

Jordan Journal of Dentistry

<https://jjd.just.edu.jo>

Periodontal Phenotype, Sagittal Root Position and Buccal Bone Thickness in Maxillary Anterior Teeth: A Clinical and Tomographic Cross-Sectional Study

Noor Mohammad Mustafa¹, Reem Sami Abdelhafez^{1*}, Yousef S. Khader², Khalid A. Kheirallah²

1 Department of Preventive Dentistry, Jordan University of Science and Technology, Irbid, Jordan.

2 Department of Public Health, Jordan University of Science and Technology, Irbid, Jordan.

ARTICLE INFO

Article History:

Received: 26/1/2026

Accepted: 30/6/2026

Correspondence:

Reem S. Abdelhafez,
Department of Preventive
Dentistry, Jordan University of
Science and Technology, Irbid,
Jordan.

rsabdelhafez@just.edu.jo

ABSTRACT

Objectives: To study the soft and hard tissue anatomy in the maxillary anterior area and to assess the relationship between sagittal root position (SRP) and periodontal phenotype and between the thickness of the facial bone and the gingival thickness (GT).

Materials and Methods: Seventy-five subjects (450 teeth) were enrolled. The clinical examination included the crown width/ length ratio, gingival width, papilla height, GT, and evaluation of gingival phenotype by transparency of the periodontal probe. The radiographic assessment, using soft-tissue tomographic scans, included the GT, thickness of buccal alveolar bone and SRP of the maxillary six anterior teeth.

Results: The frequency distribution of SRP classes among Jordanians was 87.3% Class I, 6.9% Class II, 0.0% Class III and 5.8% Class IV. The SRP was not found to be related to the different components of the periodontal phenotype. A positive correlation was found between bone and GT at all levels ($P < 0.001$) and 78% of all the examined sites showed labial plate thickness $< 1\text{mm}$.

Conclusions: Within the limitations of this study, and among the population examined, the SRP of the maxillary anterior teeth was not related to the periodontal phenotype. Yet, the bone and GT were positively correlated. Most Jordanians have a thin bone morphotype.

Keywords: Periodontal phenotype, Sagittal root position, Bone thickness, Gingival thickness.

1. Introduction

The advantages of immediate implant placement include reduced number of surgical procedures, a reduced overall treatment time, an optimal availability of existing bone and the convenience of an immediate tooth replacement (1). Nevertheless, immediate placement should be approached with caution (2,3), as thin tissue phenotype may compromise the optimal outcome (4). Therefore, detailed clinical and radiographic planning is important to ensure the presence of intact socket walls, facial bone at least 1mm in thickness, thick soft tissues and the availability of bone apical and palatal to the socket to provide primary

implant stability (5). The gingival phenotype attracted much attention lately, as thick gingival phenotype has been reported to improve the aesthetic outcome of implants (6) and to provide stability of the inter dental papilla after immediate implant insertion (7).

The consensus report of workgroup 3 of the 2017 World Workshop strongly supports the adoption of the term periodontal phenotype to describe the combination of gingival phenotype (three-dimensional gingival volume; GT and keratinized tissue width) and the thickness of the buccal bone plate (bone morphotype) (8). Several studies investigated the relationship between the gingival phenotype and the buccal plate

bone thickness with conflicting results (9). Most of these studies used the older definitions of periodontal phenotype and most used periodontal probe transparency as the only method to determine gingival thickness (10-13).

A study by Kan et al., involving Cone Beam Computed Tomography (CBCT), classified the sagittal root position (SRP) with respect to the anterior maxillary osseous housing to aid in treatment planning for immediate implant placement (14). Four classes were suggested, and it was concluded that Class I is more favorable for immediate implant placement while Class IV was considered a contraindication. The other two classes (Class II and Class III) were described as technique sensitive (14). Different prevalence rates of SRP classes among Korean, Caucasian and Brazilian populations have been reported (14-16). This might be attributed to differences in arch form and soft-tissue profiles among different populations (17-19). It is worth noting that the designation of SRP classes was independent of both labial plate thickness and gingival phenotype which have been demonstrated to affect the success of immediate implant placement (4). The correlation between buccal bone thickness and periodontal phenotype in the maxillary anterior region was investigated by Khoury et al. and a positive correlation was concluded (20). However, the direct association between periodontal phenotype and sagittal root position wasn't reported and the definition of periodontal phenotype was limited to thickness of gingiva with no other factors taken into consideration.

Understanding the relationship between periodontal phenotype and SRP would improve the clinician ability in treatment planning, identify cases best suited for immediate implant placement, and increase emphasis on pretreatment phenotype consideration along with the presence of bone anatomy favoring the achievement of good primary stability. To the best of our knowledge, only one study looked at and reported a relationship between the periodontal phenotype (in its most recent definition) and the sagittal root position in a Brazilian population (16). Thus, further investigation of the relationship using recent definitions and techniques in different populations is of great importance.

This study aimed to assess the soft-and hard- tissue anatomy in the maxillary anterior area and to evaluate the relationship between periodontal phenotype and SRP and between the gingival and facial bone thickness.

In addition, it aimed to verify the site specificity of the periodontal phenotype

2. Material and Methods

2.1 Study Design and Participants

A cross-sectional study was conducted at Jordan University of Science and Technology (JUST) dental teaching clinics. Patients attending the clinics and needing a Cone Beam Computed Tomography (CBCT) scan were initially interviewed by a trained examiner, and a questionnaire was completed to decide on their eligibility. Those who met the inclusion criteria and agreed to participate in the study underwent a clinical examination followed by referral to a dental imaging center. The need for CBCT imaging was due to several reasons (implant treatment planning purposes, problematic endodontic anatomy, etc...). The minimum sample size needed to detect a small effect size for the association between periodontal phenotype and SRP at a level significance of 0.05 and power of 80% was calculated at 62 teeth. All participants signed an informed consent following detailed explanation of the study. The study was approved by the Institutional Review Board (IRB) of JUST (2020/136/27).

