ejpmr, 2017,4(10), 124-137

SJIF Impact Factor 4.161

EUROPEAN JOURNAL OF PHARMACEUTICAL AND MEDICAL RESEARCH
www.ejpmr.com

Review Article
ISSN 2394-3211
EJPMR

BENEFITS AND DRAWBACKS OF BULK-FILL DENTAL COMPOSITES: A SYSTEMATIC REVIEW

Nujud S.A. Edrees, BDS; Hadeel S. A. Amer, BDS; Khalid M. Abdelaziz, BDS, MDSc, PhD; Wafa Alajam, BDS, MSc, PhD

King Khalid University, College Of Dentistry, Abha, Saudi Arabia.

***Corresponding Author: Hadeel Saad Amer**
King Khalid University, College Of Dentistry, Abha, Saudi Arabia.

Article Received on 12/08/2017 **Article Revised on 03/09/2017** **Article Accepted on 24/09/2017**

ABSTRACT
Introduction: Bulk-fill composites were recently introduced, the published literature about their physical and mechanical properties yield inconsistent or sometimes contradicting results. Therefore, in depth review of this literature could be a helpful guide for dentists to use these new promising restorative materials. This study aims to meticulously revise the previously published articles concerned about bulk-fill composites to highlight their benefit and drawbacks, regarding their physical and clinical properties. **Methods:** All articles published in English language and dated before Sept 2016, were eligible to be included in this review. Articles included the search terms in any fields were screened (5384 articles). After that, the duplicated and irrelevant studies were excluded based on their titles and abstracts (5339 excluded articles). Then, the full texts were retrieved for the other eligible articles to conduct in-depth screening for the tested properties of the bulk-fill composite (45 articles). Then, the exclusion of the irrelevant studies based on the full text of articles was done to yield finally included studies (32 articles). Then nine studies were excluded from 32 included studies; due to different measurement of outcomes that were not valid for comparisons with the other included studies, thus, the finally included studies were 23. **Results**: The depth of cure for flowable and paste-like composite was higher than that for conventional composite. Degree of conversion of flowable in comparison to conventional was contradicting, while paste like bulk fill was higher than condensable conventional composite. Polymerization shrinkage is higher or comparable in flowable bulk fill composite in comparison to that in the conventional composite, while in paste like composite the results was contradicting. The polymerization stress of flowable and paste-like bulk fill composite was lower than that of conventional composite. In regards to top hardness, most studies found it lower in flowable bulk fill composite in comparison to conventional composite, while in paste like composite the results was contradicting. The bottom surface hardness of flowable bulk fill composite was comparable or lower than that in conventional composite, while in paste like composite the results was contradicting. The flexure (transverse) strength of flowable bulk fill composite was lower than conventional composite, while in paste like composite the flexural strength was comparable with conventional composite. The compressive strength and tensile strength of flowable and paste like bulk fill composite was lower than that in conventional composite. The bond strength to dentine in flowable bulk fill composite was comparable or higher than conventional depend on increase in the filling thickness, no study assesse the bond strength in paste-like composite. In marginal adaptation, no comparison to the conventional composite was made. Concerning micro-leakage, the flowable bulk fill composite was comparable to the conventional composite in enamel, but lower than conventional in dentine. In paste like composite, no comparison was made with conventional composite. **Conclusions**: Regarding the chemical curing properties such as depth of cure and degree of conversion, the bulk fill composite (either flowable or paste-like) were superior to the conventional composite. In regards to the mechanical properties such as top hardness, bottom hardness, flexural strength, compressive strength and tensile strength, the flowable bulk fill composite tend to be inferior to the conventional composite. While the results were contradicting in regards to paste-like bulk fill composite. The polymerization stress was lower in the flowable and paste-like bulk fill composite in comparison to the conventional composite, while the results were inconsistent in regards to the polymerization shrinkage. Concerning the bond strength and micro-leakage, they tend to be superior in the flowable bulk fill composite than conventional composite, but more studies are required to elaborate this area.

KEYWORDS: Composite, Bulk-fill, Flowable, Paste-like, Strength, Cure.

INTRODUCTION

Resin based composite has achieved a high degree of success in the restoration of decayed or stained teeth. Thus, many efforts have been exerted to improve the composite materials in physical and clinical aspects, as well as to facilitate manipulation techniques (Deliperi and Bardwell, 2002, Kim and Park, 2011). The main drawback of composite fillings is polymerization shrinkage stress, which affects both the main body of the filling and the adhesive bonding with tooth structure. (Moraes et al., 2011, Davidson and Feilzer, 1997). This polymerization shrinkage could be a predisposing factor of numerous clinical consequences such as poor marginal adaptation, microleakage, development of secondary caries and subsequent pulpal inflammation. Another drawback associated with composite restorations is reduction in the degree of conversion, which affect physical properties of composite and increase monomer proportion (Idriss et al., 2007, Kleverlaan and Feilzer, 2005). This could result in postoperative sensitivity which leads to early failure of the composite filling (Briso et al., 2007).

Many clinical techniques have been used to reduce the occurrence of these complications including: incremental technique, application of flowable lining material, and modulation of light curing mechanism (Deliperi and Bardwell, 2002, Davidson and Feilzer, 1997). The best strategy was found to be the incremental technique by placement of composite restoration in 2 mm incremental layers. This will allow penetration of the light and subsequent curing of the resin material, as well as the reduction of polymerization shrinkage. (Liebenberg, 1996, Park et al., 2008). However, this incremental layering technique is time-consuming and dentists still need the easier and quicker method for composite manipulation.

Bulk-fill composite is recently introduced resin based material. It is considered as advancement in the resin-based restorations with claims of light curability till 4 mm thickness. It could reduce the working time of the restorations to approximately half of that in the conventional composite (Flury et al., 2012). Furthermore, bulk-fill composite divided into flowable bulk-fill composite and non-flowable (paste-like) bulk-fill composite. Flowable bulk-fill composite was firstly used in the last three decades as injectable material which is considered as a desirable manipulation property (Labella et al., 1999, Rada, 1998). The first products of flowable composite had more resin matrix and less filler content in comparison to paste-like bulkfill composite, so it was used as a lining layer. The last products of flowable bulk-fill composite such as Venus Bulk fill (VBF; Heraeus Kulzer GmbH, Hanau, Germany) and Surefil SDR Flow (SDR; Dentsply Caulk, Milford, DE, USA) have higher filler content and improved physical properties (Ikeda et al., 2009). In another hand, the bulk-fill Paste-like composite such as Tetric N-Ceram Bulk-fill (TBF; Ivoclar Vivadent, Schaan, Liechtenstein) was introduced in the recent years with no need of capping layer required for their flowable counterparts (Flury et al., 2014). Since those bulk-fill composites were recently introduced, the published literature about their physical and mechanical properties yield inconsistent or sometimes contradicting results. Therefore, in depth review of this literature could be a helpful guide for dentists to use these new promising restorative materials. This study aims to meticulously revise the previously published articles concerned about bulk-fill composites to highlight their benefit and drawbacks, regarding their physical and clinical properties.

