THE EFFECT OF ORTHODONTIC TREATMENT ON SAGITTAL ROOT POSITION OF THE MAXILLARY CENTRAL INCISOR

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Abstract

Introduction: Sagittal root position (SRP) of maxillary incisors is an important factor in implant treatment planning.
Purpose-Cone beam computed tomography (CBCT) was used in this study to analyse how the alveolar bone surrounding the maxillary incisors has changed as a result of orthodontic tooth movement and to explain the impact of those changes on SRP categorization.
Methods: In the present investigation, the labial/palatal bone surrounding the central incisors on CBCT images taken before (T1) and after (T2) orthodontic treatment were examined for changes in dimension (mm). 77 patients' initial (T1) and final (T2) CBCT pictures were imported using the digital imaging and communications in medicine (DICOM) protocol. 127 central incisors that satisfied the inclusion criteria had mid-sagittal pictures taken of them. Each incisor's SRP was noted at T1 and T2. Utilising the Wilcoxon Signed Rank Test, Mann-Whitney U Test, and Independent Samples Kruskal-Wallis Test (= 0.05), the labial, palatal, and total alveolar width changes (mm) were examined.
Results: For teeth that underwent positive inclination change (PIC), statistically different dimension changes were seen between T1 and T2. Total alveolar width dimension decreased as a result of labial bone dimensions increasing and palatal bone dimensions decreasing, with different magnitudes (p .05). Negative inclination change (NIC) group changes were generally not statistically significant. At T1, 82% of teeth were SRP class I, and 18% were SRP class II. Between T1 and T2, 54% of teeth's SRP classification changed (67% and 19% of PIC and NIC groups, respectively).
Conclusions: In teeth that suffer PIC, the alveolar process surrounding the maxillary central incisors adapts statistically significantly and in a predictable way. SRP classification varies as a result of orthodontic motion that alters inclination.

Keywords- Sagittal Root Position, Maxillary Incisors, CBCT, Orthodontic Treatment

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1. Introduction

Sagittal root position (SRP) of maxillary incisors is an important factor in implanttreatment planning in the esthetic zone, especially in immediate implant placement (IIP) situations. Initial root position in the bone in part defines the character of the post extraction site and the bony housing of the post extraction site affects initial implant stability which is a primary determinate of implant success.[1-3] The qualities of bone that have been investigated for their impact on initial implant stability include type of bone, thickness of bone, density and modulus of elasticity.[1, 4-7] Of these qualities, bone thickness consistently shows high correlation with initial implant stability.[1, 4-6] Adequate bone apical to the extraction site and socket walls without defects are also essential to thesuccess of IIP.[8]

Classifying SRP in an effort to aid implant placement treatment planning was thegoal of a study conducted by Kan et al at Loma Linda University.[9] This study defined four classes of SRP within its osseous housing for the maxillary incisors (Figure 1).

- Class I: The root is positioned against the labial cortical plate
- Class II: The root is centered in the alveolar housing without engaging either thelabial or palatal cortical plates at the apical third of the roots.
- Class III: The root is positioned against the palatal cortical plate.
- Class IV: At least two thirds of the root is engaging both the labial and palatalcortical plates.

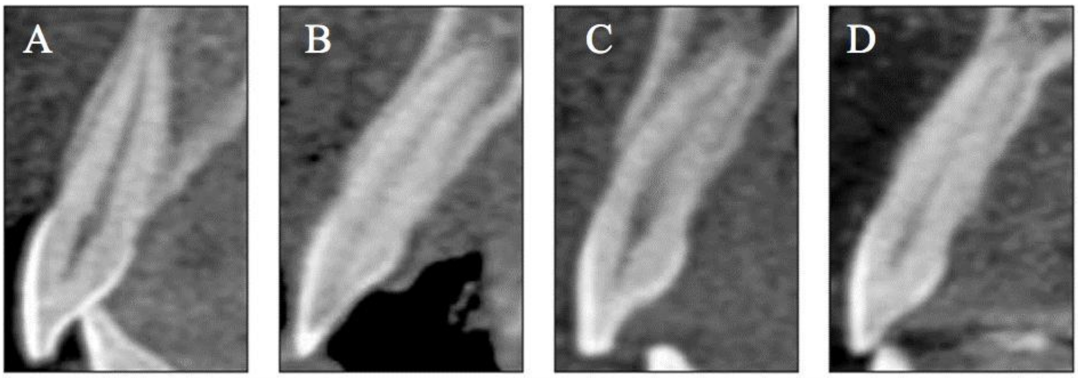


Figure 1. SRP Classification – image courtesy of Kan et al. (A) Class I, (B) Class II, (C) Class III, (D) Class IV.

