2014년 2월 석사학위 논문 입천장뼈 두께의 두부방사선사진 계측값과 CBCT 계측값 비교 김 영 재

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석사학위 논문

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조선대학교 대학원

치의학과

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조 선 대 학 교 대 학 원

치 의 학 과

김 영 재

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지도교수 임 성 훈

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치의학과

김 영 재

김영재의 석사학위 논문을 인준함

위원장 조선대학교 교 수 김 흥 중 (인)

위 원 조선대학교 교 수 임 성 훈 (인)

위 원 조선대학교 조교수 강 성 남 (인)

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ABSTRACT

Comparison of cephalometric measurements and cone-beam computed-tomography-based measurements of palatal bone thickness

Young-jae Kim
Advisor : Prof. Sung-Hoon Lim, DDS, MSD, PhD
Department of Dentistry
Graduate School of Chosun University

Introduction: 이 연구의 목적은 입천장뼈 두께를 측정하는데 있어 측모두부계측방사선사진에서의 계측값과 cone-beam computed tomography (CBCT) 영상에서의 계측값 사이의 관계를 결정하기 위한 것이다.

Methods: 환자 30명의 CBCT 영상과 측모두부계측방사선사진이 사용되었다. 입천장뼈 두께는 전후방적으로 P1P2 (제1소구치와 제2소구치 사이)에서 M1M2 (제1대구치와 제2대구치 사이)까지 두 영상 방법 모두에서 측정되었고 횡적으로는 1.5 mm off-center에서 10mm off-center까지 CBCT 영상에서만 측정되었다. 반복계측분산분석을 사용하여 두 계측값 간의 차이를 분석하였다.

Results: Bland-Altman plots에서 5 mm off-center에서의 95% limits of agreement가 가장 작게 나타났다(-0.2±1.7 mm). 5 mm off-center에서의 계측값만이 모든 전후방적 위치에서 두부계측방사선사진에서의 계측값과 통계적으로 유의한 차이를 보이지 않았다. 1.5 mm off-center에서의 계측값은 P2M1 (제2소구치와 제1대구치 사이)에서 M1M2까지만 두부계측방사선사진에서의 계측값보다 더 유의적으로 두껍게 나타났다.

Conclusions: 계측된 모든 영역 중에서, 5 mm off-center에서의 골이 측모두부계측방사선사진에서의 입천장뼈 형태를 가장 잘 나타낸다.

I . Introduction

The palate is a preferred area for orthodontic mini-implant placement because there is little danger of damaging anatomical structures other than the incisive foramen.[1,2] Also, there is a relatively large bone mass in the median and flanking regions of the palate with dense soft tissues on the surface of the hard palate, thus facilitating the formation of compact connective tissues around the cervical part of the implant.[3,4]

The most appropriate length for a mini-implant should be determined from measurements of the palatal bone thickness to ensure that the maximum thickness of palatal bone is utilized without penetrating the palate. Although cone-beam computed tomography (CBCT) can be used to measure palatal bone thickness, Jung et al[5] and Winsauer et al[6] suggested that CBCT needs to be used only in rare cases of borderline palatal bone thickness.

A cephalogram can be used to measure palatal bone thickness, but care must be taken due to the presence of magnification, which is typically 110%.[7,8] Because a cephalogram is a two-dimensional view of a three-dimensional object with a perspective projection, the magnifications of the right and left structures differ, resulting in an unequal overlap of the right and left structures. The location of an object between the X-ray source and the film determines the magnification of image, with structures closer to the X-ray source appearing larger. The distance between the source and the midsagittal plane of the subject is typically 1500 mm, and the distance between the midsagittal plane of the subject and the detector is 150 mm, with the central ray passing through the center of the mechanical porion. The half of the palatal bone that is closer to the source is projected on the film as if it were positioned more inferiorly and so it appears larger than the half on the contralateral side. To illustrate the typical magnification in the cephalogram of palatal bone thickness at 5 mm off-center, consider the following assumptions (see Fig 1): the palatal bone thickness at 5 mm off-center is 5 mm, and the vertical distance from the central ray to the superior side of the palatal bone is 25 mm.

According to the calculation of magnification illustrated in Fig 1, a 5 mm thickness of palatal bone at 5 mm off-center will be projected onto the film as a thickness of 5.7 mm, which is a magnification of 114%. Jung et al[9] reported that the vertical dimensions on lateral cephalometry reflect the minimum thickness of bone, and not the maximum thickness in the median plane. In that study[9] the nasal floors and palates of dry skulls were covered with tinfoil before the radiographs were obtained. In this condition the bony palate will probably appear thinner in the cephalogram because its apparent thickness will be determined by the oblique X-rays passing through the tinfoil on the nasal floor closer to the X-ray source and the tinfoil on the palatal side closer to the film. Covering the nasal floor and palate with tinfoil from the center to 5 mm off-center will result in 106% magnification instead of 114% when the same conditions shown in Fig 1 are assumed.

Several studies[1,2,10-13] using CBCT or computed tomography have found that the palatal bone thickness tends to decrease laterally or posteriorly. Wehrbein et al[14] reported that the thicknessof the anterior and median hard palate was 2 mm thickerthan that shown in lateral cephalograms. Cephalograms may not depict the maximum thickness of median palate,[9,14] but no previous study has investigated which part of the palate in the transverse aspect is depicted on the cephalogram.

