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PREVALENCE OF SHORT ROOT ANOMALY IN PATIENTS SEEKING ORTHODONTIC TREATMENT

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by

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ABSTRACT

Introduction: The purpose of this study was to investigate variance in prevalence and severity of short root anomaly (SRA) in patients seeking orthodontic treatment, stratified by ethnicity and sex. **Materials and Methods:** In this retrospective cross-sectional study, we evaluated 896 patients who had initial cone-beam computed tomographies (CBCTs) taken from July 1, 2014 to May 30, 2019. Panoramic radiographs and images from the CBCTs of each patient were extracted and placed in a database. The crown-to-root ratio of maxillary central incisors, lateral incisors, canines, and all pre-molars were evaluated to determine the presence, severity and associations of SRA. A Chi-square test and ordered logistic regression were used. **Results:** SRA was seen in 10.04% of the sample (90 patients). The maxillary central incisors are the most frequently and bilaterally affected. The severity of SRA among those with SRA showed statistically significant differences between the ethnic groups. Associations been SRA and Hispanic patients were found to be significant when evaluated by ordered logistic regression (P<.0001, Odds ratio=7.54, 95% CI 3.08-18.48). **Conclusions:** The prevalence of SRA was highest in Asian and Hispanic patients. Hispanic patients were most affected by severe forms, while Asian patients were most affected by mild forms. In patients classified with SRA, Hispanic and Latino patients were found to have higher odds of getting SRA of the maxillary central and lateral incisors. In patients with moderate to severe SRA, there were greater odds of having SRA if a patient were Hispanic or Latino.

INTRODUCTION

Short root anomaly (SRA) has been described as developmentally 'abnormally short roots of characteristically plump shape, affecting both maxillary central incisors'.[1] It is a condition that is not a result of orthodontic treatment, but a genetic pre-disposition for short roots often observed prior to orthodontic treatment.[1] While there is a vast amount of literature on root resorption and orthodontically induced root resorption (OIRR), a limited number of studies have focused on SRA. A growing number of graduate orthodontic clinics have observed an increased number of patients presenting with short root anomaly prior to orthodontic treatment and have started to evaluate this growing trend.[2]

SRA was first described in Sweden by Volmer Lind in 1972.[1] Abnormal and incomplete root development results in an altered crown-to-root ratio. The relationship between the crown and root lengths is usually more important than the absolute root length, which is why it is most commonly expressed as a ratio.[12] The crown-to-root ratio in SRA affected teeth is significantly decreased when compared to the crown-to-root ratio in unaffected teeth. The ratio in unaffected teeth was found to be 1.6 to 1, while the ratio in SRA affected teeth was 1.1 to 1.[1] Pretreatment orthodontic patients have been found to have a 1.2-10% incidence of developmentally short roots.[3]

Root resorption is a well-known sequalae of orthodontics. The distinction of SRA from root resorption in the 1970s was significant as it provided a specific diagnosis for this anomaly. [1] Prior to this characterization, teeth with short roots were commonly misdiagnosed and often overlooked because no clinical symptoms were evident. [1]

The first study of SRA provided initial evidence for the frequency of the condition as Lind's Swedish sample showed a prevalence of 2.4 to 2.7%.[1] Other studies have shown varying ranges of prevalence among different ethnic groups. Japanese and Mongolian samples showed a prevalence of 10%, while Turkish and Finnish populations have shown a prevalence of .3 to 1.2%, respectively.[4,5,6,7] A 2018 study by Xolo et al. found a prevalence of 9% in a Mexican population.[8] These studies indicate that there are varying levels of SRA prevalence between ethnic groups.

The relationship of ethnicity, sex, and short dental roots was examined by Edgcomb et al. in 2011. Maxillary and mandibular central and lateral incisors, as well as second premolars, were measured.[9] The measurements were compared between experimental groups consisting of Asian, African-American, Hispanic and Caucasian subjects.[9] The Asian experimental group was found to have the shortest roots, while female subjects were found to have shorter roots when compared to their male counterparts.[9]

New literature and observations indicate that Hispanic populations may have a higher tendency to develop SRA[3] As the demographics in the United States continue to evolve and change, it is likely that SRA will be seen more commonly in orthodontic practices.[3] This is important for orthodontists since orthodontic treatment has been shown to increase the risk for root resorption.[17]

To our knowledge very few studies have examined SRA with panoramic radiographs constructed from three-dimensional CBCTs. Traditionally, two-dimensional imaging has been used to assess root length. Common problems of two-dimensional imaging are patient orientation, tooth overlap, foreshortening, and elongation of roots. Three-dimensional CBCT imaging overcomes these shortcomings and provides a reliable and valid method of detecting root defects.[15.] Three-dimensional imaging enables the clinician to assess a variety of different measurements previously unavailable in two-dimensional imaging. CBCT imaging provides the ability to adjust the focal troughs to account for tooth inclinations, as well as providing a three-dimensional volume which can be rotated and adjusted to verify root position and length. CBCTs can provide high resolution images with multiplanar reconstructions providing a method for both accurate and precise assessment of root length.[14.] The accuracy of root measurement, and thus SRA assessment, can be enhanced through the use of three dimensional CBCT imaging.

