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ORIGINAL

IMPLICATIONS OF MAXILLARY ANTERIOR TEETH ALIGNMENT IN ATHLETES: A CBCT-BASED STUDY OF SAGITTAL ROOT POSITION AND ITS IMPACT ON SPORTS PERFORMANCE

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ABSTRACT

Purpose: Utilizing cone beam computed tomography (CBCT) technology, this study classifies the position of maxillary anterior teeth in Chinese individuals from the perspective of their potential impact on athletic performance. The classification was based on the position of the root relative to the alveolar bone wall and the angle between the root's long axis and the alveolar process's long axis. This study also measured the thickness of the alveolar bone wall on the labial and palatal sides in different classifications, which is critical for assessing the structural integrity that can influence breathing efficiency and facial protection in athletes. **Method:** A total of 170 patients undergoing CBCT scans were included in the study, consisting of 77 males and 93 females, aged between 18 and 76 years. The root positions were divided into nine categories based on their anatomical configuration in relation to the alveolar ridge and analyzed for variations in bone wall thickness at key sites and angular relationships significant for dental stability and alignment. **Results:** The most prevalent classifications among central incisors were B2 (75.00%) and B3 (19.41%), indicating a commonality in root alignment that could influence oral health factors relevant to sports. Similarly, the lateral incisors and canines showed predominant classifications that suggest a typical alignment pattern. Significant differences ($P<0.05$) were noted in the labiopalatine bone wall thickness and the angular orientation of the alveolar process and the root axis, with males generally displaying thicker bone walls and more pronounced angles than females. These differences are crucial for understanding gender-specific vulnerabilities in contact sports and endurance activities. **Conclusion:** The study provides a detailed classification of the sagittal plane root positions of maxillary anterior teeth and their anatomical characteristics, highlighting the variations that could potentially affect athletic performance through impacts on respiratory efficiency and facial structure integrity. The findings emphasize the need for sports medicine to consider dental assessments in athlete training and healthcare protocols, particularly in sports where oral-facial impacts are frequent.

KEYWORDS: Maxillary Anterior Teeth; CBCT; Location Classification; Immediate Planting

1. INTRODUCTION

In the evolving discipline of sports medicine, understanding the multifaceted aspects of athlete health is paramount for optimizing performance and preventing injuries. Among these aspects, dental health, particularly the anatomical characteristics of the maxillary anterior teeth, plays a crucial but often underappreciated role in athletes' overall physiological functioning and resilience in sports. The sagittal plane root position of these teeth can influence not only oral health but also critical functions such as breathing and facial protection, which are vital in high-stakes athletic environments. Recent studies have begun to illuminate the significant impact that oral structures have on respiratory efficiency, especially in sports that require endurance and high aerobic capacity (Branemark, 1977; Jung, Cho, & Hwang, 2017; Van der Weijden, Dell'Acqua, & Slot, 2009). The alignment and positioning of the maxillary anterior teeth affect the oral airway space, with potential implications for the athlete’s ability to perform at peak levels. Anomalies in tooth alignment or positioning can restrict airflow, reducing oxygen intake, which is crucial during intense physical exertion.

Cone Beam Computed Tomography (CBCT) represents a breakthrough in dental imaging, offering three-dimensional, high-resolution images that provide a comprehensive view of dental and maxillofacial structures. This technology is particularly beneficial in sports medicine, where detailed anatomical insights can lead to better protective measures and performance enhancements. CBCT’s ability to accurately assess the sagittal plane root positions allows for a more precise analysis of how these positions might correlate with issues such as increased susceptibility to impact injuries or compromised airway function (Adibi & Paknahad, 2017; De Rouck, Collys, & Cosyn, 2008; Liu & Wang; Ozemre & Gulsahi, 2018; Paula, Solon-de-Mello, Mattos, Ruellas, & Sant'Anna, 2015). The detailed data provided by CBCT can guide the design of custom mouth guards, which are critical in preventing dental and maxillofacial injuries in contact sports. Furthermore, understanding the nuances of root positioning helps sports medicine professionals anticipate and manage potential complications from facial impacts. For instance, athletes with forward-leaning root positions of maxillary anterior teeth might be at a higher risk for certain types of trauma and may benefit from specifically tailored facial protection strategies. This study aims to systematically classify the sagittal plane root positions of maxillary anterior teeth using CBCT and assess their variations across a diverse population.

By correlating these positions with physiological outcomes relevant to sports—such as respiratory efficiency and vulnerability to facial injuries—the research seeks to foster a deeper understanding of the role of dental health in athlete safety and performance. The findings from this study are expected to contribute significantly to the interdisciplinary field of sports health management, providing actionable insights that can be integrated into routine athlete assessments and preventive care protocols. By situating dental health within the broader context of athlete wellness, this research underscores the necessity of a holistic approach to health in sports, promoting not only performance optimization but also long-term well-being.

2. Materials and methods

2.1 Research subjects

The study subjects were 170 patients who had taken maxillary CBCT in the Affiliated Stomatological Hospital of Dalian Medical University from January 2018 to November 2020, including 77 men and 93 women, aged 18 to 76, with an average age of 44.1 years. The inclusion criteria are as follows: (1) The patient is over 18 years old; (2) CBCT images are clear, without artifacts, and scattered; (3) All maxillary anterior teeth exist, with at least two occlusal posterior teeth (premolars or molars) in each quadrant; (4) There are no deformed teeth, misaligned teeth, and supernumerary teeth in the anterior maxillary area; (5) No obvious dentition crowding, no maxillary tumor; (6) No obvious caries, no filling or restoration materials; (7) No periodontal disease, no alveolar Bone resorption damage; (8) No congenital Cleft lip and cleft palate or alveolar cleft. This study mainly focused on 6 anterior maxillary teeth of patients and conducted statistical measurements and analysis on a total of 1020 teeth.