2.2 Inclusion and Exclusion Criteria

The inclusion criteria were patients 1) aged 18 years or older, 2) with at least 20 natural teeth, 3) with intact anterior maxillary teeth, and 4) signing a written consent. The exclusion criteria were 1) history or present signs of periodontal disease, 2) systemic conditions or diseases that have gingival manifestations and/or influence the bone metabolism, 3) intake of medications that are known to cause gingival overgrowth 4) pregnant and lactating women, 5) previous or current orthodontic treatment, 6) crowding in the anterior maxilla, 7) mucogingival deformities and conditions, such as clear cases of altered passive eruption (presence of pseudopockets, crown width/crown length 100%) and gingival recession in the anterior maxilla, 8) restorations in the anterior maxilla, and 9) history of trauma to the anterior maxilla.

2.3 Clinical Examination

The anterior maxillary teeth were examined for plaque index (PI) (21), probing pocket depth (PPD) and bleeding on probing (BOP). The parameters were measured at 6 sites per tooth (mesio-buccal, mid-buccal,

disto-buccal, mesiolingual, mid-lingual and disto-lingual). All the participants were examined on the dental chair in a semi-supine position by a single trained examiner using University of North Carolina-15 (UNC-15) periodontal probe.

Clinical examination included assessment of:

- 1) Crown width/crown length ratio (CW/CL): alginate impression (Cavex Cream alginate/fast set) of the upper jaw was taken then poured within 15 minutes in type 4 Dental stone (die stone; high strength, low expansion). Each cast was scanned with intra-oral

scanner (Carestream CS 3600) and magnified on a screen by a special 3D Modeling software (Mesh Mixer) (Figure 1). The measurements were taken according to Olsson and Lindhe (1991) (22). CW/CL ratio was calculated to the nearest 0.01 mm. CW/CL ratio ≥ 0.8 was defined as a square-shaped tooth and <0.8 as a triangular-shaped tooth. Means (SD) of CW/CL ratios for direct intra-oral scan and die stone cast scan were compared in a pilot study of 7 participants (42 teeth).

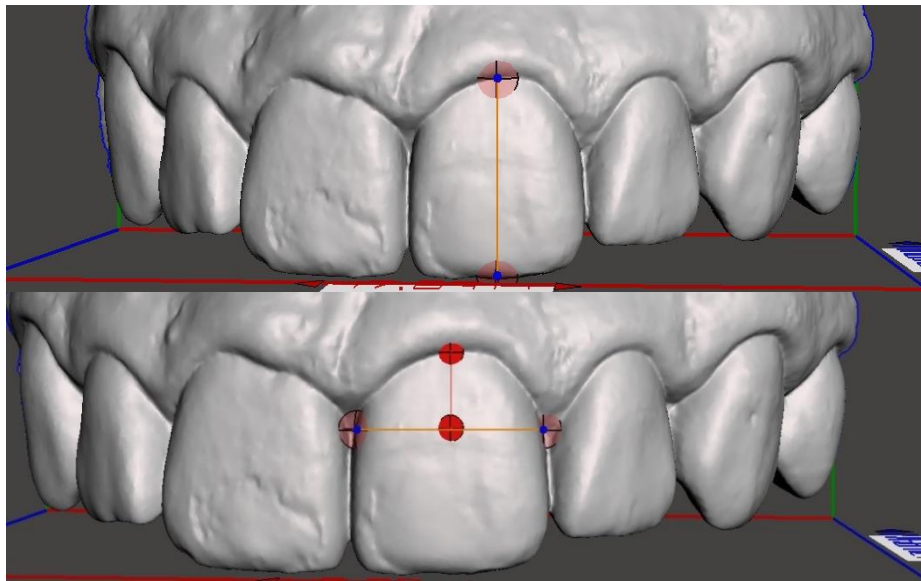


Figure 1: Measurement of crown length and width by a special 3D modeling software (Mesh Mixer)

- 2) Gingival width (GW): measured clinically at the midfacial aspect using UNC-15 probe and was defined as the distance from the free gingival margin to the mucogingival junction (Figure 2, A). The mucogingival junction was determined using “The pushing technique” (23). Gingival width ≥ 5 mm was defined as wide zone of keratinized gingiva and < 5 mm as narrow zone of keratinized gingiva (24).
- 3) Papilla height (PH): measured using (UNC-15) periodontal probe at the mesial and distal aspects of the maxillary anterior teeth (Figure 2, C). It was defined as the distance from the tip of the papilla to a line connecting the midfacial soft tissue margin of the two adjacent teeth (25). The average value for the mesial and distal papillae for each tooth was recorded as the papilla height for that tooth. PH $\leq$

3mm was defined as short PH and ≥ 3.5 mm as long PH (26).

- 4) Gingival thickness (GT) was categorized into thick or thin at tooth level. The evaluation was based on the transparency of UNC- 15 probe through the gingival margin at the midfacial aspect of maxillary anterior teeth (27) (Figure 2, B). If the probe was visible, it was categorized as thin and if not, it was categorized as thick.

2.4 CBCT Imaging

Standardized CBCT images were taken for all subjects using Care Stream (CS 8100 3D) device with the following technical specifications: Tube voltage: 90 kV, Tube current: 4 mA, Exposure time: 15 seconds, Voxel size: 150 μ m, Field of view: 8*9 cm.

