

RESEARCH AND EDUCATION

The effect of conventional, half-digital, and full-digital fabrication techniques on the retention and apical gap of post and core restorations



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The posts and cores used to rehabilitate endodontically treated teeth must accurately reconstruct and fit the canal to ensure the best biomechanical behavior and prevent micro-leakage.¹⁻³ A well-fabricated post provides passivity of fit and a homogenous layer of cement which prevents destructive torque forces.⁴

Although glass fiber posts have shown almost similar survival rates to those of cast metal posts, cast posts conform better to the irregularities of canals and provide a better fit that resists torsion forces.⁵⁻⁸ Cast metal posts are also preferable when there is an insufficient ferrule or for supporting a long-span fixed partial denture.⁹ Moreover, because metal cast posts can match the irregular canals, the need for excessive canal preparation, which may be required for prefabricated posts, is eliminated. Therefore, further tooth structure loss is prevented.¹⁰ However, cast posts may increase stress and the risk

of root fracture.¹¹ In addition, cast metal posts are not indicated for anterior teeth if esthetics might be compromised; in this zone, glass fiber or zirconia posts are preferred.¹²

ABSTRACT

Statement of problem. Conventional cast metal posts and cores are fabricated using direct and indirect techniques, both of which need impression materials and considerable laboratory work. Digital techniques have the capacity to substitute for conventional methods in fabricating the posts and cores. However, the accuracy of restorations resulting from a digital workflow is unknown.

Purpose. The purpose of this in vitro study was to compare the retention of posts and cores fabricated using full-digital, half-digital, and conventional techniques and to define the accuracy of each technique in terms of the apical gap.

Method and materials. Thirty newly extracted mandibular first and second premolar teeth were selected for this in vitro study. Impressions were made using direct acrylic resin patterns (conventional), indirect silicone impressions of the intracanal which scanned with a 3Shape laboratory scanner (half digital), and intracanal scan posts captured with an intraoral 3Shape scanner (full digital). Casting and milling were conducted for the conventional impression and digital scans. The obtained posts were cemented using zinc phosphate cement. A universal pullout test was used to measure retention at a crosshead speed of 0.5 mm/min. The apical gap of each post in the canals was defined with parallel digital radiography. The data were analyzed using the Kruskal-Wallis test ($\alpha=.05$) and Mann-Whitney test at the adjusted $\alpha=.016$.

Results. Significant differences were found among the conventional, full-digital, and half-digital techniques in terms of the apical gap (0.11, 0.29, and 0.66 mm; $P<.001$) and retention (171.6 \pm 1.9, 107.1 \pm 5.6 and 91.8 \pm 6.6 N; $P<.001$). The correlation between gap and retention in conventional ($P=.43$), full-digital ($P=.09$), and half-digital techniques ($P=.06$) was not statistically significantly different.

Conclusions. The conventional technique was more accurate and resulted in higher retention than both the full- and half-digital techniques. However, the retention and gap of all the posts fell within clinical guidelines. (J Prosthet Dent 2019;121:364.e1-e6)

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Clinical Implications

As yet, the full- and half-digital post and core fabrication techniques cannot be recommended as an alternative to the conventional technique. More *in vivo* and *in vitro* studies are needed to evaluate the efficacy of the digital workflow.

Cast metal posts are typically fabricated by either a direct or indirect technique.^{13,14} An indirect impression is made with an elastomeric material, while in the direct technique, the pattern of the post and core is formed with acrylic resin.^{14,15} The indirect technique is considered faster and easier when several teeth are involved.¹³ However, the direct technique eliminates some laboratory steps, and clinicians can form an ideal core and make changes when needed. Despite these advantages and disadvantages, both techniques result in posts that are clinically reliable and have demonstrated similar fit, retention, and accuracy.^{3,13,16}

Digital scanning can be used for post and core fabrication with either a half-digital or full-digital technique. In the half-digital technique, similar to the indirect technique, an intracanal impression is made with an elastomeric material which is scanned before the post and core is designed and milled. The full-digital technique uses a digital scan and scan posts which are compatible with specific drills that shape the canals. Scan posts are analogous to using scan bodies in scanning implant-supported restorations.^{17,18} Once scanned, special software calculates positions and depths automatically, and the post and core is designed and milled.

