-Abstract-

The Effect of the Axial Plane on Measurement of Available Bone Height for Dental Implant in Computed Tomography of the Mandible

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For the success of dental implant, accurate radiographic evaluation is prerequisite for planning the location of the osseointegrated implants and avoiding injury to vital structures. CT/MPR(computed tomography/multiplanar reformation) shows improved visualization of inferior alveolar canal. In order to obtain cross-sectional images parallel to the teeth, the occlusal plane is used to orientate for the axial plane. If the direction of axial plane is not parallel to the occlusal plane, the reformatted cross-sectional scans will be oblique to the planned fixture direction and will not show the actual dimension of the planned fixture's location. If the available bone height which measured in the cross-sectional view is much greater than the actual available bone height, penetration of canal may occur. The aim of this study is to assess the effect of the axial plane to measurement of available bone height for dental implant in computed tomography of the mandible. 40 patients who had made radiographic stents and had taken CT were selected. The sites that were included in the study were 45 molar regions. In the central panoramic scan, the length from alveolar crest to superior border of inferior alveolar canal(available bone height, ABH) was measured in direction of reformatted cross-sectional plane(uncorrected ABH). Then, length from alveolar crest to superior border of canal was measured in direction of stent(corrected ABH). The angle between uncorrected ABH and corrected ABH was measured. From each ABH, available fixture length was decided by Brånemark system. The results were following ; the difference between two ABHs was statistically significant in both first and second molar($p < 0.01$). The percentage of difference more than 1 mm was 8.7% in first molar and 15.5% in second molar. The percentage of difference more than 2 mm was 2.0% in first molar and 6.6% in second molar. The maximum value of difference was 2.5 mm in first molar and 2.2 mm in second molar. The correlations between difference of 2 ABHs and angle was positive correlations in both first and second molar. The correlation coefficient was 0.534 in first molar and 0.728 in second molar. The second molar has a stronger positive correlation. The percentage of disagreement between 2 fixture lengths from two ABHs was 24.4% in first molar and 28.9% in second molar.

Keywords : axial plane, available bone height, CT, inferior alveolar canal, dental implant

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CONTENTS

I. Introduction

These days, the use of dental implants for replacing missing teeth has been increasing. For the success of dental implant, accurate radiographic evaluation is prerequisite for planning the location of the osseointegrated implants and avoiding injury to vital structures. Especially, localization of inferior alveolar canal is very important in mandibular posterior region. Variable diagnostic methods for cross-sectional image have been introduced and used. Among these methods, conventional tomography and computed tomography are widely used.[1] Conventional tomo- graphy is reliable in relatively limited edentulous span.[2] CT/MPR(computed tomography/multiplanar reformation) shows improved visualization of inferior alveolar canal.[3-5] The reformatted images are considered to be highly reliable.[6,7]

CT scans are obtained with the patient in a supine position. The operator selects a reference plane (either occlusal plane or lower border of the mandible) and positions it perpendicular to the horizontal plane. 30-40 scans are obtained parallel to the selected plane. These transaxial scans are then reformatted using a proprietary software package. Cross- sectional images can be made perpendicular to the transaxial plane and the central panoramic curve.[8] In order to obtain cross-sectional images parallel to the teeth, the occlusal plane is used to orientate for the axial plan. But it is difficult that patients maintain the mandibular position which is parallel to the occlusal plane during taking radiography. If the direction of axial plane is not parallel to the occlusal plane, the reformatted cross- sectional scans will be oblique to the direction of planned fixture direction (ie., the direction of the stent), and will not show the actual dimension of the fixture's location.

Available bone height is measured from the crest of the edentulous ridge to the opposing landmark, such as mandibular canal in the mandibular posterior region. If the direction of axial scans is not parallel to the occlusal plane, the interpretation of the reformatted cross-sectional view must be done more carefully. In this case, the available bone height that measured in the cross-sectional view is not an actual available bone height for fixture. The actual available bone height is the length that measured in the direction of stent (ie., the direction of fixture) If the length which measured in the cross-sectional view is much greater than actual available bone height, the fixture length from the cross-sectional view will be overestimated and the possibility of canal penetration during surgery may be increased.

The aim of this study is to assess the effect of axial plane to measurement of available bone height for dental implant in computed tomo- graphy of the mandible.

II. Materials and Methods

1. Subject Selection

40 patients who visited Seoul National University Dental Hospital for dental implant therapy and planned to implant surgery in posterior mandibular regions from March 1997 to May 2001 were selected. The subject group was consisted of 21 male and 19 female. The range of age was 29 to 68 and the mean was 51.8. Radiographic stents were made and CT were taken in the department of dental radiology. CT machine was IQ (Picker, USA) and CT/MPR was ToothPix(Picker, USA). CT/MPR image was obtained under 130kV, 105mA, 2mm thickness and 1mm interval. The sites that were included in the study were 45 molar regions.

