Proximal contact tightness of class II bulk-fill composite resin restorations: An in vitro study

Hassan EL-SHAMY1,2, Helal SONBUL1, Najlaa ALTURKESTANI1, Abeer TASHKANDI1, Bas AC LOOMANS3, Christof DÖRFER4 and Wafa EL-BADRAWY5

1 Department of Operative Dentistry Faculty of Dentistry, King Abdulaziz University, Jeddah, Saudi Arabia
2 Nahda University, Faculty of Dentistry, Conservative Dentistry Department, Beni Suef, Egypt
3 Radboud University Nijmegen Medical Center, Department of Preventive and Restorative Dentistry, Nijmegen, The Netherlands
4 Clinic for Conservative Dentistry and Periodontology, School for Oral Medicine, Christian-Albrechts-University at Kiel, Kiel, Germany
5 Restorative Discipline, Faculty of Dentistry, University of Toronto, Toronto, ON, Canada

Corresponding author, Hassan EL-SHAMY; E-mail: halshamy@kau.edu.sa

This study investigated the effect of bulk-fill composites on proximal contact tightness (PCT) of composite restorations using different matrix systems. 150 standardized MO-ivorine cavity preparations were divided into 5 groups; Smart Dentin Replacement (SDR), SonicFill (SF), Tetric EvoCeram Bulk-Fill (TEB), G-ænial Universal Flo (GF) and Tetric EvoCeram (TE). Each group was subdivided into 3 sub-groups (n=10); Dixieland band in Tofflemire retainer, FenderMate and Palodent plus matrix systems. PCT was measured 24 h post-curing using Tooth Pressure Meter. PCT means were calculated and statistically-analyzed using ANOVA and Tukey’s post-hoc test (p<0.05). Means and SD of PCT for Tofflemire subgroup were: 1.75(0.13), 3.21(0.1), 3.06(0.19), 2.49(0.21) and 3.18(0.1) for (SDR), (SF), (TEB), (GF) and (TE), respectively. Using FenderMate, values were: 1.87(0.08), 3.35(0.12), 3.17(0.16), 2.64(0.1) and 3.26(0.11) for (SDR), (SF), (TEB), (GF) and (TE), respectively, while with Palodentplus; 3.16(0.17), 4.23(0.11), 4.1(0.1), 3.46(0.17) and 3.98(0.1) for (SDR), (SF), (TEB), (GF) and (TE), respectively. ANOVA revealed significant differences (p<0.05) between all samples except between (SF), (TEB) and (TE) and also significant difference between Palodentplus and two subgroups. Effect of bulk-fill composites on PCT is material dependent. Separation ring is recommended for proper PCT.

Keywords: Bulk-fill composite, Proximal contact tightness, Dental matrices, Resin composites

INTRODUCTION

Obtaining proper proximal contact tightness (PCT) is challenging in Class II resin composite restorations. It is a physiological dynamic entity of multifactorial origin that is greatly affected by tooth type, location, time of day, patient position, mastication and restorative procedures. There are significant variations in establishing proper PCT both inter- and intra-individually.

One must understand the role of a proximal contact in natural dentition and the importance of reproducing its shape and tightness during tooth restoration. The role of the proximal contact in protecting the periodontium against damage is a crucial factor. It is well known that loose proximal contacts predispose to food impaction, carious lesions, periodontal complications and tooth migration.

The challenge in getting a tight proximal contact with a resin composite has been ascribed to inherent polymerization shrinkage, absence of condensability of resin composite materials, the use of a rubber dam and the thickness of the matrix band. Several techniques and instruments have been proposed to create tighter and more anatomic proximal contacts. Generally, the key factor in producing a tight proximal contact is obtaining an interdental separation during placement of the composite restoration. Several recently introduced matrix systems are available in the market with various degrees of interdental separation. Regardless of the system used, the achieved PCT might change over time.

Several studies have investigated the effect of different matrix systems, the elasticity and thickness of the matrix band, different separation methods, consistency of the resin composite, volumetric shrinkage of different composite materials and intensity of the light curing units on the PCT. However, the effect of the recently introduced bulk-fill composite materials (bulk-fill composite resin is placed at one time rather than small increments) on PCT remains unknown. Therefore, the objectives of the present study in a laboratory setting are multi-fold; first to evaluate the PCT of different composite materials that have been released recently in the market, and second to compare the PCT of Class II composite resin restorations using different matrix systems. In this context, we hypothesize the following: 1) There is no effect of the composite material used on the PCT; and 2) There are no differences between the different matrix systems used to achieve proper contact tightness using various types of bulk-fill composites.

