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RESEARCH ARTICLE

INCISIVE CANAL AND ITS PROPINQUITY TO MAXILLARY CENTRAL INCISORS IN VARIOUS SAGITTAL GROWTH PATTERNS: A CBCT STUDY

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Abstract

Aim: To evaluate and compare the position of the incisive canal to maxillary central incisors root using CBCT among subjects with different sagittal growth patterns.

Materials and Method: Seventy subjects with ages ranging from 18 to 45 years were divided into three sagittal Skeletal malocclusion groups. 6 linear variables were measured from the CBCT images obtained from the Carestream CS 9300C 3D system which included 3 transverse and 3 anteroposterior measurements. All measurements were carried out at three different vertical levels, the palatal opening of the incisive canal (L1), mid-level (L2), and root apex of the maxillary central incisors (L3). The digitization and measurements were carried out using Trophy Dicom CS 3D software.

Results: Greatest incisive canal width (Cl-Cl) was seen in Skeletal Class III malocclusion and smallest in Class II malocclusion. Skeletal Class III malocclusion showed significantly smaller inter-root distance than Class I and Class II. In Class I malocclusion, the average anteroposterior distance between incisive canal and maxillary central incisor roots was approximately 4-5mm, 2-4mm in Class II, and 3-4mm in Class III malocclusion.

Conclusion: The incisive canal and its association to the roots of the maxillary incisors are affected by the various sagittal skeletal malocclusions. In order to minimise difficulties while contemplating a substantial amount of retraction, 3D assessment may be helpful.

Introduction:-

The location of the maxillary anterior teeth is a key factor in aesthetic balance and maxillofacial functions. It plays an important role in the functioning of the normal physiology like pronunciation and mastication[1,2]. To improve the aesthetic in patients with marked proclined anterior teeth, maximum anterior teeth retraction is required after

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premolar extraction and for a successful treatment with stability in the long term, orthodontic tooth movement within biological limits is desired[3].

The palatal cortical plate has commonly been considered as the limit for retracting maxillary anterior teeth. Certain complications such as root resorption, fenestration, and dehiscence occur if the teeth are moved out of the cortical bone[4]. However in some studies, it was found that the upper central incisor root distance to the incisive canal is lesser than to the palatal cortical plate[5,6].

The incisive canal is a mid-structure present in the maxilla that runs posteriorly and closer to the root of the central incisor surrounded by cortical bone[7,8]. Despite the well-defined anatomy of the incisive canal, there are very little available data in orthodontic literature regarding the exact position of an incisive canal and its relationship to the maxillary central incisor roots. But, recent advances in 3D imaging, help to detect the association of maxillary incisors root to the incisive canal and obtain more detailed information. Therefore, the objectives of this study were to assess the position of the incisive canal in relation to the root of the maxillary central incisors in various malocclusions using cone-beam computed tomography, as well as to compare the relationship between the incisive canal and the maxillary central incisors in various malocclusions, on the hypothesis that skeletal typology could influence the distance between the incisor roots and the incisive canal.

Materials and Method:-

The present study was conducted on CBCT records of 70 subjects which were divided into three different malocclusion groups: Group I (Skeletal Class I), Group II (Skeletal Class II), and Group III (Skeletal Class III) on the basis of ANB angle[9], β angle[10] and Wits Appraisal[11] (Table 1). The sample size was calculated using the

$$n = \frac{\left(z_\alpha + z_\beta\right)^2}{\left[\ln\left(1-e\right)\right]^2}\left[\frac{1-p_1}{p_1} + \frac{1-p_2}{p_2}\right]$$

Where $p_1 = 0.868$ (86.8%) the proportion of subjects with incisive canal width greater than central inciser at level 1

$p_2 = 0.632$ (63.2%) the proportion of subjects with incisive canal width greater than central inciser at level 1

proportion ratio e = 0.3, considered to be clinically significant

Type I error, α=5%

Type II error β=80% for setting power of study 80%

Samples were not segregated into males and females in the current study because such segregation did not show any significant difference. Approval was obtained from the Ethical Committee of the University before starting the study.

Inclusion Criteria:

1. Well-defined CBCT of subjects with ages ranging from 18-45 years which included both sexes having Class I, II, and III skeletal patterns.
2. No history of orthodontic/orthopaedic and surgical treatment.
3. No history of trauma/systemic diseases/ bone deformities/ neuromuscular deformities.
4. All permanent teeth erupted except the third molars.

