Marginal integrity of flowable and packable bulk fill materials used for class II restorations —A systematic review and meta-analysis of in vitro studies

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This systematic review evaluates the marginal integrity of flowable and packable bulk fill composite materials placed in class II cavities. Electronic databases inclusive of MEDLINE, Scopus, and Web of Science were searched without restriction to date. The titles and abstracts of publications gathered from database searches were screened by reviewers according to the inclusion and exclusion criteria. From as initial yield of 142 articles ten studies were subject to qualitative analysis. The authors emphasized that marginal integrity in enamel and dentin does not significantly differ between flowable and packable bulk fill composites used for class II restorations. Moreover, their marginal integrity was comparable to conventional resin composites with incremental techniques. The adhesive system used with a total etch technique and assessed margin located in enamel resulted in better marginal integrity.

Keywords: Bulk fill, Class II cavity, Composite material, Marginal integrity

INTRODUCTION

Increased patient motivation toward esthetic, biocompatible, cost-effective, and clinically durable restorations has led research toward improving the in vivo effectiveness and longevity of resin adhesive bonds to tooth structures in direct resin restorations⁴⁻⁵. With the advancement of dental materials and clinical techniques, composites have become the most widely used direct restorative materials⁹. The polymerization of resin-based composites generates stress due to contraction⁴⁻⁵, which affects marginal integrity. To avoid clinical consequences such as postoperative sensitivity, marginal discoloration, dental microcracking, gap formation, and pulpal irritation, the incremental layering technique is recommended for placing the composite in a cavity²⁻⁶⁻⁸. Up to now it has been a standard to achieve an adequate bonding of composite to tooth tissue⁹. It results in better light penetration and better polymerization of the composite resin, reduced cavity configuration factor, cuspal deflection, or polymerization shrinkage stresses, and ensures that the resin adheres better to cavity walls⁸⁻¹⁰. However, the technique also has many disadvantages, such as the possibility of trapping voids or contaminants between layers, the long time required to place the restoration, or difficulties placing the material after conservative cavity preparation¹⁻⁴,¹⁰.

The bulk fill composite materials were introduced to overcome these disadvantages¹¹. These materials can be divided into flowable (low-viscosity) and packable/sculptable (high-viscosity). High-viscosity bulk fill materials are much more resistant to slumping and contain more inorganic fillers, whereas low-viscosity (or flowable) bulk fill composites generally adapt better on the cavity wall, especially on irregular surfaces⁵. The significantly better marginal integrity of flowable tested materials (SDR, Sonic Fill, Filtek Bulk Fill) is claimed to be due to their flow consistency during application¹¹. On the other hand, they exhibit lower mechanical properties than packable bulk fill materials due to their lower filler content¹²⁻¹³. Generally, such materials are claimed to be curable to a thickness of at least 4 mm, resulting in a need for fewer increments and, thus, time¹²⁻¹³. The manufacturers claim that, when using bulk fill materials, the quality of restoration does not differ from conventional composite resin materials, but the time needed to place the filling is reduced up to 30%. Moreover, the manufacturers state that the polymerization shrinkage of these materials is even less than that of commonly used flowable and conventional resin-based composites, and that the flexural strength is similar to that of conventional composite resins¹⁴. Some studies have shown that bulk fill composites can be cured to an acceptable post-cure depth according to the manufacturers’ claim¹⁵. Higher curing depth has been achieved by either higher translucency of the resin material, to allow deeper penetration of the polymerizing light, or adding new photo initiators¹⁴,¹⁶. The resin composition of these materials is comparable to that of conventional materials¹⁷, and bulk fill resin composites exhibit comparable bottom/top hardness ratios to conventional materials at recommended manufacturer thickness¹⁸. However, the risk of thick layers is that the restoration is not completely cured, especially in cavities with a depth of more than 5 mm, which often appear in clinical practice and are not exactly measured by clinicians. In addition, due to the great translucency, there is a possibility that there may not be an exact color match to the tooth tissue¹⁹. In view of the relatively recent introduction of bulk fill composites, many clinical
Among numerous parameters determining the preservation of a restoration placed in a cavity, marginal integrity and absence of leakage seem to take part as the most important. It is observed especially in class II cavities, in which the problem of microleakage becomes more pronounced at the cervical margins\(^1,2,5)\) because of the difficulty accessing the cavity, the risk of incomplete polymerization around the gingival wall due to the construction of a cement-enamel junction or lack of enamel, and the presence of cementum at the cervical margin, interfering with adequate adhesion. Although a perfect marginal seal is not achievable clinically, a good marginal quality should be the main aim for clinicians\(^1\).

