2017년 2월 박사학위논문 측두하악관절 골관절염 환자의 관절음에 대한 임상적、방사선학적 평가 신 정 연

2017년 2월

박사학위논문

# 측두하악관절 골관절염 환자의 관절음에 대한 임상적, 방사선학적 평가

조선대학교 대학원

치 의 학 과

신 정 연

# 측두하악관절 골관절염 환자의 관절음에 대한 임상적, 방사선학적 평가

Clinical and radiographic evaluation about joint sounds of patients with temporomandibular joint osteoarthritis

2017년 2월 24일

조선대학교 대학원

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신 정 연

# 측두하악관절 골관절염
# 환자의 관절음에 대한
# 임상적, 방사선학적 평가

지도교수 안 종 모

이 논문을 치의학 박사학위신청 논문으로 제출함

2016년 10월

조선대학교 대학원

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신 정 연

# 신정연의 박사학위 논문을 인준함

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## 측두하악관절 골관절염 환자의 관절음에 대한 임상적, 방사선학적 평가

**신 정 연**
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**연구목적:** 측두하악관절 골관절염 환자의 관절음에 대한 임상적, 방사선학적인 평가를 하고자 한다.

**연구대상 및 연구 방법:** 조선대학교 치과병원에 내원한 환자 중 측두하악관절 골관절염으로 진단받은 환자들을 대상으로 관절음 상태, 개구량, 통증 유무 등에 대한 임상검사 및 방사선 사진(panoramic radiography, transcranial radiography, cone beam computed tomography) 상에서의 골변화 양상을 조사하여, 각각의 상관관계에 대해 분석하였다.

**결과:** 관절음이 없는 그룹보다 존재하는 그룹에서 저작시 통증 및 개구량이 증가하였으며, 염발음의 경우 편측보다 양측에서 관찰되는 그룹에서 개구량이 증가하였다. 염발음이 존재하는 그룹과 panoramic radiography, transcranial radiography, cone beam computed tomography(CBCT) 에서 관찰되는 골변화 소견이 높은 상관관계를 보였다. 또한 3가지 방사선 사진 그룹간의 골변화 소견에 대한 높은 일치도를 보였다.

**결론:** 염발음의 경우 3가지 방사선 사진상의 골변화 양상과 높은 상관관계를 보이며, panoramic radiography 와 transcranial radiography 에서도 하악과두의 골변화 소견에 대해 CBCT 와 유사한 일치도를 보였다.

**주제어:** 관절음, 방사선 사진, 측두하악관절 골관절염

# I . Introduction

The temporomandibular joint (TMJ) is one of the most complicated joints in the human body, which is composed of the mandibular condyle and temporal bone [1]. Past studies reported that 41% of the population have symptoms related to temporomandibular disease (TMD) such as myofascial pain, TMJ internal derangement, TMJ degeneration [2]. One of the symptoms of TMD is temporomandibular joint osteoarthritis (TMJ OA) [1], which causes tissue degeneration due to the imbalance between the mechanical and biological synthesis and degradation of articular cartilage chodrocytes, extracellular matrix and subchondral bone [3]. It is most commonly caused by overload on the joint tissue and the disease is induced when the articular surface is damaged by articular disc dislocation and retrodiscitis [4].

There are various symptoms for TMD such as pain during mouth opening and mastication, tenderness upon palpation on the TMJ and masticatory muscles, joint sound, and irregular mandibular movement. Joint sound is a common symptom observed on 25~35% of asymptomatic persons, but the development of joint sounds are still in debate. It is generally described by articular disc displacement due to the extension or tear of ligaments [5], irregularity of the articular surface, articular disc-articular surface ankylosis, synovial degradation, and disc deformation [6]. Clicking and crepitus are the most commonly used terms to express the various temporomandibular joint sounds. Clicking and reciprocal clicking, which occurs during both mouth opening and closing, are reported to be clinical symptoms of disc displacement with reduction and related to anterior disc displacement [7]. Crepitus is generally known as a symptom of degenerative joint diseases [8], but other studies argue that a diagnosis cannot be concluded as osteoarthritis with crepitus alone [9].

Diagnosis of TMJ OA is usually based on history taking and clinical examination. However, since there are no specific laboratory tests for the final diagnosis of TMJ OA, radiographic examinations such as panorama and conventional radiography are needed [10]. Cone beam computed tomography (CBCT) is favored for it shows similar diagnostic efficiency to computed tomography (CT) but with better accessibility and lower radiation exposure [11].

