Trabecular bone ratio of the mandibular condyle according to the presence of teeth in Koreans: a micro-CT study

Kyung-Hoon Sun, D.M.D., M.S.D.

Department of Dentistry

The Graduate School, Yonsei University

Trabecular bone ratio of the mandibular condyle according to the presence of teeth in Koreans: a micro-CT study

Directed by Professor Kee-Deog Kim, D.D.S., Ph.D.

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

Kyung-Hoon Sun

December 2010

This certifies that the Doctoral Dissertation of Kyung-Hoon Sun is approved.

Thesis Supervisor : **Prof. Kee-Deog Kim**

Thesis Committee Member : **Prof. Chang-Seo Park**

Thesis Committee Member : **Prof. Jae-Ho Lee**

Thesis Committee Member : **Prof. Hee-Jin Kim**

Thesis Committee Member : **Prof. Hyung-Jun Kim**

The Graduate School
Yonsei University

December 2010

ACKNOWLEDGEMENTS

드디어 노력의 결과물이 나왔습니다.

바쁜 일과 속에 논문을 완성한다는 것은 저 혼자의 힘으로는 불가능한 일이었습니다.

그렇기 때문에 더더욱, 논문이 나오기까지 조언을 아끼지 않으신 분들의 얼굴이 필름처럼 하나하나 스쳐 지나갑니다.

우선 아낌없는 배려와 세심한 지도를 해주신 김기덕 교수님께 더 없는 감사를 드립니다.

또한 충언과 조언을 아끼지 않으시며 많은 도움을 주신 박창서 과장님, 김형준 교수님, 이제호 교수님, 김희진 교수님, 박혁 교수님, 정호걸 교수님 고맙습니다.

지금까지 저를 믿어주시고 후원을 아끼지 않으신 사랑하는 어머니와 하늘에 계신 아버지를 비롯한 가족, 친지분들께 이 논문을 바칩니다.

아울러 친아들처럼 항상 따뜻하게 대해주시고 사랑을 베풀어주신 장인어른, 장모님께도 깊은 감사의 말씀을 전합니다.

마지막으로 내 곁에서 늘 함께하며 힘을 북돋워 주는 아내와 예쁜 딸 유나, 멋쟁이 아들 동연이에게 사랑을 전합니다.

2010년 12월

선경훈

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Abstract

Trabecular bone ratio of the mandibular condyle according to the presence of teeth in Koreans: a micro-CT study

Kyung-Hoon Sun D.M.D., M.S.D.

Department of Dentistry
The Graduate School, Yonsei University

(Directed by Professor Kee-Deog Kim D.D.S., Ph.D.)

The mandibular condyle comprises the temporomandibular joint within the glenoid fossa of the temporal bone. During mastication, mechanical pressure from the dentition is transmitted to the trabecular bone of the mandible, and the effects of mandibular movements reach not only the mandibular body but also the mandibular condyle. The occlusal forces, which could thus affect condylar growth, vary with tooth loss, age, and sex. It is known that the trabecular bone of the mandibular condyle is denser in dentate subjects than in edentate subjects. However, since the different tooth groups (incisor, premolar, and molar) have different functions, they could exert different effects on the mandibular condyle. The aim of this study was to elucidate the bone quality of the Korean mandibular condyle according to the presence of teeth using micro-computed tomography (micro-CT), thereby clarifying the influences of tooth presence on the condylar microstructure.

Thirty-one sides (24 bilateral and 7 unilateral) were prepared from fully and partially dentate Korean mandibles. The specimens were scanned and

reconstructed into a 3D structure using a micro-CT system. The specimen was sectioned vertically, passing through the medial and lateral poles of the mandibular condyle (P0) to enable measurement of the trabecular bone ratio (TBR). Likewise, three additional images from the specimen were acquired from the following sections: 2 mm posterior (Pp2), 1 mm posterior (Pp1), and 1 mm anterior (Pa1) to section P0. The TBR was then measured automatically with image-analysis software. We classified all of the specimens into three groups for each region: group I [dentate at the incisor - premolar region (IP) and the molar region (M)], group II (dentate at IP and edentulous at M), and group III (edentulous at IP and M). Likewise, another three groups based on the presence of teeth in the contralateral dental arch were classified: group IV (dentate at IP and M), group V (dentate at IP and edentulous at M), and group VI (edentulous at IP and M). Mean and standard deviation values were calculated, and the *t*-test, one-way ANOVA and post-hoc analysis (Scheffétest) were performed to examine differences among the three groups on the ipsilateral and contralateral sides, respectively, and between the sexes.

Statistical analysis indicated the presence of significant differences between all of the sectional images among the three groups from the ipsilateral side of the specimens. The mean TBR was significantly higher in the fully dentate group than in the other two groups in all sections. The results of the other three groups, classified according to the presence of the contralateral teeth, were similar to those of the corresponding ipsilateral groups. The mean TBR was higher among the males than the females in each group. However, there were no significant differences in the fully edentulous groups.

The density of the trabecular bone of the mandibular condyle was significantly associated with the presence of the molars, but not the incisors or premolars. There were significant differences between males and females. The present study has provided data regarding the bone quality and quantity of the

microstructure of the mandibular condyle according to the presence or absence of teeth.

Key words : micro-CT, mandible, condyle, teeth, trabecular bone

Trabecular bone ratio of the mandibular condyle according to the presence of teeth in Koreans: a micro-CT study

Kyung-Hoon Sun, D.M.D., M.S.D.

Department of Dentistry, The Graduate School,
Yonsei University

(Directed by Professor Kee-Deog Kim D.D.S., Ph.D.)

