Clin Oral Invest (2017) 21:709–716
DOI 10.1007/s00784-016-1940-y

ORIGINAL ARTICLE

Three-year clinical evaluation of class II posterior composite restorations placed with different techniques and flowable composite linings in endodontically treated teeth

Emel Karaman[1] · **Busra Keskin**[2] · **Ugur Inan**[3]

Received: 6 July 2015 / Accepted: 10 August 2016 / Published online: 19 August 2016

Abstract
Objective The objective of this study is to evaluate the clinical performance of direct resin composite restorations placed with different techniques (incremental or bulk) and different flowable linings (conventional or bulk-fill) in endodontically treated teeth.
Materials and methods Forty-seven pair class II (mesio-occlusal or disto-occlusal) composite restorations were placed in 37 patients. In all cavities, Adper Single Bond 2 was used. In one of the cavities of each pair, a conventional flowable composite, Aelite Flo, was applied in approximately 2 mm thick, and the remaining cavity was restored incrementally with GrandioSO. In the second cavity, a bulk-fill flowable composite, x-tra base, was applied in approximately 4 mm thick in bulk increments and the remaining 2-mm occlusal part of the cavity was restored with GrandioSO. All cavities were restored with open-sandwich technique by the same operator. At baseline and after 6-month, 1-, 2-, and 3-year follow-up visits, restorations were evaluated by modified USPHS criteria.
Results At 3-year recall, 33 restorations with Aelite Flo lining and 33 with x-tra base lining were available. Two restorations from each group (6.0 %) were scored as Bravo in terms of surface texture. One restoration's color match from x-tra base group scored as Bravo (3.0 %). All other evaluated criteria were scored as Alfa (100 %) for all restorations. No statistically significant difference between the two groups was found in all evaluated criteria during 3-year period ($p > 0.05$).
Conclusion Bulk-filling technique showed clinically acceptable performance comparable to the incremental technique.
Clinical relevance Restorations placed with bulk-filling technique with x-tra base lining and incremental technique with a conventional flowable lining showed highly clinical performance over 3-year period.

Keywords Bulk-fill composite · Resin composite restoration

Introduction

Endodontically treated teeth are weakened by the loss of strategic tooth structure through restorative procedures and caries, iatrogenic factors, and location and shape of the endodontic access rather than by the endodontic procedures [1, 2]. In this context, a restoration which restores function and preserves the remaining tooth structure against fracture, in addition to esthetic considerations, is obligatory after endodontic treatment. Clearly, the choice of appropriate restoration will depend mainly on remaining tooth structure, form of the endodontic access, and functional requirements [3].

In the case of extensive loss of tooth structure, it has been reported that coronal coverage significantly improve the survival rate of endodontically treated molar and premolar teeth [4, 5], while teeth with moderate remaining tooth structure may require more conservative approaches; such as resin composite restorations. Direct resin composite restorations are often used for endodontically treated teeth due to their bonding ability to tooth structure, which allows minimal cavity preparation, and might strengthen the tooth and offer an alternative

✉ Emel Karaman
dtemelc@yahoo.com

[1] Faculty of Dentistry, Department of Restorative Dentistry, Ondokuz Mayis University, Samsun, Turkey

[2] Balgat Oral and Tooth Health Center, Ankara, Turkey

[3] Faculty of Dentistry, Department of Endodontics, Ondokuz Mayis University, Samsun, Turkey

restorative technique with a relatively low cost to cuspal coverage restorations [6, 7].

However, the problem of resin composites' polymerization shrinkage which may result in interfacial deficiencies, cuspal movements, cracked cusps, microleakage, and secondary caries, continues to be a concern [8]. Especially for endodontically treated teeth, this stress distribution is higher in the tooth than within the restoration and tooth-restoration interface, and increases the risk of tooth fracture [9].

Several attempts at minimizing this problem has been suggested such as placement of stress absorbing intermediary layers including flowable composites in sandwich techniques [10–16] and incremental placement [17–22]. It is common in clinical practice to use flowable resin composites in sandwich technique for restoring large cavities. In this technique, flowable resin composite is used for the gingival portion of the restoration, and resin composite is used to complete the repair. The use of flowable resin composites has been advised to absorb polymerization shrinkage stresses due to their lower modulus of elasticity. Their low-viscosity, elasticity, and wettability allow them to fill irregular margins of proximal boxes [23] and improve marginal sealing of resin composites especially at the cervical level [24].

