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RESEARCH AND EDUCATION

Radial plane tooth position and bone wall dimensions in the anterior maxilla: A CBCT classification for immediate implant placement

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ABSTRACT

Statement of problem. The biological and esthetic challenge of the post-extraction ridge is relevant to restorative implant dentistry, most significantly in the anterior esthetic zone. Previous authors have discussed facial bone wall dimensions and classified their variations. A reclassification may be pertinent.

Purpose. The purpose of this observational, clinical study was to introduce a new classification system for anterior maxilla tooth position with guidelines for immediate implant placement. Data for facial and palatal bone wall height and thickness are also presented.

Material and methods. Maxillary anterior teeth (n=591) were analyzed as viewed in the radial plane of cone beam computed tomography (CBCT) scans from 150 patients. Each tooth was classified according to its position and inclination within its alveolus (class I, middle of the alveolus; IA, thick facial bone; IB, thin facial bone; class II, retroclined; IIA, thick crestal bone; IIB, thin crestal bone; class III, proclined; class IV, facially outside bone envelope; class V, both thin facial and palatal bone with apical isthmus). Bone thickness was measured for both facial and palatal walls at the following points: crestal (A), mid-root (B), apex (C), and 4 mm beyond the apex. Bone wall height was also evaluated.

Results. A thin facial bone wall predominated (≤1 mm) at the crest (83%) and the mid-root point (92%). Most palatal walls were thin (<1 mm) at the crest (63%) and thick (≥2 mm) at the mid-root point (98%) and apex (99%). Class I tooth position accounted for 6.1%, class II for 76.5%, class III for 9.5%, class IV for 7.3%, and class V for 0.7%.

Conclusions. Maxillary anterior teeth have predominantly thin facial bones, making palatal bone thickness a crucial variable. The new classification system for radial plane tooth position is a pragmatic clinical analysis for immediate implant treatment planning. (J Prosthet Dent 2018;120:50-6)

The need and clinical demand for efficient and effective tooth replacement has driven the development of immediate implant placement (IIP).[1] Recommendations for IIP stipulate ideal anatomic conditions (thick facial bone wall phenotype, thick gingival phenotype) and treatment by well-trained, experienced clinicians.[2-6] IIP is a challenging treatment option and presents a higher incidence of complications.[7,8] During surgery, incorrect angulation of the drill may lead to perforation of either the facial or palatal bone wall, a misplaced implant, incorrect emergence, dehiscence, or bone defects. Gingival recession and buccopalatal collapse are among the most common long-term complications of immediate implants, although these may also occur with the delayed approach.[7,9-11] Proper patient selection, thorough planning, and consideration of all factors involved are therefore critical for successful immediate implant treatment and long-term esthetic stability.[12-14]

Key anatomic factors that influence the outcomes of IIP include gingival phenotype, facial bone thickness and height, amount of bone beyond the apex, and buccal gap.[7,8,12,14-16] Among these factors, the alveolar bone dimensions and extraction socket have received much attention,[6,16-18] as marked post-extraction ridge changes are expected.[5,12,19,20] Although most of these variables have been evaluated, the tooth root position and inclination, which have a significant effect on IIP, have been investigated to a lesser extent.[21-23] Current guidelines for

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Clinical Implications

This study reports facial bone thickness and tooth root inclinations expected at maxillary anterior teeth. An updated classification of tooth root positions as viewed on cone beam computed tomography in the radial plane is provided. Data for the alveolar bone morphology and tooth root inclination provide useful insight for planning immediate implant placement in the anterior esthetic zone.

3-dimensional (3D) IIP suggest osteotomy preparation into the sloping palatal socket wall.[12] This approach does not apply to all clinical situations as tooth root position and inclination differ, and thus the residual tooth socket structure varies.

To the best of the current study's authors' knowledge, few studies have classified systems for position of tooth roots in the anterior maxilla relative to IIP. The classification proposed by Lau et al[24] included 2 descriptions, 1 for root angulation and the other for root position in relation to the facial and palatal walls. Although the authors did provide clinical guidelines, the double-classification system appears complex. Another pioneering classification by Kan et al,[22] although insightful, does not provide for anatomic variants and the concepts learned over the last 5 years. The purpose of the current study was to present a new working classification for the position of maxillary anterior teeth viewed in the radial plane on cone beam computed tomography (CBCT) scans. The radial plane positions classified in this study help in making decisions about implant placement strategy. This has clinical relevance for patient selection and IIP osteotomy preparation and placement.

