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Composite resin in the last 10 years – literature review. Part 4: polymerization shrinkage and postoperative sensitivity

ABSTRACT: Introduction: This is the fourth article of a series of six manuscripts about composite resins in the last 10 years. The polymerization shrinkage is part of photopolymerization process and may cause shrinkage stress. It may be related to microleakage, enamel cracks, postoperative sensitivity and secondary caries. The aim of this literature review is to synthesize shrinkage polymerization data of different composite resins and discuss the postoperative sensitivity results of several clinical studies. **Methods:** A search in PubMed database was performed and 25 and 24 articles were select for polymerization shrinkage and postoperative sensitivity, respectively. **Results:** Polymerization shrinkage, shrinkage stress and post-gel shrinkage are directly related. Factors such as resin composition, polymerization conditions and restorative technique influenced these properties. Bulk fill composites presented lower or similar values to conventional composites for both polymerization shrinkage and shrinkage stress. Fluid conventional composites showed the highest values for both properties. Postoperative

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sensitivity ranged from 0 to 52%. In general, composite resins and adhesive systems showed no difference in clinical performance. **Conclusion:** Bulk fill composites usually have a lower polymerization shrinkage and shrinkage stress. Postoperative sensitivity is related to several factors. Therefore, to avoid such discomfort, all steps of restoration must be carefully performed. **KEYWORDS:** Polymerization shrinkage. Composite resin. Postoperative sensitivity.

INTRODUCTION

Advances in technology, development of new materials, and emergence of adhesive dentistry with a more conservative view resulted in broad indication of composite resins.[1,2] Esthetics, absence of mercury, good mechanical properties, work time and mechanical properties influenced for the indication of composites for anterior and posterior restorations.[1] Moreover, bond union between composite and dental tissues create a single biomechanical body. This allows a homogeneous dissipation of masticatory forces (similar to healthy tooth), ensuring good clinical performance and greater remainder preservation.[2]

Although all advantages, one composite resin limitation is the polymerization shrinkage who is defined as a decrease of composite volume after polymerization. It results in residual shrinkage stress.[3-5] The monomers conversion in network polymer generate volumetric shrinkage and account polymerization shrinkage.[6,78] The first stage of polymerization is known as pre-gel phase. At this stage the maximum contraction occurs. However, due to low elastic modulus of material it is able to deform and dissipate part of stress.[9,10] In the next stage, defined as gel point phase, the composite elastic modulus increase and does not allow for deformation. Because of high elastic modulus and low deformation, in this stage occurs stress concentration in adhesive interface (composite/adhesive system/dental tissue).[9-12] This internal stress is designate as residual shrinkage stress and occur under confinement due to connection between composite and cavity walls.[13,14]

The resin composition influences material properties and contraction intensity. Thus, elastic modulus, viscosity, monomer type and filler content amount influence in polymerization shrinkage. Other factors like photoactivation conditions (energy intensity, light wave spectrum, direction and distance) and material insertion technique (joining or not opposite walls) modulate the volumetric reduction after polymerization and the stress magnitude.[15,16] With the aim of decrease polymerization contraction were developed composites based on silorane monomer. This monomers are smaller, with more molecular weight and ring-shaped.[15,17-19] Although reducing polymerization stress and shrinkage, these composites did not present good clinical longevity because of compromise other properties. Research continued to develop low shrinkage composites despite failure of silorane based composites. Then emerged bulk fill composites to simplify the procedure and reduce working time. This composites show lower polymerization shrinkage and allow insertion of increments up to 5mm[1, 20]. Bulk fill composites have fluid (low viscosity) and regular/sculpted consistence (medium viscosity).[14,20,21] Each manufacture chose any strategy to decrease polymerization shrinkage such as increased translucency allowing for greater light transmission; use of special monomers and photoinitiators; incorporations of different filler content as prepolymerized particles and reinforced with glass fiber.[20,22]

The polymerization shrinkage and residual stress can cause microleakage in adhesive interface, marginal staining, enamel cracks and secondary caries.[2] This can result in lower clinical longevity, because damage adhesion, esthetics and promotes biofilm accumulation.[23] Moreover, residual shrinkage stress may also be related with postoperative sensitivity (especially in posterior teeth) which is a clinical criterial for restoration failure.[13,24] Postoperative sensitivity can also be influenced by adhesive system (etch-and-rinse or self-etching), acid etching technique, restorations technique (incremental or bulk) and operator experience.[25-28] Therefore, is important understand and compare the properties of several commercial composites in order to indicate the best material for each clinical situation.

This literature review is part of 6 articles series that will approach different clinical, scientific and biomechanical aspects that affect composite resins in the last 10 years. Accordingly, part 4 proposal is to synthesize shrinkage polymerization data of different composite resins and discuss the postoperative sensitivity results of several clinical studies

MATERIALS AND METHODS

The articles used in this literature review were searched in Pubmed/Medline database with terms "shrinkage", "composite resins", "postoperative sensitivity", "flowable composite" and "flow". The publication time must be between of 2008-2018 with some exceptions. After title and abstract lecture, 951 articles of polymerization shrinkage and 179 of postoperative sensitivity were select and read integrally. Finally, 25 and 24 articles were select for polymerization shrinkage and postoperative sensitivity, respectively. The obtained data were discuss and distributed in two tables. Table 1 include polymerization shrinkage data (volumetric shrinkage, residual shrinkage stress and post-gel shrinkage). Table 2 describes data of several clinical studies that related postoperative sensitivity with procedures factors such as cavity size, composite resin and adhesive system.

RESULTS

Table 1 shows that there are different methods of measuring composites polymerization shrinkage. This explain the divergent data for the same commercial composite. All studies evaluated bulk fill, conventional or flow composites. Among these 4 researches work in photoactivation with temperature changes and other 6 studies shows that post gel shrinkage is related with polymerization shrinkage. Table 2 results demonstrate that there are few cases of postoperative sensitivity in clinical studies selected for this research. It also possible say that postoperative sensitivity generally appears in the first weeks and decrease in the firsts evaluations months.