Incremental filling technique is another attempt to reduce polymerization shrinkage stress and its clinically undesired results. With this technique, the ratio of bonded surfaces to free surfaces (configuration factor) is minimized by reducing the contact area between resin and cavity walls. Unfortunately for the clinical procedure, applying multiple small increments and polymerization process of all increments make the restorative procedure time consuming and increases void generation and failure risk [25, 26]. Despite these attempts to improve the longevity of restorations, dentists still desire easier and quicker restorations.

In order to overcome the shortcomings of incremental filling technique with conventional composites, a new class of composites called "bulk-fill composites," including low-viscosity (flowable) and high-viscosity (sculptable) material types, have been developed. The manufacturers of these newer resin composites claim that their composites can be efficiently photopolymerized at depths up to 4–5 mm in bulk and maintain low polymerization shrinkage stress at the same time.

While restoring large class II cavities, especially after endodontic treatment, it may be time-saving and practical for clinicians to complete the proximal boxes with the bulk-fill flowable composites and use conventional composites for the remaining cavity. A number of studies have been conducted to evaluate their degree of conversion [27, 28], depth of cure [29], and polymerization shrinkage [30–32], as well as their mechanical properties [33, 34]. There is no clinical evidence which compared the performance of new bulk-fill composites and placement techniques (open or closed sandwich) in endodontically treated teeth. The clinical evaluation of these bulk-fill composites is important as using these materials with open-sandwich technique will eliminate the disadvantages conventional technique which is slow and time-consuming.

The aim of this study was to investigate the clinical effectiveness of direct resin composite restorations placed with different placement techniques (incremental or bulk) with different flowable linings (conventional or bulk-fill flowable) used in open-sandwich technique, in endodontically treated class II cavities (mesio-occlusal or disto-occlusal), in a randomized controlled comparison. The null hypothesis tested was that restorations placed with different techniques and flowable linings would not show different clinical performances during 3-year period.

Materials and methods

Patient selection

The protocol and consent form for this clinical study were reviewed and approved by the Ondokuz Mayis University Human Ethics Committee (OMU-TAEK 2011/482) and registered to ClinicalTrials.gov (NCT02858947). During March–June 2011, patients attending the Restorative Dentistry clinic at Ondokuz Mayis University Faculty of Dentistry with at least two endodontic treatment requirements, caused by caries or fractures, irreversible pulpitis, or pulpal necrosis, were asked to participate in this follow-up study. All participants were informed about the study, advised of their rights, chance to deny the participation to the follow-up visits, and had signed the written informed consent prior to the first treatment. With this form, the patients accepted to participate to the study for 3 years (including follow-up visits).

Patients were excluded who needed indirect restorations due to significant loss of tooth structure, known allergies to product ingredients, had poor oral hygiene and a history of bruxism. To detect a difference between the restoration groups according to the retention rate of 30 %, with 90 % power and 5 % type one error rate, it is found that at least 47 teeth should be taken in each group. Permanent premolars and molars without any restorations were included in the study. Every tooth included in the study had neighboring teeth and were in occlusion to antagonistic teeth.

At the end of the patient-selection period, 37 patients (16 male, 21 female) aged between 19 and 41 years (mean 27) were found adequate for the current study.

Restorative procedure

The resin composites and adhesive system used in the current study are listed in Table 1. A total of 94 teeth (41 premolars, 53 molars) were endodontically treated

Table 1 Materials used in the study

Material	Type	Ingredient	Batch number (#)	Manufacturer
Aelite Flo	Microhybrid flowable composite	TEGDMA, Bis-GMA, zirconia/silica[a]	1000006652	Bısco Inc., Schaumburg, IL, USA
x-tra base	Bulk-fill flowable composite	Bis-EMA, UDMA[b]	1145403	VOCO, Cuxhaven, Germany
GrandioSO	Universal hybrid composite	Inorganic fillers in a methacrylate matrix (Bis-GMA, TEGDMA)[c]	1215105	VOCO, Cuxhaven, Germany
Adper Single Bond 2	Etch-and-rinse adhesive system	HEMA, Bis-GMA, dimethacrylate, polyacrylic and polyitaconic acids, water, ethanol[d]	N241284	3M ESPE Dental Products, St. Paul, MN, USA

Bis-GMA bisphenol A diglycidyl ether dimethacrylate, *UDMA* urethane dimethacrylate, *Bis-EMA* bisphenol A ethoxylated methacrylate, *TEGDMA* triethylene glycol dimethacrylate, *HEMA* 2-hydroxyethyl methacrylate

[a] https://www.bisco.com/catalog/MC-3154AL.pdf

[b] http://www.voco.com/us/product/x-tra_base/index.html

[c] http://www.voco.com/us/product/GrandioSO/index.html

[d] multimedia.3m.com/.../adper-single-bond-2-technical-profile.pdf

by an expert operator. In the current study, endodontically treated class II cavities were chosen since these kinds of cavities are so common in clinical practice and it is important for clinicians to decide adequate technique and material for restoring these cavities. The enamel margins of the cavities were not beveled and cavity preparations were limited to removal of carious tissue.