METHODS

Keywords and search strategy: The keywords and search strategy demonstrated by the summary of search results (table 1). The flow of the information through the different stages of the systematic review (identification, screening, eligibility, inclusion) was demonstrated in figure (1).

Eligibility Criteria: All articles published in English language and dated before Sept 2016, were eligible to be included in this review. Articles included the search terms in any fields were screened (5384 articles). After that, the duplicated and irrelevant studies were excluded based on their titles and abstracts (5339 excluded articles). Then, the full texts were retrieved for the other eligible articles to conduct in-depth screening for the tested properties of the bulk-fill composite (45 articles). Then, the exclusion of the irrelevant studies based on the full text of articles was done to yield finally included studies (32 articles).

Data Sources: An electronic search was conducted on Google Scholar, PubMed, Wiley Online Library, and Science Direct search engines. The search strategy was demonstrated in table 1.

Data Extraction: To ensure that, the extraction of all required information in regards to certain properties of bulk-fill composite was achieved properly, tow reviewers read the included studies (articles). The data were collected in data extraction form showed in table (2), which including the following properties of bulk-fill composite.

1. Depth of cure.
2. Degree of conversion.
3. Polymerization shrinkage.
4. Polymerization stresses.
5. Surface hardness (top surface).
6. Surface hardness (bottom surface).
7. Flexure (transverse) strength.
8. Compressive strength.
9. Tensile strength (DTS).
10. Bond strength to dentine.
11. Marginal adaptation.
12. Micro leakage.
13. Working time and convenience.

RESULTS AND DISCUSSION

Table. (1): Summary of search results.

Search Engine	Search Terms	Papers
Google Scholar	Bulk-fill dental composite	1200
PubMed	Bulk-fill dental composite	115
Science Direct	Bulk-fill dental composite	3983
Wiley Online Library	Bulk-fill dental composite	86
Total	Titles and Abstracts examined	5384
	Full texts retrieved	45
	Papers included in the review	**32**

Limits Activated: English language.

Table. (2): Summary of the findings.

Type	Tested property	Number of concerned articles	Percentage (Out of the total searched articles)	Reference numbers	Value range	Comparison to increment-fill Composites e.g. Comparable / Higher / Lower
Flowable bulk-Fill composites	**Depth of cure**	2	8.7%	(Benetti et al., 2015)	Mean (SD) in mm= [2.76 (0.13) - 5.57 (0.28)]	Higher than conventional
				(Li et al., 2015)	Mean in (mm)= (7.84 – 10.05)	Higher than conventional
	Degree of conversion	7	30.4%	(Alshali et al., 2013)	Mean % (SD) were Immediately= [49.5 (1.9) -62.0 (3.3)]; and 24 hours after curing= [50.9 (1.5) – 79.2 (1.8)]	Lower than conventional
				(Zorzin et al., 2015)	Mean% (SD) [0mm=56.53 (10.9) - 73.46 (9.61)] [2mm=43.69 (5.92) - 76.32 (1.27)] [4mm= 52.04 (12.45) - 80.07 (2.76)]	Comparable with conventional flowable conventional composite and Higher than conventional condensable composite
				(Guo et al., 2016)	52.5%	slightly higher conventional composite
				(Leprince et al., 2014)	(%) [43.6 - 71.2]	Comparable with conventional (57.7 - 62.8)
				(Li et al., 2015)	(%) (77.3% - 80.0%)	Higher than conventional
				(Ilie et al., 2013b)	Mean% (SD)= [48.4% (1.6)]	________
				(Czasch and Ilie, 2013)	(%) 5 min after curing for 40s Mean(SD)= [59.6 (1.9) - 67.4 (1.5)]	___
	Polymerization shrinkage	4	17.4%	(Garcia et al., 2014)	Mean (SD) in %: [3.43% (60.51) - 4.40% (60.79)]	__
				(Kim et al., 2015)	[2.99% - 3.05%]	Higher than conventional
				(Zorzin et al., 2015)	Mean (SD) %= [3.05 (0.3) - 4.03 (0.24)]	Comparable with conventional flowable composite [3.92 (0.48)]

						Higher than condensable composite [2.31 (0.57)]
				(Benetti et al., 2015)	Mean (SD) in %= [2.76 (0.13) - 3.36 (0.13)]	higher polymerization shrinkage than conventional composite
	Polymerization stresses	4	17.4%	(El-Damanhoury and Platt, 2014)	Measured in MPa =Mean (SD)= [1.607 (0.04) - 1.649 (0.06)]	lower polymerization stress than conventional composite
				(Guo et al., 2016)		lower final stress than conventional composite
				(Kim et al., 2015)	Mean stress (MPa)= [1.68 - 2.24]	Lower than conventional
				(Zorzin et al., 2015)	Mean (SD)= [1.07 (0.1) - 1.65 (0.1)]	-lower than conventional flowable composite -lower than condensable composite
	Surface hardness (top surface)	14	60.9%	(Alshali et al., 2015)	Mean (SD) after 24 storage in E/W solution= 6.3 (0.4) - 22.8 (2.1)	Lower than conventional
				(Leprince et al., 2014)	MPa (mean) Ethanol VH= [19.2 - 60.1]	Lower than conventional
				(Zorzin et al., 2015)	Mean (SD)=[0mm=34.34 (4.34) - 57.06 (2.76)] [2mm=29.15 (1.93) - 58.08 (2.75)] 4mm= [33.45(1.44) -56.96 (3.07)]	- comparable with conventional flowable composite -lower than condensable composite
				(Flury et al., 2014)	(medians at 2 mm,4 mm,6 mm)= [34.0-36.4, 35.5-38.7, 36.9-37.1]	Lower than conventional
				(Rosatto et al., 2015)	Mean (SD) in enamel= [103.9 (1.7)- 117.3 (7.2)] Mean (SD) in dentine = [52.8 (1.7) - 62.7 (2.6)]	Comparable with conventional in enamel [114.4 (7.1)], lower than conventional in dentine [115.6 (7.9)]
				(Jang et al., 2015)	Mean (SD)= [30.55 (1.17) - 32.14 (1.42)]	Lower than conventional [35.36 (4.62) -87.30 (6.41)]
				(Yousef et al., 2015)	Micro hardness Mean (SD)= [120.4 (3.8)]	
				(Alrahlah et al., 2014)	Mean (SD) of max.VHN (Vickers hardness)= [37.80 (1.10) - 62.60 (2.01)]	
				(Ilie et al., 2013b)	VHV (N/mm2) Mean (SD) at 40 s curing and 0 distance of light tip= 82.3 (9.3)	
				(Ilie et al., 2013a)	HV (Vickers hardness) = Mean (SD) N/mm2 = [38.1 (11.8) - 85.1 (11.2)]	
				(Garcia et al., 2014)	Means (SD) Knoop Hardness Values: (2mm, 3 mm, 4 mm, 5 mm)= [21.6 (2.40) -29.1 (0.77),	Means (SD) Knoop Hardness Values: Lower than conventional composite