2.2. Research Methods

2.2.1 CBCT image acquisition

CBCT image acquisition and Iterative reconstruction are obtained through SOREDEX oral special equipment, and output to the supporting OnDemand3D CD Viewer software to obtain the Sagittal plane, Coronal plane and horizontal images of the alveolar bone in the maxillary anterior tooth area. All operations are completed by the same professional imaging doctor and strictly controlled with the same parameters.

2.2.2 Use OnDemand3D CD Viewer software

To measure the plane, select Multi Plane Reconstruction (MPR) mode (as shown in Figure 1), slice thickness is 0 mm, and the measurement data is accurate to 0.01 mm. Adjust the coordinate axis so that the ordinate axis in the upper left Coronal plane plane window of Figure 1 passes through the long axis of the tooth body, that is, the root tip point to the midpoint of the incisional edge of the crown, so that the ordinate axis in the lower left axial plane window of Figure 1 passes through the midpoint of the lip and palate side of the root and the center of the root, and the abscissa axis passes through the centers of two adjacent teeth. At this time, the upper right Sagittal plane window of Figure 1 is the target tooth measurement plane.

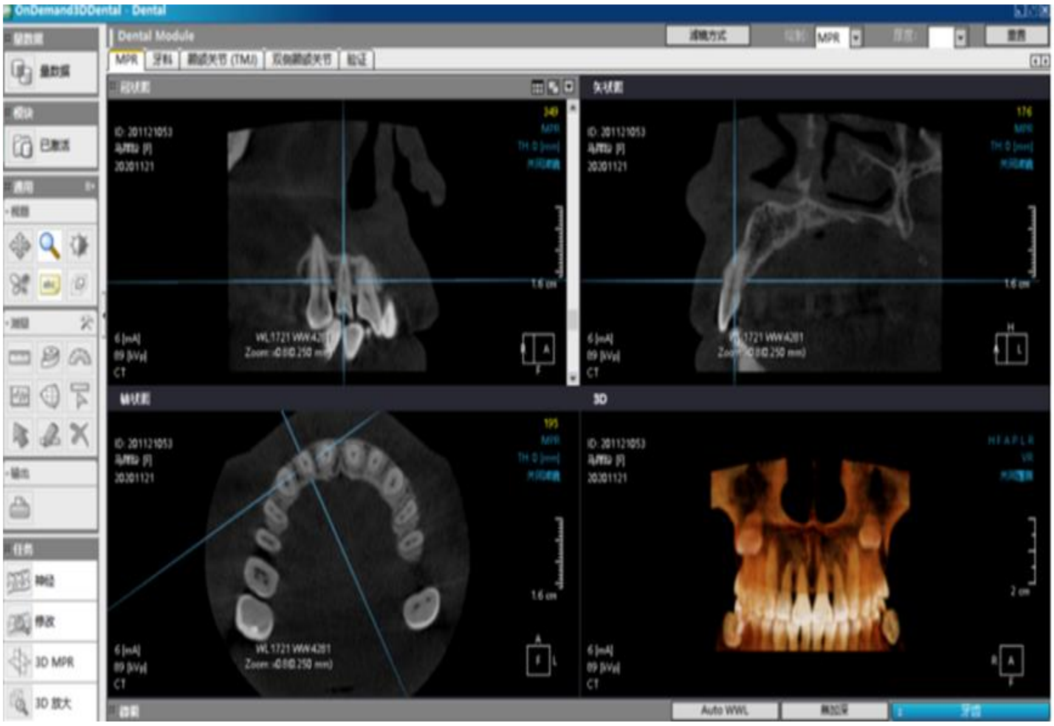

Figure 1: Determination of the tooth measurement plane using OnDemand3D CD Viewer software

2.2.3 Measurement and statistical items

(Lau, Chow, Li, & Chow, 2011) used the classification method for the position of tooth roots in alveolar bone, and classified the root positions of central incisor teeth (ci), lateral incisor teeth (li) and cusp teeth (ca) from two angles: the position of tooth roots relative to the labial-palatine bone wall of alveolar process (FIG. 2) and the Angle between the long axis of tooth roots and the long axis of alveolar process (FIG. 3).

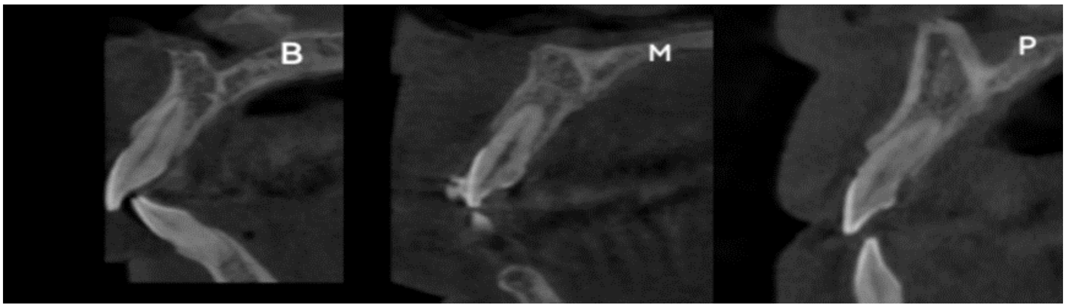

Figure 2: Lau's Dual Classification Angle One (Position of the Root Relative to the Lip Palatine Wall of the Grooved Process)

Type B: The tooth root is closer to the labial pressure groove wall bone; Type M: The root of the tooth is located in the middle of the bone wall of the lip and palate; Type P: The tooth root is closer to the palatal alveolar bone wall.