MATERIAL AND METHODS

This observational study was compliant with Strengthening the Reporting of Observational Studies in Epidemiology (STROBE).[25] The current study included CBCT scans of 150 patients referred to a private dental clinic for implant treatment at maxillary anterior tooth sites. Teeth treated by apicoectomy and those with periapical pathology, root fractures, or root resorption were excluded. Severe scattering and/or distorted images were excluded. The included CBCT scans were made with the CS 9300 3D unit (Carestream Health) regardless of the field of view (5×5, 8×8, 10×5, 10×10, 17×6, 17×11, 17×13.5) according to the manufacturer's recommended parameters. CBCT data sets were saved in Digital Imaging and Communications in Medicine (DICOM) format, and the images were analyzed using

Table 1. Classifications for radial tooth root positions and inclinations when immediate implant placement is planned

Class	Descriptor: Vertical Axial Inclination, Buccopalatal Orientation of Tooth in Ridge, Thickness of Bone Wall(s)
Class I	Tooth centrally positioned within ridge
	Class IA: thick facial bone wall (≥1 mm)
	Class IB: thin facial bone wall (<1 mm)
Class II	Tooth retroclined
	Class IIA: thick crestal bone
	Class IIB: thin crestal bone
Class III	Tooth proclined: typically, thick palatal bone, thin facial crest, thick facial wall apically
Class IV	Tooth facially positioned outside of bone envelope
Class V	Thin facial and palatal bone walls

software (Kodak Dental Imaging Software; Carestream Health). Data were reconstructed by using cross-sectional slices in the radial plane, perpendicular to the alveolar ridge at 0.9-mm intervals. For relative tooth inclination, the maxilla was orientated horizontal to the anterior nasal spine-posterior nasal spine plane. The cross-section in the radial plane of each tooth was viewed in the center of its midfacial position and evaluated relative to the surrounding alveolar bone, according to the proposed classification system in Table 1 and Figure 1.

To measure bone height and thickness, reference lines were drawn central to the tooth and its long axis, with a second line perpendicular at its apex. Bone height was measured in millimeters for facial and palatal bone from bone crest to apical line and parallel to the long axis of the tooth. Bone thickness was measured in 3 different locations parallel to the apical plane: A, crestal; B, mid; and C, apex. The bone thickness at A was measured 1 mm from the most crestal bone aspect. At C, thickness was measured at the apical line. Thickness at B was measured midway between points A and C (Fig. 2). Bone thickness was also measured 4 mm beyond the apex, also parallel to the apex line. All CBCT measurements were performed by a single examiner (C.C.P.), who was blinded to the clinical findings of the included patients.

To estimate intraexaminer reliability for calibration, the CBCT scans of 10 randomly selected patients were assessed twice with a 1-week interval between.[26] Paired-sample Student t tests were used to compare the numeric values between the duplicate measurements for each patient. The average differences (millimeters) between the first and second measurements ranged between −0.08 and 0.1 mm. No statistically significant differences were found between the 2 measurements for any of the patients (P>.1).

For statistical analysis, data were presented as mean ± standard deviation (α=.05). Analyses were performed by using statistical software (IBM SPSS Statistics v20 for Windows; IBM Corp). The Mann-Whitney U test was

