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RESEARCH AND EDUCATION

The ability to screw-retain single implant-supported restorations in the anterior maxilla: A CBCT analysis

Erin K. Edmondson, DDS, MS,[a] Pedro M. Trejo, DDS, MS,[b] Nikolaos Soldatos, DDS, MSD, PhD,[c] and Robin L. Weltman, DDS, MS[d]

ABSTRACT

Statement of problem. Evidence to validate the routine use of angled screw-channel abutments in the anterior maxilla is sparse. If properly planned, they might provide surgical and prosthetic benefits.

Purpose. The purpose of this observational study was to determine the prevalence of digitally placed implants in the anterior maxilla that would allow screw-retained implant-supported restorations with either a straight or an angled screw-channel abutment.

Material and methods. Two hundred cone beam computed tomography (CBCT) scans met the inclusion criteria for retrospective analysis and digital implant planning. Virtual implants were planned for randomly selected anterior maxillary teeth by using the anatomic crown and root position. Virtual abutments of varying angulation were attached to the implants to determine the ability to screw retain a restoration with either a straight or an angled screw-channel abutment.

Results. One hundred fifty-two (76%) sites required an angled screw-channel abutment to enable screw retention. Forty-eight (24%) sites allowed screw retention with a straight abutment. The percentage of implants requiring angled or straight abutments varied significantly among anterior teeth ($P<.005$). One hundred nine (71.7%) angled screw-channel abutment sites required a 5-degree abutment, 41 (26.9%) required a 10-degree abutment, and 2 (1.3%) required a 15-degree abutment. Among the anterior teeth, lateral incisors presented a greater need for angled screw-channel abutments. None of the implants in the present study needed cement-retained restorations.

Conclusions. Angled abutments allowed for screw-retained restorations on digitally planned implants in the anterior maxilla. The required angular correction to a screw-retained restoration was $\leq$15 degrees. Screw-retained restorations were frequently achievable (76%) with the use of angled screw-channel abutments or with straight abutments (24%), and lateral incisors presented a greater need for angled screw-channel abutments. (J Prosthet Dent 2022;128:443-9)

The anatomy of the anterior maxilla typically presents with undercuts and a thin buccal plate less than 1 mm thick in 85% of situations.[1,2] With tooth loss, bundle bone vascularity is lost, and significant bone resorption may occur.[3-5] Additionally, the natural teeth in the anterior maxilla exit the alveolus at an angle of approximately 12 degrees.[6,7] Together, the placement of dental endosseous implants with screw-retained restorations in the anterior maxilla provides esthetic and functional challenges.[8-10]

The higher complication rates of cement-retained restorations have been identified in systematic reviews.[11-16] Residual cement has been reported as an etiological factor of peri-implantitis in up to 81% of situations.[17-20] Within a physiologically tolerable range, angled abutments up to 30 degrees have been shown to transfer forces to crestal bone.[21-23] However, biomechanical complications, including abutment

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[a]Private practice, San Antonio, Texas; and Department of Periodontics and Dental Hygiene, The University of Texas School of Dentistry, Health Science Center at Houston, Houston, Texas.
[b]Clinical Associate Professor, Department of Periodontics and Dental Hygiene, The University of Texas School of Dentistry, Health Science Center at Houston, Houston, Texas; and Private practice, Houston, Texas.
[c]Associate Professor, Department of Periodontics and Dental Hygiene, The University of Texas School of Dentistry, Health Science Center at Houston, Houston, Texas.
[d]Professor and Director Advanced Education Program in Periodontics, Department of Periodontics and Dental Hygiene, The University of Texas School of Dentistry, Health Science Center at Houston, Houston, Texas.