Exclusion criteria:

1. Any radiographic evidence of pathology with the maxilla or mandible.
2. Crown or significant restorations on any anterior teeth.
3. Presence of any primary teeth.
4. Any congenital defect in the dentofacial or in the head and neck region
5. Crossbite and openbite.
6. Damage/extorted CBCT 3D acquisitions.

The DICOM (Digital Imaging and Communications in Medicine) format was used to extract the CBCT data, which was then imported into Trophy DICOM CS 9300 3D software. Each image was standardized and aligned so that the Frankfort horizontal plane was parallel to the floor. With the CS 9300 3D software, the 2D image of a lateral cephalogram was generated in the sagittal view at the slice thickness of 167.8mm to divide the samples into different malocclusions.

Orthogonal slicing was used for visualizing the incisive canal and maxillary central incisors in both sagittal (Figure 1a) and cross-sectional view (Figure 1b). In the sagittal plane, three vertical levels were determined (Figure 2) as described by Cho EA *et al*.[6] at a slice thickness of 250-750 µm.

In the axial cross-sectional view, a total of 6 linear measurements in mm were evaluated from the CBCT images based on the anatomical landmarks (Figure 3) which included 3 transverse (Figure 4) and 3 anteroposterior (Figure 5) measurements at level L1, L2, and L3. In the anteroposterior direction, bilateral measurements were taken i.e., one from an incisive canal to the right central incisor and the other to the left central incisor. The smaller of the two values was chosen as a representative value as suggested by Cho EA *et al*.[6].

All the statistical analyses were performed using SPSS 16.0 Windows software. Data were summarized as Mean + SD. Analysis of Variance (ANOVA) and Post hoc Tukey HSD test was used to evaluate group comparison.

Results:-

The mean values of transverse, as well as anteroposterior measurements in different malocclusions, are detailed in Tables 2, 3.

Incisive canal width and distance between maxillary central incisor roots (transverse measurements)

Mean incisive canal width was maximum in Class III malocclusion and minimum in Class II malocclusion. The Cl-Cl was significantly smaller at L3 than L1 ($p<0.001$) in Class I and Class II malocclusions, whereas in Class III no significant difference was observed (Table 4). On intergroup comparison, a significant difference in Cl-Cl was seen between Class II and Class III malocclusions at level L1 and L3 ($p<0.05$) (Table 5).

Mean Rm-Rm was minimum in Class III malocclusion at all three levels. Rm-Rm increased significantly from L1 to L3 ($p<0.05$) in Class I and Class II malocclusions (Table 4). Rm-Rm showed a significant difference on the intergroup comparison at level L3 ($p<0.05$) (Table 5).

Rp-Rp was significantly smaller at L3 than L1 ($p<0.05$) in all malocclusions (Table 4). No statistically significant differences among the malocclusions were found (Table 5).

Distance between the incisive canal and maxillary central incisor roots (anteroposterior measurements)

Rm-Cat was smaller significantly at L3 than L1 ($p<0.05$) in Class I and Class II malocclusions, whereas Class III malocclusion did not show any significant differences (Table 4). At all three levels, there was a significant difference ($p<0.05$) between the malocclusions, with the exception of L1 between Class II and Class III and L3 between Class I and Class III. (Table 6).

Rm-Canal and Cl-Root showed a significant difference between L1 and L3 in all the malocclusions (Table 4). Rm-Canal and Cl-Root showed significant differences ($p<0.05$) between all the malocclusions at all three levels (Table 6).

Discussion:-

The incisive canal is an intraosseous structure that is situated in the anterior portion of the hard palate and lies palatally to the maxillary incisors. Studies have shown that due to the closeness of the incisive canal to maxillary central incisors, the nasopalatine nerve and artery are susceptible to injury during dental procedures[12,13]. Compression and injury to the neurovascular tissues have been reported while placing TAD which resulted in the loss of sensory function in the anterior palate. Failure of TAD due to lack of primary stability has also been observed[14].

Cortical bone surrounds the incisive canal and because of its vicinity to the roots of maxillary central incisors, root resorption of the teeth has been reported during maximum retraction[3]. As recommended by the inner envelope of discrepancy[15], orthodontic therapy alone can retract the maxillary incisor by 7 mm. But a greater amount of retraction can be achieved effectively and easily with the help of a temporary anchorage device when compared with conventional mechanics[16]. However, this may increase the likelihood of approximation of the root to the incisive canal and lead to resorption. Chung CJ *et al*.[3] was the first to report severe root resorption of the central incisors due to their contact with the incisive canal. Imamura T *et al*.[17] reported that due to the evaluation of the anatomical structures in the anterior region of the maxilla using CBCT before treatment, the root resorption was minimized after considerable retraction and intrusion of maxillary incisors. Cho EA *et al*.[6] in their study concluded that the anteroposterior distance between the incisive canal and central incisor roots was 5-6 mm. To the best of my knowledge, no studies are available in the literature that has evaluated the incisive canal and its relation to maxillary central incisors in different malocclusions (Skeletal Class I, Skeletal Class II, and Skeletal Class III).

