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Evaluation of the Radiopacity of Contemporary Luting Cements by Digital Radiography

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This study examined the radiopacity of eight contemporary luting cements by direct digital radiography. Five disc-shaped specimens (5 mm × 1 mm) were prepared for each material tested (BisCem, Clearfil SA Luting, Duolink, Maxcem Elite, Multilink Speed, Panavia F 2.0, RelyX Unicem Clicker, V-link). The specimens were radiographed using a Kodak CS 7600 image plate (Carestream Health, Inc., Rochester, NY, USA) and an aluminum step wedge with a range of thicknesses (1.5 to 16.5 mm in 1.5 mm increments) and a 1 mm tooth used as a reference. A dental X-ray machine Kodak 2200 Intraoral X-ray System (Carestream Health, Inc., Rochester, NY, USA), operating at 70 kVp, 4 mA, 0.156 s and a source-to-sample distance of 30 cm, was used. According to international standards, the radiopacity of the specimens was compared with that of an aluminum step wedge using NIH ImageJ software (available at http://rsb.info.nih.gov/ij/).The data was analyzed by ANOVA and a Tukey's post hoc test. Maxcem Elite (5.66) showed the highest radiopacity of all materials, followed in order by Multilink Speed (3.87) and V-link (2.83). The radiopacity of Clearfil SA Luting (1.35), BisCem (1.33), Panavia F 2.0 (1.29) and Duolink (1.10) were between enamel (1.79) and dentin (0.19). RelyX Unicem Clicker (0.71) showed the lowest radiopacity, which was higher than that of dentin. All materials showed a radiopacity above the minimum recommended by the International Organization for Standardization and the American National Standards/American Dental Association with the exception of RelyX Unicem Clicker. (J Dent Rehab App Sci 2013:29(4):377 - 383)

Key words: Digital radiography, Luting cement, Radiopacity

INTRODUCTION

Dental luting cements are used to cement fixed partial dentures to abutments and post/dowel restorations to root canals. Radiopacity is a fundamental requirement in the application of luting materials because it provides the appropriate contrast between the tooth substrates (enamel/

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dentin) and material.[1-4)] The advantages of radiopaque materials over radiolucent materials include the improvements in a radiographic diagnosis of recurrent caries, faulty proximal contour, marginal adaptation, excess cement, and easing the removal of cement overhangs.[3,5-8)]

The International Organization for Standardization (ISO)[4)] and American National Standards Institute/American Dental Association (ANSI/ADA)[2)] have published regulations and standardized procedures for quantifying the radiopacity of several types of dental materials. The radiopacity of the materials should be greater than or equal to that of the same thickness of aluminum (purity ≥ 98%). Several authors evaluated the radiopacity of dental materials by a comparison with that of the same thicknesses of enamel and dentin, using an aluminum step wedge as an internal standard.[9-11)]

A digital X-ray system was introduced in dental practice because of its many advantages, such as quantitative analysis using software, low radiation exposure and no need for a film developing process.[12,13)] Many studies used digital radiography to measure the radiopacity of a variety of dental materials.[6,8,13-18)]

Recently, many luting cements have been introduced. As mentioned above, it is important to evaluate the radiopacity, as well as the physical and chemical properties. On the other hand, the radiopacity of contemporary luting cements has not been reported. This in vitro study evaluated the radiopacity of eight dental luting cements using digital radiography.

MATERIALS AND METHODS

1. Specimen preparation

Table I lists the luting cements used in the present in vitro study. Disc-shaped specimens (n = 5/group, diameter: 5 mm, thickness: 1 mm) were

Table Ⅰ. List of luting cements tested in this study

Product	Shade	Lot #	Manufacturer
BisCem	Translucent	1100009289	Bisco Inc., Schaumberg, IL, USA
Clearfil SA Luting	Universal	00251A	Kuraray Medical Inc., Okayama, Japan
Duolink	Translucent	1100006102	Bisco Inc., Schaumberg, IL, USA
Maxcem Elite	Clear	3673633	Kerr Corp., Orange, CA, USA
Multilink Speed	Transparent	P62316	Ivoclar Vivadent, Schaan, Liechtenstein
Panavia F 2.0	Light	00571A, 00110B	Kuraray Medical Inc., Okayama, Japan
RelyX Unicem Clicker	TR	451230	3M ESPE AG, Seefeld, Germany
V-link	transparent	P18601, N01551	Ivoclar Vivadent, Schaan, Liechtenstein

prepared from the materials. The materials were mixed according to the instructions of each manufacturer, compressed between two glass slides in stainless steel, and light-cured using curing light (Elipar TriLight, 3M ESPE, Seefeld, Germany; standard mode). The output intensity of 750 mW/cm^2 was monitored constantly during the experiment using a built-in radiometer. The light-cured specimens were measured with calipers to confirm that the thickness remained at the critical tolerance of 1±0.01mm. Human enamel and dentin specimens with a thickness of 1 mm were also prepared by longitudinal sectioning of a freshly extracted premolar using a slow speed diamond saw (Isomet, Buehler, IL, USA). The patients were informed that their teeth were to be extracted for orthodontic reasons and written informed consent were obtained. The slices were kept in tap water until needed.

