Mestrado Integrado em Medicina Dentária

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A review on luting techniques for indirect restorations: resin cements vs thermo-modified composite resins

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Abstract

Introduction: Adhesive cementation is a critical procedure involving the application of not only the adhesive system and resin luting agent, but also seating the indirect restoration in place. Resin cements are recommended materials to use in adhesive cementation considering their physical, mechanical and clinical properties. Classically they present low viscosity and, consequently, higher flowability, thus allowing for adequate film thickness. In recent years, thermo-modification techniques have been used to lower composite resin's viscosity, thus apparently improving resin flowability in order to facilitate their use as luting agents. Other techniques, such as adding ultrasonic vibration in the cementation procedure, have also been suggested to accomplish lower film thicknesses solely or in combination with the aforementioned ones. This review aims to scan literature in order to answer the question: Does luting indirect restorations with resin cements have better results when compared to using thermo-modified composite resins, concerning film thickness, viscosity, optical properties, shear bond strength, marginal infiltration and polymerization shrinkage?

Methods: An electronic search was performed using Cochrane Library (www.cochranelibrary.com), Embase (www.embase.com), Web of Science (www.webofscience.com) and PubMed (www.ncbi.nlm.nih.gov/pubmed) using various combinations of key words and MeSH terms. Regarding the type of intervention, studies were selected with indirect restorations cemented with resin cements or thermo-modified composite resins, in vitro and/or in vivo. Film thickness, viscosity, optical properties, shear bond strength, marginal infiltration and polymerization shrinkage were the measured outcomes.

Results: From 1389 screened titles and abstracts, 45 studies were included in this narrative review.

Conclusion: Both compared luting agents present identical behavior considering optical properties, marginal adaptation, viscosity and shear-bond-strength. However, in terms of the obtained film thickness and polymerization shrinkage, thermo-modified composite resins still need improvements to achieve the higher performance of resin cements. The use of thermo-modification or ultrasonic vibration techniques may provide enhanced mechanical properties to luting agents.

Key-words: resin cement, cementation, composite resin, viscosity, shear strength, mechanical stress, dental marginal adaptation, dental restoration failure.

Introduction

Dental restorations are either direct, if a material is placed into a prepared cavity as a soft mass which hardens, or indirect when a solid object is fabricated outside the oral cavity and then cemented in or on a prepared tooth. The latest must be sealed with a luting agent irrespective of fabrication method.[1]

Among dental luting cements commercially available, there are resin-based and non-resin-based cements, such as polycarboxylate or glass ionomer cement. Resin based cements may be classified according to their polymerization mechanisms into light-cured, chemically cured, and dual-cured. Chemically cured systems are suggested to be used under opaque or thick restorations as these limit light transmission. Light-cured cements are indicated for translucent and thin restorations, due to the possibility of light transmission through the restoration, improved color stability and extended working time. Dual-cured cements can be theoretically used in both situations however they may present higher film thickness in certain conditions and color changes related to amine oxidation present in their composition, as well as in self-cured cements.[2-5].

Resin cements can also be classified by their adhesive scheme: total-etch, self-etch, and the recently developed self-adhesive.[2,5,6] The latter do not require a dentin bonding system prior to placement, which reduces the technique sensitivity and improves ease of use. The limited interaction between self-adhesive cements and enamel or dentin in terms of either smear layer demineralization or tag formation is consensual in literature. There is indication by X-ray photoelectron spectroscopy of good chemical interaction with calcium from hydroxyapatite, which suggests a micromechanical retention, however there is no significant infiltration of more than a micrometer into the dentinal surface.[7] This is a superficial interaction and does not promote formation of a hybrid layer or resin tags in the dentinal tubules which leads to lower bond strength levels compared to conventional resin cements.[8]

Adhesive cementation is a critical procedure involving the application of not only the adhesive system and resin luting agent, but also seating the indirect restoration in place. In contrast to non-adhesive cementation, adhesively bonded restorations allow for a minimally invasive approach, as well as the reinforcement of glass-ceramic restorations[9]. Resin cements are recommended materials to use in adhesive cementation of glass ceramics (inlays, onlays, veneers, crowns) considering that they not only provide a strong and durable bonding between ceramics and the tooth substrate, but can also achieve better esthetic outcomes and maintain lower solubility and water sorption in comparison with other non-adhesive options.[1,5,10-12]

The effect of resin cement thickness on the fracture resistance of all-ceramic restorations has been lately researched and it is believed that a thin cement thickness, described as ideal between 5 and 25 µm, not exceeding the 50 µm, and a proper bond to the ceramic structure are mandatory for an improved support and increased fracture resistance of all-ceramic restorations.[2,10]

Resin cements are a combination of polymerizable monomers of methacrylates, dimethacrylates, and polymethacrylates, similar to composite restorative materials but with lower percentages of filler particles and thus, lower viscosity.[3,5]

Composite resins have been recommended for the cementation of ceramic veneers due to their lower cost, color stability and wide range of colors available.[13,14]. Compared to the resin cements composition, they differ on type of monomers used in the resin blend and the amount of filler.[15] In recent years, thermo-modification techniques have been used to lower composite resin's viscosity, thus apparently improving resin flowability in order to obtain lower film thickness.[15] Other techniques, such as adding ultrasonic vibration in the cementation procedure, have also been suggested to accomplish the same results solely or in combination with the aforementioned ones.[16,17].

An ideal cement should present the following characteristics: biocompatibility, low solubility, high shear bond and tensile bond strengths, micromechanical bonding to tooth and ceramic, radiopacity, color stability, low viscosity, thin film thickness and ease of handling.[3,5]

This study aims to scan literature in order to answer the question: Does luting indirect restorations with resin cements have better results when compared to using thermo-modified composite resins, concerning film thickness, viscosity, optical properties, shear bond strength, marginal infiltration and polymerization shrinkage?

Methods

To define the research question a PICO strategy was performed: Does luting indirect restorations using resin cements have better results when compared to using thermo-modified composite resins, concerning film thickness, viscosity, optical properties, shear bond strength, marginal infiltration and polymerization shrinkage? (Table 1)

Table 1. – PICO strategy

Population	permanent teeth rehabilitated with ceramic restorations
Intervention	cementation with resin cements
Comparison	cementation with thermo-modified composite resins
Outcome	film thickness, viscosity, optical properties, shear bond strength, marginal infiltration, polymerization shrinkage

Regarding the type of intervention, studies were selected with indirect restorations cemented with resin cements or thermo-modified composite resins, in vitro and/or in vivo. Film thickness, viscosity, optical properties, shear bond strength, marginal infiltration and polymerization shrinkage were the measured outcomes. Specific inclusion and exclusion criteria are shown in Table 2.

