

A COMPARATIVE ANALYSIS OF DUAL-AXIS IMPLANTS PLACED INTO MAXILLARY ANTERIOR EXTRACTION SOCKETS VERSUS VIRTUAL PLANNING WITH UNIAXIAL IMPLANTS: A SIMULATED CONE BEAM COMPUTED TOMOGRAPHY STUDY OF IMPLANT LENGTH AND DIAMETER

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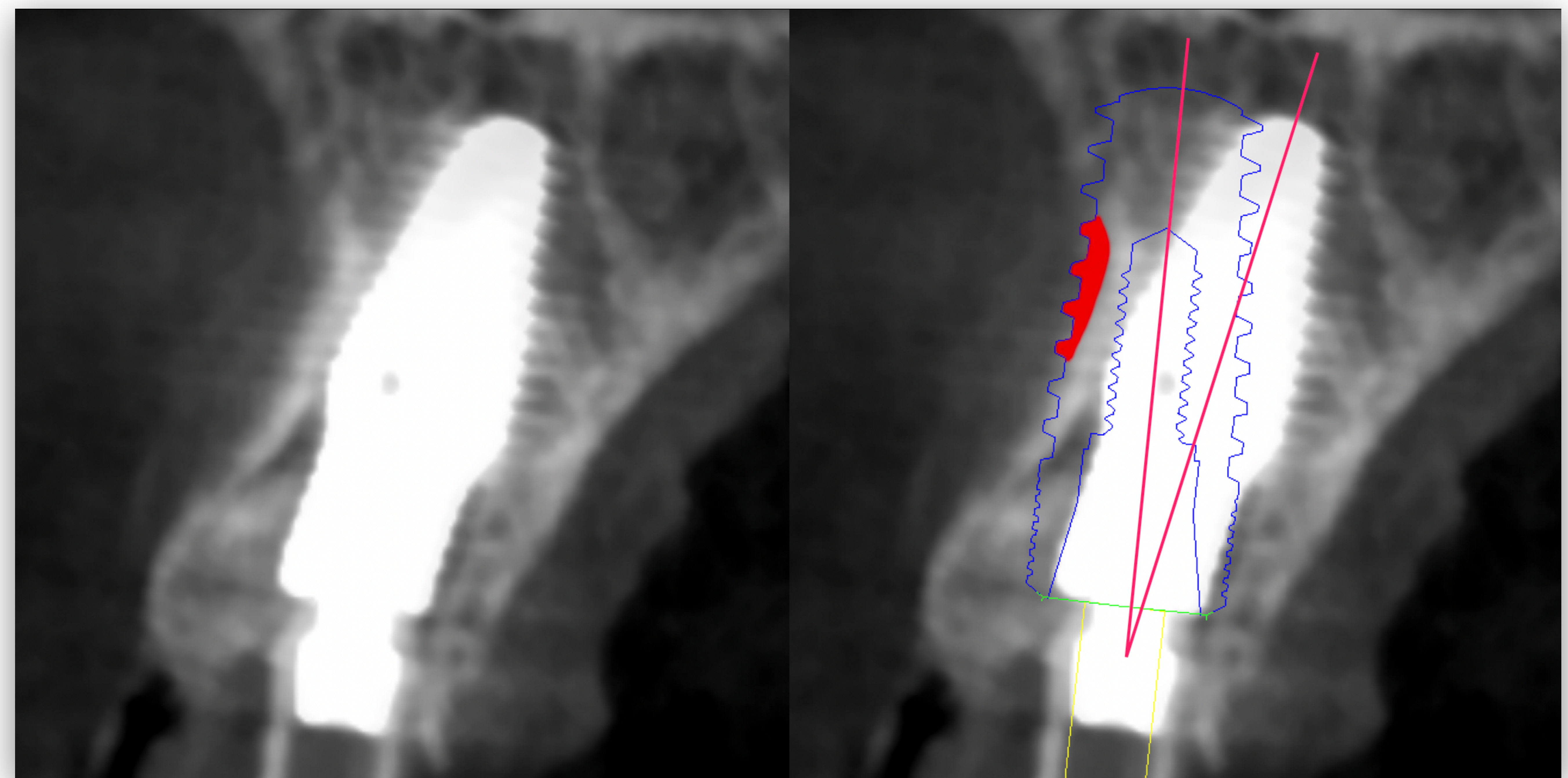
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Introduction

The anatomy of the maxilla presents unique challenges to immediate implant placement into anterior extraction sockets. One such challenge is the proclination of the alveolar ridge that is frequently not perpendicular to the occlusal plane, complicating prosthetically driven implant placement (Fig. 1).¹ In addition, the sagittal orientation of the tooth root axis is frequently positioned directly against the facial cortex of the alveolus.² Furthermore, in the maxillary anterior region, the average angle of divergence between the long axis of the tooth and the long axis of its associated alveolar bone ranges between 10-20°.³ Recently, a novel implant with an inverted body-shift design and dual-axis restorative interface was introduced to address the shortcomings of conventional uniaxial tapered implants. This implant features a 12° subcrestal prosthetic angle correction (SAC) within the implant body to allow for ideal positioning with a mitigated risk of apical socket perforation and facilitation of screw-retention of the prosthesis.⁴

Therefore, the purpose of this virtual study was two-fold: 1) to determine the apical socket perforation rate (ASPR) when a uniaxial implant was simulated in position to deliver a screw-retained restoration in the anterior maxilla (maxillary second premolar to second premolar) and, 2) to determine the affordable maximum length of a corresponding uniaxial implant that would avoid apical socket perforation.

Materials and Methods

The data used for this study was extracted from the Inverta Data Registry, secure repository for the implant with an inverted body-shift design and dual-axis restorative interface (INVERTA Implants, Southern Implants, Irene, RSA) (Fig. 2). The registry was approved by the Western Institutional Review Board (study number 1252367), and registered patients provided consent in accordance with the Declaration of Helsinki of 1975, as revised in 2013.



