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ORIGINAL ARTICLE

Interface evaluation after manual and ultrasonic insertion of standardized class I inlays using composite resin materials of different viscosity

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Abstract

Objective. The aim of the present study was to investigate the effect of manual and ultrasonic insertion of standardized class I inlays (Cerana®) using three composite resin materials of different viscosity (Tetric Flow®, Tetric®, and Tetric Ceram®) on time to seat inlays, film thickness, and filler distribution within the materials. ***Methods.*** In a preliminary test, mean loads for manual and ultrasonic insertion were measured using the high viscosity composite resin material (Tetric Ceram). These loads were then applied with all composite resin materials to evaluate the times required to seat the inlays. In addition, film thickness was assessed using scanning electron microscopy, and filler distribution (wt% silicon, barium, ytterbium) was monitored using energy-dispersive spectroscopy. ***Results.*** Ultrasonic insertion significantly reduced mean load applied to seat inlays (6.4 ± 1.4 N; mean ± SD) as compared to manual insertion (18.9 ± 3.1 N; $p < 0.001$). 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 ($p < 0.05$). The widest film thickness was recorded for the high viscosity composite resin material in combination with manual insertion ($p < 0.05$). However, when ultrasound was applied, there was no difference in film thickness between the three materials at any levels. Furthermore, the analysis of filler distribution revealed no significant differences between groups. ***Conclusion.*** Highly filled viscous composite resin materials may be used in combination with the ultrasonic insertion technique without untoward effects on film thickness or filler distribution.

Key Words: *Dental ceramics, dental inlays, luting agents, ultrasound, viscosity*

Introduction

Marginal integrity is crucial for the long-term clinical outcome of adhesive restorations [1]. A major problem with the latter is marginal gap formation due to polymerization shrinkage [2,3]. Even if bonding between composite restoration and dental hard tissues is successful, shrinkage stresses may put long-term adhesion to cavity walls at risk [4]. Therefore, indirect restoration systems have been developed to minimize shrinkage and optimize material properties. Based on microleakage measurements, studies have found that adhesively luted indirect restorations provide a superior marginal seal as compared to directly placed composites [5]. When indirect restorations are placed, inadequacies of fit may be compensated by the use of a composite resin luting material [6–8].

In the early 1980's indirect gold cast restorations were cemented using zinc phosphate, zinc oxide eugenol, ethoxy benzoic, polycarboxylate, or glass-ionomer cement materials, which provided primarily mechanical retention [9]. Their adhesive potential, however, was considered too low for cementing tooth-colored restorations [10]. Dual or light-curing composite resin materials are preferred today [11]. These provide several advantages, such as durable and strong bonds to all surfaces, good color match, polishable marginal areas, improvement of flexural characteristics, and stress-breaking properties [12]. Light-cured restorative composite resin materials in combination

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with an ultrasonic insertion technique have the additional advantage that surplus material can be easily and safely removed before polymerization.

Composite resin materials used to adhere ceramic restorations to prepared teeth, however, are still considered to be the weakest link in the restored tooth. In terms of wear at the interface, composite resin luting materials with a high filler content have been shown to be advantageous over comparable materials with a lower filler content [13,14]. On the other hand, a linear relationship between film thickness and wear rate of composite resin luting materials has been demonstrated [15]. Consequently, state-of-the-art ceramic restoration systems with pre-luting gap widths ranging from 40 to 60 μm require insertion techniques which do not further increase the film thickness after insertion [16]. Both viscosity of the composite resin material and insertion technique may influence final film thickness and the overall restoration quality [17]. It has therefore been claimed that an ideal luting composite resin material should combine maximum filler content in combination with favorable flow capacity [15]. Improved flow properties of highly filled composite resin materials may be achieved by ultrasonic insertion of the restoration [18,19]. The use of vibration may reduce film thickness via a thixotropic effect, thus enhancing wetting properties of composite resin materials and allowing better controlled seating of the restoration.