After Class I SRP-related tooth extractions, a sizable amount of palatal bone supports IIP, and any spaces between the implant and bony housing are filled with bone grafting material.[10,11] In class II SRP, there may not be enough labial and palatal plate bone after extraction to guarantee initial implant stability if there is insufficient apical bony support.8 The labial, more trabecular bone, which is less suitable for IIP because it is susceptible to post-placement remodelling, is the bone that is available in class III SRP. Class IV SRP typically requires bone augmentation and offers insufficient support for IIP. According to recommendations published in the present literature, class IV SRP might be regarded as a contraindication to IIP while class I SRP would be an indicative of appropriate bone support when planning for IIP.[8-11] In order to increase bone support and change SRP, orthodontic tooth movement may be a useful tool in getting ready for IIP.

A fundamental idea in orthodontics is that by exerting stresses on teeth, bone can change and teeth can move[12–15], but it is still unclear how teeth move and what determines how much and where bone changes. This inquiry has led to several hypotheses, each supported by proof about whether bone follows tooth movement or whether teeth move through bone. Numerous studies show that the positioning of cephalometric landmarks and alveolar bone thickness might alter as a result of orthodontic movement of teeth in the anterior maxilla.[16-21]

In some situations, bone dehiscence and fenestrations of the maxillary incisors are caused by decreases in bone thickness.[22] As a substitute, it has been demonstrated that applying modest stresses to the anterior maxilla very slightly alters the labial bone's thickness and promotes more reliable and less harmful bone remodelling. Planning for IIP would benefit from having accurate information of how the alveolar housing would react to different tooth movements.

One of the primary goals of orthodontic therapy is to position the tooth crown in the optimal functional and aesthetically pleasing manner. Root alterations within the bone are clinically manifested by changes to the position of the tooth crown. The angle between the tooth's crown and root is therefore important for orthodontic therapy since it influences both the clinical outcomes and how the tooth interacts with the bone.[25] In relation to the alveolus and cranial base, tooth position is defined by assessments of the root inclination and tooth inclination. Along with crown root angulation, a closer look at these angles can help connect clinically apparent treatment outcomes to the underlying bone changes brought on by tooth movement.

Cone beam computed tomography (CBCT) is a useful tool in the evaluation of hard tissue changes[26-28], like those being looked at in the present investigation. Compared to other image modalities, CBCT scan-derived three-dimensional images are less influenced by the orientation of the skull and have a one-to-one image-to-reality ratio, enabling physicians to make measurements with high precision and assess changes in hard tissue in three dimensions.[27,29] The precision of CBCT measures of bone thickness, particularly in the maxillary alveolar region, has been confirmed by numerous research.[27, 30] Just as CBCT has been used to evaluate buccal bone changes to posterior teeth during rapidpalatal expansion,[28] in this study CBCT will be used to analyze changes to labial andpalatal bone in the anterior maxilla.

The present investigation aimed to assess the impacts of sagittal inclination shift on the labial and palatal bone of maxillary incisors and investigate the implications of these changes on SRP classification using CBCT images. Evaluation of the maxillary incisors' crown-root angulation and root/tooth inclinations, as well as comparisons between malocclusions, served as a supplementary goal.

2. Methodology

This study was approved by the Institutional Review Board of Career Post Graduate Institute of Dental Sciences and Hospital, Lucknow. Pre- (T1) and post-orthodontic treatment (T2) cone beam computed tomography (CBCT) [NewTom 5G, 110 kV, 3.6 second exposure time,

mm voxel resolution, and 180 x 160 mm field of view; records of patients who received full orthodontic treatment at the Department of Orthodontics and Dentofacial Orthopeadics, Career Post Graduate Institute of Dental Sciences and Hospital, Lucknow from July 2017 to March 2022 were reviewed and the records fulfilling the following criteria were included in the study: (1) completed treatment with available T1 and T2 CBCT records and (2) central incisor inclination change from T1 to T2 that is ≥ 5 degrees (in either direction). Cases with missing anterior teeth, radiographic evidence of infection, trauma to maxillary incisors, cases having received any bony augmentation in the anterior maxilla, or cases with severe crowding and/or rotation of maxillary incisors that effected required measurements were excluded from the study. DICOM files from each patient were evaluated using the Osirix MD software, version 6.5.2, 64-bit. In order to keep measurements consistent, one examiner performed all reconstructions and measurements.

