The relationship of the maxillary molar and sinus on cone beam computed tomographic images in Korean population

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The relationship of the maxillary molar and sinus on cone beam computed tomographic images in Korean population

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The Doctoral Dissertation submitted to the Department of Dentistry, and the Graduate School of Yonsei University in partial fulfillment of the requirements for the degree of Doctor of Philosophy

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감사의 글

개인 사정으로 인해 10년 가까이 지나온 대학원 생활을 무사히 마칠 수 있게 따뜻하게 지도해 주신 한상선 지도 교수님께 누구보다 감사한 마음을 올립니다. 더불어 이 연구를 위해 함께 힘써 주신 최윤주 선생님, 이채나 선생님, 전국진 교수님께 깊이 감사합니다.

이미 학교를 떠났지만 연구 초기에 많은 아이디어를 주시며 힘을 실어준 나지연 선생님에게 역시 감사인사를 전합니다. 그 밖에 많은 도움과 응원을 보내주신 영상 치의학 교실 모든 선생님께 다시 한번 감사드립니다.

마지막으로 10년 동안 모든 지원을 아끼지 않은 나의 반쪽 이혜준 원장에게 사랑한다는 말 전하고 싶고 아빠를 항상 응원해주는 경회에게도 고맙다는 말 하고 싶습니다. 저를 위해 고생해 주신 장인, 장모님께도 감사드리며 무엇보다 제가 이 자리에 서 있게 만들어 주신 부모님께 이 논문을 바칩니다.

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Abstract

The relationship of the maxillary molar and sinus on cone beam computed tomographic images in Korean population

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Objective: The aim of this study was to investigate the relationship and the available alveolar bone height between the maxillary molars and the sinus floor using cone beam computed tomographic (CBCT) images in Korean population.

Materials and Methods: The CBCT scans of 188 patients older than 17 years with four molars fully erupted maxillary first and second molars were selected. A total 756 of maxillary first (M1) and second molars (M2) were categorized into 4 types according to the relationship of the molar root and the maxillary sinus floor on CBCT images. And the shortest vertical distance (VD) from the furcation midpoints of the roots to the lowest point of the sinus floor was measured using software by two observers. The frequency distribution of each type were analyzed. Correlation analyses in the mean values of VD measurements were calculated for inter- and intra-observer reliability. The independent t-test was performed for the analysis of the difference in vertical distance measurements between male and female, and right and left side.

Results: For M1, type 3 which was at least one root protruding into the maxillary sinus was the most frequent and type 2 which was enveloped the sinus followed. Meanwhile the frequency was higher in the order of type 3 and type 1 for M2. VD measurements of type 1 were 9.51±3.68 mm and 8.07±2.73 mm for M1 and M2, and those of type 3 were 3.70±1.52 mm, 4.03±1.53 mm for M1 and M2, respectively. Total mean value of VD measurements was found as 5.48±3.02 mm and 5.62±2.56 mm in M1 and M2, respectively. In VD measurements of M2, female showed higher than male with the statistically significant differences.

Conclusion: In Korean population, the type 3 was the most frequent in the maxillary molars, and the alveolar bone height of type 3 was the least among other types. Alveolar bone height of the first molar are shorter than those of the second molar. This data will help the clinician to prevent the complication related with the maxillary sinus during maxillary molar treatment and to predict the available bone height for immediate implant planning.

Keywords: Cone beam computed tomography; Maxillary molar; Maxillary sinus

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I. INTRODUCTION

The maxillary sinus is a bilateral structure located in midface of skull. The inferior borders of the maxillary sinus composed of thin cortical bone may sometimes have dehiscence of bone (Som & Curtin, 2003). The close proximity of the maxillary root with the antrum might often lead to complications such as the spread of infection from the maxillary tooth root apex, pushing canal filling material through apical foramen, or the opening into the maxillary sinus after the tooth extraction or implant surgery (Van Den Bergh et al., 2000). Thus the information about the relationship between the roots of maxillary molars and the maxillary sinus floor is important issues to consider for the treatment of maxilla in dentistry (Van Den Bergh et al., 2000; Tavelli et al., 2017; Wagner et al., 2017). In addition to the anatomical relationship, several studies were focused on

assessing the residual alveolar bone height after the tooth extraction as an essential factor for the successful implant placement (Misch & Judy, 1987; Eufinger et al., 1997; Cavalcanti et al., 2018).

