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Tomographic sagittal root position in relation to maxillary anterior bone housing in a Brazilian population

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ABSTRACT

Purpose: This cross-sectional study evaluated and categorized the tomographic sagittal root position (SRP) of the maxillary anterior teeth in a Brazilian population.

Materials and Methods: Cone-beam computed tomographic scans of 420 maxillary anterior teeth of 70 patients (35 men and 35 women, mean age 25.2±5.9 years) were evaluated. The SRP was classified as class I, II, III, or IV. In class I, the root is positioned against the buccal cortical plate; in class II, the root is centered in the middle of the alveolar housing; in class III, the root is positioned against the palatal cortical plate; and in class IV, at least two-thirds of the root engage both the buccal and palatal cortical plates.

Results: In total, 274 teeth (65.2%) were class I, 39 (9.3%) were class II, 3 (0.7%) were class III, and 104 (24.8%) were class IV. The frequency distribution over the teeth groups was different from the overall analysis. Important differences were found in the frequencies of classes I, II, and IV compared to other populations. Sex was not associated with the SRP classes ($P=0.307$). Age distribution was significantly different over the classes ($P=0.004$).

Conclusion: The findings of this study on the distribution of SRP classes among the Brazilian population compared to other populations demonstrate that the SRP should be analyzed on a case-by-case basis for an accurate treatment plan in the maxillary anterior area. ***(Imaging Sci Dent 2022; 52: 75-82)***

KEY WORDS: Cone-Beam Computed Tomography; Tooth Socket; Alveolar Process; Dental Implants

Introduction

Immediate implant placement following maxillary anterior tooth extraction is considered a successful treatment strategy. Nevertheless, it is still a challenging procedure, and rigorous treatment planning is needed to achieve favorable esthetic outcomes.[1-4] This procedure plays an important role in reducing the emotional trauma caused by losing a maxillary anterior tooth and minimizing alterations of the hard and soft tissue architecture.[2,5]

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The International Team for Implantology Consensus Statement emphasized the need for a facial bone wall of at least 1 mm in thickness, thick soft tissue, no acute local infection, and sufficient apical and palatal bone to provide primary stability.[6,7] Several factors, such as the morphology of the alveolar bone housing, root length, and sagittal root position (SRP), may affect primary stability and should be considered in immediate implant placement.[8-11] Cone-beam computed tomography (CBCT) is the most widely used method to analyze these factors, as it offers excellent image quality for evaluating the feasibility of immediate implant placement.[9-12]

The esthetic success of immediate dental implant placement requires long-term soft tissue stability.[13,14] Bone availability in all dimensions should be considered to achieve good implant esthetics in prosthetic-driven treatment. The

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angulation and position of the original tooth should be clearly visualized 3-dimensionally.[13] In addition to changes in the alveolar bone housing and post-extraction alveolar ridge, tooth root position has an important effect on immediate implant placement and provisionalization (IIPP).[11-17] Various classifications of the tooth root position in the anterior maxilla regarding IIPP have been reported.[10,13,15] In 2011, Kan et al.[10] developed the SRP classification in relation to anterior maxillary osseous housing in Caucasians. This classification describes 4 different classes, and it is important to diagnose a site as predictable or unpredictable for esthetic maxillary IIPP. In the same year, Lau et al.[13] proposed another classification that evaluated root angulation and position in relation to the buccal and palatal walls in Chinese. Other studies have also evaluated the arch form,[14] the angulation between the alveolar bone and tooth axis,[16,18] the buccal bone dimensions,[12,13,15,17,18] root inclination,[15] socket width, and buccal and palatal soft tissue dimensions.[8]

Although the SRP classification is widely used due to its clinical simplicity,[10] there is a paucity of studies on different populations. In the Caucasian and Korean populations, which present differences in the size and shape of the dental arch and soft tissue profiles,[19-23] different prevalence rates of the SRP classes have been reported.[10,16] The objective of this study was to evaluate and categorize the SRP of the maxillary anterior teeth in a Brazilian population.