Ⅰ. INTRODUCTION

Bone continues to remodel and change throughout life. The amount of trabecular bone in the mandible decreases continually in a sex- and age-specific manner (Wowern, 1985), and is lower in females than in males (Henriksson et al., 1974). In particular, menopausal women lose bone mass three times faster than men (Gulsahi et al., 2008), with this decrease in bone density beginning around the third decade of life (Gulsahi et al., 2008; Wowern et al., 1982).

The mandibular condyle comprises the temporomandibular joint within the glenoid fossa of the temporal bone; the bilateral mandibular condyles function simultaneously. During mastication, mechanical pressure from the dentition is

transmitted to the trabecular bone of the mandible (Moon et al., 2004), and the effects of mandibular movements reach not only the mandibular body but also the mandibular condyle (Kawashima et al., 1997). Thus, the occlusal forces could affect condylar growth (Kurusu et al., 2009).

Occlusal forces are affected by the presence of the teeth, tooth movement, and masticatory characteristics. Vertical bone resorption after tooth loss is the main factor underlying continuous and irreversible resorption of the mandibular condyle. Therefore, the state of the dentition, occlusal forces, internal structure, and the morphology of the mandibular condyle all seem to influence each other. Regarding the relationship between the internal structure of the mandibular condyle and the presence of teeth, Giesen et al. (2004) reported that the trabecular bone of the mandibular condyle is denser in dentate subjects than in edentate subjects. Furthermore, the mandibular condyle may be affected differently by the different tooth groups (incisor, premolar, and molar) as a result of their disparate functions. However, comparative morphometric analyses of the mandibular condyle in dentate and edentate (or partially dentate) jaws have not yet been performed.

Micro-computed tomography (micro-CT) is an effective tool for the detailed evaluation of the internal structure of bone. It is a noninvasive method and can estimate specific parameters in three dimensions. It is possible to obtain high-resolution images if the voxels have dimensions of less than 100 μm (Engelke et al., 1996). Thus, micro-CT provides 3D images with voxels having dimensions of 14 - 60 μm, which is sufficient to visualize trabecular bone patterns.

The aim of this study was to elucidate the bone quality of Korean mandibular condyles according to the presence of teeth using micro-CT, thereby clarifying the influences of the teeth on the condylar microstructure.

Ⅱ. MATERIALS & METHODS

Thirty-one sides of fully and partially dentate Korean mandibles (24 bilateral and 7 unilateral) were prepared. The mandibles were taken from 18 males (mean age 63.3 years, range 49 - 101 years) and 13 females (mean age 67.2 years, range 45 - 86 years; Fig. 1). The study protocol was approved by the Ethics Committee of Yonsei Medical Center, Korea. First, the specimens were scanned and reconstructed into a 3D structure using a micro-CT system (Skyscan 1076, Skyscan, Antwerp, Belgium). The system consisted of an X-ray microscope system with a high-definition X-ray microfocus tube with a focal spot of 10 μm, a 1.0-mm-thick aluminum filter to remove noise during X-ray scanning, a precision-controlled specimen holder, a 2D X-ray CCD camera connected to a frame grabber, and a dual-Pentium-III computer hosting a tomographic reconstruction software program. The specimen was placed on the holder between the X-ray source and the CCD camera, and rotated around the vertical axis at intervals of 0.9° for 180° while maintaining it within the field of view, thereby producing 200 projections. The beam was projected onto a phosphorus screen, which converted X-rays into visible light that could be detected by a CCD camera. The data were digitized by the frame grabber and transmitted to a computer for processing with the tomographic reconstruction software.

A 3D structural image with a voxel size of 35×35×35 mm was reconstructed from the serial 2D images, and the specimen was sectioned vertically, passing through the medial and lateral poles of the mandibular condyle (P0) in order to measure the trabecular bone ratio (TBR). Likewise, three additional images from the specimen were acquired: 2 mm posterior (Pp2), 1 mm posterior (Pp1), and 1 mm anterior (Pa1) to the P0 (Figs. 2 and

3). On the sectional images, the cortical portion—which comprised an extra layer in the bone—wasdissociated with the cancellous portion of the bone using Adobe Photoshop (Adobe, San Jose, CA, USA) software. The component ratio of the area occupied by trabecular bone in the dissociated cancellous portion was then measured automatically (Fig. 4) with image-analysis software (Image-Pro®Plus version 4.0, Media Cybernetics, Bethesda, MD, USA).

For the morphometric analysis, the dental arches were divided into two parts: the incisor - premolar (IP) and molar regions (M). All of the specimens used in the present study were classified according to the presence (or absence) of teeth in each region (IP and M). The presence of every tooth was confirmed only in cases with an antagonist tooth; cases with root rests, pontics, and removable prostheses were excluded from the tooth count. The specimens were then classified into three groups for each region: group I (dentate at IP and M), group II (dentate at IP and edentulous at M), and group III (edentulous at IP and M). For example, cases in group II include those with at least one or more incisor or premolar teeth present, but no molar tooth. Likewise, the following three groups were further identified based on the presence of teeth on the contralateral dental arch: group IV (dentate at IP and M), group V (dentate at IP and edentulous at M), and group VI (edentulous at IP and M; Fig. 5).

All of the measurements from the present study were analyzed statistically using SPSS 12.0KO for Windows release 12.0.1 (SPSS, Chicago, IL). Mean and standard deviation values were calculated, and the *t*-test, one-way ANOVA, and post-hoc analysis (Scheffé test) were used to examine whether any differences in data among three groups from the ipsilateral and contralateral sides, and between the sexes of the specimens were significant at the 95% confidence level ($p<0.05$).

