Implant-supported crowns (ISC) offer a viable and popular option for replacing missing teeth without the need to remove tooth structure, as with conventional partial fixed dental prostheses. They are also generally preferred as a treatment option for missing teeth over partial removable partial dentures.\(^1\)

Implant crowns can be retained by either cementing them over an abutment or attaching the crown to the implant or an abutment with a screw.\(^2\) Advantages and disadvantages of cement and screw-retained implant crowns have been described previously.\(^3-7\)

Screw-retained crowns (SRCs) offer the advantage of retrievability in that the crown can be recovered intact in the event of screw loosening or screw fracture. A

### Statement of problem
Access channels for retrieving ceramic implant-supported screw-retained crowns may decrease their fracture resistance.

### Purpose
The purpose of this in vitro study was to evaluate the effect of screw-access channels on 3 types of ceramic implant-supported crowns.

### Material and methods
Sixty computer-aided designed and computer-aided manufactured (CAD-CAM) ceramic implant-supported screw-retained maxillary premolar crowns were fabricated, 30 with an occlusal screw-access channel and 30 without access channels. Each group was further divided into the following 3 subgroups of 10 specimens each: monolithic zirconia, veneered zirconia, and lithium disilicate. Identical milled titanium implant abutments were fabricated. Crowns were fabricated with standardized thicknesses and subjected to cyclic loading until failure occurred. Data analysis was performed using 1-way analysis of variance test of significance followed by Tukey honest significant difference (HSD) test ($\alpha=0.05$).

### Results
No significant differences in fracture resistance were found between access channel groups and corresponding groups without access channels ($P>0.05$). Among the subgroups, monolithic zirconia recorded the highest fatigue failure mean load values (2047.8 ±83.2 N for crowns with access channels and 2028.7 ±104.5 N for crowns without access channels), which was significantly higher ($P<0.05$) than values for the lithium disilicate group (605.4 ±37.9 N for crowns with access channels and 615.3 ±76.6 N for crowns without access channels) and the veneered zirconia group (411 ±34.4 N for crowns with access channels and 461.2 ±72.7 N for crowns without access channels), which recorded the lowest fatigue failure load mean values.

### Conclusions
Screw-access channels did not affect the fatigue failure load of monolithic zirconia, monolithic lithium disilicate, or veneered zirconia ceramic crowns. Monolithic zirconia crowns recorded significantly higher fatigue failure load among the 3 types of crowns tested. (J Prosthet Dent 2016;116:214-220)
disadvantage of cement-retained crowns (CRCs) is the risk of retained excess cement, which has been reported to result in peri-implantitis, ulceration, edema, bone loss, or even implant failure.8,9 CRCs have the advantage of being more passively attached to the implant, which may prevent or reduce the concentration of stresses when there is slight misalignment among the crown, implant, and adjacent teeth. The slight cement space present between the crown and abutment offers a degree of compensation (stress relief), which is an advantage.10-12 Another advantage of CRCs is the easier laboratory fabrication procedures resulting in reduced laboratory costs compared with those of tooth-supported crowns.3 In addition, the clinical procedures are the same as those used for conventional crowns.

A disadvantage of CRCs is that they are difficult to remove should a complication occur. To increase the ease of retrievability of cemented crowns, some authors have suggested cementing crowns using interim cement.13-17 Others have suggested a lingual access channel that extends through the crown and into the abutment near the cervical crown/abutment interface.18 The crown is cemented to the abutment using an interim cement, and the channel is then filled with composite resin to serve as a locking mechanism. Removal of the composite resin allows an ultrasonic device or crown remover to be used to dislodge the crown.18

A drilling guide or template has also been proposed to show the position and angulation of the access channel accurately to facilitate the precise drilling of an access hole to find the abutment screw should removal be necessary.19 The use of surface stains on the crown at the position of the access channel has also been suggested as a way of identifying where the abutment screw can be accessed.20

An alternative design, known as “the combination implant crown,” has been suggested by McGlumphy et al,21 Rajan and Gunaseelan,10 and Uludag and Celik.22 For this design, the definitive crown is cemented to the implant abutment extraorally. Excess cement is easily removed extraorally, and the cemented assembly can be screwed onto the implant through an access screw channel in the restoration, which is later closed by composite resin. This design feature combines the advantages offered by the SRC and the CRC.