In our study samples were not segregated into males and females because such segregation did not show any significant difference as reported in previous studies[6,18].

The average canal width at the L3 level in our study was found to be similar to the findings of Song WC *et al*.[19] where they reported that the average width of the incisive canal at the apical third of the root ranges from about 3 to 5 mm. The mean of Cl-Cl decreased significantly from L1 to L3 in Group I and Group II ($p<0.001$) (Table 4). These findings were supported by the work of Cho EA *et al*.[6]; Matsumura T *et al*.[20]; Gull MA *et al*.[18] where they said that the incisive canal was significantly larger at the level of the maxillary incisor root apex than at the level of the oral-nasal opening. In Group III, no significant difference in Cl-Cl was observed from L1 to L3 ($p>0.05$) (Table 4). This could be due to morphological variances in the shape of the canal as stated by Mardingeret*et al*.[21] and Etoz M *et al*.[22] who concluded that in the cross-sectional view of CBCT scans the incisive canals vary from person to person into funnel-shaped, hour-glass shaped, cylindrical and banana-like canals. As there was no significant difference from L1 to L3 in Skeletal Class III, the shape of the incisive canal in the Skeletal Class III malocclusion group may probably be cylindrically shaped. Further studies are needed to evaluate the shape of the incisive canal in different malocclusions.

The average inter-root distance increased significantly from L1 to L3 whereas the posterior inter-root distance decreased. Our findings were consistent with the findings of Cho EA *et al*.[6]; Gull MA *et al*.[18].

In cases of camouflage treatment where incisor retraction is needed to compensate for maxillomandibular relation, there is an increased risk of root resorption induced by the contact of roots to the cortical plate of the incisive canal. Our study showed a significant difference in the anteroposterior distance between the incisive canal and maxillary central incisors root in different skeletal malocclusions. Skeletal Class II malocclusion showed the least distance whereas Skeletal Class I showed the greatest.

In the present study, it was an attempt to evaluate the incisive canal and its relation to maxillary central incisors in different malocclusions for preventing potential complications such as root resorption after maximum retraction of the anterior teeth. The transverse measurements did not show any significant difference between the Skeletal malocclusion Groups whereas the roots of the Skeletal Class II malocclusion are nearer to the incisive canal than Skeletal Class I and Class III malocclusions. The findings reveal that sagittal malocclusion has little effect on the distance between the roots of the upper central incisors and the anterior limit of the incisive canal. Therefore, when a large degree of maxillary incisor retraction and intrusion is anticipated, the 3D examination may be useful in estimating the closeness of the incisive canal. More emphasis should be given to include different inclinations of teeth, and to include different growing individuals which were the limitations of our study. Further studies using CBCT regarding the morphology of incisive canal in different malocclusions and comparison of pre-treatment and post-treatment to determine the capability of the incisive canal to remodel may be required in the future to have more detailed knowledge.

Conclusion:-

1. Sagittal skeletal patterns have little influence on the distance between the roots of upper central incisors and the incisive canal; however, orthodontic teeth movement should be carefully monitored, especially in individuals who require more retraction of upper central incisors.
2. In Skeletal Class I malocclusion, the anteroposterior distance between the incisive canal and maxillary central incisor roots was approximately 4-5 mm, 2-4 mm in Skeletal Class II, and 3-4 mm in Skeletal Class III malocclusion.
3. The current study provides a thorough understanding of the transverse and anteroposterior distances between the incisive canal and the maxillary central incisor roots, which is critical for accurate treatment planning when a

considerable amount of anterior retraction is required to reduce the risk of root resorption and to ensure long-term stability.