MATERIALS AND METHODS

A total of 150 ivorine lower left first molars (Kilgore International, Coldwater, MI, USA) were used in the present study. All teeth were prepared with MO-
cavity preparation designed to simulate a condition representing replacement of moderately-sized composite restorations. The dimensions of the proximal part of the cavity were 5.0×4.0×2.0 mm buccolingual, occlusogingival, and mesiodistal, respectively, while for the occlusal part; the dimensions were 4.0×2.5×3.0 mm for the buccolingual, occlusopulpal and mesiodistal parts, respectively (Fig. 1).

In order to standardize the cavity design and dimensions throughout the study, 150 duplicates of the prepared tooth were produced by the manufacturer (Kilgore). The lower left second premolar was replaced with a copper-zinc alloy cast replica to prevent wear of the distal surface during cavity restoration and PCT measurements (Fig. 1)13-17. After cavity preparations, teeth were equally and randomly divided into five groups (30 specimens each) according to the type of composite materials used; group1 (SDR); Smart Dentin Replacement, bulk-fill flowable composite (Dentsply, Milford, MA, USA) universal shade, group2 (SF); SonicFill system, bulk-fill composite (Kerr, Orange, CA, USA) Shade A1, group3 (TEB); Tetric EvoCeram Bulk-Fill, bulk-fill composite (IvoclarVivadent, Amherst, NY, USA) universal shade IV A, group4 (GF); G-enial Universal Flo, incremental placed flowable composite (GC Europe, Leuven, Belgium), Shade A1 and group5 (TE); Tetric EvoCeram, incrementally placed universal nano-hybrid composite (IvoclarVivadent), Shade A1. Each group was further subdivided into three subgroups (n=10) according to the type of matrix systems used; subgroup1 was restored with ultrathin (0.038 mm thickness) circumferential pre-contoured Dixieland band (Waterpik, Welshpool, Wales, UK) in a Tofflemire retainer and a medium-sized anatomical plastic wedge, subgroup 2 was restored with FenderMate stainless steel sectional matrix (0.050 mm thickness) attached -as a one unit- with a pre-curved plastic wedge (Directa, Upplands Väsby, Sweden) and subgroup3 was restored using Palodent plus system; sectional contoured deadsoft matrix (0.038 mm thickness) with a bitine separation ring (Dentsply) and a medium-sized hollow underside plastic wedge.

All restorative procedures were performed by two calibrated operators on a manikin model (Kavo Dental, Biberach, Germany) mounted in a manikin head to simulate clinical conditions. Prior to the adhesive procedures, the contact area in the matrix band was carefully burnished with a hand instrument so that no visual space was left between the matrix and the adjacent tooth. An explorer was used to check the maximum adaptation of the matrix band to the gingival margin of the prepared cavity margin. Each composite material was used in conjunction with the manufacturer-recommended adhesive system (SDR/Prime & Bond NT, SF/OptiBond Solo Plus, TEB/Adhese Universal, GF/G-enial Bond and TE/Adhese Universal). The resin composite was applied in bulk (4 mm) for groups SDR, SF and TEB while increment-layering technique (2 mm/layer) was used for group GF and group TE based on manufacturer’s recommendations. Each increment was cured for 20 s from occlusal direction at zero distance using LED light curing unit Elipar S10 (3M/ESPE, St. Paul, MN, USA) with light intensity 1,200 mW/cm². The light intensity was calibrated every five curing sessions using a radiometer (Demetron, Kerr). The restorations were additionally post-cured for 20 s buccally and lingually following matrix band removal. No finishing or adjustment was done for restorations to avoid proximal surface changes.

The manikin model was removed from the manikin head after restoration procedures and replaced in a custom-made setup to standardize proximal contact measurements (Fig. 2). The proximal contract
measurements were carried out by an investigator who was blinded to the type of composite restoration and matrix system used in the groups. PCT was measured using the Tooth Pressure Meter (TPM); a device that was invented at the University of Technology Delft in the Netherlands and was previously used in other in vitro studies.12-17)

A 0.05-mm-thick metal strip was used in this device and inserted occlusally at interdental area to measure the tightness of the proximal contact as the maximum frictional force (N) when the strip is removed occlusally. A special protocol was applied to decrease varieties in proximal contact measurements because of repositioning of the tooth in the manikin model. Three sequential readings were taken for measuring the site and then the mean value was recorded. A measurement is considered to be a failure when the result surpassed the most extreme (preset) range of 0.5 N between the three readings, for example because of deformations of the metal strip or a nonparallel expulsion of the strip from the interdental area. This reading was then rejected from the investigation and repeated. A custom composed

![Fig. 3 Mean proximal contact tightness (N) for the effect of different composite materials using different matrix systems on proximal contact tightness.](image)

**Table 1** Means and standard deviations of proximal contact tightness (N) for the effect of different composite materials using different matrix systems on proximal contact tightness.