Table 1: Residual shrinkage stress, volumetric shrinkage and post gel shrinkage of different composite resins.

AUTHORS	YEAR	COMPOSITE RESIN	SRHINKAGE STRESS (SD)
Boaro et al.[29]	2010	Durafill (Heraus Kulzer)	2,6 (0,3) MPa
		Heliomolar (Ivoclar Vivadent)	2,8 (0,4) MPa
		ELS (Saremco)	2,7 (0,3) MPa
		Filtek LS (3M ESPE)	4,3 (0,3) MPa
		Filtek Supreme Plus (3M ESPE)	4,2 (0,4) MPa
		Point 4 (Kerr)	4,3 (0,4) MPa
		Filtek Z250 (3M ESPE)	3,3 (0,2) MPa
		Venus Diamond (Heraeus Kulzer)	2,8 (0,4) MPa
		N'Durance (Septodont)	4,6 (0,5) MPa
		Aelite LS Posterior (Bisco)	3,4 (0,2) MPa
Braga et al.[18]	2012	GC Kalore (GC Corporation)	3,1 (0,6) MPa
		Gradia Direct X (GC Corporation)	2,9 (0,6) MPa
		Ice (SDI)	6,0 (0,7) MPa
		Wave MV (SDI)	3,3 (0,3) MPa
		Majesty Flow (Kuraray Dental)	4,6 (0,6) MPa
		Majesty Posterior (Kuraray Dental)	4,8 (1,2) MPa
Soares et al.[2]	2013	4 Seasons (Ivoclar Vivadent)	.
		Beautifil II (Shofu)	.
		Charisma (Heraus Kulzer)	.
		Esthet X (Dentsply)	.
		Fill Magic (Coltene)	.
		Filtek LS (3M ESPE)	.
		Filtek Supreme (3M ESPE)	.
		Filtek Z250 (3M ESPE)	.
		Glacier (SDI)	.
		Majesty Posterior (Kuraray Dental)	.
		Master Fill (Biodinâmica)	.
		Opallis (FGM)	.
		Tetric Ceram (Ivoclar Vivadent)	.
		TPH Spectrum (Dentsply)	.
		Z100 (3M ESPE)	.
		Gradia Direct X (GC Corporation)	.

VOLUMETRIC SHRINKAGE % (SD)	POST GEL SHRINKAGE % (SD)	METHODS	CONCLUSION
0,43 (0,03)	1,9 (0,03)	Dilatometer and strain gauge method	The low shrinkage composites showed similar shrinkage stress and post gel shrinkage to conventional composites. Most of the volumetric shrinkage occurs in post gel phase.
1,6 (0,03)	0,43 (0,02)		
0,35 (0,02)	2,1 (0,08)		
1,4 (0,02)	0,38 (0,02)		
2,0 (0,04)	0,64 (0,07)		
3,1 (0,02)	0,67 (0,03)		
1,7 (0,07)	0,52 (0,04)		
1,8 (0,03)	0,39 (0,03)		
2,4 (0,04)	0,65 (0,02)		
2,0 (0,13)	0,51 (0,04)		
.	0,52 (0,04)	Strain Gauge method	Composites with high elastic modulus and/or high post gel shrinkage presented higher shrinkage stress.
.	0,64 (0,04)		
.	0,83 (0,03)		
.	0,94 (0,05)		
.	0,99 (0,11)		
.	0,71 (0,04)		
.	0,41 (0,08)	Strain Gauge method	Composites with high inorganic particles volume presented higher elastic modulus. It is results in higher post gel shrinkage.
.	0,79 (0,09)		
.	0,61 (0,10)		
.	0,46 (0,09)		
.	0,67 (0,03)		
.	0,11 (0,01)		
.	0,62 (0,07)		
.	0,51 (0,05)		
.	0,45 (0,05)		
.	0,54 (0,07)		
.	0,62 (0,08)		
.	0,84 (0,02)		
.	0,47 (0,03)		
.	0,67 (0,04)		
.	0,96 (0,04)		
.	0,76 (0,04)		

Table 1: (**Continuation**) Residual shrinkage stress, volumetric shrinkage and post gel shrinkage of different composite resins.

AUTHORS	YEAR	COMPOSITE RESIN	SRHINKAGE STRESS (SD)
Bicalho et al.[15]	2014	Filtek LS (3M ESPE)	.
		4 Seasons (Ivoclar Vivadent)	.
		Filtek Z250 (3M ESPE)	.
		Beautifil II (Shofu)	.
		Z100 (3M ESPE)	.
Kim e Park[30]	2014	Filtek Z350 (3M ESPE)	24,32 (1,47) N
		SDR (Dentsply)	30,11 (1,47) N
		Gradia Direct (GC Corporation)	22,36 (2,35) N
		Filtek P90 (3M ESPE)	17,46 (4,41) N
		Charisma (Heraeus Kulzer)	28,15 (3,04) N
		Tetric N-Flow (Ivoclar Vivadent)	39,32 (3,63) N
Tauböck et al.[31]	2014	SDR bulk-fill (Dentsply)	20,0 (1,2) N
		Esthet X flow (Dentsply)	40,7 (0,9) N
		Esthet X HD (Dentsply)	22,7 (0,8) N
Aleixo et al.[32]	2014	Filtek P90 (3M ESPE)	7,05 (2,97) MPa
		Filtek Z350 XT (3M ESPE)	5,00 (2,29) MPa
		Venus Diamond (Heraeus Kulzer)	1,20 (1,37) MPa

VOLUMETRIC SHRINKAGE % (SD)	POST GEL SHRINKAGE % (SD)	METHODS	CONCLUSION
.	0,11 (0,01)	Strain Gauge method	The greater the composite elastic modulus, higher post gel shrinkage and shrinkage stress.
.	0,41 (0,08)		
.	0,51 (0,05)		
.	0,78 (0,8)		
.	0,96 (0,04)		
.	.	Load cell conected in stress custom-made device and software	The conventional flow composites showed higher shrinkage stress..
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.	.	Load cell conected in stress custom-made device and software	The flow composite presented higher polymerization shrinkage.
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.	.	Polariscope	Venus Diamond composite presented the lowest shrinkage stress.
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Table 1: (**Continuation**) Residual shrinkage stress, volumetric shrinkage and post gel shrinkage of different composite resins.