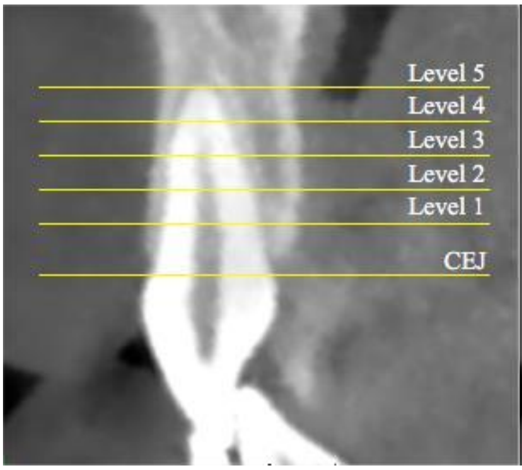
Each case included in the study was first categorized according to Steiner's ANB angle, defined as the angle formed by drawing a line from A point to Nasion and back toB point on a midsagittal cut of a CBCT scan (Figure 2). The following definitions were applied to the ANB angles of all cases:

- Class I = 0˚≤ ANB ≤ 4˚
- Class II = ANB > 4°
- Class III = ANB < 0˚

The Multiplanar Reconstruction (MPR) view was then used to alter the cone beam computed tomography (CBCT) volumes. The Sella Nasion plane (SN), which is the line linking the cephalometric landmarks Sella and Nasion, was adjusted to the horizontal plane in the mid-sagittal view (Figure 3A), and the image was screen shot and saved. This photograph was utilised to measure the ANB and classify the skeleton. Then, after centering the sagittal, coronal, and axial planes to bisect the target incisor in each respective view, pictures of each incisor were created in this SN orientation. A line that cuts through the middle of the cemento-enamel junction (CEJ) was used to assess the root inclination of each incisor in regard to SN. A line running along the long axis of the tooth was used to measure the tooth's inclination in reference to SN (Figure 4B). By deducting the T1 root inclination measurement from the T2 root inclination measurement, inclination shift was computed. A higher proclined T2 incisor placement is indicated by a positive inclination change (PIC), whereas a higher retroclined T2 incisor position is indicated by a negative inclination shift (NIC).

Table 1. Description of bone measurements.

Measurement	**Description** (1 = 3mm, 2 = 5mm, 3 = 7mm, 4 = 9mm, and 5 = 11mm from the CEJ)
L1-L5	Labial plate thickness measured from anterior border of labial cortex to labial limitof the tooth root
P1-P5	Palatal plate thickness measured from the border of the alveolar cortex nearest theoral cavity to the palatal extent of the tooth root
W1-W5	Width of alveolus measured from border of the alveolus nearest the palatal vault tothe outer border of the labial cortex



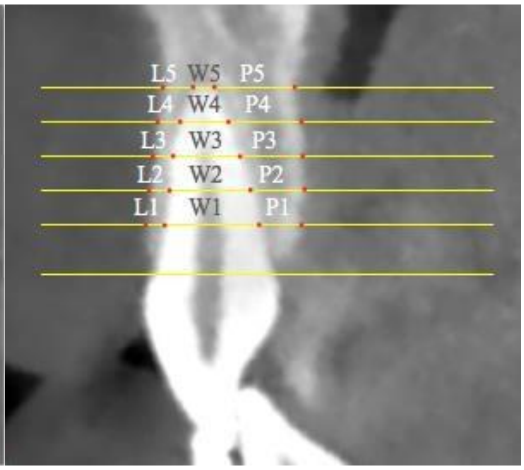


Figure 1. CEJ line and measurement levels

Figure 2. Bone thickness measurements

Statistical Analysis

SPSS Version 22 was used to conduct the statistical analysis. For data that were regularly distributed, descriptive statistics were presented as means with standard deviations, and for all other data, medians with interquartile ranges. The statistical significance between groups of normally distributed data was assessed using the Kruskal-Wallis test. The Mann Whitney U test was used to compare the medians of bone change between groups, and the Wilcoxon Signed Rank Test was employed to determine the significance of each measurement. The 0.05 level of significance was used to set alpha. Cronbach's alpha was used to evaluate the accuracy of the measurements. Twenty teeth (>15%) were measured twice, six weeks apart, to determine the intra-class correlation.

