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Research Article

CORRELATION BETWEEN ANTERIOR MAXILLARY TEETH INCLINATIONS AND CROWN/ROOT LENGTHS: A RETROSPECTIVE CBCT STUDY

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ABSTRACT

Background: Unfavourable root-crown ratios (R/C ratios) in teeth complicate dental treatments, especially during orthodontic procedures. Short Root Anomaly (SRA) adds to these challenges, requiring precise diagnosis and tailored treatment.

Objective: To investigate the relationship between maxillary anterior teeth inclination and crown/root lengths using cone-beam computed tomography (CBCT) imaging techniques.

Methods: We analysed CBCT scans of 115 orthodontic patients at Zhongnan Hospital, Wuhan University, from November 2022 to November 2023. Scans were taken using a Carestream 9300 machine. Crown and root lengths of maxillary anterior teeth were measured using Carestream 3D imaging v3.8 software, with the cemento-enamel junction serving as a reference point. Tooth inclination was assessed based on the angle between the long axis of the tooth and the SN line on the widest buccolingual dimension.

Results: Significant variations were observed in tooth angulation and dimensions among the study sample. While a significant negative correlation was found between UR3/SN angle and UL1 root length ($p < 0.05$), no significant associations were found between tooth inclination and crown/root lengths of other teeth ($p > 0.05$).

Conclusions: While tooth inclination may impact root morphology, other factors likely play significant roles in determining tooth dimensions. Further research could deepen our understanding and improve treatment outcomes. Overall, this study provides valuable insights for orthodontic management.

INTRODUCTION

Unfavourable root-crown ratios (R/C ratios) in the maxillary and mandibular incisors can significantly impact the success of dental treatments. Previous research has highlighted the susceptibility of these teeth to external apical root resorption during orthodontic procedures [1–3]. Various factors contribute to root resorption, including ethnic variations, abnormal root shape, excessive overjet necessitating extraction treatment, and prolonged treatment duration [4,5]. Root resorption, considered an iatrogenic issue associated with orthodontic treatment, results from a complex interplay of individual biology and mechanical forces, leading to the loss of cementum and dentin [6]. Reduced R/C ratios can complicate dental procedures and compromise tooth prognosis, particularly in patients with short roots who face increased risks of root resorption during orthodontic treatment[7,8]. Short Root Anomaly (SRA), a genetic condition characterized by short roots and reduced crown-to-root ratios, poses challenges in treatment planning, especially for patients requiring orthognathic surgery[6,9,10]. Awareness of SRA among orthodontists and oral surgeons is crucial to tailor treatment plans and minimize adverse outcomes such as severe root resorption and tooth loss[6,7,11,12]. Comparing R/C ratios of new patients to normal dentition aids in SRA diagnosis and treatment planning[1,13,14]. Although root resorption can occur even without orthodontic treatment, its incidence is higher in treated individuals, with about one-third of patients showing signs of resorption[15]. Objective assessment of root shortening is essential for accurate comparison of treatment plans, with R/C ratios of normal dentition serving as reference values to facilitate diagnosis and treatment planning for various dental procedures[6,16].

Most data on normal R/C ratios are obtained using panoramic radiographs, which offer acceptable reproducibility with low radiation exposure[16,17]. However, measurements on panoramic radiographs, particularly of the maxillary and mandibular central incisors, exhibit low reliability[18,19], Furthermore, the accuracy of identifying the cementoenamel junction (CEJ) on periapical radiographs obtained using the paralleling technique may be influenced by angular variations between the tooth being examined and the film.[20]

Cone-beam computed tomography (CBCT), despite requiring higher radiation dosages and being relatively expensive, provides distortion-free images suitable for measuring crown and root lengths.[18,21]

Therefore, this retrospective study aims to explore the correlation between maxillary anterior teeth inclination and crown and root lengths using CBCT imaging techniques.