Table 2. – Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Full-text papers	Non-English
English language	Letters to the editor
Resin cements	Case series, case reports, clinical trials
Thermo-modified composite resin	Temporary teeth
Adhesive cementation	Intra-canal adhesive procedures
Randomized controlled trials, reviews, systematic reviews, meta-analysis	Brackets, dental implants

PubMed (www.ncbi.nlm.nih.gov/pubmed) was used to identify Medical Subject Heading (MeSH) terms fitting this review. MeSH terms were used as often as possible, even though many papers do not comply with this controlled vocabulary thesaurus, thus making their sole use feeble and other terms were necessary. Subsequently, an electronic search was performed using Cochrane Library (www.cochranelibrary.com), Embase (www.embase.com), Web of Science (www.webofscience.com) and PubMed (www.ncbi.nlm.nih.gov/pubmed) using various combinations of the key indexing terms shown in Table 3.

MeSH terms used were: (a) resin cement, (b) cementation, (c) composite resin, (d) viscositiy, (e) shear strength, mechanical stress, (g) dental marginal adaptation, (h) dental restoration failure.

All titles and abstracts retrieved from the electronic search were independently and in duplicate screened by two reviewers. This was followed by a review to reject papers that did not meet inclusion criteria. Disagreement between reviewers was solved via debate and the opinion of a third reviewer was obtained when necessary.

The selected reference lists were manually searched for additional original and reviewed papers. Full-text copies of all papers found through this search methodology were obtained and scrutinized by each reviewer to decide which were eligible based on the inclusion and exclusion criteria. Any disagreement was solved in the same manner as previously described.

The literature search provided 1389 titles and abstracts as shown in Fig. 1.

To determine the existence of unpublished studies, authors of relevant and possibly relevant studies were contacted. Authors were also contacted when missing data and/or any clarification was needed.

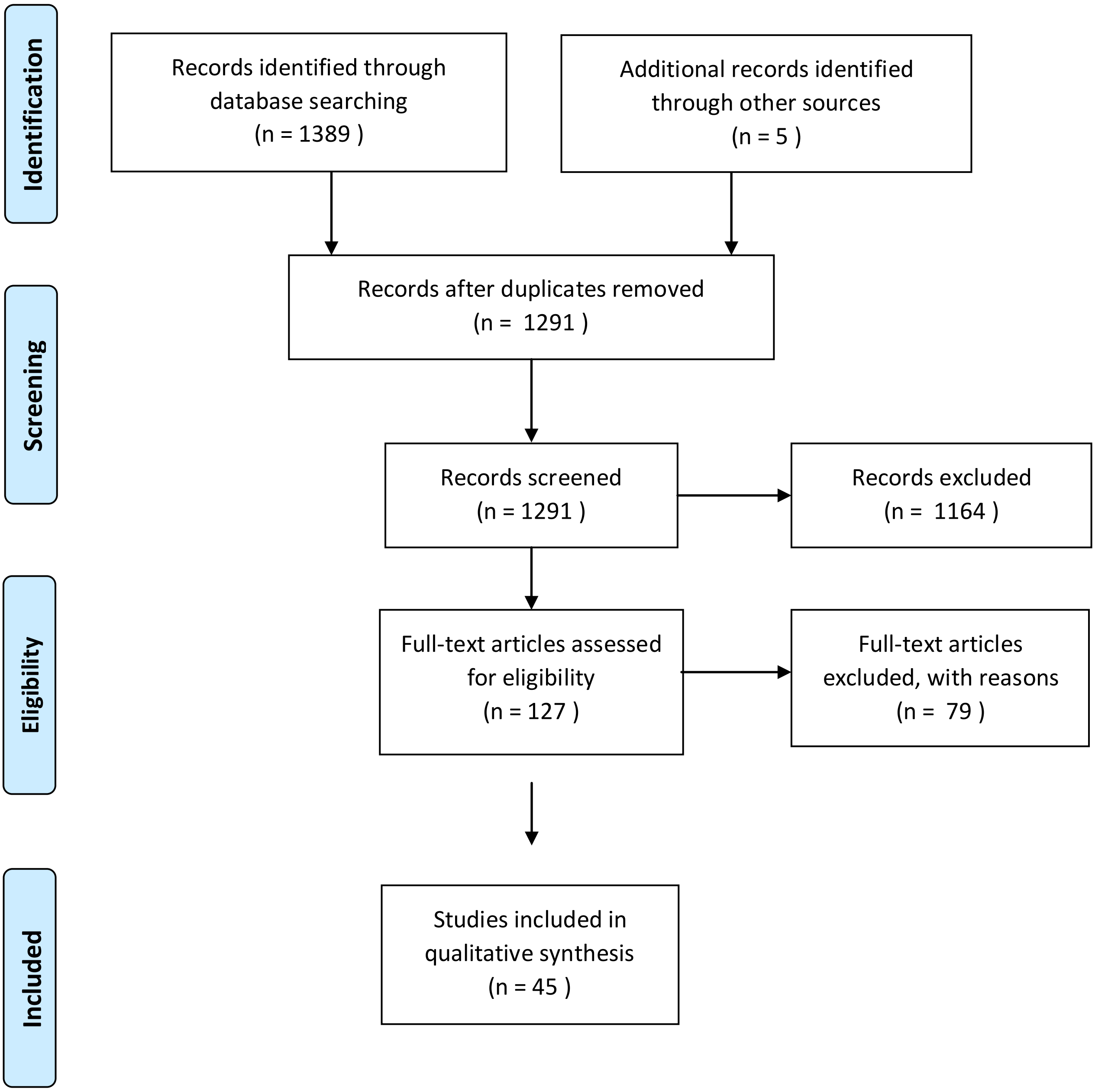
Table.3 – Combination of terms for each database.

Database	**Combination of terms used**	**Filters and limits**
PubMed	(1) “resin, cement [MeSH Terms]”	Publication date: From January 1, 2010 to June 9, 2020 Article types: Clinical trial Randomized Controlled trial Reviews Meta-analysis Systematic Reviews Language: English
	(2) (“heating composite” OR “heated composite”) AND “dentistry”	Publication date: From January 1, 2010 to June 9, 2020 Language: English
Cochrane Collaboration	(1) “composite resin” AND “dental porcelain” (2) Resin cements [Mesh]	Publication Year from 2010 to 2020, with Cochrane Library publication date Between Jan 2010 and Jun 2020, in Trials
EMBASE	(1) ('resin cement'/exp OR 'resin cement') AND resin AND ('cementation'/exp OR cementation) AND ('ceramics'/exp OR ceramics)	

Web of Science	(1) ((high temperature) OR (heating) OR (warming)) AND ((dental ceramic) OR (dental porcelain)) AND (composite resin) (2) (cementation) AND ((dental ceramic) OR (dental porcelain)) and (resin cement)	

Figure 1 – PRISMA flow diagram [18]

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). *P*referred *R*eporting *I*tems for *S*ystematic Reviews and *M*eta-*A*nalyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097