The purpose of the current study was to investigate variance in prevalence and severity of short root anomaly in patients who sought orthodontic treatment at the Graduate Orthodontic Cinic, stratified by ethnicity and sex. Root lengths and crown-to-root ratio were evaluated using panoramic radiographs generated from three-dimensional CBCTs. The central hypothesis of this study was that in patients seeking orthodontic treatment who are older than 10 years of age, there is no association between presence of SRA and the patient's ethnicity. We attempted to answer the following specific questions and each

question was tested in a null hypothesis form:

- Is the prevalence of SRA different between different ethnic groups?
- Is the severity of SRA different between different ethnic groups?
- Is the prevalence of SRA different between sexes?
- Which teeth are most at risk for SRA?

MATERIAL & METHODS

Institutional Review Board (IRB) approval was obtained from the University of the Pacific prior to the start of this study (IRB #19-118). In this retrospective cross-sectional study, a search was performed via Axium Dental Software (Portland, OR) for all patients having initial cone-beam computed tomography (CBCT) taken at the University of the Pacific, Arthur A. Dugoni School of Dentistry, Graduate Orthodontic Clinic (San Francisco, CA) from July 1, 2014 to May 30, 2019. All patients had CBCTs as part of their routine diagnostic orthodontic records prior to orthodontic treatment. The main inclusion criterion for the study was the presence of an Initial CBCT (T1) obtained during the study time frame. The initial search identified 1201patients. The exclusion criteria for the study were: 1) Previous orthodontic treatment; 2) craniofacial anomalies; 3) incomplete root development of teeth to be measured; 4) younger than 10 years of age. After applying the exclusion criteria, the final sample included 896 patients. Case numbers were assigned to patients in the sample, which allowed patients to be identified without exposing their information to the examiners.

All CBCTs scans were acquired using the i-CAT^{TM} Next Generation with 8.9 second exposure time (16 cm x13 cm or 23 cm x17 cm FOV, 0.3 mm voxel size). Panoramic radiographs were extracted from the CBCT volumes, and additional images were obtained from 3D volume rendering and placed into a database for evaluation (Figure 1).

The sample of 896 patients was equally divided and evaluated by four dentists who had been working with CBCTs and 3-dimensional imaging for at least a year. All judges were calibrated to evaluate crown-to-root ratio using the Presence of SRA Scoring Guide (Table I). Borderline cases were discussed among all judges so they could reach an agreement on the presence of SRA. Based on literature, the six anterior teeth and all premolars were evaluated. Lind defined the crown-to-root ratio in normal teeth to be 1.6 to 1, while the ratio in SRA affected teeth was 1.1 to 1.[1] Therefore, in our study, normal was defined as greater than 1:1 crown-to-root ratio with a score of 0, while SRA was defined as equal or less than 1:1 crown-to-root ratio with a score of 1.

All patients in the sample were contacted to verify their identified ethnicity in one of five different groups: Asian, Hispanic, African American or Black, White, and Other. The definition for each ethnicity used in the sample was defined by the NIH website and is seen in Table II.[10]

Once the assessment for the presence of SRA was completed, the severity of SRA was evaluated in the patients identified with having SRA. The same judges evaluated all SRA cases. At least 2 of the judges' scores had to agree for a score to be valid for the final severity score for each tooth. The average of the 4 judges' scores was used and rounded to the nearest whole number for each incisor. A score of 1 indicated mild SRA, a score of 2 indicated moderate SRA and a score of 3 indicated severe SRA (Table III & Figure 2).

