



# Effect of abutment neck taper and cement types on the amount of remnant cement in cement-retained implant restorations: an *in vitro* study

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**PURPOSE.** The present study aims to analyze the effect of abutment neck taper and types of cement on the amount of undetected remnant cement of cement-retained implant prostheses. **MATERIALS AND METHODS.** Three neck taper angles (53°, 65°, 77°) and three types of cement (RMGI: resin-modified glass ionomer, ZPC: zinc phosphate cement, ZOE: zinc oxide eugenol cement) were used. For each group, the surface percentage was measured using digital image and graphic editing software. The weight of before and after removing remnant cement from the abutment-crown assembly was measured using an electronic scale. Two-way ANOVA and Duncan & Scheffe's test were used to compare the calculated surface percentage and weight of remnant cement ( $\alpha = .05$ ). **RESULTS.** There were significant differences in remnant cement surface percentage and weight according to neck taper angles ( $P < .05$ ). However, there were no significant differences in remnant cement surface percentage and weight on types of cement. No interaction was found between neck taper angles and types of luting cement ( $P > .05$ ). The wide abutment with a small neck taper angle showed the most significant amount of remnant cement. And the types of luting cement did not influence the amount of residual cement. **CONCLUSION.** To remove excess cement better, the emergence profile of the crown should be straight to the neck taper of the abutment in cement-retained implant restoration. [J Adv Prosthodont 2022;14:162-72]

## KEYWORDS

Dental implants; Cementation; Dental abutments; Dental cements; Peri-implantitis

## INTRODUCTION

For many years, one of the main interests in implant dentistry has been the

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successful osseointegration of dental implants.<sup>1</sup> Following the development of implants, there has been considerable research interest regarding the maintenance of the function of already osseointegrated implants in the oral cavity.<sup>2</sup> Studies have actively focused on achieving esthetics and minimizing the occurrence of peri-implantitis, a potential hazard of dental implants.<sup>1,3</sup> To fabricate an esthetic implant prosthesis, it is essential for the crown margin to extend slightly into the gingival sulcus and to achieve a soft tissue morphology as physiologically realistic as possible.<sup>4,5</sup> Two main types of implant-supported prostheses are used in fixed partial dentures: screw-retained and cement-retained prostheses. The main advantage of the screw-retained implant-supported prostheses is retrievability,<sup>2</sup> and such retrievability can also be achieved for cement-retained prostheses using provisional cement.<sup>6</sup> Furthermore, cement-retained implant-supported prostheses are more esthetic than screw-retained prostheses.<sup>7</sup> In sites with high esthetic demand, such as anterior maxillary implants, there are many occasions when cement-retained types are the only option that can be taken according to the implant access hole opening location. However, a disadvantage of the cement-retained implant-supported prostheses is the difficulty of removing excess cement from the subgingival margins.<sup>2</sup> Remnant cement is generally observed after removing excess cement in the subgingival margin; in many cases, this remnant cement is associated with peri-implantitis.<sup>8-10</sup> Furthermore, incomplete cement removal causes peri-implant inflammation, soft tissue swelling, soreness, and bleeding or exudation on probing.<sup>9</sup> The screw-cement retained prostheses (SCRPs) type combines the strengths of cement type and screw type prostheses and has the advantage of retrievability. However, there are cases where it cannot be used depending on the location of the access hole.<sup>11,12</sup>

Recently, computer-aided design and computer-aided manufacturing (CAD-CAM) abutments have been commonly used in implant prosthodontics. In the process of designing the CAD-CAM abutment, the neck taper angle, margin position, and taper angle of the abutment can also be set, so it is widely used in daily practice. CAD-CAM abutments offer several ad-

vantages: esthetic emergence profile, ideal anatomic contour, angulation correction, more precise fit, and better physical properties.<sup>13-15</sup> An ideal emergence profile and optimal setting of the margin location lead to optimal esthetic results and enable the fabrication of a prosthesis that allows for easy oral hygiene management. In a study comparing residual cement between custom-made and standard abutments, the use of custom-made abutments did not guarantee the absence of residual cement. The reasons for the more significant amounts of undetected cement in the custom-made abutments might be their various neck taper angles and gingival margin locations.<sup>16</sup> Although many studies have investigated remnant cement according to the margin location,<sup>17</sup> few have assessed the effects of the neck taper angle of CAD-CAM abutments on remnant cement. Therefore, we aimed to evaluate the amounts of remnant cement according to various neck taper angles of CAD-CAM abutments and cement types. The null hypothesis was that the neck taper angle and types of cement do not affect the amount of remnant cement.

