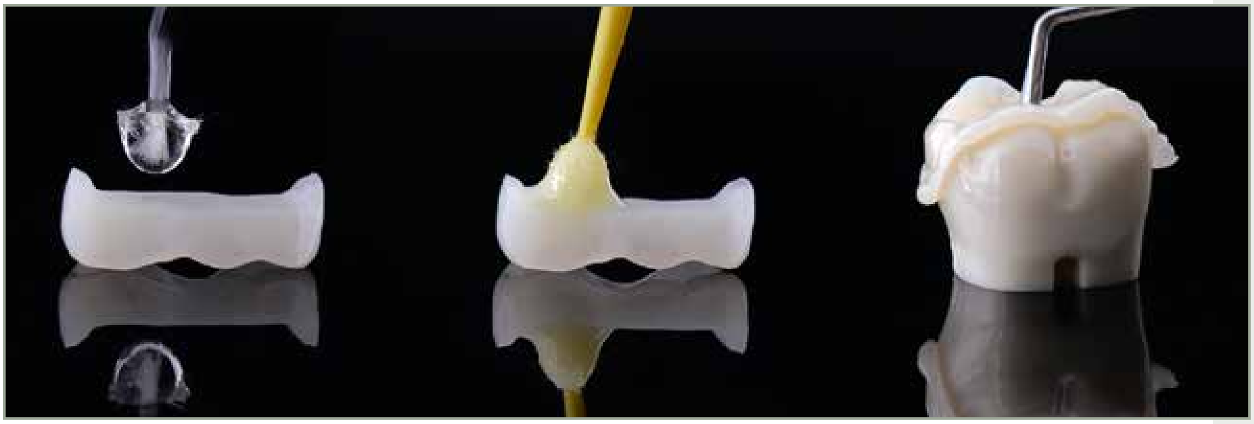
Luting of inlays, onlays, and overlays with preheated restorative composite resin does not prevent seating accuracy

Pascal Magne, DMD, PhD, PD
The Don & Sybil Harrington Professor of Esthetic Dentistry, Division of Restorative Sciences, Herman Ostrow School of Dentistry, University of Southern California, Los Angeles, California, USA

Mehrdad Razaghy, DDS
Student, Herman Ostrow School of Dentistry, University of Southern California, Los Angeles, California, USA

Marco Aurelio Carvalho, DDS, MS, PhD
Department of Prosthodontics and Periodontology, University of Campinas, Piracicaba, Brazil

Luciana Mara Soares, DDS, MS
Private Practice, Campinas, Brazil



Correspondence to: Dr Luciana Mara Soares
Rua Germano Casellatto, 60, Santa Genebra II, Campinas, SP 13084-776, Brazil;
Tel: +55 (19) 99645-7160; Email: soareslumara@gmail.com

Abstract

Purpose: To evaluate *in vitro* the vertical seating of computer-assisted design/computer-assisted manufacturing (CAD/CAM) composite resin inlays, onlays, and overlays luted with two different composite resins.

Materials and methods: Sixty plastic typodont molars were prepared for medium-sized MOD inlays, anatomic onlays, and flat overlays (n = 20); 3-mm thick at the central groove with similar morphology (Cerec biogeneric copy). Restorations were milled using Lava Ultimate blocks, and included standardized hemispherical occlusal concavity for seating measurements with an electromechanic system (force = 30 N). Restorations were luted either with preheated composite resin (Filtek Z100) or dual-cure resin cement (RelyX Ultimate). Seating of restorations was first evaluated at try-in (baseline). Seating was reevaluated after airborne-particle abrasion (Step 1), after seating with luting agent (Step 2), and after light polymerization (Step 3). The Friedman test followed by the Wilcoxon post hoc test were used to compare the seating among steps, and the Kruskal-Wallis test followed by the Mann-Whitney post hoc test were used to compare the seating between luting agents at $P < 0.05$.

Results: Seating differences varied significantly from baseline ($P < 0.0125$). All restorations seated 3.85 µm (inlays) to 5.45 µm (onlays) deeper after airborne-particle abrasion (Step 1) ($P < 0.007$). Except for cement-luted inlays, the try-in position (±1 µm) was recovered following unpolymerized luting (Step 2). After polymerization (Step 3), onlays and overlays seated 2.9 to 3.9 µm deeper than during try-in (baseline) using Z100 ($P < 0.005$), and 7.0 to 7.3 µm deeper using RelyX ($P = 0.005$). Inlays luted with RelyX seated higher than during try-in (baseline), exactly 7.9 µm after Step 2 ($P = 0.005$), and 7.7 µm after Step 3 ($P = 0.008$). Luting with Z100 sustained the seating of inlays with no statistical difference when compared to baseline ($P = 0.157$).

Conclusion: Airborne-particle abrasion significantly deepens the seating of CAD/CAM composite resin restorations, but the presence of unpolymerized restorative composite resin luting agent perfectly compensates for this discrepancy. Following polymerization, onlays and overlays seat deeper compared to inlays, especially when using RelyX. The latter, however, resulted in a slightly higher seating of inlays.

Clinical significance: With the least variation compared to baseline seating (try-in), restorative composite resin used as luting agent resulted in the seating of CAD/CAM inlays, onlays, and overlays closer to baseline when compared to dual-cure resin cement.