					21.3 (1.02) - 29.4 (1.16), 23.5 (3.25) - 29.7 (3.97), 23.0 (2.34) - 31.5 (1.42)]	
				(El-Damanhoury and Platt, 2014)	Top Hardness, Knoop (KHN) Mean (SD)= [36.60 (0.97) - 48.53 (2.38)]	Lower than conventional
				(Czasch and Ilie, 2013)	Vickers hardness HV (N/mm2) measured in 0.1, 2, 4, and 6 mm depth of samples cured for 40 s = 42.7 (4.9) - 59.1 (1.3), 46.4 (2.1) - 60.2 (1.8.), 46.4 (1.0) - 59.5 (2.9), 46.0 (1.9) - 58.9 (2.6)	
				(Bucuta and Ilie, 2014)	Measured at Surface, 2 mm, 4 mm, 6 mm= 38.4 (3.8) - 69.0 (2.5) 38.5 (0.6) - 64.6 (4.1) 34.4 (0.8) - 61.0 (0.4) 25.7 (2.0) - 50.8(2.2)	Lower than conventional in all distances
	Surface hardness (bottom surface)	4	17.4%	(Flury et al., 2014)	medians at 2 mm, 4 mm, 6 mm)= [25.8 - 26.6, 21.9 - 25.3, 26.0 - 28.9]	Lower than conventional in all distances
				(Ilie et al., 2013b)	Vickers hardness, HV (N/mm2) Mean (SD) at 40 s curing and 0 distance of light tip= 80.6 (8.1)	
				(Garcia et al., 2014)	Means (SD) Knoop Hardness Values: (2mm, 3 mm, 4 mm, 5 mm)= 17.0 (2.35) - 21.5 (2.53), 16.6 (0.70) - 21.1 (1.98), 15.6 (2.09) - 19.8 (2.78), 13.5 (0.74) - 19.4 (2.74),	Lower than conventional in 2 mm Comparable with conventional in 3 mm
				(El-Damanhoury and Platt, 2014)	Top Hardness, Knoop (KHN) =Mean (SD)= = 34.31 (2.60) - 44.27 (2.78)	Comparable with conventional [43.10 (3.18)]
	Flexure (transverse) strength	4	17.4%	(Ilie et al., 2013a)	Mean (SD) in MPa= [122.4 (9.6) - 139.4 (7.0)]	
				(Leprince et al., 2014)	Mean in (MPa) = [76 – 110.5]	Lower than conventional
				(El-Damanhoury and Platt, 2014)	Mean (SD) in (MPa)= [107.4 (3.8) - 125.5 (9.4)]	Lower than conventional [143.8 (2.6)]
				(Czasch and Ilie, 2013)	Mean in (MPa) = [131.8 (5.8) - 122.7 (6.9)]	
	Tensile strength (DTS)	1	4.3%	(Rosatto et al., 2015)	Mean (SD) in (MPa)= [38.6 (5.9) - 43.5 (3.7)]	Lower than conventional [47.3 (7.5)]

	Bond strength to dentine	1	4.3%	(Flury et al., 2014)	(MPa, medians at 2 mm/4 mm/6 mm)= [21.4 - 24.6, 20.3 - 22.7, 22.0 - 23.4]	Comparable at 2 mm and higher than conventional at 4 and 6 mm
	Marginal adaptation	1	4.3%	(Benetti et al., 2015)	Gap median in micrometer= [6.1 – 10.2]	
	Micro-leakage	3	13.0%	(Orłowski et al., 2015)	Dye leakage around examined restorations N(%)= 0 score in [86.66% - 93.33%] 1 score in 3.33% 2 score in [3.33% - 6.66%] 3 score in [0.00% -3.33%]	
				(Arslan et al., 2013)	Enamel micro-leakage with clearfil bonding N(%)= 0 score in 56% 1 score in 25% 2 score in 19% 3 score in 0%	Comparable to conventional at score 0, lower than conventional at score 1, higher than conventional in score 2 and equal at score 3.
				(Arslan et al., 2013)	Dentine with clearifil bonding microleakage N(%): 0 score in 75% 1 score in 25% 2 score in 0% 3 score in 0%	dentine microleakage with clearifil bonding was higher than conventional at score 0, equal at score 1, lower than conventional in score 2, equal at score 3
	Working time and convenience	0	0%	____	_____	____
Paste-Like bulk-Fill composites	**Depth of cure**	2	8.7%	(Benetti et al., 2015)	Measured in mm - Mean (SD)= [2.90 (0.28) - 3.82 (0.08)] =	Comparable to conventional
				(Li et al., 2015)	Mean in (mm)= - light beam cure = 3.14, - middle beam = 4.19	Higher depth of cur than conventional
	Degree of conversion	4	17.4%	(Ilie et al., 2013b)	Mean% (SD)= 48.4 % (1.6%)	____
				(Zorzin et al., 2015)	Mean % (SD)= 0mm=67.45 (6.58), 2mm= 63.00 (3.88), 4mm=63.40 (4.37)	lower than conventional flowable composite at 0mm, higher than conventional at 2 mm, lower than conventional at 4mm -Higher than condensable composite at all thicknesses
				(Abed et al., 2015)	Mean % (SD)=67.74 (2.65)	Higher than conventional
				(Leprince et al., 2014)	Mean (%)=[56.7% - 76.5%]	Comparable with conventional