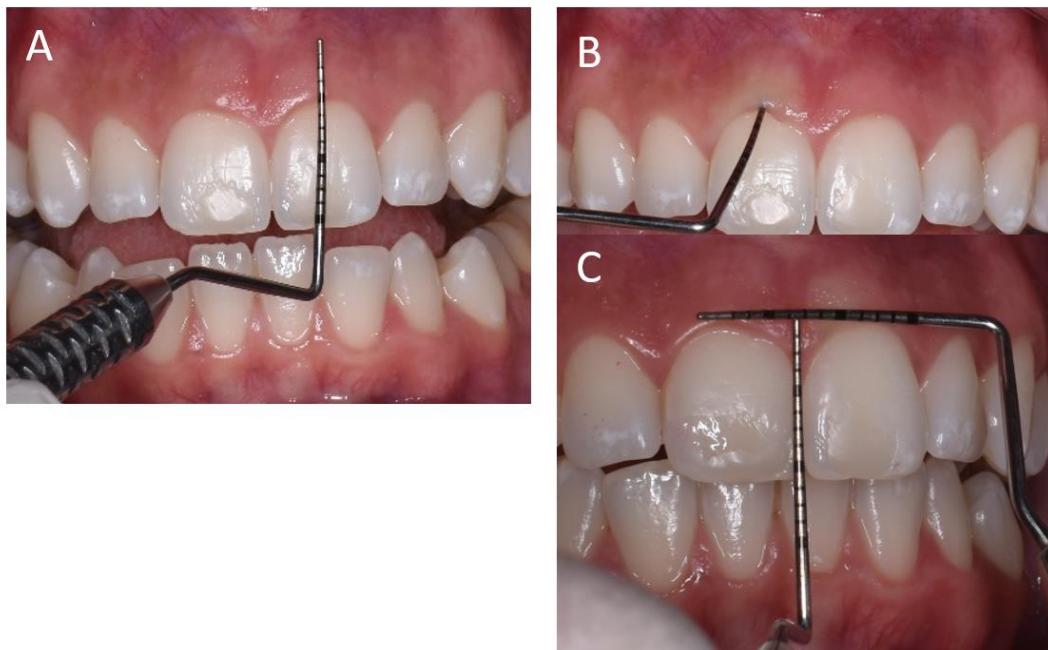


Figure 2: A. Measurement of the width of keratinized gingiva clinically using UNC-15 periodontal probe. B. Evaluation of gingival thickness through the transparency of UNC- 15 periodontal probe through the gingival sulcus. C. Measurement of the papilla height between maxillary central incisors using UNC-15 periodontal probe

Images were displayed on Care-Stream 3D imaging software with the largest possible zoom, appropriate contrast, and brightness on a 32 flat panel screen (HP Pavilion x360 Convertible 14-dh with Intel(R) Core (TM) i3-8145U CPU) with a 1920 × 1080-pixel resolution and 6-bit depth. The arch form selector tool was centered through the middle of the arch in the axial plane. All CBCT scans were viewed in the sagittal position demonstrating the entire length of the root from the cementoenamel junction to the apex, along with the supporting bone and soft tissue. All measures were rounded to the nearest 0.1 mm.

Double cotton rolls were applied on each side of the examined area to prevent the lips and cheeks from collapsing on the facial gingiva. On the panoramic view, the center of the root of each examined tooth was designated at an angle parallel to its long axis, then the following measurements were taken at the sagittal view perpendicular to the long axis of the tooth by a single trained practitioner.

- 1) The SRP of the maxillary six anterior teeth according to the classification of Kan et al., 2011 (14) (Figure 3). In Class I, the root is against the labial bone plate, Class II is when the root is centered in the alveolus and not touching the cortical plates. In Class III, the

root is against the palatal plate and in Class IV, at least 2/3 of the root is engaging both plates. When difficulty was encountered in assigning the SRP class by the first examiner due to inherent grey zones in the classification, a second experienced examiner was invited, and discussion was made to reach a final decision.

- 2) The thickness of buccal alveolar bone of the maxillary six anterior teeth at 1, 3 and 5mm from the crest of the alveolar bone (Figure 4, A). A cut-off point of 1 mm ($< 1\text{mm}$ thin and $\geq 1\text{mm}$ thick) was used to classify the BT.
- 3) The thickness of the gingiva of the maxillary six anterior teeth at 1, 3 and 5mm from the gingival margin (Figure 4, B). A cutting point of 1 mm ($\leq 1\text{mm}$ thin and $> 1\text{mm}$ thick) was used to classify the GT.

The periodontal phenotype was categorized into either thin or thick. Thin phenotype was characterized by the following features: BT $< 1\text{mm}$ at 1mm apical to the alveolar crest, gingival width $< 5\text{mm}$ and GT $\leq 1\text{mm}$ at 1mm apical to the gingival margin on CBCT. Thick phenotype was characterized by BT $\geq 1\text{mm}$ at 1mm apical to the alveolar crest, gingival width $\geq 5\text{mm}$ and GT $> 1\text{mm}$ at 1mm apical to the gingival margin on

CBCT. Only if all three variables required are present, a thick phenotype is designated, otherwise it will be