(Int J Esthet Dent 2018;13:2–16)

Introduction

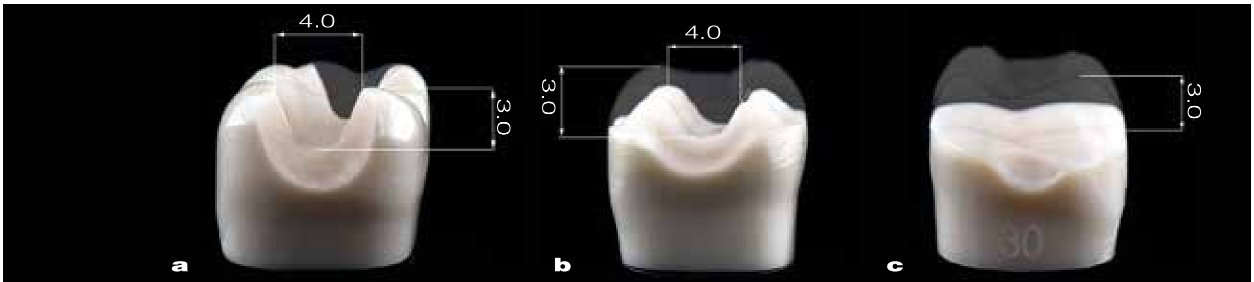
The use of computer-assisted design/computer-assisted manufacturing (CAD/CAM) posterior bonded restorations has been steadily growing. These restorations are classically delivered with an adhesive protocol, including dual-cure cement. Updated approaches now include the use of immediate dentin sealing (IDS) and are light polymerized, with only composite resins used as a luting agent. Omitting dual-cure resin cements is not a new idea. In anterior teeth, Friedman[1] demonstrated the success for over 15 years of porcelain veneers bonded with a microhybrid restorative composite resin. In 1995, Besek et al[2] may have been the first to propose the use of a restorative composite resin as a luting agent for ceramic inlays. These authors demonstrated that, with respect to polymerization rate, there were no advantages of dual-curing resin compared to light curing only. In addition, the overall handling of the light-curing composite resin was judged to be easier than that of the dual-cure material. The same conclusions were drawn by Krämer and Frankenberger,[3] who added that less luting composite overhangs were found with the solely light-polymerized composite resin because the clinician has more time for excess removal prior to polymerization.

Remaining concerns about the depth of polymerization of the luting agent and its effect on the performance of thick onlays and overlays have been resolved by several studies showing that even thick restorations demonstrate appropriate mechanical performance when delivered with a solely light-polymerized composite resin.[3-6] These authors all agreed that the thickness of the restoration can be compensated for by extended polymerization times of up to 90 s per surface. In addition, dual-cure cements still require efficient light curing to reach their optimal conversion rate.[7,8]

Another potential advantage of restorative composite resins used as a luting agent is their resistance to wear, which proved to be superior to methacrylate or phosphate-based resin cements.[9,10] Using light-curing restorative materials for luting tooth-colored inlay, onlays or overlays should therefore no longer be considered hazardous.[11]

Despite the aforementioned, clinicians are still concerned about the possibility of incomplete restoration seating due to the viscosity of the restorative material. Hence, preheating the composite resin through ultrasonic devices[12] or a small composite heater[13] has been proposed to increase the flow and facilitate the seating of the restoration. In addition, preheating proved to have positive effects on marginal adaptation.[14,15] Composite resins will polymerize better when heated;[16-18] however, this might not happen during a luting procedure because of the rapid cooling of the material before it is light polymerized.[13,14] The same syringe of material can be preheated up to 20 times without affecting the mechanical properties or polymerization rate.[19,20]

Some authors, however, have claimed that both the shrinkage and the film thickness of direct restorative composite resins were higher than those of veneer cements and flowable composite resins, whether preheated or not.[21] Although restorative composite resins might not



	Inlay		Anatomical onlay		Flat overlay	
Groups	INcr	INcem	ONcr	ONcem	OVcr	OVcem
Luting agent	Preheated restorative composite resin	Dual-cure resin cement	Preheated restorative composite resin	Dual-cure resin cement	Preheated restorative composite resin	Dual-cure resin cement

Fig 1 Preparation designs (in mm) and experimental groups. **(a)** Inlay. **(b)** Anatomic onlay. **(c)** Overlay (flat preparation).

present the lowest film thickness, there is still a lack of data to prove that this would preclude the seating of the restoration. Especially knowing that the fitting surface of composite resin inlays or onlays needs to be air abraded with aluminum oxide before bonding,[22-25] this might create the additional clearance space for the luting agent. In addition, of importance is that different parameters of air abrasion such as grit size, distance, pressure, and time of abrasion could affect this space. Therefore, the objective of this study was to evaluate *in vitro* the vertical seating of CAD/CAM composite resin inlays, onlays, and overlays luted with two different composite resins. The null hypothesis was that restorations would seat similarly, independent of the type of luting agent (restorative material vs dual-cure cement) or preparation (inlay vs onlay vs overlay).

Materials and methods

Tooth preparation

A standardized inlay (MOD) preparation with an isthmus width of 4 mm, pulpal floor depth of 3 mm, and proximal box forms was applied to 20 mandibular first molar typodont teeth (Columbia Dentoform) by using chamfer round-ended diamond burs (Brasseler) (Fig 1a). Similarly, 20 additional teeth were prepared with identical isthmus width and pulpal floor depth measurements as those of the inlay, but with an extra 2-mm reduction of cusps. A shoulder was created that was to be connected to the proximal box forms, to receive anatomic onlay restorations (Fig 1b). A flat overlay preparation with an occlusal reduction of 3 mm and flattened cusps was performed on the third group of 20 teeth. Two small