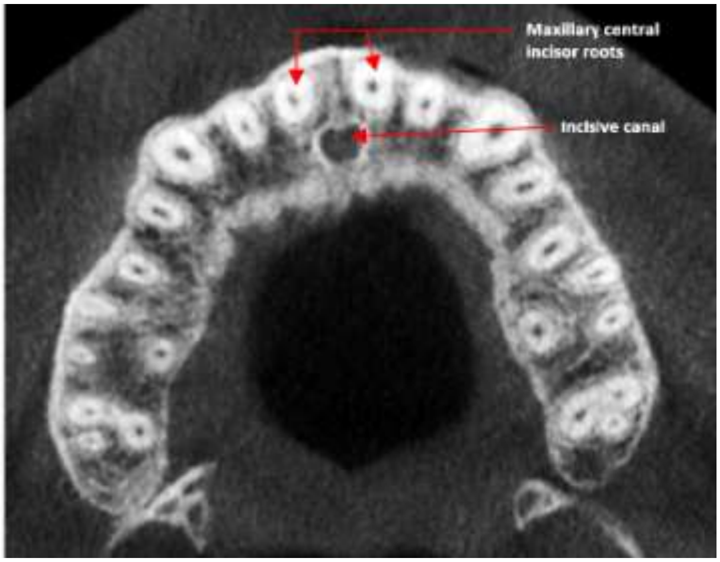

Figure 1 (a):- Incisive canal and maxillary central incisor in Sagittal plane.

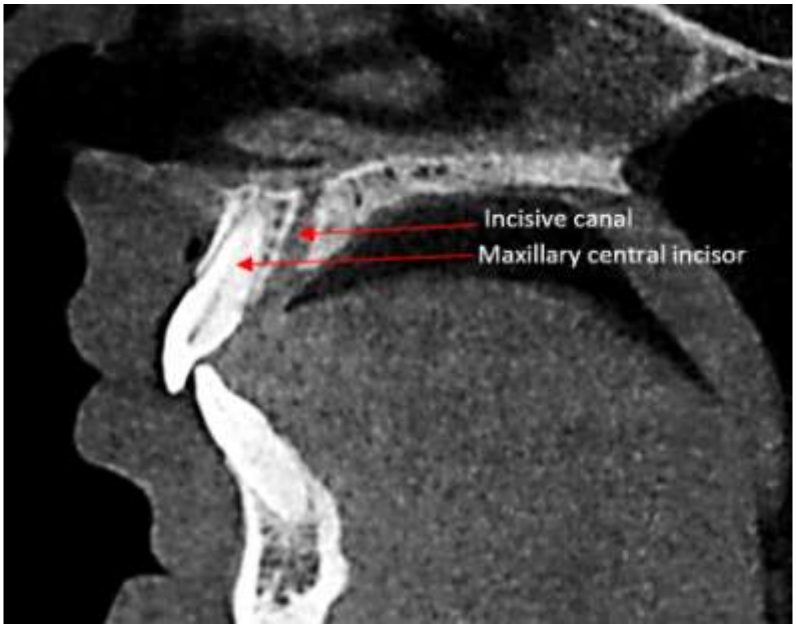

Figure 1 (b):- Incisive canal and right and left maxillary central incisor roots in cross sectional view.

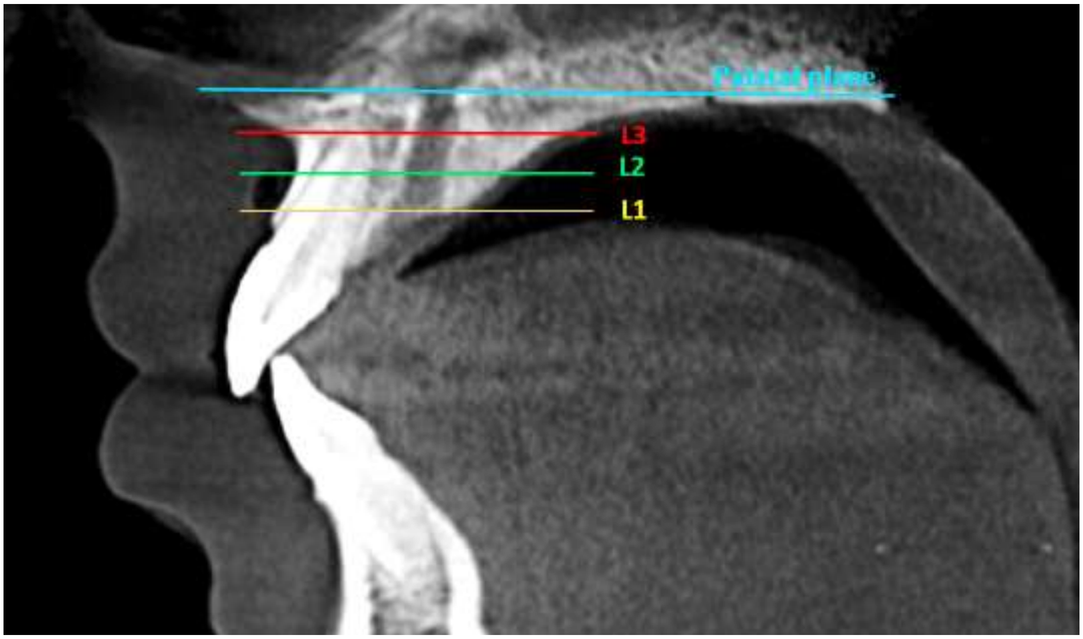

Figure 2:- Vertical levels used in the study.