Clinical Implications

The results of the present study should facilitate implant placement when the abutment angular correction possibilities offered by a screw-channel abutment system are considered.

fracture and/or screw loosening after angular correction, have been documented.[24-27] Recently developed technologies allow for screw-retained implant-supported restorations with an angled screw-channel abutment (ASCA) system, providing the retrievability of a screw-retained crown and eliminating the risk of cement-related peri-implantitis. The system respects the natural angulation of teeth in the maxilla and the common challenges of the anatomy of the esthetic zone.[26-33] The decision on whether to place an implant immediately in the esthetic zone depends on the meticulous digital evaluation of the alveolar anatomy and its tooth relationship.[34-38] The use of more recent and powerful implant software programs for planning the abutment type (ASCA or straight) along with the optimal implant position have become routine in practice.[39-41]

The purpose of this study was to determine the prevalence of digitally placed implants in the anterior maxilla that would allow screw-retained implant supported restorations using either a straight abutment or an ASCA. The specific aims were to determine the prevalence of situations that could be restored with a screw-retained implant-supported restoration either with a straight abutment or with ASCA system, to determine the average abutment angulation required for a screw-retained implant-supported restoration, and to compare the prevalence of straight abutment versus angled abutment by tooth type in the anterior maxilla. The null hypothesis was that no significant difference would be found in the prevalence of maxillary anterior teeth requiring angled screw-channel or straight abutments to enable screw retention.

MATERIAL AND METHODS

This study was an observational, retrospective analysis of implant-related data retrieved from cone beam computer tomographic scans in an electronic data base in a university clinic setting. Institutional review board approval from the University of Texas School of Dentistry was required for this study (HSC-DB-17-0938). The study qualified for exempt status according to 45CFR 46.101(b), Category 4. Cone beam computed tomography (CBCT) scans from the electronic health records from October 2012 to October 2017 were reviewed by using a viewer (MiPACS Dental Enterprise Viewer; Medicor Imaging Inc). The evaluation included a review of favorably aligned anterior maxillary teeth in dentate and partially edentulous participants. In each scan, 1 tooth (canine, lateral incisor, or central incisor) was randomly selected for virtual implant placement. Inclusion criteria for the CBCT scans were completion of facial growth (men older than 18 and women older than 15 years). Data collected from the CBCT scans were deidentified to protect personal information and were sealed in a locked storage facility to prevent duplication. From a list of CBCT scans that met the inclusion criteria, a random number generator (Google dice roller), with each number corresponding to a certain tooth from the maxillary right canine=1 to the maxillary left canine=6, was used to select the study tooth. to be included, the study teeth had to have intact buccal and lingual bone at a height no more than 3 mm from the cementoenamel junction (CEJ) in an apical coronal direction and at least 12 mm of vertical bone height from the crestal bone to the nasal floor or maxillary sinus (Fig. 1). Exclusion criteria were teeth with root malformations or anomalies, malaligned teeth, teeth positioned >2 mm outside of the alveolar housing, and images of patients with a history of periodontal disease or radiographic evidence of horizontal and/or vertical bone loss.

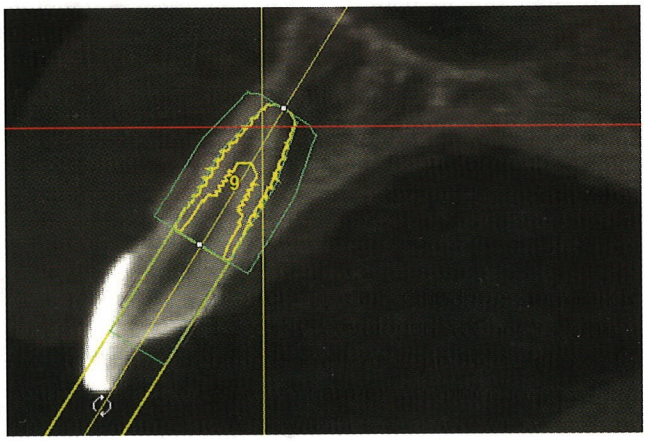

Figure 1. Inclusion criteria: Anterior maxillary tooth well aligned within arch.