The purpose of the present study was to test the null hypothesis that there is no relationship between the palatal bone thickness values in various transverse areas as measured cephalometrically and using CBCT.

Ⅱ. Materials and Methods

This work was approved by the local ethics committee of School of Dentistry, Chosun University (CDMDIRB 1218-86). Thirty sets of CBCT images and cephalograms (for 15 males and 15 females) were selected from among the CBCT and cephalogram sets obtained from patients in whom CBCT was performed as part of an orthodontic examination (Table I). Exclusion criteria included pathological findings, cleft palate, missing teeth or supernumerary teeth, and a history of previous orthodontic treatment. Lateral cephalograms and CBCT images were obtained on the same day.

Cephalometric measurements

Lateral cephalograms were obtained using an orthopantomograph equipped with a cephalostat (PM 2002 Proline, Planmeca, Helsinki, Finland). The following parameters were used for lateral cephalometry: 80 kV, 12 mA, and exposure time of 1.4 - 1.6 seconds. Cephalograms were stored in a PACS (picture archiving and communications system) server after scanning the Computed Radiography (CR) cassette. Measurements were performed using STARPACS PiViewSTAR 5.0 (Infinitt, Seoul, Korea). The occlusal plane was used as a reference plane for both cephalometric and CBCT-based measurements (Table II). The occlusal plane was determined as the plane passing the incisal edge of the maxillary left central incisor and the mesiolingual cusp tips of the right and left maxillary first molars. Average points between the right and left landmarks were used in the cephalometric measurements. Lines were then drawn that were perpendicular to the occlusal plane and passed between the first and second premolars (P1P2) and the lingual cusps of second premolars (P2), between the second premolars and first molars (P2M1), the mesiolingual cusps of first molars (M1), and between the first and second molars (M1M2). In all cases the average points between the right and left landmarks were used. Palatal bone thicknesses were measured along these lines (Table II; Fig 2).

To compare CBCT-based measurements and cephalometric measurements, the cephalometric measurements were converted to a 100% magnification. In the present study, the X-ray source to object distance was 1510 mm and the object to film distance was 128 mm, resulting in a magnification of 108.5%. Therefore, conversion to 100% magnification was achieved by dividing the cephalometric measurements of palatal bone thickness by 1.085.

Measurements in CBCT images

CBCT images were obtained using a CBCT scanner (CB MercuRay, Hitachi, Osaka, Japan) with the following parameters: field of view of 149.5 mm × 149.5 mm, 120 kV, 15 mA, scan time of 9.6 seconds, slice thickness of 0.292 mm, and isometric voxel size of 0.292 mm. Measurements from CBCT images were performed using Ondemand3D 1.0 (Cybermed, Seoul, Korea). A preset of window leveling (level: 805 HU, width: 2829 HU) was used to maintain a constant viewing condition. This window leveling ensured that only those voxels having HU values from −609 HU to 2220 HU were displayed in the program window. A midsagittal reference plane (MSR) was constructed as the plane passing through the crista galli, anterior nasal spine, and posterior nasal spine. Coronal sections that were perpendicular to the occlusal plane and passing the right and left P1P2, P2, P2M1, M1, and M1M2 were selected. For each of these coronal sections, palatal bone thicknesses were measured along vertical measurement lines parallel to the MSR and offset from it by 1.5, 5, 7.5, and 10 mm (Fig 3); these measurements were labeled as 1.5, 5, 7.5, and 10 mm off-center. The minimum palatal bone thickness was also measured within the range from the MSR to 10 mm off-center. The right and left measurements made on CBCT images were averaged for each patient.

When the incisive canal or maxillary sinus was encountered along the measurement line, the thickness value was not recorded (Table III). In cases where the maxillary sinus extends medially below the nasal cavity, the palatal bone thickness measurements will be made from the floor of the sinus to the inferior surface of the bony palate. Measurements made from the canal or sinus floor cannot be compared with the cephalometric measurements that are made from the nasal floor, which is the same as the superior surface of the bony palate, and so these measurements were treated as missing values.

Statistical analysis

All measurements for 10 samples were repeated after 2 weeks by one examiner (Y.K.), and Dahlberg's formula[15] was used to evaluate the method error of the measurements: this was 0.32 mm in cephalometric measurements and 0.24 mm in CBCT-based measurements. Kolmogorov-Smirnov normality tests showed that the data conformed to a normal distribution in all measurement areas. Bland-Altman plots[16,17] and repeated-measures ANOVA were used to examine the relationships among cephalometric measurements and various CBCT-based measurements. The results were considered significant at $P < 0.05$. Bland-Altman plots were generated using the MedCalc 12.4.0 software (MedCalc Software, Mariakerke, Belgium), and other analyses were performed using SPSS 12.0 (SPSS, Chicago, Ill).

Ⅲ. Results

The incisive canal was encountered in 60% of P1P2, 13% of P2, and 3% of P2M1 measurements in CBCT images at 1.5 mm off-center. The maxillary sinus was encountered in 57% of 10-mm-off-center measurements and in 20% of 7.5-mm-off-center measurements (Table III).

In Bland-Altman plots, the limits of agreement (LOA) were defined as ±1.96 SD, and the 95% CI values for the LOA were identified (as marked in Fig 4). The 95% LOA were 0.9±3.1 mm (mean±1.96SD) for 1.5 mm off-center, －0.2±1.7 mm for 5 mm off-center, －0.1±1.9 mm for 7.5 mm off-center, 1.6±3.5 mm for 10 mm off-center, and －1.0±1.7 mm for the minimum bone thickness (Fig 4).