AUTHORS	YEAR	COMPOSITE RESIN	SRHINKAGE STRESS (SD)	
Kim et al.[33]	2015	Premise Packable (Kerr)	457nm	10,9 (1,1) MPa
			473nm	13,2 (0,4) MPa
		Synergy D6 (Coltene)	457nm	15,7 (0,4) MPa
			473nm	16,5 (0,5) MPa
		Filtek Z350XT (3M ESPE)	457nm	12,6 (0,8) MPa
			473nm	14,2 (0,4) MPa
		Aelite All Purpose Body (Bisco)	457nm	21,2 (1,3) MPa
			473nm	23,6 (2,0) MPa
		Clearfil AP-X (Kuraray)	457nm	13,3 (2,2) MPa
			473nm	14,4 (1,2) MPa
		Filtek Z250 (3M ESPE)	457nm	12,2 (1,0) MPa
			473nm	15,0 (0,1) MPa
		Premise Flow (Kerr)	457nm	28,2 (1,3) MPa
			473nm	27,3 (2,4) MPa
		Tetric N-Flow (Ivoclar Vivadent)	457nm	30,1 (1,3) MPa
			473nm	25,2 (0,5) MPa

VOLUMETRIC SHRINKAGE % (SD)	POST GEL SHRINKAGE % (SD)	METHODS	CONCLUSION
.	.	Linometer with noncontacting inductive sensor	Laser as photoactivator unit did not present good results of shrinkage stress for the wavelenght tested.
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Table 1: (**Continuation**) Residual shrinkage stress, volumetric shrinkage and post gel shrinkage of different composite resins.

AUTHORS	YEAR	COMPOSITE RESIN	SRHINKAGE STRESS (SD)	
Benetti et al.[20]	2015	Tetric EvoCeram Bulk Fill (Ivoclar Vivadent)	.	
		SonicFill (Kerr)	.	
		SDR (Dentsply)	.	
		x-tra base (VOCO)	.	
		Venus Bulk Fill (Heraeus Kulzer)	.	
		Tetric EvoCeram (Ivoclar Vivadent)	.	
Rosatto et al.[34]	2015	Filtek Z350 XT (3M ESPE)	.	
		Filtek Bulk Fill (3M ESPE)	.	
		Venus Bulk Fill (Heraeus Kulzer)	.	
		Charisma Diamond (Heraeus Kulzer)	.	
		SDR (Dentsply)	.	
		Esthet-X HD (Dentsply)	.	
		Tetric EvoCeram Bulk Fill (Ivoclar Vivadent)	.	
Fronza et al.[22]	2015	Herculite Classic (Kerr)	3,7 (0,2) MPa	
		SDR (Dentsply)	3,3 (0,2) MPa	
		Filtek Bulk-Fill (3M ESPE)	3,5 (0,2) MPa	
		Tetric EvoCeram Bulk Fill (Ivoclar Vivadent)	2,6 (0,3) MPa	
		EverX Posterior (GC Corporation)	4,3 (0,4) MPa	
Tauböck et al.[14]	2015	Tetric EvoCeram Bulk Fill (Ivoclar Vivadent)	23°C	22,0 (0,4) N
			68°C	20,6 (0,5) N
		X-tra fil (VOCO)	23°C	17,7 (1,0) N
			68°C	15,9 (0,7) N
		QuixFill (Dentsply)	23°C	19,4 (0,7) N
			68°C	17,8 (0,8) N
		SonicFill (Kerr)	23°C	18,3 (1,4) N
			68°C	16,5 (0,8) N
		Tetric EvoCeram (Ivoclar Vivadent)	23°C	17,4 (0,7) N
			68°C	15,1 (0,8) N

VOLUMETRIC SHRINKAGE % (SD)	POST GEL SHRINKAGE % (SD)	METHODS	CONCLUSION
2,03 (0,05)	.	Bonded-disk method and linear variable differential transformer	High viscosity Bulk Fill composites (Tetric EvoCeram Bulk Fill e Sonic Fill) presented volumetric shrinkage similar to conventional composites.
1,83 (0,10)	.		
2,80 (0,06)	.		
2,76 (0,13)	.		
3,36 (0,13)	.		
1,58 (0,04)	.		
.	0,74 (0,07)	Strain Gauge method	All bulk fill composites presented lower post gel shrinkage than conventional composites.
.	0,50 (0,05)		
.	0,41 (0,03)		
.	0,44 (0,4)		
.	0,34 (0,03)		
.	0,46 (0,01)		
.	0,43 (0,04)		
.	.	Composite resins rods attached to universal testing machine and extensometer	Tetric EvoCeram Bulk Fill composite showed the lower shrinkage stress. The other composites, except EverX Posterior, did not presente difference in relation to conventional composite.
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.	.	Stress custom-made device and software	The composites pre-heating before photoactivation decreased shrinkage stress for bulk fill and conventional composites.
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Table 1: (**Continuation**) Residual shrinkage stress, volumetric shrinkage and post gel shrinkage of different composite resins.