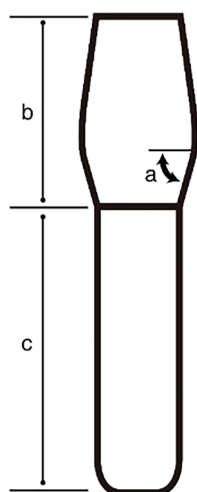
## MATERIALS AND METHODS

A sample size of 10 was chosen since a power analysis in a previous study with similar materials and methodology calculated a minimum sample size of 2 (assuming  $\alpha = .05$  and  $\beta = .05$ ).<sup>17</sup> In total, nine experimental groups were included in this study: groups with neck taper angles of 53°, 65°, and 77°; and cement types of resin-modified glass ionomer cement (RMGI; Fujicem 2, GC, Tokyo, Japan), zinc phosphate cement (ZPC; Hy-bond zinc cement, Shofu Inc., Kyoto, Japan), and zinc oxide eugenol cement (ZOE; Tempbond, Kerr, Orange, CA, USA). Ten specimens were included for each group (Table 1). The neck taper angle was defined as the angle between the axial wall of the abutment and the margin of the crown (Fig. 1).<sup>18</sup> The neck taper angles in this study imitated healing abutments with a height of 5 mm and diameters of 7, 6, and 4.5 mm (TSHA705R, TSHA605R, TSHA455R; Osstem Co., Seoul, Korea). The most common three types of definitive cementation materials in implant restoration were used as the cement in this study.<sup>19</sup>

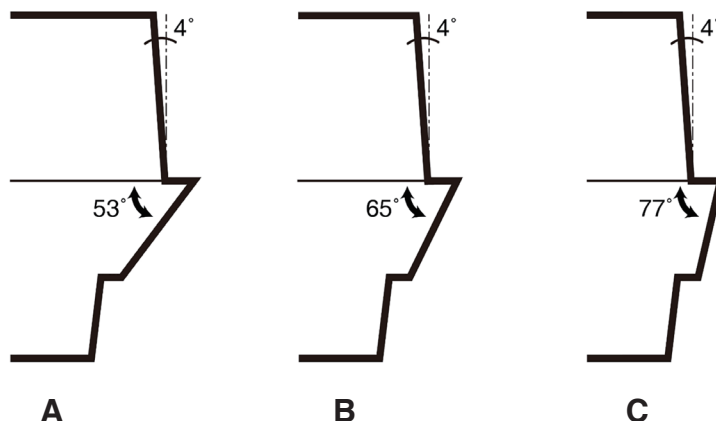
**Table 1.** Study design

	RMGI	ZPC	ZOE
53° neck taper (wide)	Group WRG (N = 10)	Group WZP (N = 10)	Group WZO (N = 10)
65° neck taper (regular)	Group RRG (N = 10)	Group RZP (N = 10)	Group RZO (N = 10)
77° neck taper (narrow)	Group NRG (N = 10)	Group NZP (N = 10)	Group NZO (N = 10)

RMGI: resin-modified glass ionomer, ZPC: zinc phosphate cement, ZOE: zinc oxide eugenol cement.



**Fig. 1.** Illustration of neck taper angle: (a) neck taper angle, (b) CAD-CAM abutment, (c) implant fixture.



**Fig. 2.** CAD-CAM abutment design. (A) wide abutment - 53° neck taper angle, (B) regular abutment - 65° neck taper angle, (C) narrow abutment - 77° neck taper angle.

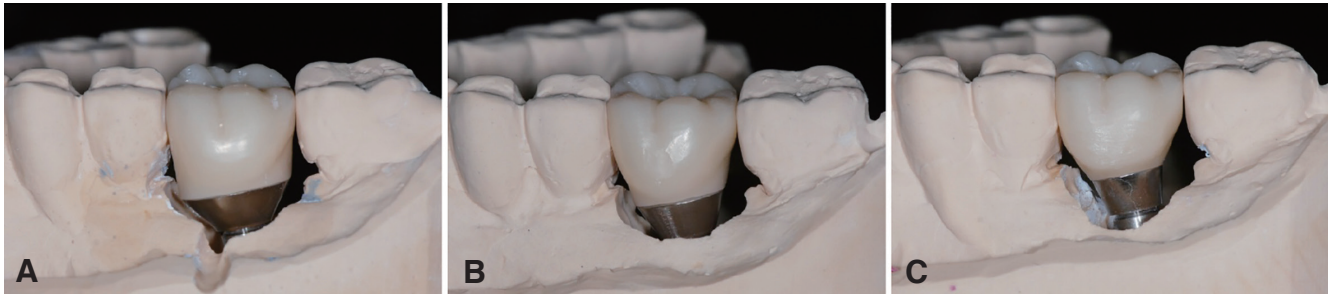
A cast in which an implant (5.0 × 10 mm, TS III; Osstem Co., Seoul, Korea) was placed in the first molar area was used. Clear autopolymerizing acrylic resin (Orthocryl; Dentaureum, Ispringen, Germany) was used to manufacture a master cast. To fabricate three CAD-CAM abutments with different neck taper angles, dental stone (GC FujiRock EP; type 4 dental stone, GC Europe, Leuven, Belgium) casts were manufactured by duplicating three identical casts.

