Original paper

Does the sagittal root position of maxillary anterior teeth affect the decision making on immediate implants in the anterior maxilla? A CBCT-based study

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Abstract

Background. Immediate implant placement in the maxillary esthetic zone is a challenging and demanding task. To achieve favorable results, proper case selection and treatment planning are necessary. Variables like the sagittal root position (SRP) and the labial bone thickness (LBT) of maxillary anterior teeth are of paramount importance for predictable outcomes.

Objectives. The aim of the present study was to evaluate the SRP and LBT of maxillary anterior teeth in the context of immediate implant placement by using cone-beam computed tomography (CBCT) in a sample of the Pakistani population.

Material and methods. A cross-sectional study was conducted using the CBCT scans of patients. The SRP of each tooth (maxillary canine to canine) was evaluated in the sagittal section of a CBCT scan according to the classification by Kan et al. The LBT of each tooth was measured perpendicularly to the long axis of tooth at 3 sites: at the alveolar crest (P1); 2 mm from the alveolar crest (P2); and 4 mm from the alveolar crest (P3). Descriptive statistics were reported for SRP and LBT. The χ^2 test was employed to assess any association between the variables.

Results. Class I SRP was the most prevalent ($n = 196$, 81.7%), while Class III was the least frequent ($n = 1$, 0.4%). The association between the tooth type and SRP was statistically non-significant ($p = 0.510$).

Conclusions. In the evaluated sample of the Pakistani population, the most frequent type of the SRP of maxillary anterior teeth was Class I, which is most favorable for immediate implant placement. Furthermore, the labial bone in the maxillary esthetic zone was found to be mostly thin – LBT was within the range of 0.5–0.9 mm – which makes immediate implant placement in the anterior maxilla a challenge. The results of the present study could serve as a guide for clinicians in terms of appropriate patient selection for immediate implant placement in the maxillary esthetic zone.

Keywords: dental implants, cone-beam computed tomography, maxilla

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Introduction

Dental implants for the replacement of missing teeth have become an increasingly predictable treatment option due to its high rate of clinical success.[1] According to Brånemark's traditional protocol, 12 months are required for adequate bone healing and remodeling before any dental implant can be placed.[2] To overcome this prolonged treatment duration, immediate implant placement has been advocated.[3] The rehabilitation of missing anterior teeth with dental implants in the maxillary esthetic zone poses unique restorative challenges to the dentist. This is due to variability in esthetic outcomes.[4] The conventional approach of delayed implant placement entails the extraction of teeth and waiting for 4–6 months for bone healing.[5] This healing period eventually results in the collapse of soft and hard tissues, leading to a decrease in the tissue volume. To compensate for these deficits, various soft and hard tissue augmentation procedures are required to get a favorable functional and esthetic outcome.[6]

Contemporary literature favors immediate implant placement in the maxillary esthetic zone, as it preserves the existing soft and hard tissue volume.[7] It has many advantages over delayed implant placement, such as a reduction in surgical steps, the preservation of peri-implant soft and hard tissues, and better esthetic outcomes.[3] To achieve optimal esthetic outcomes, proper case selection for immediate implant placement is necessary, which is technically demanding.[1,8] There is a high probability (81%) of the perforation of the labial plate, which could adversely affect esthetic outcomes.[3] Several parameters need to be evaluated prior to immediate implant placement, such as the labial bone thickness (LBT), the root length (RL), the sagittal root position (SRP), the width of keratinized gingiva (WKG), and the gingival biotype.[7,9] Among these factors, SRP and LBT in relation to the surrounding alveolar bone have been shown to have a considerable effect on treatment outcomes.[10] Clinical guidelines recommend an adequate LBT of at least 2 mm to ensure successful treatment.[10,11] In the literature, it has been reported that the volume of the labial bone significantly varies with regard to the root position.[7,8,12] For successful immediate implant placement in the maxillary esthetic zone, the assessment of the root position is mandatory to reduce the risk of treatment failure, such as the perforation of the labial plate, bone dehiscence, etc.[3] A two-dimensional (2D) radiograph cannot provide sufficient information about the root position and the surrounding alveolar bone. Therefore, the use of three-dimensional (3D) imaging, e.g., cone-beam computed tomography (CBCT), is required for the assessment of SRP, LBT and other parameters.[3]