When metal ceramic single crowns were cemented over implant abutments and compared with those containing screw-access channels, multiple studies reported that the access channel weakened the porcelain.23-25 In addition, more porcelain chipping occurred with metal ceramic partial fixed dental prostheses when screw-access channels were present compared with the prostheses with intact occlusal surfaces.26 Bompolaki et al27 reported that endodontic access preparation significantly reduced fracture resistance of lithium disilicate restorations. A number of studies addressed the fracture resistance of ceramic restorations.28-30 However, the effect of screw-access channels on the fatigue strength of ceramic single implant crowns has not been reported. In addition, no published reports have evaluated the effect of screw-access channels on the strength of different types of ceramic implant crowns, including lithium disilicate and zirconia with its possible temperature degradation.31

This study was designed to test the effect of a screw-access channel on the fracture resistance of ceramic crowns after cyclic loading.32 The primary null hypothesis of this study was that the presence or absence of screw-access channels would have no effect on the fracture resistance of ceramic crowns. The secondary null hypothesis was that no differences would be found in fatigue strengths among the 3 ceramic crown designs.

**MATERIAL AND METHODS**

Using a dental surveyor (A.M.D. Dental Mfg, Inc), 60 cylindrical internal hexagon implants, with a 4.5-mm platform and 10-mm in length (Tixos; Leader Italia Srl) were placed in autopolymerizing transparent acrylic resin (Vertex-dental B.V.) blocks so that the resin was located 1.0 mm apical to the implant platform. Resin blocks were 10×10×15 mm. Straight titanium-shouldered abutments were used (Ø 4.0, Tixos; Leader Italia Srl). Titanium abutments were milled so that they possessed a 1.5-mm occlusal reduction33 and 1.0-mm heavy chamfer finish line34 with 6 degrees of taper by using a round-end tapered diamond rotary instrument with a guiding pin (Komet, Brasseler) run at 40 000 rpm in a parallelemeter (Amann Girrbach) (Fig. 1).

Milled titanium abutments were scanned using an extraoral scanner (S50 Zenotec CAD; Wieland Dental) to create a computer-aided designed and computer-aided manufactured (CAD-CAM) model for a ceramic crown representing the maxillary right first premolar. The following 3 types of ceramic crowns were fabricated with and without occlusal screw-access channels: monolithic zirconia (MZ) crowns (Weiland Zenostar coping; Wieland Dental + Technik GmbH & Co KG); monolithic lithium disilicate (LD) crowns (IPS e.max CAD; Ivoclar Vivadent AG); and veneered zirconia (VZ) crowns.
(Weiland Zenostar coping; Wieland Dental + Technik GmbH & Co. KG) veneered with IPS e.max Ceram, (Ivoclar Vivadent AG) (Tables 1, 2). For the screw-access channel group (subgroups MZ, LD, and VZ), the CAD model was created with a screw-access channel in the center of the occlusal surface, whereas the CAD model for the crowns without access channels was designed with an intact occlusal surface. An example of an MZ crown with a screw-access channel and its assembly is shown in Figure 2. The CAD model for the VZ subgroups included a zirconia coping designed and fabricated with a standardized cutback for application of a 0.7-mm-thick ceramic veneer over the entire coping.