Materials and Methods

This cross-sectional study followed the STROBE statement (www.strobe-statement.org). This is the first part of a clinical and tomographic study that evaluated the relationship between the SRP of the maxillary anterior teeth and the periodontal phenotype in 70 participants. The participants, who were examined between January 2016 and January 2019, were drawn from patients who underwent comprehensive treatment at the Fluminense Federal University Dental School. The study protocol was approved by the Research Ethics Committee of the Federal Fluminense University School of Medicine (CEP/HUAP 506.300) and was performed in accordance with the Declaration of Helsinki. All participants were informed about the nature of the study and were asked to sign an informed consent form prior to enrollment in the study. CBCT of the maxillary anterior teeth was performed at the Petersen Image Diagnose Center (Niterói, RJ, Brazil).

All participants were aged $>$18 years, had periodontally healthy anterior teeth, and underwent CBCT for other reasons. The exclusion criteria were previous or ongoing orthodontic treatment; pregnancy or lactation; periodontal disease (defined as a periodontal probing depth of $>$3 mm); gingival recession; current smoking; the presence of diabetes or other systemic diseases; manifest bone disease; surgical treatment performed in the area; gingival enlargement; altered passive eruption; and teeth with incisal edge wear, malformation, misalignment, crowding, diastema, carious lesions, fractures, external resorption, or restorations.

The scans were acquired using a PreXion 3D Elite unit (TeraRecon Inc., San Mateo, CA, USA), with the following exposure protocol: a field of view of 5$\times$5 cm, an exposure time of 19 s, 90 kVp, 4 mA, a thickness of 0.100 mm, a voxel size of 0.100 mm, and 1,024 basis images. The images were analyzed using the PreXion 3D Viewer software (TeraRecon Inc., Foster City, CA, USA). A radiologist performed all the evaluations. The images were displayed on a flat panel screen (HP 24UH 24-inch monitor, HP Development Company, Palo Alto, CA, USA) with a resolution of 1,920$\times$1,080 pixels. All scans were aligned using a standardized protocol as described by Frost et al.[24] This was done with the following 3-dimensional guidelines: 1) along the buccolingual axis, the sagittal plane was placed in the middle of the selected tooth; 2) along the mesiodistal axis, the frontal plane was placed in the center of the selected tooth; and 3) along the apico-coronal axis, the axial plane was placed perpendicular to the long axis of the selected tooth at the level of the cementoenamel junction (Fig. 1).

The SRP of the maxillary anterior teeth was classified as proposed by Kan et al.[10] In class I, the root is positioned against the labial cortical plate; in class II, the root is centered in the middle of the alveolar housing without engaging either the labial or palatal cortical plates at the apical third of the root; in class III, the root is positioned against the palatal cortical plate; and in class IV, at least two-thirds of the root engages both the buccal and palatal cortical plates (Fig. 2).

The tomographic SRP classification was evaluated by 2 examiners (a radiologist and periodontist), which had been previously calibrated by the simultaneous evaluation of 60 randomly selected images. If any disagreements occurred regarding the classification of an image, both examiners reevaluated the scan until agreement was reached about the most appropriate classification. The intra-examiner kappa values of the 2 radiologists were 0.91 and 0.88, respectively. The final inter-examiner kappa value was 0.917.