Results

Author	Aim	Methodology	Results
Gürdal *et al.* (2018)[14]	To analyze the influence of thermocycling on the color of CAD-CAM materials with underlying resin cement.	Seven different CAD-CAM materials, composite resins and glass-ceramics were cut into 0.7-mm and 1.2-mm thicknesses and cemented with a dual- and light-polymerizing resin cement, and a preheated composite resin. Color values were measured by spectrophotometry. Specimens were subjected to thermocycling. The measured color difference (ΔE) data were analyzed by descriptive statistics.	ΔE values were significantly influenced by the CAD-CAM material and the resin composite cement but were not influenced by thickness. Significant interactions were present among thickness, cement, and CAD-CAM materials. The highest ΔE values were observed for IPS Empress CAD. The dual-polymerizing resin cement showed significantly lower ΔE values than the preheated composite resin.
Marchionatii *et al.* (2017)[19]	To evaluate the color change and marginal discoloration of dual- and light-polymerizing cement used for cementation of ceramic laminate veneers.	In 10 participants, 0.3-mm-thick ceramic laminate veneers were cemented on unprepared second premolars. A randomized application of light-polymerized cement was used on one side and a dual-polymerized cement on the contralateral side. Color was evaluated with a spectrophotometer at 24 hours and at 2, 6, 12, and 24months after cementation. USPHS guidelines were used to evaluate the marginal discoloration.	The color stability of ceramic laminate veneers was similar for both polymerizing modes for all evaluated periods Marginal discoloration was observed from the 2-year assessment.
Mundim *et al.* (2011)[20]	To assess color stability and opacity associated with the degree of conversion of a pre-heated nanohybrid composite (Tetric N-Ceram, Ivoclar/Vivadent, Schaan,	Twenty-seven specimens were prepared using a Teflon matrix following storage of compules containing the composite at temperatures of 8ºC, 25ºC or 60ºC. After photoactivation and polishing, baseline	There was no significant difference in color stability and opacity variation amongst the temperatures evaluated. The composite pre-heated at 60ºC had a higher degree of conversion (65.13%), with statistically significant

	Liechtenstein).	readings of 6 specimens were taken regarding color and opacity by a spectrophotometer. The specimens were submitted to artificial, 3 specimens for each temperature were submitted to analysis of degree of conversion.	difference compared to the other temperatures.
Gugelmin *et al.* (2020)[21]	To evaluate the color stability of ceramic veneers luted with resin cements and pre-heated composite resins (60ºC) for 12 months, and determine the degree of conversion (DC) of the luting agents	2 resin cements (AllCem Veneer, light-cured(LRC) and AllCem, dual-cured (DRC) and 3 composite resins [Z100 (MNCR minifilled),Herculite Classic (MHCR–micro-hybrid) and Durafill (MCCR–microfilled)] were used for cementing 0.8mm thick lithium-silicate glass-ceramic laminates on bovine enamel. CIELab parameters were determined at 24h after luting (baseline), 7, 30, 90, 180 days and12 months. Three specimens were prepared for DC evaluation, performed by micro-Raman spectroscopy	The groups cemented with MHCR (1 year), MCCR (90 days and 1year) and MCCR-PH (1 year) presented ΔE values above the acceptable threshold. All other groups maintained their ΔE lower than threshold after 1 year in distilled water. Regarding DC, there were no significant differences among the materials.
Turgut *et al.* (2011)[22]	To assess the effect of different resin cement systems and UV ageing on the color of full ceramic laminates with different shades.	392 discs were made with A1, A3, HO and HT shades of IPS e.max Press with 0.5 mm thickness. Different shades of light cured Variolink Veneer, Ivoclar Vivadent; Rely X Veneer, 3M ESPE; and dual cured Maxcem Elite, Kerr; and Variolink II, Ivoclar Vivadent resin cements were applied on the porcelain discs with a thickness of 0.1 mm. Color differences of the porcelain substructures after cementation and300	UV ageing caused significant color change on cemented ceramics. Whilst L* and a* values decreased, b* values increased after ageing. Discoloration was between 0.8–1.2 ΔE for ceramic discs and 1.4–3.1 ΔE for cemented ceramics. There is no significant difference on the color change of dual or light cured resin cements. Although statistically significant differences were observed for all specimens, the magnitudes of the mean

		h (150 kJ/m2) of UV ageing test, were examined with a colorimeter (Shade Eye Ex, Shofu, Japan).	color differences were at an acceptable perception level and were considered clinically acceptable (ΔE < 3.5).
Baptista *et al.* (2019)[23]	To evaluatethe adhesive strength of three composite resins when cemented to two different types of indirect restorations.	Molars were randomly divided in 2 groups according to the type of restorative material, composite resin (FiltekTM Z100 3M ESPE) or lithium dissilicate(IPS e.max CAD - Ivoclar). Each group was subdivided into 3 subgroups according to the adhesion material. 9 disks were obtained through a calibrated cylinder in composite resin and adhered to the crowns with FiltekTM Z100, FiltekTM Bulk Fill and RelyXTM Veneer. Ceramic blocks were produced and adhered with the same materials. The specimens were pulled in a universal testing machine. The resulting fractures were classified stereoscopically. The adhesive interfaces were morphologically evaluated with SEM.	Indirect restorations in both composite resin and lithium disilicate can be adhered with either Filtek TM Z100, Filtek TM Bulk Fill or RelyX TM Veneer, as no statistically significant differences were obtained when indirect restorations are adhered with these materials.The highest adhesion values were obtained by the RelyXTM Veneer resin cement.
Fróes-Salgado *et al.* (2010)[24]	To evaluate the effect of composite pre-polymerization temperature and energy density on the marginal adaptation (MA), degree of conversion (DC), flexural strength (FS), and polymer cross-linking (PCL) of a resin composite (Filtek Z350, 3M/ESPE).	For MA, class V cavities were prepared in 40 bovine incisors. The adhesive system Adper Single Bond 2 (3M/ESPE) was applied. The resin composite was either kept at room-temperature (25 ◦C) or previously pre-heated to 68 ◦C. After placement, the composite was light polymerized for 20 or 40 s at 600mW/cm2.The percentage of gaps was	The pre-heated composite showed better MA than the room-temperature groups. A higher number of gaps were observed in the room-temperature groups, irrespective of the energy density, mainly in the axial wall ($p < 0.05$). Composite pre-heating and energy density did not affect the DC, FS and PCL ($p > 0.05$).

