Comparison of Success Rates of Cone Beam Computed Tomography in the Retrieval of Metal-Ceramic vs All-Ceramic Implant-Supported Restorations: An In Vitro Study

Hamid Neshandar Asli, DDS, PhD
Dental Sciences Research Center, Department of Prosthodontics, School of Dentistry, Guilan University of Medical Sciences, Rasht, Iran.

Zahra Dalili Kajan, DDS, PhD
Negar Khozrivafard, DDS, PhD
Dental Sciences Research Center, Department of Maxillofacial Radiology, School of Dentistry, Guilan University of Medical Sciences, Rasht, Iran.

Seyyedeh Newsha Roudbary, DDS
Guilan University of Medical Sciences, Private Clinic, Rasht, Iran.

Elahe Rafiei, MS
Vice Chancellor of Research and Technology, Guilan University of Medical Sciences, Rasht, Iran.

Purpose: To assess the success rates of cone beam computed tomography (CBCT) in identifying the locations and directions of abutment screw access holes (ASAHs) in metal-ceramic and all-ceramic implant restorations. Materials and Methods: Thirty-two implants were inserted into four clear acrylic casts. Metal-ceramic and all-ceramic crowns were placed on the inserted implants in two successive tasks. A maxillofacial radiologist determined the locations and angles of the ASAHs based on the CBCT images that were taken from the casts. Locations obtained from the CBCT images were carefully transferred to the crowns as access points. A prosthodontist pierced the crowns along the proposed access points and in the direction determined based on the CBCT images. Proper crown removal was considered to be the mark of success of CBCT in detecting ASAH location and direction. Fisher exact and chi-square tests were used to compare the results between the two types of restoration. Results: Success rates of CBCT for defining ASAH location and direction were, respectively, 96.9% and 93.8% in metal-ceramic restorations and 78.1% and 59.4% in all-ceramic restorations. There were no significant differences between the two restoration types regarding the detection of location in either molar ($P = .333$) or premolar ($P = .226$) crowns. Abutment angle did not affect the success rate of CBCT in determining ASAH location or direction in metal-ceramic restorations. Conclusion: CBCT images define the locations and directions of ASAHs in metal-ceramic restorations more reliably than in all-ceramic restorations. In contrast to the metal-ceramic crowns, the success rate of CBCT in all-ceramic crowns is more dependent on abutment angle and crown morphology. Int J Prosthodont 2021;34:192–198. doi: 10.11607/ijp.6334
Various studies have proposed different techniques for achieving more reliable retrieval of cement-retained restorations, including the three-dimensional (3D) image superimposition computer-aided design/computer-aided manufacturing (CAD/CAM) technique, digital photography, and screw-access marking. Although accurate and efficient, most of these techniques become inapplicable when the patients’ previous records and casts are not available. To overcome this problem, a recent study used cone beam computed tomography (CBCT) imaging to determine the locations and directions (ie, angles) of abutment screw access holes (ASAHS) in metal-ceramic, cement-retained restorations and proved the technique to be reliable in that regard.

All-ceramic restorations have gained vast application owing to their great esthetics, wear resistance, and biocompatibility. Monolithic zirconia is a more recent type of these restorations that has been used for single-crown and full-mouth reconstructions due to its great strength in high load-bearing areas. An important question raised is: Does CBCT perform equally well when locating ASAHS in all-ceramic restorations? Therefore, the present research focused on comparison of CBCT success rates when identifying the locations and directions of ASAHS in metal-ceramic and all-ceramic monolithic zirconia cement-retained implant restorations.