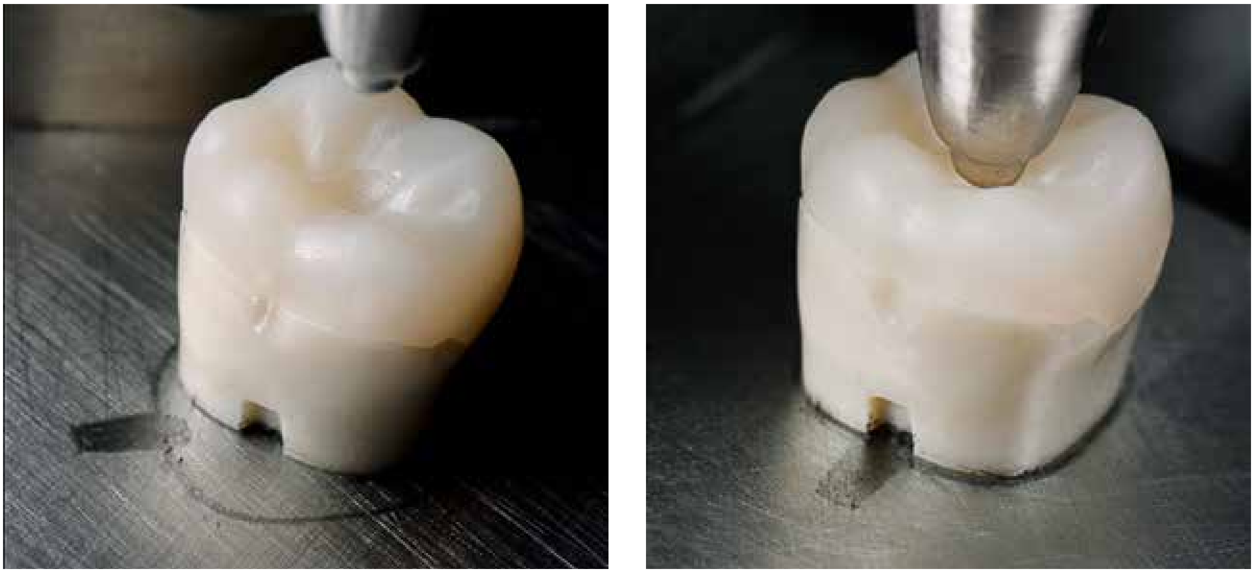


Fig 2 Base drawing used to guide the precise position of the specimen to initiate the vertical seating test.

proximal box forms were developed as an antirotational feature (Fig 1c). All preparations presented soft internal angles and rounded transitional surfaces.

All typodont teeth were sectioned at the root base 3 mm below the artificial cementoenamel junction (CEJ), and the sectioned surfaces were accurately flattened and smoothened with sandpaper to maximize stability. Subsequently, two box forms of 1-mm depth were created in the center of the buccal and lingual root surfaces to guide the positioning of the specimens during all the measurement procedures (Fig 2).

Design and manufacturing of the restorations

All specimens were restored using the Cerec 3 (Sirona) CAD/CAM system. One unprepared tooth was scanned to generate a master for the biogeneric copy mode. Subsequently, digital impression scanning of each prepared tooth was performed, aided with a contrast powder (Cerec Optispray, Sirona), and restorations were designed using the Cerec 4.4 software. All restorations were milled in nanofilled composite resin (Lava Ultimate A2, 3M ESPE), and carefully adjusted to the preparations under optical microscopy (Leica MZ 125, Leica Microsystems). A centralized hemispherical occlusal concavity (load fossa) of 1-mm depth was created by using a round diamond bur (Brasseler) on all the restorations, to precisely perform the vertical seating measurement procedure (load tip positioning).

The 60 teeth were divided into six groups according to preparation design and luting agent (n = 10) (Fig 1). The composition and properties of the luting materials used in the study are shown in Table 1.

Table 1 Material application, brand name, manufacturer, and composition of the materials used for luting in the study

Application	Preheated restorative composite resin for restoration luting	Dual-cure self-adhesive universal resin cement for restoration luting	Total-etch adhesive system	Universal adhesive system
Brand name	Filtek Z100	RelyX Ultimate	Optibond FL (Adhesive Bottle: 2)	Scotchbond Universal Primer and Adhesive
Manufacturer	3M ESPE, St Paul, USA	3M ESPE, Seefeld, Germany	Kerr, Orange, USA	3M ESPE, Seefeld, Germany
Composition	Bis-GMA and TEG-DMA Inorganic matrix: zirconia/silica (71%)	*Base paste:* methacrylate monomers containing (or not) phosphoric acid groups; silanated fillers; initiator components; stabilizers; rheological additives *Catalyst paste:* methacrylate monomers; alkaline (basic) fillers; silanated fillers; initiator components; stabilizers; pigments; rheological additives	*Adhesive:* 2-hydroxyethyl methacrylate; 3-trimethoxysilylpropyl methacrylate; 2-hydroxy-1,3-propanediyl bismethacrylate; alkali fluorosilicates (n/a)	MDP phosphate monomer; dimethacrylate resins; HEMA; Vitrebond copolymer; filler; ethanol; water, initiators; silane
Flexural strength (MPa)	300	98	n/a	n/a
Mean particle size (µm)	0.01–3.5	13	0.6	n/a
Filler content (% wt)	85	50–70	48	5–15

* TEG-DMA (triethylene glycol dimethacrylate); bis-GMA (bisphenol A-glycidyl methacrylate); MDP (10-methacryloyloxydecyl dihydrogen phosphate); HEMA (hydroxyethylmethacrylate).
* n/a: Not available.

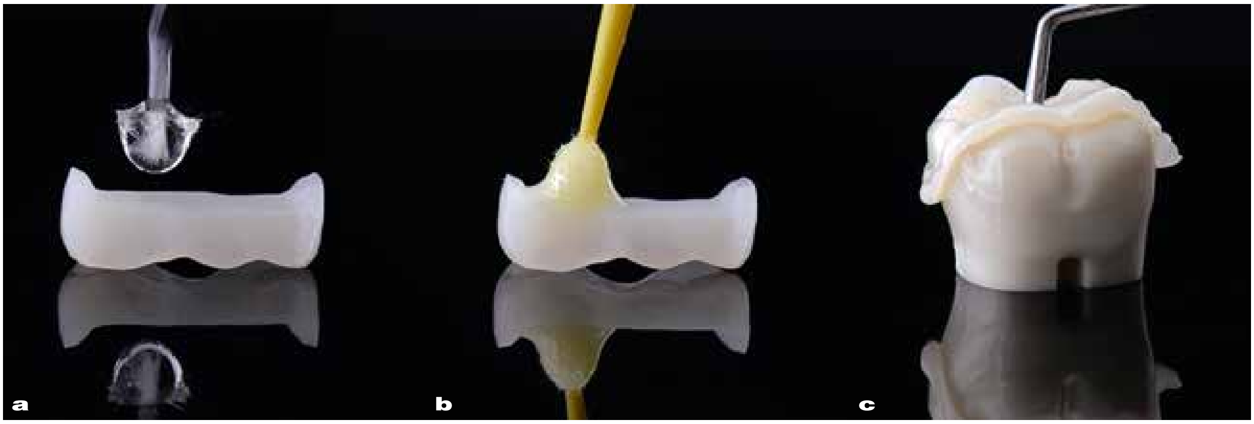


Fig 3 Luting for preheated restorative composite resin, step-by-step procedure (groups 1, 3, and 5). **(a)** Silane application. **(b)** Adhesive coating. **(c)** Seating with Filtek Z100.