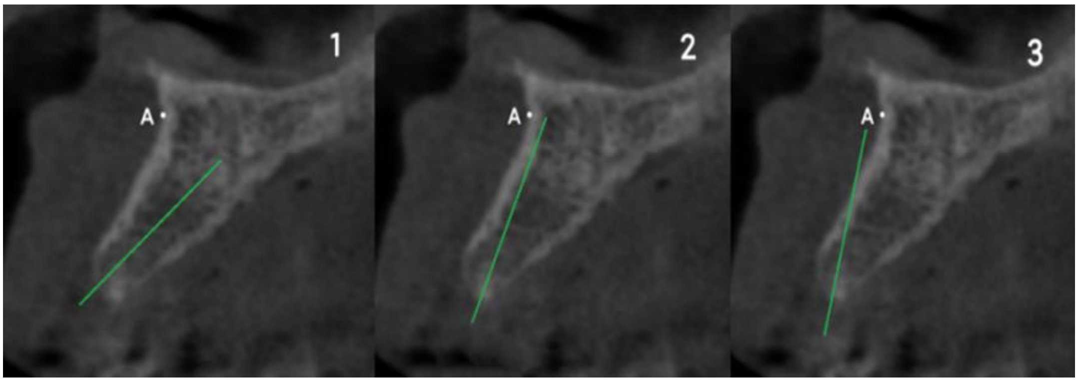

Figure 3: Lau Dual Classification Angle 2 (Angle between Root Long Axis and Alveolar Process Long Axis)

Type 1: The long axis of the tooth root (green line in the figure) faces the palatal side or is parallel to the long axis of the alveolar process: Type 2: The long axis of the tooth root faces the labial side, and passes through point A (the concave point of the labial bone wall) or behind point A; Type 3: The long axis of the tooth root faces the labial side, and the long axis faces in front of point A.

The thickness of the labial-palatine bone wall is the thickness of the labial-palatine bone wall perpendicular to the long axis of the root, and the long axis of the root is the line between the midpoint of the labial-palatine glaze cementum boundary and the apical point at the very center of the sagittal surface tooth (Figure 4). The thickness of labiopalatine bone wall A and D at 1mm from the apex of alveolar process (Figure 5), the thickness of labiopalatine bone wall B and E at the middle root (Figure 6), and the thickness of labiopalatine bone wall C and F at the apex of the root (Figure 7) were selected for measurement. The long axis of the alveolar process was determined by the midpoint of the labial-palatine bone wall surface connection 1mm away from the alveolar crest and the transapical point parallel to the above connection (1mm away from the alveolar crest) (Figure 8). The Angle G between the long axis of the root and the long axis of the alveolar process (Figure 9). Data were collected strictly according to the CBCT measurement method and the average value of three measurements was taken for each data.