		analyzed by scanning electron microscopy. DC (n = 3) was obtained by FT-Raman spectroscopy on irradiated and non-irradiated composite surfaces. FS (n = 10) was measured by the three-point-bending test. To calculate PCL density KHN (n = 6) was measured.	
Daronch *et al.* (2007)[25]	To measure in vitro intra-pulpal temperature when placing and restoring with either room-temperature or pre-heated (54 and 60ºC) composite.	A K-type thermocouple was placed in the pulpal chamber of an extracted, premolar. Physiological circulation conditions in the pulp chamber were simulated. The class V preparation was filled using composite either at room-temperature, or pre-heated to 54 or 60ºC. Temperature rise over baseline values were determined at various stages: composite placement, contouring, prior to light-curing, and immediately after light-curing.	Significant differences were found in intra-pulpal temperature when comparing preheated and room-temperature composite treatments with respect to baseline among the stages of the restorative process. However, the extent of this increase with heated composite was only 0.8ºC. A 5ºC intra-pulpal temperature rise was seen for all groups during photopolymerization.
Gresnigt *et al.* (2017)[26]	To investigate the influence of the luting agent on the application of laminate veneers (LVs) in an accelerated fatigue and load-to-failure test after thermo-cyclic aging.	Sound maxillary central incisors (N = 40) were randomly divided into four groups to receive LVs (Li2Si2O5) that were adhesively bonded: Group CEMF: Adhesive cement (Variolink Esthetic LC), fatigue test; Group CEMLF: Adhesive cement, load-to-failure test; Group COMF: Resin composite (Enamel HFO), fatigue test; Group COMLF: Resin composite, load-to-failure test. The specimens were thermo-mechanically aged and then subjected to either accelerated fatigue or	Luting with pre-heated restorative resin composite resulted in significantly higher survival and fracture resistance. Both test methods used presented similar results indicating the same significant differences between the two luting agents. Failure analysis after thermo-cyclic aging showed wear facets together with chipping or fracture in LVs that were bonded with the regular luting agent while the groups luted with preheated restorative resin composite presented only wear.

		load to failure.	
Ayub *et al.* (2014)[27]	To determine the effect of temperature on the microhardness and viscosity of 4 resin composite materials.	To investigate microhardness, samples of the 4 composite materials were divided into 2 groups (n = 10 per group). On the first group, the resin composite materials were inserted into the moulds at room temperature and cured while on the second, the resin composite was pre-heated. Microhardness after curing (immediately and after 24 hours) was determined. To viscosity, 0.5 g samples of room temperature or preheated resin composite (n = 15 per group) were placed under a 454 g load for 45s before light-curing (40s). Each sample was photographed, and the surface area calculated.	Preheating the resin composites increased the microhardness and decreased the viscosity of the samples. Filtek SupremeUltra resin composite had the highest mean microhardness, and Vit-l-escence resin composite had the lowest viscosity.
D'amario *et al.* (2013)[28]	To assess the flexural strengths of three resin composites prepared at room temperature or cured after 20 or 40cycles of preheating to a temperature of 45ºC	Three resin composites were evaluated: EnamelPlus HFO (Micerium) (HFO), Enamel PlusHRi (Micerium) (HRi), Opallis + (FGM) (OPA).One group of specimens for each composite was fabricated under ambient conditions, whereas in the other groups, the composites were cured after 20 or 40 preheating cycles to a temperature of 45ºC. 10 specimens were prepared for each group. A 3-point bending test was performed using a universal testing machine at a crosshead speed of 0.5 mm/min.	Both the material and the number of heating cycles were significant factors, able to influence the flexural strength values, however without significant interaction. For all 3 composites flexural strengths were not affected at 20 preheating cycles in comparison with the control groups (0 cycles) but were, however, significantly decreased when 40 cycles were conducted. The HRi and OPA groups had the highest flexural strengths. HFO presented significantly lower flexural strengths in comparison with HRi.
May *et al.* (2012)[29]	To determine the influence of cement thickness and	Axially symmetric FEA models were created for stress analysis of a	Failure loads depended on the bonding condition and the cement thickness for

	ceramic/cement bonding on stresses and failure of CAD/CAM crowns, using both multi-physics finite element analysis and monotonic testing.	stylized monolithic crown with resin cement thicknesses from 50 to 500µm. Ceramic–cement interface was modeled as bonded or not-bonded. Cement polymerization shrinkage was simulated as a thermal contraction. Feldspathic CAD/CAM crowns based on the FEA model were machined, etched and cemented to dentin analogs. Crowns were loaded to failure at 5 N/s, with radial cracks detected acoustically.	both FEA and physical testing. Average fracture loads for bonded crowns were: 673.5 N at 50 µm cement and 300.6 N at 500 µm. FEA stresses due to polymerization shrinkage increased with the cement thickness. At 50 µm cement thickness, bonded crowns withstood at least twice the load before failure than non-bonded crowns.
Rigolin *et al.* (2014)[8]	To compare the microtensile bond strength of two heat-pressed ceramics (leucite-based - IPSEmpress Esthetic/ Ivoclar Vivadent, and lithium disilicate-based- IPS e-max Press/ Ivoclar Vivadent) to dentin with the use of conventional and self-adhesive resin cements.	The occlusal surface of 60 intact human molars was removed and the dentin was exposed. Ceramic blocks were cemented randomly: conventional dual resincement (Variolink II/ Ivoclar Vivadent), conventional self-polymerizing resin cement (Multilink/ Ivoclar Vivadent), and dual self-adhesive resin cement (RelyX U100/ 3M ESPE). Microtensile tests were performed, the type of fracture was analyzed under a scanning electron microscope.	Average microtensile bond strength was higher for the dual resin cement (Variolink II) and the self-adhesive dual resin cement (RelyX U100). Average bond strength was lower when the self-polymerizing resin cement was used. Leucite-based and lithium disilicate-based cements presented similar bond strength to the dentin with dual resin cement (Variolink II) and a dual self-adhesive cement (RelyX U100).
Kramer *et al.* (2016)[16]	To test the impact of preheating (25, 37, 54, or 68ºC) of TetricEvoCeram (TEC), FiltekSupremeXT (FSXT), and Venus (V) on flexural strength (FS), shear bond strength (SBS) and interfacial tension (IFT).	FS was tested with TEC and FSXT. For SBS, glass-ceramic and human dentin substrate were fabricated and luted with the preheated resin composite (RC). SBSs of 1500 thermo cycled specimens were measured. For IFT, glass slides covered with the non-polymerized RC were prepared and contact angles were measured.	Preheated TEC (37–68 ºC) showed higher FS compared to the control-group (25ºC). FSXT presented higher FS than TEC. For SBS to dentin higher values for FSXT than TEC were found. The preheating temperature showed no impact on SBS to dentin. SBS to glass-ceramic revealed a positive influence of temperature for TEC 25–68ºC. IFT values increased with the