Previous studies using different methods have been reported to assess the relation between the maxillary teeth and sinuses in different population, using panoramic radiographs, computed tomography or the human cadavers (Kwak et al., 2004; Sharan & Madjar, 2006; Howe, 2009; Jung & Cho, 2012; Tian et al., 2016). Because of methodologic differences between researches in analyzing the relation of two anatomical structures, there have been variation in classification and standard reference. According to the previous studies, cone beam computed tomography (CBCT) is considered as a proper modality for the sophisticated assessment of the furcation involvement degree and root proximities, or root fusions, measurement of the bone height (Sharan & Madjar, 2006; Howe, 2009; Lee et al., 2012; Liang et al., 2014).

In recent, implant treatment is widely performed in dentistry. Especially, immediate implantation is increasing after tooth extraction since some studies have been reported that there is no significant difference in survival rate between immediate implantation and conventional delayed implantation (Liu et al., 2019). Thus, assessing the residual alveolar bone height after the tooth extraction is considered as an essential factor for the successful implant placement (Misch & Judy, 1987; Eufinger et al., 1997; Cavalcanti et al., 2018).

In this paper, the relation between the maxillary sinus and molars was categorized into the different groups focused on the considerable anatomical features, and the available

alveolar bone height from the root furcation to the sinus floor was measured and analyzed according to each classification on CBCT images from a clinical point of view.

II. MATERIALS AND METHODS

1. Ethics statement

This study was approved by Yonsei Dental College Hospital IRB (2018-0058-002) the patient consent was waived because of a retrospective.

2. Subjects

All CBCT scans of the maxilla taken during June, 2016 and to March, 2018 in the department of Oral and Maxillofacial Radiology were reviewed. As a result, 188 CBCT scans were selected as the following inclusion criteria. The age of patients was ranged between 17 - 79 years old (mean age: 30.68) and there were 70 males and 118 females.

The inclusion criteria consisted of (1) patients older than 17 years with fully erupted maxillary first and second molars (2) four maxillary molars which were completely erupted and had no radiologic specific findings with ectopic eruption in the field of view (3) maxillary molars without any pathologic findings such as periapical lesion, chronic periodontitis with furcation involvement or apical involvement, root resorption) (4) maxilla and alveolar crest without any history of the disease of previous sinus or jaw bone, implant surgery (5) patients without any malocclusion that impedes the detection of the furcation midpoint. (6) poor quality image so that is not enough to evaluate the images due to metal

artifact, blurring, and motion artifacts.

All CBCT images were obtained with Alphard 3030 (Asahi Roentgen Ind. Co., Ltd, Tokyo, Japan) with exposure condition as followed; tube voltage, 80 kVp; tube current, 8 mA; exposure time, 17 seconds; field-of-view, 15.4 × 15.4 cm; and voxel resolution, 0.3 mm. Original data were reoriented as occlusal plane set as parallel to the floor plane and cross-sectional image were reconstructed perpendicular to arch shape that was lined at the cervical level of the maxillary molars using software (OnDemand 3DTM, Cybermed Inc., Seoul, Korea) (Figure 1).