The cephalometric measurements of palatal bone thickness decreased posteriorly from 9.91±2.10 mm at P1P2 to 2.52±1.35 mm at M1M2. The cephalometric and 5-mm-off-center measurements did not differ significantly in any areas. At 7.5 mm off-center, there was a significant difference only in the M1M2 area. At 1.5 mm off-center, P2M1, M1, and M1M2 measurements were significantly thicker than the cephalometric measurements. All measurements at 10 mm off-center except for M1M2 measurements were significantly thicker than the cephalometric measurements. Minimum measurements were significantly thinner than the cephalometric measurements in all areas except P2M1 (Table IV; Figs 5 and 6).

Ⅳ. Discussion

The null hypothesis was rejected in favor of an alternate hypothesis that there is a strong correlation between cephalometric measurements and CBCT-based measurements of the palate especially at 5 and 7.5 mm off-center (Fig 4). In Bland-Altman plots, 5- and 7.5-mm-off-center measurements showed minimal mean differences and relatively small LOA, with the LOA being smallest at 5 mm off-center (－0.2±1.7 mm). This indicates that the bone at 5 mm off-center is the most likely area to be depicted in cephalograms as palatal bone contours.

The horizontal axis of the Bland-Altman plot is the average of CBCT and 100% cephalogram measurements, and this average increases from M1M2 to P1P2 because the palatal bone thickness tends to increase anteriorly. The Bland-Altman plot for 10 mm off-center showed positive proportionality. This may be due to the difference between 10 mm off-center and the 100% cephalogram increasing from M1M2 to P1P2 while the average value of the two measurements increased from M1M2 to P1P2. The smallest difference shown at M1M2 might be due to the 10-mm-off-center area becoming incorporated into the flatter area at M1M2 and being depicted in the cephalogram as a palatal contour along with the 5-mm-off-center area.

The Bland-Altman plot for 1.5 mm off-center showed negative proportionality. This may be due to the difference between 1.5 mm off-center and the 100% cephalogram decreasing from M1M2 to P2M1 while the average value of the two measurements increased from M1M2 to P2M1. The minimum measurements were significantly thinner than the cephalometric measurements in all areas except P2M1. When compared to the cephalometric measurements, the 5- and 7.5-mm-off-center measurements showed no significant differences, except in the M1M2 area at 7.5 mm off-center where the CBCT-based measurement was significantly thinner.

Flat areas parallel to the central ray appear more radiopaque than the curved areas in a cephalogram, owing to the overlapping of cortical bone in flat areas. The differences between 5 and 7.5 mm off-center were statistically insignificant except for the M1M2 area at 7.5 mm off-center, which suggest that these areas constitute relatively flat areas of the palate and are depicted in the cephalogram as the palatal bone contour except for the M1M2 area at 7.5 mm off-center. Considering that the maxillary sinus was involved in 20% of the 7.5-mm-off-center measurements, cephalograms are most likely to depict the cortical bone in the 5-mm-off-center area of the palate.

The present study selected the 1.5-mm-off-center area rather than the midpalatal area, because the palatal bone at 1.5 mm off-center should be thicker than the length of the mini-implant that is to be inserted into the bone if penetration of the palatal bone during the placement of the mini-implant is considered undesirable or unnecessary. Additionally, determination of the superior end of the nasal crest is difficult because the thin vomer bone is attached over the nasal crest.[1]

The 1.5-mm-off-center and cephalometric measurements did not differ significantly in the P1P2 and P2 areas, whereas the 1.5-mm-off-center measurements were significantly thicker than the cephalometric measurements in the other areas. When the nasal crest height was estimated indirectly using the difference in bone thicknesses measured at 1.5 and 5 mm off-center, the nasal crest height increased from P2 to M1M2 (Fig 7). Although the cephalometric measurements of palatal bone thicknesses decreased continuously from P1P2 to M1M2, the palatal bone thicknesses at 1.5 mm off-center were relatively constant in the P2M1, M1, and M1M2 areas. This can be attributed to the increasing height of the nasal crest compensating for the posteriorly directed gradual decrease in overall palatal bone thickness in the 1.5-mm-off-center area. Considering the increasing height of the nasal crest (Fig 7), the bone thickness at 1.5 mm off-center can be roughly estimated from the cephalometric measurements by adding 1 and 2 mm to M1- and M1M2-area measurements, respectively. Because the bone thickness in P1P2 and P2 areas was the same in 1.5-mm-off-center and 100% cephalogram measurements, and the bone in P2M1 to M1M2 areas was thicker for 1.5-mm-off-center measurements than for the 100% cephalograms, CBCT may not be needed when planning mini-implant placement in the midpalate when cephalograms exhibit sufficient bone thickness. However, if cephalograms show very thin palatal bone, then CBCT may be required to evaluate the precise bone thickness of the midpalate and nasal crest, or to explore other suitable areas for mini-implant placement.