All the CBCT scans were made by a qualified technician from the Diagnostic and Biomedical Sciences department at the University of Texas School of Dentistry with a scanner (Kodak 9500; Carestream Health Inc) set at 90 kVP and 10 mAs with a voxel size of 200 μm. During scanning, participants had been positioned with the Frankfort horizontal plane parallel to the floor. The radiographic section of the electronic record was used to store the CBCT data in a standard Digital Imaging and Communications in Medicine (DICOM) 3.0 format. The DICOM files were retrieved from the electronic patient records and viewed by using an implant planning software program (Simplant Pro 17.01; Dentsply Sirona).

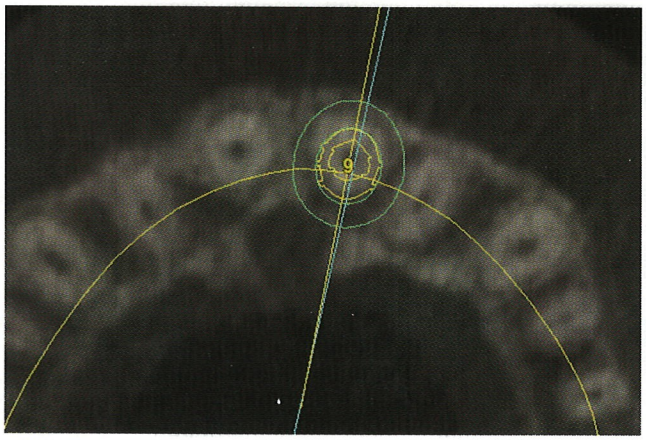

Figure 2. Occlusal view: Implant mesial-distal position centered in anatomic crown.

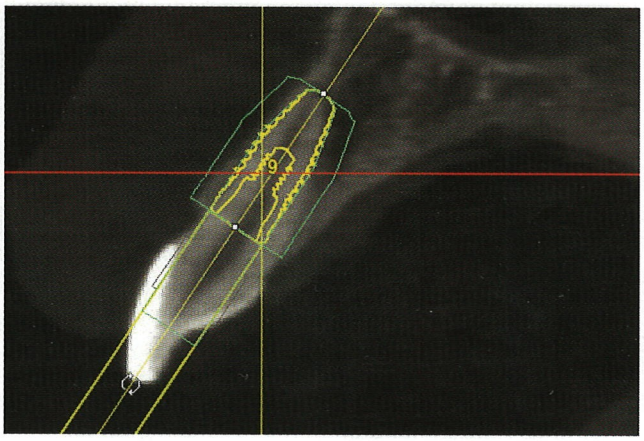

Figure 3. Sagittal view: Implant buccal-lingual angulation matching tooth long axis.

The virtual implant placement was completed as follows: the horizontal axis was oriented parallel to the occlusal plane in the frontal view to standardize the orientation of the cross-sectional views from the CBCT in the implant planning software (IPS). Then, the horizontal axis was oriented parallel to the hard palate in the sagittal view. Next, the focal trough for sagittal viewing was created in the transverse plane at the level of the CEJ on the maxillary anterior sextant. Subsequently, an implant was virtually placed for each of the randomly selected teeth using the IPS. The virtually placed implants were Nobel Replace Tapered to be compatible with the IPS angulated abutment screw system. The implant diameter for each site was predetermined based on standards for each tooth type (canine: 4.3 mm, lateral incisor: 3.5 mm, central incisor: 4.3 mm). The implant length was identical for all implants (10 mm).