	Polymerization shrinkage	5	21.7%	(Garcia et al., 2014)	Mean (SD) %=1.76% (60.53)	________
				(Mulder et al., 2013)	The sequence of total volumetric change according to the shrinkage values after 35 seconds (%)= [0.90 -1.80]	Higher than conventional
				(Kim et al., 2015)	Mean shrinkage= [2.05% - 2.22%]	
				(Zorzin et al., 2015)	Mean (SD) %= 2.36 (0.23)	- lower than conventional flowable composite [3.92 (0.48)] - comparable with condensable composite [2.31 (0.57)]
				(Benetti et al., 2015)	Mean % (SD) = [1.58 (0.04) - 2.03 (0.05)]	higher polymerization shrinkage than conventional composite
	Polymerization stresses	3	13.0%	(El-Damanhoury and Platt, 2014)	Measured in MPa =Mean (SD)= [1.883 (0.09) - 2.135 (0.07)]	Paste-like bulk-fill composite showed lower polymerization stress than conventional composite
				(Kim et al., 2015)	Mean stress MPa= [2.36 - 2.42]	Lower than conventional
				(Zorzin et al., 2015)	Mean (SD)= = 1.07 (0.1)	- lower than conventional flowable composite [1.94 (0.2)] - lower than condensable composite [2.31 1.23 (0.12)]
	Surface hardness (top surface) Top hardness	14	60.9%	(Yousef et al., 2015)	Micro hardness: (Mean ± SD)= [128.4 ± 4.4]	
				(Leprince et al., 2014)	Mean in MPa= [67.3 - 91]	Comparable to conventional
				(Abed et al., 2015)	Mean (SD)= [64.13 (6.2) - 75.79 (7.0)]	Lower than conventional
				(Alrahlah et al., 2014)	Mean (SD) of max.VHN (Vickers hardness)= 65.23 (0.92) - 77.40 (1.82)	
				(Flury et al., 2014)	(medians at 2 mm/4 mm/6 mm)= 63.5 - 103.4 59.7 - 103.9 51.9 - 101.9	Lower than conventional in 2mm Comparable with conventional at 4 mm Higher than conventional at 6 mm
				(Ilie et al., 2013b)	(N/mm2) Mean (SD) at 40 s curing and 0 distance of light tip= 80.9 (7.3)	
				(Ilie et al., 2013a)	Mean (SD) N/mm2= [78.4 (6.7) - 133.5 (32.0)]	
				(Zorzin et al., 2015)	Mean (SD)= 0mm=64.52 (2.45),	- higher than conventional flowable composite in all distances

					2mm= 60.55 (3.53), 4mm=41.92 (4.46)	-lower than condensable composite in all distances
				(Rosatto et al., 2015)	Mean (SD)= enamel=106.7 (4.2), dentine= 105.4 (6.1)	Lower than conventional in enamel and dentine
				(Garcia et al., 2014)	Means (SD) Knoop Hardness Values at (2mm, 3 mm, 4 mm, 5 mm)= [72.6 (2.40), 72.3 (3.20), 72.4 (2.11), 71.1 (2.64)]	Higher than conventional
				(El-Damanhoury and Platt, 2014)	Top Hardness, Knoop (KHN) =Mean (SD)= [55.40 (3.3) - 59.07 (6.4)]	Comparable with conventional
				(Alshali et al., 2015)	mean(SD)= [6.4 (0.3) - 26.7 (1.3)]	Lower than conventional
				(Bucuta and Ilie, 2014)	Measured at Surface, 2 mm, 4 mm, 6 mm= [77.7 (2.5) - 144.7 (18.2)] [69.5 (3.4) - 126.8(7.6)] [74.7 (1.6) - 144.3(6.2)] [57.7 (5.4) - 129.8(3.6)]	Comparable with the conventional at all distances
				(Jang et al., 2015)	Mean (SD)= [48.54 (5.39) - 49.05 (3.82)]	Comparable with conventional
	Surface hardness (bottom surface)	6	26.1%	(Jang et al., 2015)	Mean (SD)= [23.75 (1.5) - 37.83 (5.7)]	Comparable with conventional
				(Ilie et al., 2013b)	Vickers hardness, HV (N/mm2) Mean (SD) at 40 s curing and 0 distance of light tip= 73.3 (2.6)	
				(Garcia et al., 2014)	Means (SD) Knoop Hardness Values: (2mm, 3 mm, 4 mm, 5 mm)= [59.4 (2.85), 48.9 (2.06), 34.0 (1.88), 15.1 (1.29)]	Higher than conventional
				(El-Damanhoury and Platt, 2014)	Top Hardness, Knoop (KHN) =Mean (SD)= [44.13 (2.26) - 51.20 (7.61)]	Higher than conventional
				(Flury et al., 2014)	(medians at 2 mm/4 mm/6 mm)= [63.0 - 110.5] [54.9 - 107.2] [48.2 - 101.9]	Comparable with conventional at 2 and 4mm Higher than conventional at 6 mm
				(Abed et al., 2015)	Mean (SD)=	Lower than conventional

					[63.61 (5.50) - 68.66 (5.10)]	
	Flexure (transverse) strength	1	4.3%	(Leprince et al., 2014)	(MPa) means=[94.5 - 140.3]	Comparable with conventional
	Compressive strength	1	4.3%	(Rosatto et al., 2015)	MPa Mean (SD)=[213.3 (37.4)]	Lower than conventional
	Tensile strength (DTS)	1	4.3%	(Rosatto et al., 2015)	MPa Maen (SD)=[37.8 (7.7)]	Lower than conventional
	Bond strength to dentine	0	0.0%	___	___	___
	Marginal adaptation	1	4.3%	(Benetti et al., 2015)	Gap, micrometer: (median, range)= [6.6 - 7.1]	
	Microleakage	1	4.3%	(Orłowski et al., 2015)	Dye leakage around examined restorations N(%)= 0 score in 73% - 90% 1 score in 3.3% - 23.3% 2 score in 0.0% 3 score in 0.0% - 6,66%	
	Working time and convenience	0	0.0%	____	___	___

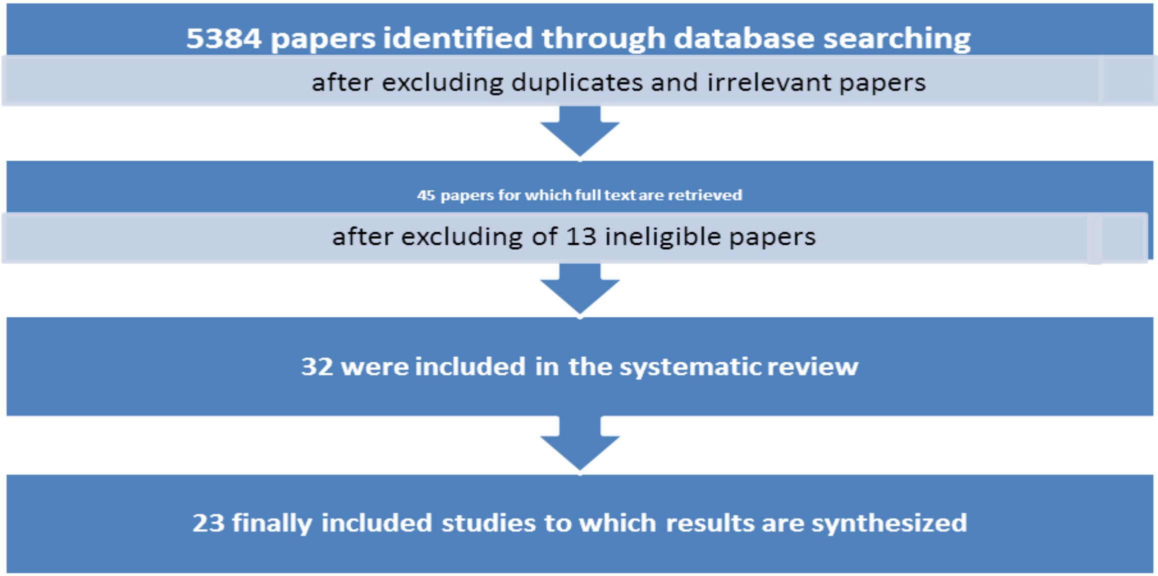

Figure. (1): Flow diagram of the included studies in the systematic review.