In the present study, three composite resin materials of different viscosity and filler composition were tested for their suitability as luting materials for standardized ceramic class I inlays in extracted human molars. In a preliminary evaluation, the load needed for manual and ultrasonic insertion using the highly filled composite resin material was assessed. These values served for the following experiments. Time for insertion, as an ergonomic factor, was then measured using all three composite resin materials. To evaluate the fitting accuracy, pre-luting gap width and post-luting film thickness were assessed using scanning electron microscopy (SEM) after manual or ultrasonic seating of the inlays. Energy-dispersive spectroscopy (EDS) was employed to evaluate filler distribution in luting composite resin films by quantitative monitoring of filler-typical elements (silicon, barium, ytterbium). It was assessed whether vibration energy influenced the composite resin material composition by separation or aggregation of the filler/matrix system. The null hypothesis tested was that there was no difference in element distribution between control resin blocks and *in situ* material.

Material and methods

Preliminary evaluation of the load for insertion

In a prelimininary set-up, six human molars free of decay, which had been stored in 0.1 mol/l thymol solution, were mounted centrally to roughened specimen carriers (SEM mounts; Baltec AG, Balzers, Liechtenstein) with superglue (Renfert Sekundenkleber Nr. 1733; Dentex AG, Zürich, Switzerland), and embedded with chemically curing acrylic resin (Paladur®; Heraeus Kulzer GmbH, Wehrheim, Germany). These specimen carriers allowed for the reproducible placement of the teeth in a drilling gauge. A standardized contour accuracy of class I inlay cavities was achieved using a tapered preparation diamond bur (Cerana—size M; Nordiska Dental, Ängelholm, Sweden) under water cooling. Three dentists experienced in adhesive dentistry were asked in a single-blind situation to seat inlays of a dimension corresponding to the standardized cavities (Cerana—size M; Nordiska Dental), using either manual or ultrasonic insertion. Prior to seating, fitting accuracy of the inlays was prejudged by the operators. Subsequently, cavity floors were covered with a high viscosity composite resin material (Tetric Ceram; IvoclarVivadent, Schaan, Liechtenstein) to a thickness of 2 mm. Insertion tips (SP-Tip; EMS, Nyon, Switzerland) were used in combination with an ultrasonic device (Master Piezon 400; EMS, Nyon, Switzerland). Insertion load was measured using an 8600 digital multimeter (Kontron Electronic AG, Zürich, Switzerland). This procedure was repeated six times per test person. Mean load values for both techniques obtained using the high viscosity composite resin material were calculated and applied for time evaluation (see below).

Measurement of time

The three operators were asked to manually and ultrasonically insert inlays with the previously assessed mean loads for the high-viscosity composite resin material. The cavity floors were filled with a 2 mm layer of high viscosity (Tetric Ceram; IvoclarVivadent), medium viscosity (Tetric; IvoclarVivadent), or low viscosity (Tetric Flow; IvoclarVivadent) material. Layer thickness was verified with a periodontal probe. Six inserts, each, were then randomly placed, while loads were maintained by visual control of the operator on the gauge reader (8600 digital multimeter; Kontron Electronic AG). Time was measured from first load application to the insert reaching proper fit, as subjectively assessed by the operator.

Gap width prior to luting

Six standardized inlay preparations were performed as described above, and inlays (Cerana—size M; Nordiska Dental) were passively inserted without luting material. For fixation, inlays were coronally bonded to surrounding enamel with a composite resin material (Tetric Ceram; IvoclarVivadent) and light-cured (Optilux 500, $>1{,}000$ mW/cm^2; Demetron Kerr Inc., Danbury, Ct., USA). Specimens were then cut in half and analyzed in a SEM (Amray 1810T;

