Original Article

Digital Measurement of Abrasion Volume of Dental Luting Cement at Different Locations of Natural Tooth

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Running title: Dental cement's abrasion resistance of different positions

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Abstract

Purpose: *As the dental root is exposed to the oral cavity, the margin of the fixed partial denture may be located at the crown, neck, or root. The purpose of this in vitro study was to evaluate the abrasion resistance of different dental luting cement at different locations of natural teeth.*

Materials and methods: *A total of thirty-six premolars were divided into four groups with an artificial gap 1mm (±0.15 mm) in depth and 0.2 mm (±0.05 mm) in width at three locations (crown, neck, and root) filled with water-based luting cement, zinc phosphate cement (ZPC), polycarboxylate cement (PC), and resin-based dental resin cement 1 (U200), and resin cement 2 (Maxcem) (n=9). In the abrasion test, all specimens were tested using an abrasion-resistant testing machine with 2 N brushing forces mixed with toothpaste and water (1: 2). Each sample underwent the wear test of 18,000 cycles of brushing, 60 times per minute. 3D-printing software 3D Sprint® (3D system) and exocad DentalCAD (exocad GmbH) software were used to measure the amount of abrasion. Statistical analysis was performed by using one-way ANOVA and repeated-measure ANOVA (α=0.05).*

Results: *From the average wear perspective of average wear, PC had the most considerable amount of abrasion, followed by ZPC, Maxcem, and U200. The average amounts of crown, neck, and root abrasion of PC were 0.403±0.212, 0.482±0.354, and 0.27±0.153 mm^3, while the average amounts of crown, neck, and root abrasions of U200 were 0.123±0.057, 0.083±0.04, and 0.086±0.042 mm^3 respectively. Among the four adhesives, the amount of abrasion on different positions of the teeth showed no significant difference (P>.05); however, water-based and resin-based luting cement were significantly different (P<.05).*

Conclusion: *This study indicated that resin-based cement is more resistant to brushing than water-based cement. There was no significant difference in wear when the same adhesive was used at different locations of the tooth.*

Key words: anti-abrasion test, water-based cement, resin-based cement, natural tooth

Introduction

When rehabilitating oral cavity with fixed partial dentures, the smallest possible marginal discrepancy between the prosthesis and abutment tooth to minimize the risk of disease development is the essential criteria. Although the marginal opening of the fixed partial denture is not clinically detected, the microscopic gaps are set in approximately 100 μm sufficient for penetration of bacteria[1,2]. Luting cement is designed to fill the microscopic gaps between a prosthesis and a prepared tooth. Cement is classified as water-based, oil-based, or resin-based products. Zinc phosphate cement (ZPC), zinc polycarboxylate cement (PC), and glass-ionomer cement (GIC) are all water-based cement with phosphate bonding or polycarboxylate chelation. Zinc oxide-eugenol cement is an oil-based cement that is useful for short-term cementation of the prosthesis, while resin-based luting cement is a variety of tooth-colored resins with high strength and low film thickness. ZPC and PC luting cement bond to the tooth structure via acid and metal oxide bases to form a salt and water. The anti-abrasion ability might be related to the property of tensile bond strength, solubility, and microleakage. Parameswari et al. [3] measured the tensile bond strength of ZPC, GIC, and PC, ZPC was found more efficacious than PC, which concluded that the PC might be weaker associated with the reduced film thickness. In terms of solubility, Karkera et al. [4] tested GIC, ZPC, polyacid-modified resin cement, PC and resin-modified glass ionomer (RMGIC) respectively. Among the above, the solubility to water for both ZPC and PC are similar. With regard to microleakage, Mohajerfar et al. [5] evaluated ZPC, glass-ionomer, Speed CEM and Panavia, while Vesna Medić et al. [6] assessed ZPC, PC, glass-ionomer and resin cement. Both parties obtained the result that ZPC had the highest microleakage and PC had microleakage close to ZPC, thus it is controversial to compare the anti-abrasion abilities of PC and ZPC.