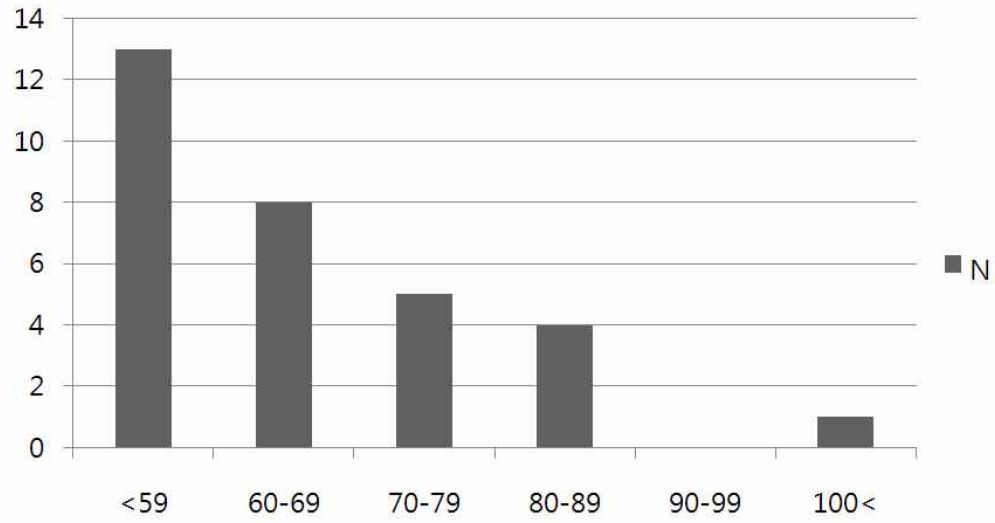

Fig. 1. The age distribution of the specimens used in the present study.

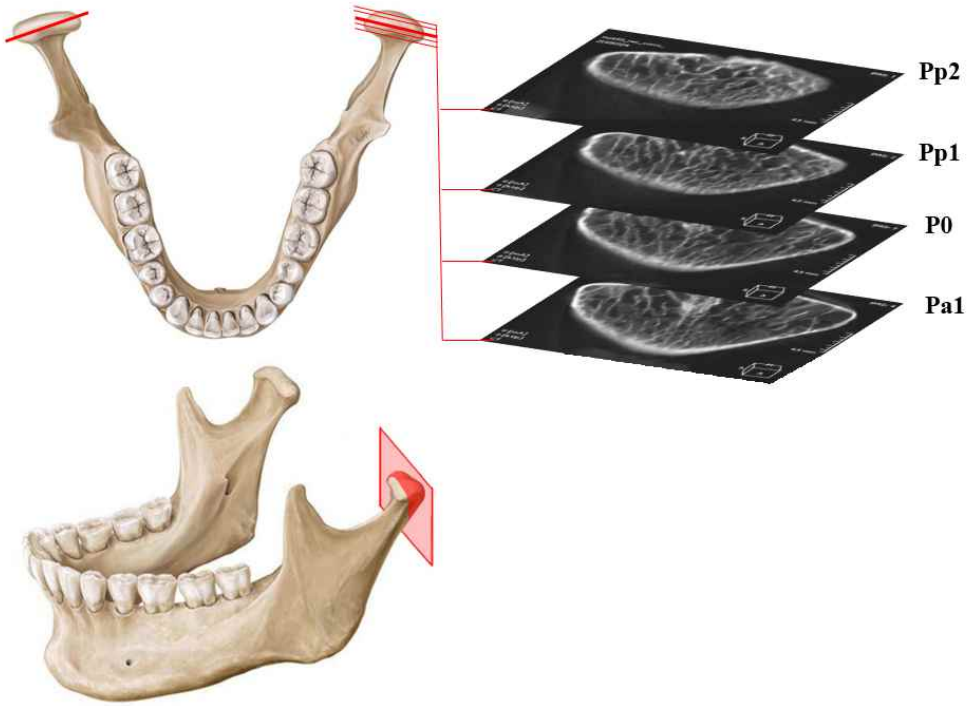

Fig. 2. The method used to obtain four sections of the mandibular condyle in order to measure the trabecular bone ratio (TBR). After reconstruction of the 3D image of the mandible, the specimen was sectioned vertically, passing through the medial and lateral poles of mandibular condyle in order to measure the TBR (section Pp2, 2 mm posterior; Pp1, 1 mm posterior; Pa1, 1 mm anterior to section P0, passing through the medial and lateral poles).

