©Operative Dentistry, 2017, **42-6,** 616-625

Radiopacity and Porosity of Bulk-fill and Conventional Composite Posterior Restorations—Digital X-ray Analysis

CJ Soares • CMP Rosatto • VF Carvalho • AA Bicalho • JCG Henriques • AL Faria-e-Silva

Clinical Relevance

Bulk-fill composites present proper radiodensity when used as posterior restorative materials and allow secondary caries or cervical marginal defects to be easily detected. Furthermore, restorations performed with bulk-fill flowable composites demonstrated a reduced incidence of voids.

SUMMARY

Objectives: To compare radiopacity and porosity as expressed by the presence of voids in restorations carried out using bulk-fill and incremental filling techniques to restore large mesio-occlusal-distal (MOD) cavities.

Methods: Fifty-five molars with MOD preparations were incrementally filled with Filtek Z-350XT (Z350XT) or bulk-fill composite: Filtek Bulk Fill/Z-350XT (FBF/Z350XT), Venus Bulk Fill/Charisma Diamond (VBF/CHA), SDR/Esthet-X HD (SDR/EST-X), Tetric EvoCeram Bulk Fill (TEC). Digital radiographic images (Vistascan scanner) were taken of restored molars and analyzed at the gingival and isthmus floors. Radiodensity measurements were performed using standardized points symmetrically distributed over each region of composite and tooth structure. Three calibrated evaluators visually assessed the presence of voids. Confidence intervals were calculated, and data were analyzed using analysis of variance and χ^2 tests.

Results: TEC and VBF/CHA showed significantly higher radiodensities, while the lowest

*Carlos José Soares, Department of Operative Dentistry and Dental Materials, Dental School, Federal University of Uberlândia, Uberlândia, Minas Gerais, Brazil

Camila M. Perez Rosatto, Department of Operative Dentistry and Dental Materials, Dental School, Federal University of Uberlândia, Uberlândia, Minas Gerais, Brazil

Valessa Flausino Carvalho, Department of Operative Dentistry and Dental Materials, Dental School, Federal University of Uberlândia, Uberlândia, Minas Gerais, Brazil

Aline Aredes Bicalho, Department of Operative Dentistry and Dental Materials, Dental School, Federal University of Uberlândia, Uberlândia, Minas Gerais, Brazil

João César Guimarães Henriques, Department of Radiology and Stomatology, Dental School, Federal University of Uberlândia, Uberlândia, Minas Gerais, Brazil

André Luis Faria-e-Silva, Department of Operative Dentistry, Dental School, Federal University of Sergipe, Aracaju, Sergipe, Brazil

*Corresponding author: Av. Pará, 1720, Bloco 4LA, Sala 42, Campus Umuarama.

Uberlândia - Minas Gerais – Brazil CEP. 38400-902; e-mail: carlosjsoares@ufu.br

DOI: 10.2341/16-146-L

values were observed for FBF/Z350XT and Z350XT. Radiodensity at the cervical regions tended to be greater than that found at the isthmus floor. The lowest incidence of voids was found for VBF/CHA, whereas the incremental insertion technique resulted in the highest rate of voids.

Conclusion: Bulk-fill composite resin demonstrated an adequate level of radiodensity and a reduced presence of voids compared with the incremental filling technique.

INTRODUCTION

Three hundred million direct composite restorations are performed annually in the world, representing one of the most common interventions in the human body.[1] In order to improve the clinical performance of these restorations, different filling techniques have been proposed, and new composites have been developed to reduce polymerization stress and improve the mechanical properties of restorative materials.[2-6] Regarding restorative technique, insertion of a composite using 2-mm oblique increments was advocated for a long time to achieve proper depth of polymerization and reduced polymerization stress.[2-4] However, due to the time-consuming nature of this technique, composites (known as "bulk-fill") that can be light cured through deeper increments while maintaining reduced polymerization stresses were recently introduced to the market.[7] Bulk-fill composites are gaining popularity among clinicians because reducing the time required to restore large cavities has resulted in a simpler restorative procedure.[1,8]

Secondary caries located under the gingival walls of the proximal box is a common cause of failure observed in posterior composite restorations,[9] although this diagnosis is hard to assess clinically. Materials used to restore cavities in posterior teeth must provide enough radiopacity to allow for the diagnosis of secondary caries.[10-12] Moreover, proper radiopacity allows clinicians to diagnose defects in adaptation, the contour of a restoration, contact with adjacent teeth, interfacial gaps, and voids in the restoration.[13,14]

Although most manufacturers state that their materials are radiopaque, there is no clear agreement on the degree of radiodensity for facilitating the detection of caries and defects adjacent to restorations.[14,15] International organizations have recommended procedures for quantifying composite resin radiopacity using an aluminum step as a reference.[16,17] Recent studies using bulk-fill composite resins reported that all composites evaluated demonstrated the minimum requirements demanded by International Organization for Standardization and American National Standards Institute/American Dental Association standards.[17,18] Varying the thicknesses of bulk-fill composite resin also affects the radiopacity,[18] demonstrating that the method used for radiopacity analysis may interfere with the material's performance. Use of a tooth with a standardized cavity preparation is a reasonable alternative for detecting radiolucency around restorations as it allows for the evaluation of the radiodensity of restorative materials in clinically relevant areas, such as the gingival margins of inlay restorations.[14]

The restorative technique is mainly determined by the composite resin used, and when a conventional composite resin is used, the incremental filling technique is recommended.[2,3] The layering methods may affect the adaptability of the composite resin to cavity walls and sequential increments, generating porosities that are expressed by voids.[19] Using a bulk-fill composite resin can eliminate this flaw by improving the homogeneity of material distribution inside the bulk restoration. The increased flowability of most bulk-fill flowable composites may also influence the presence of cavity adaptation and voids. On the other hand, past bulk-fill composites demonstrated no improvement on adaptability.