Statistical analyses

Intraclass correlation coefficient (ICC) was used to evaluate inter-judge reliability for evaluating severity of SRA scorings. Descriptive statistics were generated to report the proportion (percentage) of each ethnicity, sex, and presence of SRA for each of the ethnic group. A Chi-square test was used to evaluate inter-variable relationships between ethnic groups, SRA severity and sex. SRA severity is classified as ordinal data. To analyze the ordinal dataset, ordered logistic regression was used once a binary model was created. We used race as an independent variable for evaluation, non-Hispanic or Latino versus Hispanic or Latino patients. The proportional odds assumption has to be assumed, such that each tier is proportionally similar to each

other. An odds ratio of less than 1 would indicate that Hispanic patients had higher odds of normal root lengths when compared to not Hispanic patients. An odds ratio of greater than 1 would indicate that Hispanic patients had higher odds of shorter root length when compared to non-Hispanic patients. For the evaluation of the association of SRA with the maxillary anterior teeth, each judge's severity score for each tooth was counted independently, and calculated odds ratio (OR) for the low and high scores for each tooth were calculated separately. For each derived OR, both the P-value and the 95% confidence interval (95% CI) are presented to show the range of values for each tooth evaluated for SRA. P-values less than 0.05 were considered statistically significant. Statistical values were computed using the SAS statistical package (version 9.4, SAS, Cary, NC) and STATA (El Paso, TX).

RESULTS

ICC showed good inter-judge reliability for SRA severity scoring, ranging from 0.81- 0.89. The sex and ethnicity distributions for each group are shown in Table IV. The sample consisted of 896 patients, 41.9% male (n=375) and 58.2% female (n=521). The ethnic and sex breakdown of the sample was as follows: 210 Asian (23.4%), 397 Hispanic (44.3%), 203 White (22.7%), 74 Black (8.3%) and 12 Other (1.3%). Male and female proportions were similar among all ethnic groups (Figure 3).

Presence of SRA among the ethnic groups

The frequency and percentage for the Presence of SRA are shown in Table V. 90 patients were classified as having SRA, which was 10.04 % of the sample. 806 patients were classified as having normal crown-to-root ratios, which was 89.96% of the sample. Of the 90 patients classified with SRA, 46 were Hispanic (11.59% of Hispanic patients), 25 were Asian (11.9% of Asian patients), 15 were White (7.39% of White patients), 4 were Black (5.41% of Black patients) and 0 were from the Other group. There was no statistical difference in the prevalence of SRA between ethnic groups (P=0.1625, Chi-square Test).

Severity of SRA between ethnic groups

The descriptive statistics for the severity of SRA are shown in Table VI and figure 4. The Other group (n=12) was excluded from the data analysis because no patients were identified as having the presence of SRA. Of the 90 SRA patients, 38 were mild SRA (n=38/90, 42.22%), 37 were moderate SRA (n=37/90, 41.11%) and 15 were severe SRA (n=15/90, 16.67%). Interestingly, out of the 15 patients with severe SRA, 14 were Hispanic and 1 was Asian. Asian patients had a higher frequency of mild SRA than the other ethnicities. There was a statistically significant difference found (p= 0.0015, Chi-square Test) between the ethnic groups.

Sex Difference in SRA prevalence

The descriptive statistics for SRA by sex are seen in Table VII. Of the 806 patients that were classified as having normal root length, 57.57% (n=464) were female and 42.43% (n=342) were male. Of the 90 patients that were classified as having SRA, 63.33% (n=57) were female and 36.67% (n=33) were male. There was no statistical difference (p=0.293) in all SRA patients or within each ethnic group.

Associations of SRA with maxillary anterior teeth and ethnicity

At least one maxillary central incisor was involved in all SRA patients: The maxillary central incisors were involved bilaterally in 94% (85/90) of the SRA patients. 20% of SRA patients presented with SRA of both the maxillary central and lateral incisors, while 4 patients had all six maxillary incisors with SRA (Table VIII). In addition, short roots were seen in premolars in 26 (29%) patients who were affected with SRA incisors; half involved premolars in the mandible only and the rest included both the maxillary and mandibular premolars. With greater severity, there was a tendency for more teeth to be involved with SRA.

Ordered logistic regression was used to assess the association between race and the teeth that had the most severe forms of SRA. The results of the ordered logistic regression for maxillary central incisors, lateral Incisors, and canines are seen in the forest plot in Figure 6. In patients who have SRA, the odds

ratios indicate the odds of each tooth having SRA if the patient is Hispanic or Latino vs. non-Hispanic or Latino. For example, for the low UR1, OR = 3.43, indicating that patients have 3.43 more odds of getting SRA of the UR1 if they are Hispanic or Latino. The results of the ordered logistic regression showed statically significant values for the UR1, UR2, UL1 and UL2 (p-values ranging from .002 to .045).

The results of the ordered logistic regression to assess associations between patients with moderate to severe SRA and ethnicity was highly statistically and clinically significant (P<.0001, OR = 7.54, 95% CI 3.08-18.48). The OR indicates that patients with moderate to severe SRA are 7.54 times more odds of getting SRA if they are Hispanic or Latino.