Vertical seating test

All specimens were placed on a flat stainless steel base and the contour of their root base was drawn on the surface with a pencil to guide and repeat the precise position of the specimen at each vertical measurement undertaken (Fig 2). The specimens were then gradually subjected to a maximum 30 N of load (Acumen III, MTS Systems), axially applied by a spherical stainless steel tip (1.5-mm curvature radius) to the center of the occlusal surface of the restoration. A total of three axial measurement values were recorded for each step of the vertical seating test (baseline, after airborne-particle abrasion, after seating with luting agent, and after light polymerization). In order to maximize accuracy, the root base of the tooth and the surface of the stainless steel base were cleaned out after each measurement to remove any possible micro interferences.

At baseline (dry try-in)
Restorations were initially seated without any surface treatments or luting agent (Fig 2), and the vertical axial positioning was recorded as a baseline measurement ('zero' position).

After airborne-particle abrasion (Step 1)
The inner surfaces of all the restorations were air abraded using 30-µm silica-modified aluminum oxide (Rocatec, 3M ESPE) for 10 s at a distance of 10 mm with a pressure of 2 bars. Additional cleaning was performed by immersion in distilled water using an ultrasonic bath for 2.5 min, and then air dried. Next, the specimens were precisely positioned on the stainless steel base for the second step of the vertical seating test, following the same parameters as previously established. The axial measurement values were recorded accordingly.

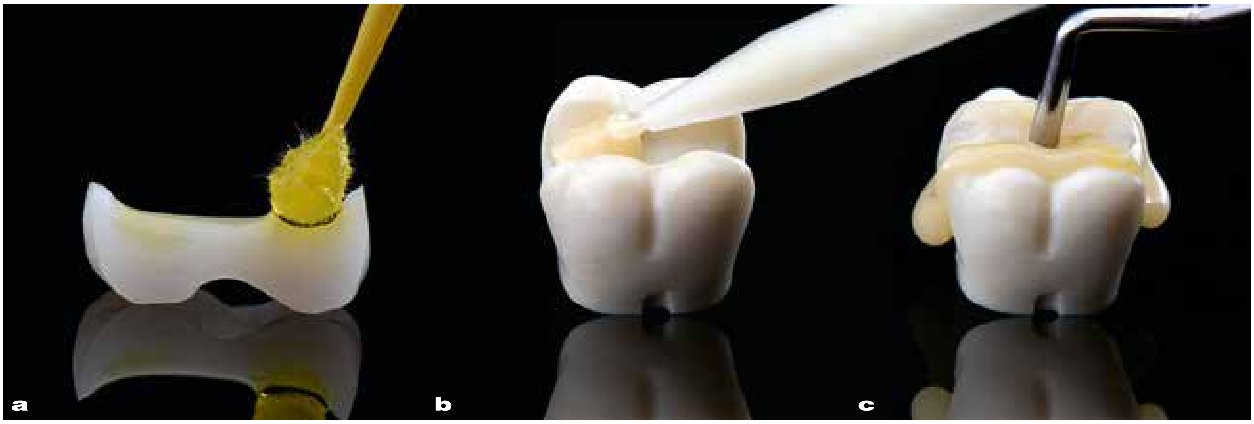


Fig 4 Luting for dual-cure resin cement, step-by-step procedure (groups 2, 4, and 6). **(a)** Application of universal bonding agent. **(b)** Injection of resin cement. **(c)** Seating of inlay.

After seating with luting agents (Step 2)
The bonding surfaces of the restorations for groups 1, 3, and 5 were subsequently treated according to the following luting protocol for preheated restorative composite resin: 1) Application of silane (Silane, Ultradent) for 20 s and heat drying at 100°C for 1 min (D.I.-500, Coltene) (Fig 3a); 2) Application of adhesive resin (Optibond FL, bottle 2, Kerr), without polymerization (Fig 3b); 3) Seating of the restorations onto the preparations with the restorative composite resin (Filtek Z100), preheated for 5 min at 68°C in a heating device (Calset, AdDent) (Fig 3c). After the removal of composite resin excesses, the specimens were placed on the stainless steel device to perform the second step of the test, following the same parameters previously established. Meanwhile, the surfaces of all the restorations for groups 2, 4, and 6, luted with dual-cure resin cement (RelyX Ultimate), were treated according to the manufacturer's instructions: 1) Application of Scotchbond Universal Primer and Adhesive (3M ESPE) to the inner surface of the restorations for 20 s, followed by rubbing and air thinning for 5 s (Fig 4a); 2) Application of the resin cement into the cavity preparation (Fig 4b); 3) Seating of the restorations onto the preparations with the resin cement (Fig 4c). The specimens were then loaded in the same way as previously described. Testing was then performed, and axial measurement values recorded.

After light polymerization (Step 3)
Each surface of the restorations was ultimately light polymerized for 60 s (VALO curing light, Ultradent) while the specimens were maintained under 30 N of pressure. The specimens were removed from the device and all margins covered with an air-blocking barrier (K-Y Jelly, Personal Products Company) for an additional 10 s per surface polymerization cycle. The specimens were again placed in the same position on the flat surface to perform the third step of the vertical seating test.