Three different CAD-CAD titanium abutments were designed with different neck taper angles (53°, 65°, and 77°). A total of 90 abutments were manufactured with different neck taper angles (Fig. 2). The convergence angle of all abutments was designed to be 8°. Furthermore, an implant-supported zirconia crown was manufactured for each CAD-CAM abutment (Fig. 3). The implant crowns were screw-cement retained prostheses (SCR type) to enable retrievability for remnant cement measurement following cementa-

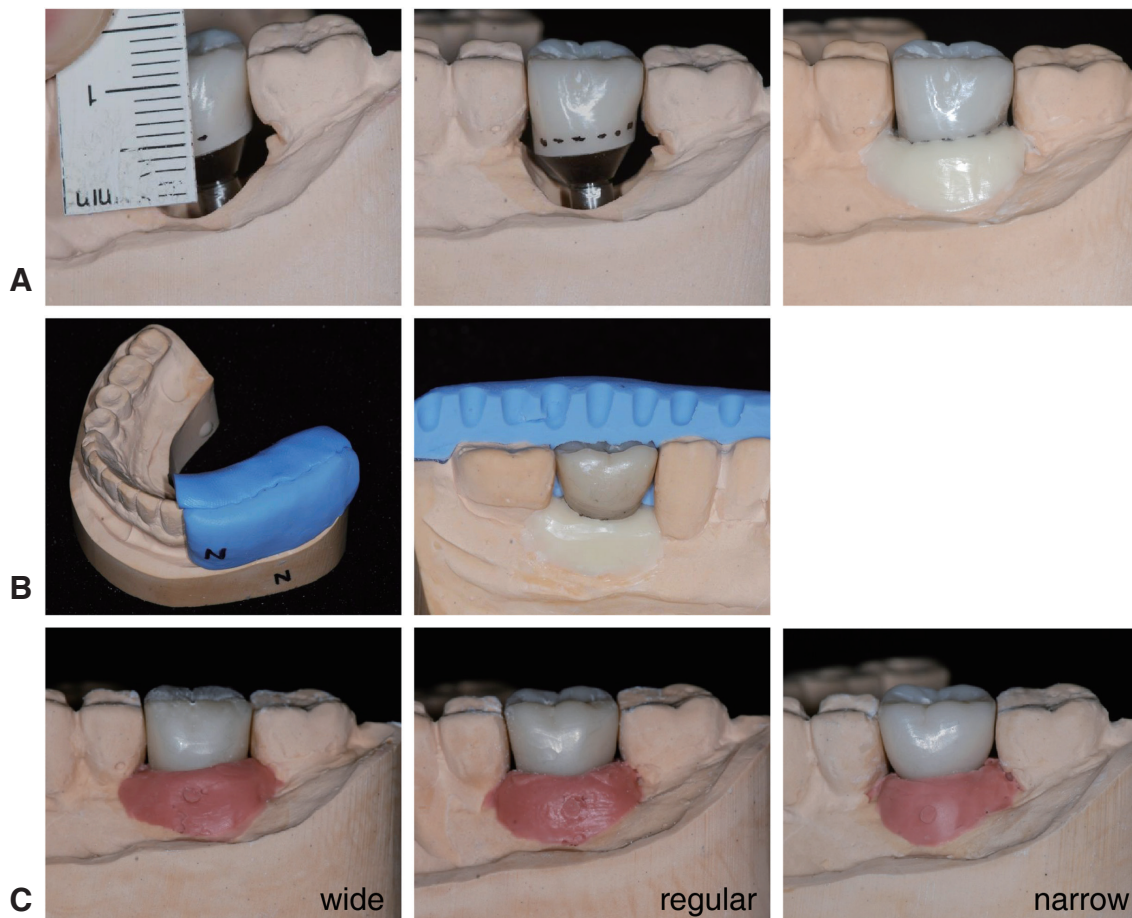
tion. After setting the CAD-CAM abutment and zirconia implant crown in the cast, the gingiva was waxed-up for each abutment to be placed 1 mm subgingival (Fig. 4A).