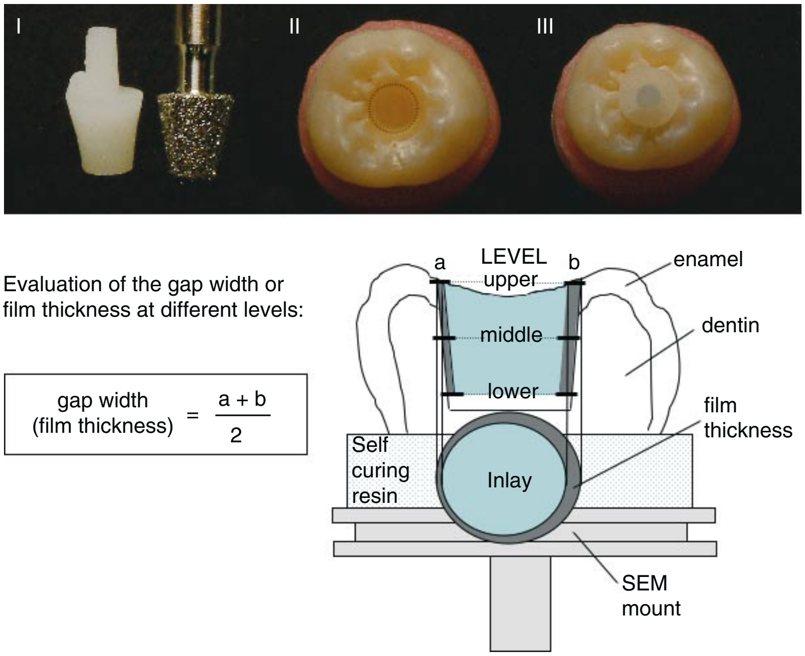

Figure 1. Panel I: Tapered ceramic size M class I inlay and the corresponding diamond-coated bur. Panel II: Embedded tooth specimen with standardized class I cavity. Panel III: Inlay placed in the cavity to check passive fit. Evaluation of gap width and film thickness was performed at three levels of the axial lateral wall. Because a perfect central placement of the inlay could not be expected, the arithmetic means of two opposite interfaces with the narrowest and widest space were calculated (see drawing of the cut specimen).

Amray Inc., Bedford, Mass., USA) to determine gap width at the upper, middle, and lower lateral axial wall (Figure 1). In addition, the distance from the cavity floor to the inlay was determined.

Film thickness after luting

Forty-eight human molars were randomly divided into six groups of eight specimens each. They were mounted centrally to roughened specimen carriers (SEM mounts; Baltec AG) with superglue (Renfert Sekundenkleber Nr. 1733; Dentex AG) and embedded with chemically curing acrylic resin (Paladur®; Heraeus Kulzer GmbH). Standardized class I inlay cavities were prepared as described above (Figure 1). Enamel was acid-etched for 60 s (Ultraetch; Ultradent Products Inc., South Jordan, Ut., USA) and dentin was conditioned for adhesive inlay placement using a three-step bonding system (Syntac Classic; IvoclarVivadent) as described by the manufacturer. For manual and ultrasonic insertion technique, the three composite resin materials of different viscosity ($n=8$, each) were used. Cavity floors were covered with the test composite resin material to a thickness of 2 mm adapted to cavity walls. Standardized ceramic class I inlays (Cerana, size M) were inserted and manually or ultrasonically seated to final position, applying mean loads evaluated previously. Restorations were polymerized for 60 s (Optilux 500; Demetron Kerr Inc.) and contoured with 15 μm finishing burs (Intensiv SA, Grancia, Switzerland). Maximum and minimum coronal luting composite resin material interface width between the round standardized inserts and the round standardized preparation finish line was determined under a stereomicroscope (Stemi 1000; Carl Zeiss AG, Oberkochen, Germany) at a magnification of 12×. Specimens were then cut in half in coronal-apical direction through these two defined points. Impressions were made (President light body surface activated; Coltène Whaledent AG, Altstätten, Switzerland) and filled with epoxy resin (Stycast 1266; Emerson & Cuming, Westlo, Belgium) for analysis of axial and pulpal floor interface dimensions using SEM.