Figure 1. A, crown to root angle disparity measured to be 11.6° in a maxillary lateral incisor; B, tooth to alveolus angle disparity to be approximately 45°.

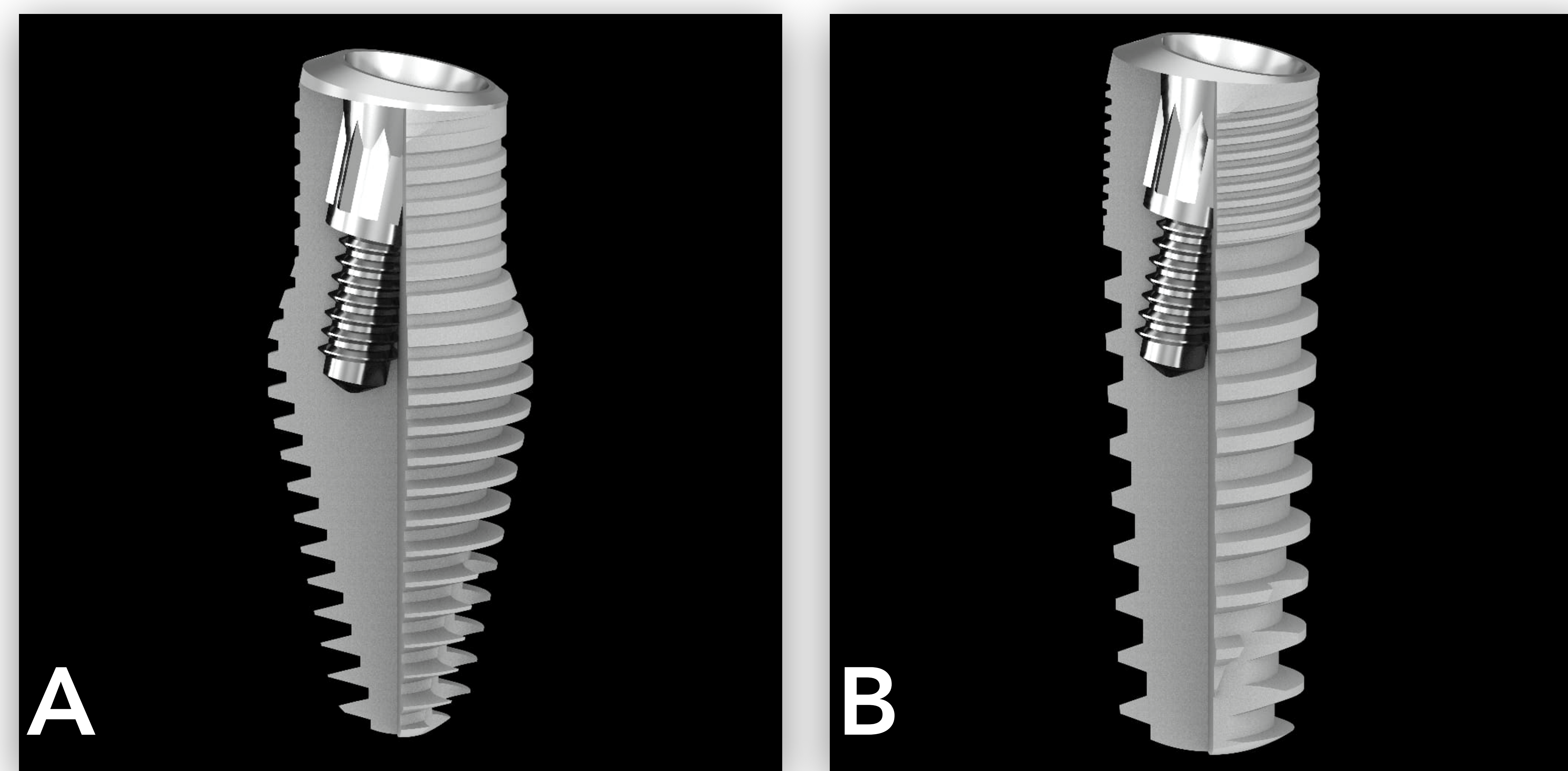


Figure 2. Dual-axis implants with 12° SAC. A, Inverta implant; B, Provata implant.

Patient Selection

Cone Beam Computed Tomography (CBCT) scans (Veraviewepocs 3D R100, Morita, Irvine, CA; GALILEOS Comfort^{PLUS}, Dentsply Sirona, York, PA; Planmeca ProMax 3D, Planmeca, Helsinki, Finland) from the database of three private practices were searched for patients who received dual-axis implants (Co-Axis Implants, Southern Implants, Irene, RSA; INVERTA Implants, Southern Implants, Irene, RSA) within the anterior maxilla (maxillary second premolar to second premolar) in immediate tooth replacement therapy between November 2019 and August 2022. Exposure parameters were 90 kV, 8 mAs, 9.3 seconds, voxel size 125 µm; 85 kV, 28 mAs, 14 seconds, voxel size 125 µm; 96 kV, 29 mAs, 4.8 seconds, voxel size 150 µm respectively. All included scans were of patients with direct or straight channel screw-retained restorations taken immediately after implant placement and subsequent provisionalization void of apical socket perforation. Scans were excluded if one of the following exclusion criteria applied: presence of artifacts⁴ (scattering and blooming) affecting the visualization of the facial bone plate; distorted images such as double margins; a field of view that did not capture the entirety of the dental implant.