The IPS allowed incremental implant movements of translation, which were set to 0.5 mm. By using these standardized movement tools, the implant was placed in the "ideal" 3-dimensional position to model the existing tooth as follows. In an occlusal view, the implant was centered within the associated crown. This determined the mesial-distal position of the implant (Fig. 2). In the sagittal view, a straight line was drawn from the root apex to the incisal tip of the tooth using the IPS measurement tool. The buccal-lingual angulation of the implant was adjusted to correspond to the buccal-lingual angulation of the long axis of the tooth (Fig. 3). In the facial 3-dimensional view, the mesial-distal angulation of the implant was matched to the long axis of the tooth (Fig. 4). In the sagittal view, the apical coronal location (depth) of the implant was adjusted by bodily movement to align the platform of the implant 3 mm apical to the CEJ of the associated tooth (Fig. 5). Then, the implant was adjusted bodily in the buccal-lingual direction until the center of the implant corresponded with the junction of the palatal and middle third of the crown width (Fig. 5). These thirds were determined by drawing a line with the measurement tool from the height of the buccal contour to the height of the contour on the lingual aspect of the anatomic crown and then calculating the junction of the middle and palatal thirds. This line was drawn such that it was perpendicular to the long axis of the tooth (Fig. 5). Consequently, digital implant placement was initially anatomically based and then restoratively driven, allowing for a palatal location of the screw channel.

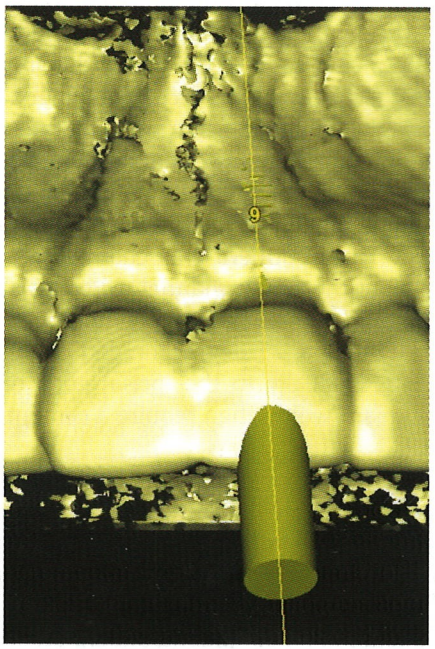

Figure 4. Three-dimensional view: Implant mesial-distal angulation along tooth long axis.

The feasibility of implant restoration with a screw or cement was determined as follows. Initially, a straight abutment with a 3-mm cuff height was placed into the

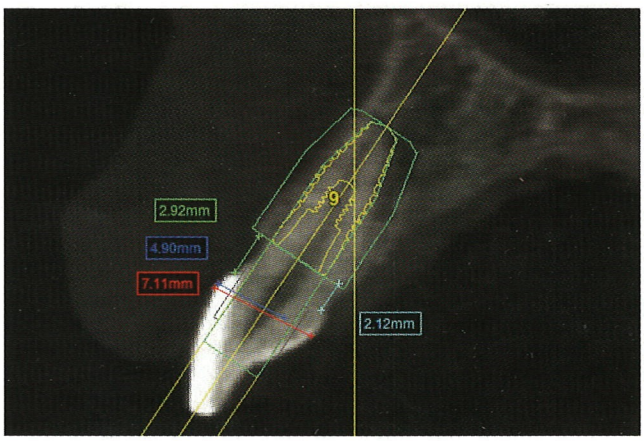

Figure 5. Final implant position: 3 mm apical to CEJ of natural tooth; implant center at junction of palatal and middle third of anatomic crown width.

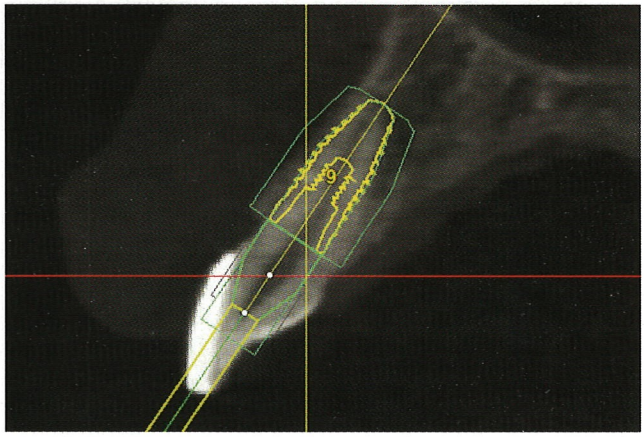

Figure 6. Straight abutment placement: screw channel through anatomic crown incisal edge.