An index was made using putty (Aquasil Soft Putty-Regular Set; Dentsply DeTrey GmbH, Konstanz, Germany) for manufacturing artificial gingiva on a model with completed wax gingiva. To obtain the correct shape of the interdental gingiva, the putty index was fabricated in two steps such that it could be separated by buccolingual. The wax gingiva was removed from the model, and the putty index with a small buccolingual hole was firmly placed (Fig. 4B). Polyvinylsiloxane material (Examixfine; GC Co., Tokyo, Japan) with low viscosity was injected into the putty index to obtain the morphology of wax gingiva (Fig. 4C).

Before cementation, the zirconia crown was sandblasted at 3 bar pressure with alumina particles for 20 s at an operating distance of 10 mm with a sand-



**Fig. 3.** Fabrication of CAD-CAM abutments and zirconia prostheses. (A) wide abutment - 53° neck taper angle, (B) regular abutment - 65° neck taper angle, (C) narrow abutment - 77° neck taper angle.



**Fig. 4.** Fabrication of artificial gingiva. (A) gingival wax-up at subgingival 1 mm, (B) fabrication of putty index, (C) injection polyvinylsiloxane to simulate the gingiva.

blaster (Renfert Basic eco; Renfert GmbH, Hilzingen, Germany).<sup>20</sup> The CAD-CAM milled titanium abutment was used as is. The constant amount of cement was mixed according to the manufacturer's protocol and placed at 1/2 the height of the inner surface of the zirconia crown. A constant force of 10 N was axially ap-

plied using a static load compression tester (Instron model 4201; Instron Co., Boston, MA, USA) to cement the zirconia crown on the CAD-CAM abutment.<sup>21</sup> After the setting time recommended by the manufacturer, excess cement was removed by the same researcher using a dental explorer (Trudent, New Delhi, India) as

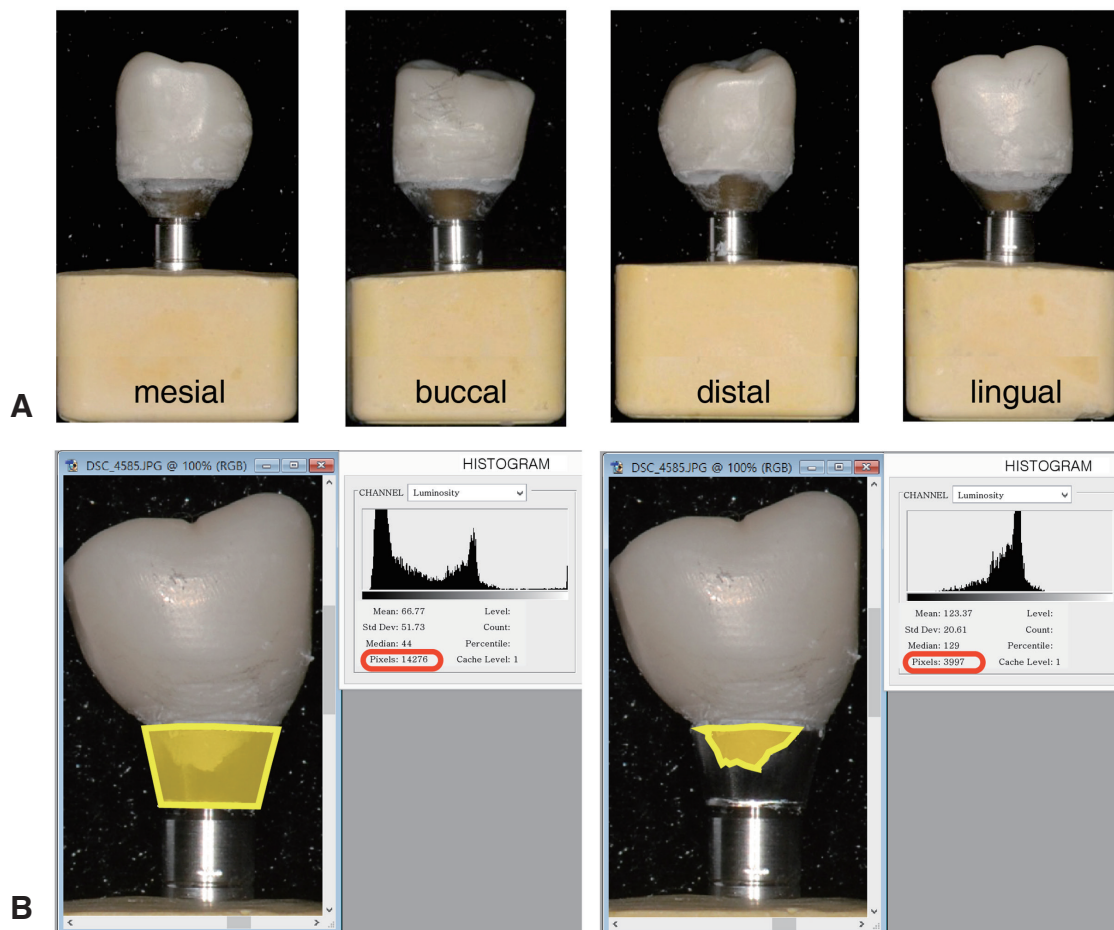
follows: five strokes each for the mesiobuccal, buccal, distobuccal, mesiolingual, lingual, and distolingual aspects.