Many studies have been conducted to evaluate the relevance between the symptoms and signs of TMD and radiographic findings. While some studies [12] report clinical symptoms such as pain and radiographs are highly associated, other studies were unable to find any relevance [13]. Despite the functional, anatomical, and histological peculiarities of TMJ, more studies are needed in regard of the relevance between TMD and radiographs. Especially, there is an ongoing debate about the correlation between the diagnostic value of joint sounds and other clinical symptoms for TMJ OA, and more studies need to be conducted that analyzes joint sound and radiographic bone change patterns. Therefore, this study aims to evaluate the correlation between joint sounds and radiographic bone change patterns along with clinical symptoms of TMJ OA patients.

# Ⅱ. Materials and Methods

## A. Study subjects

This study selected patients who visited Chosun University Dental Hospital between the dates of Jan 1, 2012 and Aug 31, 2015 with a chief complaint of joint sounds and discomfort such as temporomandibular joint pain and mouth opening limitation. A total of 191 patients (male:38, female:153, average age:41.4±17.7) were selected, who were over 19 years of age, diagnosed with temporomandibular joint osteoarthritis, and examined with TMD analysis test, panoramic radiography, transcranial radiography, and CBCT. The inclusion criteria for this study was based on the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD)axis I Group IIIb osteoarthritis of the TMJ; limited to joint pain and crepitus or the observation of erosion, sclerosis, flattening of joint surface, and osteophyte formation from CBCT images [14].

Patients under the age of 19 and those with a history of trauma or lower jaw surgery, congenital deformation, and systemic disease related to condyle absorption (rheumatoid arthritis, systemic sclerosis, lupus erythematosus, etc.) were all exempt [15].

This study protocol was approved by the Chosun University Dental Hospital Institutional Review Board (CUDH-IRB 1502 005).

## B. Methods

Information of the patients' age, chief complaint, joint sound, functional disorder, pain, and mouth opening range were collected, and bone change pattern was examined by reviewing panoramic radiography, transcranial radiography, and CBCT images. Joint sounds were measured using the practitioner's fingers, and both the subjective sound that the patient hears and the sound observed during clinical examination were included.

Radiographic interpretation was based on the comprehensive findings of dental specialists of oral medicine and oral-maxillofacial radiology.

CB MercuRay (Hitachi, Tokyo, Japan) was used for CBCT. The patient was scanned on P-mode with the head kept stationary and the occlusal surface parallel to the floor. The scanning conditions of tube voltage, tube current, and exposure time were set at 120kVp, 15mA, and 9.8sec, respectively. All scanned data were processed through CB Works (Hitachi, Tokyo, Japan) software and saved as 512 cross-sectional images that supports the DICOM 3.0 format.

## C. Statistical analysis

SPSS (version 20.0, IBM Corp, Amonk, NY, USA) was used for statistical analysis and the data were analyzed using Cohen's kappa(κ) analysis, chi-square tests, and linear by linear association.

# III. Results

## A. Distribution of patients

A total of 191 patients, 38 males (19.9%) and 153 females (80.1%), with an average age of 41.4±17.7 were selected for this study. For each age group, 6 patients were in the age between 10-19 (3.1%), 65 patients in the 20s (34.0%), 32 patients in the 30s (16.8%), 16 patients in the 40s (8.4%), 34 patients in the 50s (17.8%), 25 patients in the 60s (13.1%), and 13 patients were over 70 years of age (6.8%) (Fig. 1, Table 1).

## B. Correlation between the patient's gender, age, clinical symptoms, and radiographic bone change

The correlation between the patient's active mouth opening range and radiographic bone change was analyzed using linear by linear association and the results did not show any statistical significance. In addition, the correlation between the change in occlusion, pain during mouth opening and mastication, and radiographic bone change were each analyzed using chi-square test and the results did not show any statistical significance. There were no statistical significance in the correlation with the patient's gender and age as well (Table 2).