<table>
<thead>
<tr>
<th>Matrix systems</th>
<th>Material</th>
<th>Mean±SD</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circumferential metal (Tofflemire) matrix</td>
<td>SDR</td>
<td>1.75±0.13</td>
<td>b</td>
</tr>
<tr>
<td></td>
<td>SonicFill</td>
<td>3.21±0.1</td>
<td>c</td>
</tr>
<tr>
<td></td>
<td>Tetric EvoCeram Bulk-fill</td>
<td>3.06±0.19</td>
<td>c</td>
</tr>
<tr>
<td></td>
<td>G-ænial Universal Flo</td>
<td>2.49±0.21</td>
<td>a</td>
</tr>
<tr>
<td></td>
<td>Tetric EvoCeram</td>
<td>3.18±0.1</td>
<td>c</td>
</tr>
<tr>
<td>FenderMate</td>
<td>SDR</td>
<td>1.87±0.08</td>
<td>b</td>
</tr>
<tr>
<td></td>
<td>SonicFill</td>
<td>3.35±0.12</td>
<td>cd</td>
</tr>
<tr>
<td></td>
<td>Tetric EvoCeram Bulk-fill</td>
<td>3.17±0.16</td>
<td>c</td>
</tr>
<tr>
<td></td>
<td>G-ænial Universal Flo</td>
<td>2.64±0.1</td>
<td>a</td>
</tr>
<tr>
<td></td>
<td>Tetric EvoCeram</td>
<td>3.26±0.11</td>
<td>cd</td>
</tr>
<tr>
<td>Separation ring</td>
<td>SDR</td>
<td>3.16±0.17</td>
<td>c</td>
</tr>
<tr>
<td></td>
<td>SonicFill</td>
<td>4.23±0.11</td>
<td>e</td>
</tr>
<tr>
<td></td>
<td>Tetric EvoCeram Bulk-fill</td>
<td>4.1±0.1</td>
<td>ef</td>
</tr>
<tr>
<td></td>
<td>G-ænial Universal Flo</td>
<td>3.46±0.17</td>
<td>d</td>
</tr>
<tr>
<td></td>
<td>Tetric EvoCeram</td>
<td>3.98±0.1</td>
<td>ef</td>
</tr>
</tbody>
</table>

S.D.=Standard deviation.
P=Probability level for the effect of groups on the proximal contact tightness.
Same letter within each column are not significantly different at \(p<0.05\).
Different symbols (a, b, c, d, e and f) indicate statistically significant differences between groups (analysis of variance; \(p<0.05\)).
program in Excel (MS Office 2007 for Windows) was utilized to collect data and develop diagrams relating force to seconds.

Statistical analysis was performed with SPSS (SPSS 14, Chicago, IL, USA) using one-way analysis of variance followed by Tukey’s post hoc test to determine differences in proximal contact tightness between groups. The level of significance was set at \( p < 0.05 \).

RESULTS

The PCT values recorded for SF and TEB groups were comparable to the control group TE, these values were not statistically different when compared in all matrix systems used \( (p < 0.05) \). PCT values for SDR and GF (the flowable composites) were significantly lower than SF, TEB, and TE regardless of the matrix system used \( (p < 0.05) \).

It is worthy to mention that PCT values recorded for SF showed the highest measurement among all the other materials (Fig. 3).

Table 1 shows the means and standard deviations of PCT when the different composite materials were used with different matrix systems; with ultrathin circumferential pre-contoured Dixieland band matrix system, PCT values recorded were 1.75(0.13), 3.21(0.1), 3.06(0.19), 2.49(0.21), and 3.18(0.1) for SDR, SF, TEB, GF and TE, respectively. Using FenderMate matrix, PCT values were: 1.87(0.08), 3.35(0.12), 3.17(0.16), 2.64(0.1) and 3.26(0.11) for SDR, SF, TEB, GF and TE respectively, while with Palodent plus, PCT values were: 3.16(0.17), 4.23(0.11), 4.1(0.1), 3.46(0.17) and 3.98(0.1) for SDR, SF, TEB, GF and TE, respectively. Generally, the PCT recorded for the tested materials was higher using separating ring (Palodent plus, Dentsply) when compared to the other matrix systems, regardless of the composite material used \( (p < 0.05) \).