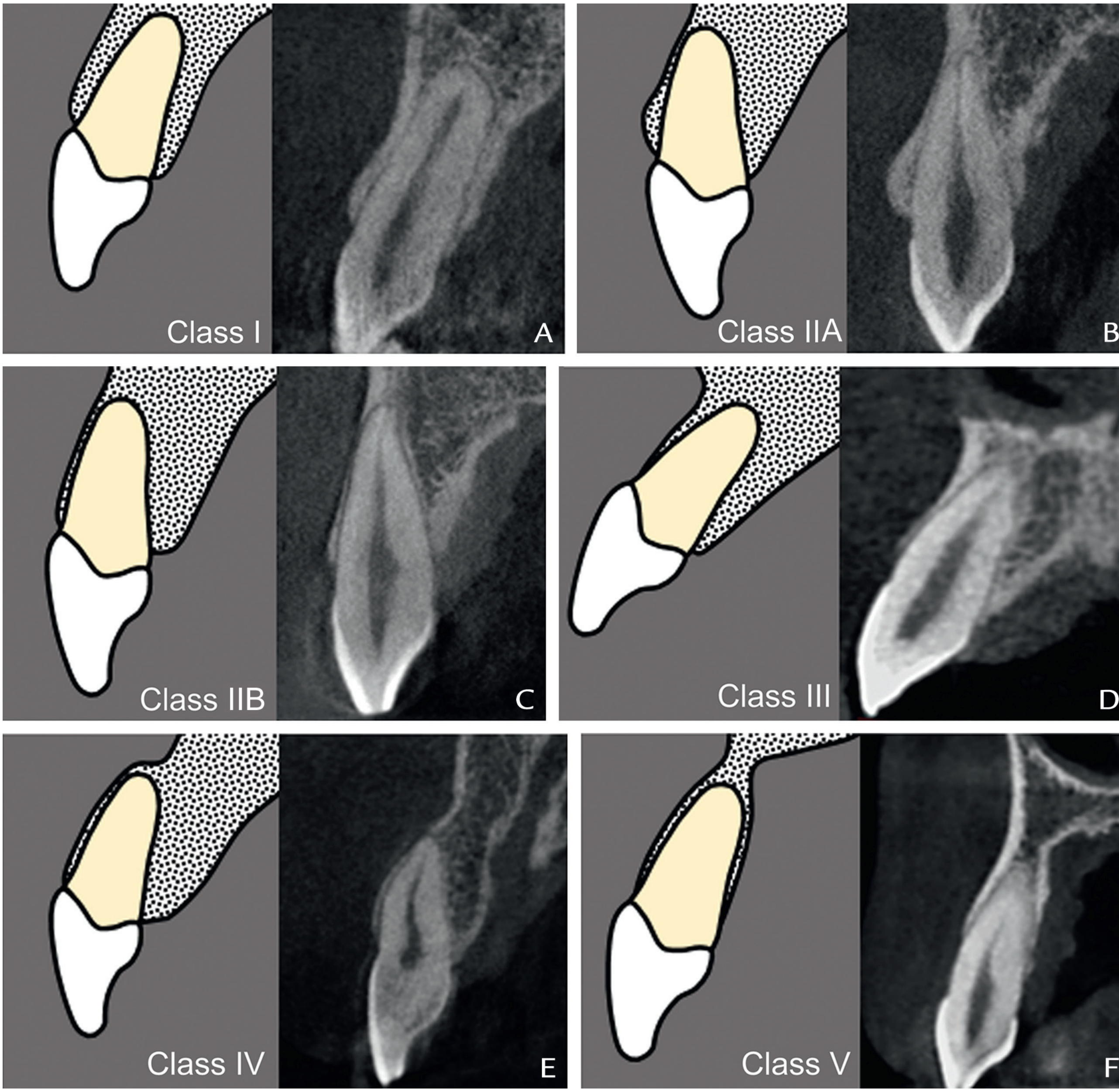

Figure 1. Radial plane tooth root positions for maxillary anterior teeth. A, Tooth centrally positioned within ridge. B, Tooth retroclined and thick crestal bone. C, Tooth retroclined and thin crestal bone. D, Tooth proclined. E, Tooth facially outside bone envelope. F, Thin facial and palatal walls.

used for comparisons between sexes. Wilcoxon signed rank tests for paired data were performed to compare contralateral teeth. For radial root position (RRP), the data were analyzed using the chi-square test.

RESULTS

A total of 150 CBCTs were analyzed, resulting in a sample size of 591 teeth. The scans were of 67 male and 83 female patients, with an average 49.4 years of age (range, 18 to 89 years of age). Regarding the classification for RRP, class II (tooth retroclined) was the most prevalent, accounting for 76.5% of all teeth (35.2% subtype IIA; 41.3% subtype IIB). Class I (centrally positioned) accounted for 6%, class III (proclined) for 9.5%, class IV (facially outside bone envelope) for 7.3%, and class V (both thin facial and palatal bone) for 0.7%. Neither sex nor tooth location were significant in terms of the frequency of classified positions. The frequency distribution for each tooth is presented in Figure 3.

