Adaptation and Retention of Conventional and Digitally Fabricated Posts and Cores in Round and Oval-Shaped Canals

Zahra Jafarian, DDS
Department of Prosthodontics and Implant School of Dentistry, Tehran University of Medical Science, Tehran, Iran; Faculty of Dentistry, Qom University of Medical Sciences, Qom, Iran.

Mohammad Moharrami, DDS
School of Dentistry, University of Alberta, Edmonton, Alberta, Canada.

Majid Sahebi, DDS, MSc
Dental Research Center, Department of Prosthodontics, Faculty of Dentistry, Tehran University of Medical Sciences, Tehran, Iran.

Marzieh Alikhasi, DDS, MSc
Dental Research Center, Dental Implant Research Center, Department of Prosthodontics, Dentistry Research Institute, School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran.

Purpose: To compare the adaptation of conventional cast posts and cores to digitally milled counterparts in round and oval-shaped canals and to evaluate the retention of the milled posts. Materials and Methods: One cast post and one milled post were fabricated for each of the 26 selected teeth, which had either round or oval-shaped canals. The apical gap was evaluated with radiography, and coronal adaptation was evaluated by weighing the silicon wash trapped between the post and canal wall and also by comparing the volumes of the stereolithographic models. The milled posts were cemented with self-curing glass-ionomer, and the pull-out test was performed to evaluate retention. A two-way analysis of variance and independent t test were used for statistical analyses, with α = .05. Results: Conventional cast posts and cores revealed significantly higher coronal adaptation and less apical gap than the milled groups (P < .001), irrespective of the type of canal. Within the milled groups, there was no significant difference between the coronal adaptation of posts in the round and oval canals. On the contrary, the apical gap of milled posts was the least in the round canals (P = .024). The pull-out test revealed no statistically significant difference between the milled posts in the round and oval canals (P = .086). Conclusion: Conventional cast posts and cores revealed significantly better adaptation compared to the milled group. However, the adequate adaptation of the milled posts to the coronal portions of the canals provided tolerable retention. Nevertheless, clinicians should be cautious with the application of the scan posts, particularly in oval canals, as they could result in a large apical gap.


Post-and-core restoration is the method of choice for reconstructing endodontically treated teeth. However, post-and-core restorations weaken the remaining tooth structures by removing the sound dentin of the pulp chambers and canals to provide enough space for the retention. Nevertheless, a proper design that ensures efficient dissipation of stress throughout the root structure can provide acceptable function and esthetics without causing serious damages such as root fracture. Adaptation of a tapered post to a prepared canal can determine the clinical survival rate of a damaged tooth. The close contact between the root canal wall and post is necessary to achieve passivity of fit. Moreover, it has been shown that uniform cement with minimum thickness will result in high adaptation and bond strength of posts, which in turn dissipates the imposed stress from the post equally throughout the canal. Increased cement space due to the application of a nonadapted post system will significantly affect the retention of the posts.

Endodontically treated teeth can be restored with prefabricated posts, conventional cast metal posts and cores, or computer-aided design/computer-assisted manufacturing (CAD/CAM)–fabricated posts. Due to great adaptation with the root canal, cast posts and cores have better rotational resistance than prefabricated posts. This method is most often used to restore skewed or extensively damaged
teeth, abutment teeth, posterior teeth in a group function, canines in a canine-rise occlusion, anterior teeth in a deep-bite occlusion, and other situations where there is a heavy occlusal load.3,17

Nowadays, CAD/CAM technology can facilitate the fabrication of different dental prostheses, ranging from a single crown to complex fixed and removable restorations. Since the accuracy of the digital workflow seems to be the same as conventional systems,18 CAD/CAM technology has been used for post-and-core fabrication as well.14 Digital workflow has several advantages over conventional casting, such as eliminating the need for impression material and transportation, reducing the time-consuming laboratory procedures, and increasing patient comfort.19–21

Until recently, scanning the intra-canal space was not possible in most cases because of the anatomy of the canal.13 However, 3Shape has developed special scan posts to improve accuracy. The full-digital dual-scan workflow using 3Shape scan posts has been claimed to accurately record the exact depth and anatomy of the root canal. This method makes it possible to design all layers of a post and core in a single digital workflow. The available commercial scan posts have a circular shape, and to the author’s knowledge, there are no data regarding the adaptation of these scan posts to circular or oval canals.