			preheating temperature. A significant difference was observed in every RC group between25 and 68 ºC
Good *et al.* (2008)[4]	To compare the mean loads and modes of failure of teeth restored with all ceramic crowns (ACCs) cemented with dual-cured (RelyX ARC; 3M ESPE) or light-cured (RelyX Veneer; 3M ESPE) luting cements.	40 extracted human premolar teeth were preparation for ACCs. IPS Empress (Ivoclar-Vivadent) crowns of standard dimensions were fabricated and 20 were cemented with each cement. The crowns were stored for 1 or 30 days in water and subjected to a compressive load to failure.	There were no significant differences in loads at failure, between each cement group, at each storage period, and there were no significant differences in loads to failure, for each cement, at 1 and 30 days of storage.
Elkaffass *et al.* (2020)[30]	To evaluate the effect of preheating on microhardness, fracture toughness and surface roughness of nano-filled resin composite	A nano-filled resin composite Filtek Z350 XT was used. 28 disc-shaped specimens were fabricated in a Teflon mold for Vickers microhardness indentation test and surface roughness test. The samples were divided into two groups: one was light-cured at room temperature (24ºC) and the other group was light-cured after preheating. Vickers hardness measurements of 14 specimens(n=7) either preheated or non-heated of the top and bottom surfaces was measured.	No significant difference between non-heated and preheated groups for all tests ($p>0.05$). However, for Vickers hardness test, there were significant differences between top and bottom surfaces for non-heated and preheated groups ($p<0.05$). Moreover, surface roughness average Ra (nm) mean values of preheated group was higher than non-heated group but no significant difference between them was found($p>0.05$).
May *et al.* (2013)[31]	To analyze the influence of polymerization shrinkage of the cement layer on stresses within feldspathic ceramic crowns, using FEA models for increasing occlusal cement thickness and bonded versus non-bonded	2-D axial symmetric models simulated stylized feldspathic crowns (1.5 mm occlusal thickness) cemented with resin-cement layers of 50–500 µm on dentin preparations, being loaded (500 N) or not. Ceramic–cement interface was either bonded or not. Maximum axial shrinkage	Changes in the polymerization shrinkage strain (from 0% to 4.65%) have little effect on the tensile stresses generated at the cementation surface of the ceramic crowns, when the occlusal cement thickness is thin (50 µm for bonded crowns). At thicker cements layers stresses within the ceramic

	ceramic-cement interfaces.	of 0%, 1%, 2%, 3%, 4% an d4.65% were simulated. The first principal stresses developing in the cementation surface at the center and at the occluso-axial line-angle of the crown were registered.	became significant.
Martini *et al.* (2019)[32]	To evaluate the stress behavior of ceramic fragment restoration, varying the thickness of the cement layer and intraoral temperature variation.	A solid model of an upper lateral incisor was obtained and a defect at enamel distal/incisal edge was restored with a ceramic fragment. Based on this initial model, 4 models were built varying the cement thickness from 0 to 200µm. The environment temperature changed from 5ºC to 50º. The finite element analysis was performed.	A thick resin cement layer contributes to a higher stress concentration on a ceramic fragment, and hot temperatures increase the risk of structural failure, as both ceramic and cement interfaces are exposed to higher compressive and tensile stresses.
Jongsma *et al.* (2015)[33]	To test the influence of temperature on contraction stress and volumetric shrinkage of Clearfil AP-X, Venus Diamond, Premise and Filtek Z250.	Volumetric shrinkage measurements were carried out using mercury dilatometry, while a constraint tensilometer set-up was used for the measurement of contraction stress. Measurements were carried out with a composite temperature of 23, 30, 37, and 44ºC.	Volumetric shrinkage increased with higher temperature. Premise and Venus Diamond had lower volumetric shrinkage than Clearfil AP-X and Filtek Z250. Clearfil AP-X showed the highest contraction stress which slightly increased with higher temperatures. The other composites only showed an increase in contraction stress between 23 and 30◦C.
May *et al.* (2015)[34]	To evaluate the influence of the occlusal resin cement thickness on the cyclic loads-to-failure of feldspathic crowns and to compare the results to data from monotonic tests.	Feldspathic ceramic crowns (Vita Mark II blocks, Vita Zahnfabrik) were bonded to dentin analog die with occlusal resin cement thicknesses of 50 µm and 500 µm (Multilink Automix, Ivoclar). The dies were prepared with microchannels for water transport to the cement	Crowns with an occlusal cement layer of 50 µm were more resistant than those cemented with 500 µm under wet cyclic testing conditions. The fatigue failure loads were reduced compared to monotonic loads.

		layer. After 96-h water storage, the specimens (n = 20) were submitted to cyclic loads (500,000 cycles).	
Cantoro *et al.* (2011)[35]	To assess the influence of the cement manipulation and ultrasounds application on the bonding potential of self-adhesive resin cements to dentin	56 class II cavities were prepared in extracted third molars. Class II inlays were made using the nano-hybrid resin composite. Half of the specimens were luted under a static seating pressure (P), while the other ones were cemented under vibration (V). The inlays were luted using self-adhesive resin and microtensiles ticks and specimens for scanning electron microscope(SEM) observations were obtained from the luted teeth.	The luting technique influenced the bond strength of RelyX Unicem. Specifically, ultrasounds were effective on microtensile bond strength. Faster and more controlled procedure was observed using the ultrasound technique.
Tomaselli *et al.* (2019)[15]	To evaluate of pre-heating, filler contents and ceramic thickness on film thickness, microshear bond strength, degree of conversion and color change on ceramic veneers.	Two experimental composites were prepared with different amounts of filler (65% or 50%wt) simulating a conventional and a flowable composite. The flowable (F) was used at room temperature and, the conventional either at room temperature (C) or pre-heated (CPH). Disk-shaped ceramics with different thickness were prepared. The microshear bond strength (n=10) was evaluated in enamel. The degree of conversion was evaluated using Raman spectroscopy and the color change of the ceramic by spectrophotometry.	C presented the thicker film thickness; CPH produced a similar film thickness in comparison to the F. All composites showed similar microshear bond strength. The degree of conversion of the F was higher than the C and CPH. The degree of conversion of the composites photo-activated through a 0.4 mm was higher than the composites photo-activated through thicker ceramics. The C showed the highest color change, while the CPH showed similar color change to the F.
Schmidlin *et al.* (2005)[36]	To investigate the effect of manual and ultrasonic insertion of	In a preliminary test, mean loads for manual and ultrasonic insertion	Ultrasonic insertion significantly reduced mean load applied to seat inlays.

	standardized class I inlays using three composite resin materials of different viscosity on time to seat inlays, film thickness, and filler distribution within the materials	were measured using the high viscosity composite resin (Tetric Ceram). These loads were then applied with composite resin materials to evaluate the times required to seat the inlays. Film thickness was assessed using scanning electron microscopy and filler distribution was monitored using energy-dispersive spectroscopy.	Using an ultrasonic device, times for insertion values were significantly lower in the high and medium viscosity composite resin material groups compared to manual insertion. The widest film thickness was recorded for the high viscosity composite resin material in combination with manual insertion.
Taschner *et al.* (2012)[37]	To compare the clinical performances of two different cementation procedures to lute IPS Empress inlays and onlays.	83 IPS Empress restorations were placed in 30 patients and divided in: group 1- 43 restorations were luted with a self-adhesive resin cement; group 2: 40 restorations were luted with an etch-and-rinse adhesive and a dual-polymerizing resin cement.	After 2 years of clinical service better marginal and tooth integrity was found in group 2 compared to the use of the self-adhesive cement while no differences were found for all remaining investigated criteria. The absence of enamel in proximal boxes did not affect marginal performance.
Campbell *et al.* (2016)[38]	To determine if preheating composite leads to changes in postoperative sensitivity in a parallel RCT	120 adults were recruited in private dental practice and randomized into 2 groups: one had room temperature composite restorations placed and the second had composite preheated to 39°C. The primary outcome was sensitivity after 24h by the visual analog scale (VAS), recorded blind by patients. Secondary outcomes were VAS scores recorded over a month.	There was no detectable difference in postoperative VAS score between preheated and room temperature composite. Postoperative sensitivity decreased throughout the first month. Postoperative sensitivity was correlated to preoperative sensitivity.
Almeida *et al.* (2015)[13]	To investigate the effects of resin-based agents and aging on the color stability of ceramic veneers bonded to enamel	Ceramic disks were cemented to bovine enamel disks with 4 resin-based luting agents: dual-polymerizing cement, light-polymerizing cement, flowable composite resin, or composite resin preheated for 30 minutes at 60ºC. CIE L*, a*, and b*	The dual-polymerizing cement had higher color variation than the light-polymerized materials when used for bonding ceramic veneers to enamel. Flowable and preheated composite resins had similar color stability to that of light-polymerizing resin-