No prior studies, according to the authors' knowledge, have analyzed the radiopacity and porosity achieved using flowable or regular viscosity bulk-fill composites compared with the incremental filling technique in posterior restorations. Therefore, the aim of this study was to evaluate the radiodensity of conventional composite resin placed incrementally in oblique layers, a high viscosity bulk-fill placed in a single bulk layer, and flowable composites placed in two layers (at the gingival walls and isthmus floor), as well as the detection of voids in the restoration. The null hypotheses were that bulk-fill composite has the same radiopacity performance as the conventional composite resin and that the presence of voids is not affected by the composite and insertion technique.

METHODS AND MATERIALS

Fifty extracted, sound, caries-free, human molars were used in this study. The teeth were selected considering an intercuspal width within a maximum deviation of 10% from the mean calculated among the teeth selected (ranging from 4.8 to 6.0 mm). The

Table 1: *Composites Used in This Study*

Composite	Manufacturer	Lot No.	Composition[a]
Filtek Z-350XT	3M ESPE (St Paul, MN, USA)	N491808	Organic matrix: Bis-GMA, Bis-EMA, UDMA, TEGDMA
			Filler type: Silica and zirconia nanofillers, agglomerated zirconia-silica nanoclusters
			Filler content: 82 wt%/ 60 vol%
Tetric EvoCeram Bulk Fill	Ivoclar Vivadent, (Schaan, Liechtenstein)	R49602	Organic matrix: UDMA, Bis-GMA
			Filler type: Barium glass, ytterbium trifluoride, mixed oxide prepolymer
			Filler content: 79 wt%/ 61 vol%
Venus Bulk Fill	Heraeus-Kuzer (Hanau, Germany)	010103	Organic matrix: UDMA, TEGDMA
			Filler type: Barium glass, ytterbium trifluoride, silicon dioxide
			Filler content: 65 wt%/ 38 vol%
Charisma Diamond	Heraeus-Kuzer (Hanau, Germany)	010049	Organic matrix: TCD-DI-HEA, UDMA
			Filler type: Bariumm, aluminium, fluoride glass
			Filler content: 81 wt%/ 64 vol%
SDR	Dentsply (Konstanz, Germany)	760231E	Organic matrix: Modified UDMA, dimethacrylate and difunctional diluents
			Filler type: Barium and strontium alumino-fluoro-silicate glasses
			Filler content: 68 wt%/ 44 vol%
Esthet-X HD	Dentsply (Konstanz, Germany)	897887F	Organic matrix: Bis-GMA adduct, EBPADMA, TEGDMA.
			Filler type: Ba-F-Al-B-Si-glass, silica.
			Filler content: 76 wt%/ 60 wt%
Filtek Bulk Fill	3M ESPE (St Paul, MN, USA)	N491808	Organic matrix: UDMA, BISGMA, EBPADMA, procrylate resin
			Filler type: Silane-treated ceramic and YbF
			Filler content: 64 wt%/ 42.5%

[a] Composition as given by manufacturers.
Bis-EMA, ethoxylated bisphenol-A dimethacrylate; Bis-GMA, bisphenol A diglycidyl dimethacrylate; EBPADMA: ethoxylated bisphenol-A dimethacrylate; TCD-DI-HEA, 2-propenoic acid, (octahydro-4, 7-methano-1H-indene-5-diyl) bis-methyleneiminocarbonyloxy-2, 1-ethanediyl) ester; TEGDMA, triethylene glycol dimethacrylate; UDMA, urethane dimethacrylate; YbF, ytterbium trifluoride.

roots were embedded in a polystyrene resin (Cristal, Piracicaba, Brazil) up to 2 mm below the cemento-enamel junction. The teeth received a Class II mesio-occlusal-distal (MOD) preparation that was 4/5 of the intercuspal width (buccal-lingual dimension = 5.1±0.8 mm), 4 mm deep in the occlusal box, and 1 mm deep in the proximal box using a diamond bur (#3146 diamond bur, Microdont, São Paulo, Brazil) performed using a high-speed handpiece and copious air-water spray. The handpiece was attached to a cavity preparation machine allowing for the control of the bur movement.[20]

The composites used to restore the cavities are described in Table 1. The cavities were randomly allocated to be restored using one of the techniques/composites described in Table 2 (n=10). The same self-etching adhesive system (Clear Fill SE Bond, Kuraray, Tokyo, Japan) was used for all groups. The composites were light-activated using a quartz-tungsten-halogen unit (800mW/cm2; Optilux 501, Kerr Manufacturing Co, Orange, CA, USA), according to the manufacturer's instructions: 40 seconds for Filtek Bulk Fill and 20 seconds for all other composites. The Tetric EvoCeram Bulk Fill (TEC) was used for restoring both dentin and enamel in a bulk increment. The flowable bulk-fill composite groups were filled in 2 horizontal layers, the first increment filled the dentin depth (3.5-4.0 mm in depth) using bulk-fill flowable composite; then, the enamel layer (1.0-1.5 mm in depth) was filled using a regular conventional composite from the same manufacturer (Table 2). Cavities in the control group were filled incrementally using six oblique increments with a conventional resin composite. A Teflon matrix was made to standardize each composite resin increment before insertion into the cavity.[2] A device was created to simulate adjacent premolars

Table 2: *Descriptions of Groups*

Group	Technique	Procedure
Z350XT	Incremental	Z350XT was inserted and light cured in increments up to 2mm until the entire cavity was filled.
TEC	Bulk fill 1-increment	Tetric EvoCeram was inserted in a single increment, filling the entire cavity.
VBF/CHA	Bulk fill 2-increment	1. The flowable composite, Venus Bulk Fill, was placed in a single increment to fill the proximal box and the region corresponding to dentin tissue in the occlusal box. 2. The restoration was completed using the composite with regular viscosity, Charisma Diamond.
SDR/EST-X	Bulk fill 2-increment	1. The flowable composite, SDR, was placed in a single increment to fill the proximal box and the region corresponding to dentin tissue in the occlusal box. 2. The restoration was completed using the composite with regular viscosity, Esthet-X HD.
FBF/Z350XT	Bulk fill 2-increment	1. The flowable composite, Filtek Bulk fill flow, was placed in a single increment to fill the proximal box and the region corresponding to dentin tissue in the occlusal box. 2. The restoration was completed using the composite with regular viscosity, Z350XT.