The complete contour crowns (subgroups MZ and LD) and copings (subgroup VZ) were milled according to CAD models and sintered in a ceramic oven (Zenotec Fire Cube; Wieland Dental + Technik GmbH & Co KG), using a fast sinter program for single crowns. Copings (subgroup VZ) were milled to design and then veneered with IPS e.max Ceram (Ivoclar Vivadent AG), using a silicone index to standardize the 0.7-mm veneer thickness. After sintering, crowns and copings were ultrasonically cleaned, and each was assigned to its corresponding abutment.

Before cementation, the intaglio surface of the crowns in subgroups MZ and VZ were airborne particle-abraded using 50-μm Al2O3 at a pressure of 0.15 MPa and at a distance of 2 cm, followed by water steaming and then ultrasonic cleaning in distilled water for 10 minutes. Intaglio surfaces for subgroup LD were acid-etched with 9.0% hydrofluoric acid (Ultradent Porcelain Etch; Ultradent Products Inc) for 90 seconds, rinsed with distilled water, and air-dried. Phosphoric acid (Ultra-Etch; Ultradent Products Inc) was then applied for 5 seconds to remove any residual ceramic salts and debris formed by the etching with hydrofluoric acid. A silane coupling agent (Ultradent Porcelain Silane; Ultradent Products Inc) was then applied to the intaglio surfaces for 1 minute and thinned using gently directed compressed air. For specimens in the screw-access channel group (group C), the screw-access channels were closed with wax (Renfert GmbH) before cementation.

For group C (with access channel), the crown was cemented with resin cement (RelyX U 200; 3M ESPE) on its corresponding abutment, excess cement was removed with a sickle scaler (Hu-Friedy Mfg Co, LLC) (Fig. 3), and the crown was screwed to the implant. For group NC (without access channel), the abutment was tightened at 35 Ncm to the implant, the crown was cemented with resin cement (RelyX U 200; 3M ESPE), and excess cement was removed with a sickle scaler (Hu-Friedy Mfg Co, LLC). For both groups, all crowns were placed under a static load of 49 N for 10 minutes.

After cement polymerization, the wax plug was removed from the access channel specimens, and all cemented abutment/crown assemblies were examined under x10 magnification. Residual cement was completely removed with a sickle scaler. Each assembly was then reseated on its corresponding implant so that the abutment screw could be inserted through the channel and tightened to 35 Ncm (Figs. 4, 5). The channel was then sealed with gutta percha followed by a composite resin plug (Filtek Z 350 XT Universal Restorative; 3M ESPE) (Fig. 6). All specimens were stored in distilled water at room temperature for 72 hours. Thermal cycling was performed on all specimens for 1000 cycles between 5°C and 55°C, with a dwell time of 30 seconds at each temperature.

All specimens were individually mounted to the lower fixed head of a computer-controlled materials testing system.

### Table 1. Specimen grouping

<table>
<thead>
<tr>
<th>Group</th>
<th>Crown Design</th>
<th>Subgroup</th>
<th>Crown Design</th>
<th>No. (N=60)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>Screw-access</td>
<td>MZ</td>
<td>Monolithic zirconia</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>channel crowns</td>
<td>VZ</td>
<td>Veneered zirconia</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LD</td>
<td>Lithium disilicate</td>
<td>10</td>
</tr>
<tr>
<td>NC</td>
<td>Crowns without</td>
<td>MZ</td>
<td>Monolithic zirconia</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>access channels</td>
<td>VZ</td>
<td>Veneered zirconia</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LD</td>
<td>Lithium disilicate</td>
<td>10</td>
</tr>
</tbody>
</table>

LD, lithium disilicate; MZ, monolithic zirconia; NC, no channel; VZ, veneered zirconia.