classified as thin

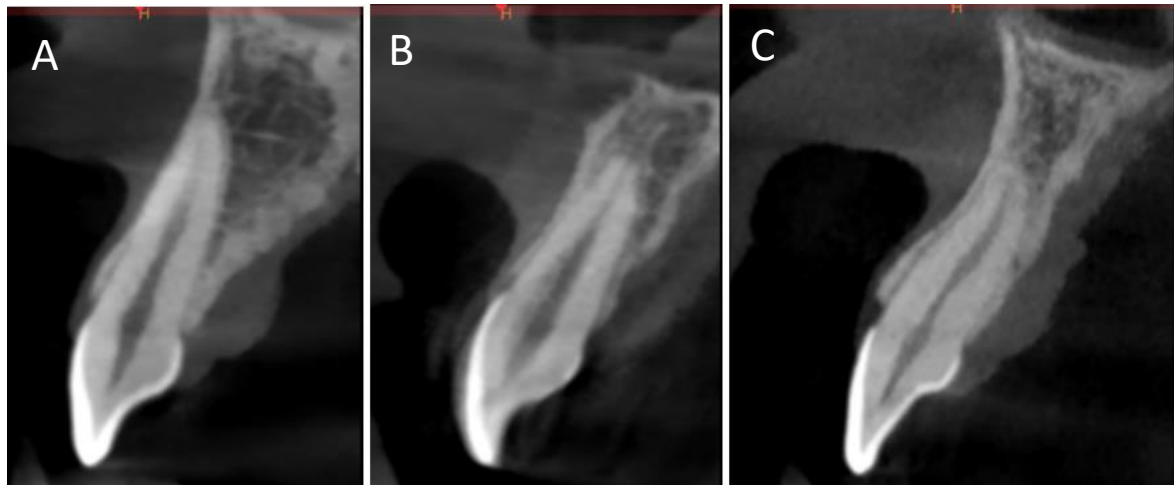


Figure 3: SRP classes. A: Class I. B: Class II. C: Class IV

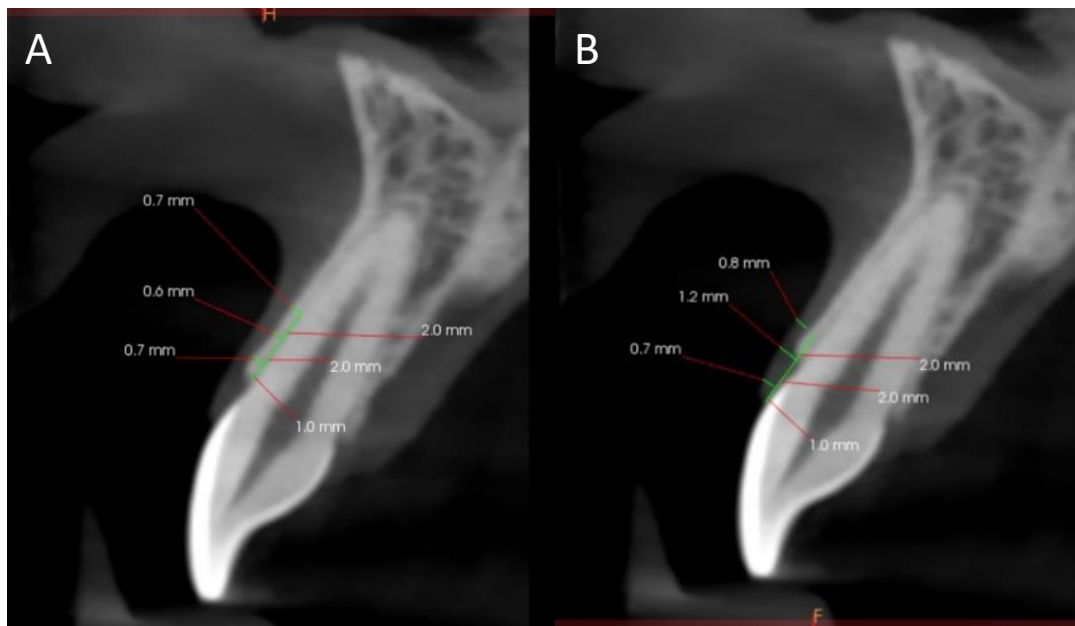


Figure 4: A. Measurement of the thickness of buccal alveolar bone at 1, 3 and 5mm from the crest of the alveolar bone. B. Measurement of the thickness of the gingiva at 1, 3 and 5mm from the gingival margin

2.5 Statistical Analysis

Data was entered into EXCEL sheet and then exported into the IBM SPSS software, version 24. The Shapiro-Wilk test was performed to evaluate the normality of the data. Accordingly, descriptive statistics were presented using percentages and means (SD). T-test was used to compare mean values of the two groups, One-way ANOVA was used to compare mean values for periodontal phenotype parameters according to tooth

type, Chi-square test was used to compare proportions. Pearson's correlation coefficient was used to quantify the correlation of CW/CL ratios for direct intra-oral scan and die stone cast scan. Cluster analysis was performed to identify two main clusters using a k-mean algorithm to reduce the within-group sum of squares. Variables included in the cluster analysis were gingival and bone BT and keratinized tissue width. Alpha level of 0.05 was used for all statistical comparisons.

3. Results

3.1 Sample Characteristics

Based on the eligibility criteria, 100 patients were recruited. Twenty-five patients were excluded due to lack of periodontal health, poor oral hygiene and restorative treatment of maxillary anterior teeth. A total sample of 450 maxillary anterior teeth were distributed as 150 canines, 150 lateral incisors and 150 central incisors from 75 patients. Participants' age ranged between 18 and 59 years (mean of 25.8 ± 8.2). More than a half (57.3%) of patients were males. Almost half (53.3%) of the participants reported smoking cigarettes and/or waterpipe with variable quantities and frequencies. All participants had good oral hygiene; the mean plaque index was 0.59 and BOP was less than 10% with a mean of 5.7% of sites.

3.2 Periodontal Phenotype Clusters

Two groups were identified. Thin phenotype (407 teeth (146 canine, 132 lateral and 129 central)) and thick phenotype (43 teeth (4 canine, 18 lateral and 21 central)). The majority (90.4%) of the teeth displayed thin phenotype while 9.6% displayed a thick one with a statistically significant difference between phenotypes by tooth type ($p < 0.001$). Of the 75 patients examined, 19 (25%) of them displayed both periodontal phenotypes within their examined teeth.

The mean values for periodontal phenotype parameters according to tooth type are shown in Table 1. A statistically significant difference was found between teeth for all parameters ($P < 0.001$ for all statistical tests). The central incisor recorded the highest CW/CL ratio and interdental papilla height whereas the lateral incisor recorded the highest gingival width.

Table 1: Mean values of CW/CL ratio, gingival width, and papilla height by tooth type (N=150)

		Mean	Std. Deviation	95% Confidence Interval for Mean		Min.	Max.	p-value
				Lower Bound	Upper Bound			
CW/CL Ratio	Canine	0.79	0.11	0.77	0.80	0.54	1.20	<0.001
	Lateral	0.75	0.10	0.73	0.76	0.51	1.05	
	Central	0.83	0.10	0.82	0.85	0.61	1.20	
	Total	0.79	0.11	0.78	0.80	0.51	1.20	
Gingival Width	Canine	5.35	1.41	5.12	5.57	2.00	10.00	<0.001
	Lateral	6.20	1.39	5.98	6.42	3.00	11.00	
	Central	5.31	1.23	5.11	5.51	2.00	10.00	
	Total	5.62	1.40	5.49	5.75	2.00	11.00	
Papillary Height	Canine	3.24	0.72	3.12	3.36	1.50	5.50	<0.001
	Lateral	3.00	0.72	2.89	3.12	1.00	5.00	
	Central	3.43	0.90	3.29	3.58	1.00	6.00	
	Total	3.23	0.80	3.15	3.30	1.00	6.00	

3.3 Sagittal Root Position (SRP)

A total of 450 images were evaluated. The SRP class was difficult to assign by the first examiner in 86 teeth (19%), these were distributed as follows: 10 canines, 52 laterals and 24 centrals. The frequency distribution of SRP classes along with tooth type is shown in Table 2. Of the sites examined 393 (87.3%) were Class I, 31 (6.9%) were Class II, 0 (0.0%) were Class III and 26 (5.8%) were Class IV. Canines exhibited the highest frequency of class I (99.3%) while lateral incisors presented the highest frequency of class II (13.3%) and class IV (12%). It is noteworthy that 43 (57%) of the 75

participants exhibited the same SRP class for all their 6 examined teeth, while 32 (43%) of them had several SRP classes.