Filler distribution

For the EDS, specimens were desiccated for 3 weeks in blue silica gel in a vacuum evaporator. Specimens were analyzed using an EDS Voyager IV system equipped with a Pioneer Norvar-148eV-detector (NORAN Instruments, Middleton, Wisc., USA). A scanning electron microscope (DSM962; Zeiss, Oberkochen, Germany) was used for the EDS analyses. Operating conditions for qualitative elemental analysis were kept constant with an accelerating voltage of 15 kV at a working distance of 25 mm. A filter-fit method was applied using the PROZA correction method. Defined areas of 50×50 μm were measured in the composite film between inlay and tooth (Figure 2). The electron penetration depth was set at 3–5 μm. Samples were scanned on backscattered electron mode. X-ray line scans across areas of interest were obtained for the K alpha lines of silicon (Si), barium (Ba), and ytterbium (Yb). The weight percentage of these elements was calculated stoichiometrically. For comparison, six specimens of all tested composite resin materials

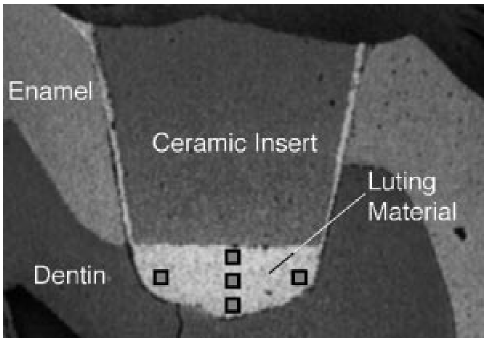

Figure 2. Areas evaluated in the composite resin material film using energy-dispersive spectroscopy.

Table I. Filler content (%wt) and mean particle size (nm; in parentheses, where available) of composite resin materials used in the present study

Filler	Tetric Flow	Tetric	Tetric Ceram
Ytterbium trifluoride	10–15 (200)	10–17 (200)	10–17 (200)
Ba-silicate glass	40–50 (1000)	40–55 (1500)	40–55 (1000)
Ba-Al-fluorosilicate glass	3–6 (1000)	0	3–8 (1000)
Spheroid mixed oxide	3–10 (250)	10–20 (250)	3–10 (250)
Microfillers	1–3 (40)	1–3 (40)	1–3 (40)

(Table I) were prepared using round Teflon molds with a diameter of 10 mm and a height of 5 mm. The composite resin materials under investigation were applied in these forms and light-cured for 60 s. These control specimens were then sectioned with a slow speed saw under water-cooling. As with the *in situ* specimens, areas of 50 × 50 µm were scanned in the central aspect of control blocks.

Data presentation and analysis

Data are presented as means ± standard deviation (SD). Load and time for insertion values were statistically compared using analysis of variance (ANOVA, Scheffé-F-test). Data pertaining to quantitative assessment of passive fit, film thickness, and filler distribution were compared with an unpaired *t*-test and two-way ANOVA. Bonferroni adjustment was applied for multiple testing. Levels of significance were set at 95%.

Results

Preliminary assessment of load

Ultrasonic insertion significantly reduced the mean load used to seat inlays (6.4 ± 1.4 N) as compared with manual insertion (18.9 ± 3.1 N; $p < 0.001$). No statistical differences between operators were found within the two test groups ($p = 0.66$).

Time for insertion

No inter-operator differences were found for the time needed to seat the inlays ($p = 0.57$). Using manual insertion, times between materials all significantly differed from each other (Table II). It took most time to seat the inlays using the high viscosity composite resin material, followed by the medium and the low viscosity materials ($p < 0.05$). When inlays were placed with an ultrasonic device, no difference between the high and medium viscosity material could be observed, whereas both materials significantly increased the time to seat inlays compared to the low viscosity material ($p < 0.05$).

Assessment of the insertion technique showed that use of ultrasound could significantly reduce the time for seating in the high and medium viscosity group ($p < 0.05$). With low viscosity composite resin material, no such difference was noted.

Gap width prior to luting

Passive fit in the upper lateral wall, i.e. in the occlusal marginal aspect, revealed a gap width of 27 ± 16 µm. Gaps were apically increasing with values of 43 ± 16 µm in the middle and 48 ± 20 µm in the lower part of the inlay. These differences, however, did not statistically differ ($p = 0.14$). Between pulpal floor and inlay, a gap width of 575 ± 13 µm was measured.