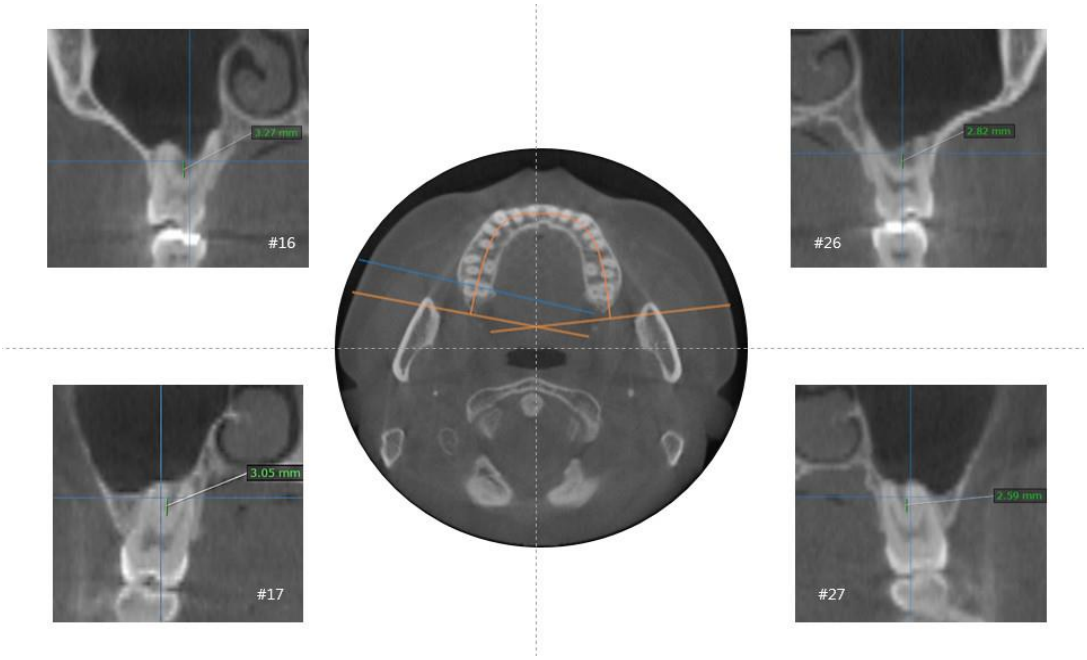


Figure 1. Cross sectional CBCT images were reconstructed perpendicular to arch shape that was lined at the cervical level of the maxillary molars

3. Classification and measurements

One oral and maxillofacial radiologists and one general dentist with over 5 year experiences examined CBCT images on the monitor (21.3 inches, resolution 1260X2048 pixels; Totoku ® Electric, Nagano, Japan) using software. They examined the relationship between the maxillary the first (M1) and second molars (M2) according to the roots protrusion into the maxillary sinus on CBCT images, and categorized into four types, and root protrusion types were divided into four subtypes again. Two observers could use digital software that control the brightness, and contrast. Classification are determined by following criteria (Figure 2) with consensus of two observers.

Type 1: the apex of all roots are contact or below the lowest border of maxillary sinus floor

Type 2: the diverged buccal and palatal root enveloping sinus

Type 3: One or more root protruding into the maxillary sinus.

A – only the buccal root is protruded into the sinus.

B – only the palatal root is protruded into the sinus

C – All roosts are protruded into the sinus

D – Fused root is protruded into the sinus.

Type 4: All roots are leaned to buccal or palatal side of maxillary sinus.

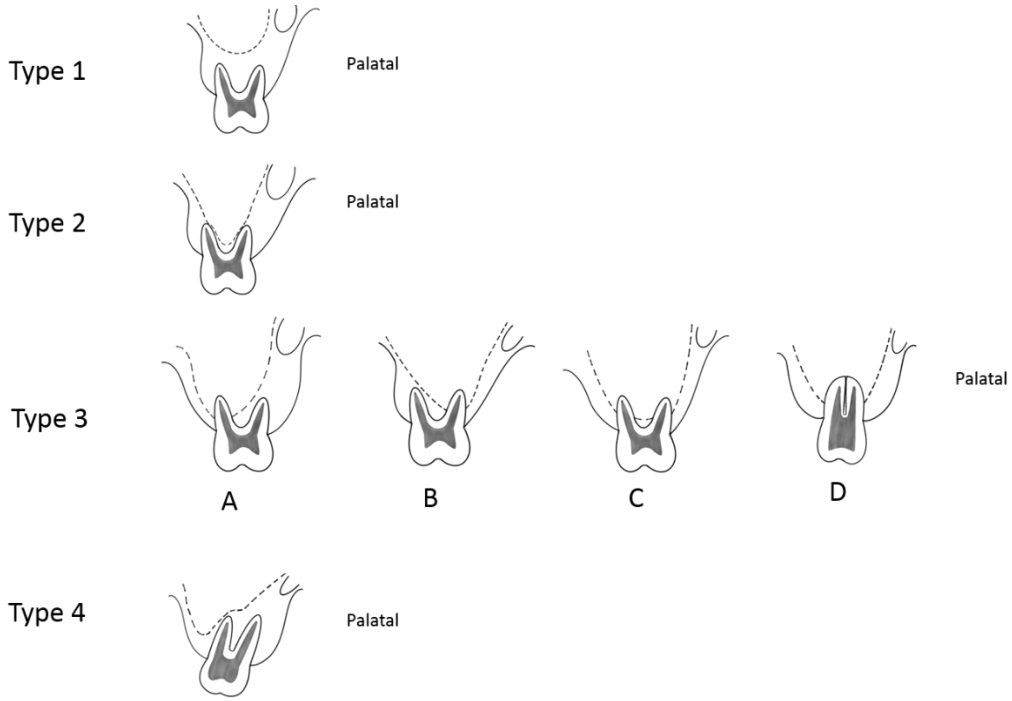


Figure 2. Illustrations of the classification according to the relationship between the maxillary first and second molars and the sinus floor

Two observers also measured the shortest vertical distance (VD) on CBCT cross sectional images (Figure 3). VD measurement was performed from the furcation midpoints of the M1 and M2 to the lowest point of the sinus floor using the software. A line drawn connecting the center of the roots at axial plane parallel to the occlusal plane was reconstructed, and the VD was measured using a line from the furcation midpoint perpendicular to the baseline. All teeth with the fused roots were excluded in the VD measurement. All linear measurements were performed twice with an interval of 2 weeks for intra-and inter observer differences by two observers.