AUTHORS	YEAR	COMPOSITE RESIN	SRHINKAGE STRESS (SD)	
Jongsma e Kleverlaan[35]	2015	Clearfil AP-X (Kuraray)	23°C	17,7 (0,5) MPa
			44°C	23,4 (0,6) MPa
		Venus Diamond (Heraeus Kulzer)	23°C	7,1 (1,4) MPa
			44°C	10,7 (0,4) MPa
		Filtek Z250 (3M ESPE)	23°C	10,8 (4,4) MPa
			44°C	15,6 (0,7) MPa
		Premise (Kerr)	23°C	9,1 (0,5) MPa
			44°C	14,2 (0,2) MPa
Han et al.[36]	2016	Filtek Supreme (3M ESPE)	4,70 (0,22) MPa	
		Charisma Diamond (Heraeus Kulzer)	4,20 (0.30) MPa	
		Amelogen Plus (Ultradent)	9,47 (0,27) MPa	
		Tetric EvoCeram Bulk Fill (Ivoclar Vivadent)	5,86 (0,22) MPa	
		Venus Bulk Fill (Heraeus Kulzer)	8,94 (0,29) MPa	
Sampaio et al.[37]	2016	PermaFlo Flowable (Ultradent)	.	
		Filtek Bulk Fill Flowable (3M ESPE)	.	
		Surefil SDR Flow (Dentsply)	.	
		Vertise Flow Self-adhering flowable (Kerr)	.	
Tsujimoto et al.[38]	2016	EverX Posterior (GC Corporation)	.	
		Tetric EvoCeram Bulk Fill (Ivoclar Vivadent)	.	
		Surefil SDR Flow (Dentsply)	.	
		Z100 Restorative (3M ESPE)	.	
		Tetric EvoCeram (Ivoclar Vivadent)	.	
		Clearfil AP-X (Kuraray)	.	

VOLUMETRIC SHRINKAGE % (SD)	POST GEL SHRINKAGE % (SD)	METHODS	CONCLUSION
2,3 (0,1)	.	Mercury dilatometry and Intron 6022 tensilometer	The composites pre-heating results in higher volumetric shrinkage and shrinkage stress.
3,0 (0,1)	.		
2,0 (0,1)	.		
3,0 (0,1)	.		
2,4 (0,1)	.		
3,3 (0,1)	.		
2,0 (0,1)	.		
2,7 (0,1)	.		
.	.	Linometer and load cell conected in stress custom-made device and software	Regular bulk fill composites presented results similar to conventional composites. Bulk fill flow presented higher shrinkage stress than others.
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4,81 (0,42)	.	Microtomograph scanning	Surefil SDR Flow composite presented lower volumetric polymerization and there was no significant difference between the others.
5,49 (1,84)	.		
3,31 (0,33)	.		
5,79 (1,13)	.		
1,62 (0,08)	.	Water-filled dilatometer	The reinforced composite (EverX Posterior) presented the best results to volumetric shrinkage when compared to bulk fill and conventional composites.
2,34 (0,12)	.		
2,07 (0,10)	.		
3,34 (0,16)	.		
3,01 (0,14)	.		
3,54 (0,23)	.		

Table 1: (**Continuation**) Residual shrinkage stress, volumetric shrinkage and post gel shrinkage of different composite resins.

AUTHORS	YEAR	COMPOSITE RESIN	SRHINKAGE STRESS (SD)
Al Sunbul et al.[39]	2016	Gradia direct posterior (GC Corporation)	5,21 (0,15) MPa
		G-aenial posterior (GC Corporation)	5,17 (0,17) MPa
		G-aenial anterior (GC Corporation)	5,13 (0,06) MPa
		G-aenial universal flow (GC Corporation)	9,08 (0,55) MPa
		Ever X posterior (GC Corporation)	5,16 (0,68) MPa
		Venus diamond (Heraeus Kulzer)	4,65 (0,20) MPa
		Venus bulk fill (Heraeus Kulzer)	6,62 (0,63) MPa
		Tetric Evoceram (Ivoclar Vivadent)	3,94 (0,40) MPa
		Tetric Evoceram bulk fill (Ivoclar Vivadent)	4,1 (0,26) MPa
		SDR (Dentsply)	5,48 (0,05) MPa
		Spectrum TPH (Dentsply)	7,20 (0,41) MPa
		Filtek supreme XTE (3M ESPE)	5,79 (0,26) MPa
		Estelite flow quick (Tokuyama)	10,19 (0,87) MPa
		Beautifil flow plus (Shofu)	10,45 (0,41) MPa
		Grandio SO heavy flow (VOCO)	9,40 (0,85) MPa
		X-tra base (VOCO)	7,21 (0,13) MPa
		N'Durance (Septodont)	6,48 (0,57) MPa
		Premise (Kerr)	5,19 (0,29) MPa

VOLUMETRIC SHRINKAGE % (SD)	POST GEL SHRINKAGE % (SD)	METHODS	CONCLUSION
2,09 (0,08)	.	Bonded-disk method and "The Bioman" instrument	Bulk fill composites showed the lowest values of shrinkage stress and volumetric shrinkage. The conventional flow composites presented the highest values of shrinkage stress.
2,13 (0,04)	.		
2,28 (0,04)	.		
4,5 (0,08)	.		
3,36 (0,13)	.		
1,89 (0,07)	.		
4,2 (0,23)	.		
1,83 (0,09)	.		
2,27 (0,11)	.		
3,30 (0,09)	.		
3,00 (0,11)	.		
2,44 (0,06)	.		
3,92 (0,08)	.		
4,6 (0,04)	.		
3,34 (0,03)	.		
3,39 (0,07)	.		
2,61 (0,08)	.		
2,01 (0,05)	.		

Table 1: (**Continuation**) Residual shrinkage stress, volumetric shrinkage and post gel shrinkage of different composite resins.

