The benefit of restoring an anterior implant with a screw-retained implant crown has been well documented. When comparing screw-retained with cement-retained implant crowns, besides ease of fabrication, lower laboratory cost, and retrievability, the use of luting cement can also be avoided. The more subgingival the abutment margin of the cement-retained implant crown, the more difficult it is to completely remove the cement. Flap reflection for the sole purpose of cement removal may affect soft tissue esthetics. Furthermore, many available cements are radiolucent, rendering residual cement virtually undetectable radiographically. Although systematic reviews did not find evidence of the difference in peri-implant marginal bone loss between cement-retained and screw-retained implant crowns, a positive relationship between excess subgingival residual cement and peri-implant disease was reported. In a 5-year follow-up study conducted by Wilson, the author examined 42 implants placed in 39 patients and found that residual cement was associated with 81% of the cases with peri-implantitis.

A successful anterior maxillary screw-retained implant crown requires the implant to be positioned/angled in such a way that the screw access channel exits palatal to the incisal edge, preferably close to the cingulum area. This is often technique-sensitive due to the inclination of the premaxilla and the frequently present Colum angle, where the clinical crown angulation deflects from the root angulation, usually in the palatal direction. In immediate implant placement and provisionalization situations, not only the presence of the root, but also its sagittal position, poses an additional challenge for
clinicians.\textsuperscript{16,17} In fact, a study reported that the roots of more than 81% of maxillary anterior teeth engage the facial bone (Class I sagittal root position),\textsuperscript{17} making it difficult for immediate implant placement and provisionalization, as the implant needs to engage sufficient bone for implant stability and at the same time allow for an appropriate screw access channel.

The purpose of this cone beam computed tomography (CBCT) study was to investigate the probability of using straight screw-channel screw-retained restorations for immediate implant placement and provisionalization in maxillary anterior teeth.

**MATERIALS AND METHODS**

**Patient Selection**

This retrospective study was approved by the Institutional Review Board (IRB) of Loma Linda University (IRB #HS5170076) and was completed at the Center for Implant Dentistry, Loma Linda University School of Dentistry, Loma Linda, California. This study was conducted in accordance with the Helsinki Declaration of 1975, as revised in 2013. Due to the retrospective nature of the study, the informed consent was waived since the study data were collected without identifiers, and they were never linked to an individual. The CBCT images for patients who were treated at the Center for Implant Dentistry from August 2007 to June 2014 were randomly selected for evaluation to achieve a sample size of 200 according to the following criteria.

Inclusion criteria were as follows. The patient must:

- Be at least 18 years of age at the time of the CBCT scan
- Have at least six maxillary anterior teeth (canine to canine) with stable posterior occlusal support
- Have a normal alignment of maxillary anterior teeth without periodontal or periapical pathologies as observed on CBCT

The exclusion criteria were as follows:

- Radiographic evidence of infection, severe root resorption, periodontally involved teeth, and/or previous records of trauma in the maxillary anterior dentition
- Radiographic evidence of surgical (guided bone/tissue regeneration) treatment in the maxillary anterior dentition
- Presence of metal restorations in the anterior maxillary area that caused a scattering effect on CBCT images

All CBCT scans were performed using the same imaging system (Classic i-CAT, Imaging Sciences International). The CBCT data were transferred and opened using implant planning software (Invivo5, Anatomage), where the midsagittal image of each maxillary anterior tooth was produced. The image with vertical and horizontal scale bars was then screen-captured and transferred to a presentation program (Keynote, Apple) for evaluation (Fig 1). The scale bars provided the reference length used to calibrate the length with the digital implant template.

**Digital Implant Template for Treatment Planning**

The digital templates for 3.5-mm-diameter (used for central and lateral incisors) and 4.3-mm-diameter (used for central incisors and canines) tapered implants with lengths of 13, 15, or 18 mm of a commercially available dental implant system (NobelActive, Nobel Biocare) were obtained from the aforementioned implant planning software. Additional lines were incorporated into the implant template to be used as a guide for immediate implant placement and provisionalization and immediate implant placement and provisionalization with a straight screw-channel screw-retained restoration (Table 1; Fig 2). All CBCT images were classified as either contraindicated (Fig 3) or indicated (Fig 4) for immediate implant placement and provisionalization. For the situations that were indicated for immediate implant placement and provisionalization, they were further evaluated to determine if straight screw-channel screw-retained restoration (Fig 5) was an option.