Digital workflow provides the advantages of simplicity, patient comfort, reduced storage requirements, rapid access to 3-dimensional (3D) diagnostic information, easy transfer of digital data, and reduction in chairside time and costs. Moreover, the digital technique has been reported to be advantageous as it eliminates steps such as choosing a tray, preparation of the impression materials, disinfection of the impressions, and transferring the impression to the laboratory.¹⁹⁻²¹

Debonding is the most common failure of posts and cores, with 37% of all reported failures.²² Factors that affect post retention and resistance include preparation design, restoration fit, material, diameter, and length of the post, post/crown ratio, cementation, and the position of the tooth in dental arch.^{2,23-25} Moreover, ferrule preparation and retentive elements such as boxes and grooves should be considered to improve retention; a loose fitting post can have minimal retention.^{26,27} An apical gap could also affect the clinical success of posts and cores. Posts more than 2 mm shorter than the

prepared post space could result in lower retention, dislodgement of the post, endodontic lesions, and even fracture.^{6,28} Therefore, the retention and gap of post and cores made with digital techniques are important to their clinical success. The purpose of this *in vitro* study was to evaluate and compare the retention and gap of the half-digital and full-digital techniques with the conventional direct technique using digital radiographs and a pullout test. The null hypothesis was that no difference would be found among the 3 techniques regarding retention and gap.

MATERIAL AND METHODS

Thirty first and second mandibular premolar teeth recently extracted for orthodontic treatment were selected for this *in vitro* study. The teeth were caries free, single rooted, without cracks, and had patent apices. From clinical and radiographic examination, teeth without internal resorptions, obstruction, incomplete apex, and more than one canal, were selected. The buccolingual and mesiodistal dimensions of the roots were measured at 3 locations using a digital caliper (ABSOLUTE Digimatic Caliper; Mitutoyo) with an accuracy of 0.01 mm to obtain specimens with similar dimensions. All external debris was removed with an ultrasonic scaler (EMS; Woodpecker). The teeth were handled with latex gloves and kept moist with saline solution during the whole procedure.

The teeth were sectioned with a diamond disk 1.5 mm coronal to the cemento-enamel junction under water irrigation using a diamond rotary instrument (BR6856.31.018; Brasseler). The root canal of each tooth was instrumented with a conventional step-back technique with stainless steel endodontic files (K-files 21 mm; Kerr Corp). A No. 45 master file (Lexicon FlexSSK; Dentsply Sirona) was used to prepare the apical constriction, and preparation continued up to a size No. 55 file, 1 mm from the apex (all the measurements corresponded to the external surface of the roots). Saline solution was used during instrumentation. The canals were dried with air and paper points (Autofit; Kerr Corp) and obturated with gutta percha and sealer (AH26; Dentsply Sirona) using a lateral condensation technique. All the specimens were stored in distilled water at 37°C for 7 days.

Ten millimeters of the obturation was removed using a No. 2 Peeso Reamer (Ultradent Products, Inc), leaving 3 to 5 mm of gutta percha in the apex. To finalize the preparation, a drill (Pivomatic; Concours) matched to the digital scan posts was used. The teeth were irrigated with 2% sodium hypochlorite, embedded in epoxy resins, and subdivided into 3 groups (conventional, half digital, and full digital) with stratified random allocation.



Figure 1. Conventional direct post and core pattern.

In the conventional group, the post and core patterns were fabricated with prefabricated plastic posts (PinJet; Angelus) which were relined with a thick mix of auto-polymerizing acrylic resin (Pattern Resin LS; GC). The acrylic resin was also inserted into the post space, and cores of 4 mm in height with a flat occlusal table were formed (Fig. 1). The post patterns were immediately placed in a 4.45-cm ring, invested with a phosphate-bonded investment (Cera-Fina; Whip Mix Corp), and cast with Type 5 cobalt-based dental alloy (Magnum Fulgens; Mesa).