The application of dyes represents the most commonly used method because of its simplicity\(^27\). It is fast and easy to perform, which validates the choice of this method in many studies\(^29\), but the defects outweigh the advantages. This method enables visualization of the inner margin of the filling–tooth border only after cutting the tooth through, resulting in irreversible damage to the sample\(^27\). Furthermore epoxy resin was reported as an adequate material for replicating details of silicone impressions in the indirect study of dentin surfaces\(^31\).

This review aims to organize current knowledge on the marginal integrity of flowable and packable bulk fill composites used for class II restorations and analyzed by SEM. The null hypothesis was that marginal integrity in enamel and dentin does not significantly differ between flowable and packable bulk fill composite materials used for class II restorations.

## MATERIALS AND METHODS

### Data sources

This systematic review is reported in accordance with the PRISMA Statement guidelines. Eligible studies were \(\textit{in vitro}\) surveys that assessed the marginal integrity of bulk fill materials placed in class II cavities with the use of SEM. Included studies should follow a question: Do the flowable and packable bulk fill composite materials allow the same marginal integrity to be obtained in class II restorations? Studies were selected based on a search strategy for each international electronic database (National Library of Medicine —MEDLINE/PubMed, Scopus, and Web of Science). The search strategy is presented in Table 1. The search and selection of studies was performed without any restriction on date or time of observation. The last search was performed on March 9th, 2018. Articles identified in the databases were imported into Endnote\(^\text{TM}\) Basic (Thompson Reuters, Philadelphia, PA, USA) to remove duplicates.

### Resources selection

Two reviewers (A.G-SZ. and K.K.) independently assessed the titles and abstracts of all of the studies. Only articles assessing the marginal integrity of flowable or/and packable bulk fill composite materials were considered. The evaluation of the results must have been performed using SEM. Included studies should be executed on permanent human teeth. Descriptive studies, reviews, case reports, articles negligible for PICO, study using a method other than SEM and articles assessing primary or animal teeth were excluded. Any disagreement regarding the eligibility of the included studies was resolved through discussion and consensus or by a third reviewer (A.N.).

### Risk of bias assessment

The risk of bias was evaluated independently by two

| Database          | Search combination                                                                 |
|-------------------|-------------------------------------------------------------------------------------|
| MEDLINE (PubMed)  | ((bulk fill\[TIAB\] OR bulk-fill\[TIAB\] OR bulk fill composite\[TIAB\] OR bulk fill \(\text{dent}a\)l composite resin\[TIAB\] OR bulk fill resin\[TIAB\] OR bulk fill resin composite\[TIAB\] OR adhesive\[TIAB\] OR gap formation\[TIAB\] OR marginal adaptation\[TIAB\] OR marginal integrity\[TIAB\] OR marginal quality\[TIAB\] OR microleakage\[TIAB\]) AND (sem\[TIAB\] OR scanning electron microscope\[TIAB\] OR class II\[TIAB\])) |
| Scopus            | ((TITLE-ABS-KEY (bulk fill) OR TITLE-ABS-KEY (bulk-fill) OR TITLE-ABS-KEY (bulk fill composite) OR TITLE-ABS-KEY (bulk fill resin) OR TITLE-ABS-KEY (bulk fill dental composite resin)) AND (adhesion OR gap formation OR marginal adaptation OR marginal integrity OR microleakage) OR TITLE-ABS-KEY (sem) OR TITLE-ABS-KEY (scanning electron microscope) OR TITLE-ABS-KEY (class II)) |
| Web of Science    | (((TS=(bulk fill) OR TS=(bulk-fill) OR TS=(bulk fill composite) OR TS=(bulk fill resin) OR TS=(bulk fill dental composite resin)) AND (adhesion OR gap formation OR marginal adaptation) OR TS=(microleakage) OR TS=(scanning electron microscope) OR TS=(class II)) |
Data extraction

Data were extracted from all of the trial documents containing demographic data (author, year), the number of cavities and size of test groups, the materials used (bulk fill composite, conventional composite and bonding agents), the aging/storage parameters, and the outcomes evaluated. If any information was missing, the authors of the studies were contacted via e-mail to retrieve the missing data. If authors did not give any answer, the missing information was not included.

Data analysis

The meta-analysis was conducted using the random and fixed-effects model. To test the heterogeneity among studies the Cochran Q test and I² statistics were used, with an error of p<0.10 and I² above 25, 50 and 75%, indicating low, moderate and high heterogeneity, respectively. A p-value<0.05 was considered statistically significant. All analyses were performed with MedCalc Statistical Software version 17.9.7 (MedCalc Software, Ostend, Belgium).