AUTHORS	YEAR	COMPOSITE RESIN	SRHINKAGE STRESS (SD)	
Shibasaki et al.[19]	2017	Tetric EvoCeram Bulk Fill (Ivoclar Vivadent)	.	
		Filtek Bulk Fill (3M ESPE)	.	
		SonicFill (Kerr)	.	
		Kalore (GC)	.	
		Filtek LS (3M ESPE)	.	
		Herculite Ultra (Kerr)	.	
		Filtek Supreme Ultra (3M ESPE)	.	
Souza-Lima et al.[40]	2017	Tetric Evo-Flow Bulk Fill (Ivoclar Vivadent)	0,77 (0,07) MPa	
		Empress Direct (Ivoclar Vivadent)	1,07 (0,15) MPa	
Jung e Park[41]	2017	SDR (Dentsply)	39,23 (1,08) N	
		Venus Bulk Fill (Heraeus Kulzer)	48,45 (1,77) N	
		Filtek Z350 (3M ESPE)	29,71 (1,57) N	
		Tetric N-Ceram BulkFill (Ivoclar Vivadent)	29,52 (1,07) N	
		SonicFill (Kerr)	27,56 (1,86) N	
Nie et al.[42]	2018	Beautifil Flow Plus F00 (Shofu)	.	
		Beautifil Flow F02 (Shofu)	.	
		Beautifil Flow Plus F3 (Shofu)	.	
		Beautifil Flow F10 (Shofu)	.	
		Beautifil II (Shofu)	.	
		Filtek Z350 (3M ESPE)	.	
		Filtek Z350 Flowable (3M ESPE)	.	
Guimarães et al.[23]	2018	Filtek Z250 (3M ESPE)	Exponencial	1,48 (0,23) MPa
			Convencional	2,46 (0,06) MPa
		Filtek Z350 (3M ESPE)	Exponencial	1,50 (0,12) MPa
			Convencional	2,08 (0,03) MPa
		Charisma Diamond (Heraeus Kulzer)	Exponencial	0,78 (0,15) MPa
			Convencional	1,39 (0,18) MPa
		NT Premium (Coltene)	Exponencial	0,96 (0,07) MPa
			Convencional	1,36 (0,15) MPa
		Ultrafill (Biodinâmica)	Exponencial	1,02 (0,03) MPa
			Convencional	1,81 (0,09) MPa

VOLUMETRIC SHRINKAGE % (SD)	POST GEL SHRINKAGE % (SD)	METHODS	CONCLUSION
2,19 (0,10)	.	Water-filled dilatometer and capillary tube	Low shrinkage and bulk fill composites showed the lowest and the highest volumetric shrinkage, respectively.
1,93 (0,06)	.		
2,91 (0,12)	.		
1,05 (0,08)	.		
0,83 (0,06)	.		
1,56 (0,10)	.		
1,58 (0,06)	.		
.	.	Composite resins rods attached to universal testing machine and extensometer	Conventional composite resin used with incremental technique presented higher shrinkage stress than bulk fill flow composite.
.	.		
.	.	Linometer and Custom-made device and software	Low viscosity bulk fill composites (Venus e SDR) showed higher shrinkage stress.
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4,63 (0,23)	.	Acuvol volumetric shrinkage analyser	Flow composites presented higher shrinkage stress than conventional composites.
5,33 (0,17)	.		
4,72 (0,24)	.		
5,20 (0,21)	.		
2,55 (0,09)	.		
2,35 (0,02)	.		
4,81 (0,04)	.		
.	.	Universal testing machine with adaptation	Radiation control during photoactivation process by and optimized mathematical function is more efficient than conventional technique to reduce the effects of composites shrinkage stress.
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Table 1: (**Continuation**) Residual shrinkage stress, volumetric shrinkage and post gel shrinkage of different composite resins.

AUTHORS	YEAR	COMPOSITE RESIN	SRHINKAGE STRESS (SD)
Oliveira et al.[43]	2018	X-tra fil (VOCO)	.
		Z100 (3M ESPE)	.
Gonçalves et al.[44]	2018	Flitek Z350 XT (3M ESPE)	.
		Filtek Z350 Flowable (3M ESPE)	.
		Aura Bulk Fill (SDI)	.
		EverX Posterior (GC)	.
		SonicFill (Kerr)	.
		Filtek Bulk Fill Posterior (3M ESPE)	.
		Filtek Bulk Fill Flow (3M ESPE)	.
		Venus Bulk Fill Flow (Heraeus Kulzer)	.
Tauböck et al.[21]	2018	SDR (Dentsply)	21,47 (1,15) N
		x-tra base (VOCO)	24,83 (1,79) N
		Bulk Ormocer (VOCO)	12,00 (0,45) N
		SonicFill (Kerr)	16,68 (1,24) N
		Esthet X flow (Dentsply)	34,41 (1,04) N
		Esthet X HD (Dentsply)	21,44 (0,74) N

VOLUMETRIC SHRINKAGE % (SD)	POST GEL SHRINKAGE % (SD)	METHODS	CONCLUSION
.	0,39 (0,04)	Strain Gauge method	The bulk fill composite showed lower post gel shrinkage.
.	0,94 (0,04)		
2,1 (0,6)	.	Strain Gauge method	The bulk fill composite showed shrinkage stress similar to conventional composite resins.
1,7(0,3)	.		
1,3 (0,2)	.		
0,7 (0,1)	.		
1,2 (0,3)	.		
1,1 (0,1)	.		
1,4 (0,2)	.		
0,4 (0,1)	.		
.	.	Linometer and custom-made stress analyzer with semi-rigid load cell	Bulk-fill composites presented lower shrinkage stress than regular conventional composites.
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Table 2: Postoperative sensitivity data of clinical studies.