### Table 2. Composition of materials

<table>
<thead>
<tr>
<th>Trade Name</th>
<th>Composition</th>
<th>Shade</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zenostar blocks</td>
<td>Zirconium dioxide (ZrO2+HfO2+Y2O3)</td>
<td>A2</td>
<td>Wieland Dental + Technik GmbH and Co KG</td>
</tr>
<tr>
<td>IPS e.max CAD blocks</td>
<td>Li2Si2O5</td>
<td>A2</td>
<td>Ivoclar Vivadent AG</td>
</tr>
<tr>
<td>IPS e.max Ceram</td>
<td>Glass ceramic and fluorapatite crystals, Ca5(PO4)3F. Material does not contain feldspar or leucite.</td>
<td>A2</td>
<td>Ivoclar Vivadent AG</td>
</tr>
</tbody>
</table>

CAD, computer-aided design.
machine (model 3345; Instron Instruments Ltd) with a load cell of 5 kN (Fig. 7). A 1-mm-thick tin foil sheet (Fig. 7) was placed between the loading tip and the occlusal surface of the crown to avoid local stress concentration. Specimens were subjected to cyclic loading by means of a 5.8-mm-diameter metallic sphere, which was attached to the upper movable head of the machine, and the load was applied at the inclined cuspal planes. The load profile was in the form of a sine wave at a rate of 1 Hz. The rate used was equivalent to the average masticatory cycle of 0.8 to 1.0 seconds. The load was cycled at first between a specified maximum (200 N) and a small but nonzero minimum (20 N) to avoid lateral dislocation of the loading tip and help stabilize each specimen during the test. These values were used because they represented the average mastication force in patients who have a single-crown restoring a molar tooth. Data were recorded using computer software (Bluehill Lite Materials Testing Software; Instron Instruments Ltd).

The cyclic compressive fatigue test at 5000 load cycles was used in accordance with the modified staircase method. In this method, tests are conducted sequentially, with the maximum applied load in each succeeding test being increased by a fixed amount, according to whether the previous load resulted in failure or no failure. When the specimen did not fail within the prescribed number (5000) of load cycles and the prescribed load (200 to 20 N), the load was then increased by a fixed increment of 10% of static compressive load until failure (Fig. 8).
Statistical analysis of data was performed using 1-way ANOVA test of significance followed by the Tukey honest significant differences (HSD) test ($\alpha=.05$).

**RESULTS**

No significant differences were found between the access channel groups and the groups without an access channel ($P>.05$) as seen in Table 3. However, within the subgroups, significant differences were recorded. The monolithic zirconia group (group MZ) for both groups C and NC recorded the highest fatigue failure mean load values (2047.8 ±83.2 N for group C and 2028.7 ±104.5 N for group NC), which was significantly higher ($P<.05$) than those of the lithium disilicate groups (group LD; 605.4 ±37.9 N for group C and 615.3 ±76.6 N for group NC) and the veneered zirconia groups (VZ; 411 ±34.4 N for group C and 461.2 ±72.7 N for group NC); the veneered zirconia group (group VZ) recorded the lowest fatigue failure load mean values. One-way ANOVA followed by Tukey HSD test revealed significant differences in fatigue load mean values among all subgroups. (Fig. 9).

**DISCUSSION**

The present study compared the fatigue failure of ceramic ISC with screw-access channels, referred to as combination implant crown,21 with that of ISC without an access channel.

Ceramic screw-retained ISCs offer the advantage of retrievability4,9 combined with better tissue tolerance.5-7 However, Torrado et al23 reported that screw-retained, implant-supported metal ceramic crowns revealed significantly lower fracture resistance than cement-retained metal ceramic crowns. Zarone et al24 reported no significant differences in fracture resistance between implant-supported screw and cement-retained metal ceramic restorations. Karl et al26 compared the effects of dynamic loading between screw-retained and cement-retained implant-supported partial fixed dental prostheses and reported more chipping fractures with screw-retained implant-supported partial fixed dental prostheses.

The fracture strength of ceramic restorations has been studied previously.28-30 However, the effect of a channel specifically designed for retrievability of cemented SR ceramic crowns on fracture strength has not been studied. This study was designed with 3 commonly used ceramic materials to test the fatigue resistance of each individual group with and without access channels.