## C. Pain pattern according to type of joint sound

Joint sound was observed in 180 patients (94.2%) and an increase in pain was observed during mastication ($p=0.037$). Out of the 49 patients (25.7%) with bilateral crepitus, 32 patients (16.8%) had pain during mastication and 35 patients (18.3%) had pain during mouth opening. Unilateral crepitus was found in 85 patients (44.5%), and among them, 61 patients (31.9%) had pain during mastication and 62 patients (32.5%) had pain during mouth opening. There was no statistical significance in the correlation between crepitus and pain during mastication (p=0.757) and mouth opening (p=0.053). Bilateral clicking was observed in 48 patients (25.1%) and 28 patients (14.7%) had pain during mastication and mouth opening. Unilateral clicking was found in 71 patients (37.2%) and among them, 48 patients (25.1%) had pain during mastication and 47 patients (24.6%) had pain during mouth opening. Pain during mastication increased more in the group with clicking than the group without clicking. Also, there was a statistically significant increase in the pain during mastication in the group with bilateral clicking than the group with unilateral clicking (p=0.023). Bilateral popping was observed in 6 patients (3.1%), and 5 patients (2.6%) had pain during mastication and mouth opening. Unilateral popping was found in 9 patients (4.7%) and among them, 5 patients (2.6%) had pain during mastication and 4 patients (2.1%) had pain during mouth opening. There was no statistical significance in the correlation between popping and pain during mastication (p=1.000) and mouth opening (p=1.000) (Table 3).

## D. Correlation between type of joint sound and active mouth opening range

The average active mouth opening range was 32.8±9.0(mm) in the group without any joint sounds and 41.2±8.5(mm) in the group with joint sounds. And the average active mouth opening range in patients without crepitus, with unilateral crepitus, and with bilateral crepitus were 38.9±10.2(mm), 41.2±8.4(mm), and 42.1±7.1(mm), respectively. Also, the average active mouth opening range was 39.6±8.0(mm) in patients without clicking, 41.1±9.8(mm) in patients with unilateral clicking, and 42.0±7.9(mm) in patients with bilateral clicking. And the average active mouth opening range was 40.9±8.7(mm) in patients without popping, 42.0±7.7(mm) in patients with unilateral popping, and

35.2±9.2(mm) in patients with bilateral popping. For the evaluation of the correlation between the type of joint sound and active mouth opening range, AMO was converted to nominal variables divided into three groups: below 30mm, 30~40mm, and over 40mm. Fisher's exact test was conducted by dividing a group without joint sounds and a group with more than one of the three joint sounds (crepitus, clicking, and popping) and mouth opening range increased in the group with joint sounds ($p=0.006$). Each joint sound was analyzed using linear by linear association. And the results showed that patients with crepitus had a higher average active mouth opening range than patients without crepitus, and the group with bilateral crepitus had a higher average active mouth opening range than the group with unilateral crepitus ($p=0.002$). There was no statistically significant correlation in the groups with clicking ($p=0.284$) or popping ($p=0.264$) (Table 4).

## E. Bone change findings for each radiography

From the observation results of bone change patterns for each radiography, bone change of both condyles was observed in 66 patients (34.6%) from panoramic radiography and transcranial radiography and 67 patients (35.1%) from CBCT. Bone change of the unilateral condyle was observed in 97 (50.8%), 96 (50.3/%), and 110 (57.6%) patients from panoramic radiography, transcranial radiography, and CBCT, respectively. The number of patients of whom bone change was not observed were 28 patients (14.7%) for panoramic radiography, 29 patients (15.2%) for transcranial radiography, and 14 patients (7.3%) for CBCT (Table 5).

## F. Correlation of radiographic bone change pattern according to type of joint sound

Based on the analytic results of the agreement by Cohen's kappa analysis, the kappa values for the relevance between the group without joint sounds and bone change patterns of the condyle observed from panoramic radiography and transcranial radiography were each κ=1.000 (p=0.001), and the kappa value for the relevance with bone change patterns observed from CBCT was κ=0.340 (p=0.013). The kappa value for the relevance between crepitus and bone change patterns of the condyle observed from panoramic radiography was κ=0.715 (p=0.000) as the kappa value for transcranial radiography was also κ=0.715 (p=0.000). And the kappa value for the relevance between crepitus and bone change from CBCT was κ=0.690 (p=0.000). The kappa values for the relevance between clicking and bone change patterns of the condyle observed from panoramic radiography, transcranial radiography, and CBCT were κ=0.540 (p=0.000), κ=0.533 (p=0.000), and κ=0.521 (p=0.000), respectively. The kappa value for the relevance between popping and bone change patterns of the condyle observed from panoramic radiography was κ=0.055 (p=0.000). Also, for transcranial radiography, the kappa value was κ=0.056 (p=0.000), and for CBCT, the kappa value was κ=0.065 (p=0.000) (Table 6).