implant. If the straight abutment screw channel exited palatal to the incisal edge of the tooth, this implant was deemed restorable with a screw-retained implant-supported single crown with a straight abutment (Fig. 6). If the straight abutment screw channel was oriented toward the labial aspect or through the incisal edge of the tooth, a custom, angled screw-channel virtual abutment was selected. This abutment was changed by 5-degree increments until the screw channel exited palatal to the incisal edge, up to 25 degrees, with the degree notated (Figs. 7 and 8). If a 25-degree angled screw-channel abutment exited labially to the incisal edge of the test tooth, the implant would then require a cement-retained restoration.

Power analyses were calculated for the primary outcome measure, which was the prevalence of straight versus angled screw-retained implant-supported restorations. The prevalence of each restoration type was then compared among central incisors, lateral incisors, and canines by using the Pearson chi-square statistical test. For the chi-square statistics, a sample size of 200 and α=.05 resulted in a statistical power of 0.99 and 0.91 to detect large and intermediate effect sizes. As statistically significant differences were found and the power was high, a Type II error was unlikely. Moreover, for the proportion test comparing straight versus angled, with a power of 0.8, α=.05, and 200 test teeth, a small effect size of h=0.198 was detected, again indicating that a Type II error was unlikely.

RESULTS

Implants were placed virtually in 200 CBCT scans from 200 dentate American Society of Anesthesiologists (ASA) I participants. The population included 136 women and 64 men ranging from 16 to 91 years of age, with a mean age of 48 years. Information on their ethnicity was

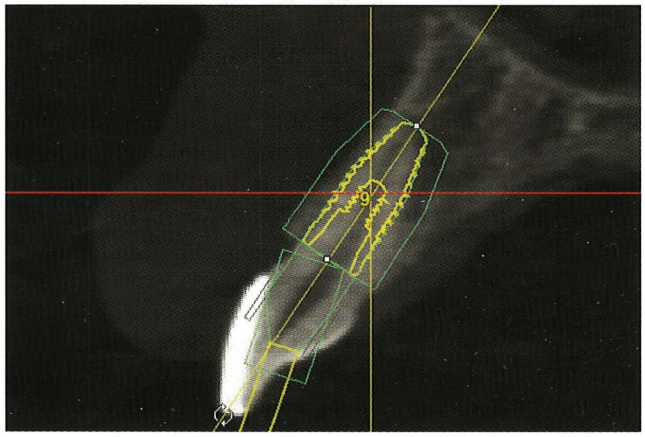

Figure 7. Five-degree angled abutment: screw channel palatal to anatomic crown incisal edge.

unavailable for most participants in the electronic health record (170/200). Of the 30 participants with available ethnicity information, the population consisted of 16 white, 13 Hispanic, and 1 Asian participant. Of the 200 teeth evaluated, the randomization process included 64 central incisors, 75 lateral incisors, and 61 canines.

Of the 200 virtually placed implants, 48 (24%) allowed screw-retained restorations with a straight abutment. The remaining 152 (76%) required an angled abutment for screw-retained restorations. The angulation required to move the screw access channel palatal to the incisal edge of the crown was 5 degrees for 109 sites (71%), 10 degrees for 41 sites (27%), and 15 degrees for 2 sites (1%) (Table 1). None of the evaluated teeth required an angulation greater than 15 degrees. Therefore, none of the digitally placed implants in the present study required cement-retained restorations (within the context of this study), as all could have been screw retained.