When it comes to resin cement, they generally have good physical properties, such as high compressive and tensile strengths, and are not easily soluble in water. There are three types of resin cement: total etch-and-rinse adhesives, self-etch adhesives, and self-adhesives. The self-adhesive resin cement without separate adhesive steps has become more and more popular for clinical use. Studies have shown that the self-adhesives' mechanical properties such as shear bond strengths and bonding resistance are not as effective as those of three-step resin cement[7-11]; besides, Furuichi[7] compared five self-adhesive resin cement (G-CEM LinkAce, BeautiCem SA, Maxcem Elite, Clearfil SA Automix, and RelyX Unicem 2) and found that Maxcem had the most volume loss after measuring the wear resistance of various resin cements.

Attrition will induce loss in occlusal enamel and no antagonist causes an abnormal eruption of the tooth. Another reason for root exposure is gingival recession[12] or crown-lengthening procedure[13]. Most enamel crystals are rod-shaped to form enamel prisms, and there are insufficient data of morphological and microchemical changes in the enamel associated with possible sign of aging[14]. The anatomic root is found below the neck and is covered with cementum. Restoration margin placement is important for those teeth where retention and resistance form is needed. The contour of the tooth may require alteration for both biological and esthetic reasons and maintain a good level of hygiene is a must.[2,15]

While preparing the tooth for a fixed partial denture, the margin of the fixed partial denture may be located at the crown, neck or root. As there are no studies on brushing resistance at different natural tooth positions, this study aimed to examine the anti-abrasive ability of different dental luting cements at different natural teeth locations under the same brushing frequency and intensity.

Materials and methods

Thirty-six premolars were collected in this study. This study was approved by the Human Research Ethics Committee of Kaohsiung Medical University Chung-Ho Memorial Hospital IRB, Kaohsiung ROC. (IRB code: KMUHIRB-E(II)-20190243).

Extracted human teeth without caries or filling restoration were stored at room temperature and used as tooth specimens. No cervically abraded teeth were included in this study.

Figure 1 shows that 5 mm above the premolars' neck and 5 mm below the neck was retained and embedded in the composite resin ring with the buccal side up. Then, two re-entrant angles off the composite resin ring were cut to let the teeth steadily stand on the pedestal of the 3D Coordinate Measuring Machine (3D CMM). Finally, low-speed handpieces (ULTIMATE XL - NSK-Nakanishi International) were used to create an artificial cut with 1mm (± 0.15 mm) in depth and 0.2 mm (± 0.05 mm) in width at three locations, being crown,

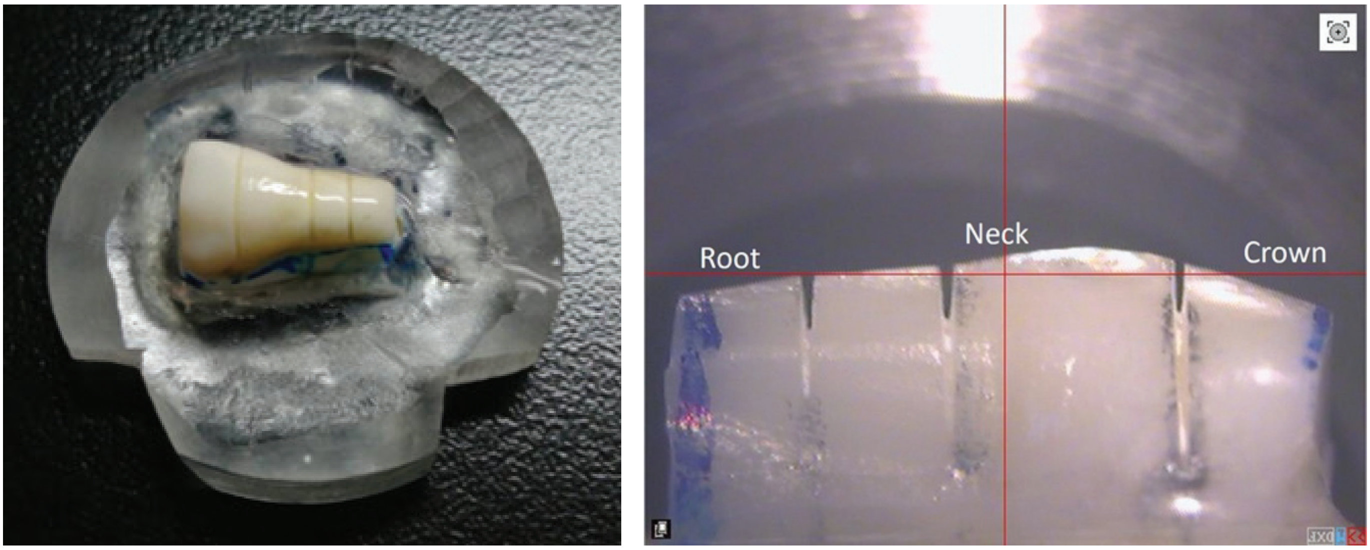

Figure 1. Pictures of sample with three artificial cut in 3D CMM. A. labial view B. proximal view.