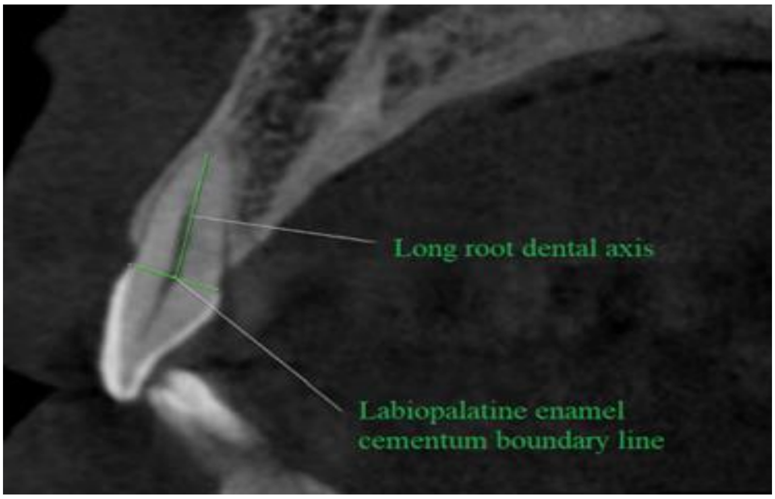

Figure 4: Long root dental axis

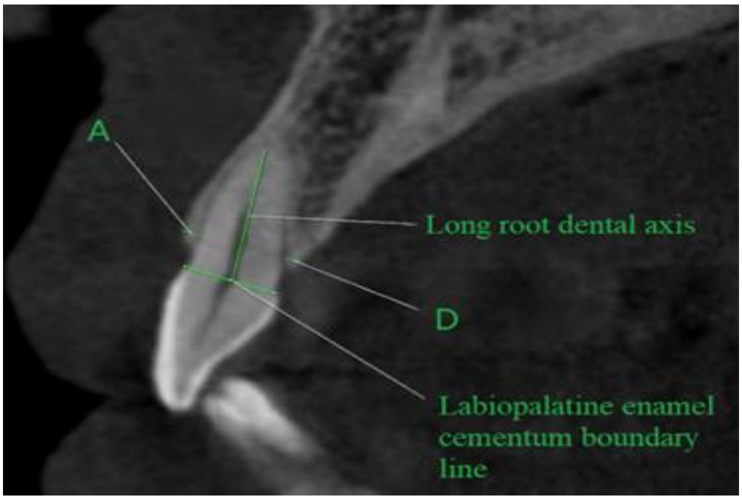

Figure 5: Thickness A and D of alveolar bone wall on the lip and palate at 1mm

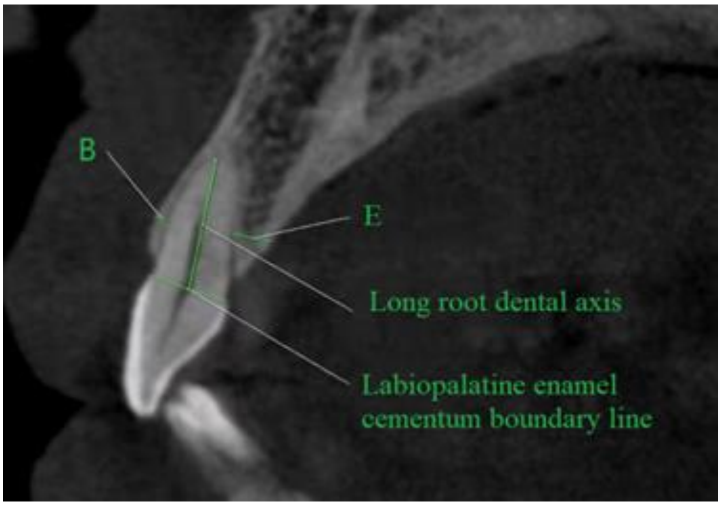

Figure 6: Thickness B and E of the alveolar bone wall on the labiopalatine side of the middle root

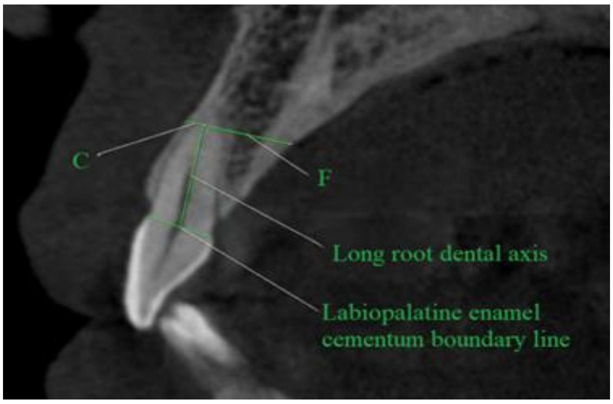

Figure 7: Thickness C and F of the alveolar bone wall on the labiopalatine side of the root apex

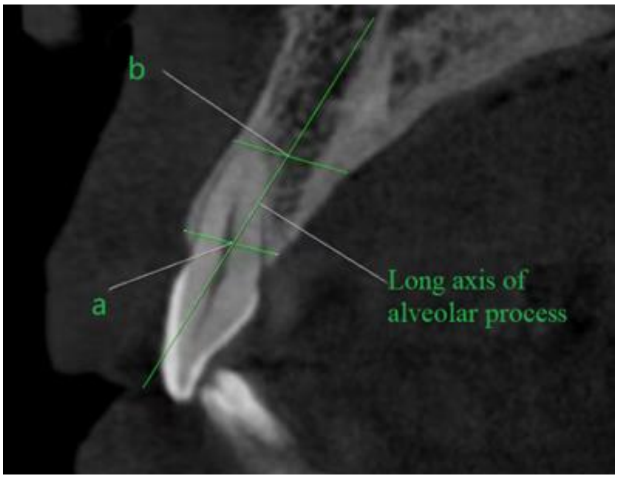

Figure 8: Determination of the long axis of the alveolar process (a: the midpoint of the line on the lip and palate bone surface 1mm from the top of the Alveolar ridge; b: the midpoint of the line on the lip and palate bone surface 1mm parallel to the top of the talus)

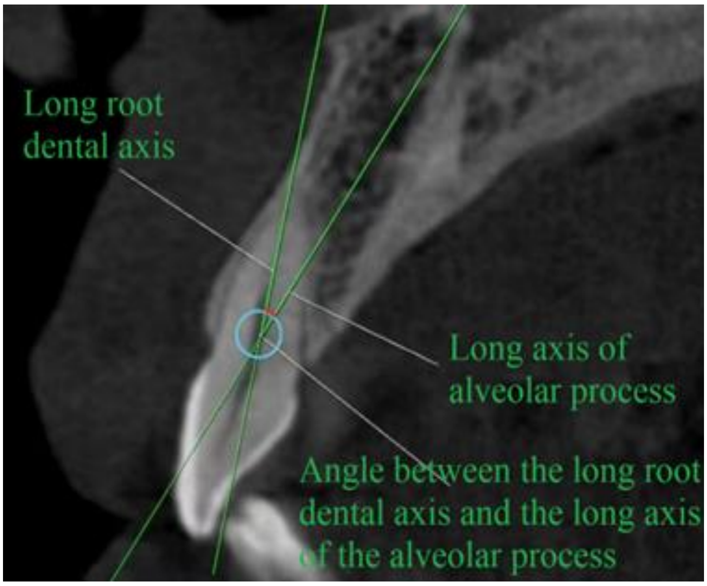

Figure 9: Angle between the long root root dental axis and the long axis the alveolar process

2.3 Statistical Analysis

SPSS26.0 statistical software was used to process the measurement statistics. The measurement data were expressed in x±s format. Descriptive statistics and frequency analysis were used to calculate the data. One-way analysis of variance was used between tooth positions, and independent sample t test was used for data between different sides and genders of teeth with the same name, with statistical difference at $P<0.05$.