AUTHORS	YEAR	Nº OF PATIENTS	Nº OF RESTORATIONS	CAVITARY CONFIGURATION	COMPOSITE RESIN (MANUFACTURER)	ADHESIVE SYSTEM
Casselli e Martins[45]	2006	104	52	Class I	Filtek Z250 (3M ESPE)	E and SE
Briso et al.[28]	2007	-	292	Classs I and II	TPH (Dentsply)	E
Unemori et al.[46]	2007	47	106	All	1. Clearfil AP-X (Kuraray), 2. Estio LC (GC), 3. Lite Fil II (Shofu) 4. Palfique Estelite (Tokuyama)	SE
Burrow et al.[47]	2009	70	108	Class I	Filtek Supreme XT (3M ESPE)	E and SE
Ermis et al.[48]	2009	33	87	Class II	Filtek Z250 (3M ESPE)	E and SE
Auschill et al.[24]	2009	231	600	All	Ceram X (Dentsply)	E
Berkowitz et al.[49]	2009	504	565	Class I	-	-
van Dijken[50]	2010	29	76	Class I	1. Dyract (Dentsply) e 2. Prisma TPH (Dentsply)	E
Agbaje et al.[51]	2010	47	58	Classs I and II	Unolux (UnoDent)	E

E: etch-and-rinse adhesive; SE: self-etching adhesive; U: universal adhesive; GLU: adhesive with glutaraldehyde; VAS: visual analogic scale; NCCL: non-carious cervical lesion.

FOLLOW-UP	SENSITIVITY TEST	MAIN OBJETIVE OF STUDY (VASLUATION)	POSTOPERATIVE SENSITIVITY RATE (%)	CONCLUSION
0, 7 days and 6 months	Cold test	Adhesive	In 7 days: E: 30.6 SE: 28.9	There was no difference between adhesives in postoperative sensitivity.
24 hours, 7, 30 end 90 days	Thermical and tactil tests	Cavities (MO/OD e MOD)	24h: 11.6 7 days: 7.5 30 days: 4.11 90 days:4.45	Postoperative sensitivity depends on the restoration procedure complexity and decrease over time.
7 days	Thermical and tactil tests.	Adhesive and pulp protection	0	Self-etching adhesives better prevents pulp complications than conventional pulp protection
7 and 30 days	Thermical test	Adhesive and use of glass ionomer cement lining	7 days: 10.7 30 days: 8.7	There was no difference in the use of glass ionomer cement lining for both adhesives.
6 months, 1 end 2 years	Air-jet test.	Adhesive	0 in all follow-ups	There was no difference in clinical performance for both adhesives.
14 days	VAS; Cold and chewing tests.	Risk factors to postoperative sensitivity	5,3	The only factor that influenced in postoperative sensitivity was cavity depth.
7 days	Interview	Risk factors to postoperative sensitivity	52	Of the teeth with no preoperative sensitivity (baseline), only 16% presented sensitivity after 1 week.
6 months and annualy up to 12 years	-	Restorative technique	6 months - 2 years: 2.6 3 – 12 years: 0	Restorative techniques showed excellent clinical performance.
7 end 42 days; 3, 6 end 12 months	-	Restorative material performance	12 months: 1.7	Restorative material showed excellent clinical performance in the evaluated factor: postoperative sensitivity and secondary caries.

Table 2: (**Continuation**) Postoperative sensitivity data of clinical studies.

AUTHORS	YEAR	Nº OF PATIENTS	Nº OF RESTORATIONS	CAVITARY CONFIGURATION	COMPOSITE RESIN (MANUFACTURER)	ADHESIVE SYSTEM
Chermont et al.[52]	2010	-	21	Class I	Filtek Supreme (3M ESPE)	E, GLU and U
Perdigão et al.[53]	2012	39	107	NCCL	Filtek Supreme Plus (3M ESPE)	E and SE
Pazzinato et al.[54]	2012	25	67	Classs I and II	1. Filtek P60 (3M ESPE) 2. Filtek Z250 (3M ESPE)	E
Ivanovic'V et al.[13]	2013	-	960	Class II	1. Els extra low shrinkage (Saremco) 2. Tetric Ceram (Ivoclar) 3. InTenSe (Ivoclar Vivadent) 4. Point 4 (Kerr)	E
Sancakli et al.[25]	2014	39	188	Class I	1. Herculite XRV (Kerr) 2. Clearfil AP-X (Kuraray) 3. Charisma (Heraeus Kulzer)	E and SE
Moosavi et al.[55]	2014	31	62	Class V	Clearfil AP-X (Kuraray)	SE
Andrade et al.[56]	2014	41	93	Class I	1. Filtek Z350 (3M ESPE) 2. Esthet-X (Dentsply) 3. Filtek Z250 (3M ESPE)	E
Yazici et al.[57]	2014	28	84	Class I	1. Filtek Supreme (3M ESPE) 2. P60 (3M ESPE) 3. Filtek Silorane (3M ESPE)	E
Delbons et al.[58]	2015	45	137	Classs I and II	Filtek Z350 (3M ESPE)	E and SE
Scotti et al.[26]	2015	204	204	Class II	Venus Diamond (Heraeus Kulzer)	E and SE
van Dijken end Lindberg[59]	2015	40	106	Class II	1. Point 4 (Kerr) 2. InTen-S (Ivoclar Vivadent)	E

E: etch-and-rinse adhesive; SE: self-etching adhesive; U: universal adhesive; GLU: adhesive with glutaraldehyde; VAS: visual analogic scale; NCCL: non-carious cervical lesion