The aim of this in vitro study was to evaluate the effect of the canal type (round or oval) on the adaptation of posts and cores fabricated using scan posts and CAD/CAM milling and also to compare the results to those of cast posts and cores. The apical gap was measured using radiography,22 and coronal adaptation was measured by weighing the silicon wash and recording the post volume.12 Moreover, the retention of CAD/CAM–milled posts and cores was compared between the round and oval canals using the pull-out test. The null hypotheses were that neither the canal type nor the method of post-and-core fabrication would affect the post adaptation, and the retention of the milled posts would not depend on the canal type.

**MATERIALS AND METHODS**

A total of 26 human single-rooted mandibular premolar teeth with round (13) or oval (13) canals were selected. The teeth were first checked visually and then with radiographs for the absence of root caries, cracks, and structural defects, such as open apex and internal resorption. The soft debris and calculus were then removed. During the whole procedure, the teeth were maintained in 0.5% chloramine T (Prolabo) in saline solution and handled with latex gloves. The diameters of the roots in the buccolingual and mesiodistal dimensions were measured at 4 and 9 mm from the anatomical apex using a digital caliper (Mitutoyo America) with an accuracy of 0.01 mm. Next, radiography was performed in both the mesiodistal and buccolingual directions using an intraoral CCD sensor (SuniRay 2, Suni Medical Imaging) and intraoral radiography device (Planmeca). The radiographs were used to determine the shape of the root canals. If the buccolingual dimension of the root was 1.6 times more than the mesiodistal dimension, the root canal was considered oval; if this ratio was less than 1.6, then the canal was considered round (Fig 1).23

**Preparation of the Specimens**

The access cavities were prepared, and the canals were cleaned, instrumented, and shaped with a conventional step-back technique. A No. 45 master file (Lexicon FlexSSK, Dentsply Sirona) was used to prepare the apical constriction, and preparation continued up to a No. 55 file, 1 mm above the apex. The canals were irrigated using saline solution during instrumentation procedures and dried with paper points (Orca). Canal obturation was accomplished using the lateral condensation technique with gutta-percha (GAPADent), AH-26 root canal sealer (Dentsply Maillefer), and finger spreader (Mani). Two days after obturation, the coronal parts of the teeth were cut up to 1 mm above the cementoenamel junction (CEJ) with a diamond disc (KG Sorensen) under water irrigation. Next, approximately 10 mm of the filling was removed using a No. 2 Peeso Reamer (Ultradent). To finalize the preparation, a special drill (Pivomatic; Concours) compatible with the digital scan posts was used to match the taper and width of the canals with those of the scan posts. Each specimen was mounted in an autopolymerizing acrylic resin (Artigos Odontológicos, Clássico). Additional light body silicone (Panasil Fast set, Kettenbach) was used as a spacer between the roots and resin blocks.

**Fabrication of Posts and Cores**

Two posts were made for each tooth, one cast post from the conventional direct impression and one milled post using a scan post and CAD/CAM. To fabricate the milled posts, a 3Shape round scan post, which was tapered in length (PS1.4 TRIOS, 1.4 mm in diameter), was chosen for scanning the canals. First, the mounted teeth were scanned using an intraoral scanner (TRIOS 3 Cart Color scanner, 3Shape) (Fig 2), and then the scan post was inserted into the canal and scanning was repeated (Fig 3). Using Dental System 2014 Premium software, the core was designed to have a 4-mm axial wall and a 1-mm distance from the margin of the tooth (Fig 4). A cement space of 45 µm for the post and 10 µm for the cores were considered for all specimens. The designs were converted to the stereolithography (STL) files and were sent to a milling machine (InLab Versamill 5X-200, Axsys). Posts and cores were milled from a hard milling
into the prepared canals. After the post pattern almost reached the gutta-percha and recorded the anatomy of the canal, the core pattern was formed by applying additional acrylic resin with a brush (Benda Brush, Centrix Dental). After initial polymerization of the post and core patterns, the core was formed with a diamond bur (No. 5878K, Brasseler) in a high-speed handpiece to reach the contour similar to the milled posts, with a 4-mm axial wall and a 1-mm distance from the margin of the tooth. Next, the acrylic pattern was mounted on a base made from acrylic resin and scanned using a 3Shape TRIOS 3 Cart Color scanner. Since the direct impression technique is known to be the standard method for
cobalt-chromium (Co-Cr) block (Co 61.65%; Cr 27.7%; 5.9% molybdenum [Mo]; tungsten [W] 8.45%; manganese [Mn] 0.25%; iron 0.2%, silicon .61%; other < 0.1%; Gebrauchsanweisung Kera-Disc). After milling, no finishing procedure was performed on the milled posts and cores.