MATERIALS AND METHODS

This in vitro study was performed on four clear acrylic casts that were fabricated based on an edentulous mandibular model. The ethical approval code for this study was IR.GUMS.REC.1396.53. Initially, four clear acrylic samples were given to a maxillofacial surgeon with a description of the study purpose. The surgeon designed and practiced the drilling directions upon consultation with a prosthodontist by tracing the drilling directions using a tooth pick and direct observation. Several samples were lost due to improper drilling direction until four ideal casts were obtained. Each cast contained eight osteotomies measuring 4 mm in diameter and 11 mm in length. Drillings were done using a surgical bur (Ufit), half in the premolar and half in the molar areas. A total of 32 GT2 implants (Ufit) were inserted into the casts. The sample size of this in vitro study was based on the only available study with a similar methodology.

The abutments used in each restoration type were either straight (n = 15) or angled 15 degrees (n = 8) or 25 degrees (n = 9). In cases where the abutment was angled, the path of crown insertion was corrected in such a way that the long axes of the abutments remained parallel to each other and in right angles to the occlusal plane. The path of the ASAH could therefore be either central in relation to the direction of implant insertion or with buccal-lingual and mesial-distal deviations. The maxillofacial radiologist (Z.D.K.) was completely blind to the locations and directions of implants throughout the process of sample preparation. Metal-ceramic crowns were made with the closed tray and indirect transfer coping techniques. After performing the impression, transfer copings were separated from the casts, attached to the analogs, and returned to the impression tray. The laboratory cast was then prepared, and the abutments were selected according to the cast. Afterwards, metal-ceramic crowns were fabricated. For the metal part, nickel-chromium alloy (VeraBond, Aalbadent) was used. The ceramic components of the crown were made out of veneering porcelain (Ceramco 3, Dentsply Sirona). The abutments were transferred to the main cast and screwed to the implants based on the torque recommended by the manufacturer. The access channels were filled with polytetrafluoroethylene tape. Crowns were then glazed and cemented on the abutments with a resin-based cement (GC FujiCEM 2, GC America). A gingival mask was used for simulation of the gingiva. For preparation of the all-ceramic monolithic zirconia crowns, casts were scanned with a laboratory scanner (Ceramill Map400, Amann Girrbach), and Ceramill Mind software (Amann Girrbach) was used to precisely design the crowns. Milling was performed with a Ceramill Motion 2 machine (Amann Girrbach). After detachment from the blanks, crowns were sintered at 1,450°C and polished and cemented on the abutments with the same cement as for the metal-ceramic crowns. At this point, the casts (whether containing metal-ceramic or all-ceramic restorations) were ready to be imaged with the CBCT device.

It is noteworthy to mention that prior to performing the main study steps, as an initial evaluation of the appearance of both metal-ceramic and all-ceramic restorations on CBCT images, a small number of the samples was cemented with interim luting agent (Temp Bond, Kerr) on the abutments in order to make it possible to retrieve these crowns without any structural damage and further use them as part of the main sample.

CBCT images of the mandibular models were acquired with Promax-3D machine (Planmeca). The models were placed in the middle of a U-shaped, water-containing lacuna so that the occlusal plane was parallel to the floor. A trained technician took images from the casts using the same standard protocol: selection of the “full” icon in the horizontal and vertical dimensions. The acquired images were viewed with Romexis software (version 3.8.3.R, Planmeca). Initially, the location of the ASAH for each implant was defined on the most superficial portion on the occlusal surface using the multiplanar reconstruction tool of the software. Subsequently, serial cross-sectional images of 1-mm thickness and 1-mm intervals were created in the buccolingual and mesiodistal directions, and the image corresponding to the clearest depiction of the ASAH was
selected. Following the adjustment of gray values and marking the ASAH with the “nerve mapping” tool of the software, location of the access channels was identified by the measurement tool as the shortest distance to the mesial or distal aspect and to the buccal or lingual aspect of the occlusal surface. Likewise, direction of the access channels was defined by the angle tool in two planes (x and y) from the mesial or distal and the buccal or lingual sides (Figs 1 and 2). Access point coordinates were then carefully transferred from the CBCT images to the crowns by means of a ruler and a protractor, and a tooth pick was used as a direction indicator (Fig 3).