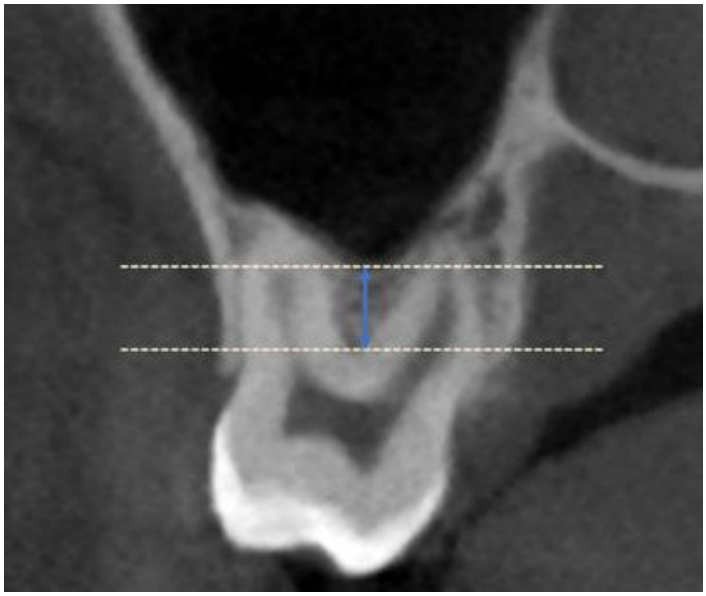


Figure 3. Measurement of the shortest vertical distance from the furcation midpoint to the sinus floor on CBCT images

4. Statistical Analysis

The frequency distribution of each classification according to the relationship between the sinus and the molars was analyzed. The intra-class correlation coefficient (ICC) was calculated for inter- and intra-observer reliability with a 95% confidence interval (CI) for VD measurements and the independent t-test were performed to analyze the differences according to sides or sexes. Statistical analyses of the data were performed using SPSS version 23.0 for Windows (SPSS Corp. Chicago, IL, USA).

III. RESULTS

1. Analysis of classification

For M1, type 3 with one or more root tip encroaching into sinus floor showed the highest frequency (44.4 %), type 2 with root tip contacting sinus floor showed the second most frequency (35. 9%) and followed by type 1 with root tips below the sinus floor (19.7 %). For M2, type 3 was also the most common (41.5 %) and unlike M1, type1 was the next frequent features presented as 31.1%. Type 4 was the least frequent in both M1 and M2 (Table 1).

Table 1. The frequency of classification in the relationship between the maxillary molars and the maxillary sinus.

n (%)

	Type 1	Type 2	Type 3	Type 4
M1	74 (19.7%)	135 (35.9%)	167 (44.4%)	0 (0%)
M2	117 (31.1%)	88 (23.4%)	156 (41.5%)	15 (4.0%)
Total	191 (25.4%)	223 (29.7%)	323 (42.9%)	15 (2.0%)

M1, maxillary first molar; M2, maxillary second molar; n, number of tooth

Figure 4 showed the frequency distribution according to male and female in M1 and M2. For M1, type 3 was the most frequent in male and female as 51.43% and 40.25%, respectively. Although type 3 was the most frequently present in M1 of female, the frequency difference was small compared to type 2 (38.56%) showing next highest frequency. For M2 of male type 3 was observed the most frequently in 52.14%, followed by type 1 in 22.86%. However, in female type 1 was 36.02% and type 3 was 35.17%, the frequency difference was not significant. Type 4 was not observed in M1 and 3.99% in M2.