Table 1. Component of Dental cement tested in anti-wearing test.

Code	Type	Product	Manufacturer	Lot No.
PC	Polycarboxylate	GC-Livcarbo	GC	1805011
ZPC	Zinc Phosphate	Super Cement	SHOFU	051547
Maxcem	Self-adhesive resin	MAXCEM	KERR	7040052
U200	Self-adhesive resin	RelyX U200	3M	4668351

neck, and root (Fig.1). The 0.2 mm (± 0.05 mm) in width simulated the marginal gap.

The following four materials were used to evaluate the anti-abrasive ability of dental cement. GC-Livcarbo (PC, Tokyo, Japan) was used to present polycarboxylate cement, SHOFU Super Cement (ZPC, Kyoto, Japan) was used to present zinc phosphate, and MAXCEM Elite Chroma (MAXCEM, KERR CA, USA) and RelyX U200 (U200, 3M, Germany) were used to present self-adhesive resin (listed in Table1). We distributed all 36 samples into four groups randomly, being PC, ZPC, Maxcem, and U200 respectively.

All of the samples were filled with the cement, which was mixed according to the manufacturer's recommended procedures. Finally, the samples were set completely before testing for both PC and ZPC; as for the other groups that included Maxcem and U200, samples were cured by dental curing light following the manufacturer's recommended time set.

The height that counts from the junction of tooth and composite resin ring to the most convex point at the surface at crown, neck and root were recorded with the 3D CMM and exocad DentalCAD (exocad GmbH) after filling with the cement. The Initial specimens were scanned with desktop scanner (3Shape, Copenhagen, Denmark), and initial data were stored as STL files.

In the abrasion test, six premolars that being unprepared were used as a pilot study. The machine used was an abrasion-resistant testing machine (PAT2012 fully automatic abrasion, Bo Yi Jing, Taiwan). The American Dental Association recommends brushing the teeth twice a day and for at least 2 min [16]. To simulate the real brushing force (2 Newtons) [16], we placed 200g on the toothbrush, then added toothpaste (SENSODYNE RAPID RELEIF) mixed in water with a ratio of 1: 2, and each sample underwent the wear test of 18,000 cycles of brushing, 60 times per minute. The wear volumes were accounted for by a 3S sprint (3D System, USA).

One-way ANOVA was used to analyze the difference between the amount of abrasion of each cement on the same tooth location, using repeated-measure ANOVA to analyze the difference between abrasion at three different locations when using the same cement. The G*Power version 3.1.9.2 was applied to estimate the sample size (Franz, Universitat Kiel, Germany), and the power analysis was used for a fixed effect