The abutment-crown assembly was removed from the model to measure the amount of remnant cement, and digital images of the mesial, distal, lingual, and buccal aspects were obtained (Fig. 5A). All four quadrants (mesial, distal, labial, and lingual) of the abutment-crown assembly were photographed using a specially constructed device to keep the standardized 16mm distance between the photo camera (Canon, Lake Success, NY, USA) and the restoration.<sup>22</sup> Using the pen tool in graphic editing software (Adobe Photoshop CS3; Adobe, San Jose, CA, USA), the entire abutment surface and the surface occupied by the remnant cement were defined. The number of pixels

in each area was recorded (Fig. 5B). The images had a resolution of 300 pixels per inch, and all images were magnified at 100% for measurements. The ratio of the area occupied by remnant cement among the total abutment area was calculated using the following formula:<sup>17</sup>

$$\text{Remnant cement ratio (\%)} = (\text{Remnant cement surface area} / \text{total abutment surface area}) \times 100$$

The amount of remnant cement was also measured by calculating the weight. The weight before and after removing remnant cement from the abutment-crown assembly was measured using an electronic scale. The difference between the two weights was calculated to measure the weight of the remnant cement according to the following formula:<sup>17</sup>



**Fig. 5.** Remnant cement surface area analysis. (A) All four quadrants (mesial, buccal, distal, lingual) of removed crown-abutment assembly were photographed using the digital camera, (B) Outlining total abutment surface and remnant cement surface and recording pixel numbers using Adobe Photoshop CS3.

Remnant cement weight (mg) = (crown-abutment weight before remnant cement removal) – (crown-abutment weight after remnant cement removal)

Statistical analysis of the data was conducted using SPSS version 18.0 (SPSS Inc., Chicago, IL, USA). The Shapiro-Wilk test was conducted to assess the normality of the data after calculating the mean and standard deviation of each experimental group. All experimental groups showed a normal distribution. A two-way analysis of variance (ANOVA) was conducted to assess the significance of remnant cement between each experimental group according to the neck taper angle of the abutment and types of cement. Duncan and Scheffe’s tests were conducted as post-hoc analysis ( $\alpha = .05$ ).

## RESULTS

The remnant cement surface was assessed according to the types of cement and neck taper angle. It was the lowest ( $25.32 \pm 9.24\%$ ) in the group with  $65^\circ$  neck taper angle (regular abutment) and RMGI cement and was the highest ( $66.17 \pm 6.35\%$ ) in the group with  $53^\circ$  neck taper angle (wide abutment) and ZPC cement (Table 2). The Shapiro-Wilk test was performed and all experimental groups showed a normal distribution. The two-way ANOVA showed a significant difference in the remnant cement surface according to the neck taper angle ( $P < .05$ ); however, there were no significant differences based on the types of cement

( $P > .05$ ). Further, there was no significant correlation between cement type and neck taper angle ( $P > .05$ ) (Table 3). Duncan and Scheffe’s tests revealed that the remnant cement surface was the greatest in the group with a neck taper angle of  $53^\circ$ , followed by the groups with neck taper angles of  $77^\circ$  and  $65^\circ$ . The differences among the three groups were significant (Fig. 6).

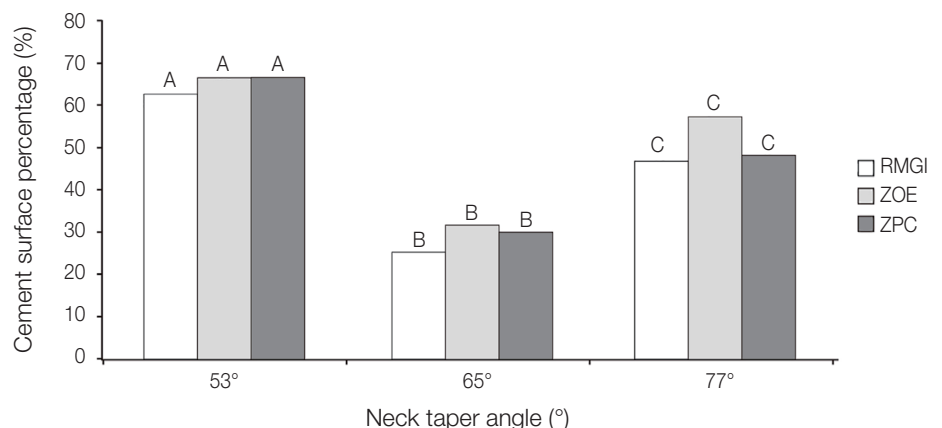
**Table 2.** Remnant cement surface percentage (%)