## G. Agreement of bone change findings for each radiography

The agreement of bone change findings for each radiography was analyzed using Cohen's kappa analysis. The kappa value between panoramic radiography and transcranial radiography, panoramic radiography and CBCT, and transcranial radiography and CBCT was κ=0.971 (p=0.000), κ=0.884 (p=0.000), and κ=0.870 (p=0.000), respectively (Table 7).

Fig.1. Distribution of the patient according to the ages

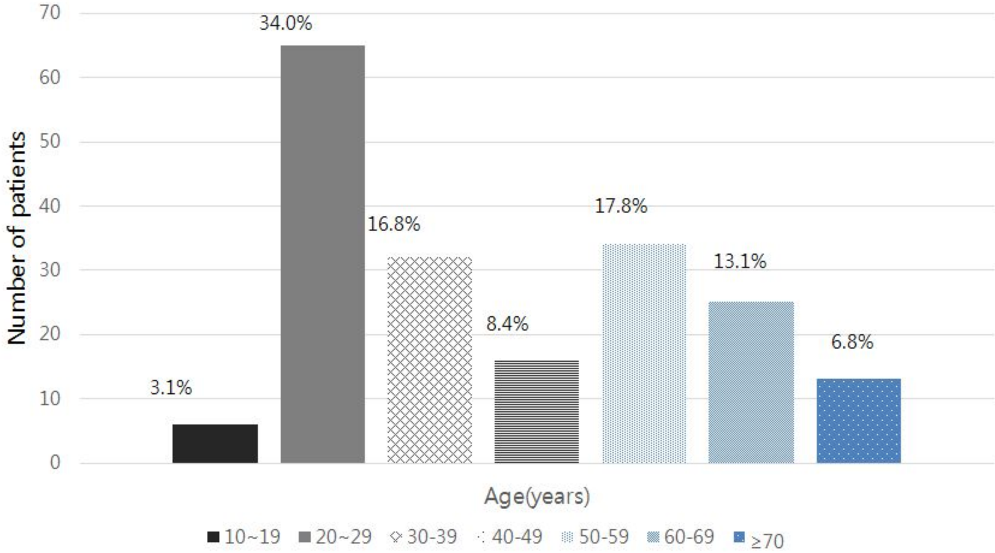


Table 1. Distribution of gender and age

| Variable | Value |
|---|---|
| Age(y) | 41.4±17.7 |
| Gender | |
| Male | 38 (19.9%) |
| Female | 153 (80.1%) |
| Total | 191 (100.0%) |

Values are presented as mean±standard deviation or number (%).

Table 2. Correlation between the patient's gender, age, clinical symptoms, and radiographic bone change

| | p-value | | | | | |
|---|---|---|---|---|---|---|
| | Gender | Age | AMO | Change in occlusion | Pain during mastication | Pain during mouth opening |
| Panoramic | 0.180 | 0.145 | 0.263 | 0.713 | 0.242 | 0.610 |
| Transcranial | 0.229 | 0.201 | 0.232 | 0.615 | 0.273 | 0.736 |
| CBCT | 0.343 | 0.565 | 0.140 | 0.596 | 0.175 | 0.471 |

P values higher than 0.05 indicate no statistically significant difference at the 95% confidence level.
(p-value by linear by linear association and chi-square test.)
CBCT, cone beam computed tomography; AMO, active mouth opening range.