In the half-digital group, a 1-step impression was made using a custom tray and a light-body material (A-silicones; Kettenbach). Next, using a prefabricated plastic post, the impression material was inserted into the canals. After polymerization, impressions were scanned using a laboratory scanner (D700 Scanner; 3Shape) to obtain digital virtual models (Fig. 2). Then, the post and core models were designed using Exocad software (CAD Software; Exocad GmbH) with a cement space of 20 μm .

In the full-digital group, the post spaces were scanned using an intraoral scanner (TRIOS 3D Intraoral scanner; 3Shape). The teeth were scanned without the scan posts and then with the scan posts (3Shape-80610041, 12 mm length, 1.2 mm diameter) inside the canal. As for the half-digital specimens, the cores were standardized to 4 mm in height with a flat occlusal table, and the cement space was set at 20 μm (Fig. 3). The post and cores of both the digital groups were milled from a Co-Cr milling alloy (Kera Disc; IDS Medical) in a dental milling machine (Arum 5X; Dwoom).

All fabricated posts and cores were adjusted, by one experienced clinician (A.R.H.), to ensure a passive and positive fit to avoid lateral stresses during insertion and cementation. All post and cores were refined, finished, and abraded with 150 μm aluminum oxide under 0.5 MPa pressure. To attach specimens to a universal testing machine, 3.5-mm-diameter wax loops were formed, invested, and soldered to the cores.

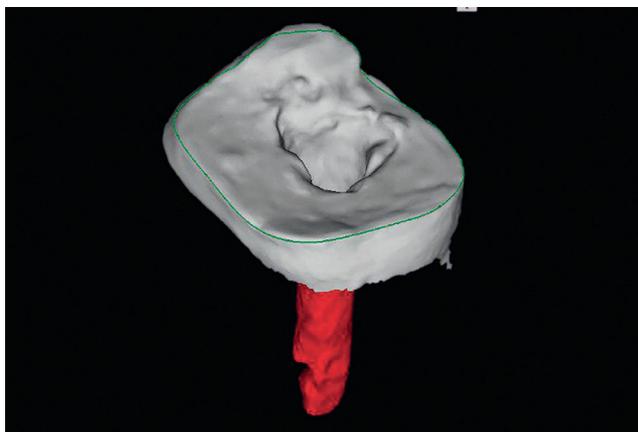


Figure 2. Digitalization of intracanal silicone impression (half digital).

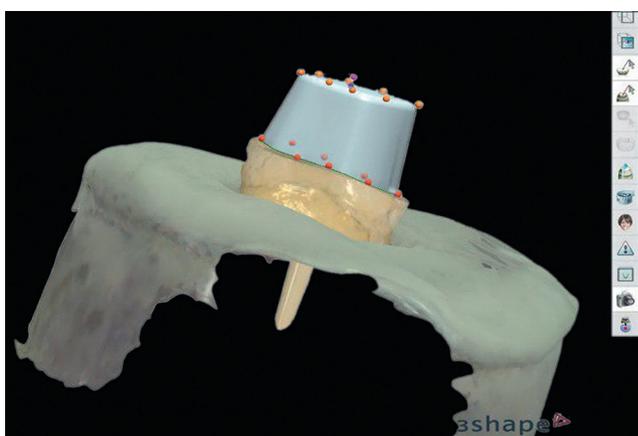


Figure 3. Designing post and core with full-digital technique.

The gap between posts and the remaining apical gutta percha were measured using periapical radiographs at 65 KVP and 10 mA with a target film distance of 25 cm (765DC X-ray Machine; Gendex) and an radiovisiography charge-coupled device receptor (Vme; Kodak) as used clinically.^{29,30} Two examiners (H.S., H.H.) measured all the radiographs, and the mean value was reported as the apical gap. The interrater agreement was determined using the Cohen kappa statistics (κ -score=0.90). The measurements were performed using the ruler tool in image editing software (Adobe Photoshop CC; Adobe). Each image was calibrated using the known length of the post.