A pilot study was conducted on 20 participants. The tooth

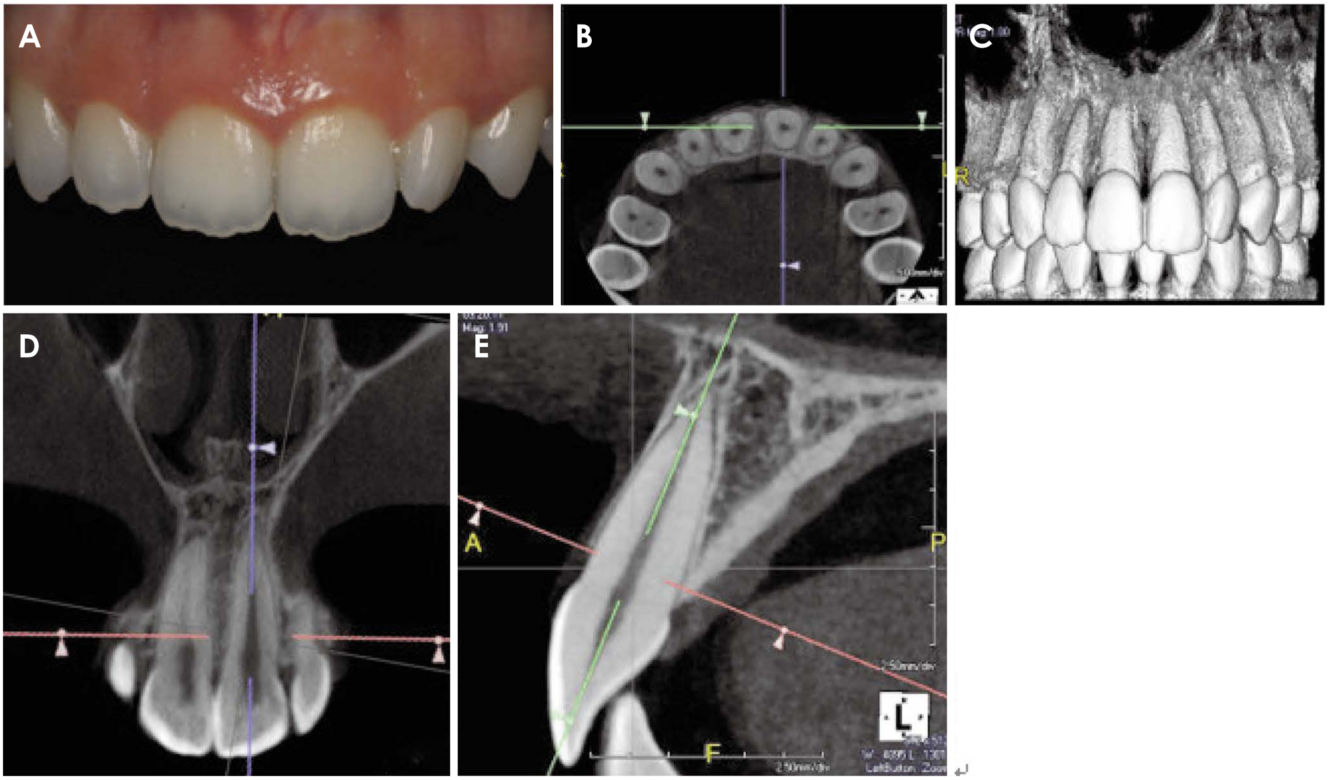

Fig. 1. Guideline for cone-beam computed tomographic (CBCT) analysis. A. Clinical examination. B. Axial cone-beam computed tomographic (CBCT) image. C. Three-dimensional CBCT image. D. Coronal CBCT image. E. Sagittal CBCT image.

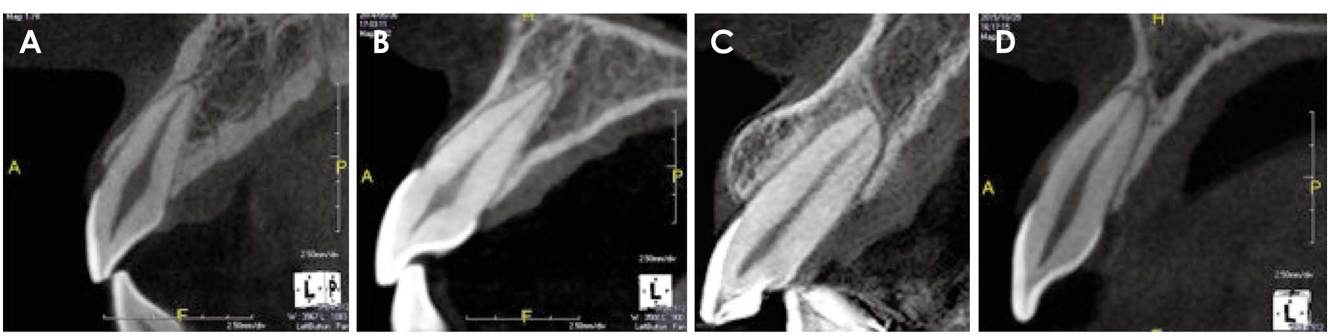

Fig. 2. Cone-beam computed tomographic scans of sagittal root position classes. A. Class I. B. Class II. C. Class III. D. Class IV.