3.4 Periodontal Phenotype – SRP Relationship

No statistically significant relationship was found between periodontal phenotype and SRP. The individual relationship between SRP and each component of periodontal phenotype was also investigated. There was no statistically significant relationship between width of keratinized gingiva and SRP of all teeth. When each group of teeth (centrals, laterals, and canines) was

investigated separately, central incisors with Class-II SRP showed less amount of keratinized gingiva in

comparison with Class I ($P = 0.055$) and Class IV ($P < 0.05$).

Table 2: Frequency distribution of SRP classification percentage (no.)

SRP	Central incisor	Lateral incisor	Canine	Overall
Class I	88 (132)	74.7 (112)	99.3 (149)	87.3 (393)
Class II	7.3 (11)	13.3 (20)	0 (0)	6.9 (31)
Class III	0 (0)	0 (0)	0 (0)	0 (0)
Class IV	4.7 (7)	12 (18)	0.67 (1)	5.8 (26)
Total	100 (150)	100 (150)	100 (150)	100 (450)

Tooth shape was associated with SRP. Classes I, II, and IV presented triangular shaped teeth (CW/CL ratio < 0.8) in 52%, 74%, and 58% of the samples, respectively. Square-shaped teeth (CW/CL ratio ≥ 0.8) were found in 48% of class I, 26% of class II, and 42% of class IV.

Moreover, there was no significant association between the height of the interdental papilla, and the SRP of all teeth and each group of teeth (centrals, laterals, and canines).

Generally, the mean buccal BT was smaller at Class I and Class IV teeth and greater in Class II teeth at all bone levels; however, this was not statistically significant ($P > 0.05$).

There was no association between GT evaluated by transparency of the periodontal probe or

radiographically and SRP classes at any gingival level. When each group of teeth (centrals, laterals, and canines) was investigated separately, central incisors with Class II SRP had a lower mean GT than Class I ($P < 0.001$) and Class IV ($P < 0.05$) at 3 mm apical to the gingival margin level. No statistically significant differences were found at any other levels or at lateral incisors and canines.

3.5 Tomographic Bone and GT

The mean BT at 1, 3, and 5mm position was $0.831 \pm 0.2676\text{mm}$, $0.823 \pm 0.3758\text{mm}$, and $0.691 \pm 0.3518\text{mm}$, respectively. Of all the examined sites, 78% showed labial plate thickness $< 1\text{mm}$ (Table 3).

Table 3: The frequency and percentage of sites with bone thickness $< 1\text{mm}$ at different bone levels

Variable	Frequency	Percent
Bone thickness at 1mm level		
$< 1\text{mm}$	334	74.2
$\geq 1\text{mm}$	116	25.8
Total	450	100
Bone thickness at 3mm level		
$< 1\text{mm}$	337	74.9
$\geq 1\text{mm}$	113	25.1
Total	450	100
Bone thickness at 5mm level		
$< 1\text{mm}$	379	84.2
$\geq 1\text{mm}$	71	15.8
Total	450	100

Likewise, the CBCT mean GT at 1, 3 and 5mm from

the gingival margin was $0.949 \pm 0.2102\text{ mm}$,

1.310±0.3985mm, and 0.801±0.3773mm, respectively. A statistically significant positive correlation was found between bone and GT at any of the 3 positions (crestal, mid, or apical) ($P < 0.001$).

Significant differences in the mean GT of the maxillary canine 0.874±0.1880mm, lateral 0.933±0.1941mm and central incisors 1.039±0.2148mm at 1 mm apical to the gingival margin were detected ($P<0.001$) with the GT of the central incisor being significantly higher than that for the canine and lateral incisor ($p<0.001$ for both). The GT increased at the 3 mm level for all teeth ($p<0.001$). The mean GT of the central incisor 1.509±0.3315mm was significantly higher than that of the lateral incisor 1.301±0.3369mm which was also significantly higher than that of the canine 1.120±0.4230mm ($p<0.001$ for both). At 5 mm apical to gingival margin, the GT tended to decrease for all teeth ($p<0.001$). The GT of the canine (0.605mm)

was significantly lower than central (0.903mm) and lateral incisors (0.895mm) ($p<0.001$ for both).

Significant differences in the mean BT of the maxillary canine 0.779±0.2868, lateral 0.887±0.2996mm and central incisors 0.827±0.1948mm at 1 mm apical to the alveolar crest were detected ($P<0.05$) with the mean BT of lateral incisor higher than the canine ($P< 0.001$) and central incisor ($P=0.122$). At 3 mm level, mean BT of the canine (0.731mm) was lower than that of the lateral incisor (0.889mm) and central incisor (0.849mm) ($P<0.001$ and $P<0.05$ respectively). At 5 mm apical to the alveolar crest, the mean BT of the maxillary canine, lateral and central incisors was 0.609, 0.675 and 0.789 mm, respectively. The mean BT of central incisor was significantly higher than that of the canine ($p<0.001$) and lateral incisor ($p<0.05$) (Table 4).