Kan et al. presented a classification for SRP.[7] In this classification, 4 classes are differentiated: Class I – the root is close to the labial cortical plate; Class II – the root is positioned in the middle of the alveolar bone, without nearing the labial or palatal cortical plates at the apical portion; Class III – the root is close to the palatal cortical plate; and Class IV – more than half of the root nears both the labial and palatal cortical plates.[7]

Several studies have evaluated SRP in relation to the alveolar bone.[3,7,11] Kan et al. reported that Class I SRP was the most common (81.1%), followed by Class IV (11.7%), Class II (6.5%), and Class III (0.7%).[7] Similarly, Shrestha et al. used the same classification, and reported that 94.9% of maxillary anterior teeth had Class I SRP, 2.4% had Class II, and 2.7% had Class IV, with no Class III observed.[11]

With the emerging scientific evidence regarding the success of immediately placed implants, the procedure has become the preferred treatment option for both patients and clinicians. To the best of our knowledge, no local study has ever addressed the issue of SRP or LBT in the population of Pakistan. Hence, it is imperative to assess these parameters in the Pakistani population to make proper decisions as to which patient is a candidate for immediate implant placement in the anterior maxilla. This will help clinicians offer predictable outcomes in cases of high esthetic demands. The aim of the present study was to evaluate the SRP and LBT of maxillary anterior teeth in the context of immediate implant placement by using CBCT in a sample of the Pakistani population.

Material and methods

This cross-sectional study was conducted at the Dental Clinics of Aga Khan University Hospital, Karachi, Pakistan, from July 2019 to September 2019. After obtaining an exemption from the institutional Ethical Review Committee (ERC No. 2019-1999-5234), the pre-existing CBCT scans of patients aged 18–60 years, stored in the hospital database, were reviewed. The CBCT scans of the patients having sound bilateral maxillary teeth (canine to canine), fully formed root apices, and with no radiographic evidence of the periapical infection or root resorption of the teeth were included. However, the CBCT scans of the patients who had a history of orthodontic treatment, teeth subjected to peri-apical surgery, alveolar bone deformities, or any pathology, such as a cyst or a trauma, affecting the anterior teeth, as well as distorted images that were not amenable for analysis, were excluded.

The sample size was calculated using a sample size calculator.[13] According to Kan et al., 81% of teeth were characterized by Class I SRP.[7] Keeping this value as an anticipated proportion with a 5% absolute precision and a 95% confidence interval (*CI*), we needed a sample of 237 teeth. As we had to evaluate 6 teeth on each CBCT scan, a total of 40 CBCT scans were needed in the present study.

The patients' demographics, i.e., age and gender, were retrieved using the medical record numbers. All CBCT

scans were obtained with the use of the Orthophos XG 3D Ready/CEPH unit (Dentsply Sirona, Charlotte, USA) operating at 60–90 kV, 3–6 mA, an image volume of 8 cm × 8 cm, a voxel size of 0.2 mm, a scanning time of 14 s, and an exposure time of 2–5 s. The images were saved using the Sidexis XG software, v. 2.63 (Dentsply Sirona). They were viewed using the implant software Galaxis/Galileos Implant Viewer (Dentsply Sirona) on a 27-inch IPS LED-backlit desktop monitor (HP EliteDisplay E271i; Hewlett-Packard, Palo Alto, USA) with a resolution of 1,920 × 1,080 at 60 Hz in a well-lit room. All measurements were taken once by the primary investigator (S.H.).

For the evaluation of SRP, we employed the Kan et al. classification,[7] as shown in Fig. 1 and Fig. 2. To determine the appropriate slice in the sagittal section, the slider tilt tool was used to alter the axial angulation of the image until the entire crown and root portion of the tooth was seen in the sagittal section. Once the appropriate slice was determined, the long axis of the tooth was established by drawing a straight line in the middle of the root. The root position was evaluated according to the classification mentioned above.

The labial bone thickness around each maxillary anterior tooth was measured at 3 points: at the alveolar crest level (P1); 2 mm from the alveolar crest (P2); and 4 mm from the alveolar crest (P3). The measurements were taken perpendicularly to the long axis of the tooth with the help of a measuring tool provided by the software. The SRP and LBT of each maxillary anterior tooth were noted down in the study proforma.