RESULTS

A total of 142 potentially relevant records were found in the databases. A flowchart summarizing the article selection process according to the PRISMA Statement is shown in Fig. 1. After removing duplicates, examining the titles and abstracts, and full text analyses, a total of 10 articles fulfilled the selection criteria and were included in this review. Twelve studies were excluded due to the use of the dye penetration method.

Six different types of bulk fill composite materials were evaluated (Table 2). Three of the materials are flowable materials placed in bulk, dedicated to use with the conventional composite as the capping material: SDR, Venus Bulk Fill, x-tra base. Two of the materials...
are packable materials, which the manufacturers claim to be used especially as posterior restorations exposed to heavy occlusal loading: Tetric EvoCeram Bulk Fill, Tetric N Ceram Bulk Fill, Sonic Fill combines the features of flowable and packable bulk fill material, while it is sonic activated when placed in the cavity. According to the application technique and no need to be covered by a conventional composite, the authors of articles included to this systematic review and meta-analysis included Sonic Fill as the packable one. The studies included and variables collected are shown in Table 3. Included studies were published between 2011 and 2018 due to the bulk fill materials being relatively new on the market and the limited research assessing marginal integrity.

In this review all included studies in general scored medium risk of bias (Table 4). Of the 10 studies included, none of them showed high risk of bias, four presented medium risk of bias\(^{4,14,43,44}\) and six presented low risk of bias\(^{5,16,45-47}\). Articles received poor scores in the fields of teeth randomization, sample size calculation and blinding of the examiner.

Out of ten qualified studies, one did not present numerical results\(^{16}\), two presented results of marginal integrity in micrometers as either mean values of the interfacial gap distances\(^5\) or median dentin gap formation and range\(^44\) and seven studies\(^2,4,16,43,45-47\) presented the result as the percentage of continuous margin. Within those seven studies, one performed by Roggendorf \(^{46}\) compared the marginal integrity of SDR when using different types of adhesives and another one by Gamarra \(^{45}\) investigated the marginal adaptation and microleakage of SonicFill composite with different photopolymerization techniques. Figure 2 shows the results of five studies that evaluated different types of bulk fill materials and presented good marginal integrity as the percentage of continuous margin.

A meta-analysis was performed only with the 3 studies that presented the most homogenous datasets\(^2,4,45,47\). The outcomes of the identified studies were divided into two analyses based on the part of the restoration margin, where the marginal integrity was assessed (enamel or dentine). Results are presented in Fig. 3. All tested materials, both flowable and packable, presented similar results. There were significant decreases of the mean values observed, when comparing the results before and after thermomechanical loading, regardless of the material tested. The differences were statistically significant \((p<0.05)\). The heterogeneity among the studies was low in part concerning marginal integrity in enamel (21.47%), but high in the part concerning marginal integrity in dentine (74.61%).

Bonding agents used in included studies were both those requiring etching (OptiBond FL\(^4,4,45\), Tetric N-Bond\(^2,5\), Excite F\(^2,5\), XP Bond\(^16,46\), Syntac\(^46\)) and self-etch adhesives (Tetric N-Bond Self Etch\(^2,5\), AdheSE\(^2,5,14\), Xeno V\(^46\), Adper Prompt L-pop\(^46\), iBondSE\(^46\), p90 Sytem Adhesive\(^46\), SEBond\(^47\)). For all surveys, where both self-etch and total-etch technique was used, etch-

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### Table 2 Bulk fill materials used in studies