The average bone height for each tooth and the differences between men and women are presented in

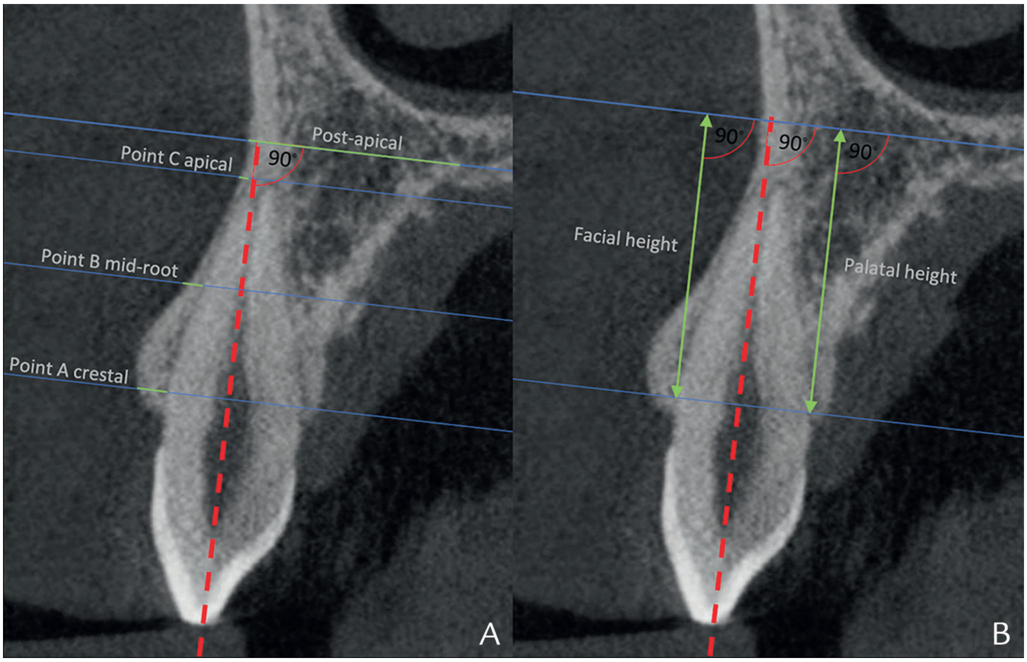

Figure 2. Alveoli measurement points. A, Horizontal. B, Vertical.

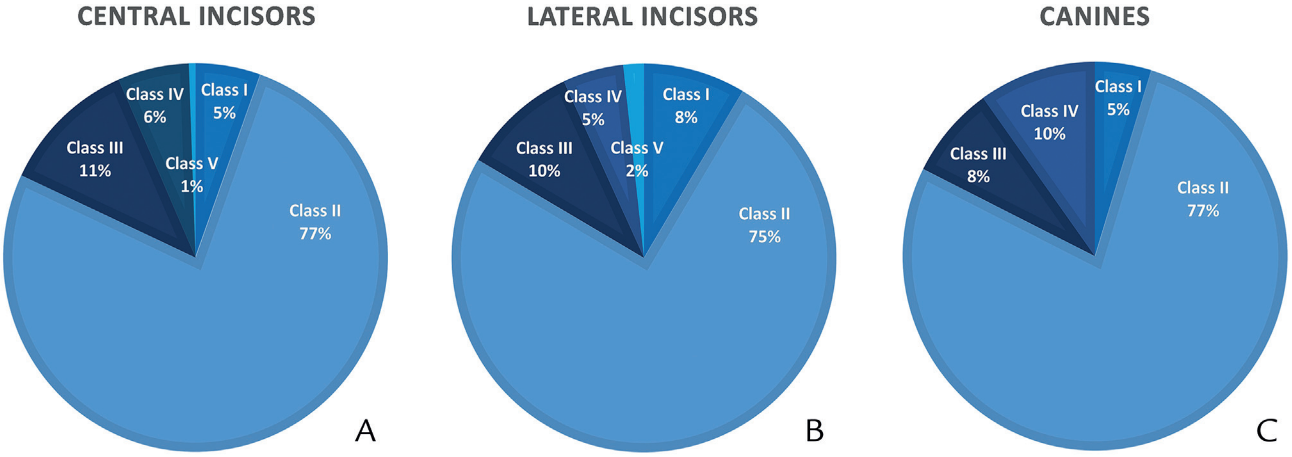

Figure 3. Frequency distributions of radial tooth root positions. A, Central incisors. B, Lateral incisors. C, Canines.