Statistical analysis

Statistical analysis was performed with SPSS (version 23) statistical software (IBM Corporation). First, to evaluate the difference in seating after airborne-particle abrasion (Step 1) for each type of preparation (inlay, onlay, and overlay), the nonparametric Kruskal-Wallis test with $P < 0.05$ was used, followed by the Mann-Whitney U post hoc test. Then, during the seating with the luting agent (Step 2), and after light polymerization (Step 3), the Mann-Whitney U test was used to compare two-by-two the means obtained according to the luting agent (preheated Filtek Z100 restorative composite resin, and RelyX Ultimate dual-cure resin cement) within each type of preparation (inlay, onlay, and overlay).

The Friedman test, followed by the Wilcoxon post hoc test with Bonferroni correction ($P < 0.0125$), was used to compare the seating among the different steps for each preparation design and luting agent.

Results

The measured mean vertical displacements and standard deviations of the seated restorations are presented in Table 2. The vertical displacements after airborne-particle abrasion (Step 1) are presented in Figure 5, according to the preparation design (n = 20). The Mann-Whitney U test revealed the presence of significant differences in the seating of inlays compared to onlays ($P < 0.05$) and overlays ($P = 0.023$), and no difference was found between onlays and overlays ($P = 0.068$).

During the seating with unpolymerized luting agent (Step 2), according to the Wilcoxon post hoc test, the baseline

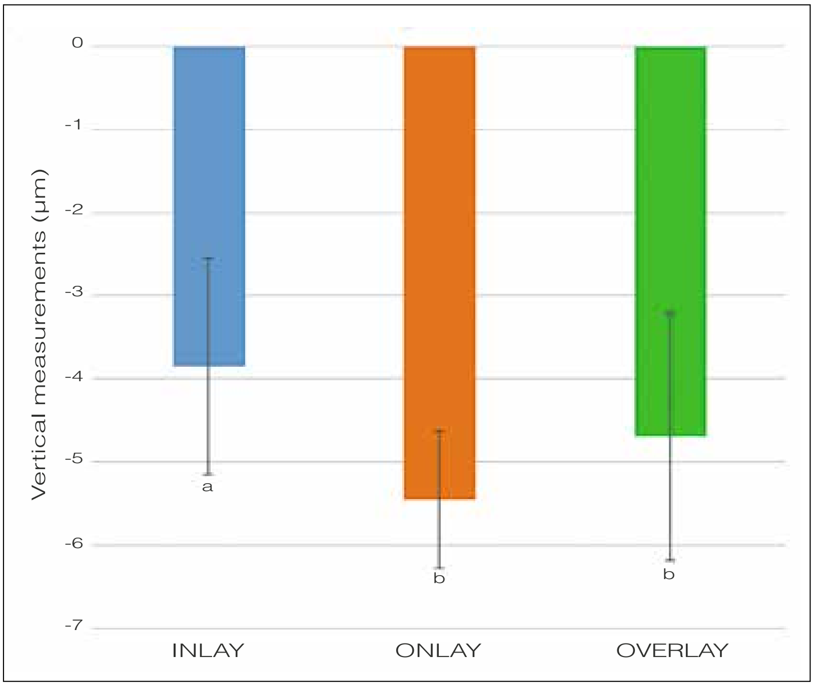


Fig 5 Vertical measurement means and standard deviation (n = 20) after airborne-particle abrasion (Step 1) for each type of preparation. Kruskal-Wallis test followed by Mann-Whitney U post hoc test ($P < 0.05$).

Table 2 Vertical measurement data during Steps 1, 2, and 3

Groups	Step 1: Vertical measurements in µm after air abrasion (SD)	Step 2: Vertical measurements in µm with unpolymerized luting agent (SD)	*P* value	Step 3: Vertical measurements in µm after luting agent polymerization (SD)	*P* value
INcr (1)	-3.85 (1.3)^{Ab}	-0.8 (1.1)^{Aa}	0	-0.7 (1.6)^{Aab}	0
INcem (2)		7.9 (3.2)^{Bc}		7.7 (5.7)^{Bc}	
ONcr (3)	-5.45 (0.8)^{Bb}	0.4 (0.7)^{Aa}	0.143	-2.9 (1.1)^{Ac}	0
ONcem (4)		-0.2 (0.8)^{Aa}		-7.3 (2.7)^{Bb}	
OVcr (5)	-4.7 (1.5)^{Bb}	-1 (2.4)^{Aab}	0.247	-3.9 (2.6)^{Ab}	0.007
OVcem (6)		-0.2 (1.2)^{Aa}		-7 (2.3)^{Bb}	

For Step 1, uppercase superscript letter indicates difference between preparation designs (inlay, onlay, overlay). Kruskal-Wallis followed by Mann-Whitney U post hoc test (n = 20).
For Steps 2 and 3, uppercase superscript letter indicates difference between luting agent for a given preparation design (column). Kruskal-Wallis followed by two-by-two Mann-Whitney U post hoc test (n = 10).
Lowercase superscript letter indicates difference between the steps (row) for a given preparation design and luting agent. Friedman test followed by Wilcoxon post hoc test with Bonferroni correction.

try-in position was recovered for all restorations ($P > 0.075$), with means varying from -1 to 0.4 µm (OVcr and ONcr, respectively), except for INcem (7.9 µm above the baseline try-in, $P = 0.005$). The Mann-Whitney U test presented no difference between the luting agents for onlays ($P = 0.143$) and overlays ($P = 0.247$), as is presented in Table 2 and Figure 6.

After polymerization (Step 3), the Wilcoxon post hoc test showed that onlays (ONcr) and overlays (OVcr) seated -2.9 to -3.9 µm deeper than baseline when using Filtek Z100 preheated composite resin ($P < 0.005$) and -7.0 to -7.3 µm deeper when using RelyX Ultimate dual-cure composite resin cement (ONcem and ONcr, respectively) ($P < 0.005$). On the other hand, inlays luted with RelyX Ultimate (INcem) seated close to their unpolymerized stage ($P = 0.838$), at 7.7 µm higher compared to the baseline try-in ($P = 0.008$). Results of the vertical seating test after polymerization (Step 3) are presented in Table 2 and Figure 7.