A prosthodontist who was blind to the abutment selection procedure pierced the crowns along the predicted points and directions. For the metal-ceramic crowns, piercing was done with a round diamond rotary instrument (Meisinger). Piercing of the all-ceramic crowns was performed with zirconia diamond burs (Z 801-018M, Prima Dental). As penetrating through zirconia crowns is generally a difficult procedure, it was possible that a number of the mentioned burs would need to be used for each crown to fully accomplish the task. Success in detecting ASAH location and direction was defined based on the criteria of Neshandar Asli et al.\textsuperscript{10}:

\textbf{Fig 1} Multiplanar CBCT images of the mandibular second premolar and first molar implants with metal-ceramic implant restorations.

\textbf{Fig 2} Multiplanar CBCT images of second premolar implant with all-ceramic monolithic zirconia implant restoration.
If the position of the ASAH was correct, it was considered a success in determination of the access hole location and if the prosthodontist could remove the crown from the implant abutment by accessing the ASAH through the hole in the crown, the result was considered as successful definition of the direction. Contrarily, if it was necessary to change the direction, the result was considered negative and unsuccessful.

However, the threshold for successful retrievability was the removal of the crown from the implant abutment through the ASAH by considering that the maximum accepted destruction was a little more than the size of the screw driver.

Data were transferred to SPSS software version 22 (IBM). Comparison of the success rates of CBCT in the retrieval of the two restoration types based on the variables abutment angulation and crown form was made using Fisher exact and chi-square tests. Chi-square test was used to compare proper direction detection between the two kinds of crown restorations in total (metal-ceramic vs all-ceramic) and based on the abutment type (straight vs angled). $P < .05$ was considered as the level of statistical significance.

RESULTS

Success rates of CBCT in identifying ASAH location and direction proved to be greater for metal-ceramic implant restorations. There was no significant difference in the success rates for detecting the location between the two restoration types ($P = .053$); however, the same fact did not exist for the direction ($P = .001$) (Table 1).

The comparison of CBCT success rates for detecting location and direction based on crown morphology between the two restoration types is shown in Table 2. There were no significant differences in the success rates for detection of location in either crown type ($P > .05$), while detection of direction in the premolar crowns was significantly better in metal-ceramic restorations ($P = .002$).

Regarding the abutment angle, 15 straight and 17 angled abutments were used for each restoration type. Except for the ASAH direction in the angled abutments, there were no significant differences between the two types of restoration. Table 3 presents the success rates of CBCT in each abutment group for the two restoration types. In both restoration types, ASAHs were positioned centrally in 15, buccally or lingually in 8, and mesially or distally in 9 crowns. Table 4 reveals that there were no significant differences in success rates of CBCT for detecting location or direction regarding the relative position within the crowns.

DISCUSSION

The success rates of CBCT for detecting ASAH location and direction in metal-ceramic restorations were 96.9% and 93.8%, respectively, which were greater than the equivalent rates in the all-ceramic restorations, 78.1% and 59.4%, respectively.
Neshandar Asli et al.\textsuperscript{10} had previously assessed the success rate of CBCT in detecting ASAHs of metal-ceramic implant restorations using CBCT images obtained with the NewTom VG device (QR srl). A long grayscale zone was applied to the multiplanar images in order to enhance the visibility of the access channels. Success rates were calculated to be 83.3\% for detecting ASAH location and 80\% for directions. A similar methodology was applied in the present study, and all-ceramic restorations were also incorporated. Images were acquired with a different CBCT device (ProMax 3D, Planmeca). Success rates for ASAH detection in metal-ceramic crowns were enhanced compared to the former study, possibly owing to further experience gained by the maxillofacial radiologist in evaluating the ASAHs more interactively through the CBCT image slices. Weaker ASAH detection in all-ceramic restorations seemed to be due to the uniformity of image density throughout the restoration and the absence of contrast between the metal and ceramic components, as encountered in metal-ceramic crowns.