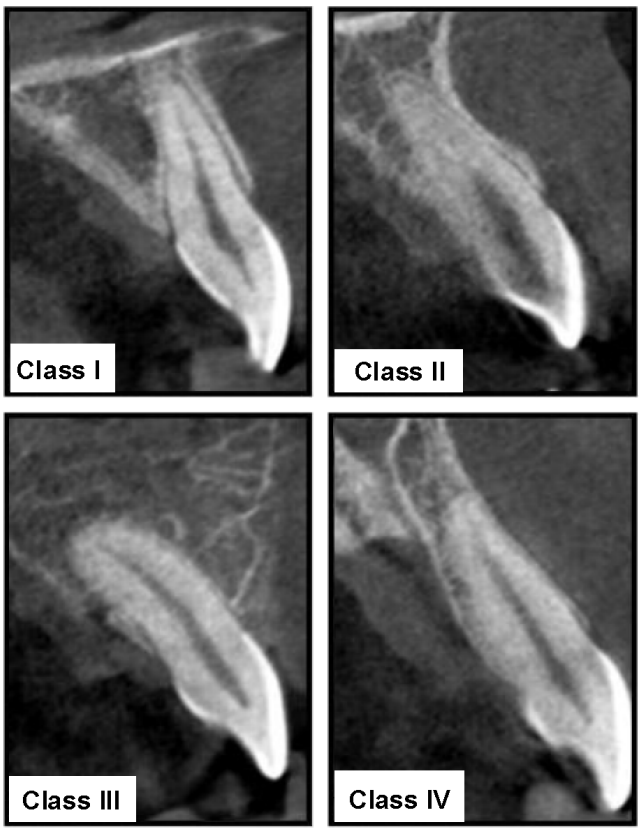

Fig. 1. Classification of the sagittal root position (SRP) of the teeth, as proposed by Kan et al.,[7] for determining the root position of maxillary anterior teeth in the sagittal plane of a cone-beam computed tomography (CBCT) scan

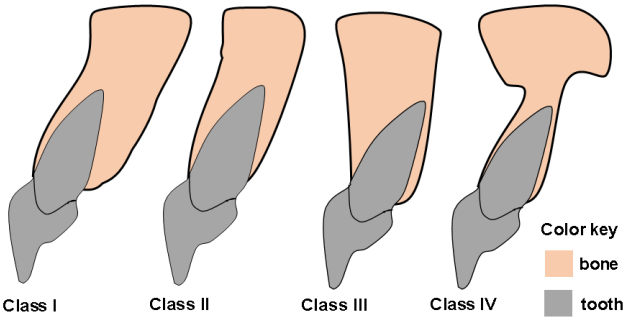

Fig. 2. Graphical presentation of the Kan et al. classification for the sagittal root position (SRP) of anterior teeth[7]

Statistical analysis

Statistical analysis was performed using the IBM SPSS Statistics for Windows software, v. 23.0 (IBM Corp., Armonk, USA). Descriptive statistics, i.e., mean and standard deviation ($M \pm SD$) for the continuous variables (age and LBT), and the frequency distribution (n (%)) for the categorical variable (SRP), were reported. The independent samples t test was applied to compare LBT in both genders and with regard to age. To determine any difference between the right and left sides, the paired samples t test was applied. The χ^2 test was used to establish the association between SRP and the tooth type. A p-value ≤0.05 was set as the level of significance. To assess the inter-examiner reliability, 10 CBCT scans were randomly selected and evaluated by the co-investigator independently. The inter-examiner reliability for the categorical variable SRP and the continuous variable LBT was assessed using Cohen's kappa coefficient (κ) and the intraclass correlation coefficient (ICC), respectively.

Results

A total of 240 maxillary anterior teeth were evaluated for SRP in a sample of the Pakistani population. The mean age of our sample was 30 ±11 years. Class I SRP was the most prevalent (81.7%), while Class III was the least frequent (0.4%). The frequency distribution of SRP is shown in Table 1. Among the tooth types, canines (n = 69/80, 86.3%) were the most frequent in Class I, followed by central incisors (n = 67/80, 83.8%) and lateral incisors (n = 60/80, 75.0%). The association between the tooth type and SRP was statistically non-significant (p = 0.510) (Table 1). The inter-examiner reliability κ statistical values for the categorical variable SRP ranged from 0.42 to 0.90. Similarly, no statistically significant differences in SRP were noted between the 2 age groups and genders.