DISCUSSION

Lind advocated for the early diagnosis of short root anomaly and prophylactically attempting to protect central incisors from unnecessary stresses that could increase the risk of resorption.[1] The risk of root resorption during tooth movement may be greater for teeth with short roots, demonstrating the importance of developing a greater understanding of SRA and its prevalence among orthodontic patients.[13]

Despite the differences in SRA prevalence between the different ethnic groups, the data was not statistically significant. The results, however, indicate that Asian and Hispanic patients have a higher tendency for SRA and short roots, when compared to White and Black patients.

The White patients in the study had a SRA prevalence of 7.39%, which is higher than previous findings of 2.4-2.7%, while the Asian patients had a prevalence of 11.90%.[1] The Asian prevalence was slightly higher than previous findings where Japanese and Mongolian populations showed an SRA prevalence of 10%.[6] The Hispanic patients had a prevalence of 11.58%, which was also slightly higher then results found by Xolo et al., which showed an SRA prevalence of 9% in a Mexican sample.[3] The SRA prevalence found in this study support previous findings that untreated patients seeking orthodontic treatment have a 1.2-10%

incidence of developmentally shorts roots.[3] Our results, however, show slighter higher percentages of prevalence among all ethnic groups. Since previous studies were evaluated on two dimensional panoramic or periapical radiographs, it is not clear if CBCT analysis allowed for a larger identification of SRA patients.

In assessing the severity of SRA, the results were statically significant between ethnic groups. Hispanic patients made up the highest percentage of SRA patients (51.11%, n=46/90), followed by Asian patients (27.88%, n=25/90). Hispanic patients also had the highest percentage of severe (93.33%, n=14/15) and moderate (59.46%, n=22/37) forms of SRA, while Asian patients had the highest percentage of mild (39.47%, n=15/38) forms of SRA. Asian patients also had the second highest percentage of moderate (24.32%, n=9/37) and severe (6.67%, n=1/15) forms of SRA. These findings were in close agreement with Edgecomb et al.[9]

Differences in SRA between sexes was not statistically significant (p=0.293). Despite this, there was a higher percentage of female SRA patients (63.33%, n=57) when compared to male SRA patients (36.67%, n=33). This result could be influenced by the larger number of female Asian participants in the study. Given these results and previous studies finding higher prevalence of short roots in females, a larger study focused on sex differences may be of interest.

Additionally, the patient demographics of this study (44.3% Hispanic) align with the findings of Puranik et al., who noted the increasing Hispanic population in orthodontic practices in the United States.[2,3.]

In agreement with previous studies, we found that the maxillary central incisors are the most frequently affected.[1,2, 7,] They were bilaterally involved in 94% of the SRA patients. The maxillary lateral incisors, mandibular second premolars, and maxillary premolars were the other most frequently affected teeth.

Statically significant associations between SRA and Hispanic patients were found in this study. Hispanic or Latino patients with moderate to severe SRA were found to be 7.54 more odds of getting SRA than non-Hispanic or Latino patients. Additionally, in all the patients with SRA, Hispanic or Latino patients were found to have a higher likelihood of getting SRA of the maxillary central and lateral incisors than non-Hispanic or Latino patients.

There were several limitations to this study. First, the teeth were not directly measured on the three-dimensional volumes using the measurement tools within the software. Second, the sample was collected from a single institution (Graduate Orthodontic Clinic), so the patient population may not reflect that of other orthodontic practices. Therefore, generalizability of the results of the study can be limited. Further study is needed in other clinical settings.

Future SRA studies may help to overcome the limitations of the current study and provide more accurate assessment of the prevalence and cause of SRA. Three-dimensional measurements of root and crown would allow for more accurate assessment of crown-to-root ratios of affected teeth. Additionally, genetic testing via saliva samples of patients with short roots would allow for the genetic component of SRA to be evaluated and to determine if genes like MSX1 and other craniofacial genes play a role in SRA.[7]

Furthermore, previous studies have identified marked sex differences when analyzing patients who fall in the extreme ends of group classifications, i.e. having extremely short or long roots by falling two standard deviations away from the mean.[12] A future analysis of not only short roots, but also long roots in patients may allow for further assessment of these observations. In addition, the role of SRA in the development of malocclusions may also serve to help the orthodontist better treat patients with the anomaly. Finally, further study is needed to investigate whether teeth affected by SRA are more susceptible to orthodontically induced external root resorption.

CONCLUSION

The current study found short root anomaly in 10.04% of the sample. While there was no statistically significant difference in SRA between ethnic groups, the prevalence of SRA was highest in the Asian patients at 11.90%, followed by Hispanic patients (11.58%), White patients (7.39%) and Black patients (5.41%).

The severity of SRA showed a statistically significant difference between the ethnic groups. Hispanic patients were most affected by severe and moderate forms of SRA, while Asian patients were most commonly affected by mild forms of SRA.