Considering whether the abutment was straight or angled, CBCT images of both metal-ceramic and all-ceramic restorations provided better ASAH detection in the straight abutments, although the technique was superior in both types of abutment for the metal-ceramic crowns. This finding was also consistent with the results reported by Neshandar Asli et al.\textsuperscript{10}

### Table 2
Comparison of CBCT Success Rates in Detecting Abutment Screw Access Hole Location and Direction in Metal-Ceramic and All-Ceramic Restorations Based on Tooth Type

<table>
<thead>
<tr>
<th>Tooth type</th>
<th>Restoration type</th>
<th>Proper location detection, n (%)</th>
<th>Proper direction detection, n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Success</td>
<td>Failure</td>
<td>Success</td>
</tr>
<tr>
<td>Molar</td>
<td>Metal-ceramic (n = 16)</td>
<td>15 (93.8)</td>
<td>1 (6.3)</td>
</tr>
<tr>
<td></td>
<td>All-ceramic (n = 16)</td>
<td>12 (75)</td>
<td>4 (25)</td>
</tr>
<tr>
<td>p\textsuperscript{a}</td>
<td>.333</td>
<td>.394</td>
<td></td>
</tr>
<tr>
<td>Premolar</td>
<td>Metal-ceramic (n = 16)</td>
<td>16 (100)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>All-ceramic (n = 16)</td>
<td>13 (81.3)</td>
<td>3 (18.8)</td>
</tr>
<tr>
<td>p\textsuperscript{a}</td>
<td>.226</td>
<td>.002</td>
<td></td>
</tr>
</tbody>
</table>

\textsuperscript{a}Fisher exact test.

### Table 3
Comparison of CBCT Success Rates in Detecting Abutment Screw Access Hole Location and Direction in Metal-Ceramic and All-Ceramic Restorations Based on Abutment Type

<table>
<thead>
<tr>
<th>Abutment type</th>
<th>Restoration type</th>
<th>Proper location detection, n (%)</th>
<th>Proper direction detection, n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Success</td>
<td>Failure</td>
<td>Success</td>
</tr>
<tr>
<td>Straight</td>
<td>Metal-ceramic (n = 15)</td>
<td>15 (100)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>All-ceramic (n = 15)</td>
<td>14 (93.3)</td>
<td>1 (6.7)</td>
</tr>
<tr>
<td>p\textsuperscript{a}</td>
<td>.999\textsuperscript{a}</td>
<td>.224\textsuperscript{b}</td>
<td></td>
</tr>
<tr>
<td>Angled</td>
<td>Metal-ceramic (n = 17)</td>
<td>16 (94.1)</td>
<td>1 (5.9)</td>
</tr>
<tr>
<td></td>
<td>All-ceramic (n = 17)</td>
<td>11 (64.7)</td>
<td>6 (35.3)</td>
</tr>
<tr>
<td>p\textsuperscript{a}</td>
<td>.085\textsuperscript{a}</td>
<td>.004\textsuperscript{b}</td>
<td></td>
</tr>
</tbody>
</table>

\textsuperscript{a}Fisher exact test.
\textsuperscript{b}Chi-square test.

### Table 4
Comparison of CBCT Success Rates in Detecting Abutment Screw Access Hole (ASAH) Location and Direction Based on Position Within Metal-Ceramic and All-Ceramic Restorations

