Influence of Volumetric Shrinkage and Curing Light Intensity on Proximal Contact Tightness of Class II Resin Composite Restorations: *In Vitro* Study

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Clinical Relevance

Volumetric polymerization shrinkage and curing light intensity should be considered when restoring proximal contact of class II cavities with resin-based materials.

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SUMMARY

Background: **Proximal contact tightness of class II resin composite restorations is influenced by a myriad of factors. Previous studies investigated the role of matrix band type and thickness, consistency of resin composite, and technique of placement. However, the effect of volumetric shrinkage of resin and intensity of curing light has yet to be determined. Thus, the aim of this study was to identify the influence of these factors on the proximal contact tightness when restoring class II cavity preparations *in vitro*.**

Methods: **Sixty artificial molars were restored with either a low-shrinkage (Filtek Silorane, 3M ESPE) or a conventional (Z100, 3M ESPE) composite and polymerized with low-intensity (Smartlite IQ2, Dentsply) or high-intensity light curing units (Demi™, Kerr). Proximal**

contact tightness was measured using the Tooth Pressure Meter. Data were statistically analyzed using one-way analysis of variance and Tukey *post hoc* test.

Results: Use of low-shrinkage composite (Filtek Silorane) resulted in significantly tighter proximal contacts compared to the use of conventional composite (Z100) when cured with the same polymerization unit ($p<0.001$). Moreover, the low-intensity curing unit (IQ2) resulted in significantly tighter contacts than the high-intensity unit when material is constant ($p<0.001$).

Conclusions: Low-shrinkage resin composite and low curing light intensity is associated with tighter proximal contact values.

INTRODUCTION

The reconstruction of tight and anatomically correct proximal contacts in class II composite restorations remains an issue for most general practitioners. The difficulty in achieving tight proximal contacts has been attributed to elasticity and thickness of the matrix[1,2] as well as lack of condensability and shrinkage of resin composite.[3] Several techniques and instruments have been proposed to obtain tight proximal contacts,[1,4] and the general consensus is that with the use of sectional matrix bands in combination with separation rings, adequate proximal contacts can be achieved.[2,3,5-8]

Along with the effect of the matrix system and separation technique on the proximal contact tightness, volumetric shrinkage that occurs during setting of the composite material might also have a significant effect. The volumetric shrinkage for traditional methacrylate-based composites ranges from 2% to 6%.[9] Recently, a low-shrinkage composite was introduced in which the methacrylate matrix is replaced by so-called siloranes. The ring-opening chemistry of this resin significantly reduces the volumetric shrinkage below 1%.[10] The main sequel of polymerization shrinkage is the development of internal contraction stress that can damage the marginal seal of the bonded restorations. Contraction stresses can lead to interfacial gap formation and produce postoperative sensitivity, marginal staining, or recurrent caries. Moreover, cusp displacement may occur, resulting in postoperative sensitivity, crack, or fracture development.[11-14] However, it is unclear if shrinkage has an effect on the obtained proximal contact tightness.

The introduction of new high-power polymerization units has initiated a debate on their effect on the properties of the resin composite material. Volumetric shrinkage, for example, was found to be lower with low-intensity curing units compared to high-intensity ones, with similar irradiation times.[15] Moreover, reduced intensity slowed down the rate of polymerization but did not reduce the conversion as long as an irradiation time of 60 seconds was employed. On the basis of obtaining optimal conversion and adaption, it was demonstrated that the irradiation time was more effective than irradiation energy and that high intensity light curing does not necessarily lead to optimal quality.[16]

The effect of variables such as the thickness and elasticity of the matrix band,[7] different separation techniques,[2-4,6,7] and consistency of the resin composite,[3,7] have already been investigated in several studies. However, the exact effect of the volumetric shrinkage on the obtained proximal contact tightness remains unknown. Therefore, the aim of this study was to investigate, *in vitro*, the effect of two resin composites with different volumetric shrinkage values and the effect of two polymerization units with different light intensities on the obtained proximal contact tightness of class II composite restorations.