| Material          | Consistency              | Manufacturer | Composition                                                                                                                                                                                                 |
|-------------------|--------------------------|--------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| SDR               | Flowable                 | Dentsply     | Barium aluminofluoroborosilicate glass, strontium aluminofluorosilicate glass, modified urethane dimethacrylate resin, ethoxylated bisphenol-A-dimethacrylate (EBPADMA), triethylene glycol dimethacrylate (TEGDMA), camphoroquinone photoinitiator, butylated hydroxytoluene (BHT), UV stabilizer, titanium dioxide, iron oxide pigments |
| Sonic Fill        | Flowable, sound          | Kerr         | Glass, oxide, chemicals (10–30%), 3-trimethoxysilylpropyl methacrylate (10–30%), silicon dioxide (5–10%), ethoxylated bisphenol-A-dimethacrylate (1–5%), bisphenol-A-bis(2-hydroxy-3-methacryloxypropyl) ether (1–5%), triethylene glycol dimethacrylate (1–5%) |
| Tetric Evo Ceram  | Packable                 | Ivoclar      | Dimethacrylates (19.7% by weight), prepolymer (17% by weight), bariom Glass fillers, ytterbium trifluoride, Mixed oxide (62.5% by weight), additives, initiators, stabilizers, pigments (<1% by weight) |
| Venus Bulk Fill   |Flowable                  | Kulzer       | UDMA, EBADMA, inorganic fillers such as Ba-Al.-F silicate Glass, YbF\(_3\) and SiO\(_2\) filler particles size 0.02–5.0 micrometers, approximately 65% by weight and 38 vol% |
| x-tra base        | Flowable                 | VOCO         | Monomers: Bis-EMA, MMA Fillers: 75 wt%, 58 vol% Si glass                                                                                                                                                   |
| Study         | Year  | Cavities | Materials                      | Aging/storage                                                                 | Percentage of continuous margins before/after TMC (%)                  | Results                                                                 |
|--------------|-------|----------|--------------------------------|-------------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|
| Agarwal et al. | 2015  | 80       | I. Sonic Fill<sup>1</sup>       | 24 h of storage in distilled water at 37°C                                    | Cervical enamel: I. 94.42/82.40                                      | Internal: I. 59.54                                                   |
|              |       |          | II. SDR+Ceram X<sup>1</sup>     | After thermo-cycled for 2,500 cycles (cyclic immersion at 57/55°C with dwell | II. 76.62/65.66                                                      | II. 55.66                                                            |
|              |       |          | III. Tetric N-Ceram Bulk Fill<sup>1</sup> | time of 2 min and transfer time of 5 s)                                        | III. 92.13/81.49                                                     | III. 49.725                                                        |
|              |       |          | IV. Tetric N Flo+Tetric N Ceram<sup>1</sup> | Thermo-cycled for 5,000 cycles (cyclic immersion at 57/55°C with dwell | IV. 93.53/81.58                                                     | IV. 56.65                                                            |
|              |       |          |                                | time of 15 s and transfer time of 15 s)                                        |                                                                                                                                     |
| Al-Harbi et al. | 2015  | 91       | TC – Tetric Ceram HB<sup>2</sup> | Thermo-cycled for 5,000 cycles (cyclic immersion at 57/55°C with dwell | ENAMEL self etch/total etch:                                                                                           |
|              |       |          | TC+EF – Tetric EvoFlow+Tetric Ceram<sup>2</sup> | time of 15 s and transfer time of 15 s)                                        | TC 7.3/3.4                                                            | CEMENTUM sel etch/Total etch:                                                                                           |
|              |       |          | TC+SD – SDR+Tetric Ceram<sup>i</sup> | Thermo-cycled for 5,000 cycles (cyclic immersion at 57/55°C with dwell | TC+EF 9.1/6.1                                                          | TC 15.5/9.5                                                          |
|              |       |          | TN – Tetric N-Ceram Bulk Fill<sup|i</sup> | time of 15 s and transfer time of 15 s)                                        | TC+SD 8.8/6.4                                                         | TC 16.3/13.4                                                         |
|              |       |          | TE – Tetric Evo Ceram Bulk Fill<sup>e</sup> | Mechanical loaded for 1,000 cycles between 25 and 100 N at 20 Hz              | SF 6.9/6.8                                                            | TC 8.4/6.8                                                          |
|              |       |          | P9 – Filtek P90<sup>f</sup>     |                                                                                                                                         | TN 8.7/6.7                                                            | SF 14.1/14.0                                                         |
|              |       |          |                                |                                                                                                                                         | TE 8.4/6.8                                                            |                                                                                                                                     |
| Al-Harbi et al. | 2016  | 91       | TC – Tetric Ceram HB<sup>2</sup> | Thermo-cycled for 5,000 cycles (cyclic immersion at 57/55°C with dwell | ENAMEL self etch/total etch:                                                                                           |
|              |       |          | TC+EF – Tetric EvoFlow+Tetric Ceram<sup>2</sup> | time of 15 s and transfer time of 15 s)                                        | TC 8.5/6.9                                                            | CEMENTUM sel etch/Total etch:                                                                                           |
|              |       |          | TC+SD – SDR+Tetric Ceram<sup>i</sup> | Thermo-cycled for 5,000 cycles (cyclic immersion at 57/55°C with dwell | TC+EF 9.4/4.9                                                          | TC 70.0/82.3                                                         |
|              |       |          | SF – SonicFill<sup>i</sup>      | time of 15 s and transfer time of 15 s)                                        | TC+SD 9.4/9.3                                                         | TC 70.0/82.3                                                         |
|              |       |          | TN – Tetric N-Ceram Bulk Fill<sup>i</sup> | Mechanical loaded for 1,000 cycles between 25 and 100 N at 20 Hz              | SF 93.1/94.6                                                          | TC 70.0/82.3                                                         |
|              |       |          | TE – Tetric Evo Ceram Bulk Fill<sup>e</sup> |                                                                                                                                         | TN 94.1/94.1                                                         |                                                                                                                                     |
|              |       |          | P9 – Filtek P90<sup>f</sup>     |                                                                                                                                         | TE 94.0/86.1                                                         |                                                                                                                                     |