Abbreviations: FBF/Z350XT, Filtek Bulk Fill/Z-350XT; SDR/EST-X, SDR/Esthet-X HD; TEC, Tetric EvoCeram Bulk Fill; VBF/CHA, Venus Bulk Fill/Charisma Diamond; Z350XT, Filtek Z-350XT.

and molars to allow for interproximal contact during restoration.[8]

Radiopacity Measurement m=Method

The samples were positioned over a phosphor plate, and the radiographic exposure was performed using the Timex 70 E (Gnatus, Ribeirão Preto, Brazil), exposing the specimens for 0.25s at 70 kV and 7.0 mA. The focal spot to object distance was set at 50 cm. Three exposures were performed for each sample. The radiographs were transferred from the phosphor plate to a computer using a Vistascan scanner (Vistascan, Durr Dental, Bietigheim-Bissingen, Germany). The radiodensity (in pixels) of the samples was determined using the resident software provided by the manufacturer. Five measurement lines were defined: two at the cervical margins, for both the mesial and distal surfaces, and three points at the isthmus floor.[14] All of the measurements were taken symmetrically on the axial plane of teeth and restorative surfaces (Figure 1). Each digital image had radiodensity measured at each measurement line (Figure 1), immediately after scanning, without any modification to contrast or brightness. The mouse cursor was positioned under this measurement line on the tooth structure or restorative material to obtain the radiodensity values for each sample, and the means of readings were calculated and used in further data analysis.[14]

The digital radiographs were analyzed by three calibrated operators to visually detect the porosity expressed by bubbles and voids. Differences in radiodensity values between the tooth structure and composite restoration were calculated for all measurement lines at each region (cervical and isthmus floor). The absence or presence of voids was recorded by analyzing the entire bulk of restorations. Further, the digital radiographs were transferred to ImageJ software (Java-based image processing and analysis software developed at the National Institutes of Health, Bethesda, MD, USA) to measure the size of each detected void (Figure 2).

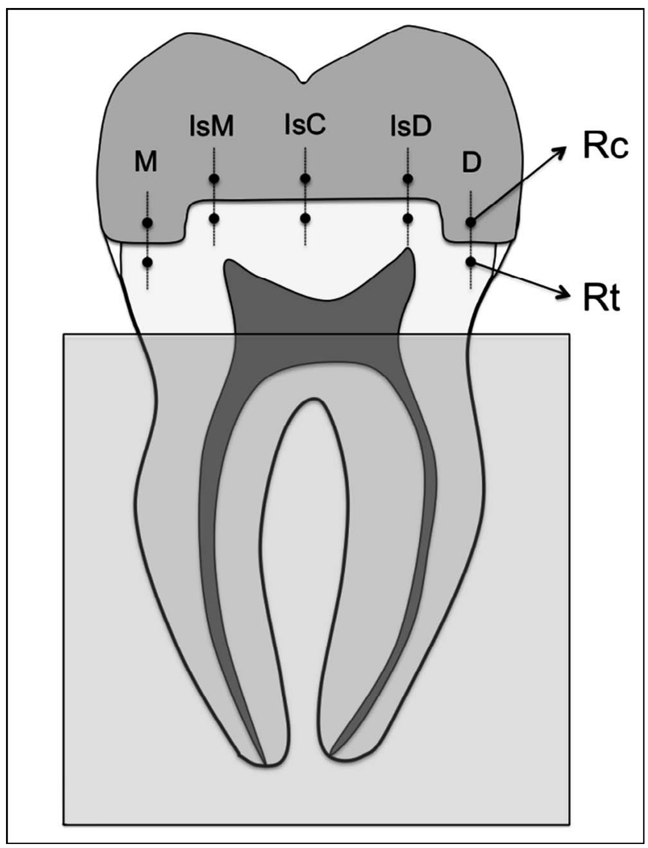

Figure 1. *Location of the cervical (M, D) and isthmus floor measurements (IsM, IsC, and IsD), radiodensity of composite resin restoration (Rc), and radiodensity of tooth (Rt).*

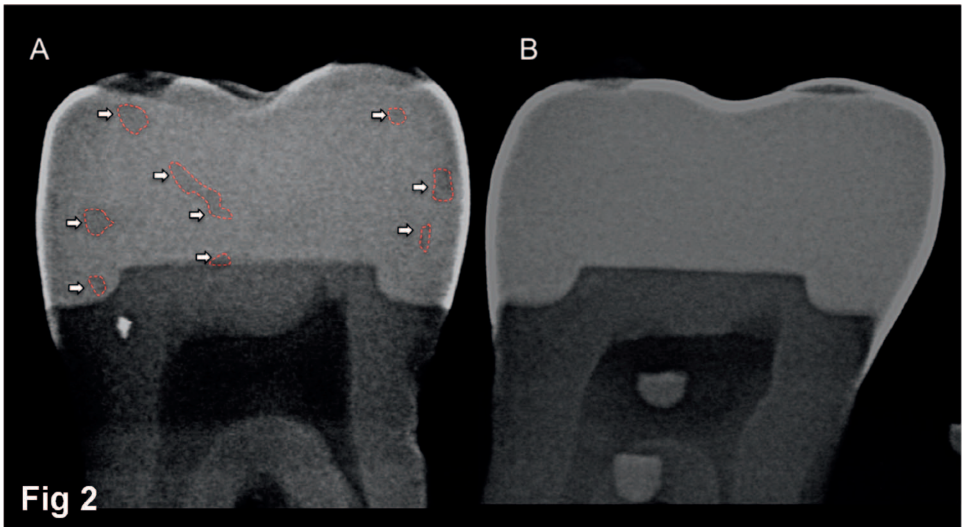

Figure 2. *Amplified radiographs of restorative techniques to detect and measure the voids. (A): tooth with several voids. (B): tooth without voids.*