1. L1 (opening level)- at the level of palatal opening of the incisive canal parallel to palatal plane
2. L2 (mid-level)- at midlevel between the opening level and the root apex of maxillary central incisors parallel to palatal plane
3. L3 (root apex level)- at the level of root apex of the maxillary central incisors parallel to palatal plane

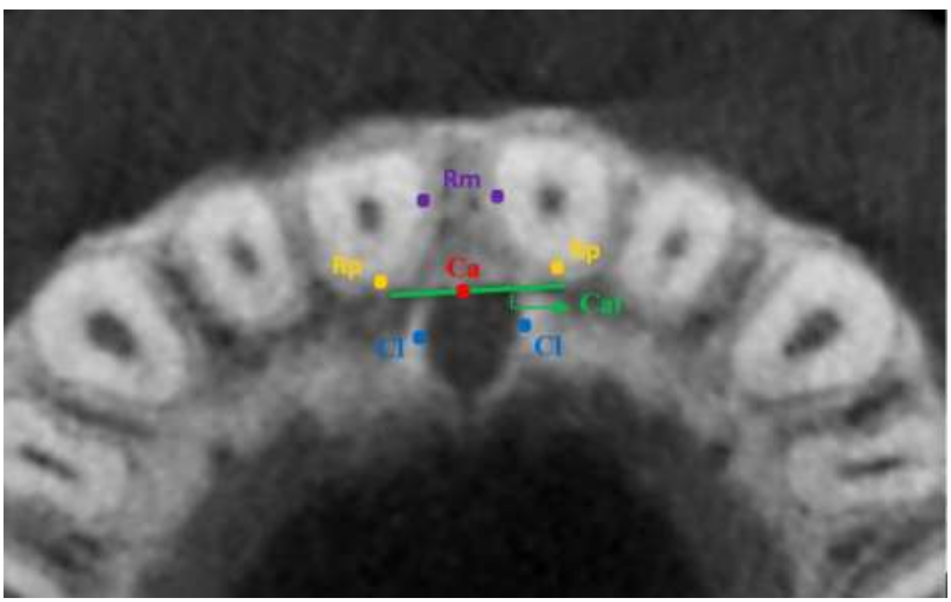

Figure3:- Anatomical landmarks used in the study.

1. Cl- the most lateral point on the incisive canal
2. Rm- the most medial point of the maxillary central incisor roots
3. Rp- the most posterior point of the maxillary central incisor roots
4. Ca- the most anterior point of the incisive canal
5. Cat- tangent line through the most anterior point of the incisive canal (Ca)