Group	Types of cement	Mean ( $\pm$ SD) (%)
Wide	WRG	62.3604 (6.7346) <sup>a</sup>
	WZP	66.1743 (6.3500) <sup>a</sup>
	WZO	66.0619 (5.4681) <sup>a</sup>
Regular	RRG	25.3241 (9.2442) <sup>b</sup>
	RZP	29.5902 (6.3158) <sup>b</sup>
	RZO	31.4357 (10.6592) <sup>b</sup>
Narrow	NRG	46.7257 (8.6218) <sup>c</sup>
	NZP	47.8273 (12.2444) <sup>c</sup>
	NZO	57.1590 (5.7737) <sup>c</sup>

Means followed by the same letter are not significantly different ( $P < .05$ ).

**Table 3.** Two-way ANOVA analysis of remnant cement surface percentage

Surface	df	Mean square	F	P
Cement	2	342.583	5.037	.317
Taper	2	9904.776	145.626	<.001
Cement + taper	4	65.679	0.966	.431



**Fig. 6.** Comparison of remnant cement surface percentage according to neck taper angle. Means followed by the same letter are not significantly different ( $P < .05$ ).

The weight of remnant cement according to the types of cement and neck taper angle was also evaluated. The remnant cement weight was the lowest ( $3.80 \pm 2.13\%$ ) in the group with  $65^\circ$  neck taper angle (regular abutment) and RMGI cement and was the highest ( $16.77 \pm 8.52\%$ ) in the group with  $53^\circ$  neck taper angle (wide abutment) and ZOE cement (Table 4). The two-way ANOVA did not reveal significant differences in the weight according to the cement type ( $P > .05$ ); however, there was a significant difference in the weight according to the neck taper angle ( $P < .05$ ). There was no significant correlation between cement type and neck taper angle ( $P > .05$ ) (Table 5). Duncan & Scheffe's tests showed that the weight of remnant cement was the greatest in the group with a neck taper angle of  $53^\circ$ , followed by those with neck taper angles of  $77^\circ$  and  $65^\circ$ . The weight of remnant cement was significantly greater in the group with a neck taper angle of  $53^\circ$  than those in the groups with neck taper angles of  $77^\circ$  and  $65^\circ$ , respectively (Fig. 7).

## DISCUSSION

The amount of remnant cement was evaluated according to the neck taper angle of CAD-CAM abutments and types of cement. The null hypothesis was that the neck taper angle and types of cement do not affect the amount of remnant cement. The results revealed that the surface area and weight of remnant cement differed significantly according to the neck taper angle ( $P < .05$ ); however, there were no significant

**Table 4.** Remnant cement weight (mg)

Group	Types of cement	Mean ( $\pm$ SD) (mg)
Wide	WRG	10.43 (4.56) <sup>a</sup>
	WZP	12.90 (4.28) <sup>a</sup>
	WZO	16.77 (8.52) <sup>a</sup>
Regular	RRG	3.80 (2.13) <sup>b</sup>
	RZP	6.04 (2.13) <sup>b</sup>
	RZO	5.12 (1.48) <sup>b</sup>
Narrow	NRG	4.81 (1.33) <sup>b</sup>
	NZP	6.08 (2.05) <sup>b</sup>
	NZO	6.10 (0.93) <sup>b</sup>

Means followed by the same letter are not significantly different ( $P < .05$ ).