| Benetti et al. | 2015  | 96       | 1. Venus Bulk Fill<sup>e</sup>  | Stored in distilled water for 10 min                                           |                                                                 | 1. median 10.2 range 3.6–31.7                                      |
|              |       |          | 2. SDR<sup>e</sup>              |                                                                                                                                         | 2. median 6.1 range 3.3–33.0                                      |
|              |       |          | 3. x-tra base<sup>e</sup>       |                                                                                                                                         | 3. median 9.3 range 5.2–36.6                                      |
|              |       |          | 4. Tetric Evo Ceram Bulk Fill<sup>e</sup> |                                                                                                                                         | 4. median 6.6 range 3.2–21.1                                      |
|              |       |          | 5. SonicFill<sup>e</sup>        |                                                                                                                                         | 5. median 7.1 range 3.9–18.0                                      |
|              |       |          | 6. Tetric Evo Ceram<sup>e</sup>  |                                                                                                                                         | 6. median 6.2 range 3.0–12.3                                      |
| Campos et al. | 2014  | 40       | A. Venus Bulk Fill/Venus Diamond<sup>e</sup> | 24 h storage in distilled water at 37°C                                       |                                                                 | 1. median 10.2 range 3.6–31.7                                      |
|              |       |          | B. Tetric EvoCeram Bulk<sup>e</sup> Fill/Tetric EvoCeram<sup>e</sup> | After thermo-cycled for 600 cycles (cyclic immersion at 57/50°C with dwell | 2. median 6.1 range 3.3–33.0                                      |
|              |       |          | C. Surefill SDR/Ceram-X<sup>e</sup> | time of 2 min and transfer time of 5 s)                                       | 3. median 9.3 range 5.2–36.6                                      |
|              |       |          | D. Sonic Fill<sup>e</sup>       |                                                                                                                                         | 4. median 6.6 range 3.2–21.1                                      |
|              |       |          | E. Ceram-X/Ceram-X<sup>e</sup> (control) | Mechanical loaded for 240,000 cycles between at max 49 N at 1.7 Hz             | 5. median 7.1 range 3.9–18.0                                      |
|              |       |          |                                |                                                                                                                                         | 6. median 6.2 range 3.0–12.3                                      |
| Study                  | Year | Class   | Material/Adhesive          | Marginal integrity as the percentage of the entire margin length (%) | Percentages of continuous margins before/after loading (%) | Percentage of the entire margin length before/after TMC (%) | Percentage of continuous marginal adaptation before/after loading (%) |
|------------------------|------|---------|-----------------------------|-----------------------------------------------------------------------|----------------------------------------------------------------|----------------------------------------------------------------|---------------------------------------------------------------------|
| De Assis et al. 16     | 2016 | Class II (n=10) | 1. SDR/conservative\(^1\) 2. SDR/extended\(^1\) 3. TPH3 Spectrum/conservative\(^1\) 4. TPH3 Spectrum/extended\(^1\) | 24 h storage in distilled water at 37°C | 1. Sonic Fill\(^e\) –conventional polymerization 20 s at 1,200 mW/cm\(^2\) (24 J/cm\(^2\)) 2. Sonic Fill\(^e\) –conventional polymerization 40 s at 1,200 mW/cm\(^2\) (48 J/cm\(^2\)) 3. Sonic Fill\(^e\) –soft-start polymerization 5 s at 650 mW/cm\(^2\) and 15 s at 1,200 mW/cm\(^2\), (21.25 J/cm\(^2\)) 4. Sonic Fill\(^e\) –soft-start polymerization 10 s at 650 mW/cm\(^2\) and 30 s at 1,200 mW/cm\(^2\), (42.5 J/cm\(^2\)) | 24 h storage in distilled water at 37°C | 1. 95.9 2. 94.4 3. 93.5 4. 90.9 | 1. 95.9/87.4 2. 96.8/62.4 3. 96.0/90.0 4. 94.8/69.2 | 1. 96.9/92.8 2. 96.9/87.2 3. 98.1/91.2 4. 94.1/69.2 | 1. 96.9/87.4 2. 96.9/87.2 3. 98.1/91.2 4. 94.1/69.2 | 1. 96.9/87.4 2. 96.9/87.2 3. 98.1/91.2 4. 94.1/69.2 |
| Gamarra et al. 18      | 2018 | Class II MOD (n=10) | 1. Sonic Fill\(^e\) –conventional polymerization 20 s at 1,200 mW/cm\(^2\) (24 J/cm\(^2\)) 2. Sonic Fill\(^e\) –conventional polymerization 40 s at 1,200 mW/cm\(^2\) (48 J/cm\(^2\)) 3. Sonic Fill\(^e\) –soft-start polymerization 5 s at 650 mW/cm\(^2\) and 15 s at 1,200 mW/cm\(^2\), (21.25 J/cm\(^2\)) 4. Sonic Fill\(^e\) –soft-start polymerization 10 s at 650 mW/cm\(^2\) and 30 s at 1,200 mW/cm\(^2\), (42.5 J/cm\(^2\)) | 24 h storage in distilled water at 37°C | 1. 95.9 2. 94.4 3. 93.5 4. 90.9 | 24 h storage in distilled water at 37°C After thermo-cycled for 2,500 cycles (cyclic immersion at 5°/55°C with dwell time of 30 s) | 1. 95.9/87.4 2. 96.8/62.4 3. 96.0/90.0 4. 94.8/69.2 | 1. 96.9/87.4 2. 96.9/87.2 3. 98.1/91.2 4. 94.1/69.2 | 1. 96.9/87.4 2. 96.9/87.2 3. 98.1/91.2 4. 94.1/69.2 | 1. 96.9/87.4 2. 96.9/87.2 3. 98.1/91.2 4. 94.1/69.2 |
| Heintze et al. 14      | 2015 | Class II (n=8) | A. Tetric EvoCeram Incremental\(^a\) B. Tetric EvoCeram Bulk Fill\(^a\) C. Tetric EvoCeram Incremental\(^c\) D. Tetric EvoCeram Bulk Fill\(^c\) | 24 h storage in distilled water at 37°C | 1. Sonic Fill\(^e\) –conventional polymerization 20 s at 1,200 mW/cm\(^2\) (24 J/cm\(^2\)) 2. Sonic Fill\(^e\) –conventional polymerization 40 s at 1,200 mW/cm\(^2\) (48 J/cm\(^2\)) 3. Sonic Fill\(^e\) –soft-start polymerization 5 s at 650 mW/cm\(^2\) and 15 s at 1,200 mW/cm\(^2\), (21.25 J/cm\(^2\)) 4. Sonic Fill\(^e\) –soft-start polymerization 10 s at 650 mW/cm\(^2\) and 30 s at 1,200 mW/cm\(^2\), (42.5 J/cm\(^2\)) | 24 h storage in distilled water at 37°C After thermo-cycled for 10,000 cycles (cyclic immersion at 5°/55°C) | 1. 95.9 2. 94.4 3. 93.5 4. 90.9 | 24 h storage in distilled water at 37°C After thermo-cycled for 2,500 cycles (cyclic immersion at 5°/55°C with dwell time of 30 s) | 1. 95.9/87.4 2. 96.8/62.4 3. 96.0/90.0 4. 94.8/69.2 | 1. 96.9/87.4 2. 96.9/87.2 3. 98.1/91.2 4. 94.1/69.2 | 1. 96.9/87.4 2. 96.9/87.2 3. 98.1/91.2 4. 94.1/69.2 | 1. 96.9/87.4 2. 96.9/87.2 3. 98.1/91.2 4. 94.1/69.2 |
| Roggendorf et al. 80   | 2011 | Class II (n=10) | 1. SDR+CeramX mono\(^l\) 2. SDR+CeramX mono\(^k\) 3. SDR+Tetric Evo Ceram\(^h\) 4. SDR+Filtek Supreme XT\(^j\) 5. SDR+Venus Diamond\(^d\) 6. CeramX mono\(^l\) 7. CeramX mono\(^k\) 8. Tetric Evo Ceram 9. Filtek Supreme XT 10. Venus Diamond | 21 days storage in distilled water at 37°C | 1. 95.9 2. 94.4 3. 93.5 4. 90.9 | 24 h storage in distilled water at 37°C | 1. 95.9/87.4 2. 96.8/62.4 3. 96.0/90.0 4. 94.8/69.2 | 1. 96.9/87.4 2. 96.9/87.2 3. 98.1/91.2 4. 94.1/69.2 | 1. 96.9/87.4 2. 96.9/87.2 3. 98.1/91.2 4. 94.1/69.2 | 1. 96.9/87.4 2. 96.9/87.2 3. 98.1/91.2 4. 94.1/69.2 |
| Shahidi et al. 40      | 2017 | Class II MOD (n=10) | TET –Tetric Evo Ceram\(^g\) SDR –SDR+CeramX mono\(^l\) ELS1 –ELSflow+ELS\(^g\) ELS2 –ELS\(^g\) SOF –Sonic Fill\(^g\) | 24 h storage in saline at room temperature | 1. 95.9 2. 94.4 3. 93.5 4. 90.9 | 24 h storage in saline at room temperature | 1. 95.9/87.4 2. 96.8/62.4 3. 96.0/90.0 4. 94.8/69.2 | 1. 96.9/87.4 2. 96.9/87.2 3. 98.1/91.2 4. 94.1/69.2 | 1. 96.9/87.4 2. 96.9/87.2 3. 98.1/91.2 4. 94.1/69.2 | 1. 96.9/87.4 2. 96.9/87.2 3. 98.1/91.2 4. 94.1/69.2 |