After endodontic treatment, all tested teeth were temporarily restored with glass ionomer cement (Riva light cure, Southern Dental Industries-SDI, Australia) for 1 week. After 1 week, the temporary restorations were removed with diamond fissure burs (DIATECH, Swiss Dental, Heerbrugg, Switzerland) in a high-speed hand-piece underwater coolant. The average buccolingual width of each preparation was greater than one third of the distance between cusp tips. The teeth were isolated with cotton rolls and suction. Thirty-five percent phosphoric acid (Scotchbond, 3 M ESPE Dental Products, St. Paul, MN, USA) was applied for 30 s for the enamel margins and 15 s for dentine, then rinsed for 15 s with water, and dried with air-syringe. After acid-etching, Adper Single Bond 2 (3M ESPE Dental Products, St. Paul, MN, USA) was applied in two coats and light cured for 10 s, in accordance with manufacturer's instructions.

By tossing a coin, a total of 94 mesio-occlusal or disto-occlusal restorations were placed on the permanent premolars and molars with either a conventional flowable resin composite lining (group 1), Aelite Flo (Bisco Inc. Schaumburg, IL, USA), or a bulk-fill flowable resin composite lining (group 2), x-tra base (VOCO, Cuxhaven, Germany). Aelite Flo used in the current study represented as a low-modulus microhybrid flowable composite specially developed with a patented long chain monomer which supplements the conventional Bis-GMA resin to provide a more elastic composite. This allows restorations to flex with the tooth for improved marginal integrity and overall restoration longevity. Low modulus of elasticity microscopically bends with the natural flexure of the tooth to prevent de-bonding and marginal breakdown [35]. The other tested flowable composite, x-tra base, is a bulk-fill composite which is one of the latest version of composites to simplify and shorten the restorative procedure.

In group 1, Aelite Flo, was applied in approximately 2 mm thick, light cured for 20 s and the remaining cavity was restored incrementally with a universal hybrid resin composite, GrandioSO (VOCO, Cuxhaven, Germany). The thickness of resin composite was not exceeding 2 mm and each increment was polymerized for 20 s. In group 2, x-tra base was applied in approximately 4 mm thick in bulk increments as needed to fill the cavity 2 mm short of the occlusal cavosurface and each increment was light cured for 20 s. The remaining occlusal part of the cavity was restored with a GrandioSO layer. GrandioSO was chosen because of its low polymerization shrinkage due to increased filler loading (71 % filler volume fraction) reported by a previous study [36]. The shade of the composite was selected according to the teeth to be restored. Metal matrices and wooden wedges were used for class II cavities. All cavities were restored with open-sandwich technique.

A LED device (Elipar S10, 3M ESPE Dental Products, St. Paul, MN, USA) with an irradiance of 1200 mW/cm^2 was used for all polymerization process. The curing light intensity was measured with a radiometer (Curing Radiometer Model 100; Demetron Corp, USA).

After placement of restorations, the occlusion was checked with articulation paper. Fine grit diamond burs (DIATECH, Swiss Dental, Heerbrugg, Switzerland) and rubber cups (Edenta AG, AU SG, Switzerland) were used for finishing and polishing. All of the restorative procedures were carried out by the same operator. Blinding of the operator was not possible, because she knew the technique and type of lining material applied. This operator did not attend the evaluation process.

Evaluation

This study was double-blinded as neither the patients nor the evaluators were unaware of which flowable resin composite had been used. At the beginning of the study, two other examiners were calibrated by rating 20 high-resolution clinical photographs of posterior composite restorations that were representative of each score for each criterion. In the case of disagreement on a rating, both re-examined the restoration and arrived at a final joint decision in order to obtain only one score for each restoration. The intra-examiner Cohen's kappa statistic was found high (0.95).

At baseline (after placement of restoration) and after 6 months, 1, 2, and 3 years, two calibrated examiners independently evaluated the restorations by Modified United States Public Health Service criteria (USPHS) [37] for the following characteristics: retention, anatomical form, marginal adaptation, color matching, marginal staining, surface texture, and secondary caries (Table 2). The resin composite restorations were evaluated with the aid of a dental explorer and an intraoral mirror and visual inspection. Bitewing radiographs were also taken at all recall time. The restorations were scored as follows: Alfa represented the ideal clinical situation, Bravo was clinically acceptable, and Charlie represented a clinically unacceptable situation. In case of disagreement between examiners, restorations were reevaluated and a consensus has been reached.