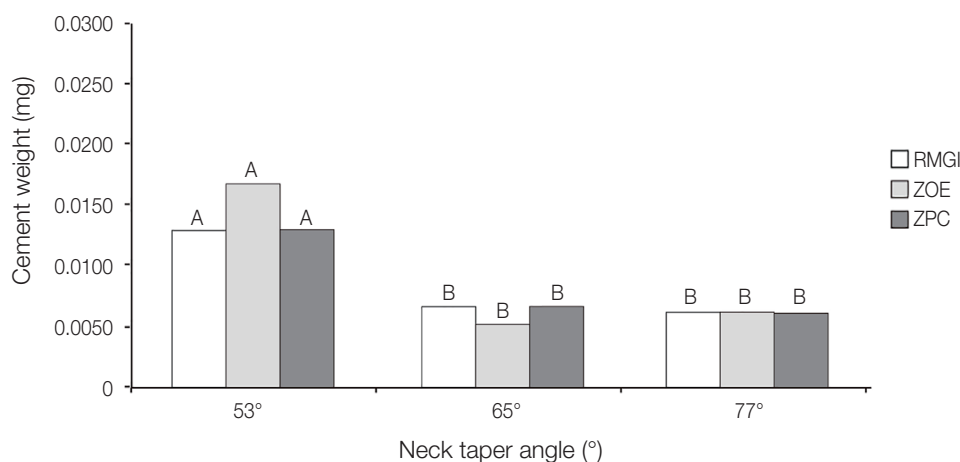
**Table 5.** Two-way ANOVA analysis of remnant cement weight

Weight	df	Mean square	F	P
Cement	2	7.168E-05	4.966	.092
Taper	2	.001	43.817	<.001
Cement + taper	4	2.805E-05	1.944	.111

differences according to the types of cement ( $P > .05$ ). Therefore, the null hypothesis was partially rejected.

Several studies have investigated the factors affecting the remnant cement of cement-retained implant-supported prostheses. Most of these studies assessed the gingival margin location.<sup>16</sup> Some studies also compared custom-made and standard abut-

**Fig. 7.** Comparison of remnant cement weight according to neck taper angle. Means followed by the same letter are not significantly different ( $P < .05$ ).



ments.<sup>17</sup> In the current study, to identify a fundamental method to reduce the amount of remnant cement, we focused on the contour of the abutment and crown. The neck taper angle of abutments is located below the prostheses and is challenging to observe in clinical situations visually. Additionally, the selection of stock abutments is often overlooked, and the operator does not carefully design CAD-CAM abutments.

To observe differences in the amount of remnant cement according to the neck taper angle of an abutment with a specific neck taper angle and crown were designed. Then, the gingiva was waxed up to make the margin location 1 mm subgingival. Next, after duplicating it, artificial gingiva was made using rubber gum. If the gingiva is manufactured first, and then abutments and prostheses of different sizes and shapes are installed, the amount of gingival displacement during installation may be different. This impedes the identical replication of the margin condition, located 1 mm subgingivally. A polyvinyl siloxane material with low viscosity and similar elasticity and strength to healthy gingiva was selected after considering the experimental model's ease to make and durability to reproduce the gingiva.

Non-eugenol temporary resin cement (Premier implant cement, Premier® Dental Products Co., Plymouth Meeting, PA, USA; ES-Temp Implant, Spident, Incheon, Korea; Cem-implant BJM Laboratories Ltd., Or-Yehuda, Israel) was first considered for inclusion in this study. However, the cement did not harden in the area where commercially available non-eugenol temporary resin cement and gingiva made of polyvinyl siloxane material were in contact. Thus, non-eugenol temporary resin cement was excluded, and the most commonly used cementation materials for implant prostheses (RMGI, ZOE, and ZPC) were selected.<sup>19</sup>

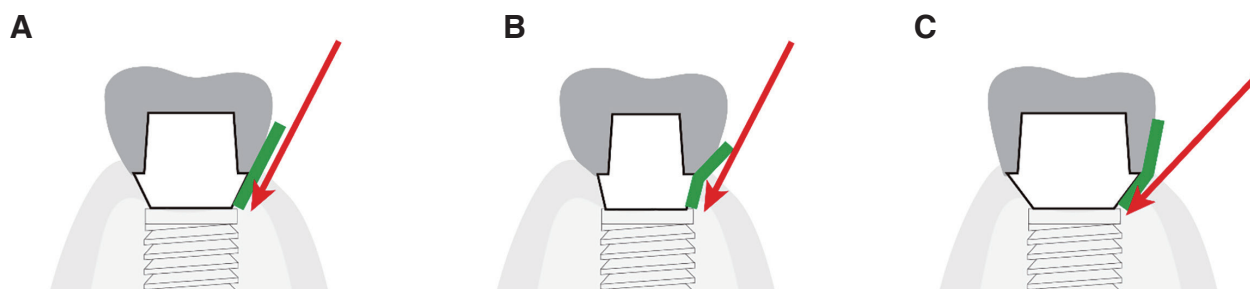
In the natural teeth, connective tissues vertically connected to the tooth surface and junctional epithelium around the tooth form a seal around the teeth. They help inhibit the penetration of excess cement into the gingival sulcus. Contrastingly, the small number of collagen fibers and Sharpey fibers in the implants spread parallel to the implant surface, allowing the excess cement to easily and deeply penetrate the gingival sulcus.<sup>23-25</sup> Moreover, in general, the diameter

of the implant fixture is smaller than that of natural teeth; this may lead to a greater undercut of the implant prostheses. Therefore, more remnant cement is observed when the margin of implant prostheses is at the subgingival level. Undercuts under the implant prostheses increase undetected cement because the instrument is difficult to access, and this excess cement cannot be removed.<sup>26</sup> The use of removal instruments in areas with low accessibility also increases the risk of unintentional scratches on the abutment.<sup>8</sup>