To ensure accuracy and consistency, the length of the implant template was calibrated with scale bars on each image. The digital implant template was positioned to the most optimal implant position (Figs 3 to 5) by two examiners (H.M., P.K.). When there were disagreements,
Table 1  Lines on Implant Template Used as Guide for Immediate Implant Placement and Provisionalization and Immediate Implant Placement and Provisionalization with Straight Screw-Channel Screw-Retained Restoration

<table>
<thead>
<tr>
<th>Lines on template</th>
<th>Guidelines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implant platform line (IPL)(^a)</td>
<td>IPL must be at facial bone level or at least 2 mm apical to facial CEJ</td>
</tr>
<tr>
<td>Cementoenamel junction line (CEJL)(^a)</td>
<td>CEJL is the line connecting facial and palatal CEJ</td>
</tr>
<tr>
<td>Surrounding bone lines (SBL)(^a)</td>
<td>SBL indicates a minimal surrounding bone thickness of 1 mm</td>
</tr>
<tr>
<td>Jumping distance line (JDL)(^a)</td>
<td>JDL indicates a minimal distance of 1.5 mm between implant and facial bone</td>
</tr>
<tr>
<td>Apical bone line (ABL)(^b)</td>
<td>At least 35% of the implant must engage bone beyond ABL</td>
</tr>
<tr>
<td>Implant long axis line (ILAL)(^b)</td>
<td>ILAL must emerge around cingulum area</td>
</tr>
<tr>
<td>Screw access channel (SAC)(^b)</td>
<td>The SAC consists of two parallel lines, which are also parallel to the ILAL and must emerge around cingulum area</td>
</tr>
<tr>
<td>Ceramic line (CL)(^b)</td>
<td>CL indicates minimal ceramic thickness (1.5 mm) and must be palatal to the incisal edge</td>
</tr>
</tbody>
</table>

\(^a\)Guidelines for immediate implant placement and provisionalization.
\(^b\)Additional guidelines used for immediate implant placement and provisionalization with straight screw-channel screw-retained restoration.

Fig 2  Digital implant template used to determine the possibility of immediate implant placement and provisionalization and immediate implant placement and provisionalization with a straight screw-channel screw-retained restoration. Abbreviations are described in Table 1.

Fig 3  Situation that is contraindicated for immediate implant placement and provisionalization.

Fig 4  Situation that is suitable for immediate implant placement and provisionalization, but not ideal for using a straight screw-channel screw-retained restoration.

Fig 5  Situation that is suitable for immediate implant placement and provisionalization with or without the use of a straight screw-channel screw-retained restoration.
the situations were re-evaluated, discussed, and finalized with the third and fourth examiners (J.K., K.R.).

**Statistical Analysis**

Descriptive statistics was used to report the frequency distribution and percentage of possible immediate implant placement and provisionalization and immediate implant placement and provisionalization with straight screw-channel screw-retained restoration according to the tooth and implant diameter.

**RESULTS**

CBCT images from 200 out of 366 patients evaluated fulfilled the inclusion criteria. This resulted in a total of 1,200 CBCT images from maxillary anterior teeth (400 central incisors, 400 lateral incisors, and 400 canines) in 200 patients with a mean age of 51.3 years (range: 20 to 83 years) that were evaluated in this study. CBCT images of central incisors were used twice for virtual placement of 3.5-mm-diameter and 4.3-mm-diameter implants. The frequency distributions and percentages of immediate implant placement and provisionalization and immediate implant placement and provisionalization with straight screw-channel screw-retained restoration possibility with 95% confidence interval are shown in Table 2. The overall frequency percentages of immediate implant placement and provisionalization and immediate implant placement and provisionalization with straight screw-channel screw-retained restoration were 84% (range = 74% to 92%) and 14% (range = 10% to 24%), respectively. Sixteen percent of the sites were not suitable for immediate implant placement and provisionalization (Fig 3).