3. Results

3.1 Classification results of the position of the roots of maxillary anterior teeth in the alveolar bone

Through CBCT statistical analysis of 170 patients with maxillary anterior teeth, it was found that the common classifications of central incisors are B2, B3, M1, M2, lateral incisors are B2, B3, M1, M2, and canine teeth are B2, B3, M1 (as shown in Table 1). There was a significant difference in the root position classification of each tooth position in the anterior tooth area ($P<0.05$, as shown in Table 2), and there was no significant gender difference in the classification ($P>0.05$, as shown in Table 3)

Table 1: Classification of root positions in the anterior tooth area

ANGLE TWO	ANGLE ONE											
	B			**M**			**P**			**TOTAL**		
	ci	li	ca	ci	li	ca	ci	li	ca	ci	li	ca
1	0(0%)	1(0.29%)	1(0.29%)	9(2.65%)	11(3.24%)	2(0.59%)	1(0.29%)	1(0.29%)	0(0%)	10(2.94%)	13(3.82%)	3(0.88%)
2	255(75%)	227(66.76%)	255(75%)	8(2.35%)	25(7.35%)	1(0.29%)	0(0%)	0(0%)	0(0%)	263(77.35%)	252(74.12%)	256(75.29%)
3	66(19.41%)	75(22.06%)	81(23.82%)	1(0.29%)	0(0%)	0(0%)	0(0%)	0(0%)	0(0%)	67(19.71%)	75(22.06%)	81(23.82%)
TOTAL	321(94.41%)	303(89.12%)	337(99.12%)	18(5.29%)	36(10.59%)	3(0.88%)	1(0.29%)	1(0.29%)	0（0%）	340	340	340

Table 2: Comparison of the location of root in alveolar bone at different tooth positions in Sagittal plane

CLASSIFICATION	FREQUENCY OF OCCURRENCE OF DIFFERENT TOOTH POSITIONS AND SUBTYPES (NUMBER OF TEETH)		
/	T_{CI}	T_{LI}	T_{CA}
B1	0	1	1
B2	255	227	255
B3	66	75	81
M1	9	11	2
M2	8	25	1
M3	1	0	0
P1	1	1	0
P2	0	0	0
P3	0	0	0
P VALUE	0.000*		

**. indicates a significant correlation of less than 0.05 (double tailed).*

Table 3: Location of Sagittal plane root in alveolar bone: gender comparison

CLASSIFICATION	FREQUENCY OF OCCURRENCE OF DIFFERENT TOOTH POSITIONS AND SUBTYPES (NUMBER OF TEETH)					
	T_{CI}		T_{LI}		T_{CA}	
	MALE	**FEMALE**	**MALE**	**FEMALE**	**MALE**	**FEMALE**
B1	0	0	1	0	0	1
B2	111	144	95	132	110	145
B3	39	27	40	35	41	40
M1	1	8	7	4	2	0
M2	2	6	10	15	1	0
M3	0	1	0	0	0	0
P1	1	0	1	0	0	0
P2	0	0	0	0	0	0
P3	0	0	0	0	0	0
P VALUE	0.746		0.698		0.682	

**. indicates a significant correlation of less than 0.05 (double tailed).*

3.2 Common Classification of Upper Anterior Teeth at Different Positions Different Measurement Sites Lip Palate Side Bone Wall Thickness

There is a significant difference in the thickness of the labial bone wall at the root tip of the maxillary anterior teeth among different classifications.

Generally, M1 is the thickest, followed by M2, B2, and B3. There is also a significant difference in the thickness of the labial bone wall at the middle of the root for lateral incisors among different classifications, with M1 being the thickest, followed by B3, M2, and B2 (P<0.05, as shown in Table 4); There is a significant tooth position difference in the thickness of the labial bone wall in the middle of the B1 classification root.

The labial bone wall in the B1 classification of the central incisor is the thickest, followed by the lateral incisors and canines. There is also a significant tooth position difference in the thickness of the labial bone wall at the root tip in the B2 and B3 classifications, mainly because the labial bone wall of the central incisor is thicker, while the lateral incisors and canines are equivalent (P<0.05, as shown in Table 4).

There were significant classification differences in the thickness of the palatal bone wall at the root tip and the thickness of the palatal bone wall in the middle of the central and lateral incisors at each tooth position of the maxillary anterior teeth, all of which were classified as B2 with the thickest thickness, followed by B1, M1, and M2 (P<0.05, as shown in Table 4). Class B2 and B3 have significant differences in the thickness of the palatal bone wall at the top of the Alveolar ridge, the middle of the root, and the tip of the root.

Except for Class B2, where the thickness of the palatal bone wall at the top of the Alveolar ridge is slightly greater than that of the canines, the rest are the thickest bone walls of the canines, which are in turn the central incisors and lateral incisors. In addition, the thickness of the palatal bone wall at the top of the alveolar ridge of the M2 middle incisors is significantly greater than that of the lateral incisors (P<0.05, as shown in Table 4).

In B2 classification, there were significant sex ratio differences in the thickness of the labial bone wall at the apical part of the central incisor and canine, the palatal bone wall at the apical part of the canine Alveolar ridge, the palatal bone wall at the central part of the lateral incisor and canine root, and the palatal bone wall thickness at the apical part of the three tooth positions, all of which showed that the thickness of the bone wall in men was greater than that in women (P<0.05, as shown in Table 5).

In B3 classification, there were significant gender differences in the thickness of the labial bone wall at the tip of the central incisor root, the palatal bone wall at the top of the Alveolar ridge of the lateral incisor, the palatal bone wall in the middle of the central incisor root and the apical root, and the palatal bone wall thickness at the tip of the lateral incisor root and the apical root, all of which showed that the thickness of the bone wall in men was greater than that in women (P<0.05, as shown in Table 5).