3. Results

The research comprised 77 patients, with a mean age of 19.0 11.4 years (range = 10.0 – 66.7 years) and 32 males and 45 females. The evaluation included 127 teeth (67 Cl I, 17 Cl II div1, 19 Cl II div2, and 24 Cl III). All examined measurements had Cronbach's alphas larger than 0.95 (Table 2), demonstrating strong repeatability for all measurements in this investigation.

Table 2. Tests for reliability.

Measure	**Cronbach's Alpha**
T1 bone thickness	.995
T2 bone thickness	.992
Inclination	.993
Collum Angle	.954

The range of changes in inclination was 5 to 29 degrees for the positive shift and -5 to -26 degrees for the negative change. The Cl II div 2 group displayed a mean inclination change of 17.1 7.6, which was the largest. According to the skeletal classification, the mean inclination change and standard deviation are shown in Table 3 for the positive inclination change (PIC) and negative inclination change (NIC) groups. The distinction between positive and negative inclination change is seen in Figures 3a and 3b.

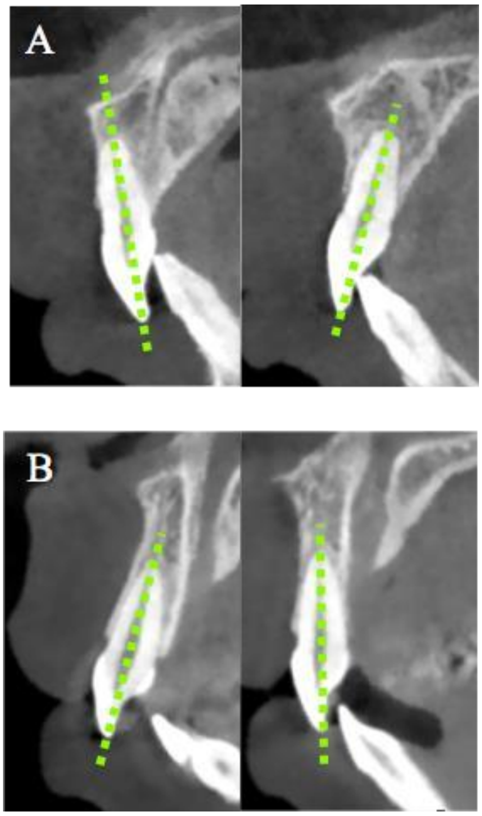


Figure8. (A) Depiction of positive inclination change, and (B) negative inclination change.

Collum Angle and Crown Angulation
Mean and standard deviations of Collum angle for Cl I, Cl II div1, Cl II div2, andCl III groups were 2.1 ± 3.5°, -0.2 ± 4.1°, 3.9 ± 3.1°, and 1.5 ± 3.6° respectively. Statistically significant difference in mean Collum angles was found only between Cl II div 1 (-0.2°) and Cl II div 2 (3.9°) groups (p = .007). Mean and standard deviations of T2 crown angulations for Cl I, Cl II div1, Cl II div2, and Cl III groups were 105.2 ± 8.5°, 103.5 ± 9.6°, 101.7 ± 7.1°, and 115.2 ± 9.0° respectively.

Table 3. Mean and standard deviation (SD) of inclination change by malocclusion classification

	Positive Inclination (degrees)	Negative Inclination (degrees)
Groups	Mean ± SD	Mean ± SD
Class I	10.8 ± 5.0	13.6 ± 7.0
(range)	(5 - 25)	(6 - 26)
[N = 67]	[51]	[16]
Class II div 1	9.0 ± 4.1	11.0 ± 5.2
(range)	(5 - 15)	(6 - 22)
[N = 17]	[5]	[12]
Class II div 2	17.1 ± 7.6	--
(range)	(6 - 29)	--
[N = 19]	[19]	[0]
Class III	11.4 ± 5.1	7.0 ± 1.8
(range)	(5 - 20)	(5 - 9)
[N = 24]	[20]	[4]
Overall	12.1 ± 6.0	11.6 ± 6.2
(range)	(5 – 29)	(5 – 26)
[N = 127]	[95]	[32]

