Filler content and gap width after luting of ceramic inlays, using the ultrasonic insertion technique and composite resin cements

An in vitro study

Göran Sjögren and Sven-Olof Hedlund
Department of Dental Materials Science, Umeå University, Umeå, Sweden

Sjögren G, Hedlund S-O. Filler content and gap width after luting of ceramic inlays, using the ultrasonic insertion technique and composite resin cements. An in vitro study. Acta Odontol Scand 1997;55:403–407. Oslo. ISSN 0001-6357.

The effect of ultrasonic insertion on the filler content and the gap width for two brands of composite resin luting agents, intended for luting with the ultrasonic insertion technique, were studied after MOD ceramic inlays (Cerec) had been placed. In addition, the internal and marginal gap widths were determined after MOD ceramic inlays (Celay) had been luted on extracted premolars with this technique. No statistically significant differences ($P > 0.05$) were observed for either brand between the filler content obtained from the internal surfaces, from the excess luting agent, or from the luting agent as delivered. There were no statistically significant differences ($P > 0.05$) between the final internal and marginal gap widths when the two brands of luting agent were compared with each other. Except for the final occlusal and internal gap widths obtained for the inlays luted with the Sono-Cem luting agent, no statistically significant differences ($P > 0.05$) were observed between the gap widths at the different locations determined. Thus, the ultrasonic insertion technique used did not significantly influence the filler ratio of the hybrid luting agents studied. Judged by the findings in this study, the properties of luting agents seem to greatly influence the final marginal and internal gap widths. □ *Dental cements; dental inlays; luting agents; ultrasound*

Göran Sjögren, Department of Dental Materials Science, Umeå University, S-901 87 Umeå, Sweden

When ceramic inlays are cemented, the use of the so-called adhesive technique is advocated, and composite resin cements are mainly used as luting agents (1–5). Although the optimum film thickness for ceramic inlays luted with composite resin cements has hitherto not been clearly defined, the marginal fit of those restorations has been debated. The luting agents are considered to be the weakest link in the restorations, and the common opinion is that well-adapted restorations are desirable. It has been asserted that wide marginal gap widths will result in extensive wear of the luting agents (6), and it has been shown in longitudinal clinical studies of ceramic inlays that resin cements wear more than the ceramic and the tooth substance (5, 7–9). It has also been shown that there is a relationship between vertical loss of the luting agent and horizontal gap width (6), and several studies dealing with the marginal fit of ceramic inlays have been published during the past few years (for example, Refs. 4, 8–11). In this context it has to be noted that it is not only the initial fit of the inlays that determines the final gap width when ceramic inlays are luted. The properties of the luting agents, such as the viscosity, seem to greatly influence the final film thickness (11, 12).

The viscosity of composite resins is in general reduced through a reduction of the filler content and/or through the composition of the monomers and/or type of filler. However, mechanical properties and wear resistance are dependent on the filler content (13–16), among other things. During the past few years composite resin cements with an increased amount of filler have therefore been introduced as luting agents for dental restorations. To reduce the effect of the increased viscosity in these cements ultrasonic insertion has been described as a technique for reducing the film thickness when dental restorations are luted with such resins (12, 17, 18). Thus, since the filler content is important for the properties of the cement, it was of interest to study whether the use of the ultrasonic insertion technique influences the filler particles and the resin matrix in different ways. That is, we wanted to study whether the filler particles migrate from the cavity or remain in the cavity to a greater extent than the resin matrix when the ultrasonic insertion technique is used. Moreover, luting agents intended for luting ceramic restorations with the ultrasonic insertion technique usually have, in accordance with the manufacturers' information, an increased amount of filler compared with most of the luting agents intended for the conventional adhesive technique. An increased amount of filler may, however, influence the viscosity of luting agents, and the possibility cannot be excluded that an increased viscosity will influence the gap widths. It was therefore also of interest to determine the marginal and internal gap widths after ceramic inlays had been luted with the ultrasonic insertion technique—that is, to study the effect of the ultrasonic insertion technique on the film thickness at different locations of the inlays.

