



Comparative study of the radiopacity of resin cements used in aesthetic dentistry

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PURPOSE. The aim of this study was to compare the radiopacity of 6 modern resin cements with that of human enamel and dentine using the Digora digital radiography system, to verify whether they meet the requirements of ANSI/ADA specification no. 27/1993 and the ISO 4049/2000 standard and assess whether their radiopacity is influenced by the thickness of the cement employed. **MATERIALS AND METHODS.** Three 3-thickness samples (0.5, 1 and 1.5 mm) were fabricated for each material. The individual cement samples were radiographed on the CCD sensor next to the aluminium wedge and the tooth samples. Five radiographs were made of each sample and therefore five readings of radiographic density were taken for each thickness of the materials. The radiopacity was measured in pixels using Digora 2.6 software. The calibration curve obtained from the mean values of each step of the wedge made it possible to obtain the equivalent in mm of aluminium for each mm of the luting material. **RESULTS.** With the exception of Variolink Veneer Medium Value 0, all the cements studied were more radiopaque than enamel and dentin ($P < .05$) and complied with the ISO and ANSI/ADA requirements ($P < .001$). The radiopacity of all the cements examined depended on their thickness: the thicker the material, the greater its radiopacity. **CONCLUSION.** All materials except Variolink Veneer Medium Value 0 yielded radiopacity values that complied with the recommendations of the ISO and ANSI/ADA. Variolink Veneer Medium Value 0 showed less radiopacity than enamel and dentin. [J Adv Prosthodont 2016;8:201-6]

KEY WORDS: Radiopacity; Resin cement; Luting cement

INTRODUCTION

A number of factors - including preparation design, occlusal forces, oral hygiene, and the restoration materials used - influence the success of fixed dental prostheses. Nevertheless, the key factor for success is the choice of suitable luting cement and cementing procedure.¹ Cementing is the final stage for indirect restoration and the most critical step for ensuring the long-term success of the dental restoration.¹

Dental luting cement is a substance that bonds juxtaposed surfaces together and provides thermal, electrical, and chemical insulation. The main purpose of such bond is to achieve marginal sealing, adaptation, and stable adhesion between the different types of substrate, as well as adequate retention and resistance.¹⁻⁴

Radiopacity is one of the main requirements for luting cements, particularly when used for cementing indirect restorations, as radiographs enable dentists to complete their diagnoses.⁵ In a radiograph, a sufficiently radiopaque material allows proper assessment of its bond with the dental tissues, particularly in the areas of difficult access.² The radiopacity also assists the detection of secondary caries under the restoration⁶ and marginal defects and enables the observation of periodontal effects of the cement overhangs. Therefore, when the luting agent is not radiopaque enough, it is impossible to detect voids,⁶ inadequate marginal adaptation, and interfacial gaps.⁶⁻¹²

For many years in the past, zinc phosphate cement had been the most commonly used luting material.¹³⁻¹⁵ However, despite its good radiopacity - Attar *et al.*¹⁶ showed it to be

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the most radiopaque cement - it has certain undesirable properties, such as solubility in the oral environment, which have prompted the search for an alternative with ideal characteristics. In recent years, the use of resin cements and resin-modified glass ionomer cements has increased significantly.^{5,17} This is largely due to the evolution of adhesive systems. These materials have the great advantage of adhering not only to the tooth structure but also to ceramics, compound resins and metal alloys. They widely used in restorations with little frictional retention, owing to their high bonding strength.^{2,13,18} However, despite the scientific advances they bring to dentistry, few studies have addressed their radiopacity.

The purposes of the present study were to compare the radiopacity of six resin cements used in dentistry with that of human enamel and dentin, verify whether they meet the requirements of the ISO 4049/2000 standard and ANSI/ADA specification No. 27/1993, and assess whether their radiopacity is influenced by the thickness of the cement employed.

MATERIALS AND METHODS

Six resin cements in this study came onto the market recently. Their chemical composition and characteristics are shown in Table 1. In order to standardize the specimens, a