Table 3. Pain pattern according to type of joint sound

| | Variable | Total, N(%) | Pain during mastication, N(%) | | p-value | Pain during mouth opening, N(%) | | p-value |
|---|---|---|---|---|---|---|---|---|
| | | | No | Yes | | No | Yes | |
| Joint sound | None | 11 (5.8%) | 0 (0.0%) | 11 (5.8%) | 0.037* | 2 (1.0%) | 9 (4.7%) | 0.344 |
| | Exist | 180 (94.2%) | 59 (30.9%) | 121 (63.4%) | | 61 (31.9%) | 119 (62.3%) | |
| | Total | 191 (100.0%) | 59 (30.9%) | 132 (69.1%) | | 63 (33.0%) | 128 (67.0%) | |
| Crepitus | None | 57 (29.8%) | 18 (9.4%) | 39 (20.4%) | 0.757 | 26 (13.6%) | 31 (16.2%) | 0.053 |
| | Unilateral | 85 (44.5%) | 24 (12.6%) | 61 (31.9%) | | 23 (12.0%) | 62 (32.5%) | |
| | Bilateral | 49 (25.7%) | 17 (8.9%) | 32 (16.8%) | | 14 (7.3%) | 35 (18.3%) | |
| | Total | 191 (100.0%) | 59 (30.9%) | 132 (69.1%) | | 63 (33.0%) | 128 (67.0%) | |
| Click | None | 72 (37.7%) | 16 (8.4%) | 56 (29.3%) | 0.023* | 19 (9.9%) | 53 (27.7%) | 0.080 |
| | Unilateral | 71 (37.2%) | 23 (12.0%) | 48 (25.1%) | | 24 (12.6%) | 47 (24.6%) | |
| | Bilateral | 48 (25.1%) | 20 (10.5%) | 28 (14.7%) | | 20 (10.5%) | 28 (14.7%) | |
| | Total | 191 (100.0%) | 59 (30.9%) | 132 (69.1%) | | 63 (33.0%) | 128 (67.0%) | |
| Popping | None | 176 (92.1%) | 54 (28.3%) | 122 (63.9%) | 1.000 | 57 (29.8%) | 119 (62.3%) | 1.000 |
| | Unilateral | 9 (4.7%) | 4 (2.1%) | 5 (2.6%) | | 5 (2.6%) | 4 (2.1%) | |
| | Bilateral | 6 (3.1%) | 1 (0.5%) | 5 (2.6%) | | 1 (0.5%) | 5 (2.6%) | |
| | Total | 191 (100.0%) | 59 (30.9%) | 132 (69.1%) | | 63 (33.0%) | 128 (67.0%) | |

N, number of patients.
*, $p<0.05$ (p-value by linear by linear association.)

Table 4. Correlation between type of joint sound and active mouth opening range

| | Variable | total, N(%) | AMO, mean±SD (mm) | AMO (mm) | | | p-value |
|---|---|---|---|---|---|---|---|
| | | | | below 30, N(%) | 30~40, N(%) | over 40, N(%) | |
| Joint sound | None | 11 (5.8%) | 32.8±9.0 | 4 (2.1%) | 4 (2.1%) | 3 (1.6%) | 0.006* |
| | Exist | 180 (94.2%) | 41.2±8.5 | 14 (7.3%) | 50 (26.2%) | 116 (60.7%) | |
| | Total | 191 (100.0%) | | 18 (9.4%) | 54 (28.3%) | 119 (62.3%) | |
| Crepitus | None | 57 (29.8%) | 38.9±10.2 | 10 (5.2%) | 21 (11.0%) | 26 (13.6%) | 0.002* |
| | Unilateral | 85 (44.5%) | 41.2±8.4 | 6 (3.1%) | 21 (11.0%) | 58 (30.4%) | |
| | Bilateral | 49 (25.7%) | 42.1±7.1 | 2 (1.0%) | 12 (6.3%) | 35 (18.3%) | |
| | Total | 191 (100.0%) | | 18 (9.4%) | 54 (28.3%) | 119 (62.3%) | |
| Click | None | 72 (37.7%) | 39.6±8.0 | 8 (4.2%) | 21 (11.0%) | 43 (22.5%) | 0.284 |
| | Unilateral | 71 (37.2%) | 41.1±9.8 | 8 (4.2%) | 19 (9.9%) | 44 (23.0%) | |
| | Bilateral | 48 (25.1%) | 42.0±7.9 | 2 (1.0%) | 14 (7.3%) | 32 (16.8%) | |
| | Total | 191 (100.0%) | | 18 (9.4%) | 54 (28.3%) | 119 (62.3%) | |
| Popping | None | 176 (92.1%) | 40.9±8.7 | 16 (8.4%) | 49 (25.7%) | 111 (58.1%) | 0.264 |
| | Unilateral | 9 (4.7%) | 42.0±7.7 | 0 (0.0%) | 4 (2.1%) | 5 (2.6%) | |
| | Bilateral | 6 3.1(%) | 35.2±9.2 | 2 (1.0%) | 1 (0.5%) | 3 (1.6%) | |
| | Total | 191 (100.0%) | | 18 (9.4%) | 54 (28.3%) | 119 (62.3%) | |

N, number of patients; AMO, active mouth opening range.
*, $p<0.05$ (p-value by linear by linear association and fisher's exact test.)

Table 5. Bone change findings for each radiography

| | Panoramic, N(%) | Transcranial, N(%) | CBCT, N(%) |
|---|---|---|---|
| None | 28(14.7%) | 29(15.2%) | 14(7.3%) |
| Unilateral side | 97(50.8%) | 96(50.3%) | 110(57.6%) |
| Bilateral side | 66(34.6%) | 66(34.6%) | 67(35.1%) |

N, number of patients; CBCT, cone beam computed tomography.