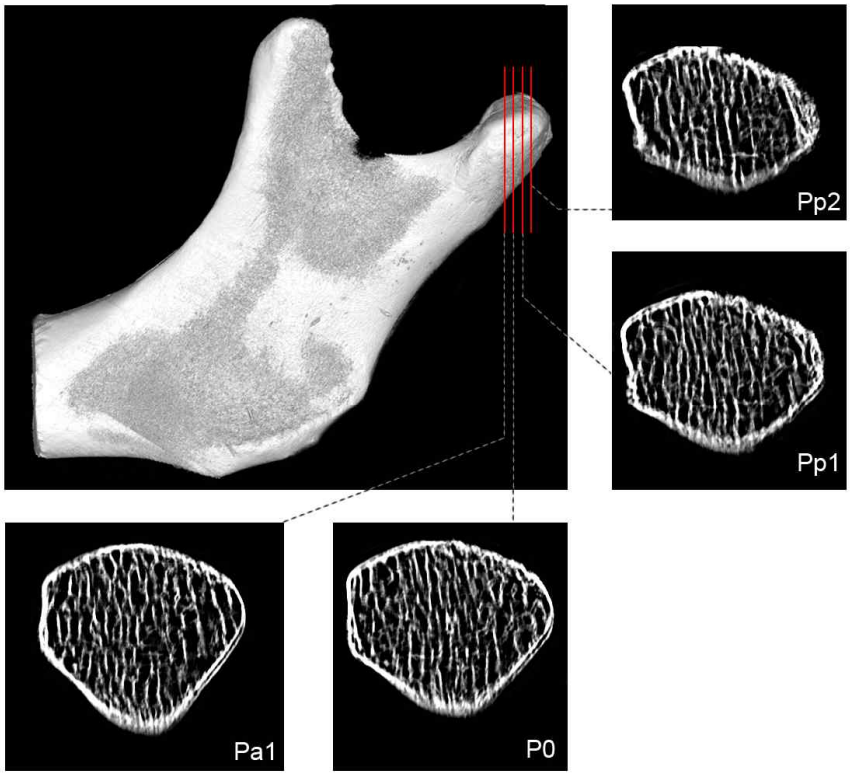

Fig. 3. Four sections acquired from a 3D image of the mandible. After reconstruction of the 3D image of the mandibular condyle, the specimens were sectioned vertically, passing through the medial and lateral poles of the mandibular condyle (P0) in order to measure the TBR. Likewise, three additional images from the specimen were acquired from the following sections: 1 mm posterior (Pp1), 2 mm posterior (Pp2), and 1 mm anterior (Pa1) to section P0 passing through the medial and lateral poles.

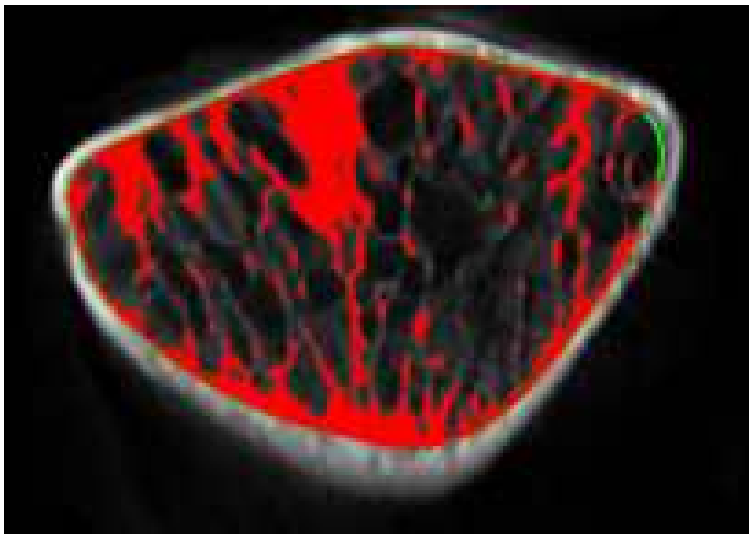

Fig. 4. The TBR measuring automatically with image-analysis software. A component ratio of the area occupied by the trabecular bone in the dissociated cancellous portion was measured automatically with image-analysis software (Image-Pro®Plus version 4.0).

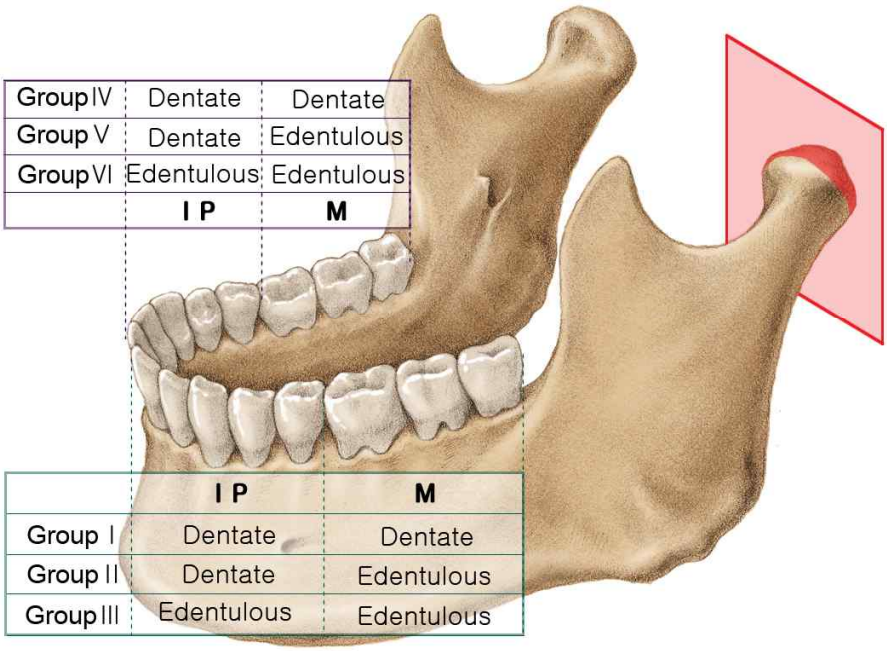

Fig. 5. Grouping of the specimens. All of the specimens used in the present study were classified according to presence of teeth in each incisor - premolar (IP) and molar (M) region. All specimens were then classified into three groups for each region: group I (dentate at IP and M), group II (dentate at IP and edentulous at M), and group III (edentulous at IP and M). Another three groups were introduced based on the presence of teeth on the contralateral dental arch: group IV (dentate at IP and M), group V (dentate at IP and edentulous at M), and group VI (edentulous at IP and M).

Ⅲ. RESULTS

Table 1 presents the mean TBR of the mandibular condyle of each group from the ipsilateral side of the specimens. Statistical analysis revealed significant differences in all of the sectional images among the three groups from the ipsilateral side of the specimens ($p<0.05$). The mean TBR was significantly higher in group I than in the other two groups in all of the sections. The mean TBR tended to decrease gradually from group I to group III in each section. However, the mean TBRs of groups II and III at section Pa1 were similar.