Table 1. List of luting cements tested

Luting cement	Manufacturer	Chemical composition	Type of cement	Type of activation	Shade	Batch No.
Calibra	Dentsply (Hanau-Wolfgang, Germany)	<ul style="list-style-type: none"> · Base: Dimethacrylates resins; camphorquinone photoinitiator; stabilizers; glass fillers; fumed silica; titanium dioxide; pigments · Catalyst: Dimethacrylate resins; catalyst; stabilizers; glass fillers; fumed silica · Silane coupling agent: Acetone, ethyl alcohol, organo-silane 	Resin cement	Dual	Medium	130417
Block Out	DenMat (Lompoc, CA, USA)	Information not supplied by the manufacturer	Resin cement	Dual	A1	R045010019
Ultradond Plus	DenMat (Lompoc, CA, USA)	Information not supplied by the manufacturer	Resin cement	Dual	A1	R043010144
Insure	Cosmedent (Friedberg, Germany)	Urethane dimethacrylate, butanediol, Bis-GMA, fumed silica, barium silicate glass, aluminum and boron	Resin cement	Light cure	Yellow Red Light	130301A
Rely X Ultimate	3M Espe (Neus, Germany)	<ul style="list-style-type: none"> · Base: Methacrylate monomers, radiopaque, silanated fillers, initiator components, stabilizers, rheological additives · Catalyst: Methacrylate monomers, radiopaque alkaline (basic) fillers, initiator components, stabilizers, pigments, rheological additives, fluorescence dye, dark cure activator for Scotchbond Universal adhesive 	Adhesive resin cement	Dual	Translucent	535206
Variolink Veneer	Ivoclar Vivadent (Schaan, Liechtenstein)	<p>Dimethacrylate, silica, barium silicate glass, which has greater radiopacity than strontium silicate glasses. It also contains catalysts and stabilizers.</p> <p>In Medium Value 0, the total content of inorganic filler is approx. 65.9% by volume. The size of the filler particles ranges from 40 nm to 300 nm. Because of its high translucency, due to having no ytterbium trifluoride or pigments in its composition. This color shade is not radiopaque.</p>	Adhesive resin cement	Light cure	Medium Value 0	R41878

stainless steel wedge was made to have 3 steps of thicknesses (0.5, 1 and 1.5 mm thick), and a light silicon mould was cast from this wedge. The moulds were filled with the cements, covered with microscopy slides to remove excess material and allow the passage of light, and cured with the LED curing lamp (Bluephase C8, IvoclarVivadent) with a power of 800 mW/cm² and wavelength of 380 - 515 nm, as verified by a radiometer. The duration of the photopolymerization was that recommended by the manufacturers.

The thickness of each specimen was checked with a digital calibrator. Specimens of more than the desired thickness (± 0.01 mm) were polished to get the correct size and were then cleaned with 70% ethyl alcohol. For each cement, 3 specimens in the form of wedges of the previously mentioned thicknesses were prepared.

To prepare of tooth specimens, sections of a third molar were cut with a low-speed diamond disc (Bredent, Senden, Germany) to obtain 0.5, 1 and 1.5 mm (± 0.01 mm) mesiodistal specimens of enamel and dentin. The final thickness of each tooth specimen was adjusted by sandpapering and checked with a digital calibrator, allowing a criti-

cal tolerance level of ± 0.01 mm. The tooth specimen was then stored in saline solution at room temperature.

The aluminum step wedge employed was machined from a single block of aluminum (Alcoa Inespal, Avilés, Asturias, Spain) with a purity of 99.889% Al, 0.0202% Si, 0.0687% Fe and 0.0001% Cu. It had 10 steps or thickness levels, rising in 0.5 mm increments, and its overall dimensions were 10 mm wide by 20 mm long.

Afterwards, each specimen was X-rayed 5 times at 65 kV and 10 mA for 0.30 seconds at a focal object distance of 30 cm, with the cement specimen, the aluminum step wedge and the three enamel-dentin specimens placed on the Sopix 2 digital sensor (Satelec, La Ciotat, France) (Fig. 1).

The images were then imported into Digora for Windows 2.5 software (Soredex, Tuusula, Finland) in order to measure the specimens' radiopacity in pixels, using the density measurement tool. Each thickness of each cement was measured at 5 different positions. Only the regions that were free of air bubbles or other defects were analyzed (Fig. 2, Fig. 3). Using a similar procedure, the radiopacity of the enamel and dentin was also measured in 5 different regions of each thickness specimen, with 15 exposures in each region.

The density of each of the 10 thicknesses of the aluminum step wedge was measured by 15 random radiographs, each yielding 5 radiopacity values. A density calibration curve was constructed from the mean values for each step of the aluminum wedge, making it possible to convert the mean radiopacity value of each luting cement into millimeters of aluminum.

Statistical analysis of the data collected in this study was performed with SPSS software at a 95% confidence level. A t-test for equality of means was used to examine the differences in radiopacity between the different materials, and an ANOVA, with post-hoc tests, was carried out to study the influence of the thickness of the materials on the radiopacities measured in this study.

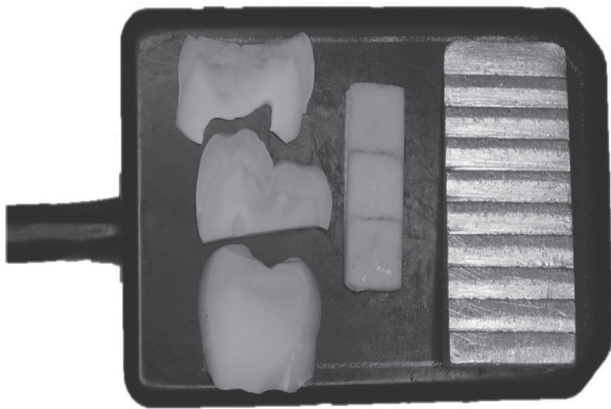


Fig. 1. Preparing materials for radiography.