		color coordinates were measured 24 hours after cementation with a color spectrophotometer and again after thermocycling. Color variation was calculated by using CIELab and CIEDE2000 methods.	based cement
Coelho *et al.* (2019)[17]	To evaluate the influence of preheating different composite resins on their viscosity and strengthening yielded to ceramic.	Degree of conversion was measured for 3 restorative composite resins and a photoactivated resin cement. Viscosity was measured during a heating-cooling curve and using isothermal analyses at 25ºC and 69ºC. Feldspar ceramic disks were bonded with the luting materials. Biaxial flexural strength, characteristic strength, and Weibull modulus were calculated. Film thickness was measured and morphology at the bonded interfaces was observed.	A gradual decrease in viscosity was noticed as temperature increased. At 25ºC, the composites were up to 38 times more viscous than the resin cement; at 69ºC the difference was 5-fold. Degree of conversion was similar between all resin-based agents. The resin cement yielded lower film thickness than the composites. Strengthening effect was higher for the preheated composite resins.
Sampaio *et al.* (2016)[45]	To evaluate the volumetric polymerization shrinkage (VS) and film thickness (FT) of various cementation techniques through 3-dimensional microcomputed tomography (µCT).	48 artificial plastic maxillary central incisors with standard preparations for veneers were provided by a mannequin manufacturer and used as testing models. They were divided into 8 groups: RelyX Veneer + Scotchbond Universal; Variolink Esthetic LC+Adhese Universal; Filtek Supreme UltraFlowable + Scotchbond Universal (FF+SBU); IPS Empress Direct Flow + Adhese Universal; Filtek Supreme Ultra Universal+ Scotchbond Universal; IPS Empress Direct + Adhese Universal;	Both the VS and the FT of direct restorative composite resins were higher than those of veneer cements and flowable composite resins, whether preheated or not preheated.

		Preheated Filtek Supreme Ultra Universal + ScotchbondUniversal; and Preheated IPS Empress Direct + Adhese Universal. Specimens were scanned and analyzed before and after polymerization using 3-dimensional µCT to calculate the VS and FT	

Discussion

1. Film thickness

Film thickness is an important factor when luting indirect restorations as a thicker film is more prone to wear, leading to consequent marginal misfit. Adding to that, larger volumes of resin material to be polymerized lead to greater volumetric shrinkage, increasing the susceptibility to failure.[15,32] Reduced film thickness has been linked to increased facture resistance of all-ceramic restorations, particularly in thin ceramic laminate veneers, increased bond-strength and low water sorption.[10]

ISO standard of film thickness is established at 25µm[6] and it has been researched and described as ideal between 5 and 25µm, not exceeding the 50µm.[3,34]

May *et al*. determined the influence of cement thickness and ceramic/cement bonding - on stress and failure of CAD/CAM crowns, showing that average fracture loads for bonded crowns were 673.5N at 50µm of cement and 300.6N at 500µm which indicates that failure loads decrease with increasing resin cement thickness. The same study also concluded that that the benefits resulting from bonding procedures were lost at thicknesses of 450–500µm due to polymerization shrinkages stress.[29] Another similar research by Gressler *et al.* concluded that cement thickness should be kept as low as possible in order to minimize potential problems regarding the resistance of ceramic crowns.[34]

Thermo-modification techniques have been used to lower composite resin viscosity by increasing molecule agitation.[15] When comparing resin cements and thermo-modified composite resins in terms of the obtained film thickness, Coelho *et al.* evaluated the influence of preheating three restorative composite resins (Z100–microhybrid; Empress Direct–nanohybrid;Estelite Omega–supranano) and one photoactivated resin cement (RelyX Veneer) regarding viscosity and strengthening yielded to ceramics. The resin cement presented significantly lower film thickness than the three restorative composite resins. Between composite resins, the film thickness of Empress Direct and Estelite Omega were significantly greater compared with Filtek Z100.[17] Sampaio *et al.* also compared the different luting agents on this parameter using 3-dimensional (3D) microcomputed tomography. Results obtained from the analysis indicated that light-polymerized veneer cements and flowable composite resins were statistically similar, presenting less thickness than either direct restorative composite resins, preheated or not. This finding reflects the percentage of inorganic fillers contained in these materials, greatest with the direct restorative composite resins.[45]

Another technique that may contribute to improving flowability and reducing film thickness when luting ceramics with preheated composite resins is the use of ultrasounds.[36] Cantoro *et al.* measured the bonding potential of resin cements to dentin by microtensile bond strength testing and microscopic observations of the bonding interface, and concluded that ultrasound techniques applied in inlay cementation promoted higher adaptation and lower porosity, as well as thinner cement layer. In addition, ultrasound-aided insertion resulted in faster seating of the restorations.[35]

2. Viscosity

Viscosity is the property that determines a composite resin's degree of molecular mobility. Increased viscosity limits molecular movement, leading to incomplete polymerization. The use of low-viscosity materials results in greater marginal adaptation due to higher fluidity and better contact with the prepared tooth surfaces. Conversely, preheated composites show increased monomer mobility, as a result of increased molecular motion by thermal energy which provides higher flowability.[17,27] These effects may result in an easier restoration placement and higher monomer conversion, resulting in an increased microhardness.[27]

Improved rheological properties even after cooling are important when thermo-modification is used. A short interval in between preheating the composite and applying it to the ceramic or tooth surface is crucial for reducing film thickness, since it has been estimated that the temperature decreases 50% after 2 minutes and 90% 5 minutes after heating is ceased.[17] However, even if the composite cools from 68ºC to about 40.8ºC, benefits may still be achieved compared to room temperature composites.[20]