We performed an explorative analysis to verify the differences in TBR between two groups by the post hoc Scheffé method (Table 2). Comparison of groups I and III was revealed statistically significant differences in each section. A significant difference between groups I and II was observed only in section Pa1, and there was no significant difference between groups II and III in any of the sections.

The results for the other three groups (i.e., IV - VI) classified according to the presence of the contralateral teeth, were similar to those of the ipsilateral groups (i.e., I - III). Group IV had the highest TBR of all of the sections. There were statistically significant differences among the three groups, with the TBR tending to decrease gradually from group IV to group VI in each section (Table 3, $p<0.05$).

Table 4 summarizes the results of the explorative analysis of differences of the TBR between two groups, respectively. TBR differed significantly only between groups IV and VI in each section ($p<0.05$). A significant difference between groups IV and VI was found only in section P0, and no significant difference was found between groups V and VI in any of the sections.

The mean TBR was higher in the males than in the females in all groups. In groups I, II, IV, and V, significant differences between males and females were commonly found in section P0. In addition, significant differences were observed in section Pp2 (groups I and IV), section Pp1 (group IV), and section Pa1 (group V). On the other hand, there were no significant differences in groups III and VI (fully edentulous; Table 5).

Table 1. Comparison of the mean trabecular bone ratio (TBR) of the mandibular condyle among the three ipsilateral groups (i.e., Ⅰ - Ⅲ).

	N	Pp2	Pp1	P0	Pa1
Group Ⅰ	18	34.35±5.15	36.13±4.25	36.31±6.26	35.29±3.97
Group Ⅱ	4	29.82±3.62	32.02±4.52	28.52±3.18	28.52±4.12
Group Ⅲ	9	28.58±5.22	28.85±4.66	27.75±4.34	28.92±5.67
p-value*		0.022*	0.001*	0.001*	0.002*

All values (%) are presented as mean ±SD.

*Statistically significant in the mean TBR among three groups ($p<0.05$)

(Section Pp2: 2mm posterior, Pp1: 1mm posterior, Pa1: 1mm anterior to the section P0, passing through the medial and lateral poles, respectively)

Table 2. Explorative analysis of differences between two groups for the three ipsilateral groups (i.e.,Ⅰ - Ⅲ).

Section	Groups	Mean differece	SE difference	p-value*
Pp2	Ⅰ - Ⅱ	4.53	2.78	0.282
	Ⅰ - Ⅲ	5.77	2.05	0.030*
	Ⅱ - Ⅲ	1.24	3.02	0.920
Pp1	Ⅰ - Ⅱ	4.11	2.43	0.256
	Ⅰ - Ⅲ	7.28	1.80	0.002*
	Ⅱ - Ⅲ	3.17	2.64	0.496
P0	Ⅰ - Ⅱ	7.78	3.04	0.053
	Ⅰ - Ⅲ	8.56	2.25	0.003*
	Ⅱ - Ⅲ	0.77	3.31	0.973
Pa1	Ⅰ - Ⅱ	6.77	2.51	0.039*
	Ⅰ - Ⅲ	6.37	1.85	0.007*
	Ⅱ - Ⅲ	-0.40	2.73	0.989

SE, standard error

* Scheffe test. Statistically significant in the mean TBR between groups ($p<0.05$).

(Section Pp2: 2mm posterior, Pp1: 1mm posterior, Pa1: 1mm anterior to the section P0, passing through the medial and lateral poles, respectively)

Table 3. Comparison of the mean trabecular bone ratio (TBR) of the mandibular condyle among the three contralateral groups (i.e., Ⅳ - Ⅵ).

	N	Pp2	Pp1	P0	Pa1
Group Ⅳ	17	34.63±5.17	36.39±4.23	36.57±6.35	35.36±4.09
Group Ⅴ	5	29.77±3.14	31.96±3.92	29.19±3.14	29.63±4.35
Group Ⅵ	9	28.58±5.22	28.85±4.66	27.75±4.34	28.92±5.67
P value*		0.013*	0.001*	0.001*	0.004*

All values (%) are presented as mean ±SD.

*Statistically significant in the mean TBR among three groups ($p<0.05$)

(Section Pp2: 2mm posterior, Pp1: 1mm posterior, Pa1: 1mm anterior to the section P0, passing through the medial and lateral poles, respectively)

Table 4. Explorative analysis of differences between two groups for the three contralateral groups (i.e., Ⅳ - Ⅵ).

Sections	Groups	Mean differece	SE difference	p-value*
Pp2	Ⅳ-Ⅴ	4.86	2.52	0.174
	Ⅳ-Ⅵ	6.05	2.04	0.022*
	Ⅴ-Ⅵ	1.19	2.76	0.911
Pp1	Ⅳ-Ⅴ	4.43	2.19	0.149
	Ⅳ-Ⅵ	7.54	1.78	0.001*
	Ⅴ-Ⅵ	3.11	2.41	0.444
P0	Ⅳ-Ⅴ	7.37	2.78	0.043*
	Ⅳ-Ⅵ	8.82	2.25	0.002*
	Ⅴ-Ⅵ	1.44	3.05	0.894
Pa1	Ⅳ-Ⅴ	5.72	2.36	0.069
	Ⅳ-Ⅵ	6.44	1.91	0.008*
	Ⅴ-Ⅵ	0.71	2.58	0.963

SE, standard error

* Scheffe test. Statistically significant in the mean TBR between groups ($p<0.05$).

(Section Pp2: 2mm posterior, Pp1: 1mm posterior, Pa1: 1mm anterior to the section P0, passing through the medial and lateral poles, respectively)

Table 5. Comparison of the mean TBR of the mandibular condyle in specimens from males and females.