Among 1.5-mm-off-center measurements, 60% of P1P2 measurements and 13% of the P2 measurements encountered the incisive canal. Therefore, placing mini-implants using the full thickness of the P1P2 or P2 midpalatal bone may result in involvement of the incisive canal. Also, the maxillary sinus was encountered in 7 - 17% and 0 - 7% of 10- and 7.5-mm-off-center measurements, respectively. Caution is required when placing mini-implants in these areas. Because the present study included CBCT-based measurements that did not involve the maxillary sinus or incisive canal, the palatal bone of an actual patient can be thinner than the mean values obtained in the present study, especially when the maxillary sinus extends medially below the nasal floor or when the incisive canal is positioned over the P1P2 area. The palatal bone was found to be thickest in the P1P2 area; however, in this area 60% of the 1.5-mm-off-center measurements encountered the incisive canal, and 7% of the 10-mm-off-center measurements encountered the maxillary sinus. Therefore, the area between 5 and 7.5 mm off-center can be safer while providing similar quantity of palatal bone—there may be a thinner mucosa and better bone quality in the midpalatal areas.

Possible limitations to this study must be considered. Although there were no significant differences between 5-mm-off-center and 100% cephalogram measurements, this does not mean that the palatal bone thickness at 5 mm off-center can be accurately measured using the cephalogram. Although the bone at 5 mm off-center may be depicted in cephalograms as palatal bone contours in most cases, there could be large interindividual variations. The characteristics of the depicted area will vary with the width of the palate. Also, a deep palate or V-shaped arch may show less flat areas, resulting in blurring of the palatal bone contour on the cephalogram. When there is a vertical difference between the right and left sides of the palatal bone, or when there is vertical asymmetry of the external auditory meatus causing misalignment of the head and palate, the palatal bone thickness shown on the cephalogram can be exaggerated with some blurring.

The presence of the palatal bone with a blurred contour on a cephalogram means that cephalometric measurements of the palatal bone thickness should not be used as a guide for mini-implant placement. The CBCT-based measurements of the palate reported herein may be used as a guideline for planning mini-implant placement in the palate. However, large interindividual variations in the palatal bone contour and thickness still need to be considered.

V. Conclusions

Among the areas measured in the present study, the palatal bone at 5 mm off-center is most likely to be depicted in cephalograms as palatal bone contours. Thicker bone exists at 1.5 mm off-center than is shown on cephalograms in the areas from P2M1 to M1M2 owing to the increasing height of the nasal crest.

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Tables

Table I. Sample characteristics

	Males (n=15)		Females (n=15)	
	Mean	SD	Mean	SD
Age (years)	19.6	3.4	19.7	3.8
ANB (°)	1.2	5.1	3.1	3.7
FMA (°)	26.5	4.7	28.0	4.1
ICW (mm)	36.0	2.6	35.7	2.1
IMW (mm)	38.7	3.2	38.2	3.3

ICW: intercanine width; IMW: intermolar width, the distance between the maxillary first molars as measured at the point of the intersection of the lingual groove with the gingival margin

Table II. Description of reference planes and landmarks

Plane/landmark	Definition
Occlusal plane	A plane passing the incisal edge of the maxillary left central incisor and cusp tips of the mesiolingual cusps of both maxillary first molars
MSR plane*	A plane constructed using the crista galli, anterior nasal spine, and posterior nasal spine
P1P2	Contact point of the maxillary first and second premolars
P2	Lingual cusp tip of the maxillary second premolar
P2M1	Contact point of the maxillary second premolar and first molar
M1	Mesiolingual cusp tip of the maxillary first molar
M1M2	Contact point of the first and second molars

*Used only for the CBCT-based measurements

Table III. Frequency of encountering the incisive canal or maxillary sinus along the measurement line during CBCT measurements

		1.5 mm off-center	5 mm off-center	7.5 mm off-center	10 mm off-center
P1P2	Canal	18 (60%)	1 (3%)		
	Sinus				2 (7%)
P2	Canal	4 (13%)			
	Sinus			2 (7%)	5 (17%)
P2M1	Canal	1 (3%)			
	Sinus			2 (7%)	4 (13%)
M1	Canal				
	Sinus			1 (3%)	4 (13%)
M1M2	Canal				
	Sinus			1 (3%)	2 (7%)

Percentage values correspond to the number of encounters divided by the total number of samples.

Table IV. Comparison of palatal bone thicknesses measured from the cephalogram (ceph) and CBCT images (in mm)