The cast posts and cores were made with the direct impression technique, and the patterns were made using acrylic resin (Pattern Resin, GC). First, the acrylic resin was injected into the previously lubricated post space (MULTI-SEP Separating Medium, GC) with a syringe (E/Z syringe, Centrix Dental), and then the plastic post patterns (ParaPost, Coltène/Whaledent) were inserted into the prepared canals. After the post pattern almost reached the gutta-percha and recorded the anatomy of the canal, the core pattern was formed by applying additional acrylic resin with a brush (Benda Brush, Centrix Dental). After initial polymerization of the post and core patterns, the core was formed with a diamond bur (No. 5878K, Brasseler) in a high-speed handpiece to reach the contour similar to the milled posts, with a 4-mm axial wall and a 1-mm distance from the margin of the tooth. Next, the acrylic pattern was mounted on a base made from acrylic resin and scanned using a 3Shape TRIOS 3 Cart Color scanner. Since the direct impression technique is known to be the standard method for

---

**Fig 1** The bucocolingual and mesiodistal width of canals 5 mm from the apex. If the (a) bucocolingual width of the root was 1.6 times more than (b) the mesiodistal dimension, the root canal was considered oval. If the ratio of (c) bucocolingual width to (d) mesiodistal width was less than 1.6, the root canal was considered round.

**Fig 2** Occlusal view of scanned tooth without scan post.

**Fig 3** Occlusal view of scanned tooth with scan post.
Evaluation of the Apical Gap and Coronal Adaptation of the Posts

Two independent examiners visually verified the proper seating of the posts using a No. 17 explorer (Hu-Friedy). Radiographs were taken from the milled and cast posts and cores using the CCD sensor and X-ray system (Planmeca) set at 60 kVp, 1 mA, and 0.08 seconds. The distance between the object, sensor, and cone beam, as well as the angulation, remained the same for all specimens. Using Dr. Suni software (Suni Medical Imaging), the apical gap was measured.

The three-dimensional (3D) adaptation of milled and cast posts was measured by weighing the silicone material trapped between the post and root canal wall. In this regard, first, the canals were moistened to facilitate separating the thin silicon layer. Next, the milled and cast posts and cores were inserted into each canal following injection of extra-light silicone impression material (Panasil initial contact X-Light, Kettenbach). After 5 minutes, the excesses beyond the core margins were removed using a sharp scalpel (Techno Cut Scalpel, HMD Healthcare). The teeth were removed, and the silicone material was obtained and weighed using an electronic balance (GH Series Analytical Balances, A&D) with an accuracy of 0.0001 g.

The volumetric differences between the milled and cast posts were measured as well. The scans of the recording the intracanal anatomy were saved as STL files and served as the reference to be compared later with digitally designed posts and cores (Fig 5). Next, the acrylic patterns were sprued, invested (Cristobalite, Whip Mix Corp), exposed to heat in an oven (ECF 44, Eurocern), and casted in an induction casting machine (INF 2010, Mikrotek Dental) with Co-Cr alloy (Co 61.1%; Cr 27.8%; W 8.5%; Si 1.7%; Mn max 0.5%; Microlit, Schütz Dental).
acrylic post patterns were considered as the reference model. Using Microsoft 3D Builder software, the post segment of the digitally designed post and core and the scan of the acrylic post and core patterns of each tooth were separated. Using Simplify 3D 4.0.0 software, the volume of the intracanal part of the posts and cores were evaluated and compared to each other (Fig 6).

**Evaluation of the Retention**

After evaluation of the post adaptation, the milled posts were prepared for the pull-out test. A stainless-steel ring (Leowireb, Leone) with a 0.9-mm diameter was soldered to the top of the core along with the long axis of the core using a gas-oxygen torch and a solder alloy (Vera Solder, Aalbadent). For cementation, the dentinal walls of the canals were etched with 37% phosphoric acid (Denfil etchant) for 40 seconds to eliminate the effect of the sealer. The post space was rinsed with water and dried with paper points (Orca). Self-curing glass-ionomer luting cement (GC FUJI I, GC Cooperation) was mixed according to the manufacturer’s recommendations and inserted into the canal using a 25-mm Lentulo Spiral (Dentsply Maillefer). The cement was also applied on the milled posts with a plastic instrument; then, the posts were inserted into the canals. A constant load of 40 to 50 N was applied to the specimens for 10 minutes until the cement was set. After initial setting of the cement for 30 minutes, the specimens were kept in normal saline for 1 week. One week after cementation, the pull-out test was performed to measure the retention of the milled posts for the oval and round canals using a universal testing machine (Zwick/ Roell Z050). Specimens were subjected to tensile force along the long axes of the posts at a crosshead speed of 0.5 mm per minute. The force required to dislodge each dowel was recorded in kilograms.