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**a:** dheSE, **b:** Adper Prompt L-pop, **c:** Excite F, **d:** iBond self-etch, **e:** OptiBond FL, **f:** P90 System Adhesive, **g:** SE Bond, **h:** Syntac, **i:** Tetric N-Bond, **j:** Tetric N-Bond Self-Etch, **k:** Xeno V, **l:** XP Bond
Table 4  Quality assessment and risk of bias

| Author                | The same type of teeth | Teeth or samples randomization | Teeth free of caries | Similar size of sample | Materials used according to manufacturers’ instructions | Control group | Sample size calculation | Blinding of the examiner | Risk of bias |
|-----------------------|------------------------|--------------------------------|----------------------|------------------------|--------------------------------------------------------|---------------|--------------------------|---------------------------|--------------|
| Agarwal et al.        | YES                    | NO                             | YES                  | YES                    | YES                                                   | YES           | NO                       | NO                        | Medium       |
| Al.-Harbi et al.      | YES                    | YES                            | YES                  | YES                    | YES                                                   | YES           | NO                       | NO                        | Low          |
| Al-Harbi et al.       | YES                    | YES                            | YES                  | YES                    | YES                                                   | YES           | NO                       | NO                        | Low          |
| Benetti et al.        | YES                    | NO                             | YES                  | YES                    | NO                                                    | YES           | NO                       | NO                        | Medium       |
| Campos et al.         | YES                    | NO                             | YES                  | YES                    | NO                                                    | YES           | NO                       | NO                        | Medium       |
| De Assis et al.       | YES                    | NO                             | YES                  | YES                    | YES                                                   | YES           | NO                       | YES                       | Low          |
| Gamarra                | YES                    | YES                            | YES                  | YES                    | YES                                                   | YES           | NO                       | YES                       | Low          |
| Heintze et al.        | YES                    | NO                             | YES                  | YES                    | YES                                                   | YES           | NO                       | NO                        | Medium       |
| Roggendorf et al.     | YES                    | YES                            | YES                  | YES                    | YES                                                   | YES           | NO                       | YES                       | Low          |
| Shahidi et al.        | YES                    | YES                            | YES                  | YES                    | YES                                                   | YES           | NO                       | NO                        | Low          |