It is relevant to highlight the intra-pulpal effects of the cumulative composite temperature and exothermic reaction promoted by the photoactivation. In fact, the in vitro intra-pulpal temperature rises after pre-heated composite placement [20] but no pulpal damage is expected as the difference observed *in vitro* was less than 1ºC when using pre-heated composite to 60ºC, compared to one tested at room temperature, which is far less than the pulpal tolerance.[16] According to Daronch *et al.*, the temperature rises 0.8ºC through 1mm wet dentine after placement of 60ºC pre-heated composite and an additional 5ºC temperature rise occurs due to the photoactivation process. These authors concluded that the temperature reduces to a value of 36ºC after complete removal from the pre-heating device. No significant differences in the intra-pulpal temperatures between room temperature or preheated composites were found.[25]

When comparing different materials, the viscosity generally increases as the filler loading is increased, which explains the higher viscosity observed in the pre-heated composite resins compared with the resin cements which have lower filler content.[17]

3. Optical properties

The color stability of luting agents influences the esthetic outcome of ceramic restorations and their long-term success, especially in highly translucent restorations. The composition of monomers used in the matrix, large filler size and their higher content, water sorption, incomplete polymerization and exogenous factors related to hygiene habits, food, and smoking are major factors of color changing.[19,20] The resin matrix of resin cements contains bisphenol A-glycidyl methacrylate (Bis-GMA), urethane dimethacrylate (UDMA), and triethyleneglycol dimethacrylate (TEGDMA). The stability of the cement color is associated with the presence of UDMA (a monomer with low rates of water sorption) and a reduction in the quantity of TEGDMA (a monomer with increased water uptake). An explanation for the yellowish appearance of resin materials is the presence of Bis-GMA monomer in their composition as it tends to turn yellow when exposed to ultraviolet light and heat. Moreover, when light transmission is limited, the resin cements undergo incomplete polymerization leading to incompletely converted monomers that may explain cement discoloration.[19,22]

Chemical-cured resin cements present long setting times and hard to control working times but may be cured even when light cannot reach the luting material. In contrast, light cured cements allow for an easier removal of excess, require no mixing, and therefore, the cement is more homogenous with reduced porosity. The lack of tertiary amines in light activated resins when compared to a chemical-cured approach provides excellent color stability. However, restoration thickness may limit light access and complete resin polymerization. Dual-cured resin cements can act in deep areas where curing light hardly reaches, but present color instability and an excessive film thickness which may lower marginal adaptation of the restoration. The composition, thickness, opacity, and shade of the ceramic material may attenuate light from the curing unit that is used to polymerize the resin cement under the ceramic restoration.[5,6] Regarding the differences in polymerization kinetics between resin cements under various conditions, clinicians need to choose the optimal materials for each case.

When researching the effects of resin-based agents and aging on the color stability of ceramic veneers bonded to enamel, Almeida *et al*. concluded that flowable and preheated composite resins may be used as luting agents for ceramic veneers, as both materials showed similar results in color stability of the light-cured cement tested**.** In addition, light cure luting agents showed better color stability than dual-cure materials. The poorer color stability of dual-cure materials is usually associated with the oxidation of the unreacted amine co-initiator from the redox polymerization system. The co-initiators in light-cure materials, classically canphoroquinone, exhibit higher chemical stability and tend to cause less color variation over time. The presence of unreacted benzoyl peroxide in dual-cure agents may also lead to shoddier optical properties**.**[13] In contrast, Turgut *et al.* found no significant differences between these two types of resin cement, with a magnitude of mean color differences (ΔE) at an acceptable perception level, considered clinically acceptable ($\Delta E < 3.5$). These results may be attributed to adequate polymerization beneath the 0.5-mm-thick highly translucent ceramic veneers used in the study. [22] Another study[14] analyzed the influence of thermocycling on the color of CAD-CAM materials with underlying resin cement. The dual-cure cement presented the lowest, whereas the heated composite resin showed the highest ΔE values. The advanced color stability of the dual cure resin cement tested in this study may be due to its highly active photo initiator content, which does not require amine co-initiators. The heated composite resin tested contains amine molecules, which are the main cause of color changes in resin materials.

Mundim *et al.* assessed the color stability and opacity associated with the degree of conversion of a nanohybrid composite (Tetric N-Ceram, Ivoclar/Vivadent) heated at 8ºC, 25ºC and 60ºC. Results showed no difference in color stability and opacity variation among the tested temperatures, however the composite pre-heated at 60ºC had a significantly higher degree of conversion. The degree of monomer conversion influences the chemical stability of the material. Non-converted double carbon-links could originate at material more susceptible to degradation reactions, reducing color stability and releasing products such as formaldehyde and methacrylic acid.[20] Despite these results, only one composite trademark has been tested in this study. Therefore, it is not possible to predict the behaviour of other composites. The degree of conversion can vary from composite to composite, including different shades of the same material.

4. Polymerization shrinkage

Polymerization shrinkage occurs as the distance between monomers is reduced when the weak van der Waals forces between monomers are converted into covalent bonds. A gradual increase in resin viscosity also occurs, resulting in loss of its fluidity (gel-point) and flowing ability (vitrification). Debonding along the restoration/tooth interface or at the restoration margins may be a consequence when shrinkage stress exceeds the bond strength, resulting in internal and marginal gaps, marginal staining, micro-cracking of either or both the restorative material and tooth structure.[39] Residual stress developing during polymerization is a multi-factorial phenomenon, determined by volumetric shrinkage, visco-elastic behavior and by restrictions imposed to polymerization shrinkage. These factors are often described by C-factor (defined as the ratio of the bonded to the unbonded surface area), bonding strength to the substrate walls and hardening vs time-dependent viscosity of the composite. High C-factor values may be of concern as shrinkage can cause the development of significant polymerization stress that leads to cohesive failures.[31]

Effect of temperature on composite polymerization stress and degree of conversion (DC) was researched by Calheiros *et al.* under isothermal and non-isothermal conditions. Data obtained in this study[40] showed both DC and isothermal maximum stress significantly increasing with temperature and exposure duration. Using a 5 seconds exposure on composite pre-heated to 40ºC or 60ºC) resulted in a 47–55% reduction in final stress compared to using a full 20 seconds (manufacturer's recommended duration) exposure with the composite maintained at room temperature. This finding is of major importance, as degree of conversion obtained isothermally 40ºC or 60ºC with a 5 seconds exposure was similar to 20 seconds at room temperature. Reduced exposure time results in fewer radicals being generated, however, their segmental mobility may be enhanced by the temperature rise, making more residual unsaturation sites accessible for reaction. The results obtained under isothermal conditions, however, do not consider the temperature variation occurring either from room temperature or the change in pre-set temperature of the heating device to the mouth temperature. To include this variable, polymerization stress under non-isothermal conditions was tested and showed significantly higher stress for 60ºC than 22ºC pre-cure temperature, corroborating the isothermal results.[40]

Conversely, another study by Jongsma *et al.* measured volumetric shrinkage and contraction stress of dental composites at temperatures of 23, 30, 37, and 44ºC. It was concluded that pre-heating of dental composites resulted in an increased volumetric shrinkage above 23ºC but interestingly no further increasing in contraction stress was observed above 30ºC. The authors recommended that most of the *in vitro* studies, which are generally carried out at room temperature, should be carried out at “mouth” temperature (32–37◦C) for more clinically relevant results.[33]