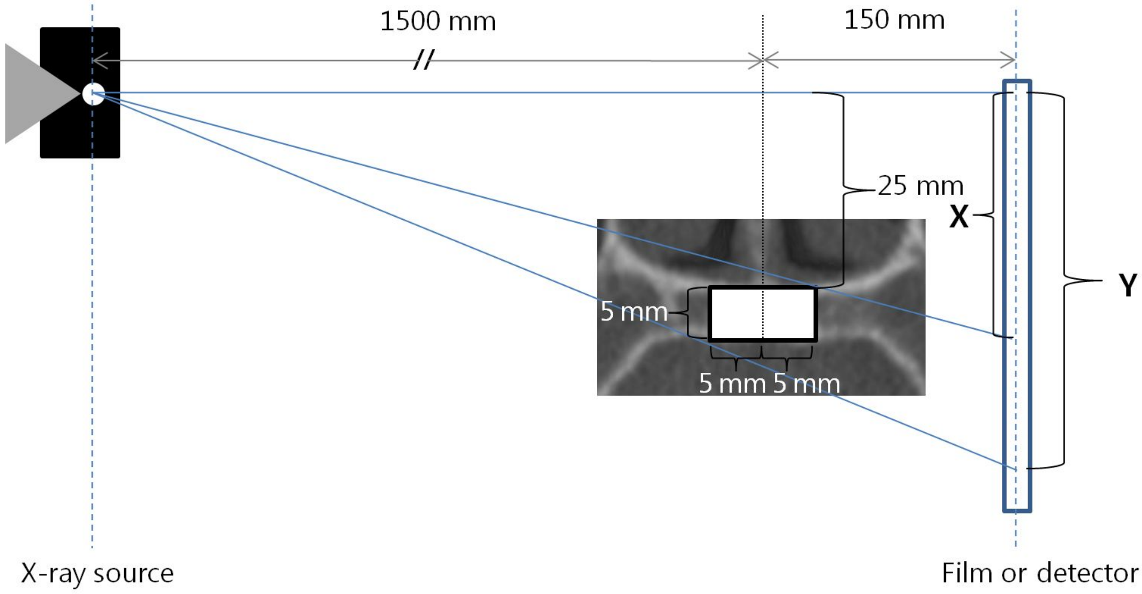
	P1P2				P2				P2M1			
	n	Mean	SD	Subgroup	n	Mean	SD	Subgroup	n	Mean	SD	Subgroup
100% ceph	30	9.91	2.10	bc	30	6.42	2.02	bc	30	4.42	1.79	c
1.5 mm off-center	12	9.90	3.28	bc	26	5.60	1.37	bc	29	4.75	1.12	b
5 mm off-center	29	9.54	2.33	c	30	5.84	2.08	c	30	4.33	1.83	c
7.5 mm off-center	30	10.41	2.51	b	28	5.98	2.04	b	28	4.13	1.59	c
10 mm off-center	28	12.91	2.72	a	25	8.26	2.65	a	26	6.05	2.31	a
Minimum	30	8.62	2.37	d	30	4.95	1.95	d	30	3.61	1.54	c

* Measurements with the same subgroup letter do not differ significantly for multiple comparisons.

Table IV. Continued.

	M1				M1M2			
	n	Mean	SD	Subgroup	n	Mean	SD	Subgroup
100% ceph	30	3.25	1.42	b	30	2.52	1.35	b
1.5 mm off-center	30	4.43	1.12	a	30	4.86	1.10	a
5 mm off-center	30	3.21	1.44	b	30	2.54	1.29	b
7.5 mm off-center	29	3.02	1.48	b	29	2.09	1.21	c
10 mm off-center	26	3.99	1.46	a	28	2.40	1.10	b
Minimum	30	2.47	1.45	c	30	1.77	1.07	d

Figures



1505 : 25 = 1650 : X   X = 27.4 mm

1495 : 30 = 1650 : Y   Y = 33.1 mm

Palatal bone thickness on the cephalogram = Y-X = 5.7 mm

Fig 1. Schematic of the magnification of palatal bone at 5 mm off-center. A bone thickness of 5 mm at the 5-mm-off-center area will be projected onto the film as a 5.7-mm bone thickness.

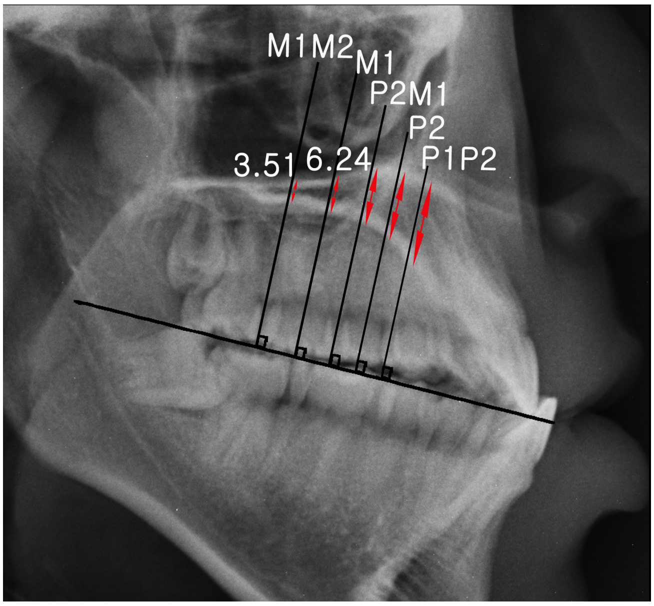


Fig 2. Cephalometric measurements of palatal bone thickness. The thickness values were measured along lines drawn perpendicular to the occlusal plane and passing through it.

