Bone Density, Arch Dimensions and Irregularity Index of Human Maxillary Arch: A Pilot Study

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Abstract

The purpose of this study was to investigate the maxillary arch bone density, arch dimensional changes and little irregularity index at completion of levelling and alignment stage of orthodontic treatment and to assess the influence on bone density instance to orthodontic treatment progression.

This pilot study consisted of 5 patients with Class II division 1 malocclusion treated with extraction of two maxillary first premolars. The data source was CBCT high volumetric data. All measurements were obtained through CBCT Planmeca Romexis TM Software 2.3.1.R (Helsinki, Finland). Variables recorded for each patient included gender, age, bone density at apical, middle and cervical region of maxillary anterior teeth, inter canine width (ICW), inter second premolar width (IPMW2), inter first molar width (IMW1), inter second molar (IMW2), arch length (AL), arch depth (AD) and little irregularity index (LII). The non-parametric Wilcoxon rank test were used for statistical analysis.

Generalized reduction was observed with significant difference (P<0.05) for bone density mostly at the apical region upon completion of levelling and alignment stage. Bone density in the apical region of central incisors and cervical region of canine were significantly different between left and right sides (P<0.05). IPMW2 was increased and the LLI was decreased with significant difference (p<0.05) after levelling and alignment stage of orthodontic treatment.

Generalized reduction in bone density were observed at the completion of maxillary arch levelling and alignment stage of orthodontic treatment especially in the apical region of central incisors and canine. The progress of orthodontic treatment has a positive impact on the arch dimensions and little irregularity index.

Clinical article (J Int Dent Med Res 2019; 12(3): 1055-1062)

Keywords: Tooth movement, Bone density, Arch dimension, CBCT.

Received date: 06 November 2018 **Accept date:** 30 March 2019

Introduction

Orthodontic force application leads to desired tooth movement, which is a biotic reaction of bone modelling and remodeling in the periodontium.[1] The newly moulded alveolar bone has low mineral density which potentially weaken the structural resistance.[2, 3] There is a correlation between the density of hyalinized alveolar bone area in the socket and root resorption. However, there is scarcity of studies explored to this issue.[1, 4, 5]

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Bone structure mineral density often scrutinized via computed tomography (CT) and cone beam computed tomography (CBCT) devices.[6, 7] The three-dimensional (3D) CBCT digital acquisition currently is a prodigious diagnostic and research tool using in dentistry. The advancement of the compact office CBCT machine and supportive software make it possible to expose the patients only once.[8] Thus, investigators can view and stockpile the patient pre and post orthodontic records for diagnostic, progress and post treatment.[9] Moreover, one CBCT radiation exposure can give us the patient records in various form of 2D, and 3D acquisitions. On contrary, the CBCT acquisition is very technique specific and sensitive.[10]

The orthodontic fixed appliances treatment consist of a stage wise procedure after bonding is leveling and alignments stage. Contemporarily, with the help of straight wire appliances it can be achieved with the sequence of nickel titanium (NiTi) wires. Due the continuous pressure by these elastic NiTi wire the teeth moved to the desired position. However, there might be some deleterious effect on tooth and its supporting structures. Researchers investigates the bone density changes for pre and post treatment observation.[9, 11] Until now no one investigated the bone density changes upon completion of leveling and alignment through 3D CBCT acquisitions. Thus, the prime purpose of this study was to investigate the maxillary arch bone density, arch dimensional changes and little irregularity index at completion of levelling and alignment stage of orthodontic treatment and to assess the influence on bone density instance to orthodontic treatment progression.

Materials and methods

All participants provided their inscribed informed consent. This pilot study consisted of 5 patients with Class II division 1 malocclusions, treated with extraction of two maxillary first premolars. Oral examinations were carried out with a cautious assortment of participants. Cross-examination of subjects was performed to minimize selection bias and error by experienced orthodontists. The following inclusion and exclusion were followed.

Inclusion criteria

- A minimum age for treatment of 18- 30 years in male and female patients.
- Patients with all erupted permanent teeth (except 3rd molar) with no history of previous orthodontic treatment.
- ¼ or half unit class II molar requiring extractions of first premolars bilaterally in upper or lower arch without special anchorage requirement.
- ¼ or half unit class II canine relationship.
- Class II skeletal pattern (ANB 5-7) and Class II incisor relationship with mild to moderate crowding.
- High quality records (cephalometric films with evident soft tissue profiles and Orthopantogram, CBCT acquisitions and digital dental model)
- Malay population (based on I/C or three generation Malaysian Malay).