Image Analysis

CBCT data sets were saved in Digital Imaging And Communications in Medicine (DICOM) files. DICOM files were exposed in multi-file, uncompressed format and were processed using a virtual surgical planning software (coDiagnostiX, Dental Wings Inc., Montreal, Canada). Virtual surgical planning was subsequently performed by one prosthodontist (SS). A simulated uniaxial implant (Deep Conical Tapered Implants, Southern Implants, Irene, RSA) was aligned to the existing dual-axis implant (Co-Axis Implants, Southern Implants, Irene, RSA; INVERTA Implants, Southern Implants, Irene, RSA) utilizing the screw access channel as a reference line (Fig. 2). The crest module of the simulated implant was aligned with the existing dual-axis implant. For the initial simulation, simulated implants were of a similar length and diameter in accordance with the dual-axis implant placed as the implant was chosen by clinicians to obtain primary stability from the bone apical to and palatal of the pre-extraction tooth (Fig. 3). ASPR by the uniaxial implant was recorded (Fig. 4). In the cases with apical socket perforation, reduced implant lengths were simulated to identify the longest length of the uniaxial implant attainable while avoiding perforation (Fig. 3). Implant length and diameter for initial and shortened length simulation are presented in Table 1.

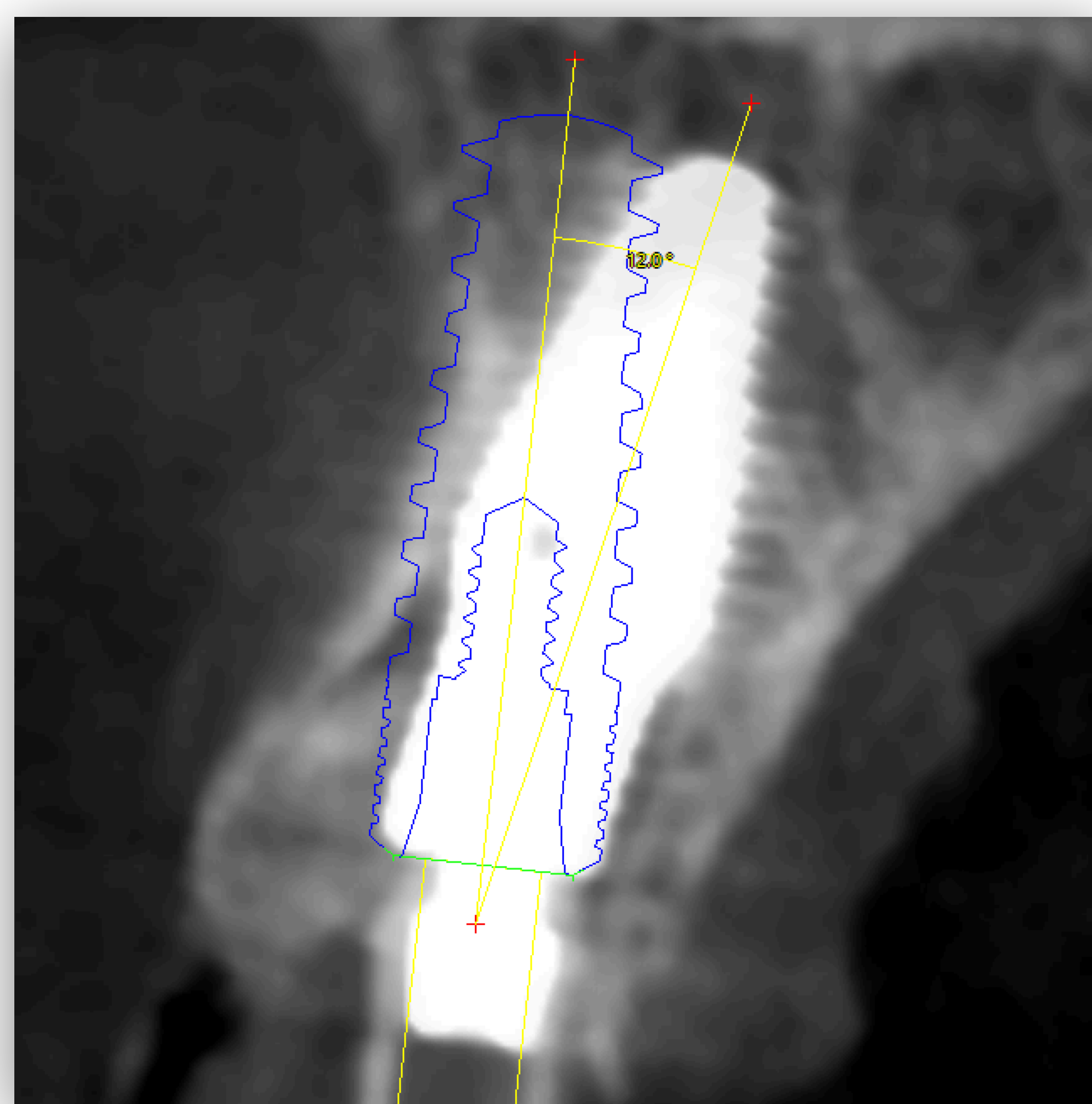
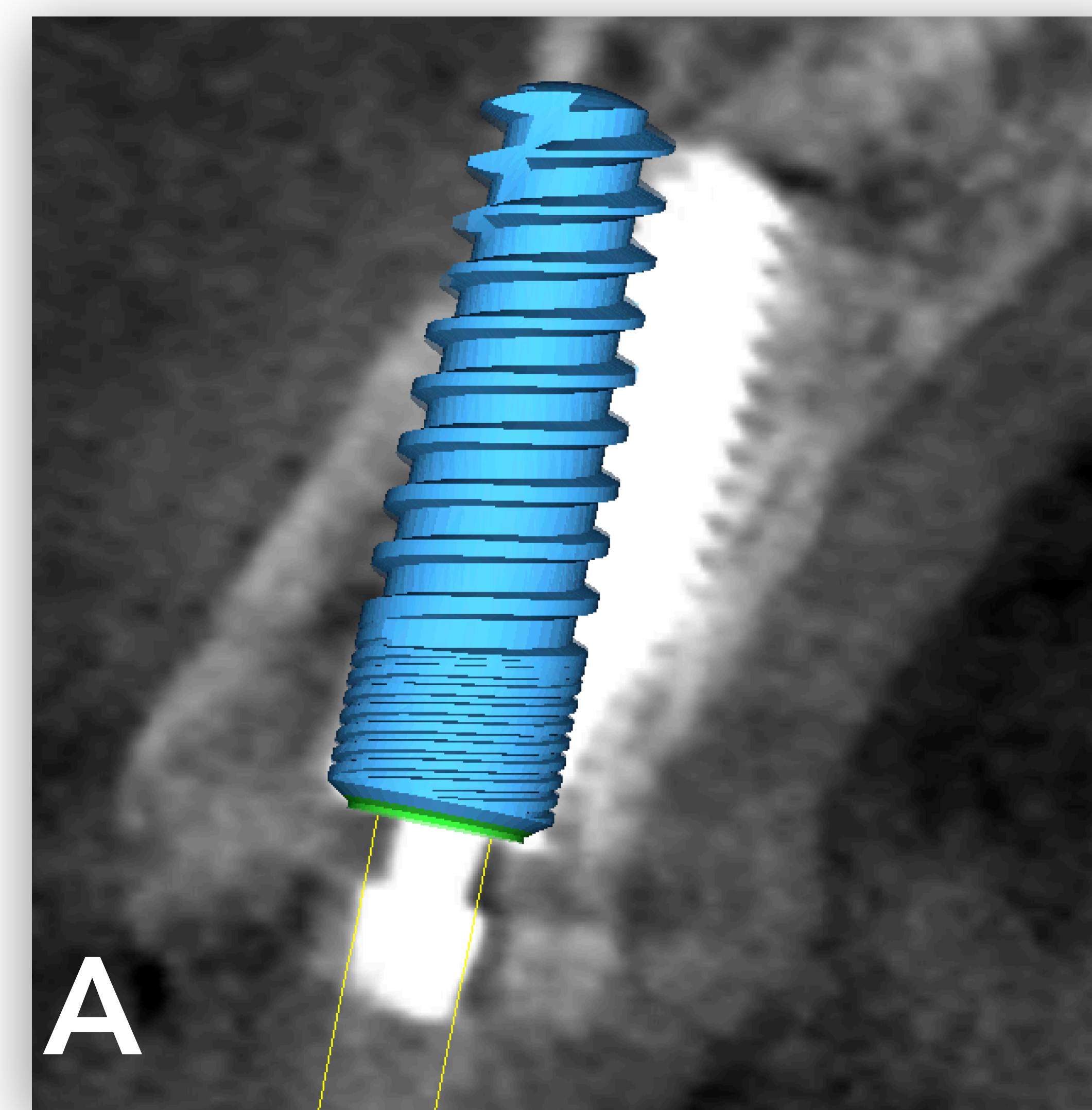
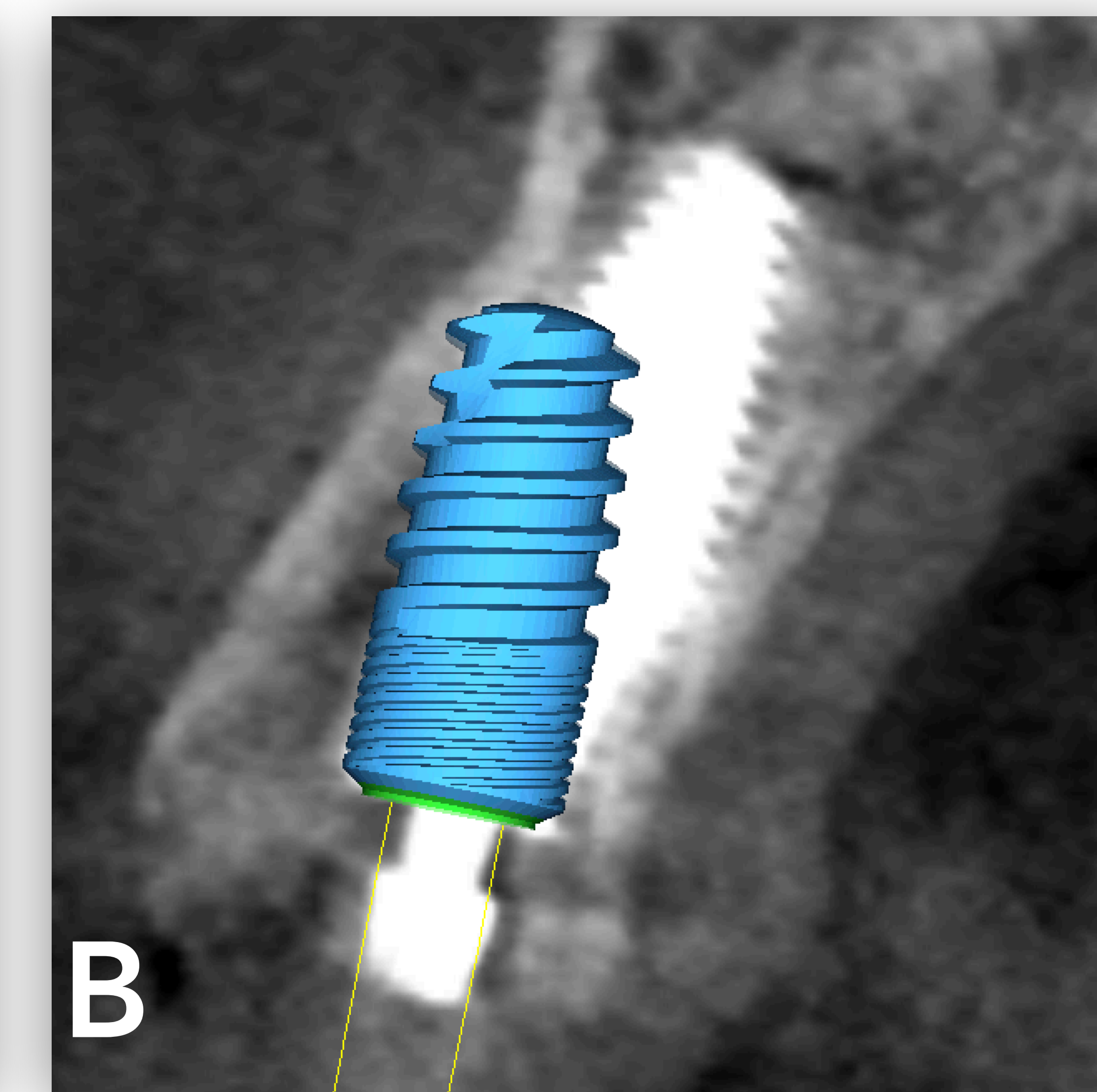