Statistical evaluation

The comparison of restorations with Aelite Flo and x-tra base linings for each category was performed with the Pearson chi square test. Within group differences of the materials at the baseline and after each recall time (6 months, 1, 2, and 3 years) was evaluated by Cochran Q test ($p < 0.05$). All data were analyzed by means of SPSS 11.5 for Windows (SPSS Inc., Chicago, IL, USA).

Table 2 Modified US Public Health Service Evaluation criteria [22]

Characteristic	Evaluation criteria
Retention	Alfa: the restoration is present.
	Charlie: the restoration is absent.
Marginal discoloration	Alfa: there is no visual evidence of marginal discoloration different from the color of the restorative material and from the color of the adjacent tooth structure.
	Bravo: there is visual evidence of marginal discoloration at the junction of the tooth structure and the restoration that has not penetrated along the restoration in a pulpal direction.
	Charlie: there is visual evidence of marginal discoloration at the junction of the tooth structure and the restoration, but the discoloration has penetrated along the restoration in a pulpal direction.
Marginal adaptation	Alfa: restoration is closely adapted to the tooth. The explorer does not catch when drawn across the surface of the restoration toward the tooth structure, or if the explorer does catch there is no visible crevice along the periphery of the restoration.
	Bravo: the explorer catches and there is visible evidence of a crevice, which the explorer penetrates, indicating that the edge of the restoration does not adapt closely to the tooth structure. The dentin and/or the base are not exposed and the restoration is not mobile.
	Charlie: the explorer penetrates a crevice defect that extends to the dentino-enamel junction.
Color match	Alfa: restoration matches the shade and translucency of adjacent tooth structure.
	Bravo: restoration does not match the shade and translucency of adjacent tooth structure, but the mismatch is within the normal range of tooth shades.
	Charlie: restoration does not match the shade and translucency of adjacent tooth structure, and the mismatch is outside the normal range of tooth shades and translucency.
Surface texture	Alfa: surface texture is similar to polished enamel as determined by means of a sharp explorer.
	Bravo: surface texture is gritty or similar to a surface subject to a white stone or rougher than the adjacent tooth structure.
	Charlie: surface pitting is sufficiently coarse to inhibit the continuous movement of an explorer across the surface.
Anatomic form	Alfa: restoration is continuous with existing anatomic form.
	Bravo: restoration is discontinuous with existing anatomic form, but missing material is not sufficient to expose dentin or base.
	Charlie: sufficient material is lost to expose dentin or base.
Secondary caries	Alfa: no caries is present.
	Charlie: caries is present.

Table 3 Distribution of the number of restorations at baseline

Flowable lining	Maxilla		Mandibula		Total
	Premolar	Molar	Premolar	Molar	
Aelite Flo	12	15	7	13	47
x-tra base	18	15	4	10	47
Total	30	30	11	23	94
	60	34			

Results

The distribution of the number of restorations at baseline is given in Table 3. One restoration from each group did not match the shade and translucency of adjacent tooth structure at baseline and gave Bravo scores in terms of color match.

The recall rate was 100 % at 6-month and 1-year recalls. At 1-year recall, one restoration from x-tra base group could not be evaluated because that tooth was prepared to be treated with a zirconia crown. There were no other restorations lost and all other evaluated criteria were scored as Alfa for all restorations during 1-year period. There was no statistically significant difference between different groups ($p > 0.05$).

Twenty-six patients (14 male, 15 female) attended the 2-year recall, and a total of 72 restorations (36 for Aelite Flo, 36 for x-tra base) were available for evaluation. Only one restoration with x-tra base lining received Bravo score in terms of color match. Two restorations with Aelite Flo lining and one restoration with x-tra base lining showed gritty surface texture and scored as Bravo.

At 3-year recall, a total of 66 restorations, 33 restorations from each group, were available for evaluation. The same restoration's color match from x-tra base group scored as Bravo during 3-year period. The surface texture of two restorations from each group received Bravo scores.

Table 4 presents the data of clinical evaluation of the materials used in this study over 3-year period. No statistically significant differences between the two groups were found for all evaluated criteria ($p > 0.05$). No secondary caries has been detected during evaluation periods.

Discussion

This study compared the clinical effectiveness of class II direct resin composite restorations placed with different placement techniques and different flowable linings, in endodontically treated teeth. The null hypothesis was accepted as resin composite restorations with different placement techniques and flowable composite linings resulted in statistically similar clinical parameters after 3 years.

