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RESEARCH ARTICLE

Computer-aided Design/Computer-aided Manufacturing Generated Ceramic Post and Core

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ABSTRACT

Purpose: To evaluate the efficacy of computer-aided design/computer-aided manufacturing (CAD/CAM) technology to fabricate an all-ceramic post and core restoration.

Materials and methods: Two master dies fabricated from a polymer material were used in this study (Acadental T Endo TM series RT_AE 401_0®8). The coronal portion of the die simulated an ideal core preparation with a 1.5 mm to 2.0 mm ferrule. The intracanal space for the first and second dies were prepared for a post length of 10 mm and 14 mm respectively. Each die was scanned 20 times. A total of 40 e.max® CAD/ CAM post and core restorations were milled. The restorations were evaluated for a precision of fit by measuring marginal gap for each post and core restoration using scanning electron microscopy and by taking radiograph to determine the post length.

Results: Results revealed that: (a) Chairside CAD/CAM Technology (Sirona CEREC BlueCam®) could produce directly all ceramic post and core restorations up to 10.0 mm of canal depth. (b) There was no pattern of relationship between the marginal gap and post lengths when comparing the two test groups.

Conclusion: The least detectable gap was 5 microns, and the greatest was 100 microns. The marginal gap results found in this study met clinically acceptable standards.

Keywords: Computer-aided Design/Computer-aided Manufacturing, Clinical restorative dentistry, Dental prosthodontics, Restoration.

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INTRODUCTION

Endodontically treated teeth pose a greater risk of failure than their vital counterparts. Due to insufficient tooth structure, they often need a post and core as a foundation for the final restoration.[1] A cast metal post and core custom fit to the post space is the traditional treatment of choice to provide the necessary retention for a complete crown. This can be achieved via a direct pattern or an indirect impression of the prepared canal space using an elastic impression material.[2] Because of the translucency of ceramics, an all-ceramic crown supported by a cast metal post and core can result in a poor aesthetic outcome if the crown thickness is less than 1.6 mm.[3,4] Vichi et al. recommended a single unit zirconia post and core in cases where the ceramic crown thickness is inadequate.[5]

Prefabricated glass fiber posts have enhanced mechanical properties, better biocompatibility, and are available in different shades.[6,7] However, their diameters cannot be customized to adapt to individual post space preparations. Custom post and core restorations are indicated in cases with wide, noncircular, or extremely tapered canals where cylindrical prefabricated posts may not achieve adequate adaptation of the post to the canal space.[8-10] The weak interface between a resin core and the fiber post may also increase the risk of failure.[11,12] According to a 10-year retrospective study by Balkenhol et al. the fit of a cast post and core directly influences the ultimate survival of the restoration.[13]

The long-term failure rate of fiber posts reportedly ranges from 7 to 11%.[7,14] Apart from endodontic problems, the primary reasons for failure have included crown dislodgement and post debonding. Assif and Gorfil[15] reported that endodontically treated teeth restored with post and core restorations could produce stresses concentrated at the coronal third of the root and the interface between the core and the post. When the modulus of elasticity differs between the materials, there is a potential for separation of the core from the post. When the post and the core are composed of the same material, such separation is less likely to occur.[16,17] Fabricating the post and core as a single unit decreases the frequency of failure by creating a monoblock, which offers advantages over multiple piece units.

A new method of fabricating custom made post and core restorations has been developed using monoblock zirconia and CAD/CAM technology. The post and core restoration is generated by means of a direct optical impression of the post space, a resin pattern, or a polyvinylsiloxane impression of the post space.[2,18,19] In 1992 Bex et al.[20] investigated the effect of dentin-bonded resin post-core restorations on the resistance to vertical root fracture and concluded that dentin-bonded resin post-core restorations provided significantly less resis-

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tance to failure than cemented custom cast post and core restorations. In every instance, the dentin-bonded resin posts and cores fractured before the roots fractured. In 1996 Saupe, et al.[21] compared the fracture resistance between a custom metal post and core castings with a resin-reinforced dowel system for structurally compromised roots. Their results indicated that resistance to a masticatory load of a resin-reinforced post-and-core system was greater than that of a morphologic post-and-core restoration. They also reported that when a bonded resin post and core was used on structurally weakened roots, there was no statistically significant difference in strength between post and core restorations that used a ferrule and those that did not.