Bone Thickness Changes
Overall median bone thickness changes (mm) by level are shown in Table 4. A one sample Wilcoxon Signed Rank Test at a significance level of $\alpha = 0.05$ was used for the statistical analysis of bone thickness change at each level. In the PIC group, statistically significant changes of all parameters were observed at all levels ($p < 0.05$, Table 4) except level 1 of labial bone (p = .492, Table 4); whereas in the NIC group, most of the changes were not statistically significant ($p > 0.05$, Table 4). When comparing bone thickness changes between the PIC and NIC groups significant differences were observed in all parameters at all levels ($p < 0.05$, Table 4) except at level 1 of the labial bone (p = .202, Table 4).

Table 4. Median and interquartile range (IQR) of overall bone thickness changes.

Positive Inclination □				Negative Inclination □			PIC and NIC comparison
Measurement	Median (IQR)	N	P value	Median (IQR)	N	P value	P value
L1 (mm)	0.0 (0.3)	94	.492	0.0 (0.4)	32	.287	.202
L2 (mm)	0.1 (0.3)	94	.000*	0.1 (0.6)	33	.428	.000*
L3 (mm)	0.3 (0.5)	94	.000*	-0.1 (0.5)	33	.428	.000*
L4 (mm)	0.6 (0.7)	93	.000*	-0.1 (0.6)	32	.247	.000*
L5 (mm)	1.2 (1.4)	80	.000*	0.0 (1.3)	29	.072	.000*
P1 (mm)	-0.9 (1.0)	94	.000*	-0.3 (0.8)	33	.059	.000*
P2 (mm)	-1.6 (1.7)	94	.000*	-0.5 (1.4)	33	.038*	.000*
P3 (mm)	-2.2 (2.1)	94	.000*	-0.5 (2.0)	33	.130	.000*
P4 (mm)	-2.4 (2.6)	93	.000*	0.0 (1.9)	32	.694	.000*
P5 (mm)	-3.1 (3.6)	80	.000*	0.7 (1.9)	29	.304	.000*
W1 (mm)	-0.8 (1.1)	94	.000*	-0.3 (0.7)	32	.222	.000*
W2 (mm)	-1.3 (1.7)	94	.000*	-0.4 (1.3)	33	.056	.000*
W3 (mm)	-1.8 (2.1)	94	.000*	-0.4 (1.8)	33	.047*	.000*
W4 (mm)	-1.8 (2.3)	93	.000*	-0.1 (2.1)	32	.247	.000*
W5 (mm)	-2.1 (2.6)	79	.000*	0.5 (2.3)	29	.647	.000*

*Statistically significant

Tables 5 – 8 show the amount of bone changes at each level according to thedifferent malocclusions.

Table 5. Median and interquartile range (IQR) of class I bone thickness changes.

Positive Inclination □				Negative Inclination □			PIC and NIC Comparison
Measurement	Median (IQR)	N	P value	Median (IQR)	N	P value	P value
L1 (mm)	0.0 (0.3)	51	.337	0.0 (0.2)	15	.093	.079
L2 (mm)	0.1 (0.3)	51	.000*	0.0 (0.6)	16	.603	.003*
L3 (mm)	0.3 (0.4)	51	.000*	-0.3 (0.8)	16	.603	.002*
L4 (mm)	0.7 (0.7)	50	.000*	-0.3 (0.6)	15	.806	.000*
L5 (mm)	1.0 (1.1)	47	.000*	0.2 (1.7)	14	.382	.000*
P1 (mm)	-0.9 (0.9)	51	.000*	-0.4 (1.1)	16	.132	.008*
P2 (mm)	-1.6 (1.2)	51	.000*	-0.1 (1.7)	16	.149	.012*
P3 (mm)	-2.2 (1.5)	51	.000*	-0.7 (2.9)	16	.164	.000*
P4 (mm)	-2.4 (1.9)	50	.000*	-0.1 (3.2)	15	.233	.000*
P5 (mm)	-3.0 (2.5)	47	.000*	-0.6 (4.2)	14	.754	.000*
W1 (mm)	-0.9 (1.1)	51	.000*	-0.3 (1.0)	15	.125	.013*
W2 (mm)	-1.3 (1.2)	51	.000*	-0.3 (1.9)	16	.118	.009*
W3 (mm)	-1.8 (1.5)	51	.000*	-0.7 (2.3)	16	.078	.001*
W4 (mm)	-1.8 (1.9)	50	.000*	-0.3 (2.6)	15	.132	.001*
W5 (mm)	-2.1 (2.0)	47	.000*	-0.5 (3.6)	14	.184	.020*