Statistical Analysis

Data of differences in radiodensity were analyzed for normal distribution and homoscedasticity using the Shapiro-Wilk test and Levene test, respectively. In the initial analysis, the goal was to compare the composites used in this study; therefore, data were analyzed by one-way analysis of variance (ANOVA). In the second analysis, the effect of the region where the measurement was carried out was included in the statistical analysis. Thus, data were analyzed using two-way ANOVA (five composites $\times$ five regions). The frequency of voids for each group was calculated, and the effect of the restorative procedure on this frequency was analyzed using the χ^2 test. For all analyses, the 95% confidence interval for experimental conditions was calculated to allow for comparisons.

RESULTS

Figure 3 shows representative radiographs for each group. Significant differences in radiodensity were found among the restorative materials ($p<0.001$). A comparison among the groups is provided in Figure 4. All of the composites tested showed a positive difference in radiodensity compared with sound tooth structure, demonstrating a higher radiopacity than dentin. TEC and Venus Bulk Fill/Charisma Diamond (VBF/CHA) showed significantly higher radiodensities than did the other materials, while the lowest values were observed for FBF/Z350XT and Z350XT.

Significant differences in radiodensity were found among regions ($p<0.001$) and among the composites ($p<0.001$); however, the interaction between these factors was not significant ($p=0.763$). The difference for values of radiodensity among the regions for each restorative procedure are presented in Figure 5. Higher differences for radiodensity were observed in the proximal regions (mesial and distal). No difference was found in the three regions of the isthmus floor, despite the tendency for reduced differences in radiodensity at the center of the isthmus. A representative illustration was plotted relating the range of colors to the averages of differences in radiodensity observed at each point of measurement (Figure 6).

The χ^2 test demonstrated that the restorative procedure affected the presence of voids ($p=0.004$). The number of voids and the average of the size for all voids per group are shown in Table 3.

The void distribution is presented in Figure 7. VBF/CHA demonstrated the lowest incidence of voids, whereas the highest occurrence was observed for Z350XT, followed by TEC.

DISCUSSION

The present study confirmed that bulk-fill composite resins have adequate radiopacity for posterior restorations and that flowable bulk-fill composite reduces the porosity in composite resin restorations. All of the bulk-fill and conventional composite resins showed higher radiopacity values compared with enamel and dentin. The method used for radiopacity analysis can involve the use of the composite resin together with the aluminum step wedge and a tooth specimen positioned over the radiograph sensor.[14,17,18] In this study, tooth selection and cavity preparation were standardized because detection of radiopacity around restorations also depends on the density and thickness of remaining tooth struc-

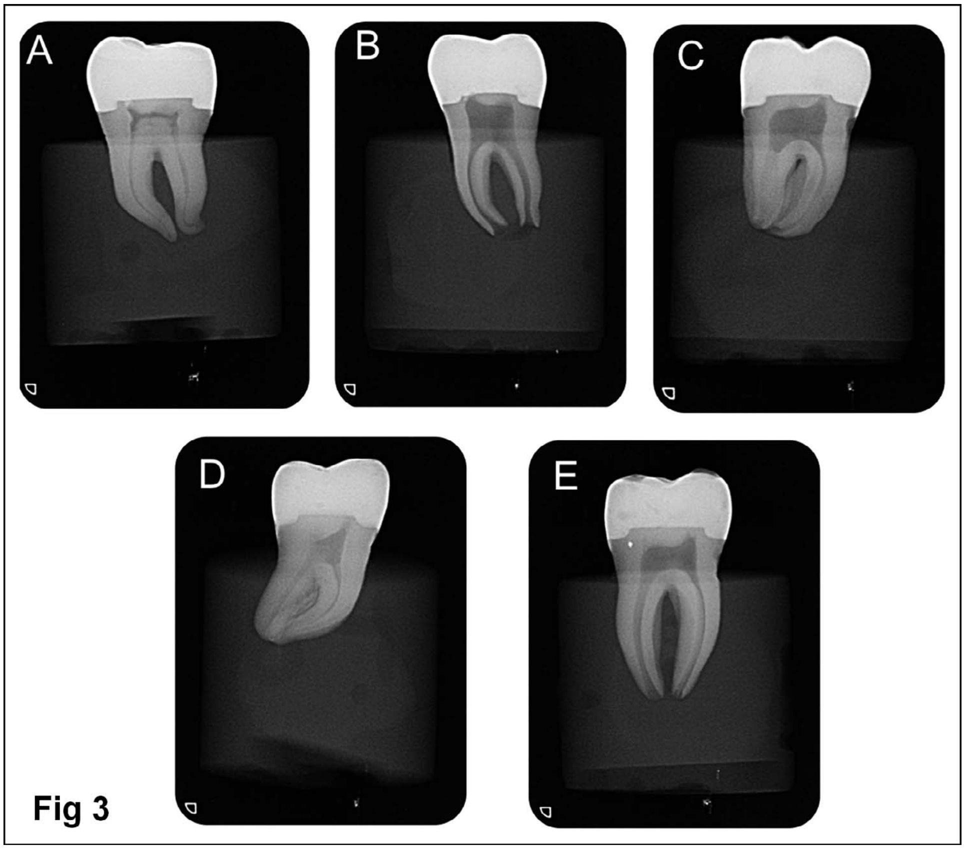

Figure 3. *Radiographs of restorative techniques. (A): SDR/EST-X. (B): TEC. (C): VBF/CHA. (D):, FBF/Z350. (E): Z350.*