METHODOLOGY

We analysed CBCT scans of patients undergoing orthodontic treatment at Zhongnan Hospital, Wuhan University, from November 2022 to November 2023, totalling 300 scans. The scans were obtained using a Carestream 9300 machine (Carestream Health, Rochester, NY) with settings of 90 kV, 4.0 mA, and a scan time of 11.3 seconds. The images had a minimal resolution of 0.3 mm voxels and a field of view of at least 16 x 13 cm. All images were stored in DICOM format.

From the initial pool of patients, 115 were included in the study based on specific inclusion criteria. These criteria required patients to have fully erupted permanent dentition and complete CBCT data available at our clinic. Patients with craniofacial anomalies, periodontal or endodontic issues, defects in the maxillary anterior area such as attrition or abrasion on crowns, previous prosthodontic or orthodontic treatment, missing anterior upper teeth, or incomplete eruption of anterior teeth were excluded.

Crown and root lengths of the maxillary anterior teeth were measured using the widest sagittal cut on the CBCT film, and analysis was performed using Carestream 3D imaging v3.8 software. A line delineating the cemento-enamel junction bucco-lingually was drawn on each tooth. From this line, two perpendicular lines were drawn: one from the root tip and one from the incisal edge, representing the root and crown lengths, respectively figure1. Tooth inclination was measured based on the angle between the long axis of the tooth and the SN line, also measured on the sagittal cut with the widest buccolingual dimension Figure 2.

Figure 1

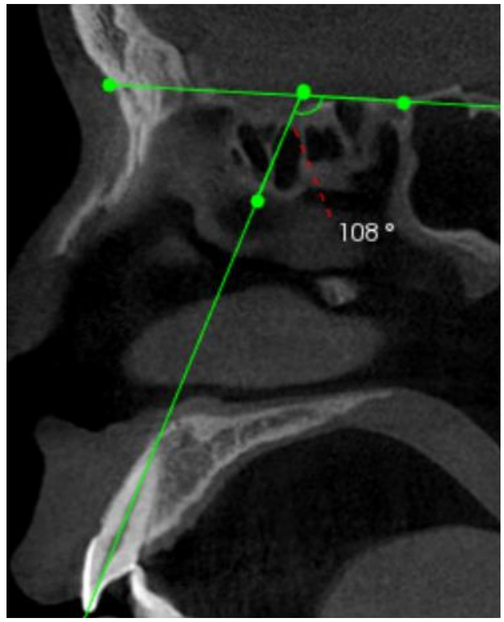

Figure 2

Statistical Analysis:

Statistical analysis was conducted using SPSS version 26 software for Windows (IBM, Armonk, NY). Initial examination of the data revealed that some variables exhibited a normal frequency distribution, while others did not. The normality of the data was assessed using the Kolmogorov-Smirnov test, and Shapiro Wilk tests Tables 1 and 2.

Descriptive statistics, including frequency, percentages, means, and standard deviations, were calculated for all measured parameters. To investigate the relationship between tooth inclination and the lengths of the crown and root, Pearson correlation analysis was performed for normally distributed data, while Spearman correlation analysis was employed for non-normally distributed data. The statistical significance level was set at $\alpha = 0.05$. Table 3.

RESULTS

Data were collected from a total of 115 patients. The mean angles of inclination for the maxillary anterior teeth were as follows: 96.03° for UR3/SN, 104.99° for UR2/SN, 106.5° for UR1/SN, 106.97° for UL1/SN, 105.56° for UL2/SN, and 96.63° for UL3/SN. The mean lengths of the maxillary anterior teeth were: 9.793 mm for UR3, 9.632 mm for UR2, 10.923 mm for UR1, 10.910 mm for UL1, 9.531 mm for UL2, and 9.719 mm for UL3. Regarding root lengths, the mean values were 15.772 mm for UR3, 12.421 mm for UR2, 12.069 mm for UR1, 12.350 mm for UL1, 12.638 mm for UL2, and 15.941 mm for UL3. Table 3.

Statistical analysis was performed using Pearson correlation for parametric data and Spearman's Rho for nonparametric data. Tables 4 and 5 in the appendices display the correlation coefficients and respective p-values.