*Statistically significant

Table 6. Median and interquartile range (IQR) of class II division 1 bone thickness changes.

Positive Inclination □				Negative Inclination □			PIC and NIC Comparison
Measurement	Median (IQR)	N	P value	Median (IQR)	N	P value	P Value
L1 (mm)	0.0 (1.9)	5	1.000	-0.1 (0.7)	12	.969	.849
L2 (mm)	0.0 (0.4)	5	.144	0.1 (0.7)	12	.865	.171
L3 (mm)	0.3 (1.1)	5	.144	0.1 (0.5)	12	.865	.171
L4 (mm)	0.0 (2.0)	5	.465	0.0 (0.6)	12	.672	.435
L5 (mm)	0.3 (1.9)	3	1.000	-0.1 (0.9)	10	.176	.776
P1 (mm)	-0.4 (1.2)	5	.279	-0.2 (0.6)	12	.498	.284
P2 (mm)	-0.6 (2.0)	5	.225	-0.4 (1.5)	12	.326	.524
P3 (mm)	-1.6 (2.4)	5	.223	-0.4 (1.5)	12	.888	.222
P4 (mm)	-1.7 (3.2)	5	.225	0.1 (1.3)	12	.262	.093
P5 (mm)	-0.7 (4.3)	3	1.000	0.8 (1.3)	10	.017*	.376
W1 (mm)	-0.5 (0.9)	5	.136	-0.2 (0.9)	12	.674	.065
W2 (mm)	-0.4 (1.8)	5	.225	-0.3 (1.6)	12	.779	.435
W3 (mm)	-0.5 (2.0)	5	.345	-0.2 (1.4)	12	1.000	.354
W4 (mm)	-0.5 (2.3)	5	.345	-0.1 (1.7)	12	.396	.171
W5 (mm)	-0.8 (2.6)	3	1.000	1.0 (1.8)	10	.107	.497

*Statistically significant

Table 7. Median and interquartile range (IQR) of class II division 2 bone thickness changes.

Positive Inclination □				Negative Inclination □	
Measurement	Median (IQR)	N	P value	Median (IQR)	N
L1 (mm)	0.0 (0.2)	19	.286	- -	0
L2 (mm)	0.2 (0.5)	19	.003*	- -	0
L3 (mm)	0.3 (0.6)	19	.003*	- -	0
L4 (mm)	0.6 (0.9)	19	.001*	- -	0
L5 (mm)	1.3 (1.6)	16	.004*	- -	0
P1 (mm)	-1.1 (1.2)	19	.000*	- -	0
P2 (mm)	-2.4 (2.5)	19	.000*	- -	0
P3 (mm)	-3.4 (2.3)	19	.000*	- -	0
P4 (mm)	-4.2 (4.7)	19	.000*	- -	0
P5 (mm)	-5.4 (5.4)	16	.001*	- -	0
W1 (mm)	-0.9 (1.3)	19	.000*	- -	0
W2 (mm)	-2.2 (2.4)	19	.000*	- -	0
W3 (mm)	-3.0 (3.0)	19	.000*	- -	0
W4 (mm)	-2.9 (2.8)	19	.000*	- -	0
W5 (mm)	-3.7 (5.2)	15	.016*	- -	0

*Statistically significant

Table 8. Median and interquartile range (IQR) of class III bone thickness changes.