	Group Ⅰ					Group Ⅳ				
	N	Males	N	Females	p-value	N	Males	N	Females	p-value
Pp2	11	36.44±5.48	7	31.06±2.13	0.011*	10	37.13±5.26	7	31.06±2.13	0.006*
Pp1	11	37.44±4.76	7	34.07±2.28	0.062	10	38.02±4.60	7	34.07±2.28	0.035*
P0	11	39.02±6.05	7	32.05±3.93	0.016*	10	39.73±5.86	7	32.05±3.93	0.009*
Pa1	11	36.18±3.99	7	33.89±3.80	0.244	10	36.39±4.14	7	33.89±3.80	0.225
	Group Ⅱ					Group Ⅴ				
	N	Males	N	Females	p-value	N	Males	N	Females	p-value
Pp2	2	30.95±4.80	2	28.68±3.34	0.643	3	30.49±3.48	2	28.68±3.34	0.603
Pp1	2	35.67±1.76	2	28.37±2.22	0.073	3	34.35±2.60	2	28.37±2.22	0.077
P0	2	31.18±1.20	2	25.87±0.82	0.046*	3	31.41±0.94	2	25.87±0.82	0.007*
Pa1	2	31.76±0.41	2	25.28±2.95	0.192	3	32.54±1.38	2	25.28±2.95	0.030*
	Group Ⅲ					Group Ⅵ				
	N	Males	N	Females	p-value	N	Males	N	Females	p-value
Pp2	5	29.43±7.04	4	27.51±1.98	0.589	5	29.43±7.04	4	27.51±1.98	0.589
Pp1	5	30.38±5.92	4	26.93±1.51	0.269	5	30.38±5.92	4	26.93±1.51	0.269
P0	5	29.28±5.53	4	25.84±0.78	0.238	5	29.28±5.53	4	25.84±0.78	0.238
Pa1	5	30.37±7.20	4	27.11±2.96	0.429	5	30.37±7.20	4	27.11±2.96	0.429

All values (%) are presented as mean ±SD.

*Statistically significant in the mean TBR between males and females ($p<0.05$).

(Section Pp2: 2mm posterior, Pp1: 1mm posterior, Pa1: 1mm anterior to the section P0, passing through the medial and lateral poles, respectively)

Ⅳ. DISCUSSION

The mandible has unique functional and structural characteristics. Unlike other bones, masticatory forces are transmitted directly to the trabecular bone in cancellous bone of the mandible (Bresin et al., 1994, 1999). At the condyle of the mandible, the trabecular bone is arranged in a network pattern located below the articular surface. These trabecular patterns run inferosuperiorly and receive the compressive forces (Hongo, 1987).

Computed tomography is commonly used in the diagnosis and postoperative follow-up of hard and soft tissues as well as in the presurgical planning of the treatment of skull and jaw pathosis. However, there is no information available regarding normal bone density and its distribution in the mandibular condyle. The present study employed micro-CT because it does not damage the microstructure and provides more flexibility when generating 3D images. Its biggest advantage is that the acquired images have less distortion, are more reliable, and have a higher resolution than conventional radiographic images. However, micro-CT is not yet available for clinical applications. The resolution and image quality of routine computed tomography has recently improved significantly to provide a slice thickness of 625 mm (Mühlberger et al., 2009).

Remodeling of trabecular bone by transmitted masticatory forces occurs throughout life. The movement of the teeth and the masticatory forces are transmitted through the periodontal ligament to the mandibular structures. In addition, the mandibular condyle, which comprises the temporomandibular joint, is seriously affected by mastication. The present study found that tooth loss was followed by changes in the mean TBR values. The results of this study indicate that the TBR values of mandibular condyles are significantly higher in

dentate subjects than in edentulous subjects. One study of the TBR of the mandibular body found that the TBR differed significantly between dentate and edentulous groups in the molar region (Won et al., 2010).

TBR was measured in this study to evaluate bone mineral density (BMD). A definite effect of tooth presence was observed, with significant differences between the fully dentate and fully edentulous groups (I - III and IV - VI, respectively) being found in each section.

However, the difference between another two groups, dentate at IP, edentulous at M group (II) and fully edentulous group (III), was not significant in all sections. The results of the other two groups (V - VI), classified according to the presence of the contralateral teeth, were similar to those of the corresponding ipsilateral groups.

There were statistically significant differences between the fully dentate group (I and IV) and dentate at IP, edentulous at M group (II and V), although only in one anterior section; difference between groups I and II was significant in section Pa1, and difference in groups IV and V was significant in section P0. These results imply that the BMD of trabecular bone of the mandibular condyle is significantly associated with the presence of molar teeth, than incisors and premolars. Most of the masticatory force is transmitted directly through the molar teeth, with the premolars assisting them in biting. Therefore, the observed significant differences in BMD are related to the presence of teeth, particularly the molars.

Since loss of teeth is associated with decreased masticatory function, it was hypothesized that the bone would react to the changed mechanical environment. Accordint to previous study, it appears that the morphology of the cancellous bone differs between edentulous and dentate subjects. The bone volume fraction was lower in edentulous subjects, which may be associated with the presence of more rod-like trabeculae. Giesen et al. (2004) reported

that the cancellous bone in the mandibular condyles was less dense in edentulous subjects than in dentate subjects, and had changed toward a more rod-like structure.s

Kawashima et al. (1997) found that the trabecular density of the mandibular condyle was lower in dentate specimens than in edentulous specimens, which may be due to the decreased functional pressure associated with loss of the teeth. The trabecular width was also decreased in the edentulous specimens. Hongo et al. (1987) compared the mandibular condyle between dentate and edentulous specimens and suggested that changes in the physical environment due to loss of the teeth impair the function of the temporomandibular joint and the strength of the masticatory muscles, resulting in narrowing of the trabecular bone. The jaw bone undergoes morphological changes due to loss of teeth and resulting physical changes in the surrounding area.