Table 2. Men had higher facial and palatal bone walls for canines ($P<.001$ for both analyses) and higher palatal walls for lateral incisors than women ($P=.02$), with no statistically significant differences for central incisors. Regarding location, no significant differences were found in bone height between the left and right sides for any of the analyzed teeth. Table 3 presents the measurements for bone thickness in 7 different locations for each tooth between the sexes. Most patients included in this study had thin facial bone (<1 mm) at crestal point A (83% of all teeth) and at mid-root point B (92% of all teeth). Most of the palatal walls (63%) were thin (<1 mm) at point A and thick (≥1 mm) at points B (98%) and C (99%). Regarding the post-apical bone thickness, 60% of all central incisors and 63% of all lateral incisors had ≥10 mm; 38% of canines had ≥10 mm, 33% had between 5 and 10 mm, and 30% had ≤5 mm.

DISCUSSION

When planning for IIP, clinicians need to evaluate a CBCT of alveolar socket bone thickness, bone height, bodily position of the tooth and root, inclination, and expected buccal gap. The root position and residual alveolar socket bone will influence the planned location of the initial osteotomy and the 3D positioning of the implant. Chappuis et al[5] demonstrated an average vertical loss of 7.5 mm of the midfacial bone wall after

Table 2. Mean ±SD bone height (mm) at the anterior maxilla

Position	Canines			Lateral Incisors			Central Incisors		
Distribution	Right (n=120), Left (n=113)			Right (n=88), Left (n=87)			Right (n=92), Left (n=91)		
	Overall	Men	Women	Overall	Men	Women	Overall	Men	Women
Buccal wall	13.3 ±2.6	14.7 ±2.5[a]	12.3 ±2.2[a]	11.0 ±1.7	11.2 ±1.7	10.5 ±1.7	10.2 ±1.8	10.6 ±2.0	9.8 ±1.5
Palatal wall	14.4 ±2.7	15.6 ±2.3[b]	13.1 ±2.2[b]	11.2 ±1.7	11.6 ±1.7[c]	10.8 ±1.7[c]	11.5 ±1.8	12.0 ±2.0	11.1 ±1.4

[a] $P<.001$. [b] $P<.001$. [c] $P=.02$.

Table 3. Average ±SD bone thickness (mm) according to tooth and sex

	Central Incisors			Lateral Incisors			Canines		
Distribution	Overall	Men	Women	Overall	Men	Women	Overall	Men	Women
Buccal wall									
Crestal	0.6 ±0.3	0.6 ±0.3	0.7 ±0.3	0.7 ±0.3	0.7 ±0.3	0.6 ±0.3	0.6 ±0.3	0.7 ±0.4	0.6 ±0.3
Mid-root	0.5 ±0.3	0.5 ±0.3	0.5 ±0.2	0.5 ±0.4	0.5 ±0.5	0.4 ±0.2	0.5 ±0.3	0.6 ±0.4	0.5 ±0.3
Apical	1.2 ±0.8	1.3 ±0.9	1.0 ±0.7	1.5 ±1.2	1.6 ±1.0	1.5 ±1.4	1.4 ±1.0	1.7 ±1.1	1.3 ±0.9
Palatal wall									
Crestal	1.0 ±0.7	1.0 ±0.5	1.0 ±0.8	0.8 ±0.4	0.9 ±0.4	0.8 ±0.4	0.9 ±0.4	0.9 ±0.4	0.8 ±0.4
Mid-root	3.8 ±1.6	4.3 ±1.7	3.4 ±1.4	3.2 ±1.4	3.6 ±1.4	2.8 ±1.4	4.4 ±1.8	4.9 ±2.0[a]	4.0 ±1.6[a]
Apical	7.7 ±2.9	8.1 ±2.7	7.3 ±2.9	6.6 ±2.2	6.9 ±2.2	6.3 ±2.2	9.0 ±3.3	9.7 ±3.5	8.6 ±3.0
Post-apical	10.2 ±3.8	10.4 ±4.0	10.1 ±3.7	10.5 ±3.2	11.2 ±2.9	10.5 ±3.2	8.5 ±4.8	8.5 ±5.0	8.5 ±4.7

[a] $P=.02$.

extraction of a maxillary anterior tooth if the facial bone wall was thin (≤1 mm). Facial bone thickness helps establish the convexity of the alveolar process and is directly related to ridge alterations after IIP. Managing these variables is critical to the achievement of long-term optimal esthetic results.[12,14,21]

In the current study, CBCT scans were used to determine the radial position of the root according to a new classification system and to determine the thickness and height of the facial and palatal socket walls of anterior maxillary teeth. The results showed that between 83% and 92% of all teeth had facial bone <1 mm between the crest and mid-root point. El Nahass and Naiem[16] reported 86% of maxillary anterior teeth as having <1 mm at the facial crest. Wang et al[23] reported that 80% of maxillary anterior teeth had thin facial bone. Chappuis et al[5] also reported that a majority of maxillary anterior teeth (69%) had thin facial bone at the midfacial point. The results of all these studies are in accordance with those of the current study—thin facial bone predominates in the esthetic zone.