Positive Inclination □				Negative Inclination □			PIC and NIC Comparison
Measurement	Median (IQR)	N	P value	Median (IQR)	N	P value	P Value
L1 (mm)	-0.2 (0.5)	20	.443	0.1 (0.2)	4	.102	.210
L2 (mm)	-0.1 (0.7)	20	.191	-0.1 (0.3)	4	.180	.249
L3 (mm)	0.1 (1.0)	20	.191	-0.1 (0.3)	4	.180	.249

L4 (mm)	0.6 (1.5)	20	.024*	-0.4 (1.0)	4	.180	.039*
L5 (mm)	1.4 (2.4)	15	.006*	-1.0 (2.1)	4	.144	.015*
P1 (mm)	-0.5 (1.5)	20	.001*	-0.4 (0.7)	4	.102	.554
P2 (mm)	-0.8 (2.0)	20	.001*	-0.7 (0.8)	4	.066	.963
P3 (mm)	-1.1 (2.4)	20	.001*	-0.2 (1.5)	4	.465	.148
P4 (mm)	-1.5 (2.1)	20	.002*	0.4 (1.6)	4	.715	.039*
P5 (mm)	-1.9 (3.7)	15	.001*	0.7 (1.6)	4	.715	.006
W1 (mm)	-0.6 (1.3)	20	.013*	-0.2 (0.7)	4	.285	.211
W2 (mm)	-0.7 (1.7)	20	.003*	-0.6 (0.7)	4	.068	.820
W3 (mm)	-0.8 (1.4)	20	.014*	-0.3 (1.8)	4	.465	.335
W4 (mm)	-0.8 (1.7)	20	.019*	-0.1 (2.5)	4	.465	.494
W5 (mm)	-0.4 (3.4)	15	.108	-0.3 (3.7)	4	.715	.703

*Statistically significant

Overall, 82% (104) of teeth were class I SRP at T1 and the remaining 18% (23) were class II SRP. No teeth included in the study were class III or IV SRP at T1. At T237% (47) were class I SRP, 53% (68) were class II SRP, and 8% (10) & 2% (2) were class III and class IV SRP respectively (Figure 4).

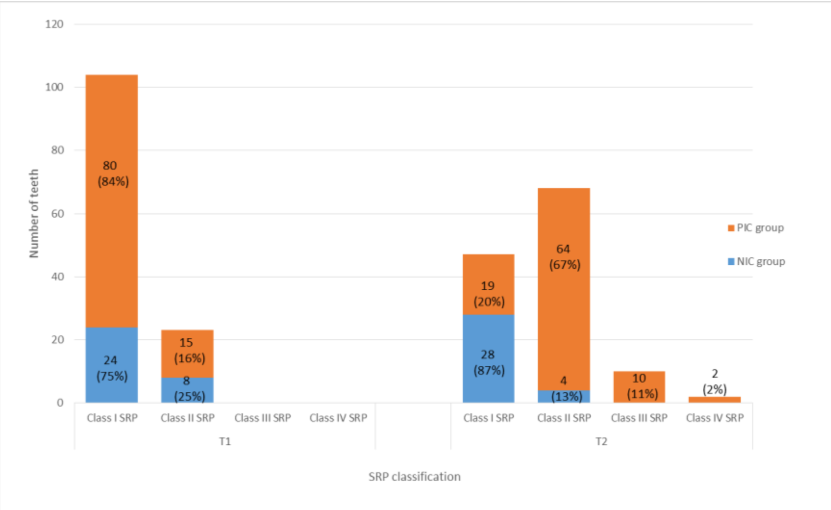


Figure 4. Frequency distribution of SRP classification for PIC and NIC groups at T1 and T2

Figure 5 shows the frequency distribution of SRP classification change according to the inclination change. In the PIC group 33% of teeth did not experience SRP change.