Table 1. Frequency distribution of the sagittal root position (SRP) among the evaluated teeth of the study participants

SRP	Central incisors	Lateral incisors	Canines	Overall	*p*-value (χ^2 test)
Class I	67 (83.8)	60 (75.0)	69 (86.3)	196 (81.7)	
Class II	8 (10.0)	10 (12.5)	9 (11.3)	27 (11.3)	
Class III	0 (0.0)	1 (1.3)	0 (0.0)	1 (0.4)	0.510
Class IV	5 (6.3)	9 (11.3)	2 (2.5)	16 (6.7)	
Total	80 (100.0)	80 (100.0)	80 (100.0)	240 (100.0)	

Data presented as number (percentage) (*n* (%)).
The Kan et al. classification.[7]

The LBT of each maxillary anterior tooth was measured at 3 sites, i.e., at the alveolar crest level (P1), 2 mm from the alveolar crest (P2) and 4 mm from the alveolar crest (P3). The mean values of LBT are shown in Table 2. For the sake of clinical relevance, we divided the LBT values into 4 categories: <0.5 mm; 0.5–1 mm; 1–2 mm; and >2 mm. The distribution of teeth with regard to the LBT categories is shown in Table 3. The *ICC* values for the continuous variable LBT ranged from 0.67 to 0.94. Statistically significant differences were found between right and left central incisors, lateral incisors, and canines for LBT at all 3 levels.

Table 2. Descriptive statistics of the labial bone thickness (LBT) values [mm] among the evaluated teeth of the study participants

Position	Central incisors		Lateral incisors		Canines	
	right	left	right	left	right	left
P1	0.56 ±0.19	0.67 ±0.21	0.53 ±0.21	0.55 ±0.34	0.58 ±0.28	0.54 ±0.35
P2	0.81 ±0.34	0.89 ±0.32	0.90 ±0.72	0.88 ±0.80	0.89 ±0.54	0.76 ±0.57
P3	0.75 ±0.42	0.85 ±0.37	0.77 ±0.99	0.77 ±1.02	0.80 ±0.50	0.74 ±0.64

Data presented as mean ± standard deviation (*M* ±*SD*).
P1 – alveolar crest level; P2 – 2 mm from the alveolar crest; P3 – 4 mm from the alveolar crest.

Table 3. Distribution of teeth with regard to the labial bone thickness (LBT) categories among the study participants

Teeth	Position	LBT categories			
		<0.5 mm	0.5–1 mm	1–2 mm	>2 mm
Central incisors *n* = 80	P1	26	72	2	0
	P2	8	63	29	0
	P3	6	73	19	2
Lateral incisors *n* = 80	P1	36	59	5	0
	P2	23	39	36	2
	P3	38	43	17	2
Canines *n* = 80	P1	30	63	7	0
	P2	20	52	25	3
	P3	25	53	20	2

Data presented as percentages (%).

Discussion

Immediate implant placement in the maxillary esthetic zone poses its own distinctive challenges.[14] When planning immediate implant placement, a clinician should critically evaluate variables such as the 3D positioning of the root in the alveolar bone, LBT and RL. The results of the present study could serve as a guide for clinicians in terms of appropriate patient selection for immediate implant placement in the maxillary esthetic zone. In this CBCT-based study, we evaluated the SRP and LBT of maxillary anterior teeth in a sample of the Pakistani population. Our study results showed that Class I SRP was the most prevalent, accounting for 81.7% of maxillary anterior teeth. These results are in accordance with a previous study by Sung et al. conducted on the Taiwanese population[3] and research by Kan et al. conducted in the United States.[7] The authors of the abovementioned studies also reported the most prevalent SRP to be Class I, i.e., 87% and 81%, respectively. On the other hand, in the present study, the least common type of SRP was Class III, which was observed in 1 tooth (0.4%) only. Previous studies also reported that Class III SRP prevalence ranged from 0.3% to 0.7%.[3,7] Shrestha et al. reported that 94.9% of maxillary anterior teeth had Class I SRP, 2.4% had Class II, and 2.7% had Class IV, with no Class III observed.[11] However, Xu et al. observed in Chinese adults a higher proportion of buccal-type root positions (95.4%).[15] This may be due to the fact that they used different criteria for the assessment of the root position. Furthermore, no ethnic differences are noted with regard to SRP, as Class I tends to be the most prevalent root position in different ethnicities.