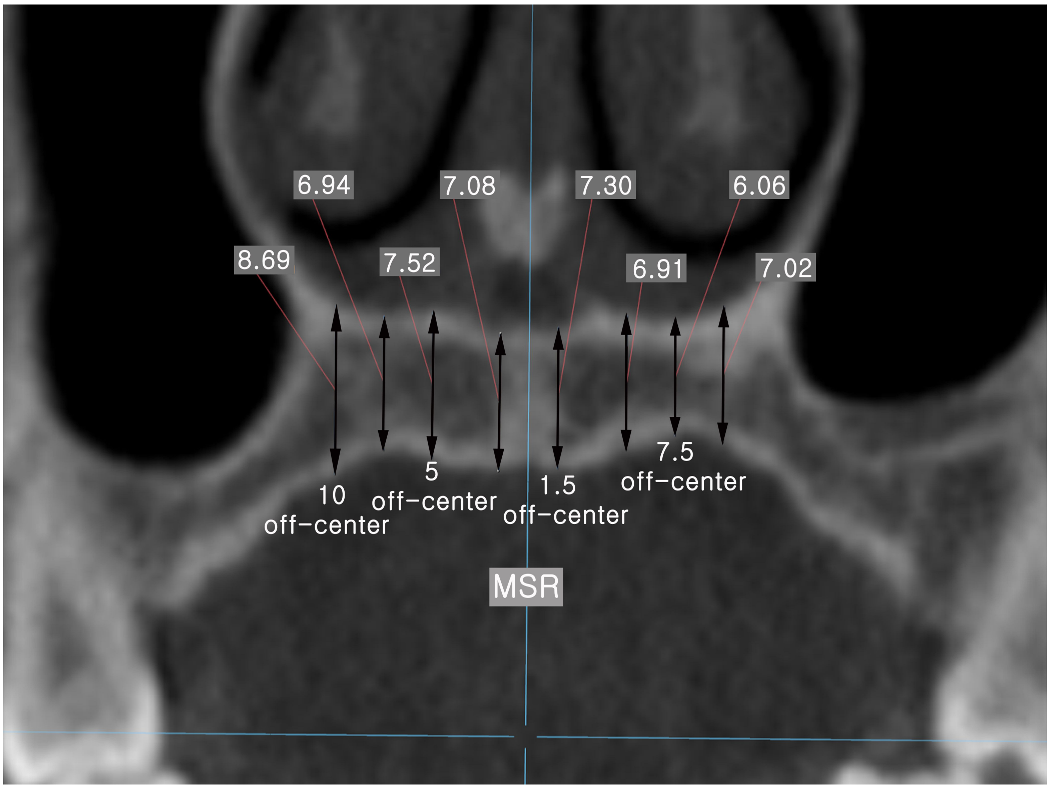


Fig 3. Measurement of palatal bone thickness on a CBCT image. In coronal sections, palatal bone thicknesses were measured along vertical measurement lines parallel to the MSR and offset from it by 1.5, 5, 7.5, and 10 mm.