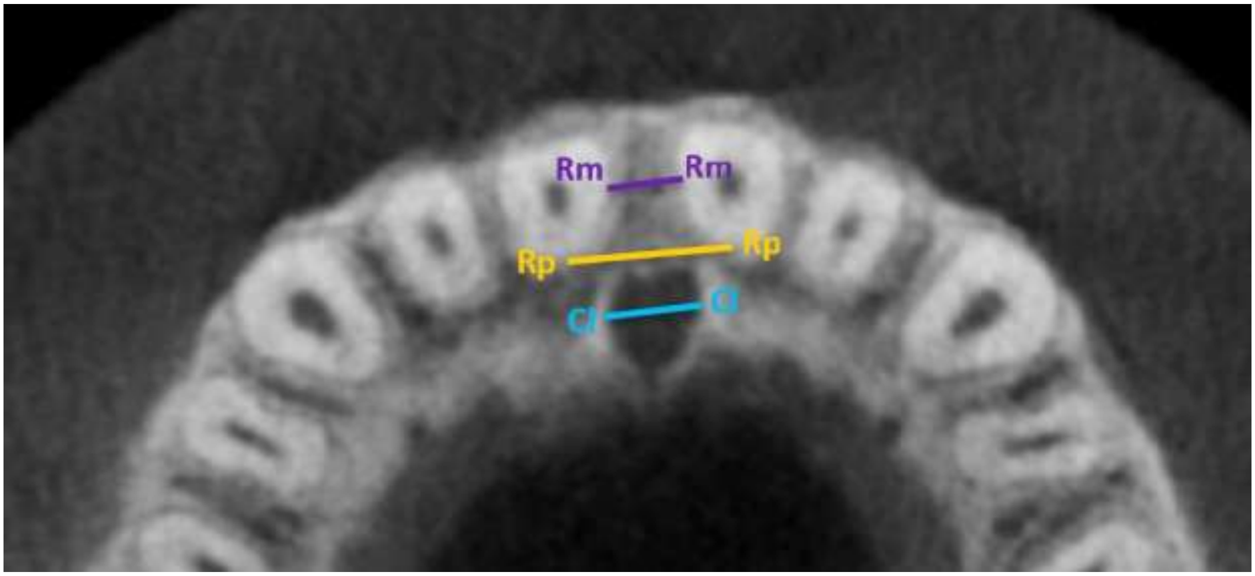

Figure 4:-Transverse linear measurements used in the study.

1. Cl-Cl: Canal width
2. Rm-Rm: Inter-root distance
3. Rp-Rp: Posterior inter-root distance

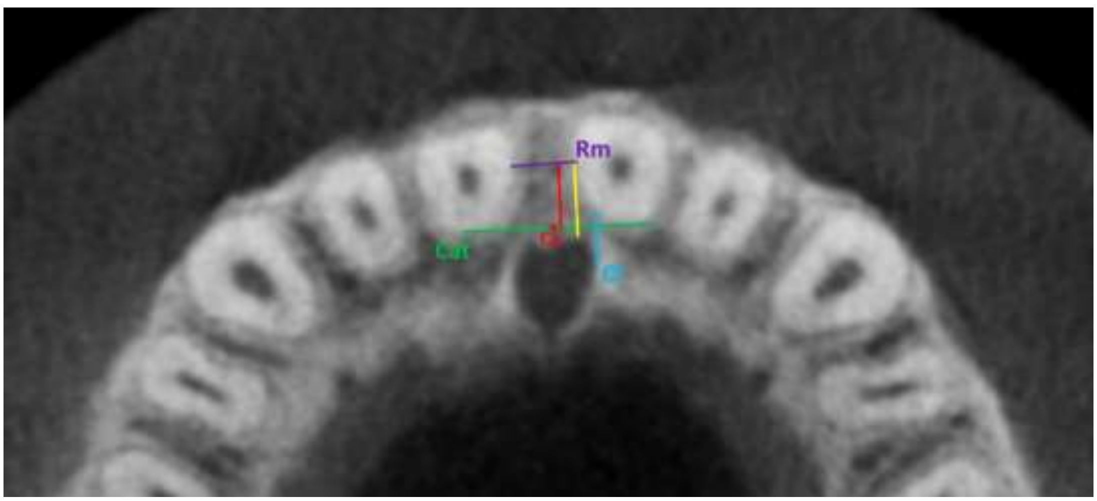

Figure 5:- Anteroposterior linear measurements used in the study.

1. Rm-Cat: The distance from the most medial point of maxillary central incisor roots to the tangent line drawn through
2. Rm-Canal: The distance from the most medial point of maxillary central incisor roots to the anterior border of incisive canal
3. Cl- Root: The distance from most lateral point of incisive canal to the posterior border of the maxillary central incisor root

Table 1:-Distribution of samples in Groups.

Groups (N=70)	**Group I (n=25)**	**Group II (n=25)**	**Group III (n=20)**
	Skeletal Class I Pattern	Skeletal Class II Pattern	Skeletal Class III Pattern
ANB angle (degree)	2.48 ± 0.65	6.76 ± 1.48	-1.50 ± 1.19

β angle (degree)	30.68 ± 2.56	21.64 ± 2.85	38.20 ± 1.73
Wits Appraisal (mm)	0.70 ± 0.70	3.50 ± 1.20	-2.43 ± 1.23

Table 2:-Mean and SD of the width of incisive canal and distance between maxillary central incisor roots (transverse measurements) in different Groups at L1, L2 and L3 levels.