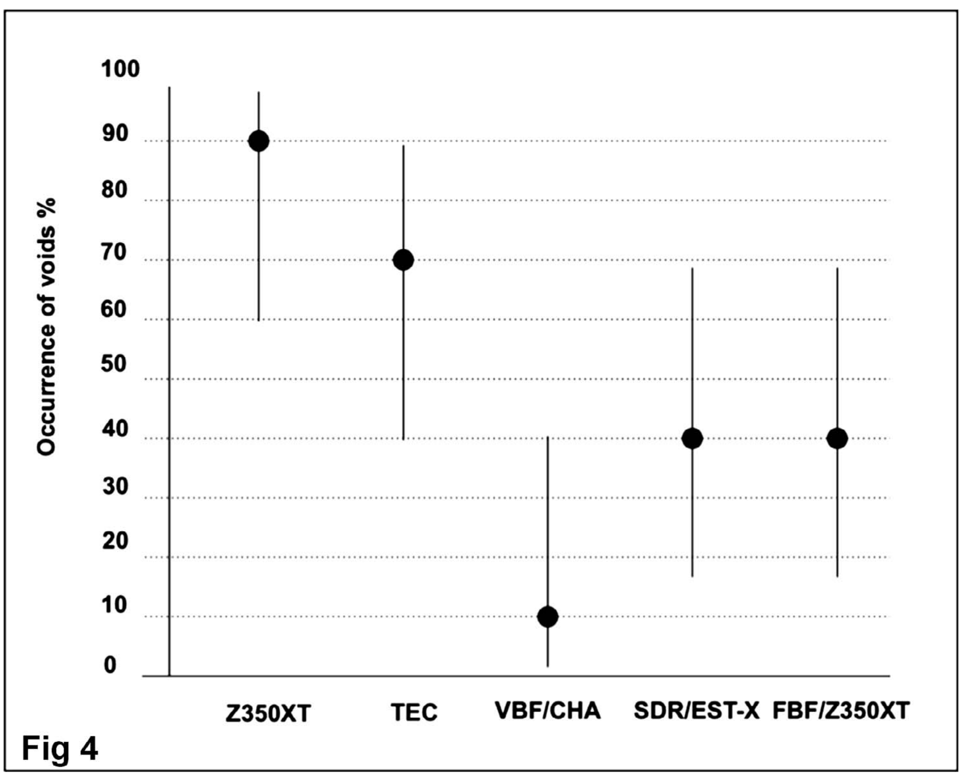

Figure 4. *The 95% confidence interval of difference for radiodensity between the composites and the tooth structure according to the restorative procedures.*

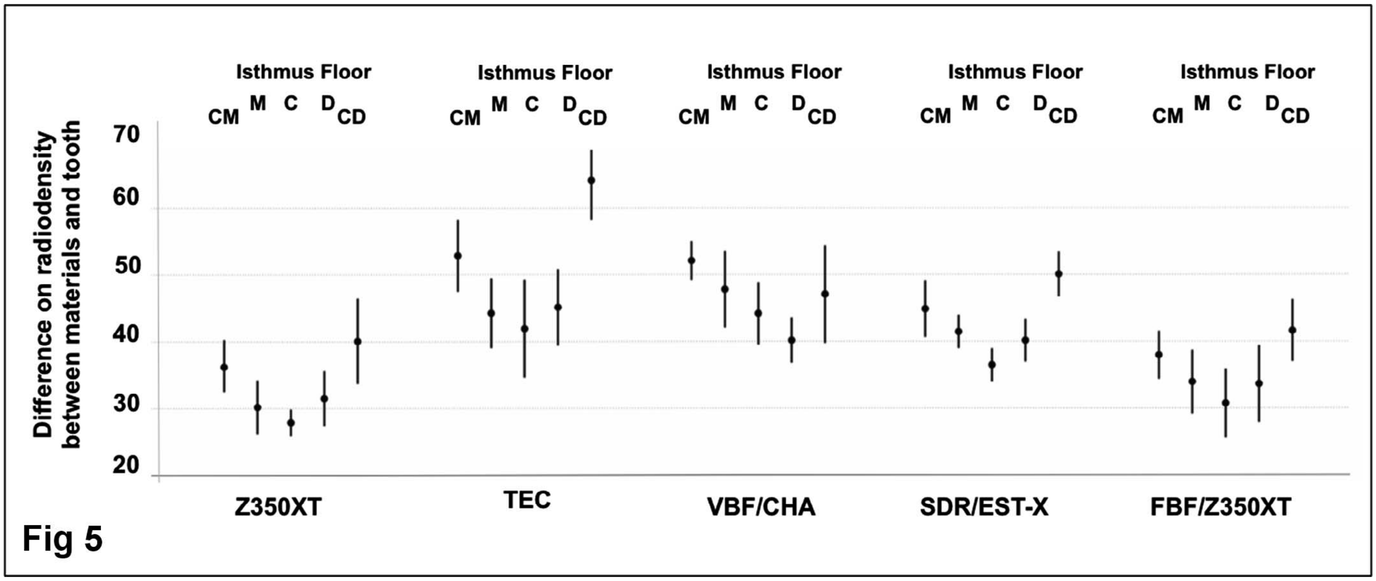

Figure 5. *The 95% confidence interval of difference for radiodensity between the composites and the tooth structure according to restorative procedures and region of measurement.*