Fasbinder et al.[22] found that the use of digital impressions required less time than was needed to make impressions and pour casts. One recent study reported that scanning was 10 minutes faster than conventional impressions for single abutments and short span fixed partial dentures.[22,23] Another noteworthy study[24] examined over 1000 crowns made with polyvinyl-siloxane impressions after 5 years of clinical service reported that a marginal gap of fewer than 120 microns would be clinically acceptable for cemented restorations. Digital systems have been reported to fabricate restorations where the marginal gap was less than this standard. One laboratory study[25] measured the fit of CEREC® crowns compared to those fabricated using different laboratory techniques. There was no significant difference in crown marginal fit between the chairside CAD/CAM and the laboratory-fabricated restorations. The CEREC crowns had a mean margin gap of 65.5 ± 24.7 microns for ceramic crowns and 66.0 ± 14.1 microns for composite crowns.[22,26,27] An in vitro study compared the accuracy of full ceramic crowns obtained from intraoral scans using Lava COS®, CEREC AC®, and iTero® systems with two different conventional impression techniques. The mean margin fit of crowns was 48 microns for Lava COS®, 30 microns for CEREC AC®, 41 microns for iTero®, 33 microns for single-step putty wash technique and 60 microns for the two-step putty wash technique.[27] The mean internal fit was 29 microns for Lava COS®, 88 microns for CEREC AC®, 50 microns for iTero®, 36 microns for single-step putty wash technique, and 35 microns for two-step putty wash technique. There was no significant difference in the marginal fit or internal adaptation of the crowns using any of the previously mentioned techniques.

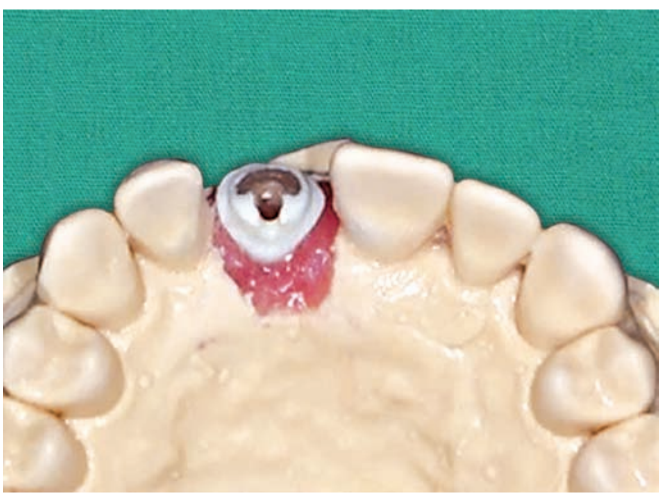


Fig. 1: Master die mounted in a dental stone block and ready for scanning

The objective of this study was to evaluate the use of chairside CAD/CAM technology as a method to fabricate accurate single-unit all-ceramic post and core restorations utilizing a direct optoelectronic scanned impression of the post space.