Figure 2. Left/ Screw access channel was utilized as a reference to align uniaxial implant to dual-axis implant.

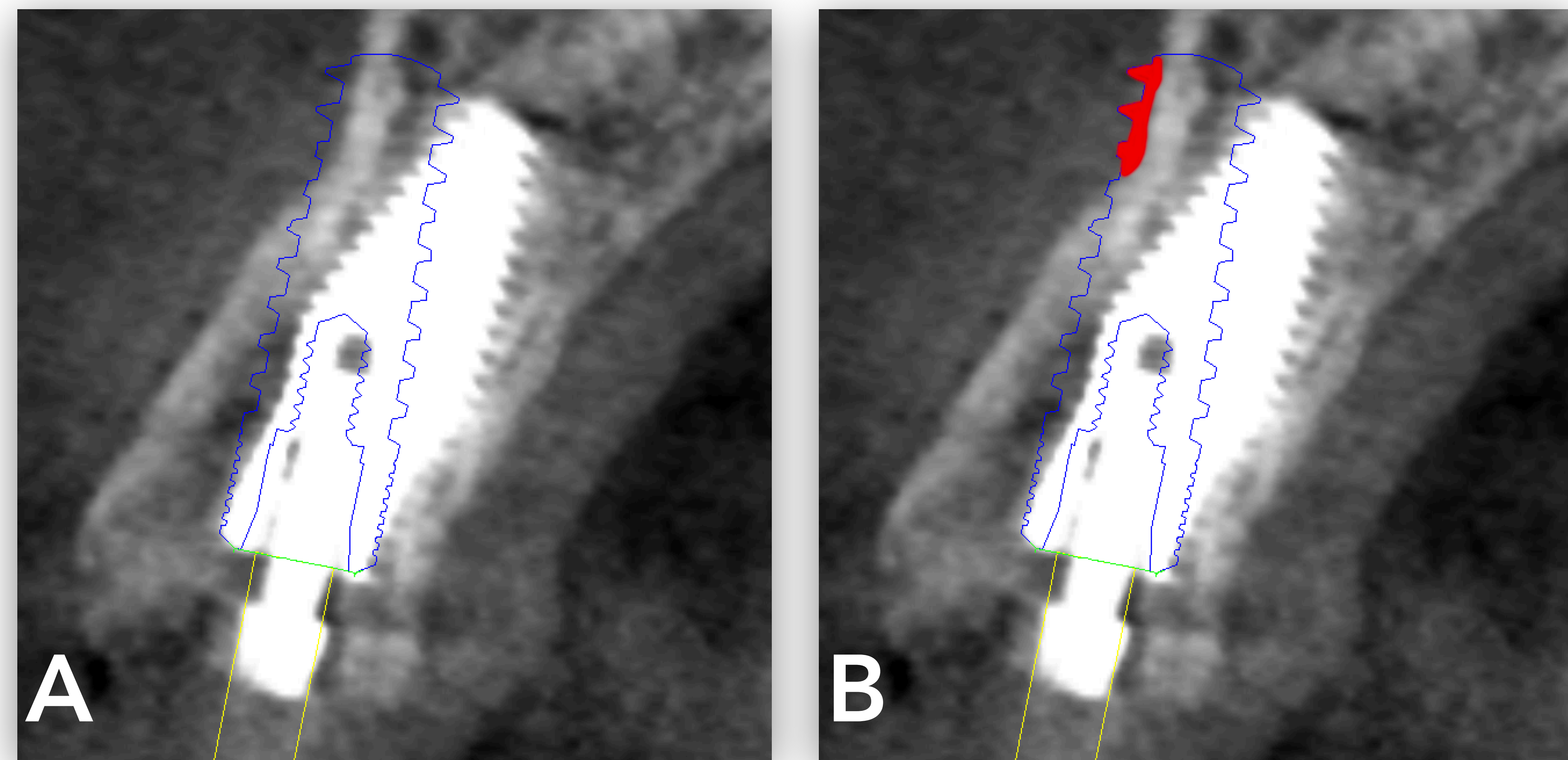
Figure 3. Right/ A, simulated placement of 4.0 x 13 mm which exhibits apical socket perforation; B, simulated placement of 4.0 x 9 mm which is within the confines of alveolus.





	Initial simulation	Shortened length simulation
3.5 / 4.5 x 11.5	4.0 x 11.0	4.0 x 9.0
3.5 / 4.5 x 13	4.0 x 13.0	4.0 x 11.0, 4.0 x 9.0
3.5 / 4.5 x 15	4.0 x 15.0	4.0 x 13.0, 4.0 x 11.0, 4.0 x 9.0
4.0 / 5.0 x 10	5.0 x 11.0	5.0 x 9.0
4.0 / 5.0 x 11.5	5.0 x 11.0	5.0 x 9.0
4.0 / 5.0 x 13	5.0 x 13.0	5.0 x 11.0, 5.0 x 9.0
4.0 / 5.0 x 15	5.0 x 15.0	5.0 x 13.0, 5.0 x 11.0, 5.0 x 9.0

Table 1. Specification of simulated implants.