Table 6. Correlation of radiographic bone change pattern according to type of joint sound

| | Type of radiography | kappa(κ) | p-value |
|---|---|---|---|
| None | Panoramic | 1.000 | 0.001* |
| | Transcranial | 1.000 | 0.001* |
| | CBCT | 0.340 | 0.013* |
| Crepitus | Panoramic | 0.715 | 0.000** |
| | Transcranial | 0.715 | 0.000** |
| | CBCT | 0.690 | 0.000** |
| Click | Panoramic | 0.540 | 0.000** |
| | Transcranial | 0.533 | 0.000** |
| | CBCT | 0.521 | 0.000** |
| Popping | Panoramic | 0.055 | 0.000** |
| | Transcranial | 0.056 | 0.000** |
| | CBCT | 0.065 | 0.000** |

CBCT, cone beam computed tomography.
**, $p<0.001$ (p-value by cohen's kappa analysis.)
*, $p<0.05$ (p-value by cohen's kappa analysis.)

Table 7. Agreement of bone change findings for each radiography

| | kappa(κ) | p-value |
|---|---|---|
| Panoramic/Transcranial | 0.971 | 0.000** |
| Panoramic/CBCT | 0.884 | 0.000** |
| CBCT/Transcranial | 0.870 | 0.000** |

**, $p<0.001$ (p-value by cohen's kappa analysis.)

# IV. Discussion

Osteoarthritis of the TMJ is degenerative disease that causes destruction of joint tissues of the condyle and articular fossa due to increased load and stimulation [16]. It is defined by the gradual decrease of the articular cartilage related to subchondral bone hypertrophy, and the bone undergoes reactive hyperplasia that forms peripheral osteophytes [17]. The symptoms of TMJ OA include pain on palpation, functional pain, joint sound, masticatory muscle pain, and mandibular movement limitation, and the pain tend to increase in the afternoon.[18] And grinding and crepitus are common [19]. especially for joint sounds, accompanied with or without clicking [20]. In cases of severe bone loss, the strong contact between molars can create a fulcrum effect, causing the rotation of the mandible and induce anterior open bite [21]. Early stages of osteoarthritis is clinically and radiographically difficult to differentially diagnose with other TMD symptoms and in late stages of osteoarthritis, ankylosis or joint instability can occur and an increased bone change pattern are observed on the radiographs [22].

In general, bone change increases as people grow older [23], but the results of this study showed that there was no significant difference in the correlation between age and radiographic bone change, and the disease was most commonly found in the 20s (Fig.1). The reason for the low incidence rate of TMJ OA in the elderly is related not only to the aging of TMJ but also to the functional aspect. Based on various study results, regenerative changes of the TMJ can occur at young ages which tells us that the pathophysiological aspects of the TMJ is different from other joints [24]. In other words, the biochemical reaction of TMJ against load is similar to other joints, but for TMJ, the way it acts against functional loading is different from other joints since TMJ has fibrocartilages on the articular surface, and it can voluntarily slide out of the fossa, as well as both joints function as one unit [25]. Also, in this study, as there were more female patients than male patients (153 females, 38 males), the reason behind the higher incidence rate of TMJ OA in females could be the effect of sex hormones, difference in pain perception, responses to stress, and psychological factors [3].

Because of the various clinical symptoms of TMJ OA, many studies have been conducted to evaluate the relevance between the symptoms and osteoarthritis, but the results are still in debate. According to the study by Wiese et al. [26], the correlation between pain and bone change pattern observed from TMJ tomography was uncertain. And there was no statistical significance in the relevance of TMJ OA and clinical symptoms such as joint sound (clicking, crepitus), tenderness on palpation, and mouth opening range [27]. Whereas, another study reported the relationship between TMJ pain and bone change patterns of osteoarthritis [28]. Bagge et al. [29] reported that moderate to severe radiographic bone change of TMJ OA was observed even from asymptomatic patients. This study included patients without any bone change observed from radiographs if they were diagnosed with TMJ OA based on clinical examination. There was no statistical significance from the analytical results of the correlation between mouth opening range and radiographic bone change using linear by linear association (Table 2). Also, the analytical results of each correlation between the change in occlusion, pain during mouth opening, pain during mastication, and radiographic bone change using chi-square test was not statistically significant (Table 2). However, the relevance between clinical symptoms and the development of osteoarthritis is still in debate, and it is important to note that TMJ OA is possible to develop on patients even though the related clinical symptoms are not observed.