There were no statistically significant differences between the sexes. However, of the patients identified as having SRA, there was a higher percentage of female patients when compared to males.

There were statistically significant associations between SRA and ethnicities. In patients with moderate to severe SRA, there were greater odds (OR=7.54) of having SRA if a patient was Hispanic or Latino versus non-Hispanic or Latino. Additionally, the maxillary central incisors are the most frequently and bilaterally affected. In patients classified with SRA, Hispanic and Latino patients were found to have higher odds of getting SRA of the maxillary central and lateral incisors than non-Hispanic or Latino patients.

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FIGURE LEGEND

Figure 1. SRA Database Image

Figure 2. Severity of SRA Scoring

Figure 3. Sample distribution by sex for each ethnic group

Figure 4. Percentages of SRA Severity between ethnic groups

Figure 5. Forest Plot: Odds Ratio for the Maxillary Anterior Teeth

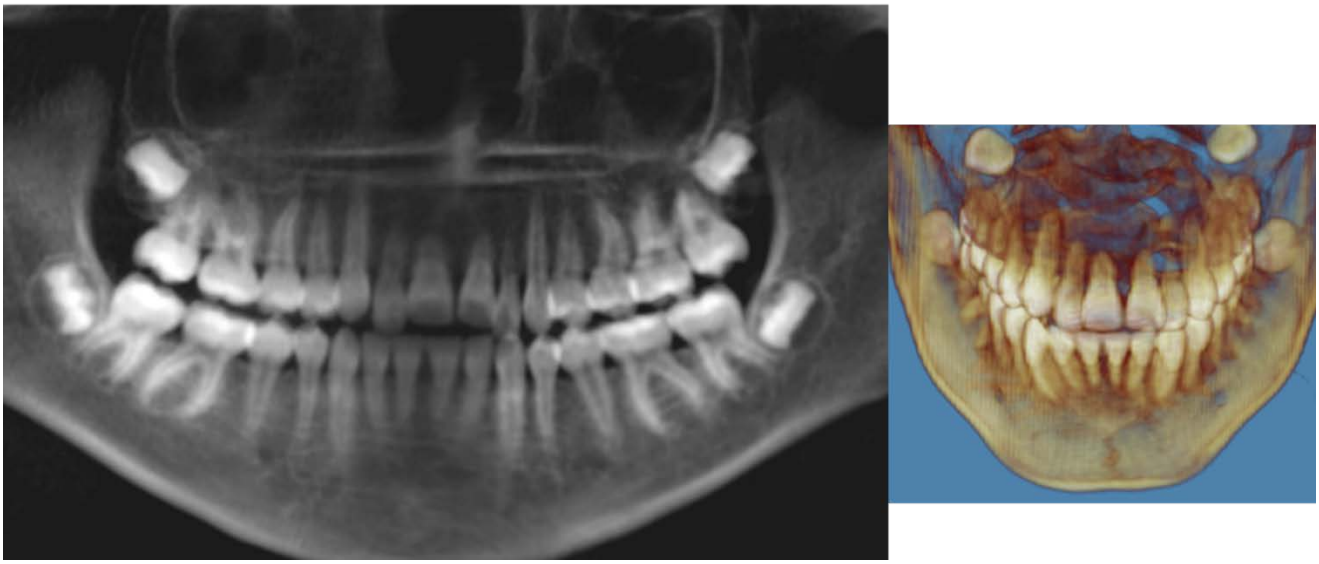