was set as the unit of analysis. The sample size necessary to compare the periodontal phenotype (gingival phenotype, keratinized tissue width, and bone morphotype) to the SRP classification was tested. The samples were compared by considering the smallest distance between the means. The sampling error ($\alpha = 0.05$; 5%) and power of the study (0.8; 80%) were previously fixed. The sample size calculated was 420 teeth.

SPSS version 20.0 (IBM Corp., Armonk, NY, USA) was used and the tooth was set as the unit for all analyses. The variables were tested for a normal distribution using the Shapiro-Wilk and Kolmogorov-Smirnov tests. Descriptive statistics were used to report the frequency (number and percentage) of each class. The distribution of each SRP class according to the tooth position was also recorded. Association and agreement between SRP classes in the contralateral teeth were tested using the chi-square and kappa test, respectively. The Kruskal-Wallis test and post-hoc pairwise analysis (Dunn test) were used for comparisons between the SRP classification and age. Statistical significance was set at $\alpha = 0.05$.

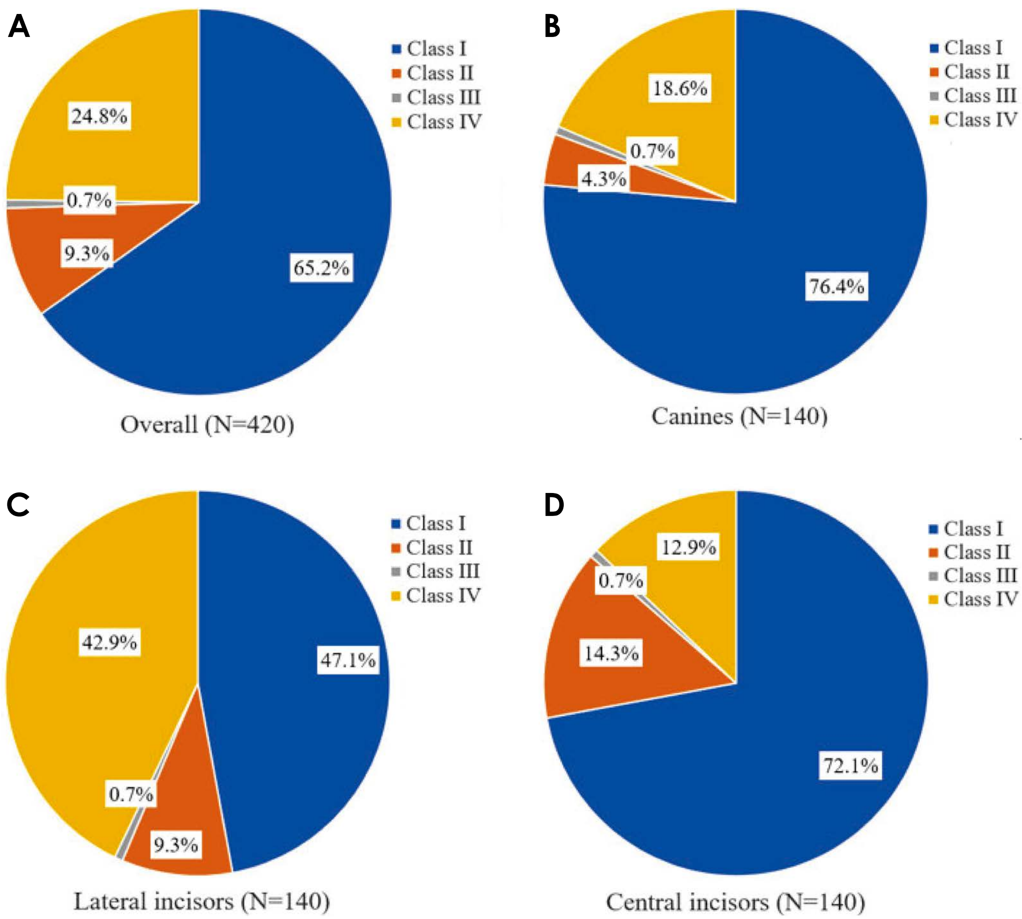

Fig. 3. Frequency distribution of sagittal root position. A. Overall results. B. Canines. C. Lateral incisors. D. Central incisors.