Open-sandwich technique has been first described in 1977. Conventional glass ionomer cements (GIC) were used as lining materials in the early version of this technique [38]. Later on, resin-modified GIC and flowable composites were also advised to be used as lining materials [39]. In this clinical study, open-sandwich technique with flowable composite lining has been employed to test manufacturers' claims. This technique has also been found to cause less microleakage and need less operator skill than closed-sandwich technique in previous studies [12, 24].

The use of a flowable composite liner as a flexible intermediate layer has been suggested for relieving the stress caused by polymerization shrinkage [13]. Using flowable composite liners has also been advised to exhibit superior contact with the floors and walls of cavity preparations [23]. Consistent with the previous data, the findings of this study showed that resin composite restorations with both of the tested flowable composite linings showed clinically acceptable performance with no secondary caries or restoration fracture at the end of the 3-year period. In contrast with our findings, some in vitro studies indicated unsuccessful cuspal deflection [19] and microleakage [14, 15] results of class II resin composite restorations with flowable linings than that without a flowable liner. These conflicting results may be due to the different materials and methodology used in these studies.

Several studies have been conducted to test the performance of bulk-fill composites. Depth of cure (DC) and polymerization shrinkage of these newer materials are some of the most common concerns about them. Par et al. [28] reported clinically acceptable DC of x-tra base at depths up to 4 mm. Similarly, Marovic et al. [31] also reported reduced shrinkage forces and high level of DC of x-tra base compared to a conventional flowable composite (EsthetX flow). The increased translucency of x-tra base due to its enlarged filler size might be a responsible factor of its high DC [33]. It is known that bigger particles decrease the filler-matrix interface and so allows more light transmission through the composite [34]. The high filler content of x-tra base (61 % volume) might be another reason for its low polymerization shrinkage because of the fact that the volume occupied by organic matrix and, therefore, the number of reactive methacrylate groups decreases [32]. Increased filler rate has also been shown to improve mechanical properties such as compressive strength, hardness, and resistance to softening [27]. The clinically good performance obtained with x-tra base may be explained by this way.

One of the main goals of adhesive dentistry is to obtain a tight interfacial adaptation, which reduces the risk of microleakage, secondary caries, and postoperative sensitivity. Incremental filling techniques have often been indicated to decrease the effects of shrinkage and stress generated at the adhesive interface and improves the marginal adaptation [40]. However, the effectiveness of incremental filling technique is controversial. Versluis et al. [9] showed that additional