MATERIALS AND METHODS

Two master dies were fabricated from a polymer material (Acadental Lenexa Kansas Real–T Endo TM series RT_AE401_08®). Each die was mounted in a scannable model made from Whip Mix Lean Rock dental stone® to facilitate the optoelectronic scanning and to enable the electronic impression to be more recognizable by the software (Fig. 1). Each die was secured in the stone model by polyvinyl siloxane light body impression material to facilitate seating and removalof each die. The dies consisted of a crown portion and a root portion which contained a post space. The coronal part of the dies simulated an ideal core preparation 2 mm above the margin with a 1.5 to 2 mm ferrule. Post space diameter was 2 mm at the most superior point of the preparation. Canal space was prepared for two lengths according to the die group. The canal length of the group (A) was prepared for a post length of 10 mm. The group (B) canal space was prepared for a post length of 14 mm. Para Post-Xsystem (Coltène Whaledent®) drills were used to prepare the length needed for each group. A handpiece surveyor was used to idealize the preparation depth (Fig. 2). A light film of CEREC Optispray® (Sirona) was distributed evenly on the core preparation and introduced into the post space. Both die, including the post space, were optoelectronically scanned using Sirona CEREC SW BlueCam® (Fig. 3) and Software 4.0 edition F. Biogeneric copy was applied as a design for the generation of a similar post and core for all test samples. Virtual models were created and the dies were electronically trimmed. The restoration parameter for a cement spacer was set at 10 microns for both groups (Fig. 4). The software generated a milling proposal. An evaluation of the restoration was made in three dimensions, and vertical sections were taken. IPS e.max CAD®

(lithium disilicate glass-ceramic) blocks were mounted in the milling unit Sirona $CEREC_3$® compact milling unit. Each restoration was milled in approximately 15 min using the fast-milling setting. Both the cylinder pointed bur, and the step bur were changed after every five cycles to prevent errors introduced because of bur wear. Following the milling procedure, the restorations were tempered to reach the fully crystallized state. In the course of this process, lithium disilicate crystals ($Li_2Si_2O_5$) form, which assures optimum material strength.

The master dies were scanned, and each sample individually designed and milled twenty times. Radiographs showed that the post length of samples fabricated for a prepared 10 mm post space could accurately be milled to a length of 10 mm. The software could only measure the post space of the second die which had been prepared to a depth of 14 mm to a 13.7 mm depth. However, the system could not accurately mill a post beyond the length of 11 mm.

Each restoration was subjected to a two step evaluation to assess the precision of fit. The marginal gap was measured for each post and core using scanning electron microscopy. Samples were secured in a machined aluminum holder that employed stainless steel socket head cap screws and springs opposing each other in a yoke. The holder firmly positioned the samples on the SEM stage. (Fig. 5). The interface between the ceramic margin and the die was measured under 200x magnification. The micrograph was transferred to micrograph analyzing software. The measurement was accomplished using the 100 microns installed ruler and a line calibration tool to measure the vertical distance between the ceramic margin of the coping and the polymer die. Three vertical measurements were made at each of three points on every sample: mesial, buccal, and distal.

A total of 40 radiographs were made of all samples to determine the ceramic post length. The machine cone was placed perpendicular to the core and die combination on the facial aspect. The die was mounted in a self-cured acrylic holding block lined with heavy body polyvinyl siloxane impression material (3M) to simulate the periodontal ligament and bone radio-opacity. Mipax® radiographic software was used to measure the post length from the core base to the end of the post using the installed ruler tool (Fig. 6). Measurement of each post length was confirmed by using a caliper.

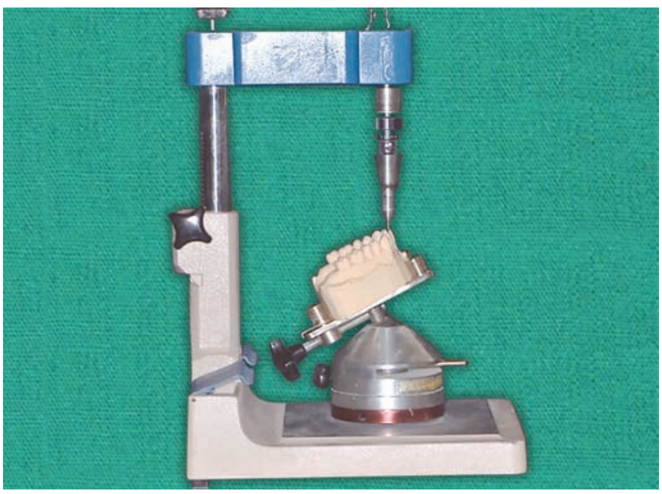


Fig. 2: A surveyor mounted handpiece was used to ideally prepare the canal space to the desired depth