We observed that the amount of remnant cement was significantly different among the three groups according to the neck taper angle of the abutment. The amount of remnant cement was the lowest in the group with a neck taper angle of 65°, followed by those with neck taper angles of 77° and 53°. Our results demonstrate that the amount of remnant cement is not proportional to the change in the neck taper angle and is low at a certain abutment angle. Abutments with a neck taper angle of 77° and 53° show different profiles concerning the crown. Thus, there is a limitation in maneuvering the instruments downward.

On the other hand, abutments with a neck taper angle of 65° have a continuous profile of the crown and abutment. Thus, it is easier to maneuver the instruments downward, allowing a more significant amount of excess cement to be removed (Fig. 8A). The neck taper angle of 77° has a steep emergence profile of the crown compared to 65°, and a large undercut occurs under the prosthesis, limiting the access of instruments to the abutment (Fig. 8B). In the case of the narrow abutment, an undercut exists due to the difference in angle between the neck taper of the abutment and the emergence profile of the zirconia crown. So, it is not possible to access the instrument in line with the neck taper angle of the abutment. The abutment with a neck taper angle of 53° had the most significant amount of remnant cement. This wide abutment requires the instrument to approach at a horizontal angle, which leads to difficulties in accessing the instruments subgingivally. The slope's length and surface area for cleaning are the largest in abutments with a 53° neck taper angle, which may have led to the retention of more remnant cement after an equal number of strokes (Fig. 8C).





**Fig. 8.** Expected pathway of excess cement removal. (A) regular abutment - 65° neck taper angle: Abutments similar to the emergence profile of crowns facilitate eliminating excess cement. (B) narrow abutment - 77° neck taper angle: The steep emergence profile creates a large undercut under the prosthesis, making it difficult to insert dental instruments. Although the insertion direction of dental instruments of B and A are similar, it is difficult for B to contact the instruments with the abutment. (C) wide abutment - 53° neck taper angle: The insertion direction of dental instruments is close to horizontal, and the cement removal area is large. (Green lines: contour of abutment and crowns, Red arrows: insertion direction of removal instruments)

The remnant cement associated with cement-retained implant-supported prostheses has a high risk of causing peri-implantitis. Peri-implant inflammation is associated with swelling, soreness, deeper probing depths, bleeding and/or exudation on probing, and radiographic loss of peri-implant bone.<sup>9</sup> Therefore, it is essential to remove the cement, especially for wide abutments with subgingival margins. For this purpose, there are methods to remove excess cement in the posterior region: direct removal and the removal of remaining outside the oral cavity by unscrewing the abutment-crown assembly after cementation with SCRIP type restoration.<sup>27</sup> In addition, there is a method of applying petroleum jelly to the transmucosal part of the abutment and using dental floss in the proximal part, which is difficult for explorers to access.<sup>28</sup> Previous studies have focused on reducing the amount of cement flowing down the abutment using Teflon tape, rubber dams, or abutment replicas.<sup>29-32</sup> Among many properties of cement, viscosity significantly affects remnant cement. Low-viscosity cement has a greater chance of entering the peri-implant sulcus than high-viscosity cement; however, there is no clinical evidence for this assumption.<sup>33</sup> The three types of cement included in this study had clinically adequate viscosity. They were used according to the manufacturer's recommendations, leading to insignificant differences between the cement types.

A few limitations must be considered while interpreting this study's findings. First, only the mandibular first molar and three neck taper angles were evaluated. Follow-up studies must also assess teeth in other regions of the oral cavity and various neck taper angles. Additionally, it cannot be evaluated in the oral cavity and is an *in vitro* study. Future studies should aim to reproduce the gingiva to resemble the characteristics of the actual gingiva more closely. And it is a limitation that only the surface area and weight were measured, while the volume was excluded from the evaluation factor for the amount of remnant cement.

## CONCLUSION

To remove excess cement better, the emergence profile of the crown should be straight to the neck taper angle of the abutment in cement-retained implant restoration with subgingival margin.

A small neck taper angle of the abutment (wide abutment) leads to an increased amount of remnant cement, so in case of a wide abutment, methods of reducing remnant cement should be considered.

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