Data Analysis
A Cohen intra-examiner agreement rate was calculated to test the accuracy of the examiner during radiographic assessment. The measurement started when the examiner reached > 90% agreement in a representative sample of 30 patients. Descriptive statistics were used to delineate the recorded data. Frequencies and percentages were used to summarize the incidence rate of observed ASPR.

Results

A total of 108 patients and 132 implants were screened. After the inclusion and exclusion criteria were applied, 81 patients (71.35% were female, age ranging from 22-91 yo with an average of 55.45 yo) with a total of 101 dual-axis dental implants (Co-Axis Implants, Southern Implants, Irene, RSA; INVERTA Implants, Southern Implants, Irene, RSA) placed within the esthetic zone (maxillary second premolar to second premolar) were selected for analysis. A Cohen intra-examiner agreement rate of 95% was reached fro the examiner before the initiation of the study. Among the 101 implants. 54.45% were placed in central incisor, 19.8% in lateral incisor. 12.87% in canine teeth, and 12.87% in premolar (first and second) position.

Overall, the most used length of the implants was 13 mm (67.33%) and the average insertion torque value (ITV) was 54.05 N/cm (range 30-90 N/cm). Incidence of apical socket perforation noted in the initial simulation is presented in Table 2.

Initial simulation with similar dimension implants revealed overall ASPR of 48.51%. Central incisor, lateral incisor and canine teeth exhibited similar ASPR of 52.72%, 55% and 53.84% respectively. Premolars showed a reduced ASPR of 15.38%. 33.33% of 10 and 11.5 mm, 54.41% of 13 mm, and 38.89% of 15 mm implants were shown to perforate with a simulated uniaxial implant. When a shortened length implant was used for simulation, no difference was noted with 13 mm implants. Similarly, only a marginal difference was observed with 11 mm implants. However, the overall ASPR was reduced to 20.79% with 9 mm implants. Results from a shortened length simulation with 11 mm and 9 mm implants are presented in Tables 3 and 4.

Figure 4. Left/ A, uniaxial implant aligned to dual-axis implant; B, apical socket perforation annotated in red with a graphics editor program (Adobe Photoshop 2022, Adobe Inc., San Jose, CA).



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	CI	LI	C	P	Total
3.5 / 4.5 x 11.5	3 (2)	2 (0)	0	2 (2)	7 (4)
3.5 / 4.5 x 13	28 (14)	18 (11)	6 (3)	4 (0)	56 (28)
3.5 / 4.5 x 15	7 (4)	0	5 (2)	0	12 (6)
4.0 / 5.0 x 10	1 (0)	0	0	0	1 (0)
4.0 / 5.0 x 11.5	3 (1)	0	0	4 (0)	7 (1)
4.0 / 5.0 x 13	9 (7)	0	2 (2)	1 (0)	12 (9)
4.0 / 5.0 x 15	4 (1)	0	0	2 (0)	6 (1)
Total	55 (29)	20 (11)	13 (7)	13 (2)	101 (49)