Exclusion criteria

- Inter proximal caries or restoration that will affect tooth size and arch dimension measurement.
- Missing or supernumerary teeth.
- Abnormal size or morphology of teeth.
- Teeth wear that affect the tooth size measurement.
- Patients with medical problems and on medication. Patients on those medications which alter the bone metabolism or tooth movement e.g. NSAIDs, Corticosteroids, Bisphosphonates etc., parafunctional habits, TMJ dysfunction, craniofacial malformation, multiple missing teeth, impacted teeth except third molars, or periodontally compromised.

Bone mineral density measurements:

The data source was CBCT high volumetric data. All measurements were obtained through CBCT Planmeca Romexis TM Software 2.3.1.R (Helsinki, Finland) (**Figure 1**). The pre-orthodontic and at leveling and alignment stage of orthodontic treatment the bone mineral density were measured for the maxillary canine to canine. The teeth were vertically divided at apical, middle and cervical region based on each tooth roots length (**Figure2**). The CBCT acquisitions were used for the allocation of the bone density at four points around apical, middle and cervical region. The four points were mesial, distal, labial and palatal area of each zone respectively (**Figure 3**).

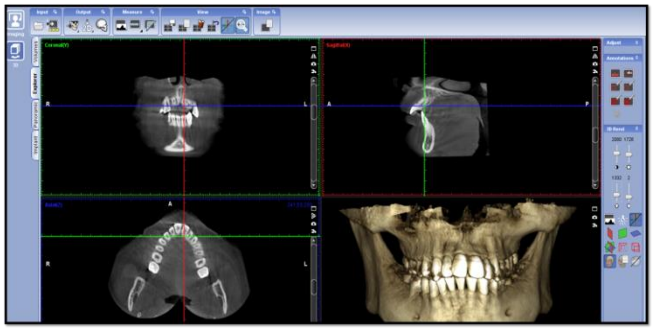

Figure 1. Data source was CBCT high volumetric data through CBCT Planmeca Romexis TM Software 2.3.1.R (Helsinki, Finland).

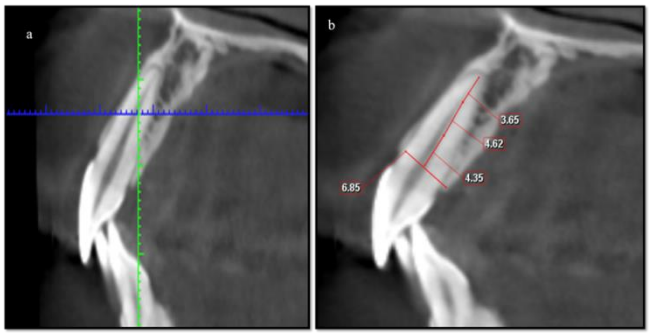

Figure 2. Vertically division of teeth at apical, middle and cervical region based on each tooth roots length.

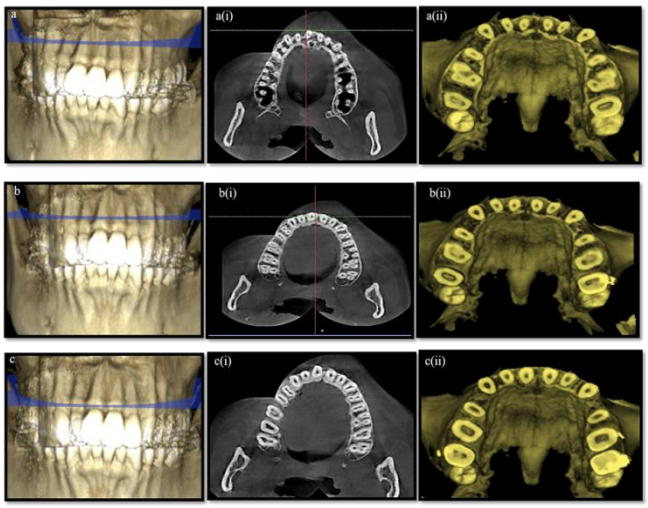

Figure 3. Bone density measurements at four points around apical, middle and cervical region.