2. Digital imaging

An aluminum step wedge was used as an internal standard to measure the equivalent radiopacity of different materials according to their thickness. A 11-step wedge (1.5 mm incremental steps) was machined from a 99.5 % pure aluminum block. Images were taken using a Kodak CS7600 image plate (Carestream Health, Inc., Rochester, NY, USA) and a dental X-ray machine Kodak 2200 Intraoral X-ray System (Carestream Health, Inc., Rochester, NY, USA) operating at 70 kVp, 4 mA and 0.156 s. The source-to-sample distance was 30 cm and the total filtration was equivalent to 2.5 mm of aluminum. Each material along with the aluminum step wedge and tooth specimens were positioned over the sensor on a 2 mm thick lead sheet. Each of the 11 steps of the aluminum step wedge was measured at three different positions for gray values. Three different positions for each specimen were measured and the gray value of each specimen was recorded from the average of the readings. Special care was taken to analyze only those regions, which were free of air bubbles, gaps or similar defects. In a similar procedure, the enamel and dentin slices were also measured in three different regions.

The images, which were free of imaging processing, were saved in 8-bit TIFF format for later radiopacity analysis. In digital radiography, the attenuation from each pixel was sampled and a numeric value representing the gray value was assigned, and used to measure the radiopacity. The gray values of the specimen were analyzed using NIH ImageJ software (available at http://rsb.info.nih.gov/ij/). Subsequently, the gray values were converted to an absorbance using the following equation: $A = -\log(T) = -\log(1-G/255)$, where A is the absorbance, T is the transmission, and G is the gray value (0-255).[14] In five radiographs, each of the 11 steps of the aluminum step wedge was measured for gray values and converted to absorbances. The absorbance of the aluminum steps was plotted as a function of the corresponding thickness and a specific linear model was calculated. The equivalent in thickness of aluminum for each material was calculated from the calibration curve.

3. Statistics

The radiopacity (mm aluminum) is reported as the mean ± standard deviation using SPSS for Windows18.0 (SPSS Inc, Chicago, IL). One-way analysis of the variance with a Tukey HSD post hoc test was used to calculate the significant differences between the groups. A *P* value <0.05 was considered significant.

RESULTS

Table II lists the radiopacity of the luting cements expressed as Al equivalent millimeters. The radiopacity ranged from 0.71 to 5.66 (mm Al). The results of most materials were higher than the radiopacity requirements of the ISO 4049 specifications, whereas the result of RelyX Unicem Clicker was lower than the criteria (0.71).The radiopacity of the dentin and enamel were 0.19 and 1.76 mm Al, respectively. Clearfil SA Luting, BisCem, and Panavia F 2.0 formed a single subunit with no significant intergroup differences, whereas the others were significantly different from each other (*P*<.05).

Table Ⅱ. Mean radiopacity values of luting cements, enamel and dentin

Luting cement/material	Radiopacity (mm aluminum)*
Maxcem Elite	5.66 ± 0.12^{a}
Multilink Speed	3.87 ± 0.15^{b}
V-link	2.83 ± 0.09^{c}
Clearfil SA Luting	1.35 ± 0.07^{d}
BisCem	1.33 ± 0.08^{d}
Panavia F 2.0	1.29 ± 0.09^{d}
Duolink	1.10 ± 0.33^{e}
RelyX Unicem Clicker	0.71 ± 0.13^{f}
Enamel	1.76 ± 0.31^{g}
Dentin	0.19 ± 0.11^{h}

*The same lowercase letters indicate statistically equivalent values among the materials (*P*>0.05).

DISCUSSION

This study was designed to determine the range of radiopacity of luting cements using a digital X-ray system. Eight commercial luting cements were selected. The ISO 4049 specifications require the minimum radiopacity of the restorative materials to be greater than or equal to that of an equivalent thickness of aluminum, which means higher than that of dentin.19) Seven of the eight luting cements met the regulations of the standard ISO. Although RelyX Unicem Clicker showed lower radiopacity than aluminum, its radiopacity was higher than that of dentin, which is sufficient for a diagnosis.