FOLLOW-UP	SENSITIVITY TEST	MAIN OBJETIVE OF STUDY (VASLUATION)	POSTOPERATIVE SENSITIVITY RATE (%)	CONCLUSION
48 hours, 7 days end 33 months	Cold and tactil tests	Adhesive	E in 48h: 10 Other follow-ups and adhesives: 0	There was no difference between etch-and-rinse, universal and glutaraldehyde adhesives.
7 days, 6 end 18 months	Air test and interview	Adhesive	7 days: 0 6 months: 3.7 18 months: E: 8.7 SE: 8.3	There was no clinical difference between adhesive systems used.
56 months	Interview	Composite resin	0	Both composite resins presented good clinical results.
14 days	Cold, hot, and chewing tests.	Composite resin and operator experience	1. 8,1 2. 7,2 3. 10,8 4. 27,5	The conventional composite Point 4 results in more cases of postoperative sensitivity than low shrinkage composites. The operator experience influence in sensitivity.
24 hours; 30, 90 end 180 days	Cold and air-jet tests.	Adhesive system and operator experience	-	The postoperative sensitivity decrease over 6 months. The conventional adhesive presented higher sensitivity for less experienced operators.
1, 14 end 30 days	Cold test.	Laser	-	Laser therapy decrease postoperative sensitivity.
6, 12, 30 end 54 months	Cold test and Interview	Composite resin	In 6, 12 end 30 months: 0 54 months: 1. 3.2 2. 3.2 3. 0	All composite resins tested showed satisfactory clinical results at the end of 54 months.
3 years	Tactil and air-jet tests	Composite resin	0	All composites shows similar results.
18 months	Interview	Adhesive	0	Adhesive system did not influence the restoration clinical performance
7 days	Cold test.	Adhesive	-	The adhesives did not present significant difference for postoperative sensitivity.
15 years	Cold and air-jet tests.	Composite resin	Up to 2 weeks: 2,8 Other follow-ups: 0	Conventional and low shrinkage composites showed good durability.

Table 2: (**Continuation**) Postoperative sensitivity data of clinical studies.

AUTHORS	YEAR	Nº OF PATIENTS	Nº OF RESTORATIONS	CAVITARY CONFIGURATION	COMPOSITE RESIN (MANUFACTURER)	ADHESIVE SYSTEM
Costa et al.[27]	2016	72	236	Classs I and II	1. Tetric N-Ceram Bulk Fill (Ivoclar Vivadent) 2. Tetric EvoCeram Bulk Fill (Ivoclar Vivadent)	E and SE
Manchorova-Veleva end Vladimirov[60]	2016	89	200	Classs I and II	Filtek Supreme (3M ESPE)	E and SE
Yazici et al.[1]	2017	50	104	Class II	1. Filtek Ultimate (3M ESPE) 2. Tetric EvoCeram Bulk Fill (Ivoclar Vivadent)	E
Heck et al.[61]	2018	-	56	Classs I and II	1. QuiXfil (Dentsply) 2. Tetric Ceram (Vivadent)	E and SE

E: etch-and-rinse adhesive; SE: self-etching adhesive; U: universal adhesive; GLU: adhesive with glutaraldehyde; VAS: visual analogic scale; NCCL: non-carious cervical lesion

DISCUSS

Researches of composite resins proprieties and their influenced in clinical success became necessary with composites advances as restorative material. This success is evaluated for FDI World Dental Federation criteria: marginal discoloration, cracks and retention, marginal adaptation, postoperative sensitivity and secondary caries.[62] Polymerization shrinkage can be responsible for composites restoration failure, because it may influenced all longevity criteria due to relationship with postoperative sensitivity, cusp deflection, enamel crack and microleakage.[14,23]

Composites polymerization is divide in two phases: pre and post gel. In the first, reactive specimens have mobility for rearrange and compensate volumetric shrinkage, causing low internal and interfacial stress.

FOLLOW-UP	SENSITIVITY TEST	MAIN OBJETIVE OF STUDY (VASLUATION)	POSTOPERATIVE SENSITIVITY RATE (%)	CONCLUSION
48 hours end 7 days	Cold, air-jet and chewing tests.	Adhesive and restorative technique	7 days: E: 19.5 SE: 21.2	Both factors did not influence in postoperative sensitivity.
7, 14 end 30 days, end 6 months	Cold and chewing tests.	Adhesive	Total: E: 31 SE: 25	The adhesives did not present difference in postoperative sensitivity.
6, 12, 18 end 36 months	Air-jet test.	Composite resin	Up to 12 months: 0.1 After 12 months: 0	Both composite resins shows satisfactory clinical performance.
14 days; 3 end 18 months; 3, 4 end 10 years	Interview	Composite resin and adhesive	In 10 years: E: 0 SE: 3.8	Both restorative materials with adhesives showed good clinical performance.

After material geleification occur post gel phase and the formation of semirigid polymer chain, which does not allow plastic deformation.[2,29] All authors that evaluate post gel shrinkage concluded that it is directly related with volumetric shrinkage, once most shrinkage stress occur in this phase.[2,17,18,29] In addition, the higher post gel shrinkage result in greater shrinkage stress.[2,15,17] Thus, volumetric shrinkage generate during this time will cause stress in the walls that lead to microleakage and marginal gaps that may be responsible for several clinical problems.[15] The literature suggests several methods to reduce the negative effects of polymerization shrinkage, such as use of alternative photoactivation modes for increase pre-gel phase, the incremental technique for conventional composites, low polymerization shrinkage as the base of restoration and improvements in resin composition.[23,41,44]

Residual shrinkage stress is related with several factor, such as material composition (material type and filler content amount), degree conversion, increment thickness, increment position and photoactivation.[2,4,5,63] Material elastic modulus influences directly in shrinkage stress. A higher elastic modulus produces a restoration that is more rigid, which in turn generates greater shrinkage stress.[34] Size and amount of filler content influence this property. A higher volume results in higher elastic modulus.[2,34] Furthermore, molecular weight and monomer concentration may also influenced shrinkage stress. Silorane monomer has a high molecular weight, so composites with this composition have lower volumetric shrinkage and shrinkage stress.[29,30] Matrix composition, molecular mobility and surface treatment of particles may have a higher impact on polymerization shrinkage.[19]

Conventional composites are available in regular or flow consistency. Flowable composites have similar composition to regular, but with less filler content amount or greater diluent amount.[34,37] This allows a higher flow and better adaptation,[37,42] however cause lower mechanical properties and increase of volumetric shrinkage.[34] The data of several articles shows that most of studies found greater polymerization shrinkage for conventional flowable composites[30,31,39,42] and bulk composites have a lower shrinkage, followed by conventional composites in regular consistency.[20,37]

Regarding polymerization conditions, the main strategy suggests was the use of different photoactivation modes to increase pre gel phase and decrease final shrinkage stress.[23,31] The low light intensity at beginning of photoactivation produces a lower polymerization shrinkage. However, it also results in low degree conversion, which significantly reduces mechanical properties[23,31] Therefore if the clinician uses this strategy to work, it is recommended to cycle photoactivation further to ensure an adequate degree of conversion (the relationship between degree conversion and photoactivation devices is discussed in part 3 of this literature review). Thus, light intensity emitted, LCUs irradiance,[23,33] and temperature[23,35] influence volumetric shrinkage.