2. Measurement

(1) Available Bone Height(ABH)

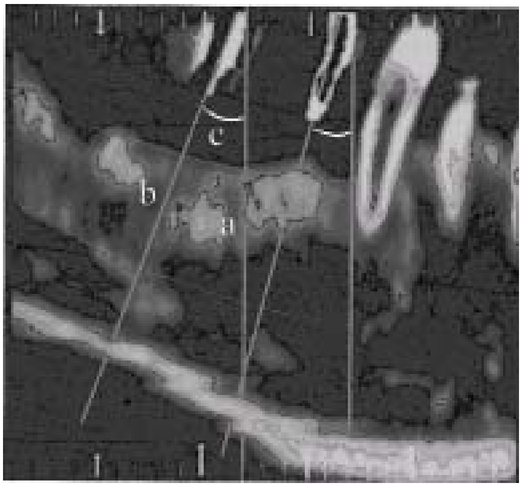


Fig 1. In the central panoramic view, the alveolar crest and superior border of inferior alveolar canal was traced. Uncorrected available bone height(a), corrected available bone height(b) and angle between two ABHs(c) were measured.

In the central panoramic view, the locations of first and second molar were marked guided by stent(Fig. 1). At each location, length from alveolar crest to superior border of inferior alveolar canal(available bone height, ABH) was measured in direction of reformatted cross-sectional plane. This bone height was named 'uncorrected available bone height (u-ABH)'. Because the superior border of canal is not always visible in the central panoramic view, we drew it by measuring lengths from alveolar crest to superior border of canal in each cross-sectional view. Then, length from alveolar crest to superior border of canal was measured in direction of radiopaque rod of stent. This bone height was named 'corrected available bone height (c-ABH)'.

All measurements were obtained twice with the interval of 1 week to 0.1mm scale by one person.

(2) Angle between two available bone heights

The angle between uncorrected available bone height and corrected available bone height was measured. (Fig. 1) All measurements were obtained twice with the interval of 1 week to 0.1 ㎜ scale by one person.

(3) Decision of fixture length

From each ABH, available fixture length was decided by Brånemark system. Surgical zone of error, 2 mm, were applied. The fixture length was decided from the value that equals ABH minus surgical zone of error. For example, if the ABH is 14.5 mm, ABH minus surgical zone of error, 2 mm, equals 12.5 mm. So, available fixture length is 11.5 mm by Brånemark system. The percentage of agreement of two fixture lengths from two ABHs was calculated.

3. Statistics

Comparison u-ABH(uncorrected available bone height) with c-ABH(corrected available bone height) was obtained by paired t-test and correlation between angle and difference of two ABHs was obtained by Pearson's correlation coeffic- ient test.

III. Results

1. Comparison of two available bone heights

The mean of u-ABH(uncorrected available bone height) was 13.9 mm and that of c-ABH(corrected available bone height) was 13.6 mm in first molar ($p=0.005$). 12.0 mm and 11.6 mm in second molar ($p=0.004$). The differences were both statistically significant. ($p < 0.01$) (Table 1)

The distribution of differences(D) of two ABHs was shown in table 2 and figure 2. The percentage of range 0 mm$\leq$D$<$ 1 mm was greatest in both first and second molars(75.6% and 68.9%). The percentage of difference more than 1 mm was 8.7% in first molar and 15.5% in second molar. The percentage of difference more than 2 mm was 2.0% in first molar and 6.6% in second molar. The maximum value of difference was 2.5 mm in first molar and 2.2 mm in second molar.

Table 1. Mean average of two ABHs(mm)

	First molar	Second molar
uncorrected available bone height	13.9±2.56	12.0±2.38
corrected available bone height	13.6±2.62*	11.6±2.25*

* : statistically significant ($p < 0.01$)

Table 2. Distribution of Difference between two ABHs

Difference between two ABHs(D)	Number	
	First molar	Second molar
$D < 0$mm	7(15.6%)	7(15.6%)
0mm$\leq D <$ 1mm	34(75.6%)	31(68.9%)
1mm$\leq D <$ 2mm	3(6.7%)	4(8.9%)
2mm$< D$	1(2.0%)	3(6.6%)

( ) : percentage

2. Correlation between angle and difference of two ABHs

The mean of angles(A) between two ABHs was 3.6° in first molar and 4.1° in second molar. The percentage of range $0° \leq A < 5°$ was greatest in both first and second molar(both 51.1%). (Table 3 and Fig. 3)

As the angle became greater, the mean difference of two ABHs had a tendency to become great. The tendency was more obvious in second molar. There was a little exception against the tendency(range $15° < A$ in first molar and range $A < 0°$ in second molar).