Of the 64 central incisor sites studied, 18 (28%) allowed screw retention with a straight abutment, and 46

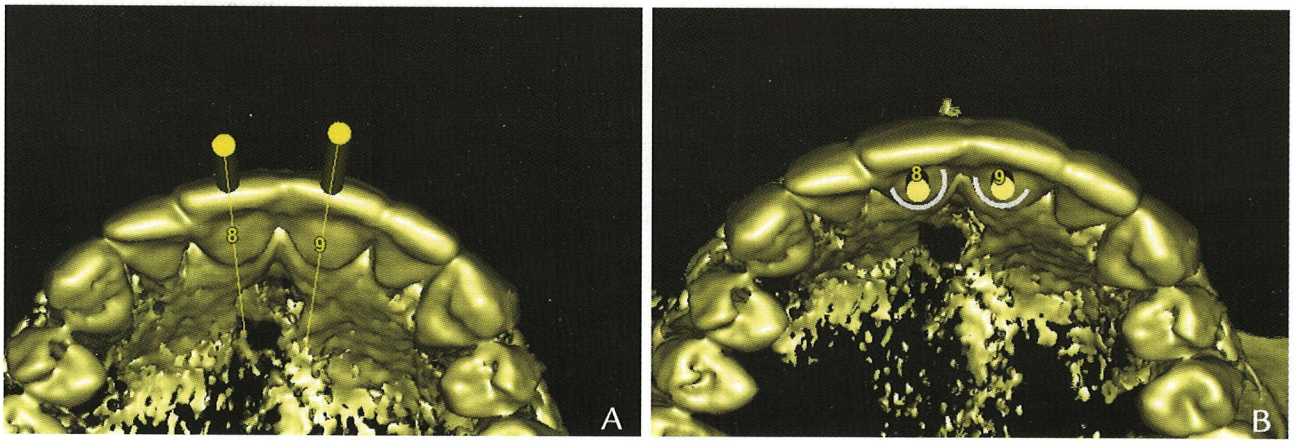

Figure 8. Three-dimensional views. A, Straight abutment screw channel through incisal edge of anatomic crown. B, Corrected with five-degree angled abutment screw channel palatal to incisal edge of anatomic crown.

Table 1. Number and percentage (%) of implants with straight or angled abutments for screw-retained implant supported restorations

	Degrees				
Abutment Type	**0**	**5**	**10**	**15**	**Total (%)**
Straight	48 (100)	–	–	–	24
Angled	–	109 (71)	41 (27)	2 (1)	76

Table 2. Number and percentage (%) of implants by tooth type requiring straight or angled abutment for screw-retained implant-supported restorations

		Tooth Type*		
Abutment Type	**Total n (%)**	**Central n=64**	**Lateral n=75**	**Canine n=61**
Straight	48 (100%)	18 (37%)	8 (17%)	22 (46%)
Angled	152 (100%)	46 (30%)	67 (44%)	39 (26%)

*Pearson chi-square, $P<.005$.

(72%) required an angled abutment for screw retention. Of the 75 lateral incisor sites studied, 8 (11%) allowed screw retention with a straight abutment, and 67 (89%) required an angled abutment for screw retention. Of the 61 canine sites studied, 22 (36%) allowed screw retention with a straight abutment, and 39 (64%) required an angled abutment for screw retention. Compared with the expected values for the Pearson chi-square statistical test, lateral incisors were more likely to require an angled abutment for screw retention, and canines were less likely to require an angled abutment for screw retention. A significant association ($P<.005$) was found between tooth type and restoration type (Table 2).

DISCUSSION

The study first determined the prevalence of digitally placed implants that could be restored either with a straight abutment or with an ASCA system and then compared the prevalence of straight versus angled-screw channel abutments by tooth type in the anterior maxilla. As the study found a significant difference in the prevalence of teeth requiring angled screw-channel or straight abutments to enable screw retention in the anterior maxilla, the null hypothesis was rejected.