<table>
<thead>
<tr>
<th>Restoration type</th>
<th>Position of ASAH</th>
<th>Proper location detection, n (%)</th>
<th>Proper direction detection, n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Success</td>
<td>Failure</td>
<td>Success</td>
</tr>
<tr>
<td>Metal-ceramic</td>
<td>Central (n = 15)</td>
<td>15 (100)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Buccal/lingual (n = 8)</td>
<td>7 (87.5)</td>
<td>1 (12.5)</td>
</tr>
<tr>
<td></td>
<td>Mesial/distal (n = 9)</td>
<td>9 (100)</td>
<td>0</td>
</tr>
<tr>
<td>p\textsuperscript{a}</td>
<td>.250</td>
<td>.274</td>
<td></td>
</tr>
<tr>
<td>All-ceramic</td>
<td>Central (n = 15)</td>
<td>14 (93.3)</td>
<td>1 (6.7)</td>
</tr>
<tr>
<td></td>
<td>Buccal/lingual (n = 8)</td>
<td>5 (62.5)</td>
<td>3 (37.5)</td>
</tr>
<tr>
<td></td>
<td>Mesial/distal (n = 9)</td>
<td>6 (66.7)</td>
<td>3 (33.3)</td>
</tr>
<tr>
<td>p\textsuperscript{a}</td>
<td>.140</td>
<td>.082</td>
<td></td>
</tr>
</tbody>
</table>

\textsuperscript{a}Fisher exact test.
In both the premolar and molar crowns, both the location and direction of ASAHS were identified better in CBCT images of metal-ceramic restorations. No statistically significant difference was observed between detection of location in the premolar vs molar crowns of metal- or all-ceramic restorations; however, detection of ASAH direction in the premolar crowns of metal-ceramic restorations was better than in their all-ceramic counterparts. The small bulk of premolar crowns in addition to the homogeneity of the image density in all-ceramic restorations could adversely affect the detection of ASAH direction in these restorations.

Regarding the centricity of ASAHS within the crowns, it was witnessed that in the CBCT images, the greatest success rates for both types of restoration and for both the location and direction of the access channels were related to the central position, followed by the mesiodistal and buccolingual eccentricities, in that order.

Various practitioners have attempted to develop techniques for proper retrieval of cemented implant-supported restorations. Doerr\(^5\) suggested a technique that, although seemingly accurate, requires the implant- and abutment-level casts to be retained. Similarly, Park and Yoon\(^6\) described a three-dimensional CAD/CAM–based technique that needs patient records to be available. The silicon putty index method proposed by Hill\(^16\) and the vacuum-formed guide technique suggested by Tarlow\(^17\) are other examples of retrieval methods, all with the same shortcoming of requiring previous patient records at the time of prosthesis retrieval.

Schoenbaum et al,\(^8\) as well as Schwedhelm and Ragodski,\(^18\) introduced access-hole marking methods that benefit from not needing patient records; however, they would not be applicable for the retrieval of restorations in the anterior region due to esthetic concerns. Rajan and Gunaseelan\(^19\) offered a method for fabrication of a retrievable cemented restoration; nevertheless, the technique does not suit patients with short interocclusal space.

Another proposed method is the use of digital photographs\(^2,20,21\) to determine the locations of ASAHS in cemented restorations; however, this technique fails to identify the angulation of the access channels. Contrarily, CBCT proved to be sufficiently accurate in revealing both the locations and angulations of ASAHS in metal-ceramic restorations and also showed acceptable success in detecting the locations of ASAHS in all-ceramic crowns.

Detection of ASAHS was more successfully accomplished in CBCT images of metal-ceramic restorations, most likely owing to the difference between the densities of the metal and ceramic components, which makes detection of the access channels more feasible. On the contrary, identifying ASAH location and, in particular, direction in the images of all-ceramic crowns was less reliable; therefore, retrieval of this type of implant restoration solely on the basis of CBCT images involves higher risk of structural destruction during the removal procedure.

An important factor to consider in the prognosis of cemented crowns that are subjected to substantial material removal during the retrieval procedure is the type of cement used. A number of studies have provided detailed information regarding the resistance to dislodgment forces of various cement types.\(^22,23\) Sheets et al\(^22\) evaluated 11 different cement materials for their retention in cement-retained implant restorations and eventually concluded that none of the investigated materials could be considered more retentive than others. Conversely, Bernal et al\(^23\) came upon more tensile resistance of acrylic/urethane cements in their survey of various cement agents. In the present study, GC FujiCem 2 was used, which is a resin-based cement with a retention high enough to put the crown at risk of substantial damage during the retrieval process.\(^22\) Nevertheless, none of the crowns were found to have visible fracture lines following their removal, according to CBCT images.