In Class I SRP, the root in its entire length is close to the labial cortical plate, which leaves an adequate amount of bone on the palatal aspect for implant engagement. Thus, it is considered to be one of the most favorable root positions for implant placement, as it spares the labial cortical plate. Moreover, placing an implant in the palatal direction creates a gap between the labial cortical plate and the implant surface called a jumping distance. This jumping distance in the maxillary esthetic zone is of utmost importance, as the labial cortical plate is trabecular and prone to resorption, which can potentially affect esthetic outcomes.[16] Clinical studies recommend placing the bone grafting material in the jumping distance when the distance is >2 mm.[17] On the contrary, Class IV SRP, which comprised 16 (6.7%) of the 240 teeth in our study, is considered a contraindication for immediate implant placement. In this configuration, the root is sandwiched between the 2 cortical plates, thus leaving a minimal amount of bone available for implant integration.[7] Complex hard tissue augmentation procedures are required to get a predictable outcome in such cases. A clinician should be aware of these different root positions and their implications in immediate implant dentistry, and modify the treatment plan accordingly.[18,19]

The labial bone thickness is a prognostic determinant with regard to the outcome of immediate implant therapy in the maxillary esthetic zone. A systematic review by Chen and Buser, comparing the esthetic results of immediate and early implant placement in the anterior maxilla, reported a high frequency of gingival recession in the immediate implant group.[4] The risk factors for gingival recession are bony defects in the labial bone wall, a thin labial cortical plate, a thin gingival biotype, and the labial-palatal malpositioning of the implant.[20] For predictable esthetic and functional outcomes, a minimum LBT of 2 mm is recommended.[21] In our study, the mean LBT for central incisors, lateral incisors and canines ranged from 0.5 mm to 0.9 mm, as shown in Table 2. These findings are in accordance with studies by El Nahass and Naiem,[9] Wang et al.,[1] and AlTarawneh et al.[22] From this, we can infer that a thin labial cortical plate is prevalent in the maxillary esthetic zone. The bone levels at P1 and P2 are crucial for determining the long-term stability of peri-implant soft tissue.[23] With the mean LBT ranging from 0.5 mm to 0.9 mm, the recession of peri-implant soft tissue is anticipated in the long run. This can drastically affect the esthetic outcomes of immediate implant therapy, which is of importance if the esthetic demands of patients are high.[23] Thus, soft and hard tissue augmentation is required in such cases to obtain optimal esthetic outcomes.[18,19] Furthermore, a thin labial bone also precludes the flapless approach for immediate implant placement due to the limited visualization of the underlying bony topography, which may result in the perforation of the facial bone wall.[24]

Cone-beam computed tomography is a common imaging modality used in pre-surgical planning and the visualization of anatomical structures.[11] However, a limitation to all CBCT-based studies is the resolution.[22] A better resolution gives an accurate measurement of the anatomical structures of the area of interest. The resolution of a CBCT scan is inversely proportional to the field of view (FoV). The smaller the FoV, the better the resolution of a CBCT image.[22,25] The CBCT unit used in this study had a medium FoV. The scans were not taken with the aim of using them in the present study; in fact, they were retrieved from the archives of the departmental database.

The present study is the first-ever investigation done on SRP and LBT in the context of immediate implant placement among a sample of the Pakistani population. Longitudinal studies are warranted to establish a temporal relationship between clinical variables and the outcomes of immediate implant therapy in the anterior maxilla.

Limitations

This study was conducted in a single center, which is a potential limitation. The scans included in our study were already stored in the departmental database. The study results can only be generalized to the patients who visited the university hospital, and thus may not be representative of the general population.

Conclusions

Within the limitations of the present study, it is inferred that the most prevalent SRP among the Pakistani subpopulation is Class I, which is favorable for immediate implant placement. However, LBT in the maxillary anterior esthetic zone was in the range of 0.5–0.9 mm, which makes the placement of an immediate implant in the anterior maxilla a challenge.

Ethics approval and consent to participate

Not applicable (an exemption from the institutional Ethical Review Committee at Aga Khan University Hospital, Karachi, Pakistan (ERC No. 2019-1999-5234)).

Data availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Consent for publication

Not applicable.

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