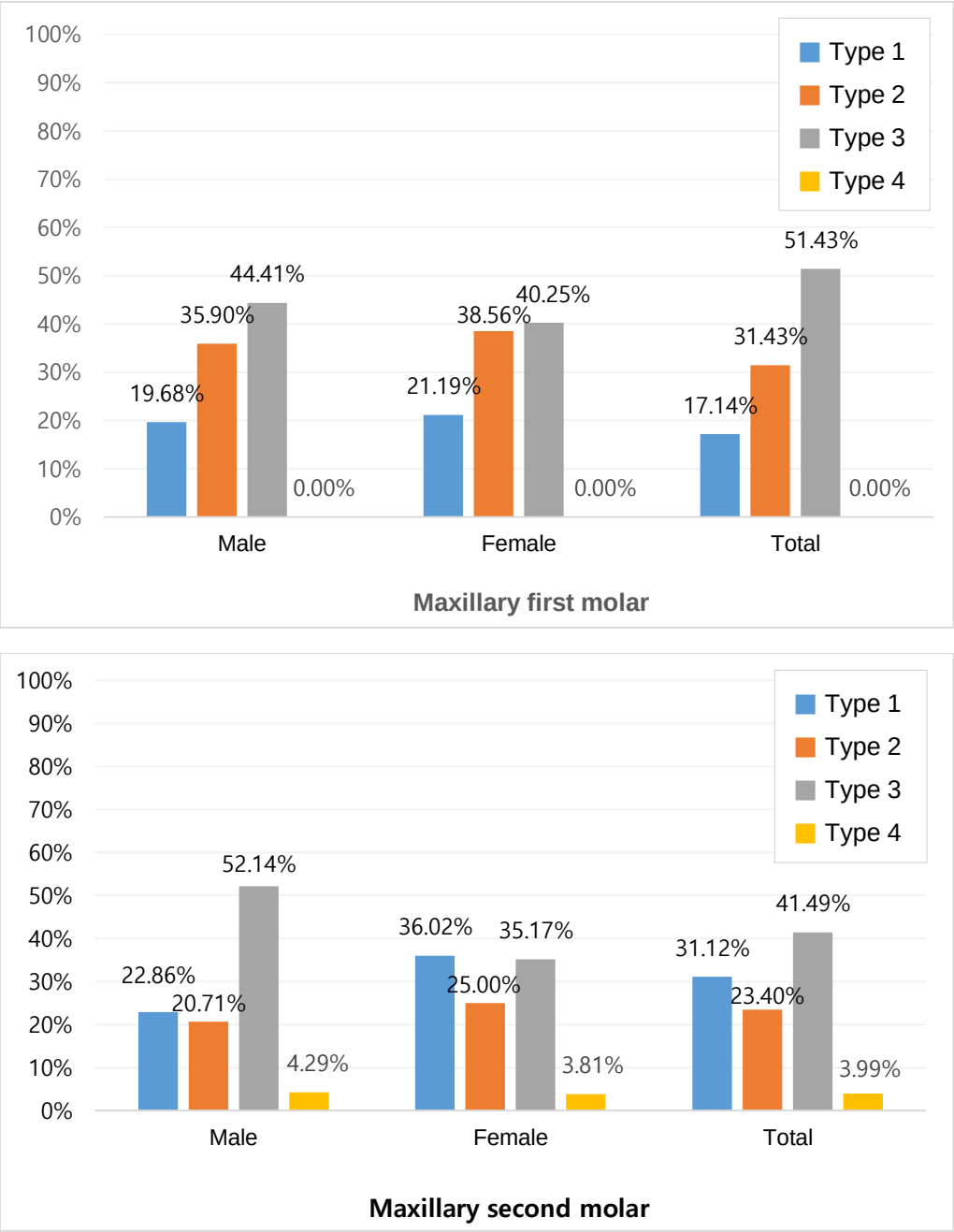


Figure 4. The frequency distribution of the classification in the maxillary first(upper) and second(lower) molars

In type 3, the buccal root of the second molar was the frequently involved in the sinus and fused root showed 11.5% (Table 2).

Table 3 showed the frequency distribution according to age range. Type 3 was most frequently observed in 10s and 20s, and type 1 was the most frequent in the 60s and 70s. Type 4 was the least frequent in all age groups.

Table 2. The subtype classification and its distribution of type 3 having at least one root protruding into the maxillary sinus.

n (%)

Tooth	Subtype classification			
	A (Buccal root protrusion)	B (Palatal root protrusion)	C (Buccal & palatal root protrusion)	D (Fused root protrusion)
M1	28 (16.8%)	59 (35.3%)	78 (46.7%)	2 (1.2%)
M2	65 (41.7%)	10 (6.4%)	63 (40.4%)	18 (11.5%)
Total	93 (28.8%)	69 (21.4%)	141 (43.6%)	20 (6.2%)

M1, maxillary first molar; M2, maxillary second molar; n, number of tooth

Table 3. The frequency distribution of tooth type over the decade of age range

n (%)

Age range (year-old)	Type 1	Type 2	Type 3	Type 4
17~19	28 (21.2%)	31 (23.5%)	66 (50.0%)	7 (5.3%)
20~29	58 (19.1%)	74 (24.3%)	168 (55.3%)	4 (1.3%)
30~39	44 (26.2%)	64 (38.1%)	57 (33.9%)	3 (1.8%)
40~49	37 (44.1%)	28 (33.3%)	18 (21.4%)	1 (1.2%)
50~59	14 (31.8%)	20 (41.5%)	10 (22.7%)	0 (0.0%)
60~69	5 (62.5%)	2 (25.0%)	1 (12.5%)	0 (0.0%)
70~79	5 (41.7%)	4 (33.3%)	3 (25.0%)	0 (0.0%)