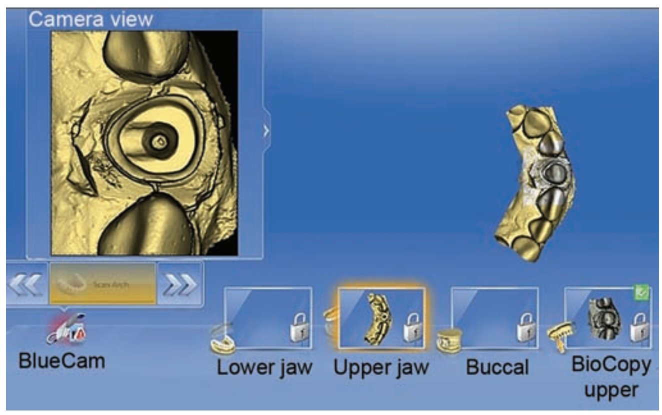


Fig. 3: Sirona Cerec BlueCam software®

Fig. 4: Restoration parameter for the cement spacer was set at 10 microns for all specimens

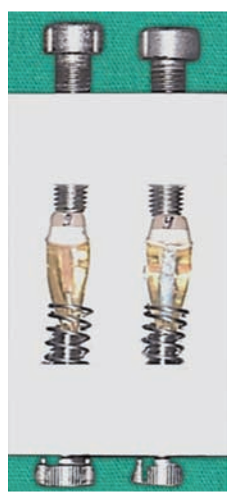


Fig. 5: Samples from the two groups were mounted in the holder, Group A (left) and Group B (right)

Test samples milled for groups A and B are illustrated in (Fig. 7).

RESULTS

One sample t-tests were used to evaluate actual post length compared to calibrated post lengths. Calibrated post lengths were set at 10 and 14 millimeters. Linear regression was appliedto evaluate the relationship between marginal gap (mesial, buccal, and distal) and post length within each group. One-way ANOVA was adapted to evaluate differences in the marginal gap among the three post length groups, with Bonferroni adjustment for pairwise comparisons. Statistical significance was determined to be $p < 0.05$. All analyses were done in version Stata 12 (College Station, TX). Mean post length for group A, which was calibrated for 10 mm, was 10.0 mm. The difference of <1 mm was not statistically significant ($p = 0.75$). Mean post length for group B, which was calibrated for 14 mm, was 11.0 mm. The difference of 3 mm was statistically significant ($p < 0.01$). Sample T test calculations for post lengths for groups A and B are illustrated in Tables 1 and 2.

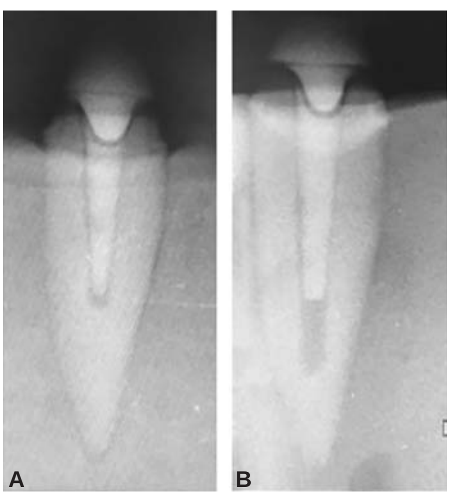
Overall, there was no pattern of relationship between marginal gap and post length between the two groups. One-way analysis of variance (ANOVA) showed no statistically significant differences in the mean marginal gap between the groups ($p = 0.36$). The mean mesial marginal gap for the two groups was 37.85 microns. The mean buccal marginal gap was 31.73333 microns and the mean distal marginal gap was 38.16667 microns.