Fig. 2  Good marginal adaptation expressed as the percentage of gap free margins (%) in studies using SEM analysis.
*: results after thermomechanical loading, E: extended preparation of the cavity, C: conservative preparation of the cavity, TE: total-etch technique, SE: self-etch technique
and-rinse adhesives performed better than self-etch adhesives\(^{2,5,14,46}\). Aging and the types of adhesives had no significant influence on the difference in marginal integrity between flowable and packable bulk fill resin composites.

Authors of the included studies emphasized, that there were no significant differences in terms of marginal integrity for both layering and bulk filling technique\(^{5,16,43,47}\). The bulk fill composites did not significantly improve marginal integrity compared to the conventional group\(^{2,4}\).

**DISCUSSION**

Long-term adhesion of dental materials used in conjunction with bonding agents is an important factor for clinical success, especially in the case of materials shrinking during polymerization, which can lead to a marginal gap and microleakage, caries, or postoperative pathological hypersensitivity reaction in the pulp of the tooth. Among many factors defining the quality of materials that restore lost tooth tissues, marginal integrity seems to be the most important\(^ {1,8}\). Due to enhanced translucency and the incorporation of a specific photoactive group, the polymerization kinetics of bulk fill materials are claimed to be better controlled, enabling the composite base to be injected and cured in layers up to a depth of 4 or even more millimeters\(^{9}\). The use of the bulk fill technique undoubtedly simplifies the restorative procedure and saves clinical time in cases of deep, wide cavities\(^ {44}\). In addition to the depth of cure, curing composites in bulk potentially affects polymerization shrinkage stress. Polymerization shrinkage stress is a serious concern for clinicians because it has been associated with postoperative sensitivity and bond failure\(^ {48}\). Despite important improvements in dental adhesives and materials, class II composite restorations with cervical margins in dentine are sensitive to marginal discontinuity\(^ {4}\). About 80% of marginal caries develop at the gingival-cervical margin of class II restorations\(^ {49}\). To the best of our knowledge this review is the first such article comparing information on the marginal integrity of flowable and packable bulk fill materials in class II cavities, which can help clinicians choose suitable materials and possibly save time while restoring class II cavities. The null hypothesis was confirmed because the flowable and packable bulk fill composites assessed in the analyzed studies presented similar results regarding marginal integrity.