Table 4: Common Classification of Upper Maxillary Anterior Teeth and Different Measurement Sites for Lip Palatine Bone Wall Thickness

LOCUS	DENTAL POSITION	THICKNESS OF LABIAL BONE WALL IN DIFFERENT SUBTYPES (MM)				
		B2	**B3**	**M1**	**M2**	**P [1]**
A	A_{CI}	0.93±0.39	1.06±0.45	1.04±0.46	0.71±0.29	0.374
	A_{LI}	0.86±0.37	1.00±0.39	0.92±0.29	0.90±0.36	0.705
	A_{CA}	0.89±0.38	1.06±0.40	1.27±0.19		0.543
	P [2]	0.101	0.656	0.431	0.193	
B	B_{CI}	0.87±0.36	1.12±0.54	1.17±0.30	1.00±0.47	0.094
	B_{LI}	0.71±0.36	1.11±0.51	1.20±0.64	1.05±0.66	0.001*
	B_{CA}	0.68±0.32	1.03±0.60	0.65±0.05		0.42
	P [2]	0.000*	0.579	0.377	0.841	
C	C_{CI}	1.86±0.59	1.46±0.39	3.10±0.50	2.79±0.62	0.000*
	C_{LI}	1.63±0.61	1.25±0.51	2.82±1.16	2.38±0.63	0.000*
	C_{CA}	1.65±0.71	1.24±0.67	3.91±0.11		0.000*
	P [2]	0.039*	0.031*	0.305	0.115	
D	D_{CI}	0.91±0.31	1.00±0.30	0.67±0.21	0.82±0.22	0.091
	D_{LI}	0.76±0.20	0.85±0.22	0.58±0.14	0.59±0.22	0.379
	D_{CA}	0.90±0.27	1.01±0.32	0.51±0.40		0.14
	P [2]	0.000*	0.003*	0.406	0.014*	
E	E_{CI}	2.53±1.06	3.09±0.81	1.24±0.54	1.23±0.32	0.048*
	E_{LI}	1.93±0.71	2.60±1.11	1.04±0.46	0.93±0.42	0.006*
	E_{CA}	3.16±1.16	3.66±1.21	1.08±0.71		0.058
	P [2]	0.000*	0.000*	0.689	0.076	
F	F_{CI}	7.01±1.75	8.56±2.01	3.57±0.73	3.51±0.55	0.000*
	F_{LI}	5.84±1.41	7.48±2.11	3.54±1.74	3.31±0.75	0.000*
	F_{CA}	8.89±2.46	10.38±2.48	4.77±0.42		0.000*
	P [2]	0.000*	0.021*	0.488	0.497	

P[1] represents the P value between different dental classifications at the same measurement position, and P 2 represents the P value between different dental classifications at the same measurement position Indicating a significant correlation of less than 0.05 (double tailed).

Table 5 (a): Gender differences in the thickness of the labiopalatine bone wall at different measurement sites for common classification of maxillary anterior teeth

SITE	DENTAL POSITION	GENDER	THICKNESS OF LABIAL BONE WALL IN DIFFERENT SUBTYPES (MM)							
			B2	*P VALUE*	B3	*P VALUE*	M1	*P VALUE*	M2	*P VALUE*
A	A_{CI}	Male	0.86±0.32	0.062	0.89±0.42	0.883	1.40±0.00	0.446	0.86±0.31	0.421
		Female	0.94±0.34		0.90±0.34		1.00±0.47		0.67±0.27	
	A_{LI}	Male	0.83±0.26	0.385	0.84±0.36	0.642	1.05±0.67	0.673	0.98±0.26	0.422
		Female	0.87±0.43		0.88±0.32		0.90±0.16		0.85±0.42	
	A_{CA}	Male	0.85±0.32	0.176	0.89±0.43	0.788				
		Female	0.92±0.41		0.91±0.32					
B	B_{CI}	Male	0.88±0.36	0.591	0.87±0.40	0.345	1.40±0.00	0.463	1.18±0.86	0.584
		Female	0.86±0.36		0.98±0.50		1.14±0.31		0.94±0.38	
	B_{LI}	Male	0.69±0.28	0.76	0.87±0.49	0.869	1.21±0.49	0.926	1.28±0.89	0.196
		Female	0.67±0.39		0.89±0.41		1.17±0.93		0.91±0.44	
	B_{CA}	Male	0.69±0.31	0.545	0.73±0.48	0.595				
		Female	0.67±0.33		0.78±0.43					
C	C_{CI}	Male	1.99±0.69	0.004*	1.52±0.35	0.000*	2.96±0.00	0.787	2.73±1.33	0.943
		Female	1.76±0.48		1.08±0.31		3.12±0.54		2.82±0.42	
	C_{LI}	Male	1.71±0.75	0.09	1.12±0.46	0.286	2.82±1.43	0.999	2.38±0.87	0.99

Table 5 (b): Gender differences in the thickness of the labiopalatine bone wall at different measurement sites for common classification of maxillary anterior teeth