Based on the analytical results of joint sounds and pain patterns (Table 3), the group with joint sounds showed an increased pain during mastication than the group without joint sounds (p=0.037). Also, the group with clicking showed an increased pain during mastication than the group without clicking, and the group with bilateral clicking showed a statistically significant increase in pain during mastication than the group with unilateral clicking (p=0.023). However, the patients selected in this study are limited to those who visited the dental hospital rather than random selection, thus, more research needs to be conducted with general persons. Moreover, additional research on the pain area, cause and pattern of pain may be needed.

Meanwhile, an interesting result was drawn from this study for joint sounds and active mouth opening range (Table 4). The active mouth opening range was converted to a nominal variable divided into three groups (below 30mm, 30~40mm, over 40mm), and then fisher's exact test was conducted by dividing it into a group without joint sounds and a group with at least one joint sound out of the three (crepitus, clicking, popping). The results showed a statistically significant increase in active mouth opening range for the group with joint sounds ($p=0.006$). Also, from the analytical results by linear by linear association, patients with crepitus showed a higher AMO than patients without crepitus (38.9±10.2mm), and the group with bilateral crepitus (42.1±7.1mm) had a higher AMO than the group with unilateral crepitus (41.2±8.4mm) ($p<0.05$). In other words, an increase in mouth opening range was observed as the developmental pattern of crepitus increases. This observation may be affected by the inclusion of patients accompanied by disc displacement without reduction in TMJ OA patients without joint sounds. And the presence of crepitus is thought to be a result of the possible sliding movement of the condyle.

According to the study by Gray et al. [30], TMJ OA occurs more commonly on one side than both sides. Also, for bilateral osteoarthritis, it is common for one side to manifest more severe symptoms than the other and that the length difference of the mandibular ramus or parafunctional habits such as unilateral mastication are related to this phenomenon [31]. These findings coincide with the study results, as bone change of the condyle was observed on both sides in 66 patients (34.6%) each from panoramic radiography and transcranial radiography, and in 67 patients (35.1%) from CBCT. Bone change on only one side of the condyle was observed in 97 patients (50.8%) from panoramic radiography, 96 patients (50.3%) from transcranial radiography, and 110 patients (57.6%) from CBCT, having more unilateral TMJ OA patients than bilateral

TMJ OA patients (Table 5).

The degeneration of the mandibular condyle can be divided into 4 classifications: sclerosis, erosion, flattening, and osteophyte, based on morphological change and cortical delineation. Sclerosis is commonly observed in early stages, while erosion or osteophyte formation is found in late stages. As this study only assessed the presence of bone change without classifying change patterns, further studies of a more subdivided evaluation of bone change patterns may be needed.

Crepitus is mentioned in various studies, while several studies report that crepitus has low sensitivity for diagnosis, other studies report that from the clinical symptoms such as pain on palpation, joint sound, subjective pain, only joint sound is related to the degenerative bone change of the condyle observed from radiographs (panoramic radiography, TMJ tomogram, transcranial radiography) [3]. Although the usefulness of crepitus for TMJ OA diagnosis is still in debate, according to the Diagnostic Criteria for Temporomandibular Disorders (DC/TMD), crepitus is an important criteria which is advised for definite diagnosis with CBCT [32]. While chronic osteoarthritis can be observed through T1- and T2-weighted magnetic resonance images (MRI) [33], according to the study by Kye et al. [34], there is a significant correlation between crepitus and osteophytes observed from MRI. Also, condyle-disc deformity can occur without pain, and crepitus is an important clinical symptom in condyle-disc degeneration. Joint sounds have been conventionally identified by using the practitioner's fingers or a stethoscope. Recently, many studies are conducted to measure joint sounds using various equipments, but the validity of error and interpretation is still in work, and the advantages are not attractive enough to be used in clinical practices [35]. From the analytical results of bone change patterns of the mandibular condyle observed from radiographs (panoramic radiography, transcranial radiography, CBCT), according to joint sounds, using Cohen's kappa analysis, a high correlation was shown from the group without joint sounds and from panoramic radiography and transcranial radiography. And the analytical results of the relevance of crepitus showed a high correlation with bone change observed from each of the three radiographs (Table 6). In this regard, crepitus is an important symptom and highly significant than other clinical symptoms in the correlation with bone change patterns observed from radiographs. However, since joint sound is inconsistent over time, varies among individuals, and has an unpredictable pattern, the incidence of joint sounds derived from epidemiologic research can be difficult to apply to an individual. Further research of comparing the patient's subjective symptoms and the objective symptoms measured by the practitioner may be needed.