Film thickness after luting

Results pertaining to the film thickness evaluation at lateral axial walls are summarized in Table III. The widest mean luting material interface was noted for the high viscosity material in combination with manual insertion, ranging from 120 ± 20 µm at the middle to 131 ± 37 µm at the lower axial wall. In the occlusal area, the interface width was 130 ± 31 µm. Film thickness significantly decreased in the upper and middle axial aspects when the medium viscosity material was used ($p < 0.05$). The low viscosity material showed the lowest film thickness, which differed significantly ($p < 0.05$) from values obtained with the high viscosity composite resin material at all levels. No statistical difference was observed between the low and the medium viscosity material. When ultrasound was applied, however, there was no difference in film

Table II. Time for seating the inlays (mean ± SD). Identical superscript capitals within one insertion technique represent statistical differences between materials at $p < 0.05$ ($n = 8$; read vertically). Superscript lower case letters represent statistical differences between insertion techniques ($p < 0.05$, $n = 8$; read horizontally)

Viscosity	Manual insertion (SD)	Ultrasonic insertion (SD)
High	^{A} 22 ± 4 ^{a}	^{A} 13 ± 3 ^{a}
Medium	^{A} 15 ± 2 ^{a}	^{B} 11 ± 2 ^{a}
Low	^{A} 3 ± 1	^{A,B} 3 ± 1

Table III. Results of film thickness measurements (mean ± SD) at the different lateral axial wall levels in μm (values in parentheses represent the pre-luting gap width, i.e. passive fit, $n = 6$). Identical superscript capitals within one level represent statistically different mean film thickness values between materials ($p < 0.05$, $n = 8$; read vertically). Superscript lower case letters represent statistical differences between insertion techniques ($p < 0.05$, $n = 8$; read horizontally)

Level (passive fit)	Viscosity	Manual insertion (μm)	Ultrasonic insertion (μm)
Lateral axial wall			
Upper (27 ± 16)	High	^{A,B} 130 ± 31 ^{a}	59 ± 21 ^{a}
	Medium	^{A} 97 ± 26 ^{a}	63 ± 20 ^{a}
	Low	^{B} 50 ± 13	49 ± 10
Middle (43 ± 16)	High	^{A,B} 120 ± 20 ^{a}	56 ± 13 ^{a}
	Medium	^{A} 84 ± 22	77 ± 25
	Low	^{B} 47 ± 17	50 ± 21
Lower (48 ± 20)	High	^{A} 131 ± 37	94 ± 24
	Medium	115 ± 21	99 ± 28
	Low	^{A} 77 ± 23	76 ± 13

Table IV. Measurement of film thickness (mean ± SD), i.e. the luting space distance between pulpal floor and inlay in μm (the value in parentheses represents the pre-luting gap width, $n = 6$). Identical superscript capitals within one insertion technique represent statistically different mean film thickness values between materials ($p < 0.05$, $n = 8$; read vertically). Superscript lower case letters represent statistical differences between insertion techniques ($p < 0.05$, $n = 8$; read horizontally)

	Viscosity	Manual insertion (μm)	Ultrasonic insertion
Floor (575 ± 13)	High	^{A,B} 1045 ± 139 ^{a}	729 ± 115 ^{a}
	Medium	^{A} 837 ± 124	802 ± 107
	Low	^{B} 749 ± 104	670 ± 160

thickness at lateral axial walls between the three materials at any levels. Mean film thickness using this technique ranged from 49 to 99 μm.

Evaluation of the effect of insertion technique revealed a significant decrease in film thickness at the upper and middle levels when the highly viscous material was used in combination with ultrasonic versus manual insertion ($p < 0.05$). Film thickness was not influenced in the medium and low viscosity groups.

At the cavity floor (Table IV), adaptation was impaired when using the high viscosity composite resin material in combination with manual insertion compared to the medium and low viscous material ($p < 0.05$). No difference between materials was noted when applying ultrasound. Ultrasound significantly decreased the film thickness when the high viscosity material was used compared to manual insertion ($p < 0.05$).

Filler distribution

The null hypothesis was confirmed in that the analysis of filler distribution revealed no significant differences for the tested element distribution between control resin blocks and *in situ* cured material after different insertion methods (Table V).