Arch dimensional changes

All the arch dimensions were measured with 3D CBCT acquisitions for the following variables before and at completion of leveling/alignment stage of orthodontic treatment.

1. Arch width: the arch with were measure for the following variables (**Figure 4**)
   - Inter canine width (ICW) were obtained in between the cusp tip via linear measurements.
   - Inter premolar width (IPMW2) were obtained in between the buccal cusp tip of maxillary premolars via linear measurements.
   - Inter first molar width (IMW1) and Inter second molar (IMW2) were obtained via linear measurements from the mesio-buccal cusp tip to the contralateral mesio-buccal cups tip.

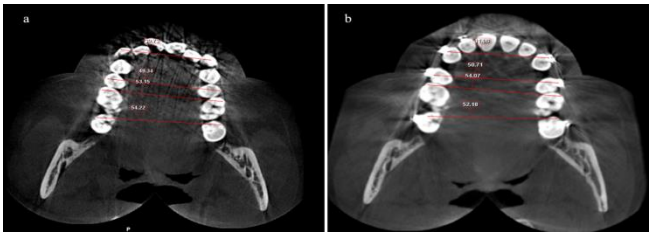

Figure 4. Arch width: the arch with were measure for the following variables.

2. Arch length (AL): were obtained by the sum of the right and left distance between the midpoint of mesioincisal edges of central incisors to the mesio-buccal cusp tips of the right and left first molars (**Figure 5a**).
3. Aarch depth (AD): were obtained by the distance measured from the midway point between the mesioincisal edges of the central incisors and the point bisecting the line connecting the mesio-buccal cusp tips of the right and left first molars (**Figure 5b**).
4. Little irregularity index (LII): the sum of the distances between the anatomic contact points from the mesial of the left canine to the mesial of the right canine (**Figure 5c**).

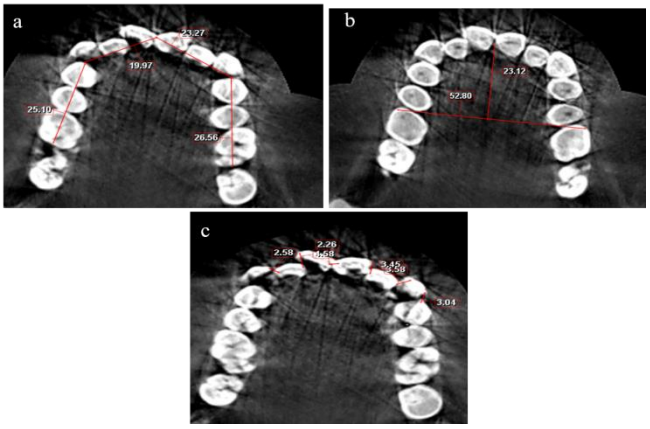

Figure 5. Measurement of arch length (Figure 5a), arch depth (Figure 5b), little irregularity index (Figure 5c).

Statistical analysis

All the statistical analyses were done with SPSS (IBM SPSS Statistics Version 22.0, Chicago, USA). The normality of the data evaluated with the skewness and kurtosis measurements. The observed data were nonparametric. Thus, for the comparison of pre-treatment and at completion of leveling/alignment stage of orthodontic treatment.

The non-parametric Wilcoxon rank test were used as statistical analysis for the comparison of bone density, arch dimensional changes and little's irregularity index.

Results

For the bone density generalized reduction were observed with significant difference (*P*<0.05) mostly at the apical region upon completion of levelling and alignment stage (**Table 1, Table 2 and Table 3)**. Bone density in the apical region of central incisors and cervical region of canine were significantly different between left and right sides (P<0.05) (**Table 4 and Table 5**). IPMW2 was increased and the LLI was decreased with significant difference (p<0.05) after levelling and alignment stage of orthodontic treatment (**Table 6**).