Nine studies were excluded from 32 included studies; due to different measurement of outcomes that were not valid for comparisons with the other included studies, thus, the finally included studies were 23.

This systematic review included 32 studies (table 1). The tested properties were 13 physical, chemical and manipulative properties of bulk fill composite. The data were extracted separately for flowable and paste-like bulk fill composite for each studied property as following.

1. Depth of cure

In regards to fowable bulk fill composite, **two** of included studies aimed to assess the depth of cure for flowable bulk fill composite (Benetti et al., 2015, Li et al., 2015). Benetti et al. found mean (sd) depth of cure of flowable composite ranged between 2.76 (0.13) mm - 5.57 (0.28) mm, while Lie et al, found mean depth of cure of flowable composite ranged between 7.84 to 10.05 mm. Both studies found the depth of cure for flowable composite higher than that for conventional composite.

About paste-like bulk fill composite, both studies also assessed the depth of cure. Benetti et al. found mean (sd) depth of cure of paste-like composite ranged between 2.90 (0.28) - 3.82 (0.08) mm, while Lie et al, found mean depth of cure of paste-like composite that ranged from 3.14 in light beam cure to 4.19 mm in middle beam cure. Benetti et al. found a depth of cure to be comparable to that in conventional composite, while Lie et al. found a higher depth in paste-like composite than that in conventional composite.

2. Degree of conversion (DC)

The degree of conversion for flowable bulk fill composite was assessed by **seve**n included studies (Zorzin et al., 2015, Guo et al., 2016, Leprince et al., 2014, Li et al., 2015, Ilie et al., 2013b, Czasch and Ilie, 2013, Alshali et al., 2013). Zorzin et al. and Alshali et al. found high levels of DC, however they were dependent on the studied thicknesses or time after curing. Zorzin et al. found mean % (sd) of DC ranged from 56.53 (10.9) to 73.46 (9.61) in 0 mm thickness, from 43.69 (5.92) to 76.32 (1.27) in 2 mm thickness, and from 52.04 (12.45) to 80.07 (2.76) in 4 mm thickness. Alshali et al. found mean % (sd) immediately after curing ranged 49.5 (1.9) to 62.0 (3.3), while at 24 hours after curing, mean % (sd) ranged from 50.9 (1.5) to 79.2 (1.8).

Zorzin et al. found means % (sd) of DC of flowable bulk fill composite to be comparable with that of conventional flowable composite and higher than that of conventional condensable composite, while Alshali et al. found lower means % (sd) of DC in flowable bulk fill composite than that of conventional composite. In addition, Li et al. found a high range of mean % DC of (77.3 - 80.0), while Guo et al., Leprince et al., and Ilie et al. found lower mean % DC with range from 43.6 to 71.2.

Concerning paste-like bulk fill composite, **four** studies which studied the mean percentage of degree of conversion. Zorzin et al. found that the mean (sd) % of DC was dependent on studied thicknesses as follows: 67.45 (6.58) in 0 mm, 63.00 (3.88) in 2 mm, and 63.40 (4.37) in 4 mm. They found mean % of DC in paste like bulk fill composite to be lower than that in conventional flowable composite at 0mm, higher than that conventional flowable at 2 mm and lower than that in conventional flowable at 4mm. However, they found percentages of DC of paste-like bulk fill composite to be higher than those found in condensable conventional composite at all studied thicknesses. In addition, Abed et al. and Leprince et al. found a range of mean % of DC in paste-like bulk fill composite from 56.7 to 76.5, while Ilie et al. found a lower mean % of DC that was 48.4 with 1.6 standard deviation.

3. Polymerization shrinkage

The polymerization shrinkage of flowable bulk fill composite was assessed by four studies, and there was no large variation between the findings of these studies (Garcia et al., 2014, Zorzin et al., 2015, Kim et al., 2015, Benetti et al., 2015). The mean percentage of polymerization shrinkage in flowable bulk fill composite was found to range from 2.76 to 4.4. Kim et al. and Benetti et al. found a higher mean percentage of polymerization shrinkage in flowable bulk fill composite than that in the conventional composite, while Zorzin et al. found polymerization shrinkage of flowable bulk fill composite comparable to that of conventional flowable composite but higher than that of conventional condensable composite.

The polymerization shrinkage of paste-like bulk fill composite was assessed by five studies, and there was no large variation between the findings of these studies (Garcia et al., 2014, Kim et al., 2015, Mulder et al., 2013, Zorzin et al., 2015, Benetti et al., 2015) . The mean percentage of polymerization shrinkage in paste-like bulk fill composite was found to range from 90 to 2.63. Mulder et al. and Benetti et al. found a higher mean percentage of polymerization shrinkage in paste-like bulk fill composite than that in the conventional composite, while Zorzin et al. found it lower to that of conventional flowable composite and comparable with that of conventional condensable composite.

4. Polymerization stresses

The polymerization stress of flowable bulk fill composite was assessed by four studies (Kim et al., 2015, Zorzin et al., 2015, El-Damanhoury and Platt, 2014, Guo et al., 2016). High level of polymerization stress was found by Kim et al. where mean stress (MPa) of flowable bulk fill composite ranged from 1.68 to 2.24. El-Damanhoury and Platt, and Zorzin et al. found that mean (sd) of polymerization stress ranged from 1.07 (0.1) to 1.65 (0.1). All these four studies found the polymerization stress of flowable bulk fill composite to be lower than that of conventional composite.

In regards to paste-like bulk fill composite, the polymerization stress was investigated by three studies (Kim et al., 2015, Zorzin et al., 2015, El-Damanhoury and Platt, 2014). A high level of polymerization stress was found by Kim et al. where mean stress (MPa) of paste-like bulk fill composite ranged from 2.36 to 2.42. El-Damanhoury and Platt and Zorzin et al. found that mean (sd) of polymerization stress ranged from 1.07 (0.1) to 2.135 (0.07). As well as its flowable counterpart, all studies found the polymerization stress of paste-like bulk fill composite to be lower than that of conventional composite.