Results of this study revealed no significant differences in fracture resistance between the ceramic crowns with and those without an occlusal screw-access channel.
The screw-access channel did not have a significant effect on the fracture resistance or fatigue strength of ceramic crowns. This finding gives greater confidence in the use of ceramic, retrievable crowns that are cemented to a titanium abutment before abutment screw tightening. This type of restoration offers unique advantages over both cemented and traditional screw-retained implant-supported restorations, such as ease of retrievability (for screw-retained) and ability to remove excess cement (for cement-retained) before clinical placement. An interesting observation is that most of the fractures of the screw-access group (group C) started cervically and proceeded occlusally, contrary to expectations. However, fracture of the complete contour crowns (group NC) started occlusally and proceeded cervically. This may explain the higher fatigue failure mean load values of the 2 monolithic subgroups (MZ and LD) in the group C compared with those in group NC. Finite element stress analysis, scanning electron microscopy analysis, and fractographic analysis along with high-speed video camera recordings are needed to further investigate these observations.

Significant differences were noted in fracture resistance among the different types of ceramic crowns. MZ revealed significant strength, followed by LD. VZ restorations revealed significantly lower fracture resistance than the other 2 subgroups. The mode of failure of the VZ subgroups was interesting. All fractures occurred within the feldspathic porcelain. None of the zirconia cores fractured.

An observation from this study supports previous research\textsuperscript{41,42} reporting that access channels had no significant effect on the retention of metal copings to implant abutments. Although our study was not conducted to study retention, the loads applied to test fatigue resistance did not result in the separation of any crowns from the titanium abutment before crown fracture. More studies designed to test retention will be required to confirm this observation.

CONCLUSIONS

Based on the findings of this in vitro study, the following was concluded:

1. No significant differences were found in fatigue fracture resistance between ceramic crowns with and those without screw-access channels.
2. Access channels did not significantly affect the fatigue fracture resistance of ceramic crowns.
3. Ceramic crown design and material do influence the fatigue fracture resistance. Monolithic zirconia implant-supported crowns showed significantly higher fatigue fracture resistance than monolithic lithium disilicate and veneered zirconia crowns.

REFERENCES

Immediate versus conventional loading of complete-arch implant-supported prostheses in mandibles with failing dentition: A patient-centered controlled prospective study

Peñarrocha-Oltra D, Peñarrocha-Diago M, Aloy-Proser A, Covani U, Peñarrocha M

Purpose. The aim of this study was to compare, from the patients’ perspective, immediate and conventional loading of fixed complete-archprostheses to rehabilitate mandibles with failing dentition.

Materials and methods. This controlled, prospective, nonrandomized study included 36 consecutive patients: 18 treated with conventional loading (control) and 18 with immediate loading (test). Patient general satisfaction and specific satisfaction with esthetics, chewing, speaking, comfort, self-esteem, ease of cleaning, and treatment duration were evaluated using 10-cm visual analog scales before treatment and 3 and 12 months after treatment. Postoperative pain and swelling were monitored daily for 1 week. Statistical analysis was performed applying Mann-Whitney and Wilcoxon tests ($\alpha = .05$).

Results. Between baseline and 3 months, satisfaction in the test group increased significantly with the exception of speech; in the control group, satisfaction increased significantly for esthetics and decreased significantly for speech, chewing, and comfort, but did not vary for general satisfaction or self-esteem. After 3 months, satisfaction was significantly higher in the test group with the exception of ease of cleaning. Between 3 and 12 months, satisfaction improved in both groups but more so in the control group, so that after 12 months there were no differences. The test group showed lower mean pain, which began after the third day postsurgery. Mean swelling and maximum pain/swelling did not show significant differences at any point.

Conclusions. Patient satisfaction was reported as significantly higher with immediate loading. However, at the end of the observation periods, reported functional differences had disappeared. Significant differences were only noted for postoperative pain after the third day.

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