Bone thickness at the palatal walls was also recorded in the current study. Most patients had thin palatal bone at crestal point A (63% <1 mm), increasing on average in thickness toward the mid-root position B (98% ≥1 mm) and to the apex point C (99% ≥1 mm). These findings are comparable with those published by Lee et al[17] and Lau et al.[24] Hyung-Ba et al[6] also showed that 60.2% of all teeth presented palatal crests between 0.5 and 1 mm, and the results of these studies are in accordance with those of the current study.

Sex had no significant influence on facial bone thickness in our study. The only sex differences were noted at the canine teeth, where men had almost 1 mm more bone on average. Previous studies have not noted this difference for palatal bone thickness, although the results of studies by El Nahass and Naiem[16] and Demircan and Demircan[18] differed from ours between sexes' facial bone at crestal point A and mid-root point B. However, these may not be clinically significant as differences ranged between 0.1 and 0.2 mm on average for both studies. Sex, however, affected bone height in the current study. The alveolar ridge was, on average, approximately 2 mm higher on the facial and palatal walls of canines and on the palatal walls of lateral incisors for men than women. According to a study by Zorba et al,[27] men tend to present longer root lengths than women for most teeth, with canines and lateral incisors being the most affected by this sex dimorphism.

Another relevant location to measure bone thickness when planning IIP is the area beyond the apex, which usually provides implant primary stability. Most lateral (63%) and central incisors (61%) had sufficient bone beyond the apex (≥10 mm). For canines, 33% had between 5 and 10 mm, and 38% had ≥10 mm, representing a challenge for primary stability in this area. To the best of the current study's authors' knowledge, this is the first CBCT study to report bone thickness in this area.

Probably the most important parameter analyzed in the current study was the RRP of each tooth. A review of published studies to date has not yet defined the cross-section through the jaws as seen on CBCT perpendicular to the facial surface, and previous classifications of this plane as "sagittal" are not correct.[22] The terms cross-section and sagittal plane do not adequately describe this

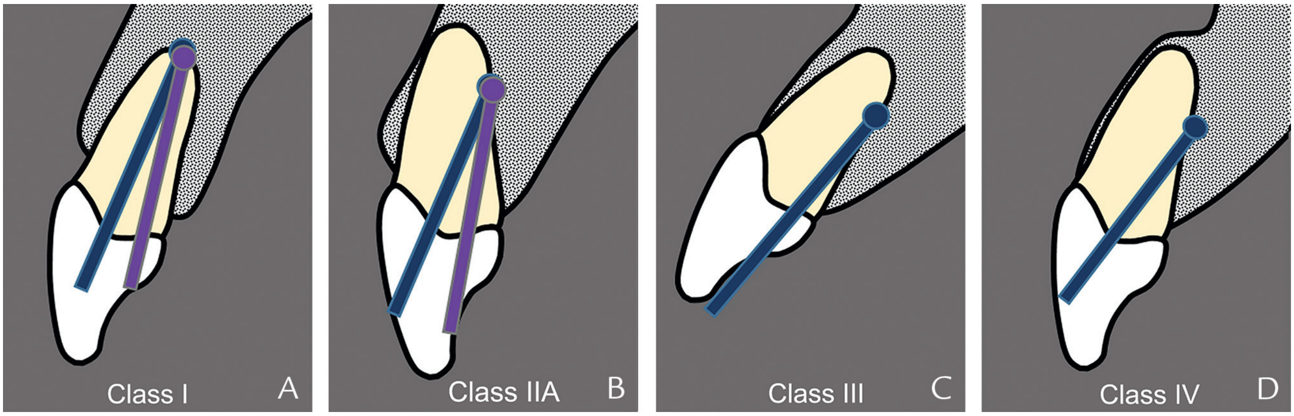

Figure 4. Guidelines for initial osteotomy preparation sites according to radial tooth root position. A, Class I. B, Class IIA. C, Class III. D, Class IV.