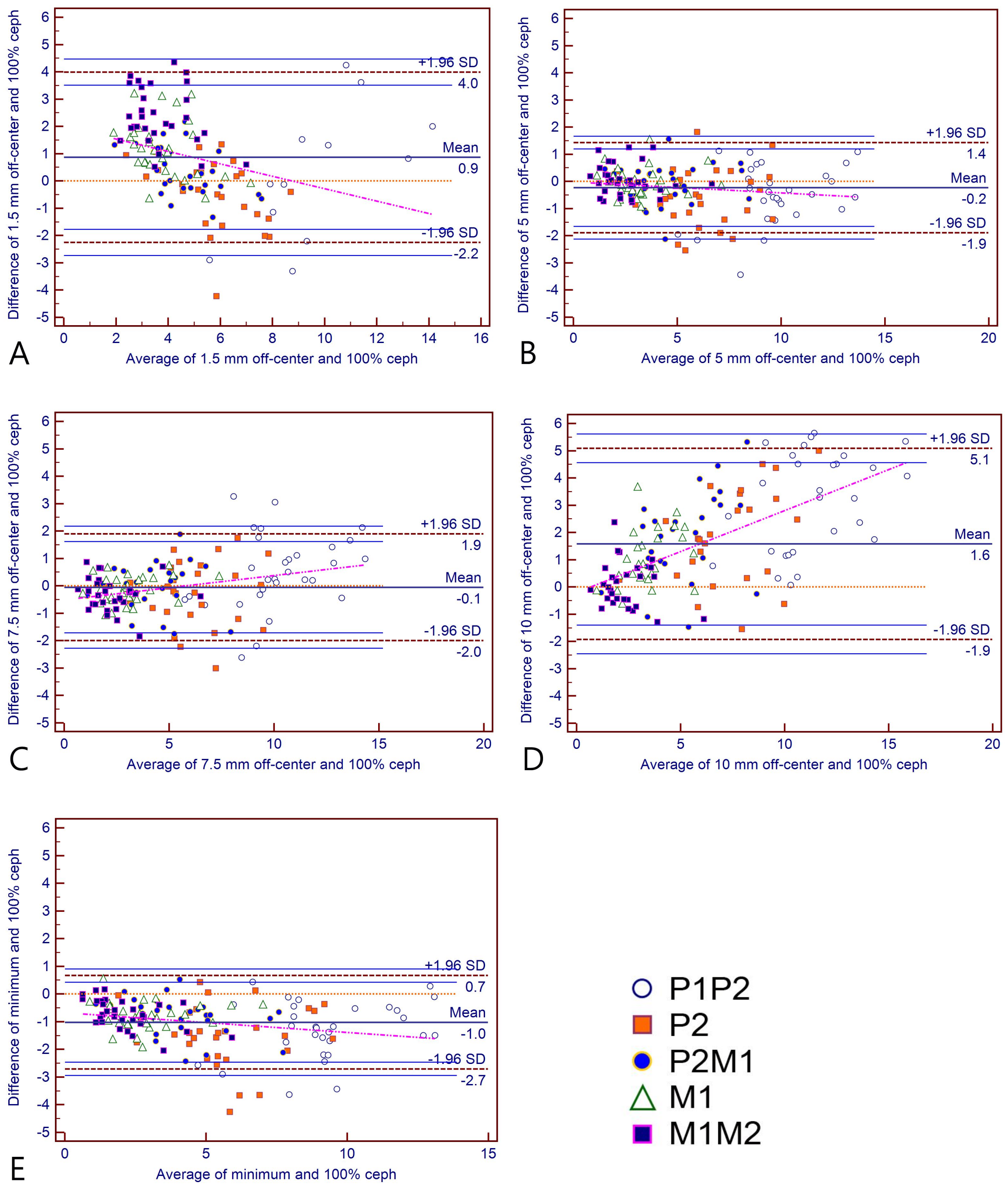


Fig 4. Bland-Altman plots: difference against the mean (*thick solid middle blue line*) of the CBCT and cephalometric (ceph) measurements. The LOA (*dashed brown lines*), 95% CI of the LOA (*thin solid blue lines*), and regression lines (*dashed pink lines*) are shown. A, 1.5-mm-off-center measurements; B, 5-mm-off-center measurements; C, 7.5-mm-off-center measurements; D, 10-mm-off-center measurements; and E, minimum-bone-thickness measurements.

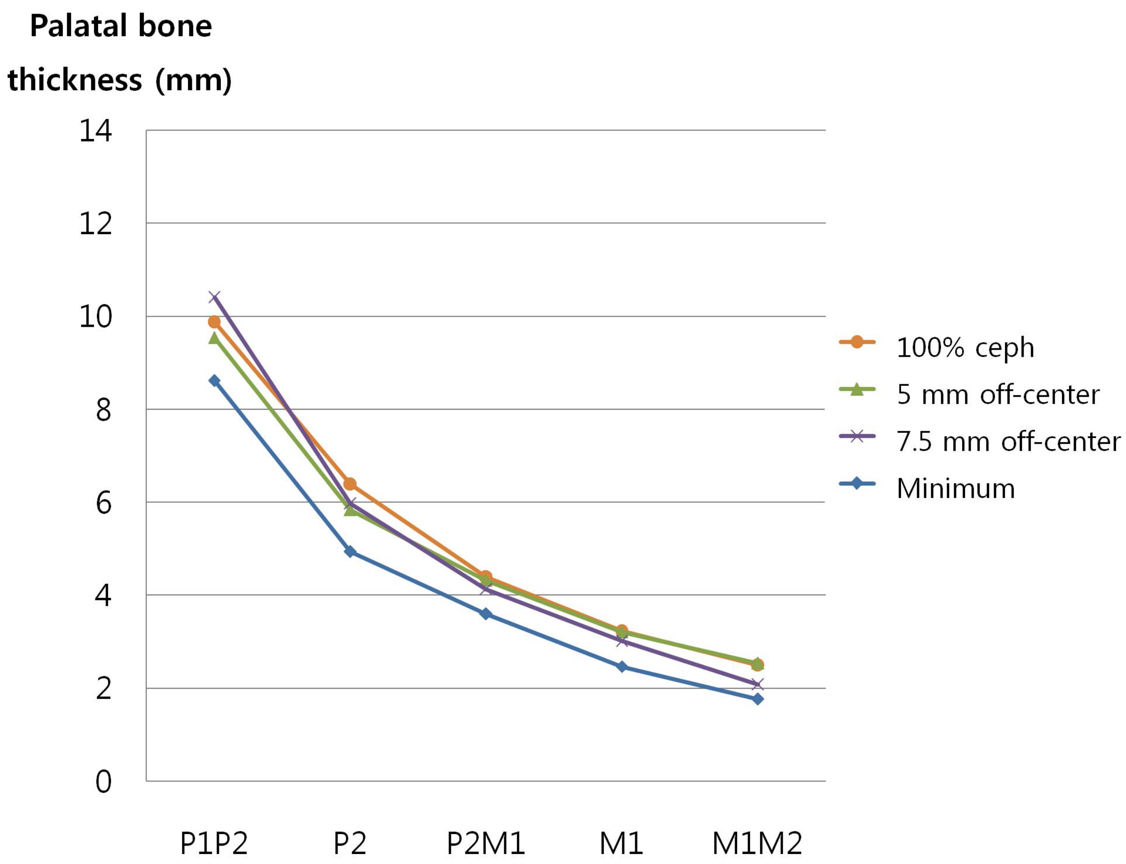


Fig 5. Comparison of palatal bone thicknesses in CBCT-based measurements at 5 mm off-center, 7.5 mm off-center, and minimum thickness, and cephalometric measurements.