Discussion

Conventional cements (zinc phosphate, zinc oxide eugenol, ethoxy benzoic, polycarboxylate, and glass-ionomer) provide primarily mechanical retention [12]. Disadvantages such as high solubility and abrasion, as well as inferior color match and flexural strength characteristics, play an underpart when highly precise cast gold restorations are placed. However, for luting all-ceramic or composite resin restorations, these materials are no longer indicated. The introduction of composite resin-based luting materials was connected with hopes of durable adhesion instead of solely macromechanical retention, good color match, creation of polishable marginal zones, improvement of flexural characteristics of ceramic inlays, cuspal stabilization and stress-breaking properties between tooth and restorative material. Light-curing composite resin materials have been used successfully in direct restorations for many years [20,21]. These materials show adequate wear resistance and mechanical properties even in stress-bearing areas [22,23]. In addition, compatible bonding agents allow the establishment of a good marginal seal based on reliable physical and chemical interactions between the resin material and dental hard tissues [24,25]. However, clinicians are still concerned about a true-to-size placement of indirect restorations using these materials. Composite resin materials used for direct fillings have a high viscosity, which may be considered beneficial for the placement of the filling but may hamper inlay seating. This compunction was justified when manual insertion technique was used in the present study. However, current and previous results have shown that the use of vibration energy to lute inlays may allay these doubts [12,18,26]. Peutzfeldt evaluated the axial discrepancy of three different resin cements in mod cavities [17]. Mean values ranged from 135 to 472 μm without ultrasonic technique and values were statistically significantly different between materials used. In contrast, when ultrasound was used, respective values of all three cements decreased significantly, ranging from 115 to 154 μm, and did not differ statistically from each other. It should be kept in mind that when trying to achieve film thickness reduction using low filled resin cements, increased wear rates must be taken into account, which may lead to more extensive ditching *in vivo* [11]. In contrast, using higher filled materials, increased mechanical properties and wear resistance can be expected, as it has been shown that wear resistance increases linearly with the filler content [27].

On the other hand, seating inlays using highly filled composite materials may result in higher insertion resistance, and higher loads and more time are needed

Table V. Wt% distribution (mean ± SD) of the elements Si (silicon), Ba (barium), and Yb (ytterbium). For the location of the element analysis, see areas depicted in Figure 2

Si	Central upper	Central middle	Central lower	Bottom left	Bottom right
High					
Manual	21.3 ± 0.3	21.6 ± 0.4	21.2 ± 0.7	21.4 ± 0.4	21.2 ± 0.4
Ultrasonic	21.6 ± 0.5	20.9 ± 0.6	20.9 ± 0.4	20.9 ± 0.4	21.1 ± 0.3
Control	21.2 ± 0.4				
Medium					
Manual	23.3 ± 0.5	23.4 ± 0.3	23.4 ± 0.4	23.3 ± 0.4	23.3 ± 0.4
Ultrasonic	23.1 ± 0.4	22.9 ± 0.5	22.9 ± 0.5	23.0 ± 0.5	23.3 ± 0.6
Control	23.5 ± 0.5				
Low					
Manual	21.2 ± 0.4	21.2 ± 0.5	21.0 ± 0.4	20.9 ± 0.4	21.1 ± 0.5
Ultrasonic	21.2 ± 0.6	20.7 ± 0.7	21.0 ± 0.6	21.5 ± 0.7	21.3 ± 0.6
Control	21.6 ± 0.4				

Ba	Central upper	Central middle	Central lower	Bottom left	Bottom right
High					
Manual	13.7 ± 0.7	14.0 ± 1.1	13.6 ± 1.5	13.7 ± 1.0	13.3 ± 0.9
Ultrasonic	13.9 ± 2.4	13.8 ± 2.4	13.6 ± 2.4	13.7 ± 2.4	13.7 ± 2.5
Control	13.5 ± 0.7				
Medium					
Manual	12.9 ± 1.0	12.6 ± 0.9	12.8 ± 0.7	13.1 ± 0.9	12.6 ± 1.1
Ultrasonic	12.5 ± 1.4	12.6 ± 1.2	12.4 ± 1.4	12.4 ± 0.9	12.9 ± 1.7
Control	12.1 ± 0.8				
Low					
Manual	14.3 ± 2.4	14.4 ± 2.1	13.8 ± 2.0	13.8 ± 2.2	14.2 ± 2.0
Ultrasonic	13.8 ± 1.9	14.0 ± 1.9	14.0 ± 2.0	14.5 ± 2.4	13.8 ± 1.7
Control	14.2 ± 0.6				