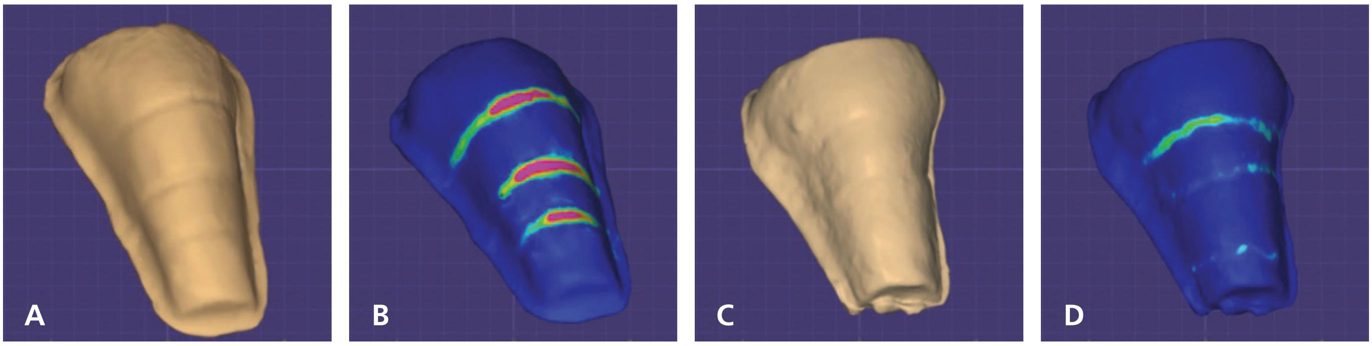

Figure 2. The abrasion picture of water-based and resin-based luting cement. A. STL file of ZPC after rest. B. 3D image superimposition before and after test of ZPC at crown, neck, and root. C. STL file of U200 after test. D. 3D image superimposition before and after test of U200 at crown, neck, and root.

Table 2. Abrasion of different types of cement and locations of marginal gap after anti-abrasive test (mm³).

Cement \ The location of cut	Crown M ± SD	Neck M ± SD	Root M ± SD	P value (same cement vs. different location)
PC (n= 9)	0.403±0.212	0.482±0.354	0.27±0.153	neck vs crown=0.1679 Crown vs root=0.4803 neck vs crown=0.7681
ZPC (n=9)	0.367±0.08	0.32±0.127	0.267±0.115	neck vs crown=0.1207 Crown vs root=0.5318 neck vs crown=0.6070
Maxcem (n=9)	0.16±0.076	0.152±0.042	0.134±0.09	neck vs crown=0.7602 Crown vs root=0.9137 neck vs crown=0.9504
U200 (n=9)	0.123±0.057	0.083±0.04	0.086±0.042	neck vs crown=0.7113 Crown vs root=0.8285 neck vs crown=0.9771

Different superscript letters in a column indicate statistical significance among groups.

$P<0.05$ * (post hoc Dunnett T3 test) *

One-way ANOVA; Repeated-measure ANOVA; M: Mean; SD: Standard deviation

one-way ANOVA. With a significant criterion of $\alpha=0.05$ and an estimated effect size of 0.67, the power was at least 82.39%.

Results

In the pilot study, there was no significant difference in the process of before and after brushing.

The average crown, neck, and root abrasions of nine samples that used PC were 0.403±0.212 (mm^3), 0.482±0.354 (mm^3), and 0.27±0.153 (mm^3) respectively. In nine samples that used ZPC, the average crown, neck, and root abrasions were 0.367±0.08 (mm^3), 0.32±0.127 (mm^3), and 0.267±0.115 (mm^3) respectively. The average crown, neck, and root abrasions of nine samples that used Maxcem were 0.16±0.076 (mm^3), 0.152±0.042 (mm^3), and 0.134±0.09(mm^3) respectively. The average crown, neck and root abrasions of nine samples that used U200 were 0.123±0.057 (mm^3), 0.083±0.04 (mm^3), and 0.086±0.042 (mm^3) respectively. Figure 2 shows the water-based and resin-based luting cement superimposition images before and after testing. These results are listed in Table 2. There was no statistical significance at different locations on the samples using different cements.

Table 3 shows the different materials at crown, neck and root representing the four cement abrasions all had a statistical difference ($P< 0.05$). Moreover, for the margin at crown and root, the abrasion volume of resin-based cement was significantly different from that of water-based cement. For the margin at neck area, P-value equaled 0.0002 representing the abrasion of the four cements exhibited statistical difference; however, besides U200 vs Maxcem and PC vs ZPC, ZPC vs Maxcem showed no significant difference at the neck area for anti-abrasion volume (P= 0.217). Further analysis of the statistical dependence between the two materials at the same location is shown in Table 3.

Table 3. P value between materials under the same tooth location.

Cement \ The location of cut	Crown	Neck	Root
P value (same location versus different cement)	<0.0001*	0.0002*	0.0005*
PC versus Maxcem	0.0005*	0.041*	0.0362*
PC versus U200	<0.0001	0.0002*	0.0027*
ZPC versus Maxcem	0.0031*	0.217	0.0419*
ZPC versus U200	0.0004*	0.002*	0.003*
Maxcem versus U200	0.906	0.245	0.751
PC versus ZPC	0.9125	0.8491	0.9999

Discussion

The results showed that the four cements had significant wear at crown, neck and root respectively; however, at different tooth positions, the trend was similar, although the water-based cement had a higher abraded volume than resin-based ones. Only ZPC versus Maxcem at the neck area showed no significant difference by using the Dunnett T3 post-hoc test. The factors might be the morphology at the neck area being more convex and easily worn, however, abraded volume for ZPC (water-based) was still higher than Maxcem (resin-based).