The aim of the present study therefore was to determine the filler content in composite resin cements intended for luting of dental restorations with the ultrasonic insertion technique after ceramic inlays had been placed by means

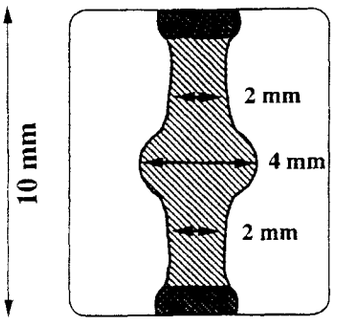

Fig. 1. Occlusal view of one of the cavities in the Plexiglas block.

of this technique. Furthermore, the purpose of the study was also to determine the internal and marginal gap widths after ceramic inlays had been luted with the ultrasonic insertion technique.

Materials and methods

Filler content

Ten MOD cavities were prepared in poly(methyl methacrylate) (Plexiglas). The cavities measured 10 × 2 mm, with an extension in the middle of the occlusal surface of 4 mm (Fig. 1). The occlusal preparation depth was 2 mm, and the depth of the proximal boxes 4 mm, with a cervical width of 5 mm. The cavities were designed for Cerec restorations (Cerec System), with sharp proximal boxes as initially recommended by the manufacturer (19) and with a taper of 10°–12°. To make the surfaces of the cavities opaque and non-reflecting before the optical impression was taken, as recommended by the manufacturer, the preparations and the surrounding areas were covered with a thin layer of Dentaco Scan white (Dentaco Dentalindustrie and -marketing GmbH, Bad Homburg, Germany). After this the inlays were manufactured by means of the Cerec CAD/CAM equipment (Cerec System, software C.O.S. 2.0, Siemens AG, Bensheim, Germany). The ceramic blocks used were Vita Cerec Mark II (Vita Zahnfabrik, Bad Säckingen, Germany).

The ceramic inlays and the Plexiglas block were cleaned in distilled water in an ultrasonic bath (Brainsonic 221). Subsequently, the internal surfaces of the ceramic inlays were etched and silane-treated in accordance with the manufacturer's instructions (19). Two different brands of dual-cured hybrid composite luting agent were studied, Sono-Cem (Sono-Cem, ESPE GmbH, Seefeld, Germany, batch X216) and Vivadent Variolink Ultra (Vivadent Variolink Ultra, Schaan, Lichtenstein, batch 662170). The base and the catalyst of each luting agent were mixed together in accordance with the manufacturers' instructions just before the luting agent was introduced into the cavity.

The Sono-Cem luting agent was first introduced into one of the cavities of the Plexiglas block by means of a plastic spatula, and the corresponding inlay was then placed in the cavity with firm finger pressure. The tip of the ultrasonic handpiece was applied on the middle of the occlusal surface of the inlay and perpendicular to the occlusal surface of the inlay. Thereafter the ultrasonic device was switched on. The ultrasonic device used was Amdent 830 (Axel Johnsson Instrument AB, Nynäshamn, Sweden) with a special tip recommended for the purpose.

To minimize heating of the tip of the ultrasonic handpiece, the ultrasonic device was used for short periods (<5 sec). This action was repeated until no new resin luting agent emerged along the inlay margins (≈30–40 sec). The excess luting agent was removed with a plastic spatula and stored in a plastic can. Thereafter the inlay was removed, and the cement layers inside the cavities and on the internal surfaces of the ceramic inlay were removed, using the other end of the plastic spatula, and stored in another plastic can. After the 10 inlays had been treated in this manner the Plexiglas block and the ceramic inlays were cleaned in distilled water in the ultrasonic bath (Brainsonic 221), and the internal surfaces of the inlays were re-etched and retreated with silane. The process described above was repeated until >0.3 g × 4 of composite resin was obtained from the cavities, from the internal surfaces of the inlays, and from the excess luting agent. Thereafter the inlays and the Plexiglas block were cleaned in distilled water in the ultrasonic bath (Brainsonic 221), and a process similar to that used for the Sono-Cem luting agent was repeated for the Vivadent Variolink Ultra luting agent. For comparison, the filler content was also determined in >0.3 g × 4 of each of the two composite resin luting agents as delivered, after the catalyst and the base had been mixed together.