DISCUSSION

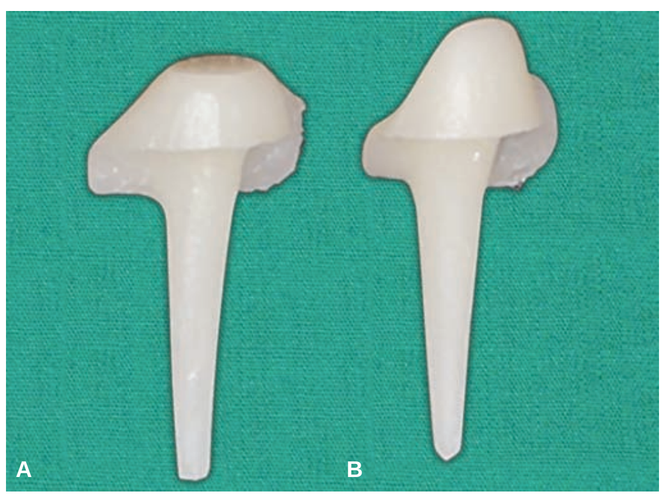
The objective of this study was to determine the focal depth of field of the CEREC BlueCam® scanner and to evaluate the capability of the system to mill ceramic post and core restorations. Two master dies were fabricated from a polymer material. The coronal portion of the die simulated an ideal core preparation 2 mm above the cementoenamel junction (CEJ) with a 1.5 to 2 mm ferrule. Canal space was prepared for two depths. The canal depth of group A was prepared for a post length of 10 mm. Group B canal depth was prepared for a post length of 14 mm. There are few publications that address CAD/CAM post and corerestorations. However, a 14 mm maximum focal length for the CAD/CAM scanner was established as a maximum focal length for the CAD/CAM camera through communication with Sirona USA and Sirona Germany.[28]

After scanning the restoration preparation 20 times for each group, it was determined that a depth of 10 mm was relatively easy to reach with the CEREC three camera®. A 13.7 mm canal space depth was captured by the camera in canals prepared for a 14 mm depth. However, the system was not able to mill a restoration beyond a post length of 11 mm. The mean post length for Group A was 10.0 mm, which was the same length as the prepared post space. The difference of <1 mm was not statistically significant ($p = 0.75$). Mean post length for Group B was 11.0 mm, which was three mm shorter than the prepared post space. The difference of 3 mm was statistically significant ($p < 0.01$).

It was determined through a pilot study that the CEREC software considers the post as apart of the internal surface of the restoration. When the cement space parameter was increased, the software increased the relief of the interface of the post and the canal space. This resulted in shortened posts. The longest posts in the pilot study were milled at a zero cement space parameter. Those posts engaged the canal and did not passively seat without significant adjustment. Posts milled at the 20-micron space setting were 1 mm shorter but passively seated. A 10-micron cement space setting was chosen for



Figs 6A and B: Mipax ® software radiographs for sample number 10 for group A (left) and group B (right)



Figs 7A and B: Samples milled for group A (left) and group B (right)

Table 1: One sample T test Group A

Variable interval	*Obs*	*Mean*	*Std. Err.*	*Std. Dev*	*95% Conf.*
Post length	20	10.0295	0.0900394	0.4026684	9.841045–10.21795

Mean = mean (post length) t = 0.3276
Ho: mean = 10degrees of freedom = 19
Ha: mean < 10 Ha: mean ! = 10 Ha: mean > 10
Pr (T < t) = 0.6266 Pr (|T| > |t|) = 0.7468 Pr (T > t) = 0.3734