Table 1. Distribution of sagittal root positions in left and right upper anterior teeth

Tooth	Class I % (n)	Class II % (n)	Class III % (n)	Class IV % (n)	Chi-square	Kappa	*P* value
Left canine	74.3 (52)	4.3 (3)	1.4 (1)	20.0 (14)	25.559	0.399	<0.05
Right canine	78.6 (55)	4.3 (3)	0.0 (0)	17.1 (12)			
Left lateral incisor	47.1 (33)	14.3 (10)	0.0 (0)	38.6 (27)	25.707	0.419	<0.05
Right lateral incisor	47.1 (33)	4.3 (3)	1.4 (1)	47.1 (33)			
Left central incisor	72.9 (51)	10.0 (7)	1.4 (1)	15.7 (11)	37.156	0.455	<0.05
Right central incisor	71.4 (50)	18.6 (13)	0.0 (0)	10.0 (7)			

Results

Seventy participants aged 18-42 years (mean age: 25.2 ± 5.9 years) participated in this study. The mean age of the men and women were 25 ± 5.78 and 22 ± 5.9 years, respectively.

An analysis of the frequency distribution of SRP over the 420 teeth demonstrated that 274 (65.2%) were class I, 39 (9.3%) were class II, 3 (0.7%) were class III, and 104 (24.8%) were class IV (Fig. 3). The distribution of SRP classes was different among the canines, lateral incisors, and central incisors (Fig. 3). The lateral incisors presented the highest prevalence of class IV SRP.

The association between the right and left canines and lateral and central incisors was statistically significant, and the kappa agreement was moderate (Table 1). Higher differences between the right and left maxillary anterior teeth were found for the lateral and central incisors in class II, and for lateral incisors in class IV.

The age distribution was not the same across the SRP classes (Kruskal-Wallis test, $P = 0.004$). Sex was not associated with the SRP classification (Table 2). However, it is important to consider that of the 104 class IV teeth, 59 (56.7%) were from women and 45 (43.3%) from men.

Different results were found for the frequency distribution of SRP classes compared with other studies that used the SRP classification[10] (Table 3). The frequency distribution of SRP classes found in the present study was compared to those reported by other studies using the SRP classification of the maxillary central incisors (buccal, middle, and palatal-type) described by Lau et al.[13] The prevalence of SRP classes was different among the analyzed populations (Table 4).

Table 2. Distribution of sagittal root position classification of teeth according to sex

	Female % (n)	Male % (n)	Overall % (n)
Class I	48.9 (134)	51.1 (140)	100.0 (274)
Class II	41.0 (16)	59.0 (23)	100.0 (39)
Class III	33.1 (1)	66.7 (2)	100.0 (3)
Class IV	56.7 (59)	43.3 (45)	100.0 (104)
Overall	100.0 (210)	100.0 (210)	100.0 (420)

Discussion

This study evaluated the tomographic SRP of 420 maxillary anterior teeth in a Brazilian population, and found a different prevalence of classes I, II, III, and IV compared to the other 3 studies that used the same classifcation.[10,14,16]

According to Kan et al.,[10] class I is the most favorable and predictable for IIPP. Classes II and III are more experience- and technique-sensitive, and class IV is contraindicated, requiring additional procedures for hard and soft tissue augmentation before implant placement. This study found a distribution of 65.2% for class I and a considerable percentage (24.8%) for class IV. These results were different from those obtained by Kan et al.[10] and Petaibunlue et al.,[14] which found prevalence rates of almost 80% and 10% for class I and class IV, respectively. The different frequency of class II between the studies may not influence treatment decisions. However, the SRP classification of specific tooth groups must be carefully evaluated. In this study, the lateral incisors had an almost equal distribution between class I and IV (47.1% and 42.9%, respectively). The proportion of lateral incisors belonging to class IV in the present study