**DISCUSSION**

For immediate implant placement and provisionalization in the anterior maxilla to be successful, implant position/angulation must be optimal for adequate primary implant stability and esthetic implant restoration. Factors affecting the success of immediate implant placement and provisionalization include those that are patient-dependent, such as root length and diameter, sagittal root position, proclination and concavity of the labial bone, and available bone width and height; implant-dependent (implant shape, length, and diameter); and clinician’s level of expertise. Since screw-retained definitive implant crowns have been shown to mitigate biologic complications from residual cement, the probability of achieving immediate implant placement and provisionalization with straight screw-channel screw-retained restoration in the anterior maxilla is a topic of clinical interest. However, the fact that the screw access channel must exit around the cingulum area for esthetic and functional restoration adds another layer of complexity to the already-technique-sensitive immediate implant placement and provisionalization procedure.

Different implant systems carry implants of different shapes, lengths, and diameters. Tapered implants were used in this study, as they had been shown to experience significantly less rotational instability in immediate implant placement situations than cylindrical implants. Furthermore, the narrow apical portion of tapered implants allows for more room to maneuver within the sagittal bony housing without perforation than the cylindrical implant counterpart, increasing the probability of achieving immediate implant placement and provisionalization with straight screw-channel screw-retained restoration. The diameters (3.5 and 4.3 mm) and lengths (13, 15, and 18 mm) of the implants used in this study are comparable to most commercially available implant systems, rendering the results universally applicable regardless of the implant system used.

Implant stability in immediate implant placement can be achieved by engaging at least 4 to 5 mm of bone apical to the root tip socket and bone palatal or facial to the socket. While there is no definitive/objective guideline as to what percentage of the implant

---

**Table 2** Frequency Distributions (Percentage) of Immediate Implant Placement and Provisionalization with Straight Screw-Channel Screw-Retained Restoration

<table>
<thead>
<tr>
<th>Implant diameter (mm)</th>
<th>N</th>
<th>Immediate implant placement and provisionalization (%; 95% CI)</th>
<th>Immediate implant placement and provisionalization with straight screw-channel screw-retained restoration (%; 95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central incisor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.3</td>
<td>400</td>
<td>296 (74; 69–78)</td>
<td>41 (10; 7–14)</td>
</tr>
<tr>
<td>3.5</td>
<td>400</td>
<td>369 (92; 89–95)</td>
<td>96 (24; 20–28)</td>
</tr>
<tr>
<td>Lateral incisor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.5</td>
<td>400</td>
<td>361 (90; 87–93)</td>
<td>39 (10; 7–13)</td>
</tr>
<tr>
<td>Canine</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.3</td>
<td>400</td>
<td>317 (79; 75–83)</td>
<td>45 (11; 8–15)</td>
</tr>
<tr>
<td>Total</td>
<td>1,600</td>
<td>1,343 (84; 82–86)</td>
<td>221 (14; 12–16)</td>
</tr>
</tbody>
</table>

CI = confidence interval.
must be engaged in bone for successful immediate implant placement, the clinically acceptable apical bone engagement of 4 to 5 mm translates to approximately 27% to 38% of frequently used implant lengths (13 to 15 mm). This indicates that, though arbitrary, the minimum of 35% apical implant bone engagement used in this study is sufficient to provide primary implant stability for immediate implant placement and provisionalization.