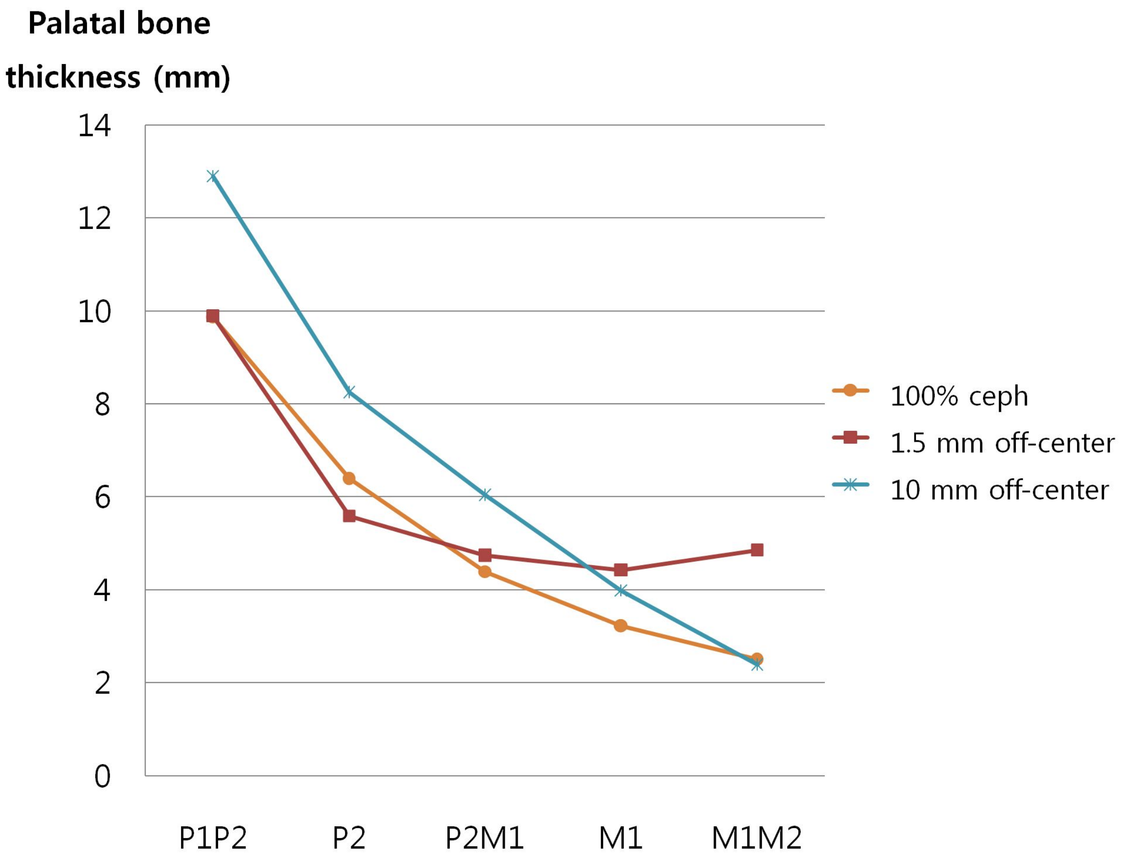


Fig 6. Comparison of palatal bone thicknesses in CBCT-based measurements at 1.5 mm off-center and 10 mm off-center, and cephalometric measurements.

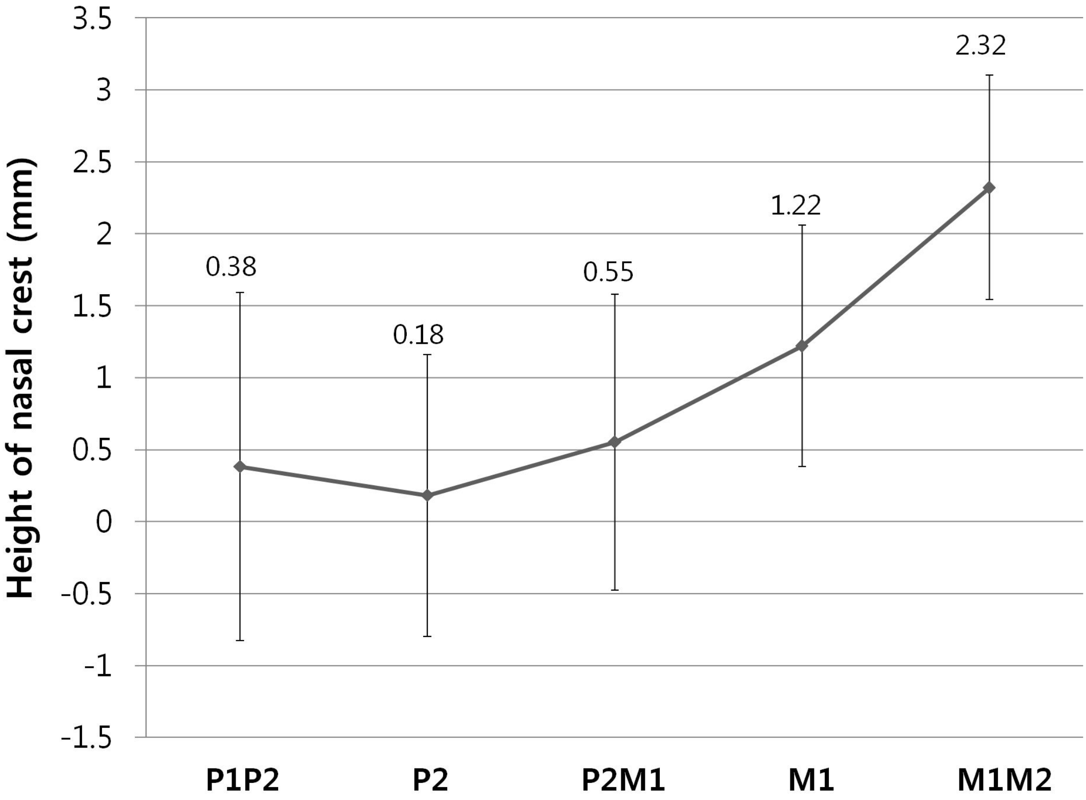


Fig 7. Change in nasal crest height from P1P2 to M1M2. Nasal crest heights were estimated indirectly as the bone thickness at 1.5 mm off-center minus the bone thickness at 5 mm off-center. Data are mean and SD values.