A significant negative relationship was observed between UR3/SN angle and only UL1 root length ($p < 0.05$), with a weak correlation coefficient of -0.189. However, no significant associations were found between the inclination of each tooth (UR3-SN, UR2-SN, UR1-SN, UL1-SN, UL2-SN, UL3-SN) and the lengths of the crown and root of each tooth (UR3 crown length, UR3 root length, UR2 crown length, UR2 root length, UR1 crown length, UR1 root length, UL1 crown length, UL1 root length, UL2 crown length, UL2 root length, UL3 crown length, UL3 root length) ($p > 0.05$), as indicated in Tables 4 and 5.

	Tests of Normality						Result	CORRELATION TEST
Variable	**Kolmogorov-Smirnov[a]**			**Shapiro-Wilk**				
	Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**		
UR3/SN angle	0.072	115	0.197	0.994	115	0.883	Normal	PEARSON
UR2/SN angle	0.068	115	.200*	0.966	115	0.005	Normal	PEARSON
UR1/SN angle	0.079	115	0.073	0.966	115	0.005	Normal	PEARSON
UL2/SN angle	0.071	115	.200*	0.978	115	0.060	Normal	PEARSON
UL3/SN angle	0.068	115	.200*	0.984	115	0.186	Normal	PEARSON
UR3 crown length	0.052	115	.200*	0.988	115	0.433	Normal	PEARSON
UR3 root length	0.055	115	.200*	0.992	115	0.753	Normal	PEARSON
UR2 crown length	0.064	115	.200*	0.991	115	0.613	Normal	PEARSON
UR2 root length	0.076	115	0.097	0.980	115	0.092	Normal	PEARSON
UR1 crown length	0.060	115	.200*	0.991	115	0.651	Normal	PEARSON
UR1 root length	0.070	115	.200*	0.952	115	0.000	Normal	PEARSON

UL1 root length	0.042	115	.200*	0.988	115	0.421	Normal	PEARSON
UL2 crown length	0.064	115	.200*	0.991	115	0.653	Normal	PEARSON
UL3 crown length	0.083	115	0.051	0.991	115	0.658	Normal	PEARSON
UL3 root length	0.044	115	.200*	0.990	115	0.546	Normal	PEARSON

Table 1: Results of Normal Distribution, Pearson Correlations

Tests of Normality							**Result**	**CORRELATION TEST**
Variable	**Kolmogorov-Smirnov^a**			**Shapiro-Wilk**				
	Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**		
UL1/SN angle	0.118	115	0.000	0.931	115	0.000	Not Normal	SPEARMAN
UL1 crown length	0.091	115	0.021	0.981	115	0.096	Not Normal	SPEARMAN
UL2 root length	0.123	115	0.000	0.963	115	0.003	Not Normal	SPEARMAN

Table 2: Results of Normal Distribution, Spearman Correlations (H3 and H6)

Variable	**Minimum**	**Maximum**	**Mean**	**Standard Deviation**
UR3/SN angle	**73.00**	**117.00**	**96.030**	**8.828**
UR2/SN angle	**69.00**	**127.00**	**104.990**	**9.991**
UR1/SN angle	**68.00**	**129.00**	**106.500**	**11.563**
UL1/SN angle	**67.00**	**127.00**	**106.970**	**10.416**
UL2/SN angle	**79.00**	**128.00**	**105.560**	**9.751**
UL3/SN angle	**65.00**	**126.00**	**96.630**	**9.499**
UR3 crown length	**7.50**	**13.00**	**9.793**	**1.084**
UR3 root length	**11.50**	**20.90**	**15.772**	**1.957**
UR2 crown length	**7.30**	**2.60**	**9.632**	**0.952**

UR2 root length	**9.80**	**16.40**	**12.421**	**1.297**
UR1 crown length	**9.10**	**13.10**	**10.923**	**0.870**
UR1 root length	**3.00**	**16.10**	**12.069**	**1.901**
UL1 crown length	**9.00**	**13.70**	**10.910**	**0.869**
UL1 root length	**8.30**	**18.90**	**12.350**	**1.812**
UL2 crown length	**6.80**	**12.00**	**9.531**	**0.886**
UL2 root length	**9.90**	**16.70**	**12.638**	**1.416**
UL3 crown length	**7.10**	**12.60**	**9.719**	**1.063**
UL3 root length	**11.10**	**20.40**	**15.941**	**1.957**