Table 3. Distribution of differences between two ABHs by angle

Angle(A)	First molar		Second molar	
	Number	Mean difference of two ABHs(mm)	Number	Mean difference of two ABHs(mm)
A〈 0°	4(8.9%)	-0.16±0.40	4(8.9%)	0.69±0.37
0 ≦A〈 5°	23(51.1%)	0.06±0.20	23(51.1%)	0.07±0.18
5 ≦A〈 10°	12(26.7%)	0.63±0.47	8(17.8%)	0.59±0.16
10 ≦A〈 15°	4(8.9%)	1.00±1.35	5(11.1%)	0.85±0.53
15 ≦A	2(4.4%)	-0.15±0.85	5(11.1%)	1.33±1.17

( ) : percentage

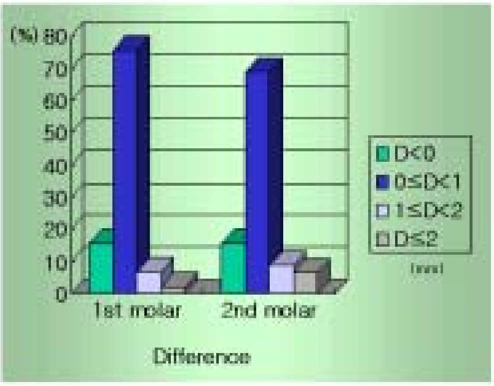


Fig 2. Distribution of difference between two ABHs.

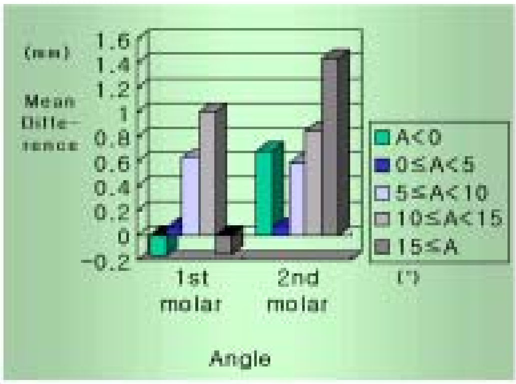


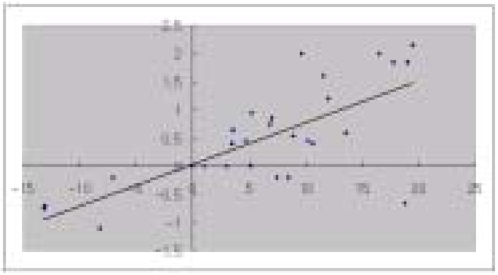
Fig 3. Distribution of differences between two ABHs by angle

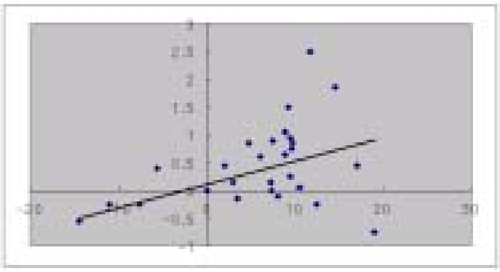
The correlation coefficients were 0.534 in first molar and 0.728 in second molar. The correlations were positive in both first and second molars and the positive correlation was more obvious in second molar.(Fig. 4)

The percentage of range A〈 0° was 8.9% in both first and second molars. The fact means that patient's occlusal plane has an obtuse angle to the horizontal plane. The mean difference of two ABHs was also a negative value in first molar(-0.16 mm) but not in second molar(0.69 mm).

3. Decision of fixture length

The percentages of agreement and disagreement were shown in table 4. The percentage of agreement was 75.6% in first molar and 71.1% in second molar. In the group of disagreement, the percentage that fixture length from u-ABH(uncorrected available bone height) was greater than it from c-ABH(corrected available bone height) was 20.0% in first molar and 22.2% in second molar. (Table 4)





A B

Fig 4. The correlation coefficient. 0.534 in first molar(A) and 0.728 in second molar(B)

Table 4. Agreement and disagreement of two fixture lengths

		First molar	Second molar
Agreement		34(75.6%)	32(71.1%)
Disagreement	u-ABH〉c-ABH	9(20.0%)	10(22.2%)
	u-ABH〈 c-ABH	2(4.4%)	3(6.7%)