The TBR is influenced by various factors. According to previous studies, the TBR is lower for women than for men (Henriksson et al., 1974); this sex-related difference is even apparent after the menopausal period (Solar et al., 1994). The present study also found significant differences between males and females. However, the TBR was not significant in the fully edentulous specimens in both the IP and M regions. Bone loss commences at the age of about 35 years, and continues at different rates throughout life (Drozdzowska et al., 2002). In the present study, the TBR did not differ between the dentate and the edentulous subjects, although an age-related decrease in the TBR has been reported (Won et al., 2010).

The mean age of the specimens used in the present study was 64.9 years, ranging from 45 to 101 years; 13 of the specimens were in their 50s, 8 were in their 60s, 5 were in their 70s, and 4 were in their 80s. None of the specimens were in their 90s, and only 1 was over 100 years old (Fig. 1). The age distribution ranged from 45 to 86 years (median 63.7 years), with the

exception of one specimen. Therefore, the age of the specimens was not evenly distributed over a wide range, which may explain why a significant age-related difference was not found in each group.

Bone is composed of compact bone and cancellous bone. Cancellous bone bears trabeculae and medullary cavities. The BMD of cancellous bone affects the mechanical support and osteogenic potential change (Moon et al., 2004). A high BMD in cancellous bone indicates a high proportion of trabeculae, from which mechanical support can be obtained. Conversely, a low BMD means a high proportion of medullary cavities, from which osteogenic potential may be gained. Information regarding the bone density of fractured bones can be used by surgeons to guide the choice of specific osteosynthesis materials and estimation of exercise and stress stability in terms of surgical care (Bitterling et al., 2005).

Ⅴ. CONCLUSION

The conclusions of this study are as follows:

1. Statistical analysis revealed significant differences in all of the sectional images among the three groups from the ipsilateral side of the specimen (i.e., Ⅰ–Ⅲ). The mean TBR was significantly higher in the fully dentate group than in the other two groups in all of the sections.
2. The results of the other three groups, which were classified according to the presence of contralateral teeth (i.e., Ⅳ–Ⅵ), were similar to those of the ipsilateral groups.
3. The mean TBR was higher for males than for females in all groups. However, there were no significant differences in the fully edentulous groups.

In conclusion, the density of the trabecular bone of the mandibular condyle is significantly associated with the presence of the molars, but not the incisors or premolars. There were significant differences between males and females. The present study provides data regarding the bone quality and quantity of the microstructure of the mandibular condyle according to the presence (or absence) of the teeth.

REFERENCES

Bitterling H, Vogel T, Dobler T, Mutschler W, Pfeifer KJ, Reiser M, Eibel R (2005) Role of osteoporosis in trauma diagnostics. Rofo 177, 1663-1669

Bresin A, Johansson C, Kilaridis S (1994) Effects of occlusal strain on the development of the dentoalveolar process in the growing rat. A morphometric study. Eur J Musculoskelet Res 3, 112-122

Bresin A, Kiliaridis S, Strid KG (1999) Effect of masticatory function on the internal bone structure in the mandible of the growing rat. Eur J Oral Sci 107, 35-44

Drozdzowska B, Pluskiewiez W, Tarnawska B (2002) Panoramic-based mandibular indices in relation to mandibular bone mineral density and skeletal status assessed by dual energy X-ray absorptiometry and quantitative ultrasound. Dentomaxillofac Radiol 31, 361-367

Engelke K, Song SM, Gluer CC, Gluer CC, Genant HK (1996) A digital model of trabecular bone. J Bone Miner Res 11, 480-489

Giesen EBW, Ding M, Dalstra M, van Eijden TMGJ (2004) Changed Morphology and Mechanical Properties of Cancellous Bone in the Mandibular Condyles of Edentate People 83, 255-259

Gulsahi A, Yuzugullu B, Imirzalioglu P, Genc Y (2008) Assessment of panoramic radiomorphometric indices in Turkish patient of different age groups, gender and dental status. Dentomaxillofac Radiol 37, 288-292

Henriksson PA, Wallenius K (1974) The mandible and osteoporosis (1). A qualitative comparison between the mandible and radius. J Oral Rehab 1, 67-74

Hongo T (1987) Quantitative and morphological studies on the trabecular bones in the processus condylaris of the Japanese mandebula; The comparison between dentulous and edentulous specimens and differences in ages. Shikwa Gakuho 87, 1583-1611

Kawashima T, Abe S, Okada M, Kawada E, Saitoh C, Ide Y (1997) Internal structure of the temporomandibular joint and the circumferential bone: comparison between dentulous and edentulous specimens. Bull Tokyo Dental Coll 38, 87-93

Kurusu A, Horiuchi M, Soma K (2009) Relationship between occlusal force and mandibular condyle morphology. Angle Orthod 76, 1063-1069

Moon HS, Won YY, Kim KD, Ruprecht A, Kim HJ, Kook HK, Chung MK (2004) The three-dimensional microstructure of the trabecular bone in the mandible. Surg Radiol Anat 26, 466-473

Mühlberger G, Svejda M, Lottersberger C, Emshoff R, Putz R, Kuhn V (2009) Mineralization density and apparent density in mandibular condyle bone. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 107, 573-579

Solar P, Ulm CW, Thornton B, Matejka M (1994) Sex-related differences in the bone mineral density of atrophic mandibles. J Prosthet Dent 71, 345-349