**Statistical Analyses**

All of the analyses were performed using the Statistical Package for the Social Sciences (SPSS) version 22.0 (IBM SPSS Statistics; IBM). Kolmogorov-Smirnov test was used to verify the normality of the collected data. Levene tests measured heterogeneity of variance among the groups. A two-way analysis of variance (ANOVA) was implemented to assess the effect of canal shape and fabrication technique on adaptation (wash weight, apical gap, post volume). The t test was used to assess the simple effects of canal shape and fabrication technique on adaptation when there was a meaningful interaction between the main effects. For evaluating the impact of the canal shape on the retention of the milled posts, independent t test was used. A P value of less than .05 was considered to be statistically significant.

**RESULTS**

The mean and standard deviation (SD) of the wash weight, apical gap, and post volume for each canal type and fabrication technique, as well as the tensile resistance of the milled posts, are presented in Table 1. The two-way ANOVA analyses showed that there was no interaction between the canal type and fabrication technique for the wash weight (P = .180) or post volume (P = .551). While the cast posts were significantly more accurate than milled posts regarding the wash weight (P < .001) and post volume (P = .045), the canal type did not change the results for wash weight (P = .676) or post volume (P = .341).

On the other hand, the two-way ANOVA showed that there was an interaction between the canal type and fabrication technique for apical gap (P = .011). Therefore, independent t test was run, which showed that the apical gap of milled posts in the round canals was significantly lower than the oval canals (P = .024), but there was no significant difference between the cast posts (P = .268). Moreover, similar to post volume and wash weight, the cast posts were more accurate than milled posts regarding the apical gap (P < .001).

Regarding the tensile resistance, t test revealed no significant difference between the milled posts in the round and oval canals (P = .864).

**DISCUSSION**

Based on the results of this study, considering the wash weight, apical gap, and post volume, the cast posts and cores exhibited significantly superior adaptation than the milled group in both the round and oval canals. Round and oval canals did not alter the post-and-core adaptation, except for the apical gap of the milled groups. Regarding the evaluation of retention, which
was the secondary aim of this study, the authors did not intend to compare the differences between the cast and milled posts. A different design would have been needed to compare the retention between cast and milled posts, as it was not possible to cement both the cast and milled posts into the canals. In a previous study, the same authors showed that retention of cast posts was higher than milled posts.\textsuperscript{29} In this study, retention of the milled posts was compared between the round and oval posts, which showed no differences.

With the application of digital technology, posts and cores can be designed and manufactured in a single laboratory session, which is convenient and time-saving, especially in patients needing multi-unit restorations. Therefore, a digital workflow eliminates the complications of conventional casting, such as choosing a tray, preparation of the impression materials, disinfection of the impressions, and transferring the impression to the laboratory.\textsuperscript{30,31} Nevertheless, digital workflow should meet some criteria to be used in clinical settings. A 10-year retrospective study concluded that adequate post adaptation dramatically increases tooth survival rate.\textsuperscript{32} Active fit of a post and a nonhomogenous cement layer might exert off-axis stress on the tooth structure and increase the stress peaks, which in turn increase the fracture risk of the restored teeth.\textsuperscript{5,7}

In this study, the cast posts had less apical gap compared to the milled posts, which agrees with a previous report.\textsuperscript{29} Cast posts conform better to irregularities and fit perfectly with the canal, which is evident from their long history of success in clinical settings.\textsuperscript{33} Among the milled posts, as it was anticipated, the round canals resulted in less apical gap than the oval canals, as the scan posts could reach further into the round canals. However, the apical gaps in this study were larger than a 2-mm apical gap is an acceptable clinical cut-off point, below which dislodgment and fracture may occur.\textsuperscript{23} Considering the mean and SD and the fact that only one milled post in the round canals resulted in an apical gap of more than 2 mm, the scan post used in this study can be employed with caution in clinical settings. However, the same scan post does not seem to be suitable for oval canals, as it resulted in seven posts with an apical gap of more than 2 mm.