The weight fraction of the inorganic fillers was determined by burning at 575 ± 25°C for 30 min, as previously described by Ruyter & Sjøvik Kleven (20). The precision of the weight of each sample of the luting agent was ± 0.0001 g. Four determinations were made for each of the three groups of resin luting agent—that is, from the samples obtained from the internal surfaces, from the samples obtained from the excess, and from the samples obtained from the luting agents as delivered.

Gap widths

Twenty MOD cavities were prepared in 20 sound, caries-free extracted premolars that had been stored in 0.5% benzalconium chloride solution. The design of the cavities was based on the concept of the standard class-II preparations with a flat bottom and all angles rounded. No cavosurface bevels were made. Diestone models (Kerr Vel-Mix Stone ISO Type IV, Kerr Europe AG, Basel, Switzerland) were made of each prepared tooth after impressions with an A-silicone (President, Coltène, Altstätten, Switzerland). Thereafter 20 Celay inlays were manufactured by a specially trained dental technician at the Department of Dental Materials Science, Umeå Uni-

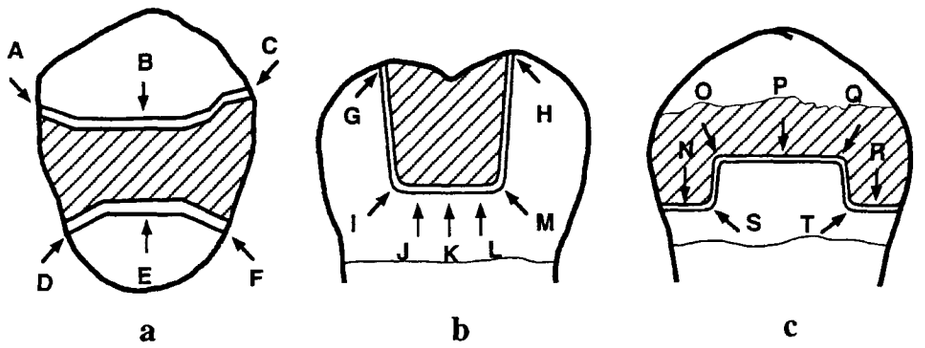

Fig. 2a. Location of the occlusal measuring points. 2b. Location of the mesial and distal measuring points. 2c. Mesiodistal section showing location of the internal measuring points.

versity, Umeå, Sweden. The ceramic blocks used for the Celay inlays were Vita Celay Blanks (Vita Zahnfabrik). The internal surfaces of the inlays were etched with 4.9% HF-acid for 1 min. The enamel of the prepared teeth was etched with a 37% phosphoric acid gel, rinsed with water and subsequently dried with compressed air.

On a randomized basis half the number of the Celay inlays were luted with the Sono-Cem luting agent (batch 8865), and the rest with the Vivadent Variolink Ultra luting agent (batch 662170) by means of the ultrasonic device (Amdent 830). All inlays were judged to be clinically acceptable for positioning in patients. The ultrasonic device was used for short periods (<5 sec). This was repeated until no new resin luting agent emerged along the inlay margins (≈ 30–40 sec). Polymerization of the luting agents, removal of excess cement and polishing, staining of the luting agents, measuring the points, and the measuring technique were carried out in the same manner as in a study by Sjögren (11) of marginal and internal fit of ceramic inlays. All measurements were carried out by the same person as in the previous study (11). The measuring points used are shown in Fig. 2.

Table 1. Mean values and standard deviations of the inorganic filler content (% w/w) in the composite resin cements

Sample	Sono-Cem ($n = 4$)	Vivadent Variolink Ultra ($n = 4$)
Excess of cement	76.43 ± 0.12	78.28 ± 0.01
Cement from the internal surfaces of the inlays and cavities	76.46 ± 0.09	78.25 ± 0.08
Composite resin cement as delivered	76.28 ± 0.15	78.22 ± 0.03

Statistical analysis

The values obtained for the filler content were analyzed statistically by using the unpaired Student's t test with a significance level of 0.05. The gap widths were analyzed statistically using analysis of variance and Bonferroni multiple tests (21) with a significance level of 0.05.