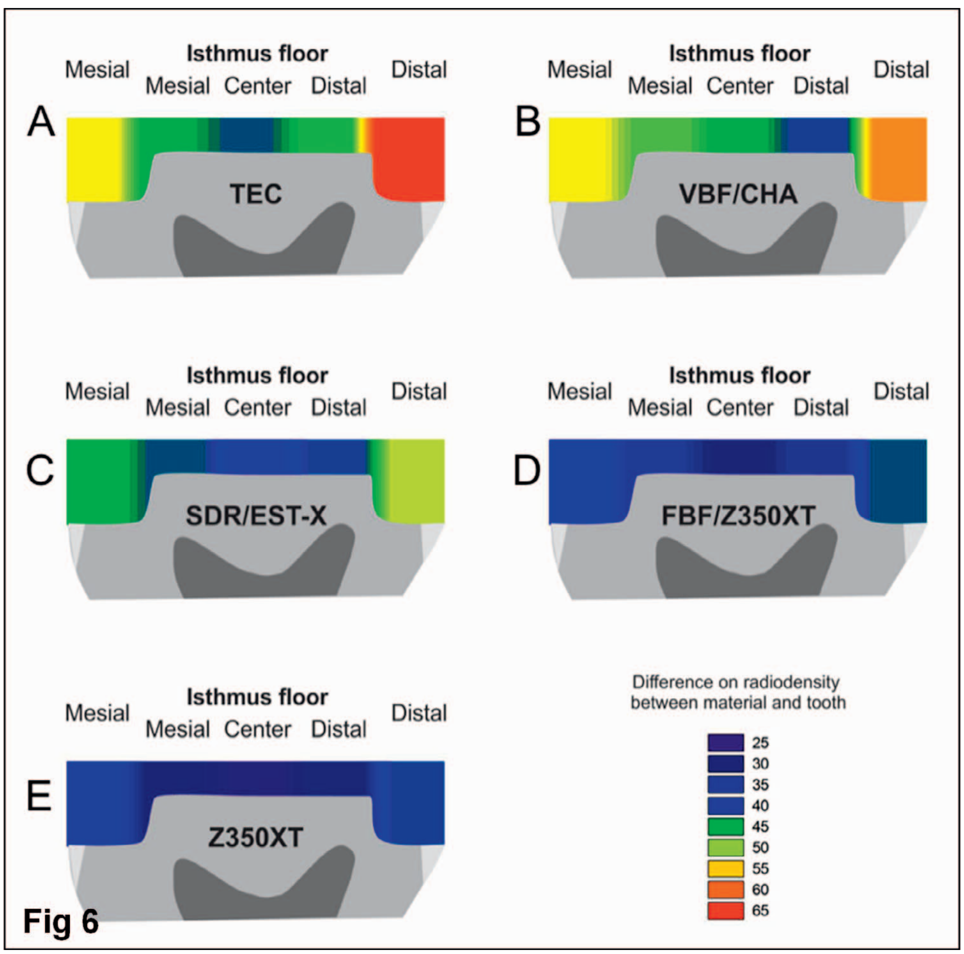

Figure 6. *The representative illustration associating colors with the average of differences on radiodensity. In general, a higher difference was observed in the proximal box.*

Table 3: *Quantitative Analysis of the Void Presence for All Groups*

Group	Total Voids per Group (10 teeth)	Average No. of Voids per Tooth	Average Void size (mm) per Group
Z350XT	44	4.4	0.40
TEC	18	1.8	0.30
VBF/CHA	7	0.7	0.35
SDR/EST-X	12	1.2	0.34
FBF/Z350XT	14	1.4	0.33

Abbreviations: FBF/Z350XT, Filtek Bulk Fill/Z-350XT; SDR/EST-X, SDR/Esthet-X HD; TEC, Tetric EvoCeram Bulk Fill; VBF/CHA, Venus Bulk Fill/Charisma Diamond; Z350XT, Filtek Z-350XT.

ture.[14,21] An important factor in the radiodensity analysis method employed in this study was the systematic evaluation of the restoration placed in the prepared tooth, which allowed clinicians to analyze material radiodensity where that property is clinically critical, at the cervical margin of restorations.[14] The absence of appropriate marginal adaptation is responsible for several problems observed in posterior composite restorations, mainly when the failure occurs in the proximal area.[22] Thus, a composite with a radiopacity lower than that of enamel is not suitable for use as the first increment when an incremental technique is carried out.[17,18] The adequate radiopacity of this increment facilitates the visualization of any defect at the tooth/restoration margin.[15] The results of this study showed that the radiodensity of a material is greater at the cervical region, and that composite resin voids are easier to detect because the remaining tooth region is minimized in this region due to the anatomy of the tooth.[13,20]

The inherent radiopacity of a composite is mainly related to the chemical composition and content of the filler.[17,18,23] Considering that the thickness of composites was similar for all specimens, the difference in the radiodensity detected in this study is strictly related to the inorganic phase of the composites evaluated.[20] This aspect seems to be the most important factor affecting radiopacity.[14,24] The radiopacity of a material tends to increase with a higher filler content and when elements with high atomic numbers are present in the filler particles.[18,25,26] Flowable composites usually contain a reduced filler content since that composite phase is responsible for increasing the viscosity of the material. Therefore, Filtek Bulk Fill and SDR Bulk Fill showed lower radiopacity values compared with the other materials evaluated due to their lower weight and volume percentages of filler.[18] On the other hand, despite the reduced filler content of the flowable composite, Venus Bulk Fill, this composite presented a higher radiopacity compared with other