( ) : percentage

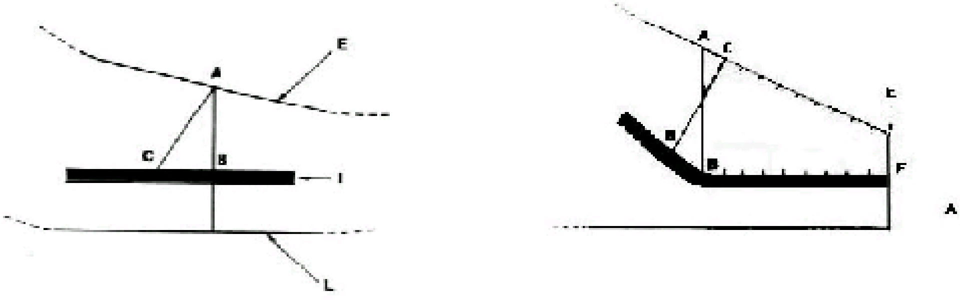
IV. Discussion

For the reformatted cross-sectional view shows the axis of fixture, the axial plane must be parallel to the occlusal plane. So, patients have to lift and maintain the mandible. Scout view must be taken repeatedly for checking the angulation of axial plane. However, the posture is very uncomfortable to patients and repeated taking of scout view is not favorable because of the increase of irradiation. So, it is often that films are taken in mandibular position not being parallel to occlusal plane and there may be some degree of angle between axial plane and occlusal plane. In this study, the percentage of range 0 ≦A〈 5°was greatest in both first and second molar(both 51.1%).

Kohavi et al showed that the axial plane deviation affected on cross- sectional height.[9] They set the axial plane on the basis of inferior border of mandible, not occlusal plane. They investigated the mean difference betw- een actual bone length and image length. The axial plane deviations of 10° and 20° resulted in a mean error of 1% and 2.85% respectively and when the angulation was greater than 10°, the maximum error was about ±30%. Choi et al also reported about similar topic. When the axial cut have an angulation to the occlusal plane and the gantry angle is not controlled, the length between alveolar crest and canal in the reformatted cross- sectional plane would be different with the length of real surgical field.[10] In this study, the results were similar to those of the above studies. The mean difference between two ABHs was an increasing tendency according to increasing angle.

The correlation between the angle and difference of two ABHs was positive in both first and second molars. The second molar had a stronger positive correlation than first molar (0.534 in first molar and 0.728 in second molar). It may result from the curvature of the canal. The inferior alveolar canal seems to be straight in first molar region but in the second molar regions, it often has a curvature. The operation in second molar region should be done more carefully to avoid canal penetration.

It is often that patients feel pain during surgery on mandibular posterior region even though local anesthesia. It may result from some reasons ; misinterpretation of a pressure pheno- menon or bur vibration ; additional sensory mandibular nerve pathways may be present within bone.[11] However, actual enchroachment of the canal is also possible. If the difference between two ABHs is so great, the penetration of the canal may occur. Wise described that the angulation of the axial cut could have an affect on the interpretation of the reformatted sections.[12] The error could be incorporated if the axial cut is parallel to the lower border of the mandible, not occlusal plane. If the canal dose not curve upwards in the proposed fixture sites, errors would err on the side of safety.(Fig. 5-A) Whereas if there is a curve, overestimation of available bone height could occur.(Fig 5-B) So, he recommended to allow 2 mm margin of error when calculate fixture height from the reformatted sections and also recommended to reduce the chosen fixture length accordingly. There is another study that suggest 1-2 mm of safety margin.[3] In this study, the difference between two ABHs was over 2 mm in 1 case in first molar and 3 cases in second molar. Practically, it may not correct to conclude that the canal was penetrated in the above 4 cases because the lengths which were



A B

Fig 5. The Effect of axial cut angulation.

A : Axial cut parallel to the lower border of the mandible(L). Reformatted section AB perpendicular to this, bone height above the anal is AB. An implant placed at A perpendicular to the ridge crest(E). AC is longer than AB and so the measuring error errs on the side of safety.

B : This figure is oversimplification. The distance FB is 18 mm from F on the axial cut. If the fixture starting point is 18 mm from E (being the equivalent point to F intraorally), then this is at C anterior to the plane of the reformatting section AB. The fixture site is CD. If the canal curves, the fixture at 18 mm from the anterior landmark(E or F) leads to canal penetration.

compared are bone height, not fixture length. The operator prepares bone to the fixture length that was decided from available bone height in cross- sectional view. When the sum of the fixture length which was decided from corrected available bone height and 'Y dimension' of drill[11] is over the uncorrected available bone height, the situation of canal penetration may occur. In this study, the number of cases which the sum was greater than uncorrected available bone height was 2 in first molar and 3 in second molar. The number of cases that the difference between the sum and corrected available bone height was less than 0.5 mm was 0 in first molar and 5 in second molar. 0.5 mm is too little that the operator can disrupt easily the amount of bone and can penetrate the canal. So, the total possibility of canal penetration is 3.3% in first molar and 17.8% in second molar.