Table 4: CBCT gingival and bone thickness readings at different levels

		N	Mean	Std. Deviation	95% Confidence Interval for Mean		Minimum	Maximum	p-value
					Lower Bound	Upper Bound			
Gingival thickness 1mm	Canine	150	0.87	0.19	0.84	0.90	0.50	1.70	<0.001
	Lateral	150	0.93	0.19	0.90	0.97	0.40	1.50	
	Central	150	1.04	0.21	1.00	1.07	0.60	2.10	
	Total	450	0.95	0.21	0.93	0.97	0.40	2.10	
Gingival thickness 3mm	Canine	150	1.12	0.42	1.05	1.19	0.30	2.10	<0.001
	Lateral	150	1.30	0.34	1.25	1.36	0.30	3.00	
	Central	150	1.51	0.33	1.46	1.56	0.60	2.40	
	Total	450	1.31	0.40	1.27	1.35	0.30	3.00	
Gingival thickness 5mm	Canine	150	0.61	0.29	0.56	0.65	0.10	1.60	<0.001
	Lateral	150	0.90	0.41	0.83	0.96	0.30	2.60	
	Central	150	0.90	0.35	0.85	0.96	0.40	2.40	
	Total	450	0.80	0.38	0.77	0.84	0.10	2.60	
Bone thickness 1mm	Canine	150	0.78	0.29	0.73	0.83	0.40	1.90	0.002
	Lateral	150	0.89	0.30	0.84	0.94	0.40	2.20	
	Central	150	0.83	0.19	0.80	0.86	0.50	1.50	
	Total	450	0.83	0.27	0.81	0.86	0.40	2.20	
Bone thickness 3mm	Canine	150	0.73	0.36	0.67	0.79	0.00	2.10	0.001
	Lateral	150	0.89	0.45	0.82	0.96	0.00	2.70	
	Central	150	0.85	0.28	0.80	0.89	0.40	2.20	
	Total	450	0.82	0.38	0.79	0.86	0.00	2.70	
Bone thickness 5mm	Canine	150	0.61	0.33	0.56	0.66	0.00	2.60	<0.001
	Lateral	150	0.68	0.41	0.61	0.74	0.00	3.30	
	Central	150	0.79	0.28	0.74	0.83	0.30	2.20	
	Total	450	0.69	0.35	0.66	0.72	0.00	3.30	

The effect of gender and smoking was also investigated; the labial plate thickness in smokers was

significantly higher than in non-smokers at all levels ($P< 0.05$). Regarding GT, there was no statistically

significant difference between smokers and non-smokers at all levels. Males recorded higher measures of gingival and BT at all levels; however, this was not statistically significant. Higher papilla levels and lower CW/CL ratio values were found in males ($P < 0.05$) while higher gingival width values were recorded in females ($P < 0.05$).

4. Discussion

In this study, Class I SRP recorded the highest percentage in this sample (87.3%). In contrast, Class III SRP wasn't found (0%), emphasizing the rarity of this type. This is in accordance with the results reported by Kan, Khoury et al., in which Class I recorded the highest frequency, and Class III the lowest (14,20). In addition, Lau and co-workers reported that most of the central incisors (78.8%) were buccal within the alveolar bone and only 1.8% were palatal (28).

Class II SRP recorded a frequency of 6.9%, which is close to that reported by Kan et al. (6.5%) and Khoury et al. (7.1%) (14,20). Only 5.8% of the study samples were Class IV SRP, in contrast to the 11.7% reported by Kan et al. (2011) (14) and the 8.5% reported by Khoury et al. (2016) (20). This could be explained by different populations and different age and sex distributions among the samples.

The decision to place immediate implants is not limited to SRP only, but also affected by other factors, such as periodontal phenotype (29). The periodontal phenotype was determined by assessing the labial BT, GT, and gingival width measured on tooth level, not on patient level. Cluster analysis was applied to join teeth of similar features into respective categories. Two groups were identified: cluster A and cluster B. Thin phenotype was identified in 90.4% of the teeth (cluster A) while 9.6% displayed a thick one (cluster B) with a statistically significant difference between phenotypes for each tooth type ($p < 0.001$). The methodological differences with other studies and the fact that this study chose three factors including labial plate thickness ≥ 1 mm to identify thick periodontal phenotype is the reason behind its low percentage. This is in accordance with the studies that clearly stated that a high percentage of patients have a facial bone plate of the teeth in the anterior maxilla that is either missing or thin (70 % in Nikiforidou et al., 2016 and 90% in Braut et al., 2011) (30,31). A similar conclusion was also reported by Januario et al., 2011 and Vera et al., 2012 (32,33).

No association was detected between GT (evaluated by the two methods) and SRP classes at any gingival level, a result that was also reported by Rodrigues et al. at the bone zone, but not at the tissue zone where the gingiva presented the highest thickness in Class II and the lowest in class I (16). In the current study, Class I at the level of 5mm apical to gingival margin (bone zone) also recorded the lowest thickness in comparison with other classes; however, this was not statistically significant.

The different SRP classes were found to be related to the width of keratinized tissue; however, this was only significant in central incisors. Central incisors with Class IV SRP had higher amount of keratinized tissue in comparison with Class II ($P < 0.05$) and Class I ($P = 0.196$). This is consistent with what was reported by Rodrigues et al. (16).

Another significant component of periodontal phenotype is the interdental papilla. Kolte et al. measured the mesial and distal interdental papilla heights in the maxillary anterior teeth, which were 3.85mm and 3.9mm, respectively (34). In this study, the overall mean of interdental papilla height was 3.2mm. The SRP did not affect the papilla height in our study, unlike the 1mm higher papilla levels reported in Class IV compared to class I by Rodrigues et al. (16).

Rodrigues et al. found a mean CW/CL ratio of 0.81 ± 0.13 (16), while 0.85 ± 0.08 ratio was found by Sterret et al. (1999) (35). In this study, the mean CW/CL ratio was 0.79 ± 0.11 . A high percentage of triangular shaped teeth (74%) was found in Class II SRP, while the other SRP classes I and IV were almost equally distributed between triangular and square shapes. This association is of clinical value for clinicians in decision making when considering the timing of implant placement by providing an initial visual clue to the possible SRP. In the study by Rodrigues et al. a high percentage (89%) of triangular shaped teeth was found in class IV and square shaped central incisors (70%) were found in class I (16).

Gingival thickness was measured at different levels on CBCT scan (1,3,5 mm apical to the gingival margin). The GT increased significantly from the 1mm level (0.949mm) towards the 3mm level (1.310mm), whereas at the 5mm level, it was notably smaller (0.801mm). This was in line with other studies (36,37,30). Minor differences might be found due to the different techniques used to measure GT. Assessing each tooth

type separately, the results were comparable to those of Muller and Eger (38).