5. Surface hardness

There are wealth of studies in the literature that assessed surface hardness (Vickers hardness of bulk fill composite, thus 14 studies were included in this review (Alshali et al., 2015, Leprince et al., 2014, Zorzin et al., 2015, Flury et al., 2014, Rosatto et al., 2015, Jang et al., 2015, Yousef et al., 2015, Alrahlah et al., 2014, Ilie et al., 2013b, Ilie et al., 2013a, Garcia et al., 2014, El-Damanhoury and Platt, 2014, Czasch and Ilie, 2013, Bucuta and Ilie, 2014). Many of these studies assessed surface hardness at different depths of top surface and also at the bottom surface, two studies assessed surface hardness after ethanol storage of fillings, and one study assessed it at enamel and dentine levels.

According to the depth of assessment, the mean (sd) of top surface hardness of flowable bulk fill composite that measured in (N/mm2) at surface, 2 mm, 4mm, and 6 mm depths were reported. They were as follows: from 34.3 (4.3) to 82.3 (9.3) at top surface, from 21.6 (2.40) to 64.6 (4.1) at 2 mm depth, from 23.5 (3.25) to 61.0 (0.4) at 4 mm depth, and from 25.7 (2.0) to 58.9 (2.6) at 6 mm depth.

After storage in ethanol, the top hardness of flowable bulk fill composite was found to diminish to a range of 6.3 (0.4) to 22.8 (2.1) due to softening effect of ethanol (Alshali et al., 2015). The maximum mean (sd) top hardness of flowable bulk fill composite was 120.4 (3.8) and reported by Yousef et al. Most of the studies reported lower top hardness of flowable bulk fill composite in comparison to conventional composite (Alshali et al., 2015, Leprince et al., 2014, Zorzin et al., 2015, Flury et al., 2014, Rosatto et al., 2015, Jang et al., 2015, Garcia et al., 2014, El-Damanhoury and Platt, 2014, Bucuta and Ilie, 2014).

In regards to paste-like composite, according to the depth of assessment, the mean (sd) of top surface hardness for paste-like bulk fill composite that measured in (N/mm2) at surface, 2 mm, 4mm and 6 mm depths were reported. They were generally higher than levels of top hardness reported in flowable bulk fill composite. They were as follows: from 64.52 (2.45), to 144.7 (18.2) at top surface, from 60.55 (3.53) to 126.8(7.6) at 2 mm depth, from 41.92 (4.46) to 144.3(6.2) at 4 mm depth, and from 57.7 (5.4) to 129.8(3.6) at 6 mm depth. Lower levels of top hardness that ranged from 48.54 to 91 were found in many studies (Zorzin et al., 2015, Garcia et al., 2014, Bucuta and Ilie, 2014, Ilie et al., 2013b). In addition, high levels of top surface hardness reached 128.4 and 133.5 were found by Yousef et al. and Ilie et al. respectively. Lower levels.

In the comparison with the conventional composite, the findings of included studies were contradicting. Few studies reported lower top surface hardness of paste-like bulk fill composite in comparison to conventional composite (Abed et al., 2015, Alshali et al., 2015), while the top surface hardness was found comparable in paste-like bulk fill and conventional composite in studies of (Jang et al., 2015, Bucuta and Ilie, 2014, El-Damanhoury and Platt, 2014, Leprince et al., 2014). Garcia et al. found top hardness higher in paste-like in all studied depths, while Flury et al. found it higher than conventional at 6 mm depth only. Zozrin et al. found top hardness higher in paste-like bulk fill composite in comparison to conventional flowable composite in all studied depths, but lower than conventional condensable composite in all depths.

6. Surface hardness (bottom surface)

The bottom surface hardness of flowable bulk fill composite was assessed by four included studies (Ilie et al., 2013b, Flury et al., 2014, Garcia et al., 2014, El-Damanhoury and Platt, 2014). Generally, the bottom surface hardness reported had lower level than top surface hardness. A maximum level of mean (sd) bottom surface hardness of 80.6 (8.1) was reported by Ilie et al. in HV (N/mm2) at 40 seconds of curing and 0 distance of light tip. Flury et al. and Garcia et al. assessed the bottom surface hardness at different depths, however flurry et al. describe their results in medians while Garcia et al. used means to describe their results. Garcia et al. found mean (sd) of bottom surface hardness to range from17.0 (2.35) to 21.5 (2.53) at 2 mm, from 16.6 (0.70) to 21.1 (1.98) at 3 mm, from 15.6 (2.09) to 19.8 (2.78) at 4 mm, and from 13.5 (0.74) to 19.4 (2.74) at 5 mm. A higher range of mean (sd) bottom surface hardness of 34.31 (2.60) - 44.27 (2.78) was found by El-Damanhoury and Platt, this range was comparable with bottom surface hardness in conventional composite. Flury et al. found the bottom hardness of flowable bulk fill composite lower than that of conventional composite, while Garcia et al. found alower bottom hardness in flowable bulk fill composite than that in conventional composite at 2 mm depth and comparable with conventional at 3 mm depth.

In regards to the bottom surface hardness of paste-like bulk fill composite, it was assessed by six included studies (Jang et al., 2015, Ilie et al., 2013b, El-Damanhoury and Platt, 2014, Flury et al., 2014, Garcia et al., 2014, Abed et al., 2015). The highest level of mean (sd) bottom surface hardness of 73.3 (2.6) was reported by Ilie et al. in HV (N/mm2) at 40 seconds of curing and 0 distance of light tip. In addition, a high range of mean (sd) bottom hardness of 63.61 (5.50) to 68.66 (5.10) was reported by Abed et al., while the lowest mean (sd) of bottom surface hardness that reached 23.75 (1.5) was reported by Jang et al. The findings of comparison with conventional composite were also contradicting. Garcia et al. and El-Damanhoury and Platt. reported a higher bottom surface hardness in paste-like bulk fill composite than that in conventional composite, while Abed et al. and Jang et al. reported lower and comparable bottom hardness in paste-like composite rather that in conventional composite, respectively.

7. Flexure (transverse) strength

Concerning the flexure (transverse) strength of flowable bulk fill composite, it was assessed by four included studies (Czasch and Ilie, 2013, El-Damanhoury and Platt, 2014, Ilie et al., 2013b, Leprince et al., 2014). High flexural strength (in MPa) were found by most of these studies and it ranged from the lowest limit of 76.0 reported by Leprince et al. to the highest limit of 139.4 reported by Ilie et al. Only two studies compared the flowable bulk fill composite to conventional composite, and they found lower levels of flexural strength in flowable bulk fill composite (El-Damanhoury and Platt, 2014, Leprince et al., 2014).

The flexural strength of paste-like bulk fill composite was assessed by only one included study (Leprince et al., 2014). A range of (94.5 - 140.3) of mean flexural strength was found, and it was comparable with conventional composite.

8. Compressive strength

The compressive strength of flowable bulk fill composite was assessed by only one included study (Rosatto et al., 2015). A range from 182.3 (14.6) to 245.1 (37.4) of mean (sd) compressive strength was found and it was lower than that in conventional composite.

