systematically examined.

CONCLUSION

The results of this study indicate that composite resin restorations of extended areas, eg, direct resin veneers or core buildups, may experience a decrease of bond strength at their periphery if they are built up as a single increment which covers the whole area to be bonded.

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REFERENCES


Clinical relevance: Composite resin reconstructions of extended areas, such as direct resin veneers or core buildups, if accomplished in one layer extending to the whole area to be bonded, may experience a decrease of bond strength in their periphery.