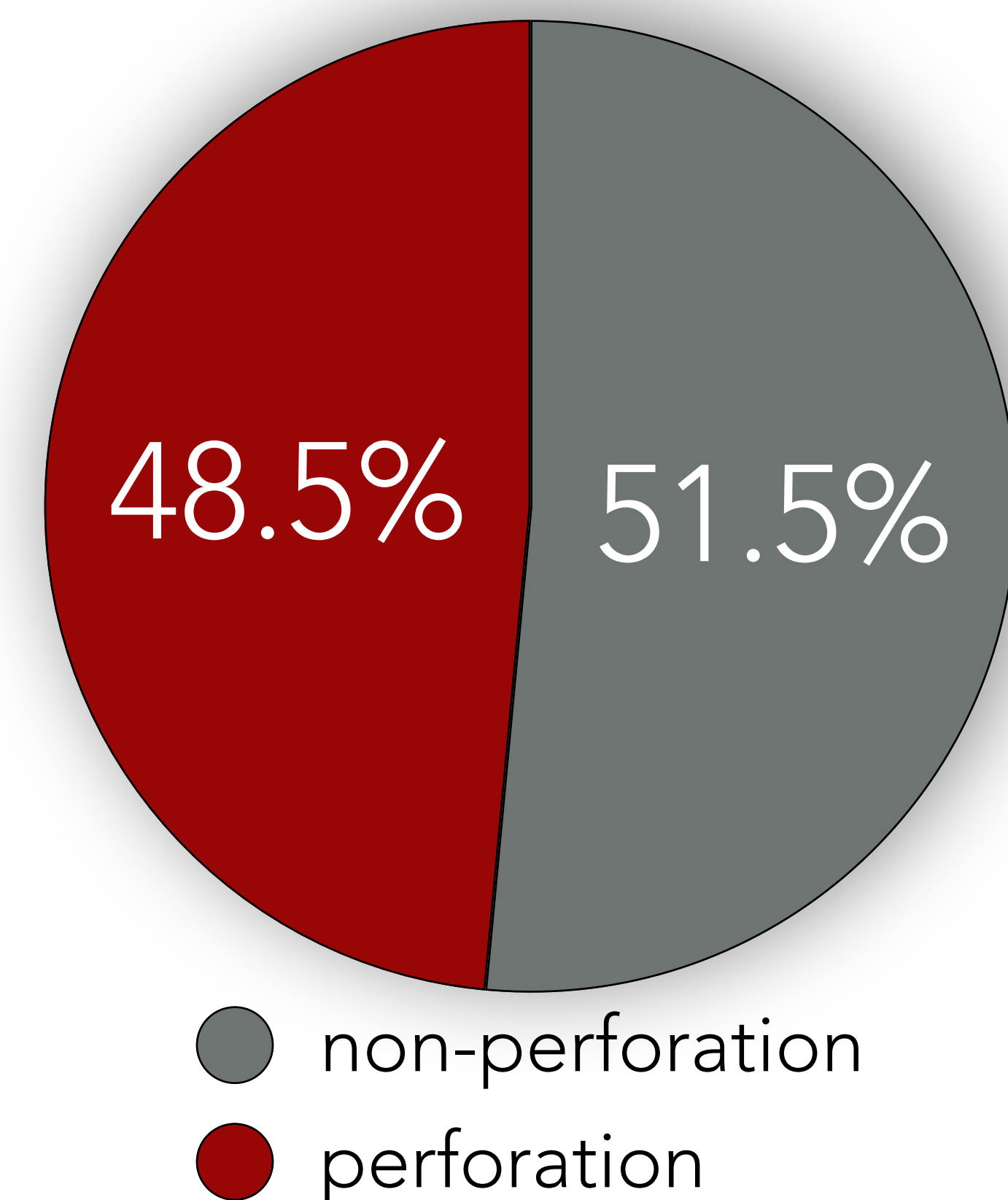


Table 2. Overall simulated incidence of apical socket perforation by implant length and diameter. Similar dimension (length and diameter) implant was used. Number of perforations is denoted in parentheses. CI: central incisor; LI: lateral incisor; C: canine teeth; P: premolar.

	CI	LI	C	P	Total
3.5 / 4.5 x 11.5	3 (2)	2 (0)	0	2 (2)	7 (4)
3.5 / 4.5 x 13	28 (11)	18 (10)	6 (1)	4 (0)	56 (22)
3.5 / 4.5 x 15	7 (4)	0	5 (2)	0	12 (6)
4.0 / 5.0 x 10	1 (0)	0	0	0	1 (0)
4.0 / 5.0 x 11.5	3 (1)	0	0	4 (0)	7 (1)
4.0 / 5.0 x 13	9 (6)	0	2 (2)	1 (0)	12 (8)
4.0 / 5.0 x 15	4 (1)	0	0	2 (0)	6 (1)
Total	55 (25)	20 (10)	13 (5)	13 (2)	101 (42)

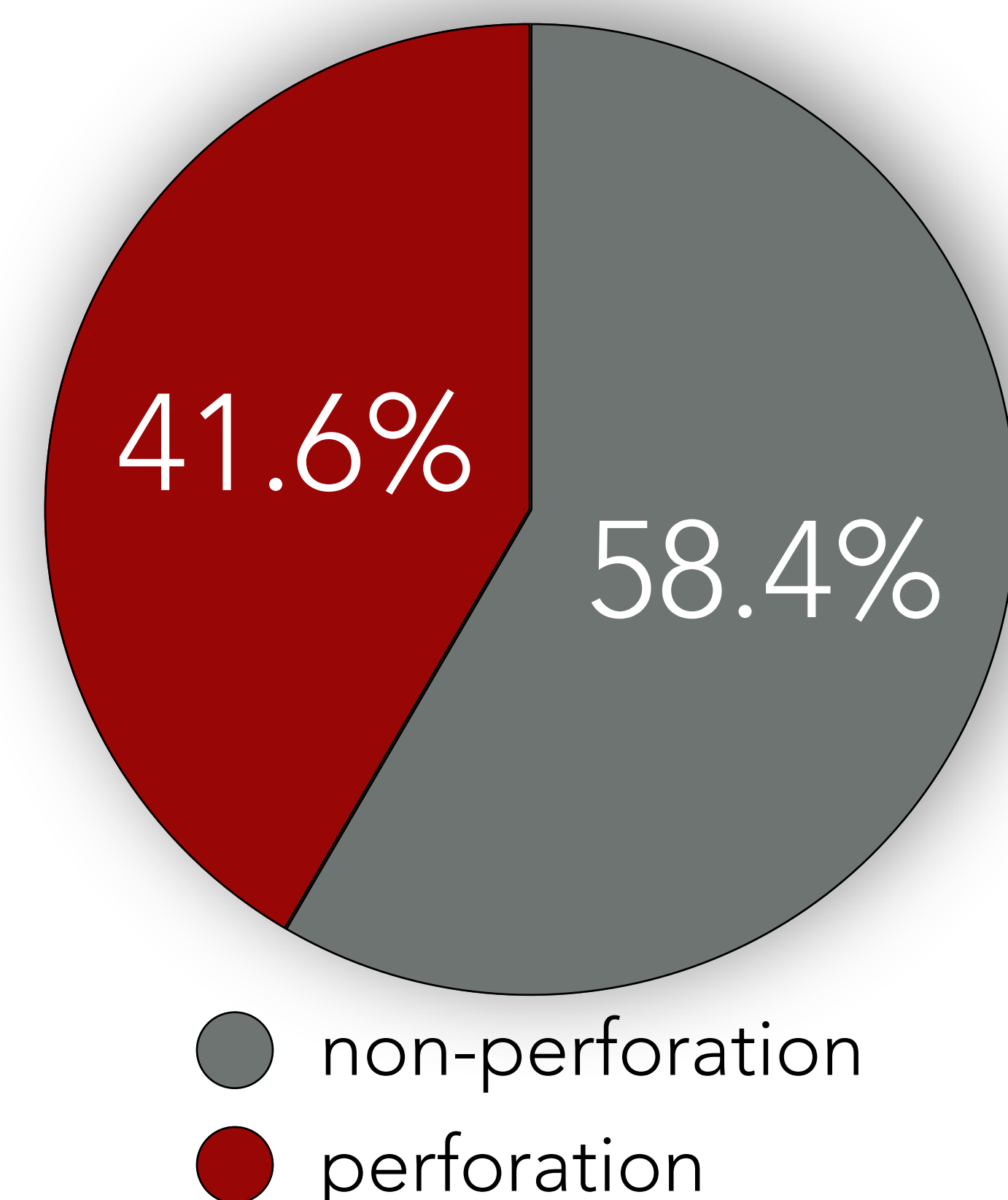


Table 3. Overall simulated incidence of apical socket perforation by implant length and diameter when shortened length (11 mm) implant was used. Number of perforations is denoted in parentheses. CI: central incisor; LI: lateral incisor; C: canine teeth; P: premolar.