The null hypothesis (H_0) of this study was that the amount of volumetric shrinkage of resin composite and the intensity of the curing light will have no statistical significant effect on the proximal contact tightness when restoring class II cavity preparations with resin composite.

MATERIALS AND METHODS

A class II MO-cavity preparation was prepared in an artificial ivorine lower left first molar (Kilgore International, Coldwater, MI, USA). The cavity dimensions for the proximal portion were $5.0 \times 4.0 \times 2.0$ mm buccolingual, occlusogingival, and mesiodistal, respectively, while for the occlusal portions, the dimensions were $4.0 \times 2.5 \times 3.0$ mm buccolingual, occlusopulpal, and mesiodistal, respectively. This preparation was the master model and was duplicated by the manufacturer (Kilgore), resulting in 60 identical preparations. Teeth were placed in a manikin model (Kilgore) and phantom head (KaVo Dental, Biberach, Germany) during all restorative procedures in order to simulate clinical conditions. A copper-zinc alloy cast of the second premolar was used to prevent wear of the distal surface of this tooth during the restorative procedures and proximal contact tightness measurements (Figure 1).[6,7]

Figure 1. *Cavity design used for all test groups*

Specimens were equally divided over four groups according to type of composite and polymerization unit used (n=15). All restorative procedures were performed by one operator (HS). Composite materials used were a low-shrinkage silorane-containing composite material with a volumetric shrinkage of <1%[9] (Filtek Silorane, 3M ESPE, St. Paul, MN) and a conventional methacrylate-based composite material, with a volumetric shrinkage of 2.26-2.61%[17] (Z100, 3M ESPE). Each composite material was polymerized using two light polymerization units: a low-power LED unit (Smartlite IQ2, Dentsply, York, PA, USA, light intensity 700 mW/cm^2) and a high-power LED-unit (Demi[TM], Kerr Corp, Orange, CA, USA, light intensity 1100–1300 mW/cm^2). Both polymerization units had a light guide tip of 8 mm in diameter. The light intensity was measured with the Demetron L.E.D. Radiometer (Detection range: 0–2000 mW/cm^2, Kerr Corporation) at the beginning of the study and every 15 specimens thereafter.

For all groups, a circumferential precontoured matrix (1101c, KerrHawe SA, Bioggio, Switzerland) placed in a Tofflemire retainer (Kerr Corporation) was used. A wedge (Premier Dental Products Co, Plymouth Meeting, PA, USA) was placed from the lingual aspect followed by the application of the separation ring (V-ring, TrioDent, Katikati, New Zealand). The matrix band was lightly burnished with a hand instrument (PFI 49, Dentsply Ash, Weybridge, Surrey, United Kingdom) until no visual space was left between the matrix and adjacent tooth. Also, an explorer was used to check the fit of the matrix band at the gingival margin of the proximal box.

The composite materials were used in combination with the manufacturer-recommended adhesive system. For the low-shrinkage material (Filtek Silor-ane), a special adhesive system (Silorane System Adhesive Self-Etch Primer and Bond, 3M ESPE) was used. For the conventional composite material, a three-step etch-and-rinse adhesive system (Scotchbond Multi-Purpose, 3M ESPE) was employed. Both adhesive systems were applied and polymerized according to the manufacturer's instructions. In all groups, the composite material was placed in three increments of less than 2 mm using a strategic incremental technique to minimize the C-factor.[18] The first increment was applied to the gingival seat, and the second and third increments were applied in an oblique manner to the buccal and lingual cavity walls, respectively. Each increment was cured individually after placement for 20 seconds. After removal of the matrix band, the restorations were postcured for an additional 20 seconds from the buccal and lingual sides. Restorations were not finished or adjusted in order to prevent changes of the proximal surface.