variables	Mean	SD	95% CI		P-Value
			Lower	Upper	
A11Mpre - A11Mpost	242.6	163.5	39.5	445.7	0.029
A12Mpre - A12Mpost	360.2	370.9	-100.4	820.8	0.096
A13Mpre - A13Mpost	197.0	287.0	-159.4	553.4	0.200
A21Mpre - A21Mpost	123.2	100.5	-1.6	248.0	0.052
A22Mpre - A22Mpost	359.2	220.4	85.5	632.9	0.022
A23Mpre - A23Mpost	235.6	292.9	-128.1	599.3	0.146
A11Dpre - A11Dpost	368.4	164.3	164.4	572.4	0.007
A12Dpre - A12Dpost	403.8	144.7	224.1	583.5	0.003
A13Dpre - A13Dpost	121.4	144.5	-58.1	300.9	0.134
A21Dpre - A21Dpost	167.8	180.1	-55.9	391.5	0.106
A22Dpre - A22Dpost	223.6	306.9	-157.4	604.6	0.179
A23Dpre - A23Dpost	190.2	280.9	-158.6	539.0	0.205
A11Bpre - A11Bpost	53.6	180.8	-170.9	278.1	0.544
A12Bpre - A12Bpost	136.0	119.5	-12.4	284.4	0.064
A13Bpre - A13Bpost	60.2	466.0	-518.4	638.8	0.787
A21Bpre - A21Bpost	-103.8	139.6	-277.1	69.5	0.172
A22Bpre - A22Bpost	-79.8	406.0	-583.9	424.3	0.683
A23Bpre - A23Bpost	95.4	384.5	-382.0	572.8	0.609
A11Ppre - A11Ppost	181.0	144.4	1.7	360.3	0.049
A12Ppre - A12Ppost	1.0	167.9	-207.4	209.4	0.990
A13Ppre - A13Ppost	203.4	259.7	-119.1	525.9	0.155
A21Ppre - A21Ppost	191.4	172.9	-23.3	406.1	0.069
A22Ppre - A22Ppost	104.6	298.7	-266.3	475.5	0.477
A23Ppre - A23Ppost	-41.0	118.2	-187.8	105.8	0.481

Table 1. Comparison of apical pre and post bone density at the completion of orthodontic.

Variables	Mean	SD	95% CI		P-Value
			Lower	Upper	
M11Mpre - M11Mpost	73.8	265.3	-255.6	403.2	0.568
M12Mpre - M12Mpost	225.2	254.5	-90.7	541.1	0.119
M13Mpre - M13Mpost	299.2	309.0	-84.5	682.9	0.096
M21Mpre - M21Mpost	-24.8	437.3	-567.8	518.2	0.905
M22Mpre - M22Mpost	194.4	198.5	-52.1	440.9	0.094
M23Mpre - M23Mpost	53.2	388.4	-429.0	535.4	0.775
M11Dpre - M11Dpost	86.8	204.5	-167.1	340.7	0.396
M12Dpre - M12Dpost	44.2	42.4	-8.4	96.8	0.080
M13Dpre - M13Dpost	-32.2	213.7	-297.6	233.2	0.753
M21Dpre - M21Dpost	199.2	205.5	-55.9	454.3	0.096
M22Dpre - M22Dpost	164.4	191.8	-73.7	402.5	0.128
M23Dpre - M23Dpost	150.2	310.3	-235.0	535.4	0.340
M11Bpre - M11Bpost	126.2	138.4	-45.6	298.0	0.111
M12Bpre - M12Bpost	187.0	256.8	-131.9	505.9	0.179
M13Bpre - M13Bpost	166.8	166.8	-40.3	373.9	0.089
M21Bpre - M21Bpost	77.2	170.1	-134.0	288.4	0.367
M22Bpre - M22Bpost	92.6	140.0	-81.3	266.5	0.213
M23Bpre - M23Bpost	141.4	219.9	-131.7	414.5	0.224
M11Ppre - M11Ppost	50.6	387.2	-430.2	531.4	0.785
M12Ppre - M12Ppost	-11.6	295.8	-378.9	355.7	0.934
M13Ppre - M13Ppost	127.8	367.0	-327.8	583.4	0.480
M2Ppre - M21Ppost	-30.8	225.3	-310.5	248.9	0.775
M22Ppre - M2Ppost	33.8	288.9	-325.0	392.6	0.807
M23Ppre - M23Ppost	-88.4	498.7	-707.7	530.9	0.712

Table 2. Comparison of middle pre and post bone density at the completion of orthodontic leveling and alignment stage.