	CI	LI	C	P	Total
3.5 / 4.5 x 11.5	3 (2)	2 (0)	0	2 (2)	7 (4)
3.5 / 4.5 x 13	28 (5)	18 (5)	6 (1)	4 (0)	56 (11)
3.5 / 4.5 x 15	7 (4)	0	5 (1)	0	12 (1)
4.0 / 5.0 x 10	1 (0)	0	0	0	1 (0)
4.0 / 5.0 x 11.5	3 (0)	0	0	4 (0)	7 (0)
4.0 / 5.0 x 13	9 (4)	0	2 (1)	1 (0)	12 (5)
4.0 / 5.0 x 15	4 (0)	0	0	2 (0)	6 (0)
Total	55 (11)	20 (5)	13 (3)	13 (2)	101 (21)

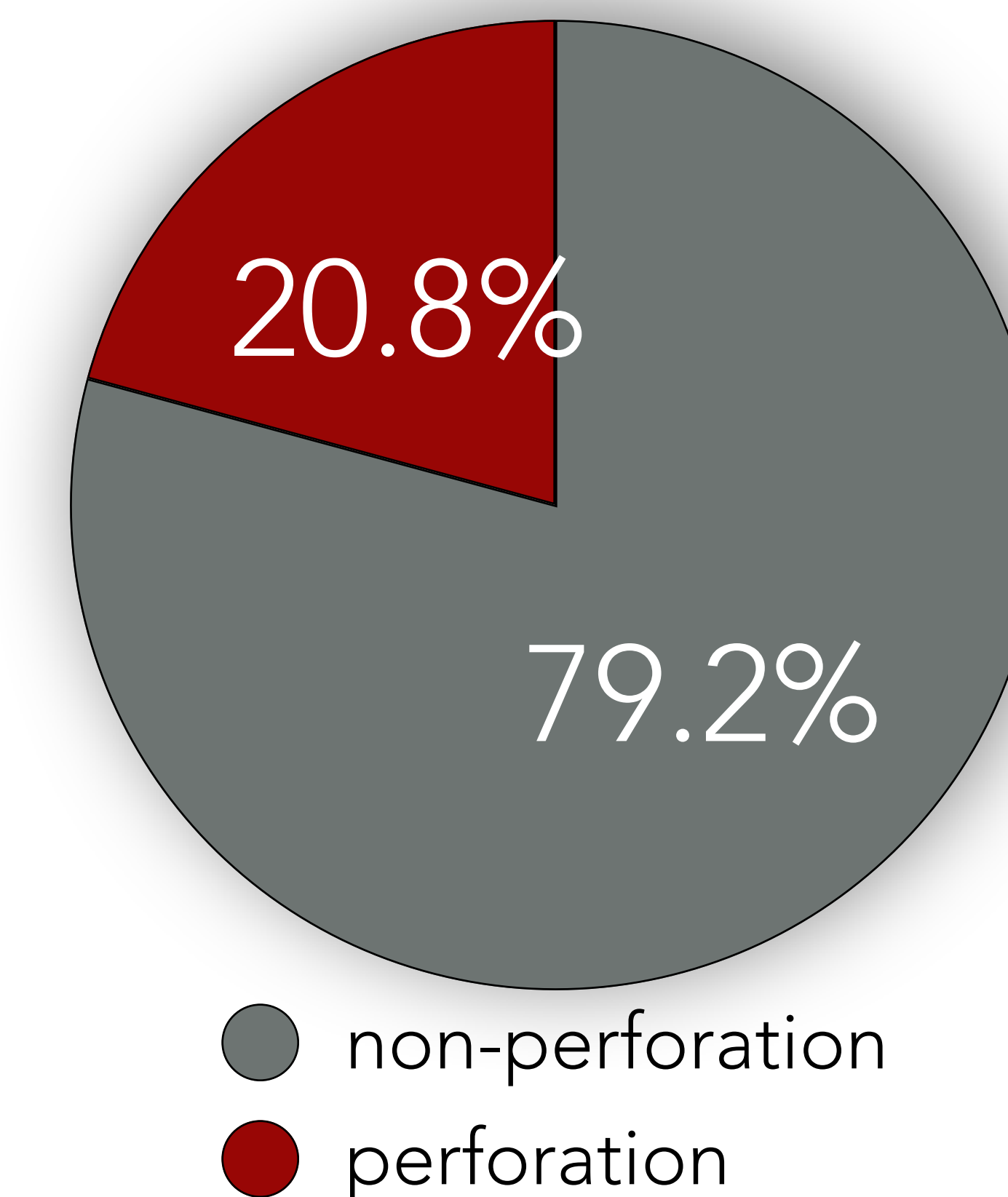


Table 4. Overall simulated incidence of apical socket perforation by implant length and diameter when shortened length (9 mm) implant was used. Number of perforations is denoted in parentheses. CI: central incisor; LI: lateral incisor; C: canine teeth; P: premolar.

Conclusions

A simulated virtual surgical planning with uniaxial implants in sites which previously had dual-axis implants placed with screw retained prostheses revealed a high ASPR (48.51%). When the length of the uniaxial implant was reduced to 11 mm and 9 mm, the ASPR was decreased to 41.58% and 20.79% respectively. A dual-axis implant design effectively evades anatomical challenges in the anterior maxilla (esthetic zone). Considering the current evidence, efforts should be made to carefully consider the angular disparity between the extraction socket-alveolus complex and future restorative emergence so that a harmonious biologic-esthetic result may be more predictably and consistently obtained.

References

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