The labial bony plate of a maxillary anterior extraction socket tends to be thin and is usually 1 mm or less. In the esthetic zone, when the mesiodistal width of the failing tooth is appropriate, the implant diameter for immediate implant placement is dictated by the most coronal faciopalatal width of the tooth socket. It is recommended to select an implant with a smaller diameter so that a gap left between the implant and the facial bone can be grafted for improving esthetics. This gap between the implant and the facial bony plate is defined as “jumping distance.”1,23 Roe et al, in a CBCT study, reported up to 1.2 mm of labial contour collapse due to bone remodeling following immediate implant placement and provisionalization despite grafting the facial implant-socket gap.23 Since < 1 mm of implant facial bone thickness can be associated with increased gingival esthetic problems,24 it is therefore recommended that a minimal gap of 1.5 mm is left between the implant and labial bone (jumping distance) with bone grafting to compensate for this inherent bone remodeling, which is the basis of the jumping distance line (Table 1) used in this study. Besides the facial jumping distance, a minimal palatal implant-socket gap (0.5 to 1.0 mm) is also needed for the prosthetic emergence profile. Since anterior maxillary palatal bone is usually thick and stable, the palatal implant-socket gap does not need to be a physical gap, and the implant or prosthetic emergence profile may encroach into the palatal bone. It has been reported that the average coronal faciopalatal widths of the maxillary central incisor, lateral incisor, and canine were 6, 5, and 7 mm, respectively.25 Based on the above information, the appropriate implant diameter for esthetic maxillary anterior implant restoration should be substantially smaller than the coronal faciopalatal width of the socket and/or overall alveolar housing.23,25 In this study, 3.5-mm-diameter and 4.3-mm-diameter implants were used for virtual planning for lateral incisors and canines, respectively. However, both 3.5-mm-diameter and 4.3-mm-diameter implants were used for central incisors to evaluate the impact of implant diameter on the probability of achieving immediate implant placement and provisionalization with straight screw-channel screw-retained restoration.

Besides the amount of available bone adjacent to the tooth socket, achieving immediate implant placement and provisionalization with straight screw-channel screw-retained restoration also highly depends on the sagittal root position.17 In the Class I sagittal root position, where the root engages the facial bone, the ample availability of palatal bone makes it a favorable scenario for immediate implant placement and provisionalization. A study showed that 81% of maxillary anterior teeth belong to the Class I sagittal root position, which is in line with the 84% probability of immediate implant placement and provisionalization observed in this study. However, for immediate implant placement and provisionalization with straight screw-channel screw-retained restoration, where the implant apex needs to be angulated more facially so that the screw access channel can exit close to the cingulum, Class I sagittal root position, more often than not, does not provide adequate apical bone for primary implant stability. In addition, there is a finite area around the cingulum in which the screw access channel and implant long axis line (ILAL) must emerge in order to achieve immediate implant placement and provisionalization with straight screw-channel screw-retained restoration. If it is positioned too palatally, an over-contoured crown palatally may result. If the screw access channel exits too facially, the integrity of the facial incisal porcelain will be compromised, increasing the risk of fracture. In this study, a minimum of 1.5-mm ceramic thickness (CL line, Table 1) was factored in during the virtual planning to ensure ceramic integrity during function. Furthermore, the proclination and labial concavity of the premaxilla often present anatomical challenges, as they limit the degree of implant angulation, which adversely affects the probability of achieving immediate implant placement and provisionalization with straight screw-channel screw-retained restoration. With the aforementioned limitations, it is not surprising that the probability of attaining immediate implant placement and provisionalization with straight screw-channel screw-retained restoration in this study was low at 14% (10% to 24%). When implants with conventionally appropriate diameters were used (3.5 mm in maxillary lateral incisors; 4.3 mm in maxillary central incisors and canines), the frequency percentages of immediate implant placement and provisionalization with straight screw-channel screw-retained restoration were very low (10% to 11%). However, the probability of attaining immediate implant placement and provisionalization with straight screw-channel screw-retained restoration in the maxillary central incisor increased more than twofold (from 10% to 24%) when a smaller-diameter implant (3.5 mm) was used. Nevertheless, it is important to note that this virtual planning represents the most precise implant placement that might not be replicable clinically. In reality, the probabilities of achieving immediate implant placement...
and provisionalization with straight screw-channel screw-retained restoration are likely lower than those reported in this study.

CONCLUSIONS

Thorough treatment planning and precise execution are prerequisites for achieving immediate implant placement and provisionalization with straight screw-channel screw-retained restoration in the esthetic zone. Although the probability of being able to employ such a procedure in the esthetic zone is low, the use of a smaller-diameter implant can substantially increase the probability.

ACKNOWLEDGMENTS

The authors do not have any financial interests in the products or information listed in the paper. The authors reported no conflicts of interest related to this study.

REFERENCES