The posts were cemented with zinc phosphate cement (Harvard) following the manufacturer's instructions. Each post was coated with the mixed cement, and cement was inserted into the root canal with a clockwise rotating lentulo spiral (Dentsply Sirona). The posts were seated with finger pressure. The teeth were stored in distilled water at 37°C for 24 hours and submitted to a pullout test in a universal testing machine (Zwick Z020; Zwick) at a crosshead speed of 0.5 mm/min.

Table 1. Pairwise comparison among fabrication techniques (dependent variable: retention)

P	Z Score	Median	Standard Deviation	Mean	Techniques
<.001	-3.781	171.745	1.850	171.554	Conventional
		107.055	5.576	107.075	Full digital
<.001	-3.781	171.745	1.850	171.554	Conventional
		93.380	6.652	91.833	Half digital
<.001	-3.780	107.055	5.576	107.075	Full digital
		93.380	6.652	91.833	Half digital

GPower v3.0.1 software was used to estimate the sample size for 1-way ANOVA.³¹ A relatively large effect size equal to 0.6, a significance level of $\alpha=.05$, and statistical power of $1-\beta=.80$ were considered to determine the minimum sample size. Based on these inputs, the sample size was established at $n=10$ for each group.

Statistical analyses were performed using statistical software (IBM SPSS Statistics, v22.0; IBM Corp). The Kolmogorov-Smirnov test was used to verify the normality of the collected data. The Pearson correlation coefficient was used to measure the linear correlation between gap and retention in each fabrication technique. However, owing to the considerable heterogeneity of variance among the 3 fabrication techniques, as measured by the Levene tests, nonparametric analysis was applied. The Kruskal-Wallis test was used to compare differences in gaps and retention (dependent variables) between the 3 fabrication methods ($\alpha=.05$). The pairwise comparisons between groups were performed using the Mann-Whitney test ($\alpha=.016$).

RESULTS

No significant difference was found in prepared post space among the 3 fabrication techniques ($P=.747$). The mean \pm standard deviation retention of the conventional, full-digital, and half-digital techniques were 171.6 ± 1.9 , 107.1 ± 5.6 , and 91.8 ± 6.6 N, respectively. The smallest apical gap was observed in teeth fabricated by the conventional direct technique (0.11 ± 0.06 mm) followed by the full- and half-digital groups (0.29 ± 0.12 and 0.66 ± 0.19 mm). Significant differences in both retention and gap were found among the 3 fabrication groups ($P<.001$). Moreover, the pairwise comparison revealed significant differences between each 2 fabrication techniques for retention and gap (Tables 1 and 2). The correlation between gap and retention in conventional ($P=.43$), full-digital ($P=.09$), and half-digital ($P=.06$) groups was not statistically significant (Fig. 4).

DISCUSSION

The null hypothesis was rejected as both the retention and apical gap were significantly different between the half-digital, full-digital, and conventional fabrication

Table 2. Pairwise comparison among fabrication techniques (dependent variable: gap)

P	Z Score	Median	Standard Deviation	Mean	Techniques
<.001	-3.600	0.150	0.066	0.118	Conventional
		0.285	0.115	0.294	Full digital
<.001	-3.788	0.150	0.066	0.118	Conventional
		0.670	0.189	0.665	Half digital
.001	-3.404	0.285	0.115	0.294	Full digital
		0.670	0.189	0.665	Half digital

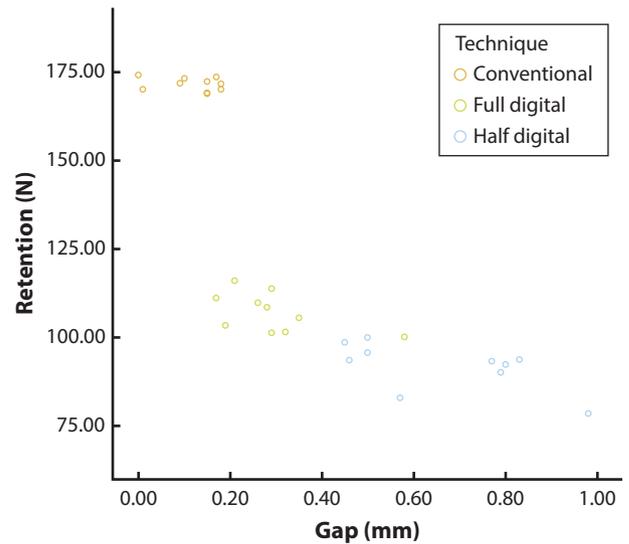


Figure 4. Correlation of retention and apical gap in 3 fabrication techniques.