The use of materials with radiopacity that is less than or equal dentin might create diagnostic difficulties.5) In contrast, higher radiopacity, as in amalgam, can cause interference with the detection of voids and the diagnosis of recurrent caries, which can decrease the diagnostic discrimination in areas covered by the restoration.11,20-22) Moderate radiopacity, which is slightly greater than that of enamel, is helpful for diagnosing carious affected or infected tooth structures adjacent to a restoration as well as in determining the homogeneity of the luting cement.23,24)

Direct digital radiography was used to obtain precise and accurate numerical values in the present study. A digital image enables a more detailed analysis using imaging software, which provides gray pixel values.15) The results were compared with the mean values of the aluminum step wedges and dentin. In addition to the reduction of the operator's potential exposure to radiation and elimination of the need for film development chemicals, digital method shows more consistent results.14) Unless performed carefully, the development process can produce significant variations in the final film radiograph. Moreover, film images must be scanned or photographed for software-based analysis, which require extra time.14)

Variations in the radiopacity of the same dental materials among different studies can occur because there are a number of methodological factors, such as those related to the film or sensors, X-ray machines, radiographic processing, and image analysis.8,18,25,26) Another important factor to be considered is the purity of the Al step wedge used as the internal standard, considering the different alloys used as potent filtering objects for radiation. Any alloy changes related to a contaminating agent with a higher or lower atomic number, can significantly alter the radiation spectrum and lead to a different image.27)

Some authors have emphasized the importance of dental tissue cuts as a secondary standard, and expressed the relative radiopacity of materials, enamel, and dentin as the aluminum equivalent values (in mm).9,11) The use of dental tissue cuts as a secondary standard is helpful for evaluating materials with radiopacity between dentin and aluminum with the same thickness, such as RelyX Unicem Clicker.

The physical properties, including radiopacity of dental luting cements can be affected principally by the differences in the quantity and quality of their chemical components.28) In resin-based materials, barium, yttrium, ytterbium, zinc, aluminum, strontium, and zirconium are additives that increase the radiopacity.29) Among the tested luting cements, Maxcem Elite containing ytterbium fluoride was found to be the most radiopaque material followed in order by Multilink Speed and V-link including trifluoride, which is a good radiopacifier and fluoride releasing agent. Barium glass contributes to the high radiopacity of Panavia F 2.0, Clearfil SA Luting and V-link.

CONCLUSION

In the present study, the radiopacity of all materials had a higher equivalent thickness of aluminum indicating that they all fulfilled the ISO requirements except for RelyX Unicem Clicker. Although RelyX Unicem Clicker did not pass the ISO requirements, it shows significantly higher radiopacity than that of dentin.

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디지털방사선촬영술을 이용한 합착용 시멘트의 방사선불투과성 평가

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이 연구의 목적은 치과임상에서 사용되는 8종의 합착용 시멘트의 방사선불투과성을 디지털 방사선 촬영술로 평가하는 것이었다. BisCem, Clearfil SA Luting, Duolink, Maxcem Elite, Multilink Speed, Panavia F 2.0, RelyX Unicem Clicker, V-link의 8종의 재료를 5개의 원형 시편 (직경: 4 mm, 두께: 1 mm)으로 제작하였고 사람 치아의 법랑질과 상아질 시편을 1 mm 두께로 준비하여 알루미늄 스텝 웨지와 함께 촬영하였다. 관전압 70kVP, 관전류 4 mA, 노출시간 0.156초, 초첨 필름간 거리는 30 cm으로 영상판을 이용하여 촬영하였으며, ImageJ 소프트웨어를 이용하여 평균 회색조 수치를 측정하고, 이를 흡수계수로 환산한 후 검량선(calibration curve)을 이용하여 각 합착용 시멘트의 등가 알루미늄 두께를 구하였다. 합착용 시멘트의 평균 방사선불투과성은 알루미늄 두께 0.71 ~ 5.66 mm로, RelyX Unicem Clicker (0.71 mm Al)을 제외하고는 등가 알루미늄 두께 보다 높은 방사선불투과성을 보여 ISO 규격을 만족하였으며, 법랑질은 1.79 mm, 상아질은 0.19 mm 두께의 알루미늄에 해당하는 방사선불투과성을 나타내었다. (**구강회복응용과학지** 2013:29(4):377 – 383)

주요어: 디지털 방사선 촬영술, 합착용 시멘트, 방사선불투과성

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