After restoration, the model was removed from the phantom head and placed in a custom-made setup to standardize proximal contact measurement procedures (Figure 2). A second investigator (MS), blinded to the material and curing technique, was asked to perform the proximal contact measurements. Proximal contact tightness was measured using the Tooth Pressure Meter, a device that is constructed at the University of Technology Delft in the Netherlands and was previously used in

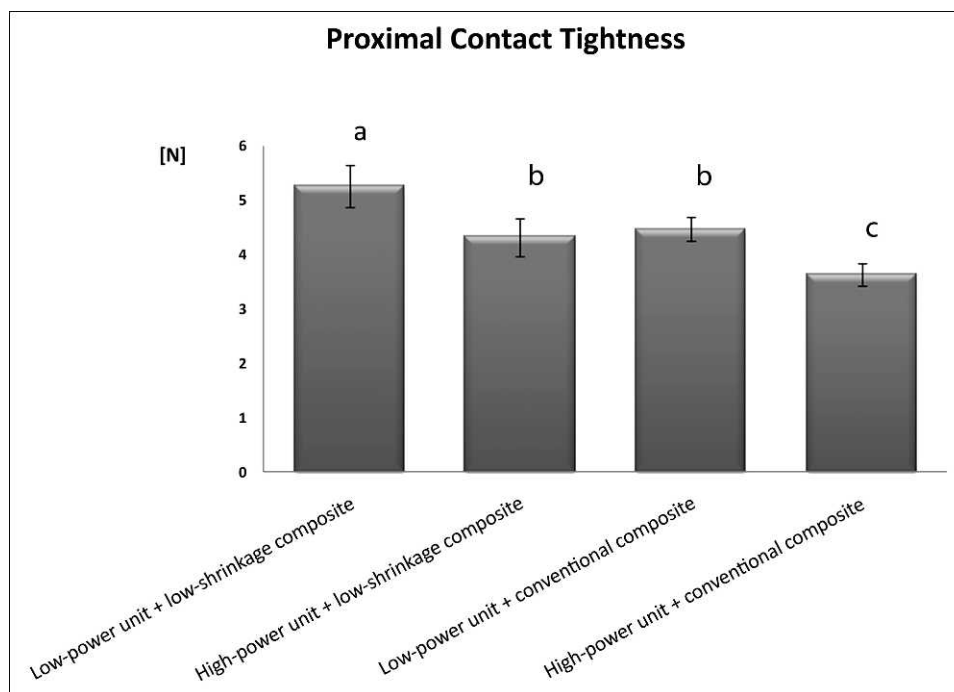Figure 2. *Custom-made setup to standardize measurement using the Tooth Pressure Meter*

Figure 3. *Mean proximal contact tightness (N) with standard deviations for the four groups tested. Different symbols (a, b, and c) indicate statistically significant differences between groups (analysis of variance;* p<*0.05).*

other *in vitro* studies.[6-8,19] This device uses a 0.05-mm-thick metal strip that is inserted interdentally from an occlusal direction. The tightness of the proximal contact is quantified as the maximum frictional force (N) when the strip is removed in the occlusal (vertical) direction. To obtain a standardized measurement of all proximal contact areas, the manikin model and the Tooth Pressure Meter were mounted in a special device allowing a standardized insertion and removal of the metal strip, as shown in Figures 2 and 3. To minimize variations in proximal contact measurements due to repositioning of the tooth in the manikin model, a special protocol for proximal contact measurements was applied. The final result for a measuring site was the mean value of three consecutive measuring procedures. Each procedure included the removal and repositioning of the tooth in the manikin model followed by three consecutive contact measurements using the Tooth Pressure Meter. A measurement failed when the outcome exceeded the maximum (preset) range of 0.5 N between the three measurements, such as due to deformations of the strip or a nonparallel removal of the strip from the interdental area. This measurement was then excluded from the analysis and repeated. Custom-written software in Excel (MS Office 2000 for Windows) was used for data acquisition and for construction of diagrams relating force to seconds.

To determine differences in proximal contact tightness between groups, a one-way analysis of variance followed by Tukey *post hoc* test was performed. The level of significance was set at $p<0.05$.