view. Because the reconstructed CBCT is a cylinder, the viewer scrolls through the ridge(s) in cross-section and sees a plane from the center of the cylinder. This is in fact a circle's radius. Thus, we propose naming this view the radial plane or radial view. The radial plane positions classified in this study help make decisions about implant placement strategy. During planning, these radial plane positions also assist with optimal osteotomy positioning. With the growing evidence for partial extraction therapies, classifying the RRP also assists in planning the socket-shield and implant placement. Although such a classification system may be essential for patient selection, to the best of these authors' knowledge only 2 studies[22,24] have classified the root position of maxillary anterior teeth. Lau et al[24] categorized the proximity of the root to the bone walls (mesial, middle, and palatal), and each of them is subclassified into 3 possible root angulations, resulting in 9 possible categories. Although a direct comparison is not possible and the authors only included central incisors, 78.8% were positioned more facially, which is similar to the class II proposed in this study (76%). The present study has further developed the groundwork laid by Kan et al[22] by improving the classification to incorporate omitted anatomic variants and to apply concepts learnt since its publication.

Decision making and planning for IIP includes variables affecting angulation of placement, whether the prosthesis should be screw- or cement-retained, use of angled and anatomic abutments, inclination of neighboring and opposing teeth, occlusion, and so forth. With this in mind and based on the results from 150 CBCT scans of the 591 maxillary anterior teeth classified, we propose clinical guidelines for pilot osteotomy preparation (Fig. 4). Class I represents only 6% of maxillary anterior teeth. This clinical situation with thick facial bone (subtype IA) is rare. In such cases, the pilot osteotomy preparation may be initiated at the socket apex, and the apical bone will contribute largely to primary stability. For a cement-retained option, this may represent the ideal scenario. Alternatively, angulation for screw retention may provide a residual buccal gap to graft, supported by a thick facial bone wall. In subtype IB, resorption of the facial bone must be anticipated and grafting considered. Class II represents the majority (76.5%), with 2 variations, thick (subtype IIA) or thin (subtype IIB) bone crest. The unpredictability of the facial bone, especially in type IIB, as with type IB, must be approached with caution. In accordance with current research, a delayed approach may be better. However, for a screw-retained option, type IIA may present the ideal scenario. If IIP is selected, a class IIA-positioned tooth site may benefit from a palatally positioned osteotomy. Palatal bone will contribute largely to primary stability. Class III represents only 9.5%, with a thin facial bone crest. In accordance with current studies, a delayed approach may be better, and the high risk of facial resorption must give caution. If IIP is selected, class III-positioned tooth sites may benefit from a palatally positioned osteotomy. Palatal bone will contribute largely to primary stability. Class IV represents only 7.3%, with a thin facial bone wall. In accordance with current studies, a delayed approach may be better. If IIP is selected, class IV-positioned tooth sites should be prepared even more palatally, as palatal and apical bone will provide the entire primary stability. Class V represents 0.7%, with neither bone facially, palatally, or apically to provide primary stability. We regard class V tooth root position as a contraindication to IIP.

The ideal indication for IIP would be thick facial bone; however, results from this study and from previous studies indicate this is a rare clinical finding. The next best situation would be the presence of a thick palatal wall. Studies demonstrate at least 50% loss of the overall alveolar ridge width after extraction,[19] and a 7.5-mm vertical loss of the facial bone wall in the esthetic zone[5] of most patients. Bearing this in mind, IIP dictates prudent planning and the appropriate caution to best manage long-term peri-implant tissue stability. Within the limits of the planned restoration, IIP should be as far palatally as possible (except for class I and possibly class IIA).[11,20] This study emphasizes the importance of the palatal bone for IIP as the key factor for the initial osteotomy, for anchorage, for the final implant positioning, and possibly for overall long-term success. Studies are still required to further elucidate the role of the palatal bone and its post-extraction behavior.

CONCLUSIONS

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

1. Most maxillary anterior teeth have thin facial bone walls, which may negate the benefits of immediate implant placement if management of these tissues is not adequately planned for.
2. The classification system proposed here is a straightforward, didactic clinical tool for evaluating the radial tooth root position to help select placement timing as well as osteotomy positioning for immediate implant placement.

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