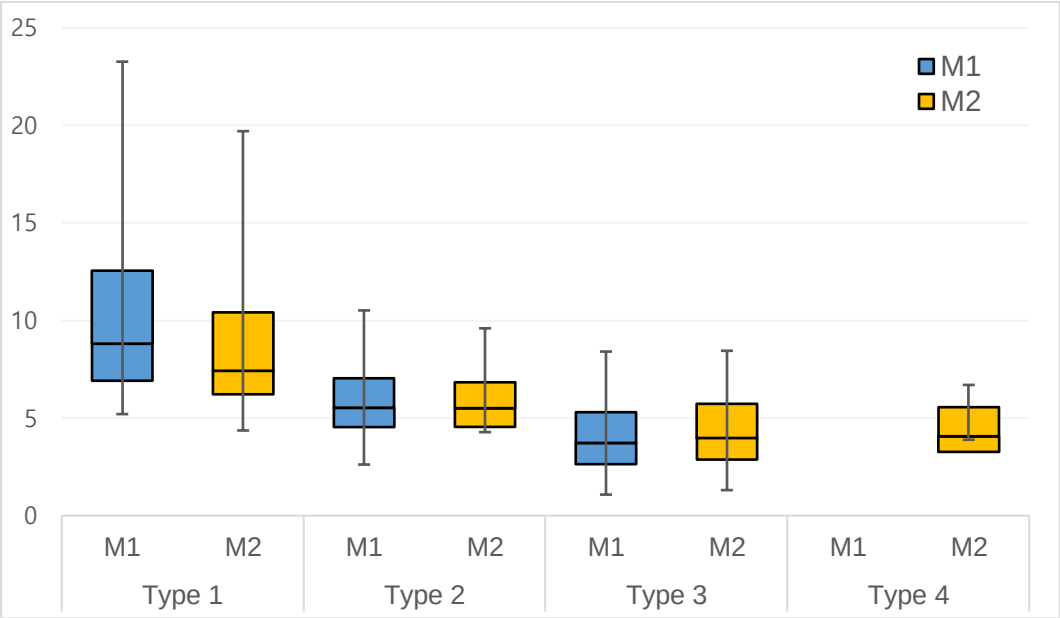
2. Analysis of vertical distance measurement

The intra- and inter-observer ICC values of VD measurements were 1.000 (95% CI:1.00-1.00) and 0.977 (95% CI: 0.971-0.981), respectively. Total VD mean values were 5.48±3.02 mm and 5.62±2.56 mm in M1 and M2, respectively (Table 4) For M1, the VD mean value of type 1 was the largest as 9.51±3.68 mm and that of type 3 is the shortest as 3.70±1.52 mm. For M2, the VD mean value in type 1 was slight shorter than that of M1 as 8.07±2.73 mm. Although the type 1 of M1 was found to have the largest vertical bone, type 3 of M1 was observed to the shortest values (Figure5).

Table 4. Mean value and standard deviation of the shortest vertical distance from furcation midpoint to the sinus floor according to in the relationship between the maxillary molars and the maxillary sinus

	Mean ± standard deviation, mm				
Tooth	Type 1	Type 2	Type 3	Type 4	Total
M1	9.51±3.68	5.46±1.51	3.70±1.52	-	5.48±3.02
M2	8.07±2.73	5.49±1.28	4.03±1.53	4.04±1.35	5.62±2.56

M1, maxillary first molar; M2, maxillary second molar



M1, maxillary first molar; M2, maxillary second molar

Figure 5. Boxplot distribution of the vertical distance measurement according to the classification

For M1, there was no statistically significant difference between male and female. In other hands, for M2, VD measurements in female was larger than those in male with the statistically significant difference ($p<0.05$, independent t-test) (Table 5). No significant differences in the VD measurements were observed between the right side and left side in both M1 and M2. ($p<0.05$, independent t-test) (Table 6).

Table 5. Difference in vertical distance mean value between the maxillary molars according to sex

	Male mm	Female mm	p-value
M1	5.38±3.00	5.55±3.04	0.595
M2	5.25±2.67	5.86±2.48	0.033 *
Total	5.31±2.84	5.69±2.79	0.106

M1: Maxillary first molar, M2: Maxillary second molar.