RESULTS

Figure 3 shows means and standard deviations of the proximal contact tightness. The use of the low-shrinkage composite (Filtek Silorane) resulted in statistically significant tighter proximal contacts compared to conventional composite (Z100) when polymerized using the same curing light ($p<0.001$). Moreover, the low-intensity curing light (IQ2) resulted in statistically significant tighter proximal contacts than the high-intensity one when used with the same composite material ($p<0.001$). The tightest proximal contacts were obtained when the low-shrinkage composite (Filtek Silorane) was cured with low-intensity polymerization unit (IQ2) (5.25 $\pm$ 0.39 N), while the weakest contacts were observed when the conventional composite was polymerized with the high-intensity unit (3.63 $\pm$ 0.20 N). In the case of low-shrinkage composite cured with the high-intensity curing unit (DEM), the obtained proximal contact tightness was 4.32 $\pm$ 0.34 N, which was not statistically significant different from the proximal contacts measured in the conventional composite

cured with the low-power unit (4.47 ± 0.22 N; $p=0.71$).

DISCUSSION

Based on the statistical results, the low-shrinkage resin composite provided significantly higher proximal contact tightness between the materials, while among the polymerization units, the low-power unit resulted in significantly higher proximal contact tightness (IQ2). Thus, the null hypothesis of the study (H_0) was rejected.

The magnitude of volumetric shrinkage experienced by a composite is determined by its filler volume fraction and the composition and degree of conversion of the resin matrix.[20] Volumetric shrinkage is an inherent property specific to each monomer. Studies have shown that silorane-based resin composites exhibit less shrinkage than methacrylate-based resin composites.[10] In methacrylate-based resins, when monomers in proximity react to establish a covalent bond, the distance between the two groups of atoms is decreased, translating into volumetric shrinkage.[20] However, as silorane-based resin polymerizes, ring monomers connect by opening, flattening, and extending toward each other (cationic ring opening process), resulting in less volumetric shrinkage compared to methacrylate-based resins.[10] This difference in curing dynamic is a possible explanation for the difference in proximal contact tightness observed between the two materials. However, this difference in contact tightness could be attributed to differences in the consistency and handling characteristics of the resin composites used in this study. Also, operator bias regarding the material could be a possible influencing factor. The limitations of the study precluded identifying a direct cause-and-effect relationship.

Additionally, the light intensity of the polymerization unit was found to have a statistically significant effect on the proximal contact tightness. Previous studies have shown that low-intensity polymerization units resulted in less volumetric shrinkage than the high-intensity units.[21,22] The volumetric shrinkage of resin composite has been shown to be proportional to its degree of conversion.[23,24] In photoactivated materials, the degree of conversion depends on radiant exposure (J/cm^2), which is the product of light irradiance (intensity) and exposure time.[25] Thus, lower degree of conversion is obtained with low-power intensity at a fixed exposure time, resulting in less volumetric shrinkage. Moreover, the slower curing process will delay the gel point.[9] This allows stress relaxation to occur within the resin and at the interface, reducing the volume of the shrinkage.[9,26] These phenomena may contribute to the greater proximal contact tightness values observed when a low-power unit was used.

In the current study, an *in vitro* model was used to compare the various systems. The validity of this model was demonstrated by Loomans and others[6] and Saber and others,[19] where it was concluded that the *in vitro* model is representative of the clinical situation. Natural tooth movement cannot be reproduced in a laboratory setting. However, the standardization of tooth movement in the current model enabled the authors to determine the influence of the experimental variables on proximal contact tightness.

Finally, it must be pointed out that the provision of interdental separation is the most important consideration when restoring proximal contact of class II resin composite restorations. This can be best achieved by using separation rings.[5-7,19] Nevertheless, this study showed that type of composite, possibly volumetric shrinkage, and intensity of polymerization light influence proximal contact tightness. However, a direct cause-and-effect relationship between shrinkage and contact tightness was not established.

CONCLUSION

The volumetric shrinkage of resin composite and intensity of the curing light should be considered influencing factors during restoration of proximal contact with resin-based materials.

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