Vertical levels	**Sl no.**	**Variables**	**Group I**		**Group II**		**Group III**	
			Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
L1 level (Opening)	1.	Cl-Cl (mm)	3.78	0.33	3.53	0.32	4.01	0.99
	2.	Rm-Rm (mm)	3.96	1.00	4.13	0.50	3.68	0.56
	3.	Rp-Rp (mm)	7.20	0.64	7.28	0.44	7.17	0.70
L2 level (Midlevel)	1.	Cl-Cl (mm)	3.31	0.41	2.99	0.43	3.45	1.04
	2.	Rm-Rm (mm)	4.59	0.91	4.70	0.53	4.10	0.51
	3.	Rp-Rp (mm)	6.80	0.67	6.73	0.39	6.77	0.69
L3 level (Root Apex)	1.	Cl-Cl (mm)	3.09	0.42	2.57	0.39	3.33	1.29
	2.	Rm-Rm (mm)	6.29	0.64	5.34	0.56	4.66	0.65
	3.	Rp-Rp (mm)	6.45	0.60	6.34	0.44	6.52	0.67

Table 3:- Mean and SD of the distance between the incisive canal and maxillary central incisor roots (anteroposterior measurements) in different Groups at L1, L2 and L3 levels.

Vertical levels	**Sl no.**	**Variables**	**Group I**		**Group II**		**Group III**	
			Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
L1 level (Opening)	1.	Rm-Cat (mm)	4.52	0.73	3.44	0.67	3.83	0.49
	2.	Rm-Canal (mm)	5.24	0.48	3.89	0.33	4.60	0.68
	3.	Cl-Root (mm)	4.18	0.95	1.76	0.29	3.13	0.86
L2 level (Midlevel)	1.	Rm-Cat (mm)	4.12	0.71	2.81	0.54	3.57	0.74
	2.	Rm-Canal (mm)	4.85	0.52	3.39	0.38	4.24	0.77
	3.	Cl-Root (mm)	4.68	0.89	2.23	0.35	3.73	1.12
L3 level (Root Apex)	1.	Rm-Cat (mm)	3.79	0.66	2.19	0.52	3.31	1.06
	2.	Rm-Canal (mm)	4.43	0.48	3.01	0.51	3.92	0.87
	3.	Cl-Root (mm)	5.09	0.83	2.54	0.40	4.17	1.27

Table 4:- Comparison of variables in Group I, II and III at L1 (Opening), L2 (Midlevel) and L3 (Root Apex) levels using ANOVA and Post hoc Tukey HSD test.

			Group I							**Group II**							**Group III**						
Measurements	**Sl no.**	**Variables**	**Among L1, L2 and L3 (p value)**	**L1 vs L2**		**L1 vs L3**		**L2 vs L3**		**Among L1, L2 and L3 (p value)**	**L1 vs L2**		**L1 vs L3**		**L2 vs L3**		**Among L1, L2 and L3 (p value)**	**L1 vs L2**		**L1 vs L3**		**L2 vs L3**	
				Mean Diff.	**p value**	**Mean Diff.**	**p value**	**Mean Diff.**	**p value**		**Mean Diff.**	**p value**	**Mean Diff.**	**p value**	**Mean Diff.**	**p value**		**Mean Diff.**	**p value**	**Mean Diff.**	**p value**	**Mean Diff.**	**p value**
TRANSVERSE	1.	Cl-Cl (mm)	**<0.001*** **	0.47	**<0.001*** **	0.68	**<0.001*** **	0.21	0.172^{NS}	**<0.001*** **	0.54	**<0.001*** **	0.96	**<0.001*** **	0.41	**0.001** **	0.129^{NS}	0.48	0.541^{NS}	0.62	0.239^{NS}	0.14	1.000^{NS}
	2.	Rm-Rm (mm)	**<0.001*** **	-0.62	**0.033***	-2.33	**<0.001*** **	-1.70	**<0.001*** **	**<0.001*** **	-0.56	**0.001** **	-1.20	**<0.001*** **	-0.63	**<0.001*** **	**<0.001*** **	-0.42	0.075^{NS}	-0.96	**<0.001*** **	-0.54	**0.013***
	3.	Rp-Rp (mm)	**<0.001*** **	0.40	0.090^{NS}	0.75	**<0.001*** **	0.35	0.166^{NS}	**<0.001*** **	0.55	**<0.001*** **	0.94	**<0.001*** **	0.38	**0.007** **	**0.014***	0.25	0.779^{NS}	0.57	**0.034***	0.32	0.473^{NS}
A	1.	Rm-Cat	**0.002** **	0.40	0.143^{NS}	0.74	**0.001** **	0.32	0.321^{NS}	**<0.001*** **	0.62	**0.001** **	1.24	**<0.001*** **	0.62	**0.001** **	0.134^{NS}	0.12	1.000^{NS}	0.44	0.251^{NS}	0.32	0.649^{NS}