DISCUSSION

The main finding of the present study is that, SF and TEB showed PCT values comparable to TE; a universal nano-hybrid resin composite. However, when compared to SDR, bulk-fill composite (flowable) and GF; incremental composite (flowable), SF and TEB produced proximal contacts that were significantly tighter than those produced by the two flowable composites examined, thus the first null hypothesis of the study was rejected. These results might be due to the fact that the consistency and handling characteristics of SF and TEB composites used in this study resemble to a great extent the conventional composite used (TE). SF and TEB are both highly filled materials and exhibit stiff consistency compared to SDR and GF which have more flowable consistency. Loomans et al. showed that the use of medium or high-viscosity composite resulted in statistically significant tighter proximal contacts than a low-viscosity composite resin\(^{10}\). Although high viscosity composite resins are often recommended to obtain a tight proximal contact, previous studies indicated that the ‘packability’ of the resin composite did not help to achieve better proximal contacts\(^{5,6}\). This was also confirmed in this study as both bulk fill composites, TEB and SF showed similar PCT results in spite of the difference in the placement technique for each material. The SF composite utilizes sonic energy that renders the material less viscous during placement. The manufacturer claims that the material contains sonic modifiers that cause the viscosity to drop by 87\(^{14,18}\).

Moreover, some studies revealed that the degree of polymerization shrinkage may influence the PCT. The higher the polymerization shrinkage, the less is the PCT\(^{16,19}\). This confirms our findings. According to Benetti et al., SDR (a flowable bulk-fill composite) produced significantly larger polymerization shrinkage compared to a conventional resin composite, whereas, they found high-viscosity bulk-fill composites SF and TEB exhibited small increase in polymerization shrinkage\(^{14,19}\). This is in agreement with our PCT results where SF and TEB exhibited tighter proximal contacts when compared to the low viscosity materials tested SDR and GF. Other studies also agree with our findings where they showed that a bulk-fill (TEB) had comparable shrinkage to the conventional composite\(^{20,21}\).

The light curing intensity was shown to have a statistically significant difference on the PCT of the polymerized resin composite in previous studies, where the low intensity light-curing unit causes less volumetric shrinkage than the high intensity light-curing unit\(^{16}\). Hence, a fixed light curing intensity was used in this study which was calibrated every five samples using a radiometer throughout the study.

Our results indicated that separation ring groups showed the highest PCT measurement in relation to the other matrix systems. Thus the second null hypothesis of the study was rejected. This might be related to the constant pressure and the interdental separation produced by the tines of the rings on the interdental contact; whereas, the extent of a wedge separation is less than what has been obtained from a separation ring system. Moreover, flexible wedge (FinderMate) that adapts itself to the natural anatomic tooth contours, resulting in even less interdental separation. This was in agreement with the previous studies that considered interdental separation as the most critical factor during reestablishing proximal contact of class II resin composite restorations, they explained this as separation rings create separation force vectors at the height of the proximal contact, which remains stable as long as the ring remains activated\(^{5,6,8,9,16}\). The separation ring used in this study is an improved form of matrix separation ring. It features the same tooth hugging soft silicone tip design that eventually eliminates buccal and lingual flash and is suitable for wide proximal cavities.

PCT is used to be evaluated clinically by passing dental floss interdentally and recording the PCT as ‘satisfactory’, ‘acceptable’ or ‘unacceptable’\(^{22-25}\). This technique is considered unreliable for measurement of minor changes in contact tightness and is often considered to be more subjective. Therefore, TPM device
was used in this study. It was invented at the University of Technology Delft in the Netherlands according to the principles described by Dörfer et al.19 This device is considered more reliable method to evaluate PCT clinically and has been implemented in many laboratory and clinical studies to objectively measure minor changes.2,3,13-17,26-28.

CONCLUSIONS
Under the conditions of this study, it was concluded that:

1. The effect of bulk-fill composites on PCT is material dependent as SonicFill and Tetric EvoCeram Bulk-Fill composites showed comparable PCT.
2. Separation ring is recommended method to obtain proper PCT in MO composite restorations with bulk-fill composite materials.

CONFLICT OF INTEREST
The authors of this manuscript certify that they have no proprietary, financial or other personal interest of any nature or kind in any product, service and/or company that is presented in this article.

ACKNOWLEDGMENTS
This project was funded by Deanship of Scientific Research (DSR) at King Abdulaziz University, Jeddah, under grant no. (G-335-165-1433). The authors, therefore, acknowledge with thanks DSR for technical and financial support. We also acknowledge 3M/ESPE, IvoclarVivadent, Dentsply, Directa, GC Europe and Kerr for material donations.

REFERENCES