Results

The mean values and standard deviations of the filler content of each of the three groups studied are listed in Table 1. There were no statistically significant differences ($P > 0.05$) between the groups.

The mean values, standard deviations, and ranges of the final marginal and internal gap widths are shown in Table 2. There were no statistically significant differences ($P > 0.05$) between the values obtained for the final internal and marginal gap widths when the two brands of luting agents were compared with each other.

When the final gap widths determined at different locations were compared with each other, for each brand studied, there was no statistically significant difference ($P > 0.05$) between the values obtained, with the exception of the occlusal and internal measuring points obtained for the Sono-Cem luting agent. The internal gap width was

Table 2. The distance (μm) between the inlay and tooth substance measured at occlusal, proximal, gingivoproximal, and internal locations and the standard deviations and ranges (within parentheses): mean values and standard deviations for 10 MOD inlays of each type

Type	Occlusal*	Proximal*	Gingivoproximal*	Internal*
Sono-Cem	214 ± 53 (30–615)	243 ± 95 (50–705)	260 ± 118 (50–705)	293 ± 79 (0–720)
Variolink Ultra	239 ± 84 (60–565)	262 ± 119 (30–780)	279 ± 130 (30–780)	268 ± 140 (0–940)

* Definition of measuring points in accordance with Fig 2: Occlusal = measuring points A–F; Proximal = measuring points G–M; Gingivoproximal = measuring points I–M; Internal = measuring points N–T.

significantly wider ($P < 0.05$) than the occlusal gap width for the inlays luted using the Sono-Cem luting agent.

Discussion

Since the two luting agents, according to the manufacturers' information, did not contain any organic fillers, only the inorganic filler content was determined in the present study. The reason for using Plexiglas blocks instead of extracted teeth for the cavities when the filler content was determined was to avoid contamination from tooth substance, such as fractured enamel prisms, in the luting agent. Contamination from inorganic tooth substance could have influenced the weight of the inorganic fraction of the luting agent after burning.

According to the manufacturers' information, the Sono-Cem composite resin luting agent used in the present study is classified as a hybrid with an inorganic filler content of 77.3% w/w, and the Vivadent Variolink Ultra as a hybrid with an inorganic filler content of 78.8% w/w. In the present study the filler content of the luting agents as delivered was determined to be 76.4% w/w for Sono-Cem and 78.2% w/w for Vivadent Variolink Ultra—that is, values close to those given by the manufacturers. After the inlays had been placed by using the ultrasonic insertion technique the filler content in the samples obtained from the inner surfaces of the inlays and the cavities and in the samples obtained from the excess luting agents did not differ significantly from the filler content of the parent luting agents (Table 1). In other words, the ultrasonic insertion technique used had not influenced the filler ratio of the hybrid luting agents studied significantly. The two luting agents studied were dual-cured, and the working time was sufficient to remove the luting agents from the surfaces of the inlays and of the cavities and, thus, made it possible to determine the filler content.