Radiographic examination used for the diagnosis of osteoarthritis include panoramic radiography, transpharyngeal radiography, transcranial radiography, conventional tomography, CT, MRI, and CBCT. Panoramic radiography, commonly used in dentistry, can be used to observe bone change of TMJ, but 3-dimensional images such as CT or CBCT are thought to be more suitable for diagnosis due to the superimposition of anatomical structures, structural distortion [36], and the low reliability and sensitivty for bone change in panoramic radiography. CBCT is especially favored since it shows diagnostic efficiency similar to CT, and has better accessibility and lower radiation exposure than CT. Meanwhile, Barghan et al. [37] and Meng et al. [38] reported that transcranial radiography is not useful than panoramic radiography, transpharyngeal radiography, and CBCT. However, in this study, based on the analytical results by Cohen's kappa analysis of the agreement in bone change findings from 3 groups of paired radiographs (panoramic radiography/ transcranial radiography, panoramic radiography/ CBCT, transcranial radiography/ CBCT) (Table 7), all 3 groups showed high agreement. Thus, unlike previous studies, panoramic and transcranial radiography can also be useful in the observation of bone change patterns of the mandibular condyle. However, since the radiographic interpretations were decided through a simple discussion without considering inter-examiner reliability and intra-examiner reliability, further studies may be needed to compensate in this regard. Also, while panoramic radiography is useful to observe the medial surface of the condyle and transcranial radiography is useful to observe the lateral surface of the condyle, in this study, the agreement between the two radiographs was high (Table 7). This result may present the possibility that bone change of the mandibular condyle in some TMJ OA patients does not progress only on one side of the medial or lateral surface but comprehensively around the condyle. Thus, it may be more efficient to use both types of radiographs for the evaluation of TMJ OA.

As advised from RDC/TMD [39] and DC/TMD [32], CBCT is more useful and valuable for the diagnosis of bone change patterns. But this study presented significant results (Table 6,7) in the evaluation of the correlation with crepitus and bone change of osteoarthritis patients from panoramic radiography or transcranial projection. According to a study comparing the accuracy of TMJ observation with CBCT, panoramic radiography showed accuracy of 90.64% and transcranial projection showed accuracy of 86.97% [38]. Since most TMD patients do not scan CBCT for initial examination, panoramic radiography and transcranial projection may be helpful in the diagnosis of TMJ OA through careful observation. Also, panoramic radiography is significant from the fact that it projects the whole lower jaw in one image. And transcranial radiography has the advantage of showing the movement of the mandibular condyle along with the clear projection of cortical bone during maximum mouth opening without any superimposition of anatomical structures. Therefore, in terms of cost, practicality, and usefulness, one may reconsider of scanning CBCT as a must during initial examination for TMJ OA patients.

# V. Conclusion

Temporomandibular diseases have common clinical symptoms, making it difficult to simply diagnose osteoarthritis. Since TMJ OA can occur without any symptoms, history taking, clinical examination, and radiographic examination are required for differential diagnosis and treatment of TMJ OA. In the early stages of TMJ OA, it is possible that bone change is not observed on radiographs. Also, there can be cases of which bone change pattern is observed from radiographs, but is actually in a clinically stable state of arthrosis through the remodeling of bone. Therefore, patients should be diagnosed through comprehensive consideration of various test results. Especially, as seen from the study results, since crepitus shows a high correlation with radiographic bone change patterns, careful observation may be needed during clinical examination. Also, while CBCT is useful with its advantages compared to other radiographs, the results of this study presents that panoramic radiography and transcranial radiography show similar agreement to CBCT in terms of bone change findings of the mandibular condyle. Therefore, osteoarthritis findings should be carefully observed in panoramic radiography and transcranial radiography for the evaluation of bone change patterns.

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# 감사의 글

먼저 본 논문이 완성되기까지, 많이 부족한 저에게 아낌없는 격려와 지도를 해주신 안종모 교수님께 진심으로 감사드립니다. 또한 논문에 대한 지도와 심사 뿐 아니라 수련생활에 있어서도 큰 가르침을 주시는 윤창륙 교수님과 유지원 교수님께도 깊은 감사를 드립니다. 그리고 바쁘신 와중에도 저의 논문 심사를 맡아주시고 소중한 충고와 조언을 해주셨던 김흥중 교수님, 임현대 교수님께 진심으로 감사드립니다.

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