Fig 1. Panoramic radiograph and volume rendering view

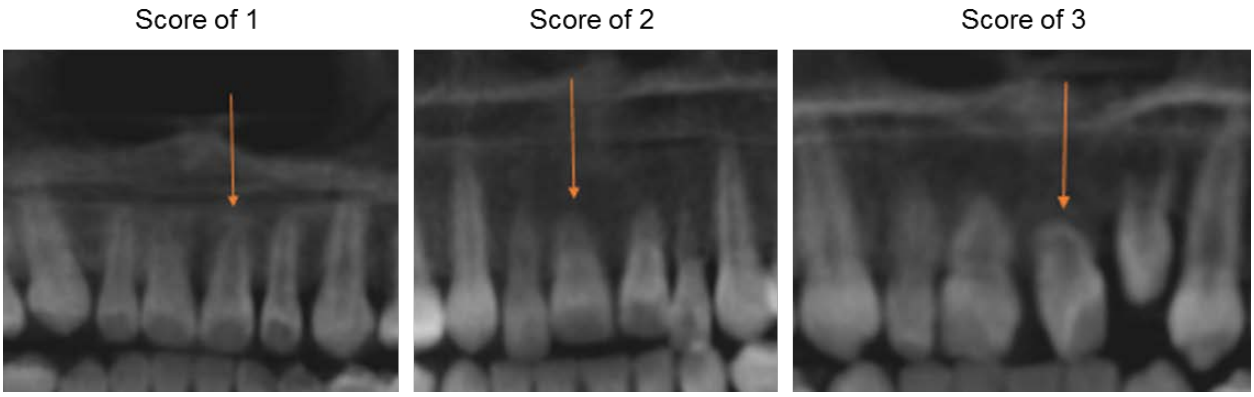

Fig 2. Severity of SRA Scoring

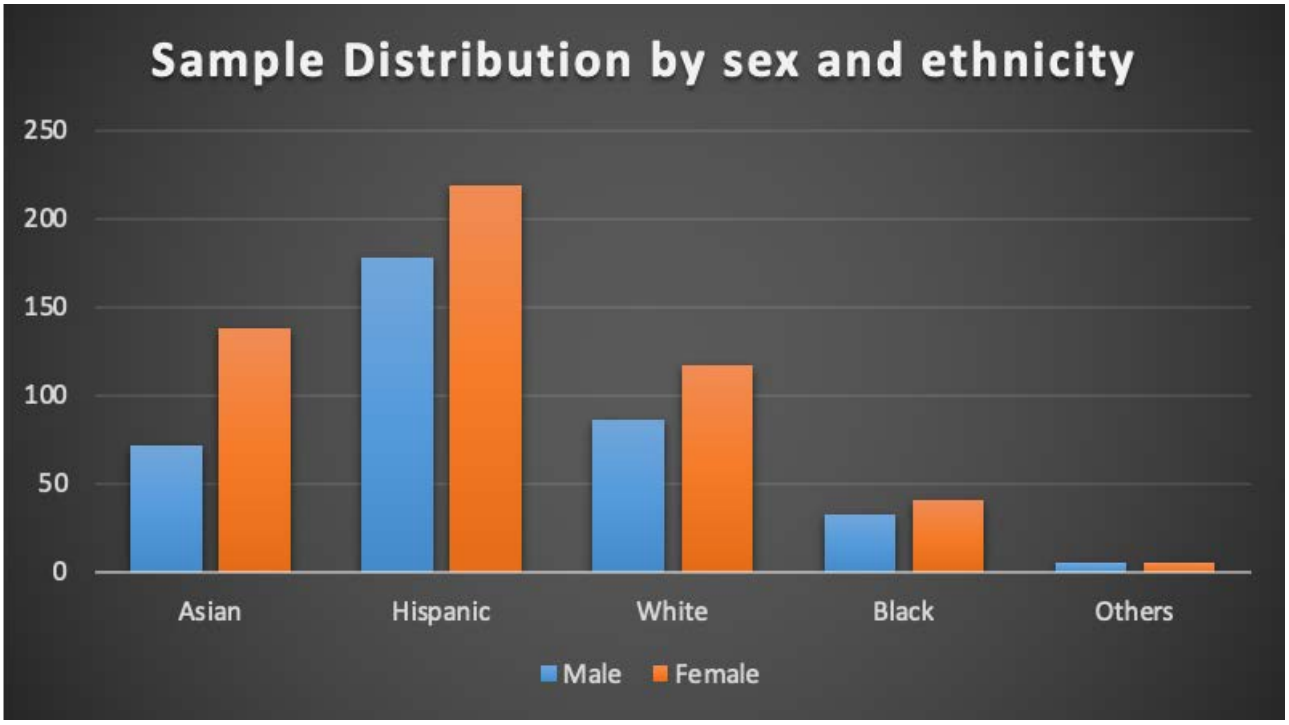

Fig 3. Sample distribution by sex for each ethnic group

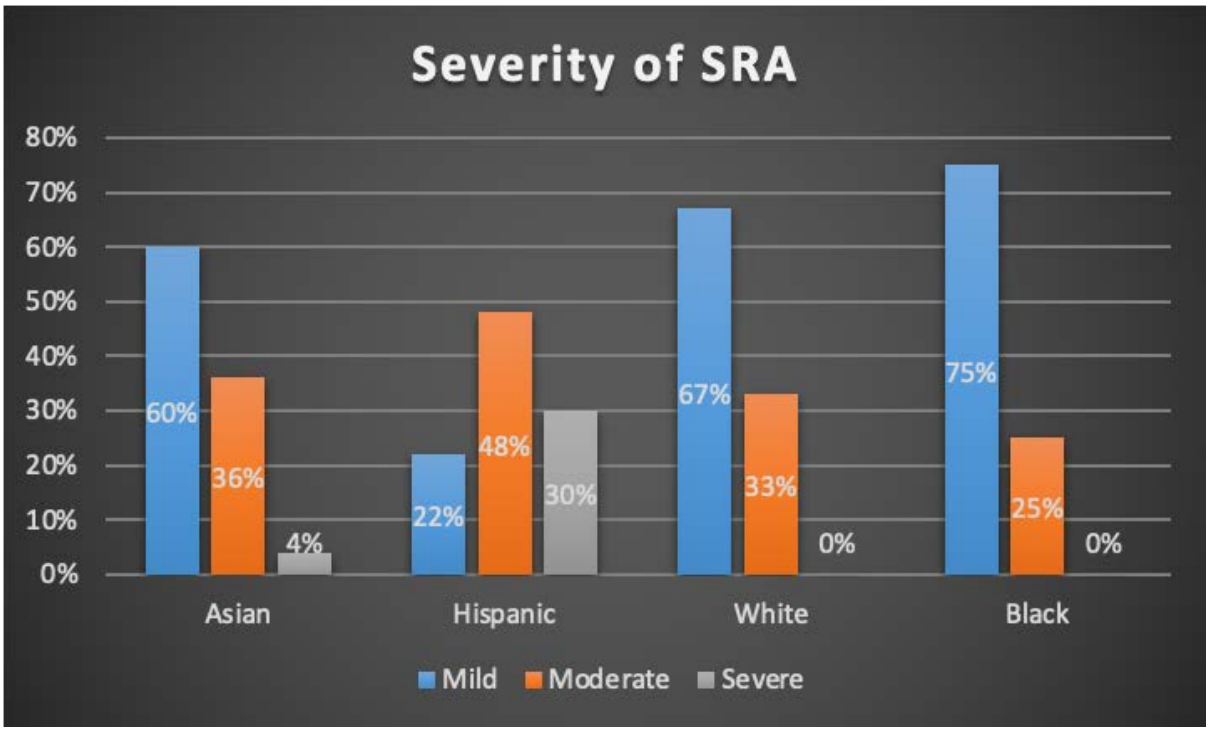

Fig 4. Percentages of SRA Severity between ethnic groups

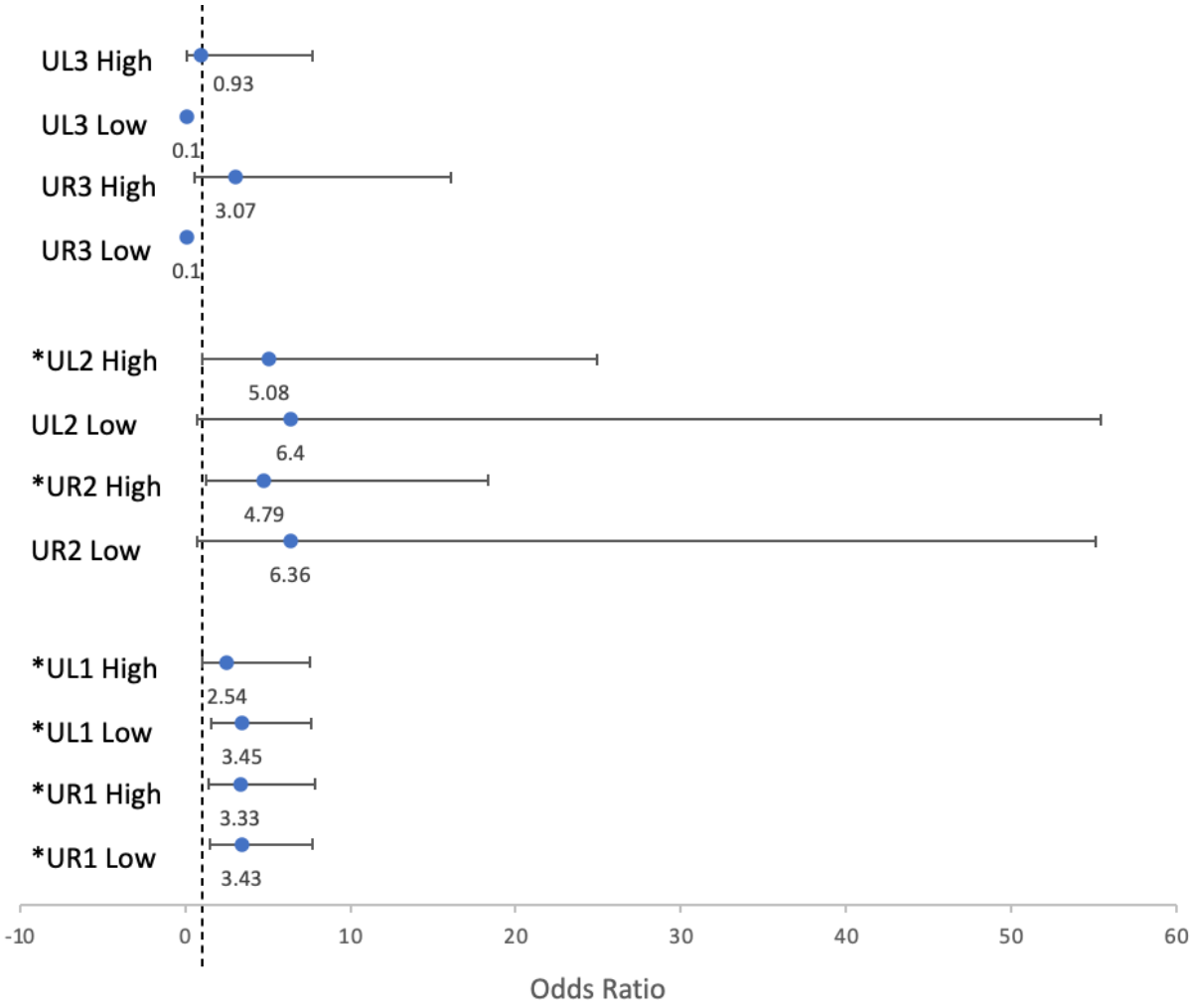

Fig 5. Forest Plot: Odds Ratio for the maxillary anterior teeth

* Indicates statistically significant; 95% CI was presented

Table I. Presence of SRA Scoring Guide

C:R Ratio	Score	Classification	Definition
> 1 : 1	0	Normal	length of the root is longer than the length of the crown
≤ 1 : 1	1	SRA	length of the root is shorter than the length of the crown

Table II. Sample Ethnic Categories and NIH Definition

ASIAN A person having origins in any of the original peoples of the Far East, Southeast Asia, or the Indian subcontinent including, for example, Cambodia, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand, and Vietnam.