Table 4 Clinical evaluation of the materials used in this study over 3 years

	Aelite Flo				X-tra base				Between group p
	n	A	B	C	*n*	A	B	C	
Retention									
Baseline	47	47 (100 %)	–	0 (0.0 %)	47	47 (100 %)	–	0 (0.0 %)	
6-month	47	47 (100 %)	–	0 (0.0 %)	47	47 (100 %)	–	0 (0.0 %)	
12-month	47	47 (100 %)	–	0 (0.0 %)	46	46 (100 %)	–	0 (0.0 %)	
24-month	36	36 (100 %)	–	0 (0.0 %)	36	36 (100 %)	–	0 (0.0 %)	
36-month	33	33 (100 %)	–	0 (0.0 %)	33	33 (100 %)	–	0 (0.0 %)	
Within group p									
Color match									
Baseline	47	46 (97.8 %)	1 (2.1 %)	0 (0.0 %)	47	46 (97.8 %)	1 (2.1 %)	0 (0.0 %)	
6-month	47	46 (97.8 %)	1 (2.1 %)	0 (0.0 %)	47	46 (97.8 %)	1 (2.1 %)	0 (0.0 %)	
12-month	47	46 (97.8 %)	1 (2.1 %)	0 (0.0 %)	46	45 (97.8 %)	1 (2.1 %)	0 (0.0 %)	
24-month	36	36 (100 %)	0 (0.0 %)	0 (0.0 %)	36	35 (97.2 %)	1 (2.7 %)	0 (0.0 %)	
36-month	33	33 (100 %)	0 (0.0 %)	0 (0.0 %)	33	32 (96.9 %)	1 (3.0 %)	0 (0.0 %)	
Within group p									
Marginal discoloration									
Baseline	47	47 (100 %)	0 (0.0 %)	0 (0.0 %)	47	47 (100 %)	0 (0.0 %)	0 (0.0 %)	
6-month	47	47 (100 %)	0 (0.0 %)	0 (0.0 %)	47	47 (100 %)	0 (0.0 %)	0 (0.0 %)	
12-month	47	47 (100 %)	0 (0.0 %)	0 (0.0 %)	46	46 (100 %)	0 (0.0 %)	0 (0.0 %)	
24-month	36	36 (100 %)	0 (0.0 %)	0 (0.0 %)	36	36 (100 %)	0 (0.0 %)	0 (0.0 %)	
36-month	33	33 (100 %)	0 (0.0 %)	0 (0.0 %)	33	33 (100 %)	0 (0.0 %)	0 (0.0 %)	
Within group p									
Marginal adaptation									
Baseline	47	47 (100 %)	0 (0.0 %)	0 (0.0 %)	47	47 (100 %)	0 (0.0 %)	0 (0.0 %)	
6-month	47	47 (100 %)	0 (0.0 %)	0 (0.0 %)	47	47 (100 %)	0 (0.0 %)	0 (0.0 %)	
12-month	47	47 (100 %)	0 (0.0 %)	0 (0.0 %)	46	46 (100 %)	0 (0.0 %)	0 (0.0 %)	
24-month	36	36 (100 %)	0 (0.0 %)	0 (0.0 %)	36	36 (100 %)	0 (0.0 %)	0 (0.0 %)	
36-month	33	33 (100 %)	0 (0.0 %)	0 (0.0 %)	33	33 (100 %)	0 (0.0 %)	0 (0.0 %)	
Within group p									
Surface texture									
Baseline	47	47 (100 %)	0 (0.0 %)	0 (0.0 %)	47	47 (100 %)	0 (0.0 %)	0 (0.0 %)	
6-month	47	47 (100 %)	0 (0.0 %)	0 (0.0 %)	47	47 (100 %)	0 (0.0 %)	0 (0.0 %)	
12-month	47	47 (100 %)	0 (0.0 %)	0 (0.0 %)	46	46 (100 %)	0 (0.0 %)	0 (0.0 %)	
24-month	36	34 (94.4 %)	2 (5.5 %)	0 (0.0 %)	36	35 (97.2 %)	1 (2.7 %)	0 (0.0 %)	
36-month	33	31 (93.9 %)	2 (6.0 %)	0 (0.0 %)	33	31 (93.9 %)	2 (6.0 %)	0 (0.0 %)	
Within group p									
Anatomical form									
Baseline	47	47 (100 %)	0 (0.0 %)	0 (0.0 %)	47	47 (100 %)	0 (0.0 %)	0 (0.0 %)	
6-month	47	47 (100 %)	0 (0.0 %)	0 (0.0 %)	47	47 (100 %)	0 (0.0 %)	0 (0.0 %)	
12-month	47	47 (100 %)	0 (0.0 %)	0 (0.0 %)	46	46 (100 %)	0 (0.0 %)	0 (0.0 %)	
24-month	36	36 (100 %)	0 (0.0 %)	0 (0.0 %)	36	36 (100 %)	0 (0.0 %)	0 (0.0 %)	
36-month	33	33 (100 %)	0 (0.0 %)	0 (0.0 %)	33	33 (100 %)	0 (0.0 %)	0 (0.0 %)	
Within group p									
Secondary caries									
Baseline	47	47 (100 %)	–	0 (0.0 %)	47	47 (100 %)	–	0 (0.0 %)	
6-month	47	47 (100 %)	–	0 (0.0 %)	47	47 (100 %)	–	0 (0.0 %)	
12-month	47	47 (100 %)	–	0 (0.0 %)	46	46 (100 %)	–	0 (0.0 %)	
24-month	36	36 (100 %)	–	0 (0.0 %)	36	36 (100 %)	–	0 (0.0 %)	
36-month	33	33 (100 %)	–	0 (0.0 %)	33	33 (100 %)	–	0 (0.0 %)	
Within group p									

There were no Charlie ratings and no statistical increase in the number of unacceptable ratings in any category over the recall times

A Alfa, *B* Bravo, *C* Charlie

increments by incremental filling technique could produce higher shrinkage stresses at the adhesive interface and increase the cuspal deformation of the weakened cusps. Campodonico et al. [20] also reported no obvious advantage of incremental technique compared to bulk-filling technique in terms of cuspal deflection. In addition, incremental filling technique is a time-consuming procedure, may increase the contamination risk and include voids in the restoration [8]. In contrast, a recent in vitro study conducted by Bicalho et al. [21] reported that the negative effects of residual shrinkage stresses could be minimized by using a low post-gel shrinkage composite and increments that are not exceeding 2-mm thickness. Reduced cuspal deflection [18, 22] and higher resin–dentin micro-tensile bond strength in large cavities [41, 42] with incremental filling technique compared to the bulk filling technique have also been reported by previous studies.