Table 2: One sample T test Group B

Variable interval	*Obs*	*Mean*	*Std. Err.*	*Std. Dev*	*95% Conf.*
Post length	20	11.0475	0.0712183	0.3184978	10.89844–11.19656

mean = mean (post length) t = –41.4571
Ho: mean = 14degrees of freedom = 19
Ha: mean < 14 Ha: mean ! = 14 Ha: mean > 14
Pr (T < t) = 0.0000 Pr (|T| > |t|) = 0.0000 Pr (T > t) = 1.0000

this study because it balanced post length and passive fit of the restoration. Minimum adjustments were needed upon seating with this setting. Overall, there was no pattern of relationship between the marginal gap and post length among the two groups.

The results of this study fell within standards set by adenosine deaminase (ADA) specification number 8,[29] which states that the layer of luting cement for a crown should not exceed 40 microns when using a type II luting agent. Christenson's study agrees.[30] Another scaning electron microscope (SEM) study by Lofstrom et al.[31] of cemented cast gold restorations showed acceptable margins from 7 to 65 microns. Additional studies were found in the literature where the acceptable mean marginal gap for cemented castings ranged from 9 to 82 microns.[32-36]

The Sirona CEREC AC BlueCam® and the Sirona CEREC three compact milling machine® used in this study had limitations. This system captures images using a visible blue light emitted from an LED blue diode as its light source. The CEREC AC BlueCam® is able to digitally impress one quadrant within 1 minute. The Bluecam® must be used with an opaque powder coating of titanium dioxide before scanning to enable uniform light dispersion and to improve scan efficiency.[37] The newest CEREC system, CEREC AC Omnicam®, utilizes a continuous imaging mode where serial data capturing generates a 3D model. In addition, the Omnicam can be used for a single tooth, a quadrant or an entire arch. A final advantage of the Omnicom over the BlueCam is powder-free, scanning and precise 3D images with natural color. The powder-free criteria provide a superior advantage with a larger scanning area.[38] It is probable that introducing the Optispray powder into a 14 mm post length might introduce a screening challenge to capture the full depth of the prepared canal. Accumulation of the powder at the end of the prepared canal could possibly explain the reduced length of the milled post. Nevertheless, the virtual model created by the software was able to detect a canal depth up to 13.7 mm. However, posts could not be milled beyond 11 mm. Use of the latest Omnicam technology could eliminate errors introduced by the Optispray powder.

A post length up to 11 mm was milled successfully in this study which is adequate depth for a post space. According to Torabinejad et al.[39] 5 mm of gutta-percha is needed to maintain an apical seal of endodontically treated teeth.[39-41] For anterior teeth and bicuspids, it is recommended that 5 mm of apical gutta-percha is retained and that the post does not extend beyond that level. For molars, the length is determined by root thinning or perforation. Posts in molars should only extend 5 mm into the canal length.[39,42] Shillingburg et al. noted that making the post length equal to the clinical crown length would cause the post to encroach on the 4.0-mm "safety zone" of gutta-percha in some teeth.[43] Zillich and Corcoran[44] presented data comparing length guidelines to average, long, and short root lengths and the need to retain adequate apical seal. Whenposts were half of the length of average roots, the endodontic seal (5 mm) was rarely compromised. When posts were two-thirds, the root length, average and short rooted teeth had compromised apical seals. It should be emphasized that an average crown length is 10 mm.

CONCLUSION

This study concluded that chairside CAD/CAM technology can accurately produce directly all ceramic post and core restorations up to 10 mm of canal depth. It further found that the focal length of the Sirona CEREC AC Bluecam is accurate up to 13.7 mm. However, the technology is incapable of consistently producing accurate milled post and core restorations beyond 11 mm.

The mean marginal gap for both test groups was 38 microns. There was no pattern of relationship found between the marginal gap and post length in either group. The least detectable gap observed was 5 microns, and the greatest was 100 microns. The marginal gaps found in this study met acceptable clinical standards according to Holmes definition.

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