Yb	Central upper	Central middle	Central lower	Bottom left	Bottom right
High					
Manual	19.7 ± 2.0	18.4 ± 2.4	19.3 ± 2.1	18.6 ± 1.9	19.7 ± 1.2
Ultrasonic	19.7 ± 2.7	21.0 ± 3.0	21.2 ± 2.0	20.3 ± 2.3	20.4 ± 2.8
Control	20.3 ± 2.8				
Medium					
Manual	19.0 ± 2.3	17.8 ± 2.1	18.3 ± 1.2	17.2 ± 1.6	17.7 ± 1.9
Ultrasonic	19.1 ± 1.6	17.6 ± 1.8	19.2 ± 1.7	17.8 ± 2.1	17.6 ± 2.2
Control	18.6 ± 2.0				
Low					
Manual	19.6 ± 3.3	19.3 ± 3.2	21.1 ± 2.5	19.9 ± 3.6	19.6 ± 2.4
Ultrasonic	20.0 ± 3.3	20.8 ± 2.5	19.8 ± 2.6	18.4 ± 2.6	19.9 ± 1.2
Control	19.5 ± 1.4				

for seating. In this study, we used a prefabricated tapered class I inlay, which provided high resistance to seating when combined with a composite resin of unfavorable flow characteristics, as the composite material was placed on cavity floors and there was no possibility for drainage through inter-proximal gaps. Despite these selected adverse conditions, load and time could be significantly reduced when the thixotropic effects were harnessed. Results of the present study are comparable to the findings of Walmsley and co-workers [19], who also showed that digital insertion or use of an instrument produced loads of 2100 g and 1100 g, respectively. When sonic or ultrasonic vibrations were used, loads also significantly decreased to 250 g. In the present study, corresponding values of 1922 ± 321 g were found for the manual and 656 ± 144 for the ultrasonic insertion technique. Higher pressures may be of importance when placing indirect restorations. Critical dimensions in restoration thickness or width may result in microfractures during or even prior to definitive seating of the restoration. Perfect fit of the indirect restoration may have another clinical implication: If the restoration is not completely seated in the cavity, occlusal contacts are too high, and the restoration needs to be adjusted, leading to pronounced substance loss and polishing/finishing sequences. This procedure may additionally reduce material thickness, remove glacing material and thus lead to additional weakening of the restoration [28,29]. As for the time to seat the inlay, highly filled materials still required significantly more time to be placed compared to low filled composite resin materials [26]. However, advantages not assessed in this study, such as good overhang control and the superior radio-opacity of highly filled composite resin materials, must also be taken into account. Overhang control is estimated more readily when a high viscous composite resin material in combination with the ultrasonic insertion technique is applied [12].

Finally, it has been suspected that the use of vibration energy utilizing the thixotropic effect may cause changes in the filler/matrix distribution. Sjögren & Hedlund thus investigated the filler content obtained from internal surfaces, from excess luting agent and from the luting agent as delivered (control), and found no changes in the inorganic filler weight fraction by burning at $575 \pm 25°C$ [26]. Their results are supported by the present study. The current evaluation, however, would be the first to assess filler distribution in luting composite resin material films by elemental analysis *in situ*.

In conclusion, when ultrasound was used in combination with the high-viscosity material under investigation, film thickness could be significantly reduced and was comparable to the film dimensions obtained with a low-viscosity composite resin material. Whether using manual or ultrasonic insertion technique, no changes in filler distribution were detected within the composite film between inlay and tooth compared to corresponding control materials cured without mechanic agitation or contact to tooth/inlay surfaces. Within the limitation of the present *in vitro* study, it can be stated that composite resin materials with high viscosity may be used for placement of indirect adhesive restorations. Ultrasound-aided inlay insertion results in faster seating, and pressure on the inlay is reduced. Reducing the film thickness without hampering the composition of the luting space material should be a first-order clinical consideration.

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