In the current study, restorations placed with incremental technique and bulk-fill technique showed similar clinical performance during 3-year period. This clinically good performance of bulk-fill technique may be attributed to the reduced remaining cusp length after filling the cavity with x-tra base within 2 mm of the palatal cusp. It has been reported that the deformation of teeth is a cubed power of the cusp length [43, 44], and to reduce the deformation, cusp length should be reduced [16]. Similar with our results, the only study in the literature which evaluated the effectiveness of bulk fill flowable composite in a randomized controlled clinical study over 3 years reported that bulk-fill technique showed comparable clinical performance with incremental technique [8]. However, that study was conducted on vital teeth without endodontic treatment, so direct comparison of their results and the results of current study would be improper. Further clinical studies with bulk-fill composites are needed to confirm the reproducibility of the current study's findings.

Conclusion

Within the limitations of the present study, it can be concluded that bulk-filling technique with x-tra base lining showed clinically acceptable performance comparable to the incremental technique with a conventional flowable lining over 3-year period.

Compliance with ethical standards

Conflict of interest All authors declare that they have no conflict of interest.

Funding The work had no funding source.

Ethical approval All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

References

1. Reeh ES, Messer HH, Douglas WH (1989) Reduction in tooth stiffness as a result of endodontic and restorative procedures. J Endod 15:512–516
2. Wagnild GW, Mueller KI (2002) Pathways of the pulp. Mosby Inc., St Louis
3. Faria ACL, Rodrigues RCS, de Almeida Antunes RP, MdGC d M, RF R (2011) Endodontically treated teeth: characteristics and considerations to restore them. J Prosthodont Res 55:69–74
4. Salehrabi R, Rotstein I (2004) Endodontic treatment outcomes in a large patient population in the USA: an epidemiological study. J Endod 30:846–850
5. Aquilino SA, Caplan DJ (2002) Relationship between crown placement and the survival of endodontically treated teeth. J Prosthet Dent 87:256–263
6. Soares PV, Santos-Filho PC, Queiroz EC, et al. (2008) Fracture resistance and stress distribution in endodontically treated maxillary premolars restored with composite resin. J Prosthodont 17:114–119
7. Taha NA, Palamara JE, Messer HH (2014) Fracture strength and fracture patterns of root-filled teeth restored with direct resin composite restorations under static and fatigue loading. Oper Dent 39: 181–188
8. 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 Mater 30:245–251
9. Versluis A, Douglas WH, Cross M, Sakaguchi RL (1996) Does an incremental filling technique reduce polymerization shrinkage stresses? J Dent Res 75:871–878
10. van Dijken JW, Pallesen U (2011) Clinical performance of a hybrid resin composite with and without an intermediate layer of flowable resin composite: a 7-year evaluation. Dental Mater 27:150–156
11. Andersson-Wenckert IE, van Dijken JW, Horstedt P (2002) Modified class II open sandwich restorations: evaluation of interfacial adaptation and influence of different restorative techniques. Eur J Oral Sci 110:270–275
12. Korkmaz Y, Ozel E, Attar N (2007) Effect of flowable composite lining on microleakage and internal voids in class II composite restorations. J Adhes Dent 9:189–194
13. Leevailoj C, Cochran MA, Matis BA, Moore BK, Platt JA (2001) Microleakage of posterior packable resin composites with and without flowable liners. Oper Dent 26:302–307
14. Ozel E, Soyman M (2009) Effect of fiber nets, application techniques and flowable composites on microleakage and the effect of fiber nets on polymerization shrinkage in class II MOD cavities. Oper Dent 34:174–180
15. Sadeghi M, Lynch CD (2009) The effect of flowable materials on the microleakage of class II composite restorations that extend apical to the cemento-enamel junction. Oper Dent 34:306–311
16. Alomari QD, Reinhardt JW, Boyer DB (2001) Effect of liners on cusp deflection and gap formation in composite restorations. Oper Dent 26:406–411
17. Visvanathan A, Ilie N, Hickel R, Kunzelmann KH (2007) The influence of curing times and light curing methods on the polymerization shrinkage stress of a shrinkage-optimized composite with hybrid-type prepolymer fillers. Dental Mater 23:777–784
18. Park J, Chang J, Ferracane J, Lee IB (2008) How should composite be layered to reduce shrinkage stress: incremental or bulk filling? Dental Mater 24:1501–1505
19. Kwon Y, Ferracane J, Lee IB (2012) Effect of layering methods, composite type, and flowable liner on the polymerization shrinkage stress of light cured composites. Dental Mater 28:801–809
20. Campodonico CE, Tantbirojn D, Olin PS, Versluis A (2011) Cuspal deflection and depth of cure in resin-based composite restorations filled by using bulk, incremental and transtooth-illumination techniques. JADA 142:1176–1182
21. Bicalho AA, Valdivia AD, Barreto BC, et al. (2014) Incremental filling technique and composite material—part II: shrinkage and shrinkage stresses. Oper Dent 39:E83–E92