With regard to the values of the gap widths, there were no statistically significant differences ($P > 0.05$) between the two brands of luting agents studied in the present study (Table 2). When the values of the final internal and marginal gap widths obtained in a previous study (11) of Celay inlays luted with the conventional adhesive technique were compared (analysis of variance and Bonferroni multiple tests) with the values in the present study, there were statistically significant differences ($P > 0.05$). The values of the final gap widths in the present study—that is, those of the Celay inlays luted by means of the ultrasonic device and the Sono-Cem or Vivadent Variolink Ultra luting agents—were significantly greater than the values for the Celay inlays luted with the conventional adhesive technique, with the exception of the occlusal gap width for the inlays luted with the Sono-Cem luting agent. That is, at the occlusal margins there was no significant difference between the inlays luted with the Sono-Cem luting agent as compared with the Celay inlays in the previous study (11), whereas the inlays luted with the Vivadent Variolink Ultra luting agent showed a significantly greater occlusal gap width than the Celay inlays in the previous study (11). The mean values and the standard deviations obtained for the Celay inlays in the previous study (11) were 174 ± 43 μm for the occlusal gap width, 169 ± 59 μm for the proximal gap width, 163 ± 62 μm for the gingivoproximal gap width, and 190 ± 51 μm for the internal gap width, respectively. However, it is difficult to predict the clinical significance of the differences in the gap widths between the different luting agents. The luting agent used in the previous study (11) was, according to the manufacturer's information, a dual-cured hybrid composite resin luting agent with a filler content of 68% w/w. The lower filler content can be one reason for the differences between the luting agents studied with regard to the final internal and marginal gap widths. In an in vitro study, however, Peutzfeldt (12) reported that the axial discrepancy for MOD composite inlays, luted with composite resin cements with different viscosities and ultrasonic insertion techniques, did not depend on the viscosity of the cement, whereas the axial discrepancy increased with the viscosity of the cement when the inlays were luted using finger pressure. The composite resin cement intended for luting with the conventional adhesive technique in the study by Peutzfeldt (12) had, according to the manufacturer's information, a higher filler content than the luting agent used in the previous study by Sjögren (11). The ceramic inlays in the present study were all MOD inlays, based on the concept of the standard class-II preparations. The possibility that the geometric configuration of the inlays and of the cavities and the direction of the applied load when inlays are luted influence the final gap widths at different locations cannot be excluded. It has been shown in a study by Walmsley & Lumley (22) that the film thickness at different locations is influenced by the probe orientation of the ultrasonic device.

The marginal and internal gap widths in the present study were determined with a similar measuring technique and corresponding numbers and locations of the measuring points as in the previous study of the Celay inlays (11). In addition, the measuring was carried out by the same person, using the same equipment as in this previous study, and the impressions of the teeth and the die stone models were manufactured by using the same technique. The materials used for the impressions and the die stone models were of the same types and of the same brands in both the studies. Moreover, all the Celay inlays in the previous study (11) and in the present study were manufactured by the same dental technician, using the same equipment. Thus, the values obtained for the internal and marginal gap widths in the two studies can be compared. Therefore, the results from those studies also indicate support for the hypothesis (11, 23) that the properties of the luting agents greatly influence the final marginal and internal gap widths.

To judge from the findings in the present study, the filler content in the composite cements, intended for luting by means of ultrasound, was retained after the inlays had been positioned, but the film thickness was in most cases

wider than when the conventional adhesive technique and a conventional composite resin luting agent had been used. Commonly used composite resin luting agents intended for luting with conventional adhesive technique, according to the manufacturers' information, usually have a filler content varying between about 55% and 70% by weight; that is, the two luting agents studied in the present study have a slightly higher filler content and therefore are considered to be more wear-resistant and to have improved mechanical properties. However, the gap widths were significantly wider for the ceramic inlays luted with these cements, with the exception of the occlusal gap width for the inlays luted with the Sono-Cem luting agent. Moreover, there are other factors than just the filler content which influence the wear resistance and mechanical properties of composite resin luting agents (24–26). In the light of this, potential clinical advantages of highly loaded cements therefore have to be confirmed with long-term follow-up studies.

Acknowledgements.—This work was financially supported by the Swedish Medical Research Council (project 09447) and by the County Council of Västerbotten, Sweden.