The BT decreased slightly from the 1mm level (0.831mm) to the 3mm level (0.823mm), then notably at the 5mm level (0.691mm). This is in accordance with previous studies (39,31,40). Studying each tooth type separately, the values of this study were slightly higher than what was reported by Januário et al. on a population of 250 patients (32). It should be noted that the lateral incisor recorded the highest BT in both studies. The differences in the stated values can be explained by the diversity in the study sample, in the parameters of scanning and tomographic characteristics. Of all the examined sites, 78% showed labial plate thickness < 1mm. Despite the methodological differences, similar results have been found in most of the studies (30-33). The thickness of the bundle bone which is a tooth-dependent structure that resorbs following tooth extraction or loss is around 0.2-0.4 mm (41); this means that the bundle bone and facial bone wall of maxillary anterior teeth generally share a similar thickness. The ITI Consensus Conference recommended at least 1mm facial bone thickness when considering immediate implant placement (29). It seems, considering the previous information, that this is rarely encountered, emphasizing the need for bone augmentation procedures, or alternative timing of implant placement.

In the current study, there was a statistically significant positive correlation between bone and GT at any of the 3 positions (crestal, mid, or apical) ($P < 0.001$). Nevertheless, it was found to be a mild correlation at the crestal level (Pearson Correlation=0.191) and a moderate one at the mid and apical levels (Pearson Correlation=0.435, 0.396, respectively). These results were consistent with the results of Stein et al. and Fu et al. (37,39,42). Moreover, Cook et al. and Amid et al. found that thin phenotype was associated with a thinner labial plate thickness (43,44). On the other hand, no association between bone and GT was found in La Rocca et al.'s study; in their study, GT was measured by transgingival probing and BT was measured directly on CBCT scan (36). Similarly, a study by Kim et al. did not find any correlation between bone and GT at any depth level; in

this study, BT was measured on CBCT scan, and GT using an optical scanner (45).

A significantly higher labial plate thickness in smokers compared to non-smokers was depicted in this study. This does not coincide with previous studies that reported no significant difference in labial plate thickness between smokers and non-smokers (20, 46, 47). This could be due to the relatively small sample size of smokers in this study, not necessarily being reflective of the population and possibly by the differences between populations examined and the type and frequency of smoking.

Limitations of this study include the inherent limitations of the resolution of CBCT. In addition, the lack of Class III SRP in this sample limits the ability to evaluate this subgroup. Recruiting a larger sample size with an adequate number of each class and an adequate number of each phenotype is recommended to allow better assessment of potential relationships.

5. Conclusions

Within the limitations of this study, a higher prevalence of thin phenotype (90.4%) and thin labial plate thickness (78% with thickness < 1mm) was found in the anterior maxillary region among this sample of the Jordanian population. The SRP was not found to be significantly related to the periodontal phenotype, nor to any of its components. A significant relationship between GT and BT was clearly detected.

Acknowledgment

We would like to acknowledge Jordan University of Science and Technology, Irbid, Jordan, for the offered grant to support this study.

Conflict of Interests

The authors declare no conflict of interest and do not have any financial interest in the companies whose materials are included in this article.

Funding Information

This research was funded by a grant from Jordan University of Science and Technology (Grant Number: 20200610).

statements and recommended clinical procedures regarding the placement of implants in extraction sockets. *Int J Oral Maxillofac Implants.* 2004;19:26-28.

References

1. Hämmerle CH, Chen ST, Wilson TG Jr. Consensus

2. Grunder U, Polizzi G, Goené R, Hatano N, Henry P, et al. A 3-year prospective multicenter follow-up report on the immediate and delayed-immediate placement of implants. *Int J Oral Maxillofac Implants*. 1999;14:210-216.
3. Polizzi G, Grunder U, Goené R, Hatano N, Henry P, et al. Immediate and delayed implant placement into extraction sockets: A 5-year report. *Clin Implant Dent Relat Res*. 2000;2:93-99.
4. Evans CD, Chen ST. Esthetic outcomes of immediate implant placements. *Clin Oral Implants Res*. 2008;19:73-80.
5. Chen ST, Buser D. Esthetic outcomes following immediate and early implant placement in the anterior maxilla: A systematic review. *Int J Oral Maxillofac Implants*. 2014;29:186-215.
6. Kois JC. Predictable single-tooth periimplant esthetics: Five diagnostic keys. *Compend Contin Educ Dent*. 2004;25:895-896.
7. Romeo E, Lops D, Rossi A, Storelli S, Rozza R, et al. Surgical and prosthetic management of interproximal region with single-implant restorations: 1-year prospective study. *J Periodontol*. 2008;79:1048-1055.
8. Jepsen S, Caton JG, Albandar JM, Bissada NF, Bouchard P, et al. Periodontal manifestations of systemic diseases and developmental and acquired conditions: Consensus report of workgroup 3 of the 2017 World Workshop. *J Clin Periodontol*. 2018;45:S219-S229.
9. Kao RT, Curtis DA, Kim DM, Lin GH, Wang CW, et al. American Academy of Periodontology best evidence consensus statement on modifying periodontal phenotype in preparation for orthodontic and restorative treatment. *J Periodontol*. 2020;91:289-298.
10. La Rocca AP, Alemany AS, Levi P Jr, Juan MV, Molina JN, et al. Anterior maxillary and mandibular biotype. *Implant Dent*. 2012;21:507-515.
11. Amid R, Mirakhori M, Safi Y, Kadkhodazadeh M, Namdari M. Gingival biotype and facial tissue dimensions. *Arch Oral Biol*. 2017;79:1-6.
12. Shao Y, Yin L, Gu J, Wang D, Lu W, et al. Assessment of periodontal biotype in a young Chinese population using different measurement methods. *Sci Rep*. 2018;8:1-8.
13. Ghassemian M, Lajolo C, Semeraro V, Giuliani M, Verdugo F, et al. Relationship between biotype and bone morphology in the lower anterior mandible: An observational study. *J Periodontol*. 2016;87:680-689.
14. Kan JY, Roe P, Rungcharassaeng K, Patel RD, Waki T, et al. Classification of sagittal root position in relation to the anterior maxillary osseous housing for immediate implant placement: A CBCT study. *Int J Oral Maxillofac Implants*. 2011;26:873-876.
15. Kong HJ. A study on sagittal root position of maxillary anterior teeth in Korea. *J Dent Rehabil Appl Sci*. 2020;36:88-94.
16. Rodrigues DM, Petersen RL, Montez C, de Moraes JR, Januário AL, et al. Relationship between anterior maxillary tooth sagittal root position and periodontal phenotype: A clinical and tomographic study. *Clin Oral Investig*. 2022;26:1309-1321.
17. Lee KY, Lee DJ. A comparative study of teeth and dental arches of Korean and Caucasian Populations *Oral Biol Res*. 1993;17:1-15.
18. Kook YA, Nojima K, Moon HB, McLaughlin RP, Sinclair PM. Comparison of arch forms between Korean and North American white populations. *Am J Orthod Dentofacial Orthop*. 2004;126:680-686.
19. Hwang HS, Kim WS, McNamara JA Jr. Ethnic differences in the soft-tissue profile of Korean and European-American adults with normal occlusions and well-balanced faces. *Angle Orthod*. 2002;72:72-80.
20. Khoury J, Ghosn N, Mokbel N, Naaman N. Buccal bone thickness overlying maxillary anterior teeth. *Implant Dent*. 2016;25:525-531.
21. Silness J, Løe H. Periodontal disease in pregnancy. II. Correlation between oral hygiene and periodontal condition. *Acta Odontol Scand*. 1964;22:121-135.
22. Olsson M, Lindhe J. Periodontal characteristics in individuals with varying forms of the upper central incisors. *J Clin Periodontol*. 1991;18:78-82.
23. Guglielmoni P, Promsudthi A, Tatakis DN, Trombelli L. Intra- and inter-examiner reproducibility in keratinized tissue width assessment with three methods. *J Periodontol*. 2001;72:134-139.
24. Cortellini P, Bissada NF. Mucogingival conditions in the natural dentition: Narrative review, case definitions, and diagnostic considerations. *J Periodontol*. 2018;89:S204-S213.
25. Olsson M, Lindhe J, Marinello CP. Relationship between crown form and clinical features of the gingiva in adolescents. *J Clin Periodontol*. 1993;20:570-577.
26. De Rouck T, Eghbali R, Collys K, De Bruyn H, Cosyn J. The gingival biotype revisited. *J Clin Periodontol*. 2009;36:428-433.