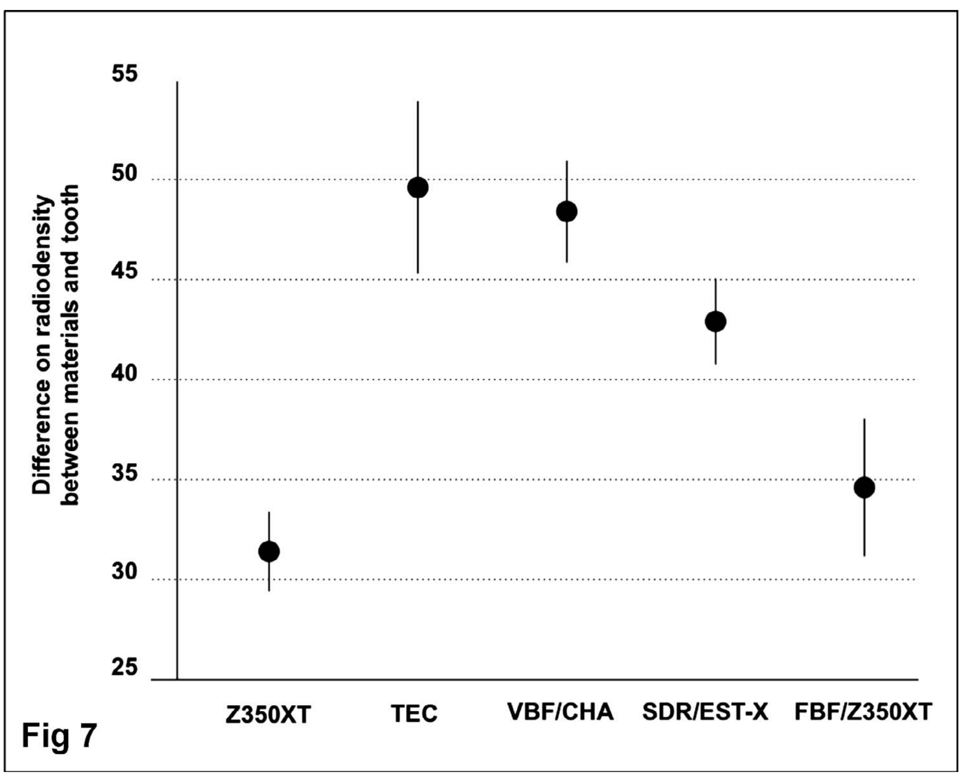

Figure 7. *The 95% confidence interval for occurrence of voids according to restorative procedures.*

tested flowable bulk-fill composites. This finding can be explained by the type of fillers used in this composite, which is similar to those employed in TEC. Those composite materials include radiopaque fillers that are composed of elements with higher atomic numbers (barium and ytterbium trifluoride glasses), resulting in significantly higher radiopacity values compared with the other flowable composites.[17,18]

However, using a bulk-fill flowable composite allows the clinician to fill the entire volume of a cavity corresponding to dentin tissue, while only a single increment of the regular composite is required to complete the restoration. Thus, when considering that the increment contacting the cavity floor and proximal margins is a flowable composite, the radiopacity of this material seems to be more important. Filtek Bulk Fill and Filtek Z-350XT (Filtek Z-350XT) had similar radiodensity despite the reduced filler content of the former. Filtek Bulk Fill compensates for this lower filler content with the presence of elements with higher atomic numbers (ytterbium trifluoride glass). Thus, the first hypothesis of this study was rejected, since the materials evaluated demonstrated differences regarding radiopacity.

Few studies have analyzed the internal adaptation for bulk-fill composites.[11] The porosity generated by the incorporation of bubbles and voids into the composite volume and a composite's failure to adapt to the cavity walls may influence its biomechanical performance. The location of the voids for bulk-fill composites tended to concentrate at the gingival/axial angles; few voids were observed between the flowable composite layer and conventional composite layer used. However, the voids clearly coincided with the region between the increments for Z350XT, thereby rejecting the second hypothesis of study. The insertion of several increments may result in the incorporation of voids due to the difficulty in adequately condensing the increments. A prior study using the same materials demonstrated that the incremental filling technique resulted in lower fracture resistance compared with bulk-fill composite Class II restorations. Interestingly, the fracture lines observed for Filtek Z-350 XT samples coincided with the area of transition between increments, suggesting that the presence of voids can reduce the cohesive strength of the restoration. The necessity of inserting increments with a maximum thickness of 2.0 mm when a regular composite is used, a technique used to allow for adequate polymerization of each increment, indicates that a large number of increments are required to fill large cavities like those used in this study. Voids located at the pulp floor or gingival angles may be caused by the fluid movement that results in postoperative sensitivity. Incorporation of voids inside the bulk volume of the composite was not significant, although this occurrence needs to be carefully analyzed. It may be caused by incorrect insertion of the flowable material or by voids incorporated inside the composite during the manufacturing process.

Although the method used for analyzing the presence of voids is clinically relevant, it cannot detect the volume of the voids. Future microcomputed tomography studies should be performed to detect the void location and volume and to correlate this occurrence with the mechanical performance of the bulk and incremental filling technique.

This study demonstrated that bulk-fill composites have sufficient radiodensity to facilitate detection of secondary caries in marginal defects located at the proximal areas. Additionally, the findings of the present study showed that bulk-fill flowable composites have improved adaptation to the cavity walls, which was demonstrated by a reduced incidence of voids. Thus, bulk-fill composite seems to be a viable option as a direct restorative material to simplify the procedure as it shows proper radiopacity and cavity adaptation.

CONCLUSION

All composite resins demonstrated a positive variation in radiodensity compared with the dental structure. In general, bulk-fill composites demonstrated an adequate level of radiodensity, although the lowest values were observed for Filtek Bulk Fill. The incremental filling technique resulted in a higher incidence of voids, whereas the association of Venus Bulk-fill and Charisma demonstrated significantly fewer voids.

Acknowledgements

This study was supported by FAPEMIG, Fundação de Amparo a Pesquisa do Estado de Minas Gerais, MG, Brazil, and by CNPq, The National Council for Scientific and Technological Development. This research was performed at CPbio-Biomechanics, Biomaterials and Cell Biology Research Center, UFU.

Regulatory Statement

This study was conducted in accordance with all the provisions of the local human subjects oversight committee guidelines and policies of the Ethics Committee in Human Research at Federal University of Uberlândia. The approval code for this study is #721985.

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.