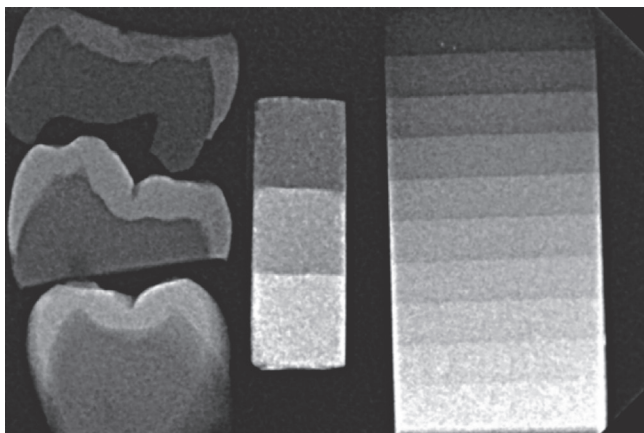


Fig. 2. Radiograph of Block Out.

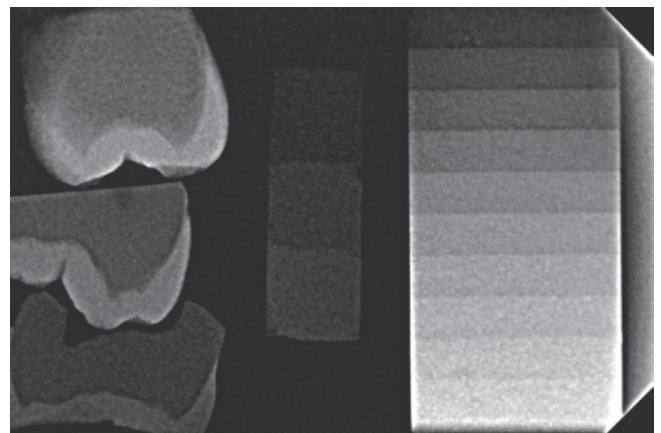


Fig. 3. Radiograph of VariolinkVeneer Medium Value 0.

RESULTS

Firstly, the independent specimens t-test for equality of means was used to discover any statistically significant differences between the mean radiopacity of each cement and that of the enamel and dentin at the three thicknesses studied. At every thickness level, statistically significant differences ($P < .05$) between the radiopacities of the enamel and dentin and those of all the cements were encountered. The results also demonstrate that the Calibra, Block Out, Ultrabond Plus, Insure and Rely X Ultimate cements were significantly more radiopaque than the enamel and dentin at each of the study thicknesses, while the radiopacity of the Variolink Veneer cement with medium value 0 shade was lower than that of the tooth specimen at all the thicknesses studied.

To verify whether the materials comply with current standards, the independent specimens t-test for equality of means was used. The mean radiopacity of all the materials differed significantly from that of aluminum ($P < .001$). Observing the Mean Differences column values, it may also be stated that Calibra, Block Out, Ultrabond Plus, Insure and Rely X Ultimate show a positive difference compared to the value for aluminum - in other words, their mean radiopacity is higher than that of aluminum - while the mean radiopacity of the Variolink Veneer cement with medium value 0 shade is significantly lower than that of aluminum at all the thicknesses tested. This demonstrates that all the cements except Variolink Veneer cement with medium value 0 shade comply with the current standards.

The present study also examined whether the radiopacity values presented statistically significant differences depending on the thickness of the cement (Table 2). For all the materials studied, the ANOVA and Welch statistic findings provide statistical evidence that the radiopacity of the cements depends to a significant degree on its thickness, as the radiopacity results fall into three groups, significantly

differentiated by thickness, and the thicker the material, the greater its radiopacity (Fig. 4).

DISCUSSION

In the present study, the radiopacity of six resin luting cements was compared with human enamel and dentin and with the mean values of the aluminum step wedge employed as a standard control material. The latter is essential for comparison with radiopacity measurements performed by other researchers. The radiopacity of dentin and enamel specimens can vary, but pure aluminum provides a constant reference value.^{6,9}

It should be pointed out that it is difficult to compare the findings of the present study with those of previous researchers who examined older luting cements. Advances in materials are constantly being made and the present study examined cements that have only recently come on the market.

Enamel is a radiopaque structure, as it has a 90% mineral content, whereas dentin is less mineralized (75%) and therefore less radiopaque.¹⁹

Van Dijken¹⁹ showed that the radiopacity of dentin is approximately equivalent to that of aluminum of the same thickness, while enamel has approximately twice the radiopacity of aluminium. These findings agree with the values reported by Salzedas *et al.*¹¹ The present study yielded similar results for the three thicknesses examined, as the enamel values were approximately double those of dentin.