*p <0.05. p-value by independent t-test

Table 6. Difference in vertical distance mean value between the maxillary molars according to side

	Right mm	Left mm	p-value
M1	5.42±2.94	5.54±3.11	0.308
M2	5.68±2.71	5.56±2.42	0.180
Total	5.55±2.83	5.55±2.81	

M1: Maxillary first molar, M2: Maxillary second molar.

*p <0.05. p-value by independent t-test

IV. DISCUSSION

The maxillary sinus is a major anatomical structure located behind the inferior orbital rim, each sinus roof leans obliquely upward so that the highest point of the sinus is in the posteromedial portion, lying directly beneath the orbital apex (Som & Curtin, 2003). It is the first of the paranasal sinuses to develop. In infancy, the it appears as a small sac, and the floor lies at the level of the middle meatus. But through the two pneumatization event, 8-9 and 12th year, the it can reach the adult sizes of 14-18 years (Som & Curtin, 2003). When a maxillary tooth erupts, the empty space becomes pneumatized, thus expanding the sinus lumen and the roots of the maxillary molar teeth often form conical elevations into the sinus floor. These points can lead to considerable variation in the anatomy of the maxillary sinus floor. Histological study showed that the maxillary molar roots that protrude radiographically into the sinus are actually enveloped by a thin cortical layer with a risk of perforation (Sharan & Madjar, 2006).

Several researchers (Walter et al., 2014; Matsuda et al., 2016) studied the bone height using panoramic radiography and suggested that short alveolar bone height of maxilla increases the possibility of complications, such as sinusitis, penetration, oro-antral fistula during surgical procedure. However, the diagnostic information obtained from the panoramic radiograph is limited because of the drawbacks of the image of own, such as distortion, magnification, artifacts, blurring, or superimposition of structures (Perschbacher,

2012). Otherwise, the accuracy of CBCT was prove to be more acceptable among different modalities. Howe evaluated the concordance CBCT images and gross dissection for dimensions of maxillary bone around 69 first molar roots in 37 cadaveric specimens (Howe, 2009). Sharan et al. (2006) compared the vertical relationship between the maxillary molars and the maxillary sinus on panoramic radiography with the CBCT images, they reported that only 39% of the protruded root type on panorama were observed as the inserted root on the CBCT images.

In the present study, the available alveolar bone height after tooth extraction as well as the relationship between the molar and the maxillary sinus were analyzed in order to provide necessary anatomical information, especially for immediate implant placement planning using CBCT images.

As a results, type 3 with at least one root protrusion to the sinus floor was the most common on the maxillary first and second molars at 44.4% and 41.5%, respectively. This was higher rate than the results of the previous studies, which, in a study of 50 patients, Pagin et al (2013). Reported 21.6% root had intimate contact and 14.3 % of the root protruded into the maxillary sinus floor (Pagin et al., 2013). In the evaluation of 848 Chinese patients on CBCT, Tian et al. suggested that the most maxillary molar roots were located below the border of the maxillary sinus floor (Tian et al., 2016). These results of other population such as Brazilian and Chinese were not in agreement with those of the present study based on Korean population (Pagin et al., 2013; Estrela et al., 2016; Tian et al., 2016). The reason is hypothesized to due to be the anatomical shapes of teeth and the

maxillary sinus from racial difference. Thus a study of the positional relationship is assumed to be important for the clinical outcome of studied population. However, there are only two previous studies focused on Korean population, one was consisted of the small sampled size (15 cadaver) due to limitation of cadaveric study, and the other had a lack of information about available alveolar bone height after tooth extraction (Kwak et al., 2004; Jung & Cho, 2012).

In type 3. we divided into four subgroups according to root position with the antrum. For the first molar, it was the most common when both buccal and palatal roots were protruded into the maxillary sinus and there was no fused root. Meanwhile, the buccal root of the second molar was the frequently involved in the sinus and fused root showed 11.5% . In a Chinese study (Zhang et al., 2019), there was no fused root in the first molar similar to the present study, however, the frequency of fused root in the second molar was higher than those in Koreans at 20.5%. These findings could be helpful data to prevent of complications from endodontic treatment or surgical extraction as well as implant surgery.

According to age distribution, the higher the age, the more often the molar roots are located below the maxillary sinus. This result is consistent with the previous study (Tian et al., 2016). However, it is still controversial over the change of age after completion (Jun et al., 2005; Aktuna et al., 2019). Thus the additional research is needed.

Immediate implant surgery has become accepted despite controversial beginnings and the variable literature consistently cites high levels of success, ranging from 94-100% on average (Wagenberg & Ginsburg, 2001; McNutt & Chou, 2003). For this treatment, it is

highly needed to obtain the data about the morphologic characteristics, the orientation of the residual alveolar ridge. Especially, the information of the quantity of available bone before extracting from the root furcation to the bottom of maxillary sinus is more needed for planning of immediate implant operation. Although this information is also assumed to be crucial to the studied population, this paper is also useful as the approximate data for other population.