The percentage of disagreement of two decided fixture length was 24.4% in first molar and 28.9% in second molar. But it does not mean that the canal penetration would have occurred in 24.4% in first molar and 28.9% in second molar because of surgical zone of error. The fact means that there were many cases that shorter fixture had to been selected to reduce the possibility of canal penetration.

These results suggest that the angulation of axial plane can affect the measurement of available bone height and may result in canal penetration in some cases. However, there are some difficulties of selecting the CT films which showed the favorable stent angulation. The radiopaque rod of stent should be perpendicular to the occlusal plane. In this study, the stent did not be standardized before selection, so we selected films which had acceptable stent angulation comparing the proximal teeth. Further study which has the standardized stent and the standardized angulation of axial plane should be done.

V. Conclusion

The difference between two ABHs was statistically significant in both first and second molar. The percentage of difference more than 1 mm was 8.7% in first molar and 15.5% in second molar. The percentage of difference more than 2 mm was 2.0% in first molar and 6.6% in second molar. The maximum value of difference was 2.5 mm in first molar and 2.15 mm in second molar.

The correlation between difference of 2 ABHs and angle was statistically significant and positive correlation in both first and second molar. The correlation coeficeint was 0.534 in first molar and 0.728 in second molar. The second molar has a stronger positive correlation.

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국문초록

하악의 전산화 단층사진에서 횡단면이 임플랜트를 위한 가용골 높이의 결정에 미치는 영향

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임플랜트의 성공을 위해서 정확한 방사선학적 검사는 가용골의 높이와 하악관의 위치를 평가하고 중요구조물의 손상을 방지하는데 있어 필수적이다. CT촬영법 중 영상재구성법을 이용한 방법(CT/MPR)은 하악관의 위치를 잘 보여준다. 치아에 평행한 협설 단면 (cross-sectional plane)을 얻기 위해서는 횡단면(axial plane)이 교합면과 평행하도록 해야 한다. 횡단면(axial plane)이 교합면과 평행하지 않으면 재구성된 협설단면(cross-sectional plane)은 계획된 fixture의 방향과 각을 이루게 되어 그 fixture의 실제 dimension을 보여주지 못하게 된다. 협설단면(cross-sectional view)에서 측정한 가용골 높이가 실제 가용골 높이보다 너무 큰 경우, 수술시 하악관을 침범할 가능성이 있게 된다. 이 연구의 목적은 하악 임플랜트 CT 촬영시 횡단면이 임플란트를 위한 가용골 높이의 측정에 미치는 영향을 알아보는 것이다. 하악 대구치 부위의 임플랜트를 계획하고 radiographic stent를 만든 후 치과 방사사선과에서 하악 임플랜트 CT를 촬영한 40명의 환자, 45개 부위를 선택하였다. 임플랜트 CT의 central panoramic view에서 치조정과 하악관, stent를 tracing한 후, 치조정과 하악관간의 거리(available bone height, ABH)를 재구성된 협설단면상에서 측정하였다(uncorrected ABH). 다음으로, .stent 방향으로 그은 직선상에서 측정하였다(corrected ABH). 두 거리사이의 각을 측정하였다. 두 거리로부터 각각 fixture의 길이를 결정하였다. 연구 결과, 두 가용골의 높이간에는 제 1 대구치와 제 2 대구치에서 모두 유의성있는 차이를 보였다 ($p < 0.001$). 차이가 1 mm 이상인 경우는 제 1 대구치에서 8.7%, 제 2 대구치에서 15.5%였다. 차이가 2 mm 이상인 경우는 제 1 대구치에서 2.0%, 제 2 대구치에서 6.6%였다. 최대값은 제 1 대구치에서 2.5 mm, 제 2 대구치에서 2.2 mm 였다. 두 가용골의 높이차와 각과의 상관 관계는 제 1 대구치와 제 2 대구치에서 모두 양의 상관관계를 보였다. 상관 계수는 제 1 대구치에서 0.534, 제 2 대구치에서 0.728 였다. 제 2 대구치가 더 강한 양의 상관관계를 보였다. 두 가용골의 높이로부터 결정한 fixture의 길이가 일치하지 않는 경우는 제 1 대구치에서는 24.4%, 제 2 대구치에서는 28.9%였다.

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