techniques. The primary aim of this study was to determine the impact of the post and core fabrication technique on post retention by controlling confounders including the position and type of the tooth, the post length and width, and cement. All posts were cemented with zinc phosphate, which has a successful history in luting procedures and is easy to manipulate.³²

Regarding the force needed to dislodge the posts and cores in the pullout test, still no gold standard or cutoff point has been defined to determine the minimum retention needed. However, a variety of forces ranging between 85 N and 342 N have been reported.^{13,27,33-35} In this study, the greatest mean force was recorded for the conventional technique (171.6 N), and the lowest value for the half-digital group (91.8 N), which fell between the minimum and maximum forces required to dislodge posts derived from conventional direct and nondirect techniques.

The gap between the remnant of gutta percha and tip of the posts was measured using parallel radiographs. Scan posts used in the full-digital technique could not reach and record the terminal end of the post space as accurately as posts fabricated using acrylic resin.

Therefore, the gap in the full-digital group was larger than in the conventional direct group. The half-digital group had a larger gap because of inherent distortion of impression material and the difficulty of access to the apical part. Nevertheless, all 3 groups exhibited an apical gap shorter than 1 mm. The recorded gap values were less than the acceptable cutoff point (2 mm) defined for clinical success^{6,28}; therefore, all the posts could be cemented. Moreover, the results showed that when the fabrication technique was excluded from the analysis, the correlation between gap and retention was not significant in any of the groups. Thus, the association between gap and retention can be attributed to the effect of fabrication techniques.

The results showed that the retention of full-digital posts was better than the half-digital specimens. This finding might be because the full-digital technique scanned the coronal third of the canal directly. The scan posts used to record the other two thirds of the canal length conformed to the canal shape because the drills used to prepare the canals were matched with the scan posts. However, in the half-digital group, the scanner might not have accurately transformed the indirect impression of the canal to the virtual model. Another possible explanation for differences in retention may be attributed to milling versus casting in making sharp angles. In the half-digital group, air bubbles in the impression may lead to negative edge in the milled posts.³⁶ As reproducing sharp angles in milling is poorer than casting,³⁷ the half-digital technique may have resulted in less-accurate posts and cores.

An explanation for the larger apical gap in the full-digital technique compared with the conventional technique might be attributed to the fact that the length of the scan posts was larger than the canal space (12 and 16 mm versus 10 mm) and the scan bodies were not scaled. Therefore, the clinician could not determine the exact penetration length of the scan posts. In the half-digital group, insufficient space makes it difficult to ensure the flow of light-body material, which leads to the entrapment of air at the end of the canal. Therefore, the light-body material cannot record the apical part of the post space as accurately as for the conventional group.³⁶

The study had some limitations. The in vitro nature of this study prevented the prediction of the efficacy of the 3 methods in the clinical setting, where parameters such as saliva and temperature may have affected the results. Not all the parameters related to accuracy were measured, as digital radiography was used to measure the gap. However, other parameters, including marginal and internal fit of the fabricated posts, should be measured as well. The impressions were easy to make in the laboratory, but limitations regarding the space in the oral cavity may affect the clinician's accuracy and, consequently, the final results. The thermal change of light-body material used

for the half-digital technique was not modeled in this study, which may cause more inaccuracy in clinical settings.³⁸ Finally, the possible role of different types of cement should be measured in future studies; self-adhesive or bonded resin cement may result in varying levels of retention.

CONCLUSIONS

Based on the results of this in vitro study, the following conclusions were drawn:

1. Conventional techniques for fabricating posts and cores were more accurate than digital techniques in terms of the gap.
2. The conventional technique led to more retention than either the half- or full-digital techniques.
3. Digital techniques may be acceptable because they result in posts and cores with gap and retention values within the acceptable normal range.

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