Discussion

The use of preheated restorative composite resin (instead of resin cement) as a luting agent for inlays, onlays, and overlays was investigated, especially in view of the risk of incomplete restoration seating due to the viscosity of the composite. The null hypothesis can be rejected because all restorations seated closer to baseline with the restorative

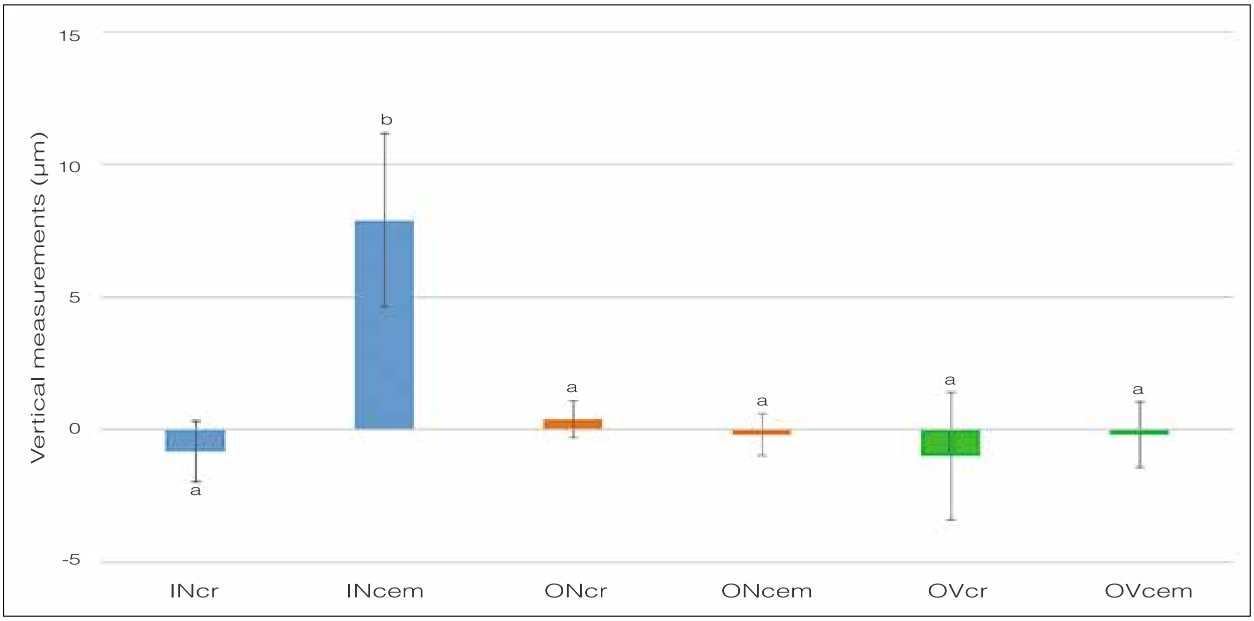


Fig 6 Vertical measurement means and standard deviation during restoration seating with unpolymerized luting agent (Step 2). Different bar colors represent different preparation types (IN for inlay, ON for onlay, and OV for overlay). Within each preparation type, 'cr' stands for preheated composite resin, and 'cem' for dual-cure composite resin cement. Within each preparation type, different letters represent statistically significant differences according to the two-by-two Mann-Whitney U test.

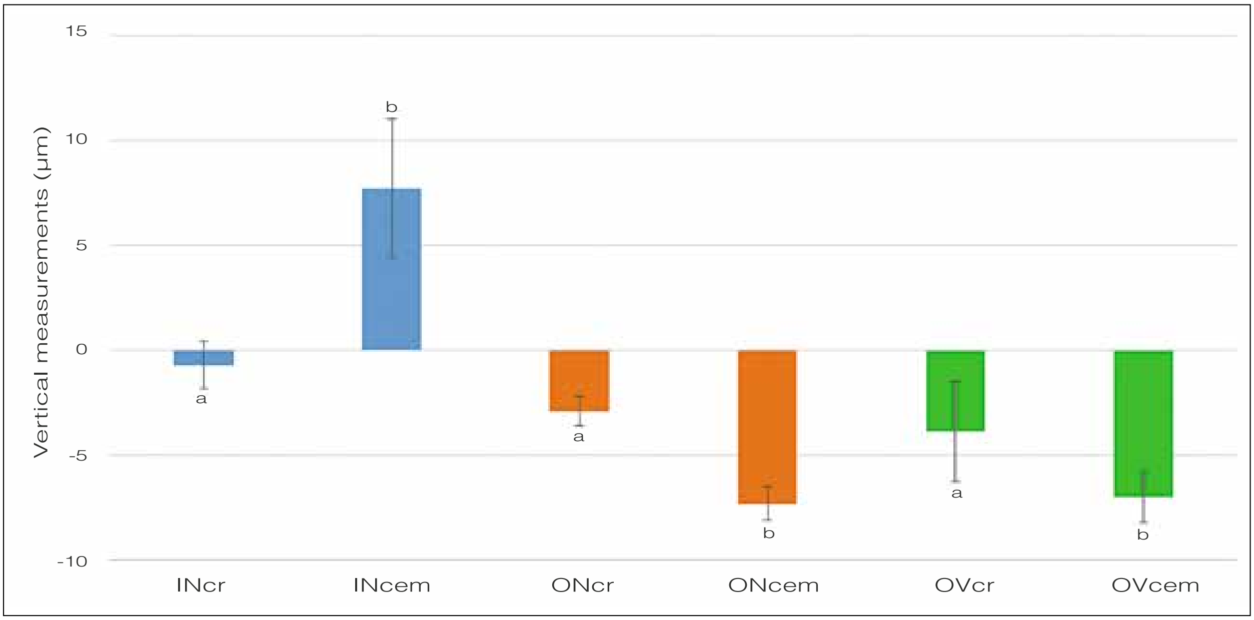


Fig 7 Vertical measurement means and standard deviation after luting agent polymerization (Step 3). Different bar colors represent different preparation types (IN for inlay, ON for onlay, and OV for overlay). Within each preparation type, 'cr' stands for preheated composite resin, and 'cem' for dual-cure composite resin cement. Within each preparation type, different letters represent statistically significant differences according to the two-by-two Mann-Whitney U test.

material when compared to the dual-cure cement, in addition to the fact that the onlays and overlays seated deeper than the inlays.