Still with respect to polymerization conditions, two studies evaluated the pre-heating of composite resin prior to photoactivation.[14,35] These procedure has become popular because it reduces composite viscosity, improving marginal adaptation and decreasing microleakege.[14,35] It increases monomers mobility, also increasing degree conversion, which can cause a greater volumetric shrinkage.[14] In study by Tauböck et al.[14], the pre-heating of composites decrease shrinkage stress both for bulk fill and conventional composites. Jongsma e Kleverlaan[35] found higher volumetric shrinkage and higher shrinkage stress for all composites tested after pre-heating. Both articles evaluated different composite resins with different methods, which may explain divergent results. However, this data shows that there is still no consensus about the effect of pre-heating on polymerization shrinkage. Thus, clinical are needed to evaluate longevity related to this technique.

The restorative technique can also influence volumetric shrinkage and shrinkage stress. Initially, the incremental technique, although more complex, was suggested to optimize polymerization.[2,44] It is improve marginal adaptation and reduce polymerization shrinkage because by photoactivation each increment separately, the polymerization shrinkage would be lower.[22,34] However, this concept has been questioned.[15,17] Bicalho et al[15,17] have shown that incremental technique with conventional composites, while ensuring an adequate polymerization of each increment, generate higher final stress in the cavity. This can generate cracks that increase the chance of restorative procedure failure.[15,17] Although demonstrate that larger increments even joining opposite cavity walls would generate less tension, this restorative protocol is not recommended because increments polymerization could be difficult. The clinician should consider that when restoring a tooth with 8 increments of 1mm, which could be restored wit 4 increments of 2mm, a unnecessary greater shrinkage stress is being generated in the tooth/restoration. Teeth restoration with increments greater than 2mm simplify clinical practice and facilitates restorative procedure, but should only be performed with bulk fill composites.[34]

According to postoperative sensitivity data in Table 2, the sensitivity rate ranged from 0 – 52%. All studies that present any case of postoperative sensitivity evaluated less them 100 restauration. Therefore, the sample size may have influenced this result.[45,48,54,57] Another important factor to be observed and that may directly influenced research results is the method used as stimulate to sensitivity evaluate. Since the air-jet test causes more sensitivity than other tests (cold, tactile, chewing).[27] The study that showed the highest postoperative sensitivity rate also had high values of preoperative sensitivity, which justifies its results.[49]

For the studies that tested different composites, no significant difference was found between materials regardless of composition.[1,54,56,57,59,61] In general, different adhesive systems also no influenced in postoperative sensitivity.[26,27,48,52,53,58,60] However, when the adhesive evaluation is associated of operator experience, conventional adhesive (three steps etch-and-rinse) may present more cases of sensitivity. This may be explained because it is technically more difficult to use and have more sensitivity to technique due to critical stage of acid etching.[13,25]

In study by Auschill et al.[24] which evaluate postoperative sensitivity, risk factors, stimulus and sensitivity type, 32 of the 36 failed restoration (6%) were due to postoperative sensitivity.[24] This sensitivity usually disappears in first weeks, however if the stimulus stays for a long period, the restoration must be replaced, which indicates its failure.[24] Corroborating with this result, both Berkowitz et al[49] and Briso et al[28] showed that postoperative sensitivity decrease over time, being higher in first weeks and reducing with the passage of months. Therefore, postoperative sensitivity can directly influence the successes and longevity of restoration. This and others factors related to restoration longevity are discuss in part 6 of this literature review.

The conformation of cavity to be restored can influence both shrinkage polymerization and other factor related with clinical procedures.[34] For the study that evaluate the influence of cavities in postoperative sensitivity, it was concluded that class II restorations show greater sensitivity than class I.[28] This result is because most class II restoration are more complex.[28] In addition, the restoration depth may also be a risk factor for postoperative sensitivity, because cavity are more complex and close to the pulp.[24] For treatment and prevention of postoperative sensitivity, it has been suggested that low power laser therapy, already used for hypersensitivity treatment, is effective and reduces patient discomfort.[55]

Importantly, as a literature review, this study has some limitations due to articles chronology leaving most studies out of evaluation. In addition, the included articles do not have objective and methods standardized, which compromise the results comparison and discussion. Thus, many composites were not evaluated, making it impossible for any specific result of which is more advantageous to be used.

Finally, the relation between shrinkage polymerization and postoperative sensitivity is unquestionable. However, it is important to note that microcracks and microleakage causes for polymerization shrinkage haven no prove clinical influence. In addition, the postoperative sensitivity have other causes and risk factors. Therefore, more studies are necessary to understand the clinical influence of polymerization shrinkage and shrinkage stress, as well as the causes and which can be done to avoid postoperative sensitivity at the end of each restoration, always seeking patient comfort and clinical success of restoration treatment.

CONCLUSION

After literature approach, it was possible conclude that a large part of bulk fill composites had a lower residual stress shrinkage compared to conventional (flow or non-flow). In addition, it should be noted that factors related to photoactivation, restorative technique and cavity type influence in shrinkage polymerization. Postoperative sensitivity is related to restorative complexity and depth, as well as to operator experience. Its prevalence is low and materials and techniques do not show difference in clinical performance when restorative procedure is done correctly at all stages.

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