22. Lee MR, Cho BH, Son HH, Um CM, Lee IB (2007) Influence of cavity dimension and restoration methods on the cusp deflection of premolars in composite restoration. Dental Mater 23:288–295
23. Attar N, Tam LE, McComb D (2003) Flow, strength, stiffness and radiopacity of flowable resin composites. J Can Dent Assoc 69: 516–521
24. Fabianelli A, Sgarra A, Goracci C, et al. (2010) Microleakage in class II restorations: open vs closed centripetal build-up technique. Oper Dent 35:308–313
25. El-Safty S, Silikas N, Watts DC (2012) Creep deformation of restorative resin-composites intended for bulk-fill placement. Dental Mater 28:928–935
26. Flury S, Hayoz S, Peutzfeldt A, Husler J, Lussi A (2012) Depth of cure of resin composites: is the ISO 4049 method suitable for bulk fill materials? Dental Mater 28:521–528
27. Alshali RZ, Silikas N, Satterthwaite JD (2013) Degree of conversion of bulk-fill compared to conventional resin-composites at two time intervals. Dental Mater 29:e213–e217
28. Par MGO, Marovic D, Klaric E, Tarle Z (2015) Raman spectroscopic assessment of degree of conversion of bulk-fill resin composites—changes at 24 hours post cure. Oper Dent 40:000–000
29. Leprince JG, Palin WM, Vanacker J, et al. (2014) Physico-mechanical characteristics of commercially available bulk-fill composites. J Dent 42:993–1000
30. Garcia D, Yaman P, Dennison J, Neiva G (2014) Polymerization shrinkage and depth of cure of bulk fill flowable composite resins. Oper Dent 39:441–448
31. Marovic D, Taubock TT, Attin T, Panduric V, Tarle Z (2014) Monomer conversion and shrinkage force kinetics of low-viscosity bulk-fill resin composites. Acta Odontol Scand 73:1–7
32. Baroudi K, Saleh AM, Silikas N, Watts DC (2007) Shrinkage behaviour of flowable resin-composites related to conversion and filler-fraction. J Dent 35:651–655
33. Bucuta S, Ilie N (2014) Light transmittance and micro-mechanical properties of bulk fill vs. conventional resin based composites. Clin Oral Investig 18:1991–2000
34. Czasch P, Ilie N (2013) In vitro comparison of mechanical properties and degree of cure of bulk fill composites. Clin Oral Investig 17:227–235
35. Product specification for Aelite flo.(Bısco Inc. Schaumburg I, USA)
36. Moorthy A, Hogg CH, Dowling AH, et al. (2012) Cuspal deflection and microleakage in premolar teeth restored with bulk-fill flowable resin-based composite base materials. J Dent 40:500–505
37. Cvar JF RG. (1971) Criteria for the clinical evaluation of dental restorative materials US Public Health Service Publication No 790–244 Government Printing Office, San Francisco.
38. McLean JW, Wilson AD (1977) The clinical development of the glass-ionomer cement. II. Some clinical applications. Aust Dent J 22:120–127
39. Simi B, Suprabha B (2011) Evaluation of microleakage in posterior nanocomposite restorations with adhesive liners. J Conserv Dent 14:178–181
40. Versluis A, Tantbirojn D, Pintado MR, DeLong R, Douglas WH (2004) Residual shrinkage stress distributions in molars after composite restoration. Dental Mater 20:554–564
41. He Z, Shimada Y, Tagami J (2007) The effects of cavity size and incremental technique on micro-tensile bond strength of resin composite in class I cavities. Dental Mater 23:533–538
42. Nikolaenko SA, Lohbauer U, Roggendorf M, et al. (2004) Influence of c-factor and layering technique on microtensile bond strength to dentin. Dental Mater 20:579–585
43. Hood JA (1991) Biomechanics of the intact, prepared and restored tooth: some clinical implications. Int Dent J 41:25–32
44. Chuang SF, Chang CH, Chen TY (2011) Spatially resolved assessments of composite shrinkage in MOD restorations using a digital-image-correlation technique. Dental Mater 27:134–143