Regarding the coronal adaptation of the milled posts, the insignificant differences between the round and oval canals for wash weight and post volume can be due to the fact that the coronal one-third of the canal was recorded directly with the scanner, which constitutes the majority of post volume and the wash material. Therefore, unlike the apical gap, the canal type makes little difference for the post volume and wash weight. Having a good seal in the coronal one-third of the canal is crucial for clinical success, as the cement tends to be dissolved faster in coronal sites than in apical parts. These findings also agree with a previous study with a different design, which showed that oval and round fiber posts in the oval canals reached the same level of adaptation.\textsuperscript{34}

To the authors’ knowledge, only one study has compared retention of the cast and milled posts to one another, which did not account for canal type. In Hendi et al, the tensile retention of the milled posts was almost similar to the present study, but the retention of the cast posts was higher.\textsuperscript{29} There is no standard cut-off point for the retention of posts, and the retention can change depending on several parameters such as post length, diameter, and taper; the luting cement; cementing technique; and whether a post is active or passive.\textsuperscript{35}

That being said, the retention of the milled posts in this study was in the lower band of the range reported for

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Mean (Standard Deviation) Values of Tensile Resistance, Apical Gap, Wash Weight, and Post Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Round canals</td>
</tr>
<tr>
<td>Apical gap (mm)</td>
<td>Cast: 0.275 (0.225)</td>
</tr>
<tr>
<td>Wash weight (g)</td>
<td>Cast: 0.008 (0.004)</td>
</tr>
<tr>
<td>Post volume (mm(^2))</td>
<td>Cast: 1.492 (0.241)</td>
</tr>
<tr>
<td>Tensile resistance (N)</td>
<td>Milled: 122.41 (59.22)</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Two-way ANOVA showed an interaction between fabrication technique and canal type (\(P = .011\)).

\textsuperscript{b}Two-way ANOVA showed no interaction between fabrication technique and canal type (\(P = .551\)).

\textsuperscript{c}Two-way ANOVA showed no interaction between fabrication technique and canal type (\(P = .180\)).
retention of cast posts cemented with glass-ionomer (101 to 286 N).²⁷,³⁶–³⁸ It seems that the adaptation of the milled posts to the coronal parts of the canals can be accounted for compensating the retention lost due to the weak conformity of the posts to the apical sites. Moreover, there was no significant difference between the milled posts in the round and oval canals, which agrees with a previous report—albeit with a different design—that showed circular and oval fiber posts resulted in similar push-out bond strength.³⁹

There were some limitations to this study. First, as was explained earlier, the retention of the cast posts was not measured. Second, all of the evaluations and measurements were performed in the laboratory setting, which disregards the conditions in the oral cavity. In the clinical setting, many parameters, such as saliva and temperature, may affect the results. Third, the clinicians easily make impressions in the laboratory, but limitations regarding space in the oral cavity may affect the results. Fourth, despite the milled posts, no specific cement space was considered for the cast posts, as the standardized casting procedure results in shrinkage and undersized posts and cores that provide enough space for cementation. Fourth, the possible role of different types of cement should be measured in future studies, as different self-adhesives and bonded resin cements may result in varying levels of retention.⁴⁰,⁴¹

**CONCLUSIONS**

Within the limitations of this study, the cast posts and cores made from the conventional direct impression showed better fit in the round and oval canals compared to milled posts and cores fabricated using a fully digital system. However, as the coronal part of the canal was well captured with the scanner, the retention of the posts in the round and oval canals did not fall dramatically. However, the scan posts should be applied with caution, particularly in the oval canals due to the large apical gap.

**ACKNOWLEDGMENTS**

This study was funded and supported by Dental Research Center, Dentistry Research Institute, Tehran University of Medical sciences in grant no: 96-01-70-34507. The authors report no conflicts of interest.

**REFERENCES**

Physical activity was associated with reduced incidence of vascular dementia (VaD), compared to slower skiers. In the Malmö Diet and Cancer Study (median age 57.5 years), 29,639 participants in the Swedish population-based Malmö Diet and Cancer Study during 18 years of follow-up (median 15 years, IQR 9 to 15 years). Next, they studied the association between self-reported physical activity, stated twice 5 years apart, and incident VaD and AD in 20,639 participants in the Swedish population-based Malmö Diet and Cancer Study during 18 years of follow-up (median 15 years, IQR 9 to 15 years). Finally, a mouse model of AD was used to study brain levels of amyloid-β (Aβ) to 17 years).