Typodont plastic teeth were chosen because of their availability but also because tooth preparations, restorations, and positioning in the measuring device could be standardized, thus limiting the confounding variables. A load of 30 N was applied consistently through the accurate electromechanic system in the exact same location at each step of the procedure. This 30-N value was chosen after simulating the luting pressure in a pilot test. The MTS Acumen system provided highly precise load and motion control. The actuator includes a high-resolution digital encoder to ensure accurate control and measurement of the vertical restoration position. Three consecutive measurements were taken to confirm the exact vertical positioning, with a consistent variation of < 1 µm.

Airborne-particle abrasion is necessary to enhance resin-to-resin bonding of both laboratory and CAD/CAM composite resin restorations.[22-25] This potentially creates an additional gap in the tooth preparation. The present data confirms this fact because air abrasion with Rocatec sand (3M ESPE) resulted in significantly deeper seating into the tooth (3.85 to 5.45 µm). It goes without saying that special care needs to be taken when subjecting the restoration to sandblasting, so as to preserve marginal adaptation (such as protecting the margins with a finger pressed onto the occlusal surface of the restoration). Note that the effect of sandblasting was slightly stronger in onlays and overlays compared to inlays.

Once inserted with the luting composite resin, the seating of all the restorations returned to within 1 µm of the baseline position (dry try-in). This is to be expected due to the film thickness of the composite resin. The inlays cemented with RelyX Ultimate, which were 7.9 µm higher than baseline, were an exception. As per the manufacturer's instructions for use, the particle size (D 90%) is about 13 µm for RelyX Ultimate compared to 0.01 to 3.5 µm for Filtek Z100. As most of the preparation is formed by the vertical walls in inlays, it is expected that the seating would be more affected by the larger filler size of RelyX Ultimate. Apart from this surprising finding about inlays, no statistically significant difference was found between the cement and the restorative material for onlays and overlays, proving that the film thickness might not have an influence on the seating. Hence, although restorative composite resins might not present the lowest film thickness,[21] this did not prevent the appropriate seating of the restoration in the present study.

Prior to light curing, the viscosity affects the application and manipulation of the composite resin. The viscosity of restorative composite resins varies significantly between brands, even though they might be included in the same class.[26] In addition, as temperature increases, the viscosity of the composite resin decreases. However, each material responded differently, with a decrease ranging from 40% to 92%.[27] Hence, many composite resins are not suitable for luting because their viscosity is not optimized, even after preheating.[28] Filtek Z100 restorative composite resin was selected for luting purposes in this study due to its optimized viscosity.[26]

In order to understand the effects of polymerization shrinkage on restoration seating, it needs to be borne in mind that composite resins do not shrink toward the light but rather toward the surfaces to which they are bonded.[29] Therefore, the main direction of shrinkage vectors is affected by the type of preparation. As expected, the seating of all the inlays remained very similar after light polymerization (variations of less than 0.2 µm). This can be explained by the main vectors of shrinkage (buccal and lingual) being perpendicular to the long axis of the tooth. As explained by Lutz et al,[30] in medium-sized adhesive MOD composite inlays, the polymerization contraction of the composite resin cement is non-destructively compensated for by an inward flexing of each cavity wall of approximately 10 µm. The situation is different with onlays and overlays. In those preparations, the shrinkage vectors are along the axis of the tooth, hence they pull the restoration against the preparation. Unlike inlays, those restorations demonstrated significant positional changes (deeper seating) after polymerization. The change was even larger with the dual-cure cement (6.8 to 7.1 µm) compared to the restorative material (3.3 to 4.9 µm). These figures fit with the linear shrinkage values of Filtek Z100, if one considers a luting gap of 150 µm with 2.3% of linear shrinkage.[31] The difference between luting agents is also consistent with findings by Bertolotto et al[32] that showed significantly less linear shrinkage and polymerization forces when restorative materials were used as a luting agent compared to resin cement. These results (pertaining to the positional changes of onlays/overlays) are also in accordance with the present authors' experience when delivering such restorations. When occlusion is perfectly preadjusted during try-in, the positional change (deeper seating) during adhesive delivery will often result in the weakening or loss of occlusal contacts.

The present results are clearly in favor of the use of preheated restorative materials as a luting agent for inlays, onlays, and overlays. In addition, there are clear, practical advantages to using preheated composite resin over traditional resin cements[11] such as ease of excess removal because of the firm consistency and unlimited working time until light polymerization.

Conclusions

The use of preheated restorative composite resin as a luting agent for inlays, onlays, and overlays can be recommended. Clinicians' concerns regarding incomplete restoration seating due to the viscosity of the composite are not justified, according to the present findings. Airborne-particle abrasion significantly deepens the seating of CAD/CAM composite resin restorations, but the presence of the unpolymerized restorative composite resin luting agent perfectly compensates for this discrepancy. With the least variation compared to baseline seating (try-in), the restorative composite resin resulted in a more predictable seating of the CAD/CAM inlays, onlays, and overlays when compared to the dual-cure resin cement.

Acknowledgments

The authors wish to express their gratitude to 3M-ESPE (St Paul, MN, USA), Kerr (Orange, CA, USA), Ultradent (South Jordan, UT, USA), Patterson Dental (Los Angeles, CA, USA), and Sirona Dental Systems (Bensheim, Germany) for providing materials for this study. Also, Reyes Enciso, PhD (Associate Professor of Clinical Dentistry, Herman Ostrow School of Dentistry, University of Southern California), for guidance with the statistical analysis presented in this study.