Further practice would certainly be beneficial for radiologists to more accurately define ASAHS in CBCT images of all-ceramic restorations. Furthermore, technical improvements in the design of CBCT devices to enhance visualization of the differences in gray values might result in better ASAH detection in all-ceramic restorations.

**CONCLUSIONS**

CBCT is generally more reliable for ASAH detection in metal-ceramic implant restorations; however, it could be helpful for the retrieval of all-ceramic monolithic zirconia restorations in the posterior areas as well. Both crown morphology and abutment angle are factors affecting the success rate of CBCT in the retrieval of these restorations. Finally, radiation dose concerns could be properly managed by taking advantage of smaller fields of view.

**ACKNOWLEDGMENTS**

This study was supported financially by the Vice Chancellery for Research and Technology and the Dental Sciences Research Center of Guilan University of Medical Sciences, IR.GUMS.REC.1396.53. The authors declare no conflicts of interest.

**REFERENCES**


Literature Abstract

Adhesion to Zirconia: A Systematic Review of Current Conditioning Methods and Bonding Materials

Reliable bonding between composite resin cements and high-strength ceramics is difficult to achieve because of chemical inactivity and lack of silica content, which makes etching impossible. The purpose of this review was to classify and analyze the existing methods and materials suggested to improve the adhesion of zirconia to dental substrates using composite resins in order to explore current trends in surface-conditioning methods with predictable results. The current literature examining the bond strength of zirconia ceramics was analyzed. The search for the literature was carried out using PubMed and the Cochrane Library databases for papers in English published online from 2013 to 2018. The following keywords and their combinations were used: zirconia, 3Y-TZP, adhesion; adhesive cementation; bonding; resin; composite resin; composite material; dentin; and enamel. The literature search provided 390 titles with abstracts. From these, a total of 93 publications were chosen for analysis. After a full-text evaluation, 7 articles were discarded. Therefore, the final sample was 86, including in vitro studies, clinical studies, and one systematic review. Various adhesive techniques with different testing methods were examined. Airborne-particle abrasion and tribochemical silica coating are the pre-treatment methods with the most evidence in the literature. Increased adhesion could be expected after physicochemical conditioning of zirconia. Surface contamination has a negative effect on adhesion. There is no evidence to support a universal adhesion protocol.


Literature Abstract

Clinical Assessment of Short Implants Retaining Removable Partial Dentures: 4-Year Follow-Up

The purpose of this study was to prospectively evaluate the 1- and 4-year survival rates of short implants retaining removable partial dentures (RPDs) in Kennedy Class I and II edentulism. Twenty patients (Kennedy Class I and II) rehabilitated with RPDs were selected for the insertion of one short implant in the distal edentulous ridge connected to the RPD with a Locator attachment after osseointegration. The following data were recorded at the 1- and 4-year follow-ups: bone loss, bleeding on probing (BOP), probing depth (PD), implant mobility, and survival. Thirty-five implants were placed from September 2012 to April 2014. At the 4-year follow-up, 12 implants showed BOP. For PD, 15 implants showed 2 mm; 16 implants showed 3 mm; and 2 implants showed 4 mm. One implant showed mobility, and 2 were lost (survival rate: 94.3%; 95% CI: 80.84 to 99.30). The mean bone loss was 1.04 ± 1.88 mm. Within the limitations of this study, the implant survival rate and the mean bone loss values reported are comparable with those reported by other authors. The use of short implants for retaining RPDs may be considered a viable treatment option for patients with distal edentulism and contraindications for more complex implant rehabilitation.