SITE	DENTAL POSITION	GENDER	THICKNESS OF LABIAL BONE WALL IN DIFFERENT SUBTYPES (MM)							
			B2	*P VALUE*	B3	*P VALUE*	M1	*P VALUE*	M2	*P* VALUE
		Female	1.56±0.48		1.01±0.40		2.82±0.67		2.38±0.46	
	C_{CA}	Male	1.75±0.78	0.041*	1.05±0.45	0.284				
		Female	1.57±0.65		0.93±0.56					
D	D_{CI}	Male	0.93±0.40	0.359	0.96±0.29	0.301	0.55±0.00	0.59	0.89±0.09	0.685
		Female	0.89±0.22		0.89±0.19		0.67±0.21		0.80±0.25	
	D_{LI}	Male	0.78±0.21	0.192	0.83±0.24	0.039*	0.57±0.16	0.778	0.55±0.26	0.498
		Female	0.74±0.19		0.72±0.21		0.60±0.11		0.62±0.18	
	D_{CA}	Male	0.94±0.28	0.011*	0.95±0.30	0.385				
		Female	0.86±0.25		0.89±0.30					
E	E_{CI}	Male	2.62±1.22	0.238	3.03±0.76	0.041*	1.00±0.00	0.684	1.44±0.29	0.34
		Female	2.46±0.92		2.60±0.88		1.24±0.54		1.17±0.32	
	E_{LI}	Male	2.16±0.79	0.000*	2.21±0.97	0.396	1.01±0.56	0.781	0.92±0.53	0.881
		Female	1.76±0.60		2.01±1.08		1.10±0.30		0.94±0.35	
	E_{CA}	Male	3.41±1.16	0.003*	3.53±1.24	0.015*				
		Female	2.97±1.12		2.89±1.08					
F	F_{CI}	Male	7.35±1.70	0.008*	8.29±1.91	0.251	4.70±0.00	0.181	3.90±1.16	0.278
		Female	6.76±1.74		7.70±2.19		3.58±0.73		3.38±0.27	
	F_{LI}	Male	6.37±1.46	0.000*	7.25±2.40	0.030*	3.82±2.13	0.495	3.57±0.92	0.185
		Female	5.45±1.25		6.17±1.78		3.03±0.65		3.14±0.59	
	F_{CA}	Male	9.43±2.41	0.002*	10.48±2.65	0.009*				
		Female	8.48±2.42		9.14±1.80-					

**. indicates a significant correlation of less than 0.05 (double tailed).*

3.3 Common Classification of Upper Anterior Teeth: Angle between Root and Alveolar Process Long Axis

There are significant differences in the angle between the root and alveolar process of the maxillary anterior teeth in each classification, with B3 having the highest angle, followed by B2, M2, and M1 (P<0.05, as shown in Table 6). There is a significant difference in the included angle of Class B2 among different tooth positions, with the highest included angle being the canine, followed by the central incisor and lateral incisor (P<0.05, as shown in Table 6). There is a significant gender difference between the lateral incisors classified as B2 and the central incisors and lateral incisors classified as B3, with the angle between the root and alveolar process of male teeth being greater than that of female teeth (P<0.05, as shown in Table 7).

Table 6: Common Classification of Maxillary Anterior Teeth: Angle between Root and Alveolar Process Long Axis

CLASSIFICATION	ANGLE G BETWEEN THE LONG AXIS OF THE TOOTH ROOT AND THE LONG AXIS OF THE ALVEOLAR PROCESS (°)			
	G_{ci}	G_{li}	G_{ca}	P^2
B2	12.92±3.25	11.93±3.64	14.66±3.84	0.000*
B3	17.51±3.62	18.09±5.11	18.47±5.25	0.479
M1	-1.25±1.46	-0.77±1.43	-0.80±1.13	0.744
M2	5.79±2.95	6.91±4.07		0.479
P^1	0.000*	0.000*	0.000*	

P^1 represents the P value between different tooth positions in the same tooth position, while P2 represents the P value between different tooth positions in the same tooth position Indicating a significant correlation of less than 0.05 (double tailed). ("-" indicates that the long axis of the tooth root deviates from the palatal side)

Table 7: Gender differences in the angle between the long axis of the root and alveolar process in common classifications of maxillary anterior teeth

CLASSIFICATION	GENDER	ANGLE G BETWEEN THE LONG AXIS OF THE TOOTH ROOT AND THE LONG AXIS OF THE ALVEOLAR PROCESS (°)					
		CENTRAL INCISOR	P VALUE	LATERAL INCISOR	P VALUE	CANINE TEETH	P VALUE
B2	Male	13.02±3.33	0.684	12.75±4.15	0.006*	15.20±4.49	0.062
	Female	12.85±3.20		11.35±3.11		14.25±3.22	
B3	Male	18.31±3.33	0.030*	20.00±4.84	0.000*	19.32±5.18	0.144
	Female	16.35±3.77		15.91±4.59		17.61±5.26	
M1	Male	0	0.437	-1.21±1.66	0.101		
	Female	-1.26±1.46		0			
M2	Male	5.35±3.18	0.830	5.37±2.56	0.270		
	Female	5.93±3.17		6.43±1.94			

**. indicates a significant correlation of less than 0.05 (double tailed).*

4. Discussion

The study of the anatomical characteristics of the maxillary anterior tooth area provides good guidance for immediate implantation in clinical practice. (Kan et al., 2011) roughly divided the root position into labial, intermediate, and palatal categories based on the position of the root in the labiopalatine direction of the alveolar bone. At the same time, they pioneered the subdivision of the intermediate category into an independent fourth category. (Chung, Park, Chung, & Shon, 2014) further refined the classification based on the morphological characteristics of the labial bone wall by Kan et al. However, Kan and Chung's classification studies did not consider the direction of the long axis of the tooth root. (Lau et al., 2011) classified tooth root positions from two angles: the position of the tooth root relative to the labiopalatine bone wall of the alveolar process, and the angle between the long axis of the tooth root and the long axis of the alveolar process. This method can more comprehensively display the position of the tooth root in the alveolar process and includes various anatomical variants, but he only conducted classification research on the maxillary central incisor. This study drew inspiration from the classification method of (Lau et al., 2011) to comprehensively classify canines, lateral incisors, and central incisors, making up for the shortcomings of incomplete anatomical parameters in previous studies.