Variables	Mean	SD	95% CI		P-value
			Lower	Upper	
C11Mpre - C11Mpost	179.0	279.1	-167.5	525.5	0.225
C12Mpre - C12Mpost	124.2	186.7	-107.6	356.0	0.211
C13Mpre - C13Mpost	256.6	305.7	-123.0	636.2	0.134
C21Mpre - C21Mpost	85.4	388.5	-397.0	567.8	0.649
C22Mpre - C22Mpost	275.6	204.1	22.1	529.1	0.039
C23Mpre - C23Mpost	-152.0	222.0	-427.7	123.7	0.201
C11Dpre - C11Dpost	-26.0	96.5	-145.8	93.8	0.579
C12Dpre - C12Dpost	233.2	183.4	5.5	460.9	0.047
C13Dpre - C13Dpost	181.0	330.2	-228.9	590.9	0.287
C21Dpre - C21Dpost	243.4	275.8	-99.1	585.9	0.120
C22Dpre - C22Dpost	298.4	285.2	-55.7	652.5	0.079
C23Dpre - C23Dpost	12.4	231.4	-274.9	299.7	0.910
C11Bpre - C11Bpost	167.2	236.5	-126.5	460.9	0.189
C12Bpre - C12Bpost	-20.0	404.1	-521.7	481.7	0.917
C13Bpre - C13Bpost	40.6	360.4	-406.9	488.1	0.814
C21Bpre - C21Bpost	-13.0	201.1	-262.7	236.7	0.892
C22Bpre - C22Bpost	-5.2	331.2	-416.4	406.0	0.974
C23Bpre - C23Bpost	17.8	187.3	-214.8	250.4	0.842
C11Ppre - C11Ppost	275.0	170.6	63.2	486.8	0.023
C12Ppre - C12Ppost	56.6	260.9	-267.3	380.5	0.653
C13Ppre - C13Ppost	212.4	349.3	-221.3	646.1	0.246
C21Ppre - C21Ppost	349.4	242.2	48.7	650.1	0.032
C22Ppre - C22Ppost	130.2	218.6	-141.2	401.6	0.254
C23Ppre - C23Ppost	318.4	191.2	81.0	555.8	0.020

Table 3. Comparison of cervical pre and post bone density at the completion of orthodontic leveling and alignment stage.

Variables	Mean	SD	95% CI		P-value
			Lower	Upper	
A11Mpre - A21Mpre	224.6	273.6	-115.1	564.3	0.140
A12Mpre - A22Mpre	-41.8	123.2	-194.8	111.2	0.490
A13Mpre - A23Mpre	40.2	132.1	-123.9	204.3	0.534
A11Dpre - A21Dpre	-86.0	129.0	-246.2	74.2	0.210
A12Dpre - A22Dpre	7.0	212.0	-256.2	270.2	0.945
A13Dpre - A23Dpre	-27.8	289.3	-387.0	331.4	0.840
A11Bpre - A21Bpre	49.8	121.3	-100.9	200.5	0.411
A12Bpre - A22Bpre	-4.4	233.7	-294.5	285.7	0.968
A13Bpre - A23Bpre	-102.0	383.6	-578.3	374.3	0.584
A11Ppre - A21Ppre	-63.0	158.7	-260.0	134.0	0.425
A12Ppre - A22Ppre	169.4	245.8	-135.8	474.6	0.198
A13Ppre - A23Ppre	137.8	236.9	-156.4	432.0	0.263
M11Mpre - M21Mpre	222.2	184.3	-6.6	451.0	0.054
M12Mpre - M22Mpre	75.0	126.5	-82.1	232.1	0.256
M13Mpre - M23Mpre	111.2	204.8	-143.1	365.5	0.292
M11Dpre - M21Dpre	-139.8	119.6	-288.4	8.8	0.059
M12Dpre - M22Dpre	-289.6	140.4	-464.0	-115.2	0.010
M13Dpre - M23Dpre	-184.2	200.4	-433.1	64.7	0.109
M11Bpre - M21Bpre	22.8	401.0	-475.1	520.7	0.905
M12Bpre - M22Bpre	120.2	160.0	-78.4	318.8	0.168
M13Bpre - M23Bpre	110.8	305.7	-268.7	490.3	0.463
M11Ppre - M2Ppre	-18.6	207.4	-276.1	238.9	0.851
M12Ppre - M22Ppre	125.6	226.0	-155.1	406.3	0.282
M13Ppre - M23Ppre	91.6	142.7	-85.6	268.8	0.225
C11Mpre - C21Mpre	185.2	232.3	-103.2	473.6	0.149
C12Mpre - C22Mpre	127.6	161.6	-73.1	328.3	0.152
C13Mpre - C23Mpre	181.8	164.2	-22.1	385.7	0.069
C11Dpre - C21Dpre	-150.0	220.0	-423.2	123.2	0.202
C12Dpre - C22Dpre	-199.2	160.3	-398.2	-0.2	0.050
C13Dpre - C23Dpre	23.8	111.2	-114.3	161.9	0.657
C11Bpre - C21Bpre	57.6	178.3	-163.8	279.0	0.510
C12Bpre - C21Bpre	-20.2	207.6	-278.0	237.6	0.838
C13Bpre - C23Bpre	-73.6	172.0	-287.2	140.0	0.393
C11Ppre - C21Ppre	-38.6	173.4	-253.9	176.7	0.645
C12Ppre - C22Ppre	-43.2	161.6	-243.9	157.5	0.582
C13Ppre - C23Ppre	76.0	242.0	-224.5	376.5	0.521