The influence of resin cement polymerization shrinkage on stresses in porcelain crowns was tested by May *et al.* Under thin occlusal cement thickness (approx. 50 µm for bonded crowns), changes in the polymerization shrinkage strain (from 0% to 4.65%) had little effect on the tensile stresses created at the cementation surface of the ceramic crowns. However, as the cement film became thicker stresses within the ceramic increased, highlighting once again the importance that film thickness presents in the big picture.[31]

Soares *et al.* concluded that a delay of 3 to 5 minutes in light activation of dual curing resin cements for cementing ceramic inlays reduced the post-gel shrinkage (the portion of the total shrinkage that causes residual stresses) and decreased the shrinkage stresses at the pulpal floor, which may reduce post-operative sensitivity.[39] Sampaio *et al.* evaluated the volumetric polymerization shrinkage of various cementation techniques and observed that light-cured veneer cements and flowable composite resins showed less volume shrinkage than direct restorative composite resins, regardless of preheating. The increased volume of material observed in the direct restorative composite resins groups may explain this finding, as an increased volume of material and/or an increased thickness is expected to increase shrinkage when light-cured in a single moment.[45]

5. Shear bond strength

Shear bond strength (SBS), the ability of the material to resist shear load until failure, of porcelain laminate veneers to enamel, dentine and enamel-dentine complex bonded with different light-cure and dual-cure resin cements was measured by Öztürk *et al.* . These authors found that the type of resin cements, either dual-cure or light-cure, had no significant effect on the ceramic shear bond strength. Higher SBS values were registered for enamel and enamel–dentine complex groups, outlining the importance of luting ceramics to enamel.[9] Compared with other types of cements such as self-adhesive resin cements or non-resin based cements, conventional resin cements show superior shear and tensile bond strength, as the adhesive nature of resin cements results in restorations with increased retention and fracture resistance.[5,41,42]

To test the impact of preheating (25, 37, 54, or 68ºC) of 3 different composites on shear bond strength (SBS), flexural strength (FS), and interfacial tension, glass-ceramic and human dentin substrates were luted with preheated luting agents. According to the results, the SBS test values did not show a decrease due to preheating. Higher temperature even showed a positive impact on the adhesion of one group of SBS tests. Besides, it can be assumed that the observed higher degree of conversion of preheated composite resins has a positive influence on the flexural strength. Comparison with other studies is quite difficult due to the variety of used components and methodologies.[16]

Considering other physical properties, D'amario *et al.* assessed the flexural strength of three resin composites prepared at room temperature or cured after 20 or 40 cycles of preheating to a temperature of 45ºC. After 20 pre-heating cycles, flexural strength was not affected if compared with the unheated group. However, when 40 pre-heating cycles were conducted before light curing, the mean flexural strength of the tested composite resins showed a significant decrease. Dental clinicians should adopt the use of single-use composite compules instead of syringes to avoid loss of mechanical properties.[28]

Baptista *et al.* evaluated the adhesive strength of three composite resins (Filtek TM Z100, Filtek TM Bulk Fill or RelyX TM Veneer) when cemented to two different types of indirect restorations (composite resin and lithium disilicate). No statistically significant differences were obtained between the different adhesion materials, regardless of restorative material, indicating that according to these authors any of the materials may be used in luting indirect restorations.[23]

The influence of luting agents on the application of laminate veneers in an accelerated fatigue and load-to-failure test after thermo-cyclic aging was assessed by Gresnigt *et al*. Luting with pre-heated restorative resin composite resulted in significantly higher survival and fracture resistance than the resin cement. Both used test methods presented similar results indicating the same significant differences between the two luting agents. Failure analysis after thermo-cyclic aging showed wear facets together with chipping or fracture in laminate veneers that were bonded with the resin cement while the groups luted with thermo-modified resin composite presented only wear. However, these results are not consensual with the overall literature implying further research.[26]

6. Marginal Infiltration

The clinical success of cemented restorations has been evaluated by measuring marginal fit and microleakage. In the case of all-ceramic restorations, microleakage has been correlated with the loss of bond to tooth structure, leading to other complications such as secondary caries, post-operative sensitivity, pulpal inflammation, staining and plaque accumulation due to the clinically undetectable infiltration of bacteria, fluids, molecules or ions between tooth-restoration interface.[43]

Froés-Salgado *et al.* studied the effect of composite resin pre-heating at 68ºC (Filtek Z350, 3M/ESPE) on marginal adaptation, monomer conversion, flexural strength, microhardness, and polymer cross-linking under a non-isothermal condition, analyzing the percentage of gaps by scanning electron microscopy. Pre-heating the composite prior to light curing, similarly to a clinical situation, showed better marginal adaptation than the room-temperature groups which presented higher number of gaps. This could be attributed to the reduction in the composite resin viscosity which should facilitate the adaptation of the material. Thermo-modification did not affect mechanical properties and monomer conversion of the composite.[20]

According to Ayub *et al.*, the clinician should also guarantee the conditions for complete polymerization of the luting agent, as incomplete polymerization can lead to bonding failures and increased wear due to reduced mechanical strength.[27]

Regarding resin cements, marginal infiltration is increased by higher film thickness which leads to quicker marginal degradation and thus more infiltration.[5] In a review produced by Santos *et al.*, some longitudinal studies have shown marginal degradation over time due to wearing of the resin cement. Cements with greater amounts of filler had less wear, this fact is in favor of composite resins which present higher filler content than resin cements, as previously mentioned. However, these statements need to be analyzed with caution once higher filler amounts generate thicker cement layers which leads to marginal infiltration.[44]

Answering the research question "Does luting indirect restorations with resin cements have better results when compared to using thermo-modified composite resins, concerning film thickness, viscosity, optical properties, shear bond strength, marginal infiltration and polymerization shrinkage?", it can be partially accepted. Studies present discrepancies and broad disparity regarding the evaluated materials, measured parameters and *in vitro* conditions, thus not always allowing direct comparisons between them. Within this heterogeneity, both of the compared luting agents present identical behavior considering optical properties, marginal adaptation, viscosity and shear-bond-strength. However, in terms of the obtained film thickness and polymerization shrinkage, thermo-modified composite resins still need to be improved in order to achieve the higher performance of resin cements.

Conclusion

The bond between glass ceramics and resin cements is one of the key factors to long-term clinical success. Intense research activity has brought many contributions to the understanding of ceramic–resin bonding in the past few years. Both compared luting agents present identical behavior considering optical properties, marginal adaptation, viscosity and shear-bond-strength. However, in terms of the obtained film thickness and polymerization shrinkage, thermo-modified composite resins still need improvement to achieve the higher performance of resin cements. The use of thermo-modification or ultrasonic vibration techniques may provide enhanced mechanical properties to luting agents. Literature would benefit with more scientific evidence comparing the different materials and techniques in accurate experimental models that simulate clinical situations.

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