References

1. Isenberg BP, Essig ME, Leinfelder KF. Three-year clinical evaluation of CAD/CAM restorations. J Esthet Dent 1992;4: 173–6.
2. Sjögren G, Bergman M, Molin M, Bessing C. A clinical examination of ceramic (Cerec®) inlays. Acta Odontol Scand 1992; 50:171–8.
3. Krejci I, Krejci D, Lutz F. Clinical evaluation of a new pressed glass ceramic inlay material over 1.5 years. Quintessence Int 1992;23:181–6.
4. Walther W, Reiss B, Toutenburg H. Longitudinale Ereignisanalyse von Cerec®-Einlagefüllungen. Dtsch Zahnaertztl Z 1994; 49:914–17.
5. Sjögren G, Molin M, van Dijken J, Bergman M. Ceramic inlays (Cerec) cemented with either a dual- cured or a chemically cured composite resin luting agent. A 2-year clinical study. Acta Odontol Scand 1995;53:325–30.
6. Kawai K, Isenberg BP, Leinfelder KF. Effect of gap dimension on composite resin cement wear. Quintessence Int 1994;25:53–8.
7. van Dijken JW, Hörstedt P. Marginal breakdown of fired ceramic inlays cemented with glass polyalkenoate (ionomer) cement or resin composite. J Dent 1994;22:265–72.
8. Mörmann W, Krejci I. Computer-designed inlays after 5 years in situ; clinical performance and scanning electron microscopic evaluation. Quintessence Int 1992;23:109–15.
9. Van Meerbeek B, Inokoshi S, Willems G, Noack MJ, Braem M, Lambrechts P, et al. Marginal adaptation of four tooth-coloured inlay system in vivo. J Dent 1992;20:18–26.
10. Isenberg BP, Essig ME, Leinfelder KF, Mueninghoff LA. Clinical evaluation of marginal integrity; two-year results. Proceedings of the International Symposium on Computer Restorations: State of the Art of the Cerec Method. Berlin: Quintessence Publishing; 1991. p. 163–72.
11. Sjögren G. Marginal and internal fit of four different types of ceramic inlays after luting. An in vitro study. Acta Odontol Scand 1995;53:24–8.
12. Peutzfeldt A. Effect of the ultrasonic insertion technique on the seating of composite inlays. Acta Odontol Scand 1994;52:51–4.
13. Øysæd H, Ruyter IE. Composites for use in posterior teeth: mechanical properties tested under dry and wet conditions. J Biomed Mater Res 1986;20:261–71.
14. Li Y, Swartz ML, Phillips RW, Moore BK, Roberts TA. Effect of filler content and size on properties of composites. J Dent Res 1985;64:1396–401.
15. Braem M, Finger W, Van Doren VE, Lambrechts P, Vanherle G. Mechanical properties and filler content of dental composites. Dent Mater 1989;5:346–8.
16. Ferrcane JL, Matsumoto H, Okabe T. Time-dependent deformation of composite resins-compositional considerations. J Dent Res 1985;64:1332–6.
17. Noack MJ, Locke LS, Roulet JF. Das Randverhalten adhäsiv befestigter und mittels Ultraschall eingesetzter Porzellaninlays in vivo. Dtsch Zahnaerztl Z 1993;48:720–3.
18. Noack MJ, Roulet JF, Bergman P. A new method to lute tooth colored inlays with highly filled composite resins [abstract 1528]. J Dent Res 1991;70:457.
19. Mörmann W, Brandistini M. Die Cerec computer reconstruction, inlays, onlays and veneers. Berlin: Quintessence Verlag GmbH; 1989.
20. Ruyter IE, Sjøvik Kleven IJ. Monomers and filler content of resin-based crown and bridge materials. Dent Mater 1987;3: 315–21.
21. Dawson-Saunders B, Trapp RG. Basic and clinical biostatistics. Clifton Heights (NJ): Prentice-Hall Int.; 1990.
22. Walmsley AD, Lumley PJ. Applying composite luting agent ultrasonically: a successful alternative. J Am Dent Assoc 1995; 126:1125–29.
23. Sjögren G. Dental ceramics and ceramic restorations. An in vitro and in vivo study. Swed Dent J 1996;Suppl 111:3–50.
24. Ferrance JL. Correlation between hardness and degree of conversion during the setting reaction of unfilled dental restorative resins. Dent Mater 1985;1:11–4.
25. Asmussen E. Restorative resins: hardness and strength vs. quantity of remaining double bonds. Scand J Dent Res 1982;90:484–9.
26. Peutzfeldt A. Dual-cure resin cements: in vitro wear and effect of quantity of remaining double bonds, filler volume, and light curing. Acta Odontol Scand 1995;53:29–34.

Received for publication 14 September 1996
Accepted 25 July 1997