Table 4. Comparison of pre right and left side bone density.

Variables	Mean	SD	95% CI		P-value
			Lower	Upper	
A11Mpost - A21Mpost	105.2	123.4	-48.0	258.4	0.129
A12Mpost - A22Mpost	-42.8	185.7	-273.4	187.8	0.633
A13Mpost - A23Mpost	78.8	157.6	-116.8	274.4	0.326
A11Dpost - A21Dpost	-286.6	175.5	-504.5	-68.7	0.022
A12Dpost - A22Dpost	-173.2	113.6	-314.3	-32.1	0.027
A13Dpost - A23Dpost	41.0	214.7	-225.6	307.6	0.691
A11Bpost - A21Bpost	-107.6	164.8	-312.2	97.0	0.218
A12Bpost - A22Bpost	-220.2	338.9	-641.0	200.6	0.220
A13Bpost - A23Bpost	-66.8	208.7	-325.9	192.3	0.514
A11Ppost - A21Ppost	-52.6	180.0	-276.1	170.9	0.549
A12Ppost - A22Ppost	273.0	264.8	-55.7	601.7	0.082
A13Ppost - A23Ppost	-106.6	271.9	-444.3	231.1	0.430
M11Mpost - M21Mpost	123.6	236.8	-170.4	417.6	0.308
M12Mpost - M22Mpost	44.2	139.6	-129.2	217.6	0.518
M13Mpost - M23Mpost	-134.8	357.4	-578.5	308.9	0.446
M11Dpost - M21Dpost	-27.4	329.3	-436.3	381.5	0.861
M12Dpost - M22Dpost	-169.4	105.9	-300.8	-38.0	0.023
M13Dpost - M23Dpost	-1.8	226.7	-283.2	279.6	0.987
M11Bpost - M21Bpost	-26.2	245.4	-330.9	278.5	0.823
M12Bpost - M22Bpost	25.8	227.2	-256.3	307.9	0.812
M13Bpost - M23Bpost	85.4	280.4	-262.7	433.5	0.533
M11Ppost - M21Ppost	-100.0	227.7	-382.7	182.7	0.382
M12Ppost - M2Ppost	171.0	364.4	-281.5	623.5	0.353
M13Ppost - M23Ppost	-124.6	400.0	-621.3	372.1	0.524
C11Mpost - C21Mpost	91.6	241.2	-207.9	391.1	0.444
C12Mpost - C22Mpost	279.0	252.2	-34.1	592.1	0.069
C13Mpost - C23Mpost	-226.8	242.6	-528.1	74.5	0.105
C11Dpost - C21Dpost	119.4	220.0	-153.8	392.6	0.292
C12Dpost - C22Dpost	-134.0	301.0	-507.7	239.7	0.376
C13Dpost - C23Dpost	-144.8	245.4	-449.5	159.9	0.257
C11Bpost - C21Bpost	-122.6	137.1	-292.8	47.6	0.116
C12Bpost - C22Bpost	72.6	356.4	-369.9	515.1	0.672
C13Bpost - C23Bpost	-96.4	255.6	-413.8	221.0	0.447
C11Ppost - C21Ppost	35.8	249.6	-274.1	345.7	0.764
C12Ppost - C22Ppost	30.4	281.6	-319.3	380.1	0.821
C13Ppost - C23Ppost	182.0	165.4	-23.4	387.4	0.070

Table 5. Comparison of post right and left side bone density.