Wowern N (1982) Microradiographic and histomorphometric indices of mandibules for diagnosis of osteopenia. Scand J Dent Res 90, 47-63

Wowern N (1985) In vivo measurement of bone mineral content of mandibles by dual-photon-absorptoomtry. Scand J Dent Res 93, 162-168

Won SY, Kim SH, Kim ST, Paik DJ, Song WC, Koh KS, Chung MK, Kim HJ, Hu KS (2010) Trabecular Bone Ratio of Mandible Using Micro-Computed Tomography in Korean. J Craniofac Surg 21, 920-924

Yu IH, Wong YK (2008) Evaluation of mandibular anatomy related to sagittal split ramus osteotomy using 3-dimensional computed tomography scan images. Int J Oral Maxillofac Surg 37, 521-528

Abstract (in korean)

Micro-CT로 분석한 치아 존재에 따른 한국인 아래턱뼈 관절돌기 잔기둥뼈 양의 변화 양상

<지도교수 김 기 덕>

연세대학교 대학원 치의학과

선 경 훈

아래턱뼈의 관절돌기는 교합력을 직접적으로 전달 받으며 일생동안 이로 인한 뼈의 재구성 과정을 겪는다. 저작 시 교합력은 아래턱뼈를 통해 전달되어 관절돌기 내부의 해면뼈의 밀도에 영향을 미칠 수 있다. 무치악과 유치악을 비교한 기존의 연구에서 교합력의 차이로 인해 관절돌기 내부의 뼈 양상에도 차이가 있음이 보고된 바 있다. 그러나 치아는 위치와 형태에 따라 저작작용 동안 서로 다른 기능을 하며 각 치아가 관절돌기의 뼈구성에 미치는 영향도 다를 것으로 예상된다. 이에 저자는 micro-CT를 이용하여 관절돌기의 해면뼈 부분에서 뼈지주가 차지하는 양을 계측하여, 각 아래턱 치아의 존재에 따른 관절돌기 해면뼈 양상에 미치는 영향을 밝히고자 본 연구를 시행하였다.

재료로는 31쪽의 아래턱뼈를 사용하였다 (남;18쪽, 여;13쪽, 평균 연령; 64.9). 먼저 아래턱뼈를 micro-CT로 촬영하고 (Skyscan 1076, Skyscan, Antwerp, Belgium), 2차원 이미지를 바탕으로 3차원으로 재구성하였다. 3차원 영상에서 양쪽 pole을 지나고 아래턱뼈 아래모서리와 수직인 단면을 얻었으며 이것을 P0라고 하였다. P0에서 앞, 뒤 방향 1mm 간격으로 2장씩 추가적인 단면을 더 획득하여 앞쪽의 단면을 각각 Pa1, Pa2 라고 하였으며 뒤쪽의 단면을 각각 Pp1, Pp2라고 하였다. 이 단면이미지에서 이미지 분석 소프트웨어(Image-Pro®Plus version 4.0)를 통해 Trabecular Bone Ratio를 계측하였다.

통상적으로 치아를 ①앞니, ②작은어금니, ③큰어금니의 세 부분으로 나누지만

본 연구에서는 치아를 ①앞니 또는 작은어금니(IP), ②큰어금니 부위(M) 부위의 두 부분으로 나누었다. 그리고 각 표본에서 관절돌기와 같은 쪽 턱의 치아가 두 부분에 존재하는지의 여부에 따라 표본을 세 군 (Three ipsilateral-groups)으로 분류하였다. 두 부분에 모두 치아가 존재하면 1군, IP부분에만 치아가 존재하고 M부분에 존재하지 않으면 2군, 두 부분 모두 치아가 존재하지 않으면 3군으로 분류하였다. 또한 관절돌기와 반대쪽 턱의 치아의 존재 여부에 따라서 또 다른 세 군(Three contralateral-groups)으로 분류하였다. 마찬가지 방법으로 4군, 5군, 6군으로 분류하였다. 마지막으로 성별에 따라 두 군으로 분류하였다. 그리고 각 군들 간에 관절돌기의 TBR이 차이가 있는지 SPSS program을 이용하여 분석하였다. 결과는 다음과 같다.

관찰한 관절돌기의 같은 쪽 치아의 존재에 따라 분류한 세 군의 TBR은 모든 단면에서 세 군 간에 유의한 차이를 나타내었다. 관절돌기의 뒤 부분 (Pp2, Pp1, P0)에서는 상실된 치아가 많을수록 TBR이 감소하는 경향을 보였으며, 1군과 3군의 TBR 차이가 특히 컸으며, 단면 Pa1에서는 1군과 2군의 TBE도 유의한 차이를 나타내었다. 관찰한 관절돌기의 반대 쪽 치아의 존재에 따라 분류한 세 군에서, 모든 단면에서 TBR은 세 군간에 유의한 차이를 나타내었으며, 상실된 치아가 많을 수록 TBR이 감소하는 경향을 보였다. 4군과 6군의 TBR 차이가 특히 컸으며, 단면 P0에서는 4군과 5군의 TBR도 유의한 차이를 나타내었다. 모든 군에서 남자의 TBR이 여자의 TBR보다 높았다.

이상의 결과를 종합하여 볼 때, 교합기능을 담당할 수 있는 치아의 수가 많은 표본이 그렇지 않은 표본보다 아래턱뼈 관절돌기 잔기둥뼈의 밀도가 높았으며, 특히 큰어금니의 존재가 뼈의 밀도에 중요한 영향을 미치는 것을 알 수 있었다.

핵심되는 말 : micro-CT, 아래턱뼈, 관절돌기, 치아, 해면뼈