The statistical results of incisors in this study are quite different from those of (Lau et al., 2011) Class B2 accounts for a significantly higher proportion, while Class B3, M1 and M2 account for a relatively small proportion, and Class B1 does not appear. This difference may be due to regional differences, or it may be slightly different from the method used in this study to determine the long axis of the Sagittal plane alveolar process from Lau et al. Meanwhile, the classification result of lateral incisors in this study was B1: 0.29%; B2: 66.76%; B3: 22.06%; M1: 3.24%; M2: 7.35%; P1: 0.29%; The classification results for canines were B1: 0.29% and B2: 75.00%; B3: 23.82%; M1: 0.59%; M2: 0.29%. In addition, statistical analysis found significant differences in the classification of central incisors, lateral incisors, and canines. In summary, the majority of the root positions of the maxillary anterior teeth in the alveolar bone are inclined towards the labial side, and most of the root axes are located after the concave point on the labial side, indicating that the implant should be placed in a position that deviates from the palatal side and avoids compression or penetration into the buccal bone, minimizing the opening of the labial bone wall and fenestration. Research has shown that a thicker labial bone wall and thick gingival biotype are key factors for immediate implant success (Araújo, Sukekava, Wennström, & Lindhe, 2005; Botticelli, Berglundh, & Lindhe, 2004; Gluckman, Pontes, & Du Toit, 2018; Kim, Lee, Han, & Kim, 2011; Qahash, Susin, Polimeni, Hall, & Wikesjö, 2008). Many scholars at home and abroad have conducted extensive measurements and statistics on the thickness of the labial and palatal bone wall at different positions and have concluded that the labial bone wall in the maxillary anterior tooth area is relatively thin.

However, few scholars have conducted further measurement and analysis on the labial and palatal bone wall at different root positions. This study found that although M1 and M2 in the maxillary anterior tooth area have relatively thick bone walls in the labial root tip, the thickness of the bone wall in the middle of the root and the top lip of the Alveolar ridge is not significantly different from B2 and B3, and the thickness of the palatal bone wall in the middle of the root and the root tip is significantly smaller than B2 and B3, which is not conducive to immediate implant use of the palatal bone wall to obtain initial stability. The thickness of the labial bone wall at the B2 root tip is better than that of Class B3, and the probability of labial fenestration during immediate implantation is lower than that of Class B3. Although the thickness of the palatal bone wall is lower than that of Class B3, it is sufficient for immediate implantation and utilization to achieve initial stability. In the B2 and B3 classifications, the thickness of the labial bone wall at the root tip of the central incisor is significantly greater than that of the lateral incisor and canine. In the measurement points on the palatal side, the bone wall of the canine is significantly thicker, followed by the central incisor.

The thickness of the palatal bone wall of the lateral incisor is significantly smaller, indicating that the available bone mass at the lateral incisor position is relatively less during immediate implantation, making it relatively difficult. In addition, there are certain gender differences in the thickness of the labial and palatal bone walls at the root tips of B2 and B3 types, both of which are greater in males than females. It can be seen that during immediate implantation, males may have more available bone mass than females. The use of CBCT to measure the angle between the long axis of the maxillary anterior teeth and the long axis of the alveolar process has also been used to guide immediate implantation in various anatomical forms of the maxillary anterior teeth (Kim et al., 2011). Unlike previous studies, after classifying and analyzing the root positions of maxillary anterior teeth, we also conducted statistical analysis on the angle between the root long axis and the alveolar process long axis of common classification teeth in each tooth position. There were significant differences in the root long axis and alveolar process long axis of different classification teeth in the three tooth positions, and the B3 type angle was significantly larger, followed by B2, M2, and M1. This study also found that there was a significant difference in the angle between the long axis of the root and the long axis of the alveolar process among the three tooth positions of Class B2 teeth.

The angle between the canine teeth was larger, followed by the central incisor, and the lateral incisor was the smallest. At the same time, there is a significant gender difference in the angle between the root long axis and the alveolar process long axis of Class B3 of the central incisors and Class B2 and B3 of the lateral incisors, both of which are measured by males and females. This study on the classification and anatomical characteristics can provide anatomical references for clinical doctors when determining the implant axis for immediate implantation in different types of maxillary anterior teeth.

5. Conclusion

The comprehensive classification of the sagittal plane root positions of maxillary anterior teeth provided by this study, utilizing advanced CBCT imaging technology, offers significant insights into the anatomical variations that could potentially influence athletic performance. The findings reveal a predominant alignment in the maxillary anterior teeth that leans towards the labial side, which could have implications for both respiratory efficiency and the structural integrity of facial protection in sports settings. The distinct differences in the thickness of the labiopalatine bone wall and the angular orientation between the alveolar process and the root long axis highlight anatomical features that are critical in understanding how athletes might be affected by facial impacts or respiratory challenges during high-intensity activities.

Particularly, the greater bone wall thickness and more pronounced angular orientation observed in males suggest gender-specific considerations that should be taken into account in sports medicine and dental protective gear design. Moreover, the prevalence of certain root position classifications, such as B2 and B3, indicates common patterns that could be strategically targeted in preventive and therapeutic dental interventions aimed at athletes. Given the general thinness of the labial bone wall and its vulnerability to impact, protective strategies and custom-fitted mouth guards designed with these anatomical insights could enhance safety and performance in contact sports. This study underscores the importance of integrating detailed dental assessments into the sports health management of athletes.

By understanding the specific dental anatomies that predominate among athletes, sports medicine professionals can better predict and mitigate the risks associated with oral and maxillofacial injuries. Additionally, the insights gained from this research could guide the development of more effective, anatomically tailored protective gear, contributing to safer sporting environments and more focused athlete care protocols. Future research should explore the direct impact of these dental configurations on specific sports activities, examining how variations in tooth and bone structure affect breathing and facial protection under athletic stress. Such studies will further enhance the ability of sports medicine to provide comprehensive care that includes the often-overlooked aspect of dental health and its impact on overall athletic performance.

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