Variables	Z	P-value
LIRI post – LIRI pre	-2.023b	**0.043**
ICW post – ICW pre	-.944c	0.345
IPM2post - IPM2pre	-2.023c	**0.043**
IM1post - IM1pre	-.944c	0.345
IM2post - IM2pre	-.674b	0.500
AD post – AD pre	-1.214c	0.225
AL post – AL pre	-.405b	0.686

Table 6. Maxillary arch pre and post arch dimensional changes.

Discussion

Orthodontic treatment improves the quality of life and confidence of the patient. Consequently, its and popular oral convalescence. This treatment usually spot-on relationship between the soft and hard tissue of the oral cavity for the improvement of malocclusion and facial exteriors. However, orthodontic treatment has some deleterious effect on the surrounding structure such as bone density and root resorption.

Bone density is the bone mass or thickness which is the assessment of bone mineral packed into the specific segment. Various researchers investigates the orthodontic pre and post treatment alveolar bone density on faunae[12, 13] and computer imitations.[14, 15] The new bone production in response to orthodontic treatment is less dense.[2, 9] The current study have focused on the bone density changes until the leveling and alignment stages of orthodontic treatment in human subjects (**Figure 6**).

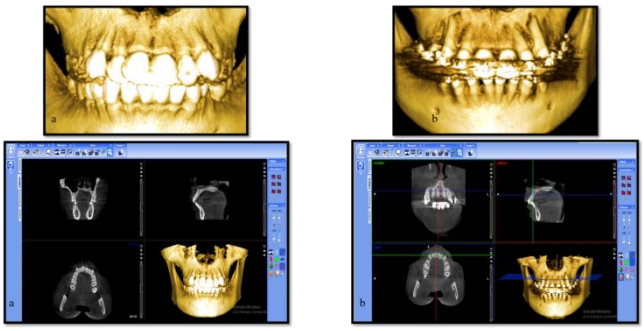

Figure 6. Bone density changes pre and until the leveling and alignment stages of orthodontic treatment in human subjects.

The X-ray absorptiometry, micro radiographs and ultrasound were the non-invasive modalities applied for the bone density measurements.[16-18] Nevertheless, all the approaches have some limitations for instance non obtainability of 3D acquirements.[9] The CBCT is an alternative for the measurement of bone density. Moreover, it has less radiation dosage than conventional CT.[19] Researcher on animal investigation observed the reduction in the alveolar bone density of rats.[12] Studies on human subject observed the bone density reduction around the maxillary anterior teeth and along the direction of the tooth movement on the few specific teeth with limitation in measurements of bone density.[2, 20] Present study investigate the bone density of maxillary arch pre orthodontic and at leveling and alignment stage of orthodontic treatment the bone mineral density were measured for the maxillary canine to canine. The CBCT acquisitions were used for the allocation of the bone density at four points around apical, middle and cervical region. The four points were mesial, distal, labial and palatal area of each zone respectively. At the completion of maxillary arch levelling and alignment stage, generalized reduction in bone density were observed. Reduction in bone density might be risk factors to orthodontic treatment stability. The bone density changes need to be investigated in more detail upon completion of orthodontic treatment along the various modalities which accelerate the tooth movements. Researches used the 2D and 3D radiographic acquisitions for liner methods of measurements in orthodontics.[21, 22] However, researches also used the digital dental models for such tooth size and arch size linear measurements, with the ese of keeping as a digital record.[23-25] Current study also compare the 3D linear attenuation of arch widths (ICW, IPMW and IMW), AL, AD and LII upon the completion of levelling and alignment stage of orthodontic treatment. However, the progress of orthodontic treatment has a positive impact on the arch dimensions and little irregularity index.

Conclusions

At the completion of maxillary arch levelling and alignment stage of orthodontic treatment generalized reduction in bone density were observed. The bone density changes need to be investigated in more detail upon completion of orthodontic treatment along the various modalities which accelerate the tooth movements. Reduction in bone density might be risk factors to orthodontic treatment stability and might need long period of retention phase. However, the progress of orthodontic treatment has a positive impact on the arch dimensions and little irregularity index.

Declaration of Interest

The authors report no conflict of interest and the article is granted by RUI Grant No: PPSG/ 812154 & Vice chancellor award 2016.

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