Table 3. Frequency distribution of sagittal root position according to the classification of Kan et al.[10] in different studies

	Class I % (n)	Class II % (n)	Class III % (n)	Class IV % (n)	Total % (n)
Kan et al.[10]					
Canines	81.0 (162)	6.0 (12)	0.0 (0)	13.0 (26)	100 (200)
Lateral incisors	76.0 (152)	8.5 (17)	1.5 (3)	14.0 (28)	100 (200)
Central incisors	86.5 (173)	5.0 (10)	0.5 (1)	8.0 (16)	100 (200)
Overall	81.1 (487)	6.5 (39)	0.7 (4)	11.7 (70)	100 (600)
Present study					
Canines	76.4 (107)	4.3 (6)	0.7 (1)	18.6 (26)	100 (140)
Lateral incisors	47.1 (66)	9.3 (13)	0.7 (1)	42.9 (60)	100 (140)
Central incisors	72.1 (101)	14.3 (20)	0.7 (1)	12.9 (18)	100 (140)
Overall	65.7 (274)	9.3 (39)	0.7 (3)	24.8 (104)	100 (420)
Petaibunlue et al.[14]					
Canines	99.0 (194)	0.5 (1)	0.0	0.5 (1)	100 (196)
Lateral incisors	84.2 (160)	5.1 (10)	0.0	10.7 (21)	100 (191)
Central incisors	79.6 (156)	20.4 (40)	0.0	4.5 (35)	100 (231)
Overall	82.5 (510)	8.3 (51)	0.0	9.2 (57)	100 (618)
Kong[16]					
Canines	87.5 (120)	6.7 (8)	0.8 (1)	5.0 (6)	100 (120)
Lateral incisors	81.7 (98)	5.8 (7)	3.3 (3)	9.2 (11)	100 (120)
Central incisors	74.2 (89)	18.3 (22)	1.7 (2)	5.8 (7)	100 (120)
Overall	81.1 (292)	10.3 (37)	1.9 (6)	6.7 (24)	100 (360)

Table 4. Distribution of the sagittal root position of upper central incisors according to the classification of Lau et al.[13] in different studies

	Middle % (n)	Middle % (n)	Palatal % (n)	Overall % (n)
Kan et al. in USA[10]	86.5 (173)	13.0 (26)	0.5 (1)	100.0 (200)
Lau et al. in Hong Kong[13]	78.8 (134)	19.4 (33)	1.8 (3)	100.0 (170)
Chung et al. in Korea[9]	94.0 (235)	5.6 (14)	0.4 (1)	100.0 (250)
Xu et al. in China[11]	95.4 (891)	4.4 (41)	0.2 (2)	100.0 (934)
Kheur et al. in India[8]	63.0 (95)	31.0 (46)	6.0 (9)	100.0 (150)
Gluckman et al. in South Africa[15]	83.8 (495)	16.2 (15)	0.0 (0)	100.0 (501)
Jung et al. in Korea[17]	93.1 (741)	6.7 (53)	0.2 (2)	100.0 (796)
Petaibunlue et al. in Thailand[14]	82.5 (510)	17.5 (108)	0.0 (0)	100.0 (618)
Present study in Brazil	72.1 (101)	27.2 (38)	0.7 (1)	100.0 (140)

was significantly different from those reported by Kan et al. (14%),[10] Petaibunlue et al. (10.7%),[14] and Kong (9.2%).[16] This high proportion of class IV in the present study may contraindicate IIPP and suggests the need for guided bone regeneration procedures in approximately 40% of lateral incisors prior to implant placement. Almost 100% of canines were class I in the study of Petaibunlue et al.,[14] and 87.5% of canines belonged to class I in Kong's[16] study. The present study showed that 76.4% of canines were class I, suggesting that IIPP should not be considered in more than 20% of canine teeth. The results found in class II central incisors (technique-sensitive for IIPP) in the present study (14.3%), in the study of Petaibunlue et al.[14] (20.4%) and in the study of Kong[16] (18.3%), were higher than the 5% reported by Kan et al.[10] Important differences were found between the 3 studies that used the SRP classification and the present study.[10,14,16] However, clinicians should not rely exclusively on the reported results. The importance of CBCT as a standard method to determine the alveolar bone housing structure and aid in the planning of IIPP is crucial for a customized treatment plan.[25]