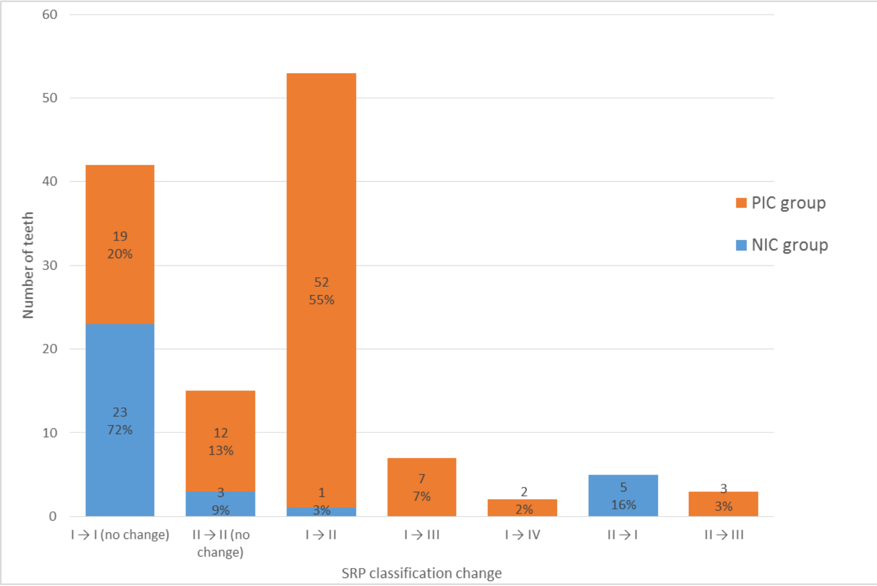


Figure 5 Frequency distribution of SRP classification change according to the inclination change

4. Discussion

Orthodontic tooth movement is made possible in part by interactions of teeth and bones with the periodontal ligament (PDL).[12] The PDL plays a central role in the “pressure-tension theory” of tooth movement and is responsible for the symmetric zones of apposition and resorption that allow teeth to move through bone - according to this theory.[23] Different hypotheses of tooth motion focus on the mechanical transduction of forces - forces that, in the "stretched fibre hypothesis," cause bone to be removed in the absence of strain or, on the other hand, forces that, through alveolar bending, cause new bone to emerge.[24] The reorganization of intra- and extracellular matrices as well as local vascularization are always the outcomes of pressures occurring on teeth that are translated to a biological level. The movement of teeth is ultimately caused by these biological processes.

Orthodontic movement of teeth within bone occurs either by movement of teeth through the bone or with the bone.[12] In tooth movement with bone, resorption and apposition by osteoclasts and osteoblasts in the periodontal ligament space is balanced much like in physiological tooth movement.[12] Apposition at the external surface of the alveolus and resorption along the inner surface in the direction of the force allows teeth tobe moved beyond the boundaries of the original alveolar process and maintains bone thickness dimension.[25] Correction of defects through coordinated resorption and apposition is also possible as has been shown in patients with periodontal compromised teeth characterized by infrabony defects that demonstrate significant improvements to marginal bone height and bone defect radiologic dimension following orthodontic tooth movement.

The frequency distribution of SRP in this study at T1 (82% Class I, 18% Class II) was somewhat different from that reported by Kan et al (86.5% Class I, 5% Class II, 0.5% Class III and 8% Class IV).[9] The fact that cases were selected based on change in inclination rather than from random selection may have contributed to this result. At T2, however, the frequency distribution of SRP was markedly different (37% Class I, 53% Class II, 8% Class III and 2% Class IV). These results suggest that orthodontic tooth movement appears to have an impact on SRP classification. Since 67% of the teeth in the PIC group altered SRP classification compared to 19% of the teeth in the NIC group, positive inclination change appears to have a greater impact on change in SRP classification than negative inclination shifts. A NIC (labial root movement) would probably not change the SRP classification because the labial plate is currently situated next to the root because 82% of teeth were Cl I SRP at T1. This means that the roots of most teeth nearly approached the labial cortical plate. Due to the presence of more bone in the root's travel direction in PIC, the probability of altering SRP classification is more significant.

With the exception of one tooth, every tooth in the NIC group that had SRP classification shift went from class II SRP to class I SRP, which is consistent with the expected direction of bone change. The one incisor that underwent retraction therapy and went from class I SRP to class II SRP despite a shift in negative inclination may have been impacted by physical movement. This kind of movement might be able to move the tooth about in the alveolus so much that bony modifications wouldn't occur in the same way as isolated roots migrate through the bone. The confounding effects of diverse tooth movements may be the cause of the sparse results for all bone thickness increases in the NIC group.[26,2]

5. Conclusion

As a result of data gathered and analyzed in the current study the authors can make the following conclusions:

1. The impact of positive inclination change on the alveolar bone is different than negative inclination change.
2. Orthodontic tooth movement that causes inclination change can affect maxillaryincisor SRP classification.
3. Crown position in Cl I, Cl II Div 1, and Cl II div2 cases are treated to similar positons clinically despite differences in T1 inclination and crown-root morphologies.

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