		(mm)																					
	3.	Rm-Canal (mm)	**<0.001*** **	0.39	**0.020***	0.80	**<0.001*** **	0.41	**0.012***	**<0.001*** **	0.50	**<0.001*** **	0.88	**<0.001*** **	0.38	**0.005** **	**0.027***	0.25	0.941 NS	0.62	**0.042***	0.36	0.445 NS
	2.	Cl-Root (mm)	**0.002** **	-0.50	0.154 NS	-0.91	**0.002** **	-0.41	0.321 NS	**<0.001*** **	-0.46	**<0.001*** **	-0.78	**<0.001*** **	-0.31	**0.006** **	**0.014***	-0.71	0.126 NS	-1.08	**0.007** **	-0.36	0.877 NS

<0.05 Justsignificant;**<0.01 Moderately significant ;<0.001 Highly significant; NS>0.05 Non significant***

Table 5:- Intergroup comparison of incisive canal width and distance between maxillary central incisor roots (transverse measurements) at L1 (Opening), L2 (Midlevel) and L3 (Root Apex) levels using Post hoc Tukey HSD test.

Vertical levels	Sl No	Variables	Group I vs Group II		Group I vs Group III		Group II vs Group III	
			Mean Diff.	**p-value**	**Mean Diff.**	**p-value**	**Mean Diff.**	**P-value**
L1 level (Opening)	1.	Cl-Cl (mm)	0.25	0.299 NS	-0.23	0.403 NS	-0.48	**0.023***
	2.	Rm-Rm (mm)	-0.17	0.698 NS	0.28	0.405 NS	0.45	0.107 NS
	3.	Rp-Rp (mm)	-0.08	0.874 NS	0.02	0.989 NS	0.10	0.818 NS
L2 level (Midlevel)	1.	Cl-Cl (mm)	0.32	0.207 NS	-0.14	0.754 NS	-0.46	0.508 NS
	2.	Rm-Rm (mm)	-0.10	0.843 NS	0.49	0.051 NS	0.60	**0.013***
	3.	Rp-Rp (mm)	0.07	0.904 NS	0.02	0.989 NS	-0.04	0.962 NS
L3 level (Root Apex)	1.	Cl-Cl (mm)	0.52	0.050 NS	-0.23	0.559 NS	-0.76	**0.004** **
	2.	Rm-Rm (mm)	0.96	**<0.001*** **	1.63	**<0.001*** **	0.67	**0.001** **
	3.	Rp-Rp (mm)	0.10	0.797 NS	-0.07	0.908 NS	-0.17	0.564 NS

****p<0.05 Just significant; **p<0.01 Moderately significant; ***p<0.001 Highly significant; NS>0.05 Non significant***

Table 6:- Intergroup comparison of the distance between the incisive canal and maxillary central incisor roots (anteroposterior measurements) at L1 (Opening), L2 (Midlevel) and L3 (Root Apex) levels using Post hoc Tukey HSD test.

Vertical levels	Sl. No	Variables	Group I vs Group II		Group I vs Group III		Group II vs Group III	
			Mean Diff.	**p-value**	**Mean diff.**	**p-value**	**Mean Diff.**	**P-value**
L1 level (Opening)	1.	Rm-Cat (mm)	1.07	**<0.001*** **	0.68	**0.002** **	-0.39	0.119 NS
	2.	Rm-Canal (mm)	1.34	**<0.001*** **	0.63	**<0.001*** **	-0.71	**<0.001*** **
	3.	Cl-Root (mm)	2.41	**<0.001*** **	1.04	**<0.001*** **	-1.37	**<0.001*** **

L2 level (Midlevel)	1.	Rm-Cat (mm)	1.30	**<0.001*** **	0.54	**0.022***	-0.75	**0.001****
	2.	Rm-Canal (mm)	1.46	**<0.001*** **	0.60	**0.002****	-0.85	**<0.001*** **
	3.	Cl-Root (mm)	2.44	**<0.001*** **	0.94	**0.001****	-1.50	**<0.001*** **
L3 level (Root Apex)	1.	Rm-Cat (mm)	1.60	**<0.001*** **	0.477	0.097^{NS}	-1.12	**<0.001*** **
	2.	Rm-Canal (mm)	1.42	**<0.001*** **	0.51	**0.022***	-0.91	**<0.001*** **
	3.	Cl-Root (mm)	2.54	**<0.001*** **	0.91	**0.003****	-1.63	**<0.001*** **

p<0.05 Just significant; **p<0.01 Moderately significant; ***p<0.001 Highly significant; ^{NS}>0.05 Non significant

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