The replica SEM method is a well-established procedure that allows for qualitative and quantitative evaluation of the margin\(^ {2}\). Moreover, it can be applied for in vitro and in vivo screening of restorations\(^ {2}\). Using SEM analysis of the marginal integrity of replicas, the results were more precise and expressed as a percentage of the continuous gap-free margin before and after thermocycling\(^ {2,4,16,43,45,47}\). According to the authors of included studies, despite the difference in physical parameters used, all results indicated better marginal integrity in enamel than in dentine\(^ {4,43,47}\), with the worst results in the internal margin\(^ {43}\). A high variability before and after thermocycling and mechanical loading was also noted\(^ {4,43,47}\), which suggests that further surveys need to be conducted under similar conditions, as they reflect the clinical situation accurately. It is believed that the existing occlusive load of the oral cavity and the thermal
changes favor the formation of a marginal gap at the contact surface between the tooth and material\textsuperscript{10}. Meta-analysis presented in this review showed a significant decrease of the mean values of the marginal integrity after thermomechanical loading. The decrease was observed both for the flowable (SDR, Venus Bulk Fill) and packable (Sonic Fill, Tetric N Ceram Bulk Fill, Tetric Evo Ceram Bulk Fill) bulk fill composite materials. Gap formation was larger for x-tra base and Venus Bulk Fill than conventional composite, and not much difference in gap formation was observed between the conventional resin composite and SDR, Tetric EvoCeram Bulk Fill, or Sonic Fill\textsuperscript{44}. The bulk fill composites did not meaningly improve the marginal integrity compared to conventional composite\textsuperscript{5}. In the studies using SEM analysis, Sonic Fill had satisfactory results among bulk fill materials, probably due to the initial flowability induced by the sonic energy and the low volumetric shrinkage and high filler loading compensating for bulk curing by reducing polymerization contraction stress\textsuperscript{9}. Tetric EvoCeram Bulk Fill, a packable bulk fill material, seemed to have the most repeatable results, possibly because of high filler volume and lower polymerization contraction than flowable bulk fill materials\textsuperscript{12,44}. The influence of the kind of bonding agent was evaluated in two reports\textsuperscript{14,46}. Within the same adhesive system, the percentage of regular margin was not much influenced by either the incremental technique or the evaluation method; the type of filling technique and filling material also had no significant influence on the results\textsuperscript{14}. However, in recent studies, phosphoric acid-etching remained the most reliable method for achieving a fatigue-resistant enamel bond\textsuperscript{125,60}. All of the studies showed that a bonding agent requiring total etching results in better marginal integrity in enamel and dentine. In terms of stability and degradation resistance, the total-etch bonding technique has been reported to produce more reliable resin-dentin hybrid layers than self-etch adhesives, particularly at the enamel margin\textsuperscript{5}. The bond in self-etching adhesive systems is based on mild acid demineralization, the formation of stable calcium salts, and a weak chemical bond to hydroxyapatite\textsuperscript{46}.

There is no standardized method for assessing marginal integrity. Therefore, the variations in the results may be explained by differences in restorative materials, flowable liners, bonding systems, and especially testing procedures\textsuperscript{5}. In addition, different polymerization sources or restoring cavities with different designs or C-factors can decrease the marginal microleakage\textsuperscript{30}. There is also no standardized protocol for thermocycling, as several different regimens have been proposed to simulate clinical function\textsuperscript{8}. Taking this into consideration, one standardized protocol for thermocycling, mechanical loading, and assessment should be introduced to obtain the most reliable results.

CONCLUSION

The present review indicates that flowable and packable bulk fill composites present similar marginal integrity when used for the restoration of class II cavities. However, more long-term clinical studies are needed to fully assess their mouth conditions.

CLINICAL SIGNIFICANCE

According to the general desire to simplify the procedure of filling cavities, bulk fill composites may prove to be commonly used materials.

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