Some authors consider that to allow correct diagnosis, these restoration materials should be at least as radiopaque as the same thickness of dentin, and have highlighted the importance of using sections of dental tissues as a secondary standard.^{6,7,12} Papers by Altintas *et al.*⁶ and Furtos *et al.*²⁰ present similarities with the present study as regards encountering similar or higher radiopacity to that of dentin in

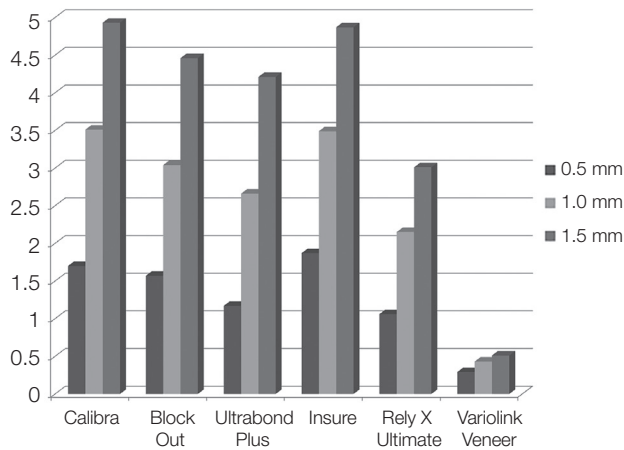


Fig. 4. Influence of thickness on the radiopacity of material.

Table 2. Mean radiopacity by thickness (mm Al)

Materials	Radiopacity (mm Al/mm thickness sample)		
	0.5 mm	1.0 mm	1.5 mm
Calibra	1.7	3.51	4.93
Block Out	1.57	3.04	4.46
Ultrabond Plus	1.17	2.66	4.21
Insure	1.87	3.49	4.87
Rely X Ultimate	1.06	2.15	3.01
Variolink Veneer	0.29	0.43	0.51
Enamel	1.02	1.97	2.94
Dentine	0.52	1.02	1.6
Aluminium	0.5	1	1.5

most of the cements they studied.

However, other researchers consider that restoration materials need to be slightly more radiopaque than enamel.^{9,12}

Pedrosa *et al.*¹⁰ state that materials with higher levels of radiopacity than enamel facilitate diagnosis as the contrast differentiates the dental structures, whereas radiopacity values between those of enamel and dentin or lower than in dentin tend to confuse the examiner, so there is a greater possibility of false positive diagnoses of secondary caries. Along the same lines, Takuma Tsuge⁴ studied 8 resin cements and reported that 5 were more radiopaque than enamel and 3 less radiopaque, as was found with the Variolink Veneer cement Medium Value 0 shade in the present study.

According to the ISO and ANSI/ADA standards,^{21,22} the minimum acceptable radiopacity for a restoration material is equivalent to that of the same thickness of aluminium. The results of the present study fell within the radiopacity requirements required for cementing agents included in the standards issued by the ISO 4049 and ANSI/ADA,^{21,22} that is to say, the radiopacity of any thickness of the resin cement materials studied is significantly higher than that of aluminium, with the exception of Variolink Veneer Medium Value 0, which is less radiopaque than the standard.

According to the bibliography, the radiopacity of resin cement is typically attributed to its inorganic load, with little contribution from the matrix.^{2,3,7,20}

The physical properties of dental cements can vary considerably as a result of differences in the quantity and quality of their chemical components. Including elements with a high atomic weight among the filler particles of a resin-based cement helps to increase the radiopacity of these materials.^{3,13}

Furtos *et al.*²⁰ verified that the cements with the highest filler content were the most radiopaque (a direct correlation between filler content and radiopacity), and that level of radiopacity was significantly higher than that of enamel. However, the cement with the lowest percentage load was still significantly more radiopaque than dentin.

Information on the correct, detailed chemical composition of resin cements is scarce and most manufacturers consider these data confidential. Owing to the limited data available on this aspect of the materials studied, it has not proved possible to construct a correlation between filler content, organic matrix and type of radiopacity.

CONCLUSION

At each of the study thicknesses, the Calibra, Block Out, Ultrabond Plus, Insure and Rely X Ultimate cements are significantly more radiopaque than enamel and dentin, while Variolink Veneer Medium Value 0 is significantly less radiopaque than either at all these thicknesses. With the exception of Variolink Veneer Medium Value 0, all the cements studied comply with the ISO and ANSI/ADA standards at all three thicknesses. Furthermore, the radiopacity of all these luting cements depends to a significant

degree on their thickness: the thicker the material, the greater its radiopacity.

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