The compressive strength of paste-like bulk fill composite was assessed by only one included study (Rosatto et al., 2015). A mean (sd) of compressive strength was found to be 213.3 (37.4), and it was lower than that in conventional composite.

9. Tensile strength (DTS)

The tensile strength of flowable bulk fill composite was assessed by only one included study (Rosatto et al., 2015). A range of 38.6 (5.9) to 43.5 (3.7) of mean (sd) tensile strength was found and it was lower than that in conventional composite.

The tensile strength of paste-like bulk fill composite was assessed by only one included study (Rosatto et al., 2015). A mean (sd) of tensile strength was found to be 37.8 (7.7) Mps, and it was lower than that in conventional composite.

10. Bond strength to dentine

The bond strength to dentine in flowable bulk fill composite was assessed by only one included study at different depths (2, 4, and 6 mm) (Flury et al., 2014). The median bond strength to dentine measured in Mpa ranged from 21.4 to 24.6 at 2 mm, from 20.3 to 22.7 at 4 mm and from 22.0 to 23.4 at 6 mm. In comparison to conventional composite, the bond strength in flowable bulk fill composite was found comparable at 2 mm and higher than conventional composite at 4 and 6 mm. In regards to paste-like bulk fill composite, there was no study found in the literature aimed to assess the bond strength to dentine, according to the search strategy used in this review.

11. Marginal adaptation

The marginal adaptation of flowable bulk fill composite was assessed by only one included study (Benetti et al., 2015). Median of marginal gap in micrometer ranged from 6.1 to 10.2. The same study assessed the marginal adaptation of paste- like composite, and they found a median gap ranged from Gap 6.6 – 7.1 micrometer. There was no comparison made to the conventional composite.

12. Micro-leakage

The micro-leakage is usually assessed according to the following scores, score 0 = no micro-leakage, score 1 = Leakage ≤ 1/2 length of occlusal/gingival walls, score 2 = Leakage ≥ 1/2 length of occlusal/gingival walls, score 3 = Leakage that covers entire length of occlusal/gingival walls and also involves the axial wall. In this review, two included studies assessed the micro-leakage of bulk fill composite filling using these scores (Arslan et al., 2013, Orłowski et al., 2015).

These two studies assessed the micro-leakage of flowable bulk fill composite, Orłowski et al. found low levels of micro-leakage, where no micro-leakage reported in 86.7% - 93.3% of studied specimens, while score 1 was found in 3.3%, score 2 in 3.3% - 6.7%, and score 3 in 0.0% - 3.3% of studied specimens. Arslan et al. studied micro-leakage in enamel and dentine with clearfil bonding agent, and they found higher levels of micro-leakage than those found by Orlowski et al. No micro-leakage was found in 56% of enamel specimen and 75% of dentinal specimens, while score 1 micro-leakage was found in 25% of both enamel and dentinal specimens. Score 2 micro-leakage reported in 19% of enamel specimens only, and no specimen reported score 3 micro-leakage. In comparison to conventional composite, the enamel micro-leakage in flowable bulk fill composite was found comparable to conventional at score 0, lower than conventional at score 1, higher than conventional in score 2 and equal at score 3. However, the dentine micro-leakage was higher than conventional at score 0, equal at score 1 and 3, lower than conventional at score 2.

In regards to paste-like micro-leakage, only one included study assessed the extent of micro-leakage using dye penetration (Orłowski et al., 2015). They found no micro-leakage in 73% - 90% of studied specimens (which was lower than flowable bulk fill composite). In addition, they found score 1 micro-leakage in 3.3%-23.3% of studied samples, while score 2 and 3 were found in only 0.0%-6.6% of studied samples. There was no comparison made to the conventional composite.

13. Working time and convenience

There was no study in the literature assessed working time and convenience for bulk fill composite, using the search strategy that have used in this review to identify included studies.

CONCLUSIONS

The depth of cure for flowable and paste-like composite was higher than that for conventional composite. Degree of conversion of flowable in comparison to conventional was contradicting, while paste like bulk fill was higher than condensable conventional composite. Polymerization shrinkage is higher or comparable in flowable bulk fill composite in comparison to that in the conventional composite, while in paste like composite the results was contradicting. The polymerization stress of flowable and paste-like bulk fill composite was lower than that of conventional composite.

In regards to top hardness, most studies found it lower in flowable bulk fill composite in comparison to conventional composite, while in paste like composite the results was contradicting. The bottom surface hardness of flowable bulk fill composite was comparable or lower than that in conventional composite, while in paste like composite the results was contradicting. The flexure (transverse) strength of flowable bulk fill composite was lower than conventional composite, while in paste like composite the flexural strength was comparable with conventional composite. The compressive strength and tensile strength of flowable and paste like bulk fill composite was lower than that in conventional composite.

The bond strength to dentine in flowable bulk fill composite was comparable or higher than conventional depend on increase in the filling thickness, no study assesse the bond strength in paste-like composite. In marginal adaptation, no comparison to the conventional composite was made. Concerning micro-leakage, the flowable bulk fill composite was comparable to the conventional composite in enamel, but lower than conventional in dentine. In paste like composite, no comparison was made with conventional composite.

CONFLICT OF INTEREST

The authors declared no conflict of interest and no financial sponsorship was received.

ACKNOWLEDGEMENT

The authors want to thank teaching staff in College of Dentistry, King Khalid University for their great help and support.