This study analyzed CBCT scans of the anterior maxilla with intact teeth. The premise was to simulate the anatomy of the anterior maxilla in a scenario for immediate implant placement and determine the distribution of restorations requiring cement, rather than screw-retained implant restorations in each of the canine, lateral, and central incisor positions.[34-38] The results showed that most of the virtually placed implants (76%) required an angled screw-channel abutment system to allow for screw retention. Furthermore, the angulation required for the screw access channel to be palatal to the incisal edge of the crown ranged from 5 to 15 degrees, with 71% of sites requiring a 5-degree angled channel. This finding is consistent with that of Misch and Resnik,[6] who reported that the average angle of emergence of maxillary anterior teeth from the alveolus is approximately 12 degrees. Additionally, a significant association was found between tooth type and the need for an angled channel for screw retention. Implants placed in the lateral incisor position more often required an angled screw-channel abutment than those positioned in the central incisor or the canine positions. Nelson[42] described the labial surface of maxillary lateral incisors as more convex than that of maxillary central incisors. The convex anatomy of the lateral incisors may have accounted for the required angular correction. Furthermore, Zhang et al[2] reported that the labial surfaces of the alveoli of 77% of maxillary lateral incisors had undercuts, in contrast with the 41% of maxillary central incisors and 33% of maxillary canines.

None of the virtual implants in the present study required cement-retained restorations, although 76% of

the implant restorations required an angled screw-channel abutment, and only in 24% could a straight screw channel exit palatal to the incisal edge. Hence, the use of ASC abutments would eliminate the risk of leaving excess cement and the associated risk of peri-implantitis.[15-20]

ASC systems are a recent development.[28] In a retrospective chart review, Greer et al[26] reported that of 60 patients with 81 implant-supported restorations with angled screw-channels, only 3 patients (4% of the implant-supported restorations) had complications that included a loose screw, a ceramic fracture, or an implant failure that was associated with poor occlusal management. The fracture strength of the zirconia ceramic crowns with ASCA has been assessed in vitro by Drew et al,[29] who reported fractures in the zirconia in all 5 of the ASC crowns and 4 of the 5 straight channel crowns. The authors suggested that the thickness of the zirconia in the cingulum area may have been the weak point, with the straight channel exhibiting a slightly greater thickness than the 25-degree screw-channel restorations. Opler et al[30] and Hu et al[31] compared the reverse torque values for the implant abutment screws positioned from 0-degree up to 28-degree channels. Both groups reported statistically significant differences in the reverse torque values between the differing angulations, with the 20- and 28-degree groups exhibiting more change than the 0- or 10-degree channel groups. When cyclical loading was incorporated in the study model, no significant percentage torque loss differences were found between the 0- and 20-degree screw-retained crowns.[32] Goldman et al[33] reported no differences between torque removal values when a dynamic abutment screw was initially tightened to 25 Ncm in a 0-, 20-, or 28-degree screw channel. Additionally, no differences were found between groups (0-, 20-, and 28-degree channels) when fracture strength was measured for each of the screw-retained restorations. These findings suggest that if a screw-retained restoration is fabricated with an ASC abutment (up to 20 degrees) and secured with a properly tightened screw, a biomechanically stable screw-retained restoration should be expected. Correcting implant angulations of more than 20 degrees (major corrections) with ASCA systems might result in biomechanical complications. In addition, if correcting the angulation with newer systems demands tightening of the screws to less than 25 Ncm, this suggests a risk of screw loosening. If a digitally planned implant placement requires more than 20 degrees of correction to allow for a screw-retained restoration, bone regenerative procedures may be necessary to subsequently place an implant requiring an abutment with less angulation.

Limitations of the present study included the retrospective design with an implant with a predetermined length and diameter being placed virtually. The results for each tooth type would have been affected if implants of different diameters had been used. As new ASC abutment systems become available, clinical research is needed to validate their long-term biomechanical behavior.

CONCLUSIONS

Based on the findings of this observational study, the following conclusions were drawn:

1. Angled screw-channel abutments allowed for screw-retained restorations on digitally planned implants in the anterior maxilla.
2. The required angular correction to a screw-retained restoration was less than or equal to 15 degrees.
3. Screw-retained implant supported restorations were always achievable with the use of angled screw-channel abutments (76%) or with straight abutments (24%).
4. Lateral incisors presented a greater need for angled screw-channel abutments.

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Corresponding author:
Dr Pedro M. Trejo
Periodontal and Implant Surgeons of Houston
2600 South Gessner Road
Suite 304
Houston, TX 77063
Email: docptrejo@yahoo.com

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