27. Kan JY, Rungcharassaeng K, Umezu K, Kois JC. Dimensions of peri-implant mucosa in maxillary anterior single implants. *J Periodontol.* 2003;74:557-562.
28. Lau SL, Chow J, Li W, Chow LK. Classification of maxillary central incisors: Implications for immediate implant placement. *J Oral Maxillofac Surg.* 2011;69:142-153.
29. Morton D, Chen ST, Martin WC, Levine RA, Buser D. Optimizing esthetic outcomes in implant dentistry. *Int J Oral Maxillofac Implants.* 2014;29:216-220.
30. Nikiforidou M, Tsalikis L, Angelopoulos C, Menexes G, Vouros I, et al. Classification of periodontal biotypes with CBCT. *Clin Oral Investig.* 2016;20:2061-2071.
31. Braut V, Bornstein MM, Belser U, Buser D. Thickness of the anterior maxillary facial bone wall: A retrospective radiographic study using cone beam computed tomography. *Int J Periodontics Restorative Dent.* 2011;31:125-131.
32. Januario AL, Barriviera M, Duarte WR. Soft tissue CBCT for gingival tissue measurement. *J Esthet Restor Dent.* 2008;20:366-373.
33. Vera C, De Kok IJ, Reinhold D, Limpiphipatanakorn P, Yap AK, et al. Buccal alveolar bone dimensions assessed by CBCT. *Int J Oral Maxillofac Implants.* 2012;27:1514-1519.
34. Kolte AP, Kolte RA, Pajnigara NG, Pajnigara NG. A clinical and radiographic assessment of positional variations of gingival papilla and its proportions. *Int J Periodontics Restorative Dent.* 2016;36:213-218.
35. Sterrett JD, Oliver T, Robinson F, Fortson W, Knaak B, et al. Width/length ratios of maxillary anterior crowns. *J Clin Periodontol.* 1999;26:153-157.
36. La Rocca AP, Alemany AS, Levi P Jr, Juan MV, Molina JN, et al. Anterior maxillary and mandibular biotype. *Implant Dent.* 2012;21:507-515.
37. Stein JM, Lintel-Höping N, Hammächer C, Kasaj A, Tamm M, et al. Gingival biotype measurements. *J Clin Periodontol.* 2013;40:1132-1139.
38. Müller HP, Eger T. Gingival phenotypes in young male adults. *J Clin Periodontol.* 1997;24:65-71.
39. Fu JH, Yeh CY, Chan HL, Tatarakis N, Leong DJ, et al. Tissue biotype and bone morphology. *J Periodontol.* 2010;81:569-574.
40. Huynh-BaG, Pjetursson BE, Sanz M, Cecchinato D, Ferrus J, et al. Socket bone wall dimensions in the upper maxilla. *Clin Oral Implants Res.* 2010;21:37-42.
41. Schroeder HE. Development, structure, and function of periodontal tissues. In: *The Periodontium.* Berlin: Springer; 1986. p. 1-200.
42. Younes F, Eghbali A, Raes M, De Bruyckere T, Cosyn J, et al. Buccal bone and gingival thickness relationship. *Clin Oral Implants Res.* 2016;27:523-528.
43. Cook DR, Mealey BL, Verrett RG, Mills MP, Noujeim ME, et al. Relationship between clinical periodontal biotype and labial plate thickness: An in vivo study. *Int J Periodontics Restorative Dent.* 2011;31:345-354.
44. Amid R, Mirakhori M, Safi Y, Kadkhodazadeh M, Namdari M. Gingival biotype and facial tissue dimensions. *Arch Oral Biol.* 2017;79:1-6.
45. Kim YJ, Park JM, Kim S, Koo KT, Seol YJ, et al. New method of assessing the relationship between buccal bone thickness and gingival thickness. *J Periodontal Implant Sci.* 2016;46:372-381.
46. Farahamnd A, Sarlati F, Eslami S, Ghassemian M, Youssefi N, et al. Evaluation of impacting factors on facial bone thickness in the anterior maxillary region. *J Craniofac Surg.* 2017;28:700-705.
47. Rojo-Sanchis J, Soto-Peñaloza D, Peñarrocha-Oltra D, Peñarrocha-Diogo M, Viña-Almunia J. Facial alveolar bone thickness and modifying factors of anterior maxillary teeth: A systematic review and meta-analysis of cone-beam computed tomography studies. *BMC Oral Health.* 2021;21:143.