HISPANIC OR LATINO A person of Cuban, Mexican, Puerto Rican, South or Central American, or other Spanish culture or origin, regardless of race. The term, "Spanish origin," can be used in addition to "Hispanic or Latino.
AFRICAN AMERICAN OR BLACK A person having origins in any of the black racial groups of Africa. Terms such as "Haitian" or "Negro" can be used in addition to "Black or African American.
WHITE A person having origins in any of the original peoples of Europe, the Middle East, or North Africa.
OTHER American Indian, Alaska native, Native Hawaiian, Other Pacific Islander, anyone not identifying with other ethnicities

Table III. Severity of SRA Scoring

C:R Ratio	Score	Classification	Description
1 : 1	1	Mild SRA	length of the root is about the same as the length of the crown
1 : 1 ~ 0.5	2	Moderate SRA	length of the root is shorter than the length of the crown but longer than half of the crown length
1: < 0.5	3	Severe SRA	length of the root is shorter than a half of the crown length

Table IV. Sample Distribution by Sex and Ethnicity

	Male		Female		Total	
Ethnicity	N	%	N	%	N	%
Asian	72	34.3	138	65.7	210	23.4
Hispanic	178	44.8	219	55.2	397	44.3
White	86	42.4	117	57.6	203	22.7
Black	33	44.6	41	55.4	74	8.3
Others	6	50	6	50	12	1.3
Total	375	41.9	521	58.2	896	100

Table V. Presence of SRA between the ethnic groups

	No SRA		SRA		Total
Ethnicity	N	%	N	%	N
Asian	185	88.1	25	11.9	210
Hispanic	351	88.4	46	11.6	397
White	188	92.6	15	7.4	203
Black	70	94.6	4	5.4	74
Other	12	100	0	0	12
Total	806	90	90	10	896

Table VI. Severity of SRA between ethnic groups.

	Mild (1)		Moderate (2)		Severe (3)		Total
Ethnicity	N	%	N	%	N	%	N
Asian	15	60.0	9	36	1	4.0	25
Hispanic	10	21.7	22	47.8	14	30.4	46
White	10	66.7	5	33.3	0	0	15
Black	3	75.0	1	25.0	0	0	4
Total	38	42.2	37	41.1	15	16.7	90

Table VII. Sex difference in SRA prevalence

	Male		Female		Total
	N	%	N	%	N
Normal	342	42.4	464	57.6	806
SRA	33	36.7	57	63.3	90
Total	375	42	521	58	896

Table VIII. Number and distribution of tooth with short root in patients with SRA

Tooth group	N	%
Unilateral maxillary central incisor	5	5.6
Bilateral maxillary central incisors	63	70
Bilateral maxillary central and lateral incisors	18	20
All maxillary six anterior teeth	4	4.4
Total	90	100