(Accepted 26 September 2016)

REFERENCES

1. Heintze SD, & Rousson V (2012) Clinical effectiveness of direct class II restorations—A meta-analysis *Journal of Adhesive Dentistry* **14(5)** 407-431.
2. Soares CJ, Bicalho AA, Tantbirojn D, & Versluis A (2013) Polymerization shrinkage stresses in a premolar restored with different composite resins and different incremental techniques *Journal of Adhesive Dentistry* **15(4)** 341-350.
3. Bicalho AA, Pereira RD, Zanatta RF, Franco SD, Tantbirojn D, Versluis A, & Soares CJ (2014) Incremental filling technique and composite material—Part I: Cuspal deformation, bond strength, and physical properties *Operative Dentistry* **39(2)** E71-E82.
4. Bicalho AA, Valdívia AD, Barreto BC, Tantbirojn D, Versluis A, & Soares CJ (2014) Incremental filling technique and composite material—Part II: Shrinkage and shrinkage stresses *Operative Dentistry* **39(2)** E83-E92.
5. van Dijken JW, & Pallesen U (2014) A randomized controlled three year evaluation of "bulk-filled" posterior resin restorations based on stress decreasing resin technology *Dental Materials* **30(9)** e245-e251.
6. van Dijken JW, & Pallesen U (2015) Randomized 3-year clinical evaluation of Class I and II posterior resin restorations placed with a bulk-fill resin composite and a one-step self-etching adhesive *Journal of Adhesive Dentistry* **17(1)** 81-88.
7. Ilie N, & Hickel R (2011) Investigations on a methacrylate-based flowable composite based on the SDR™ technology *Dental Materials* **27(4)** 348-355.
8. Rosatto CM, Bicalho AA, Veríssimo C, Bragança GF, Rodrigues MP, Tantbirojn D, Versluis A, & Soares CJ (2015) Mechanical properties, shrinkage stress, cuspal strain and fracture resistance of molars restored with bulk-fill composites and incremental filling technique *Journal of Dentistry* **43(12)** 1519-1528.
9. Brouwer F, Askar H, Paris S, & Schwendicke F (2016) Detecting secondary caries lesions: A systematic review and meta-analysis *Journal of Dental Research* **95(2)** 143-151.
10. Campos EA, Ardu S, Lefever D, Jassé FF, Bortolotto T, & Krejci I (2014) Marginal adaptation of class II cavities restored with bulk-fill composites *Journal of Dentistry* **42(5)** 575-581.
11. Scotti N, Alovisi C, Comba A, Ventura G, Pasqualini D, Grignolo F, & Berutti E (2016) Evaluation of composite adaptation to pulpal chamber floor using optical coherence tomography *Journal of Endodontics* **42(1)** 160-163.
12. Fronza BM, Rueggeberg FA, Braga RR, Mogilevych B, Soares LE, Martin AA, Ambrosano G, & Giannini M (2015) Monomer conversion, microhardness, internal marginal adaptation, and shrinkage stress of bulk-fill resin composites *Dental Materials* **31(12)** 1542-1551.
13. Fonseca RB, Branco CA, Soares PV, Correr-Sobrinho L, Haiter-Neto F, Fernandes-Neto AJ, & Soares CJ (2006) Radiodensity of base, liner and luting dental materials *Clinical Oral Investigation* **10(2)** 114-118.
14. Soares CJ, Santana FR, Fonseca RB, Martins LR, & Neto FH (2007) In vitro analysis of the radiodensity of indirect composites and ceramic inlay systems and its influence on the detection of cement overhangs *Clinical Oral Investigation* **11(4)** 331-336.
15. Bouschlicher MR, Cobb DS, & Boyer DB (1999) Radiopacity of compomers, flowable and conventional resin composites for posterior restorations *Operative Dentistry* **24(1)** 20-25.
16. Gu S, Rasimick BJ, Deutsch AS, & Musikant BL (2006) Radiopacity of dental materials using a digital X-ray system *Dental Materials* **22(8)** 765-770.
17. Yasa E, Yasa B, Aglarci OS, & Ertas ET (2015) Evaluation of the radiopacities of bulk-fill restoratives using two digital radiography systems *Operative Dentistry* **40(5)** E197-E205.
18. Yasa B, Kucukyilmaz E, Yasa E, & Ertas ET (2015) Comparative study of radiopacity of resin-based and glass ionomer-based bulk-fill restoratives using digital radiography *Journal of Oral Science* **57(2)** 79-85.
19. Ibarra ET, Lien W, Casey J, Dixon SA, & Vandewalle KS (2015) Physical properties of a new sonically placed composite resin restorative material *General Dentistry* **63(3)** 51-56.
20. Soares CJ, Fonseca RB, Gomide HA, & Correr-Sobrinho L (2008) Cavity preparation machine for the standardization of in vitro preparations *Brazilian Oral Research* **22(3)** 281-287
21. Farman TT, Farman AG, Scarfe WC, & Goldsmith LJ (1996) Optical densities of dental resin composites: A comparison of CCD, storage phosphor, and Ektaspeed plus radiographic film *General Dentistry* **44(6)** 532-537.
22. Soares CJ, Celiberto L, Dechichi P, Fonseca RB, & Martins LR (2005) Marginal integrity and microleakage of direct and indirect composite inlays: SEM and stereomicroscopic evaluation *Brazilian Oral Research* **19(4)** 295-301.
23. Pedrosa RF, Brasileiro IV, dos Anjos Pontual ML, dos Anjos Pontual A, & da Silveira MM (2011) Influence of materials radiopacity in the radiographic diagnosis of secondary caries: Evaluation in film and two digital systems *Dentomaxillofacial Radiology* **40(6)** 344-350.
24. Hara AT, Serra MC, Haiter-Neto F, & Rodrigues AL Jr (2001) Radiopacity of esthetic restorative materials compared with human tooth structure *American Journal of Dentistry* **14(6)** 383-386.
25. Watts DC (1987) Radiopacity vs. composition of some barium and strontium glass composites *Journal of Dentistry* **15(1)** 38-43.
26. Ergucu Z, Turkun LS, Onem E, & Guneri P (2010) Comparative radiopacity of six flowable resin composites *Operative Dentistry* **35(4)** 436-440.