In order to accurately estimate the amount of alveolar bone remaining after tooth extraction, we measured the true alveolar bone height on CBCT images of the cross section perpendicular to arch that was lined at the cervical level of the maxillary molars.

As a result, alveolar bone height of type 3 case found the most common was the smallest among four types as 3.70±1.52 mm and 4.03±1.53 mm in the first and second molars, individually. Especially, the alveolar bone height of the first molar was slightly shorter than those of the second molar. The values of male were found to be shorter than those of female in both the first and second molars, for the second molar, was found to show the statistically significant difference between male and female. Meanwhile, there are no significant differences in alveolar height measurements between right and left sides. This result is consistent with the research that for the most part the maxillary sinuses develop symmetrically, with only minor common variations (Som & Curtin, 2003).

In conclusion, Korean population showed the most frequently the type 3 with at least one root protrusion into the maxillary sinus, and its alveolar bone height is the smallest among four types. The available alveolar height in male is shorter than those of female, and

those of the first molar is shorter than those of the second molar. Although this data is crucial to studied population, the information about true available alveolar bone height can useful as an approximate data for immediate implant placement.

V. CONCLUSION

1. In the relationship between maxillary molars and the sinus, the type 3 that at least one more roots were protruded into the sinus floor was the most frequent in the both first and second molars.
2. As the protrusion evaluation of each root in type 3, the frequency of all roots protrusion was the highest in the first molar, meanwhile buccal root protrusion in the second molars.
3. Mean value of vertical distance measurements from the furcation to maxillary sinus floor was 5.48±3.02 mm and 5.62±2.56 mm in the first and second molar, respectively. In type 3, mean value of vertical distance measurements was the smallest among those of the types as 3.70±1.52 mm and 4.03±1.53 mm in the first and second molars, individually.
4. Vertical distance measurements in male is shorter than those of female, especially for the second molar with significant differences.

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국문요약

콘 빔 씨티(CBCT) 영상에서 한국인의 상악 구치와 상악동의 관계 연구

목적: 본 연구의 목적은 콘 빔 씨티(CBCT)를 이용해 한국인의 상악 구치부와 상악동 바닥과의 관계를 조사하고 둘 사이의 수직적 거리를 측정하는 것이다.

도구 및 방법: 상악 대구치가 완전 맹출된 17세 이상인 188 명의 환자의 CBCT 영상을 선택했다. 상악 제1대구치와 제2대구치 총 756개의 치아가 CBCT 단면영상에서 상악동으로의 함입관계에 따라 4개의 타입으로 분류되었다. 두 명의 관찰자가 소프트웨어를 이용하여 상악 제 1 대구치와 제 2 대구치의 치근 분지부 중간 점에서 상악동 최하연의 수평연장선까지의 최단 거리를 측정하였다. 각 타입의 빈도가 분석되었고 단면 영상에서 관찰자 간 및 내적 신뢰도에 대한 상관 분석이 이루어졌다. 남성과 여성, 좌 우측 사이의 수직거리 측정값의 차이를 분석하기 위해 independent t-test가 시행되었다.

결과: 상악 제1대구치에서 가장 빈번한 타입은 상악동으로 적어도 하나의 치근이 함입된 TYPE 3이고 그 다음이 상악동을 둘러싸고 있는 타입2였다. 상악 제2대구치는 타입3와 타입1의 순서였다. 상악 제1,2 대구치에서 타입1의 평균 수직거리는 각각 9.51±3.68 mm, 8.07±2.73 mm였다. 타입3에서 수직거리는 3.70±1.52 mm, 4.03±1.53 mm 였다. 전체 평균 수직거리 값은 5.48±3.02 mm and 5.62±2.56 mm 로 측정되었다. 상악 제2대구치에서 수직거리는 통계적으로 유의하게 남성보다 여성이 더 높게 나타났다.

결론: 한국인은 타입3가 상악 구치부에서 가장 빈번하게 관찰되고 타입3의 치조골의 높이가 가장 낮았다. 제1대구치의 치조골의 높이가 제2대구치보다 짧았다. 이 결과는 상악 구치의 치료계획을 세우고 즉시 식립 임플란트를 위한 사용 가능한 골량을 예측하여 상악동과 관련한 부작용을 예방하는 데 도움을 줄 것이다.

중심단어: 콘빔 컴퓨터 단층촬영, 상악대구치, 상악동