These differences might be partially explained by differences in populations (in terms of arch shape, sex distribution, tooth location, and age range), CBCT equipment, and orthodontic treatment. In the present study, patients who underwent orthodontic treatment were excluded. Most of the literature regarding the different SRP classifications did not evaluate the association between sex and SRP.[8-10,12-14,16,17] Nonetheless, similar to the results of the present study, Xu et al.[11] and Gluckman et al.[15] showed no association between sex and the different SRP classes. It is important to highlight that in the sample of the current study, female participants presented significantly more class IV teeth. The distribution of the SRP classes in the present study showed statistically significant differences according to age, which was corroborated by Zhang et al.[18] One of the limitations of the present study was the age distribution of the sample. In this context, Feher et al.[26] found that patients show angular changes in the anterior maxilla in the long term. It would be interesting to understand changes in the SRP with age. Gluckman et al.[15] showed that tooth location had no influence on the frequency of SRP. The present study showed that different SRP classes were also found for the right and left maxillary anterior teeth, with greater differences in class II lateral and central incisors, highlighting the importance of the SRP evaluation for each maxillary anterior tooth.

The tomographic evaluation of the root position in the alveolar process has also been discussed in the literature, considering different classifications and underscoring the importance of this analysis to the esthetic sensitivity of immediate implant placement.[8-15] To compare different classifications, this study adapted and grouped some SRP classes to fit into the classification proposed by Lau et al.[13] These results considered only the buccal-, middle-, and palatal-type central incisors. The palatal-type that corresponds to class III in SRP classification was rarely found in 9 studies.[8-11,13-17] The prevalence of middle-type central incisors ranged between 4.4% and 37.2%. It is important to consider that the middle type corresponds to classes II and IV in the SRP classification,[10] with different scenarios for IIPP, ranging from technique-sensitivity to contraindications. This demonstrates that the classification into 3 positions is less accurate than that proposed by Kan et al.[10] Buccal-type central incisors, such as in class I SRP, represent the most feasible situation for IIPP. However, the results obtained from 9 previous studies revealed large variations in frequency, ranging between 63%[8] and 95.4%,[11] which suggests that each patient must be evaluated individually, disregarding the mean frequencies reported in the literature.

The SRP classification is crucial for determining the esthetic treatment planning of IIPP. In some cases, immediate implant placement is not possible and procedures, such as guided bone regeneration, are necessary to ensure predictable esthetic outcomes, mainly in classes II and IV. Other dental specialties may consider this classification as a treatment plan. A limitation of the present study is that it only evaluated periodontally healthy participants, while Zhang et al. found a significant difference in the SRP of periodontally compromised participants compared to healthy individuals.[27]

It is important to highlight that the classification of Kan et al.[10] involves a certain level of subjectivity. The SRP should be evaluated together with other parameters, such as alveolar dimensions, palatal bone thickness, apical bone height, presence of buccal undercuts, and tooth angulation. In addition, a pioneering study recently published by the authors' group[28] demonstrated that the root position of the different SRP classes of the maxillary anterior teeth was related to the periodontal phenotype. Significant differences in gingival thickness, keratinized tissue width, buccal bone thickness, supra-crestal gingival tissue dimensions, papilla height, and tooth shape were found. The incorporation of these data into the SRP classification may mitigate the risk of errors.

In conclusion, important differences were found in the prevalence of SRP classes I, II, and IV in the central incisors, canines, and lateral incisors in the Brazilian population compared with other populations. The different frequencies of SRP classes across populations demonstrate that when performing a CBCT exam, considering each maxillary anterior tooth is mandatory as part of the decision-making process for immediate or delayed implant placement.

Conflicts of Interest: None

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