Table 3: Minimum, Maximum, Mean, and Standard Deviation Statistics

Table 24. Results of PEARSON Correlations (H6)

		UR3/SN angle	UR2/SN angle	UR1/SN angle	UL2/SN angle	UL3/SN angle	UR3 crown length	UR3 root length	UR2 crown length	UR2 root length	UR1 crown length	UR1 root length	UL1 root length	UL2 crown length	UL3 crown length	UL3 root length
UR3/SN angle	Correlation Coefficient	1														
	Sig. (2-tailed)															
	N	115														
UR2/SN angle	Correlation Coefficient	.501**	1													

	Sig. (2-tailed)	0.000				
	N	115	115			
UR1/SN angle	Correlation Coefficient	.567**	.710**	1		
	Sig. (2-tailed)	0.000	0.000			
	N	115	115	115		
UL2/SN angle	Correlation Coefficient	.508**	.682**	.711**	1	
	Sig. (2-tailed)	0.000	0.000	0.000		
	N	115	115	115	115	
UL3/SN angle	Correlation Coefficient	.703**	.571**	.549**	.625**	1

	Sig. (2-tailed)	0.000	0.000	0.000	0.000				
	N	115	115	115	115	115			
UR3 crown length	Correlation Coefficient	-0.005	0.049	0.032	0.083	0.038	1		
	Sig. (2-tailed)	0.956	0.600	0.730	0.379	0.685			
	N	115	115	115	115	115	115		
UR3 root length	Correlation Coefficient	-0.165	-0.059	-0.068	-0.052	-0.140	-0.086	1	
	Sig. (2-tailed)	0.077	0.530	0.470	0.580	0.135	0.358		
	N	115	115	115	115	115	115	115	
UR2 crown length	Correlation Coefficient	-0.103	0.105	0.060	0.077	-0.031	.653**	0.024	1

	Sig. (2-tailed)	0.275	0.264	0.523	0.412	0.740	0.000	0.799				
	N	115	115	115	115	115	115	115	115			
UR2 root length	Correlation Coefficient	0.020	0.073	0.074	0.009	-0.144	0.177	.566**	0.086	1		
	Sig. (2-tailed)	0.834	0.439	0.435	0.921	0.124	0.059	0.000	0.360			
	N	115	115	115	115	115	115	115	115	115		
UR1 crown length	Correlation Coefficient	-0.168	-0.022	0.018	0.022	-0.102	.642**	0.030	.667**	0.154	1	
	Sig. (2-tailed)	0.073	0.817	0.851	0.818	0.280	0.000	0.753	0.000	0.100		
	N	115	115	115	115	115	115	115	115	115	115	
UR1 root length	Correlation Coefficient	-0.177	0.027	0.082	0.022	-0.134	-0.044	.628**	-0.004	.627**	-0.048	1

	Sig. (2-tailed)	0.059	0.776	0.382	0.816	0.153	0.637	0.000	0.970	0.000	0.614				
	N	115	115	115	115	115	115	115	115	115	115	115			
UL1 root length	Correlation Coefficient	-.189*	0.011	0.037	0.027	-0.181	-0.106	.661**	0.000	.588**	-0.083	.838**	1		
	Sig. (2-tailed)	0.043	0.909	0.695	0.771	0.053	0.261	0.000	0.999	0.000	0.379	0.000			
	N	115	115	115	115	115	115	115	115	115	115	115	115		
UL2 crown length	Correlation Coefficient	-0.067	0.053	0.046	0.067	-0.020	.611**	0.089	.784**	0.118	.590**	0.005	0.004	1	
	Sig. (2-tailed)	0.474	0.577	0.622	0.475	0.836	0.000	0.345	0.000	0.208	0.000	0.958	0.967		
	N	115	115	115	115	115	115	115	115	115	115	115	115	115	
UL3 crown length	Correlation Coefficient	0.052	0.108	0.085	0.094	0.133	.807**	-0.016	.560**	.188*	.601**	0.041	-0.024	.579**	1