This finding was consistent with Trumpaite-Vanagiene's research[17]. He also indicated that water-based cement was inclined to wear due to its material property and powder-liquid formulation; similarly, Fernando Carlos Hueb had noted that the polymers formed during the polymerization process incorporated water molecules through hydrogen[18-20], altering the composition of the solid substances formed. This cross-binding enhances the microhardness of resin-based cement and makes it more durable to the ones that are water solution derived[21].

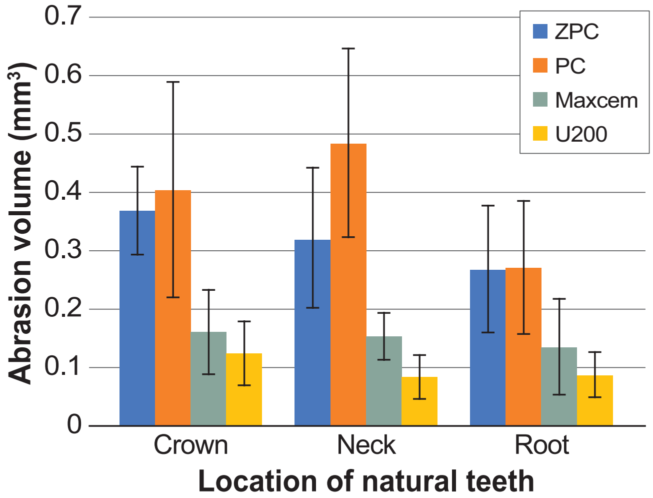

Figure 3. The abrasion of different locations and cements.

Further analysis of PC and ZPC differences revealed that PC has higher average abrasion than ZPC (Fig 3.). Therefore, despite both PC and ZPC being water-soluble dental cements, ZPC showed better abrasion resistance[20,22,23]. ZPC is a water-based material which is fully set following by acid-base reaction between zinc-oxide powder and an aqueous phosphate acid solution. Polycarboxylate cement is mainly formed by zinc oxide and polyacrylic acid in water, and these two materials showed the hydrophilic nature of a polymer in the results of monomers and polymerization linkages; however, the PC presents hydroxyl, carboxyl groups in monomers and their resultant polymer make them more hydrophilic and more prone to water absorption in their formulation. Ghanim has confirmed these findings[24].

This study determined that the polycarboxylate cement showed the highest value of abrasion followed by zinc phosphate. The two types of resin-based cement revealed that their abrasion-tested values were much lower than it is for the water-based cement. The anti-abrasive ability would be influenced more by cement types rather than the position where the cement was filled. These results could further infer that the anti-abrasive ability might be associated with the cement's water solubility of cement used. Neshandar Aslli et al discovered that PC is the most water-soluble, follow by ZPC, and the resin-based cement is the least soluble one[25].

The results showed that ZPC wear on the

crown tended to be greater than the wear on the neck and root. These factors might be related to the structure of dentin and enamel. After cutting, the dentin will have many cross-cut dentin tubules on the cut surface, and the cut surface of the enamel will be relatively smoother. Although the formation process is formed by stacking layers of rods, interrod enamel will fill the gaps in the formation of rods[26], so the dentin tubules on the dentin provide a rougher environment than does enamel. On the other hand, It might be due to PC was more prone to water solubility and the neck's morphology was more convex and therefore more readily contacted by the brush, thus PC wear at the neck was greater than that at the crown and root..

The purpose of this experiment was to determine the anti-abrasive ability of different cements when the cement was applied to the different locations of crown, root, or neck. However, the study's limitation was the insufficient sample size, which needs to be increased to gather more evidence and the morphology of tooth size, which could not be controlled completely. Further research could evaluate the property of tensile bond strength, solubility of luting cement, apply additional cement types, samples and change the brush force to validate the anti-abrading ability of dental luting cement.

Conclusions

Within the limitations of this study, the following conclusions can be drawn:

1. Resin-based cement performs better in abrasion resistance than water-based cement.
2. There is no significant difference in the amount of wear at three different tooth locations when using resin-based or water-based cement.

Conflicts of interest

The authors declare no conflicts of interest.

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