References

1. Friedman MJ. Current state-of-the-art porcelain veneers. Curr Opin Cosmet Dent 1993:28–33.
2. Besek M, Mörmann WH, Persi C, Lutz F. The curing of composites under Cerec inlays [in German]. Schweiz Monatsschr Zahnmed 1995;105:1123–1128.
3. Krämer N, Frankenberger R. Clinical performance of bonded leucite-reinforced glass ceramic inlays and onlays after eight years. Dent Mater 2005;21:262–271.
4. Schulte AG, Vöckler A, Reinhardt R. Longevity of ceramic inlays and onlays luted with a solely light-curing composite resin. J Dent 2005;33:433–442.
5. Gregor L, Bouillaguet S, Onisor I, Ardu S, Krejci I, Rocca GT. Microhardness of light- and dual-polymerizable luting resins polymerized through 7.5-mm-thick endocrowns. J Prosthet Dent 2014;112:942–948.
6. Goldberg J, Güth JF, Magne P. Accelerated Fatigue Resistance of Thick CAD/CAM Composite Resin Overlays Bonded with Light- and Dual-polymerizing Luting Resins. J Adhes Dent 2016;18:341–348.
7. Hasegawa EA, Boyer DB, Chan DC. Hardening of dual-cured cements under composite resin inlays. J Prosthet Dent 1991;66:187–192.
8. Darr AH, Jacobsen PH. Conversion of dual cure luting cements. J Oral Rehabil 1995;22:43–47.
9. Suzuki S, Leinfelder KF, Shinkai K. Wear resistance of resin cements. Am J Dent 1995;8:83–87.
10. Duarte S Jr, Sartori N, Sadan A, Phark J-H. Adhesive resin cements for bonding esthetic restorations: a review. QDJ 2011:40–66.
11. Dietschi D, Spreafico R. Current clinical concepts for adhesive cementation of tooth-colored posterior restorations. Pract Periodontics Aesthet Dent 1998;10:47–54.
12. Roulet JF, Lösche GM, Noack M. Inlays and onlays. Curr Opin Cosmet Dent 1993:41–54.
13. Daronch M, Rueggeberg FA, Moss L, de Goes MF. Clinically relevant issues related to preheating composites. J Esthet Restor Dent 2006;18:340–350.
14. Lohbauer U, Zinelis S, Rahiotis C, Petschelt A, Eliades G. The effect of resin composite pre-heating on monomer conversion and polymerization shrinkage. Dent Mater 2009;25:514–519.
15. Fróes-Salgado NR, Silva LM, Kawano Y, Francci C, Reis A, Loguercio AD. Composite pre-heating: effects on marginal adaptation, degree of conversion and mechanical properties. Dent Mater 2010;26:908–914.
16. Daronch M, Rueggeberg FA, De Goes MF. Monomer conversion of pre-heated composite. J Dent Res 2005;84:663–667.
17. Daronch M, Rueggeberg FA, De Goes MF, Giudici R. Polymerization kinetics of pre-heated composite. J Dent Res 2006;85:38–43.
18. Lucey S, Lynch CD, Ray NJ, Burke FM, Hannigan A. Effect of pre-heating on the viscosity and microhardness of a resin composite. J Oral Rehabil 2010;37:278–282.
19. Daronch M, Rueggeberg FA, Moss L. Effect of repeated and extending heating on conversion of composites. AADR Abstract 2005:605.
20. D'Amario M, Pacioni S, Capogreco M, Gatto R, Baldi M. Effect of repeated pre-heating cycles on flexural strength of resin composites. Oper Dent 2013;38:33–38.

21. Sampaio CS, Barbosa JM, Cáceres E, et al. Volumetric shrinkage and film thickness of cementation materials for veneers: An in vitro 3D microcomputed tomography analysis. J Prosthet Dent 2017;117:784–791.
22. Swift EJ Jr, Brodeur C, Cvitko E, Pires JA. Treatment of composite surfaces for indirect bonding. Dent Mater 1992;8:193–196.
23. Stokes AN, Tay WM, Pereira BP. Shear bond of resin cement to post-cured hybrid composites. Dent Mater 1993;9:370–374.
24. Latta MA, Barkmeier WW. Bond strength of a resin cement to a cured composite inlay material. J Prosthet Dent 1994;72:189–193.
25. Kassotakis EM, Stavridakis M, Bortolotto T, Ardu S, Krejci I. Evaluation of the Effect of Different Surface Treatments on Luting CAD/CAM Composite Resin Overlay workpieces. J Adhes Dent 2015;17:521–528.
26. Lee IB, Cho BH, Son HH, Um CM. Rheological characterization of composites using a vertical oscillation rheometer. Dent Mater 2007;23:425–432.
27. Al-Ahdal K, Silikas N, Watts DC. Rheological properties of resin composites according to variations in composition and temperature. Dent Mater 2014;30:517–524.
28. Blalock JS, Holmes RG, Rueggeberg FA. Effect of temperature on unpolymerized composite resin film thickness. J Prosthet Dent 2006;96:424–432.
29. Versluis A, Tantbirojn D, Douglas WH. Do dental composites always shrink toward the light? J Dent Res 1998;77:1435–1445.
30. Lutz F, Krejci I, Barbakow F. Quality and durability of marginal adaptation in bonded composite restorations. Dent Mater 1991;7:107–113.
31. Fogleman EA, Kelly MT, Grubbs WT. Laser interferometric method for measuring linear polymerization shrinkage in light cured dental restoratives. Dent Mater 2002;18:324–330.
32. Bortolotto T, Guillarme D, Gutemberg D, Veuthey JL, Krejci I. Composite resin vs resin cement for luting of indirect restorations: comparison of solubility and shrinkage behavior. Dent Mater 2013;32:834–838.