	Sig. (2-tailed)	0.581	0.250	0.368	0.316	0.157	0.000	0.869	0.000	0.045	0.000	0.663	0.799	0.000		
	N	115	115	115	115	115	115	115	115	115	115	115	115	115	115	
UL3 root length	Correlation Coefficient	-0.139	-0.079	0.016	0.042	-0.133	-0.023	.835**	0.064	.581**	0.039	.613**	.629**	0.131	-0.031	1
	Sig. (2-tailed)	0.139	0.402	0.864	0.659	0.157	0.811	0.000	0.499	0.000	0.679	0.000	0.000	0.163	0.745	
	N	115	115	115	115	115	115	115	115	115	115	115	115	115	115	115

****. Correlation is significant at the 0.01 level (2-tailed).**

***. Correlation is significant at the 0.05 level (2-tailed).**

Table 4: Results of PEARSON Correlations (H6)

Table 25. Results of Spearman's Correlations (H6)

	Spearman's rho	**UL1/SN angle**	UL1 crown length	UL2 root length
UL1/SN angle	Correlation Coefficient	1		
	Sig. (2-tailed)			
	N	115		
UL1 crown length	**Correlation Coefficient**	**-0.051**	1	
	Sig. (2-tailed)	**0.588**		
	N	**115**	115	
UL2 root length	**Correlation Coefficient**	**0.049**	0.083	1
	Sig. (2-tailed)	**0.606**	0.377	
	N	**115**	115	115

Table 5: Results of Spearman's Correlations (H6)

DISCUSSION

This study provides novel insights into the anatomical and positional characteristics of maxillary anterior teeth, particularly regarding tooth inclination and dimensions. To the best of our knowledge, no previous research has explored the relationship between tooth inclination and crown and root lengths of maxillary anterior teeth using CBCT imaging. Therefore, our findings fill a significant gap in the existing literature and offer valuable information for orthodontic practice.

The variability observed in the inclination and dimensions of maxillary anterior teeth underscores the complexity of dental anatomy. Each tooth exhibited distinct values for inclination, crown length, and root length, highlighting the unique dentofacial structure of each patient. These results emphasize the need for individualized treatment approaches in orthodontics, as generalized patterns may not accurately represent the diverse patient population.

Our correlation analysis revealed a weak but significant negative relationship between the inclination of the UR3 tooth and the root length of the UL1 tooth. This finding suggests a potential influence of tooth inclination on root morphology, albeit to a limited extent. However, the lack of significant associations between tooth inclination and crown/root lengths of other teeth indicates that factors other than inclination may play dominant roles in determining tooth dimensions.

One of the limitations of this study is the relatively small sample size, which may limit the generalizability of the findings. Additionally, the measurements obtained from CBCT scans may have inherent limitations, including potential errors in image acquisition and interpretation. Despite these limitations, our study provides valuable preliminary data on the relationship between tooth inclination and dimensions, laying the groundwork for future research in this area.

In conclusion, this study contributes to our understanding of dental morphology and its implications for orthodontic treatment. While tooth inclination may have some impact on root morphology, other factors likely play more significant roles in determining tooth dimensions. Future research with larger sample sizes and improved measurement techniques could further elucidate the complex interplay between tooth morphology and orthodontic outcomes, ultimately enhancing treatment efficacy and patient care.

CONCLUSION

In conclusion, this study contributes to our understanding of dental morphology and its implications for orthodontic treatment. While tooth inclination may have some impact on root morphology, other factors likely play more significant roles in determining tooth dimensions. Future research with larger sample sizes and improved measurement techniques could further elucidate the complex interplay between tooth morphology and orthodontic outcomes, ultimately enhancing treatment efficacy and patient care.

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