REFERENCES

1. ABED, Y., SABRY, H. & ALROBEIGY, N. Degree of conversion and surface hardness of bulk-fill composite versus incremental-fill composite. Tanta Dental Journal, 2015; 12: 71-80.
2. ALRAHLAH, A., SILIKAS, N. & WATTS, D. Post-cure depth of cure of bulk fill dental resin-composites. Dental Materials, 2014; 30: 149-154.
3. ALSHALI, R. Z., SALIM, N. A., SATTERTHWAITE, J. D. & SILIKAS, N. Post-irradiation hardness development, chemical softening, and thermal stability of bulk-fill and conventional resin-composites. Journal of dentistry, 2015; 43: 209-218.
4. ALSHALI, R. Z., SILIKAS, N. & SATTERTHWAITE, J. D. Degree of conversion of bulk-fill compared to conventional resin-composites at two time intervals. Dental Materials, 2013; 29: e213-e217.
5. ARSLAN, S., DEMIRBUGA, S., USTUN, Y., DINCER, A. N., CANAKCI, B. C. & ZORBA, Y. O. The effect of a new-generation flowable composite resin on microleakage in Class V composite restorations as an intermediate layer. Journal of Conservative Dentistry, 2013; 16: 189.
6. BENETTI, A., HAVNDRUP-PEDERSEN, C., HONORÉ, D., PEDERSEN, M. & PALLESEN, U. Bulk-fill resin composites: polymerization contraction, depth of cure, and gap formation. Operative dentistry, 2015; 40: 190-200.
7. BRISO, A. L. F., MESTRENER, S. R., DELICIO, G., SUNDFELD, R. H., BEDRAN-RUSSO, A., DE ALEXANDRE, R. & AMBROSANO, G. Clinical assessment of postoperative sensitivity in posterior composite restorations. Operative dentistry, 2007; 32: 421-426.
8. BUCUTA, S. & ILIE, N. Light transmittance and micro-mechanical properties of bulk fill vs. conventional resin based composites. Clinical Oral Investigations, 2014; 18: 1991-2000.
9. CZASCH, P. & ILIE, N. In vitro comparison of mechanical properties and degree of cure of bulk fill composites. Clinical Oral Investigations, 2013; 17: 227-235.
10. DAVIDSON, C. & FEILZER, A. Polymerization shrinkage and polymerization shrinkage stress in polymer-based restoratives. Journal of dentistry, 1997; 25: 435-440.
11. DELIPERI, S. & BARDWELL, D. N. An alternative method to reduce polymerization shrinkage in direct posterior composite restorations. The Journal of the American Dental Association, 2002; 133: 1387-1398.
12. EL-DAMANHOURY, H. & PLATT, J. Polymerization shrinkage stress kinetics and related properties of bulk-fill resin composites. Operative dentistry, 2014; 39: 374-382.
13. FLURY, S., HAYOZ, S., PEUTZFELDT, A., HÜSLER, J. & LUSSI, A. Depth of cure of resin composites: is the ISO 4049 method suitable for

bulk fill materials? Dental Materials, 2012; 28: 521-528.
14. FLURY, S., PEUTZFELDT, A. & LUSSI, A. Influence of increment thickness on microhardness and dentin bond strength of bulk fill resin composites. Dental Materials, 2014; 30: 1104-1112.
15. GARCIA, D., YAMAN, P., DENNISON, J. & NEIVA, G. Polymerization shrinkage and depth of cure of bulk fill flowable composite resins. Operative dentistry, 2014; 39: 441-448.
16. GUO, Y., LANDIS, F. A., WANG, Z., BAI, D., JIANG, L. & CHIANG, M. Y. Polymerization stress evolution of a bulk-fill flowable composite under different compliances. Dental Materials, 2016; 32: 578-586.
17. IDRISS, S., ABDULJABBAR, T., HABIB, C. & OMAR, R. Factors associated with microleakage in Class II resin composite restorations. Operative dentistry, 2007; 32: 60-66.
18. IKEDA, I., OTSUKI, M., SADR, A., NOMURA, T., KISHIKAWA, R. & TAGAMI, J. Effect of filler content of flowable composites on resin-cavity interface. Dental materials journal, 2009; 28: 679-685.
19. ILIE, N., BUCUTA, S. & DRAENERT, M. Bulk-fill resin-based composites: an in vitro assessment of their mechanical performance. Operative dentistry, 2013a; 38: 618-625.
20. ILIE, N., KEßLER, A. & DURNER, J. Influence of various irradiation processes on the mechanical properties and polymerisation kinetics of bulk-fill resin based composites. Journal of Dentistry, 2013b.; 41: 695-702.
21. JANG, J., PARK, S. & HWANG, I. Polymerization shrinkage and depth of cure of bulk-fill resin composites and highly filled flowable resin. Operative dentistry, 2015; 40: 172-180.
22. KIM, M. & PARK, S. Comparison of premolar cuspal deflection in bulk or in incremental composite restoration methods. Operative dentistry, 2011; 36: 326-334.
23. KIM, R. J.-Y., KIM, Y.-J., CHOI, N.-S. & LEE, I.-B. Polymerization shrinkage, modulus, and shrinkage stress related to tooth-restoration interfacial debonding in bulk-fill composites. Journal of dentistry, 2015; 43: 430-439.
24. KLEVERLAAN, C. J. & FEILZER, A. J. Polymerization shrinkage and contraction stress of dental resin composites. Dental Materials, 2005; 21: 1150-1157.
25. LABELLA, R., LAMBRECHTS, P., VAN MEERBEEK, B. & VANHERLE, G. Polymerization shrinkage and elasticity of flowable composites and filled adhesives. Dental Materials, 1999; 15: 128-137.
26. LEPRINCE, J. G., PALIN, W. M., VANACKER, J., SABBAGH, J., DEVAUX, J. & LELOUP, G. Physico-mechanical characteristics of commercially available bulk-fill composites. Journal of dentistry, 2014; 42: 993-1000.
27. LI, X., PONGPRUEKSA, P., VAN MEERBEEK, B. & DE MUNCK, J. Curing profile of bulk-fill resin-based composites. Journal of dentistry, 2015; 43: 664-672.
28. LIEBENBERG, W. H. Successive cusp build-up: an improved placement technique for posterior direct resin restorations. Journal (Canadian Dental Association), 1996; 62: 501-507.
29. MORAES, R. R., GARCIA, J. W., BARROS, M. D., LEWIS, S. H., PFEIFER, C. S., LIU, J. & STANSBURY, J. W. Control of polymerization shrinkage and stress in nanogel-modified monomer and composite materials. Dental Materials, 2011; 27: 509-519.
30. MULDER, R., GROBLER, S. R. & OSMAN, Y. I. Volumetric change of flowable composite resins due to polymerization as measured with an electronic mercury dilatometer. Oral Biology and Dentistry, 2013; 1: 1.
31. ORŁOWSKI, M., TARCZYDŁO, B. & CHAŁAS, R. 2015. Evaluation of marginal integrity of four bulk-fill dental composite materials: In Vitro Study. The Scientific World Journal, 2015.
32. PARK, J., CHANG, J., FERRACANE, J. & LEE, I. B. How should composite be layered to reduce shrinkage stress: incremental or bulk filling? Dental Materials, 2008; 24: 1501-1505.
33. RADA, R. E. The versatility of flowable composites. Dentistry today, 1998; 17: 78-83.
34. ROSATTO, C., BICALHO, A., VERÍSSIMO, C., BRAGANÇA, G., RODRIGUES, M., TANTBIROJN, D., VERSLUIS, A. & SOARES, C. Mechanical properties, shrinkage stress, cuspal strain and fracture resistance of molars restored with bulk-fill composites and incremental filling technique. Journal of dentistry, 2015; 43: 1519-1528.
35. YOUSEF, M. K., REEM, A. I. A. E. N. & AJAJ, A. 2015. Effect of Different Light-Curing Units on Microhardness of Different Bulk Fill Materials. Life Science Journal, 12.
36. ZORZIN, J., MAIER, E., HARRE, S., FEY, T., BELLI, R., LOHBAUER, U., PETSCHELT, A. & TASCHNER, M. Bulk-fill resin composites: polymerization properties and extended light curing. Dental Materials, 2015; 31: 293-301.