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Hounsfield Unit and Maximum Standardized Uptake Value of Temporomandibular Joint Osteoarthritis in SPECT/CT

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Hounsfield Unit and Maximum Standardized Uptake Value of Temporomandibular Joint Osteoarthritis in SPECT/CT

Directed by Professor Jong-Ki Huh, D.D.S., Ph. D.

A Master Thesis
Submitted to the Department of Dentistry
and the Graduate School of Yonsei University
in a partial fulfillment of the
requirements for the degree of
Master of Dental Science

Joon-Ho Jung

December 2022

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정준호의 석사 학위논문을 인준함

심사위원 ___허 종 기___ 인

심사위원 ___전 국 진___ 인

심사위원 ___김 재 영___ 인

연세대학교 대학원

2022 년 12 월 일

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감사의 글

석사과정 2학기와 본 학위논문을 마치기까지 저에게 도움을 주신 많은 분들께 짧은 지면을 빌려 감사의 말씀을 전하고자 합니다.

본 논문을 작성하며 처음부터 끝까지 부족한 저를 바쁘신 와중에도 지도해주신 허종기 교수님께 진심으로 감사드립니다. 교수님께서 보여주신 학자로서의 모습을 항상 깊이 존경하며 아낌없는 가르침을 주셔서 다시 한 번 감사드립니다. 또한 논문이 완성될 때까지 세심한 가르침과 조언으로 논문을 검토해주시고 이끌어 주신 김재영 교수님과 이 심사를 기꺼이 맡아 주신 전국진 교수님께도 깊은 감사의 말씀 올립니다. 더불어 구강악안면외과 수련의로서 임상 경험을 넓히고, 대학원생으로서 지식의 깊이를 더할 수 있도록 많은 가르침을 주신 연세대학교 치과대학 구강악안면외과학 교실의 모든 교수님들께도 감사의 말씀 올립니다.

그리고 함께 수련을 받으며 서로 힘이 되어주고, 즐거운 수련 생활을 할 수 있게 해주고, 바쁜 수련과정 중에도 본 연구에 있어 많은 도움을 준 동기 고지훈 선생과 의국 선, 후배님 들에게도 모두 감사의 말을 전합니다.

마지막으로 저에게 언제나 힘이 되어주는 아내 정보영 그리고 항상 응원해주시는 어머니 그리고 하늘에서 지켜보고 계실 아버지에게 감사와 사랑의 말씀을 전합니다.

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Abstract

Hounsfield Unit and Maximum Standardized Uptake Value of Temporomandibular Joint Osteoarthritis in SPECT/CT

Joon-Ho Jung

Department of Dentistry
The Graduate School, Yonsei University
(Directed by Professor Jong-Ki, Huh D.D.S., M.S.D., Ph.D.)

Temporomandibular joint (TMJ) is a synovial joint that performs the most complicated movement in the human body. TMJ osteoarthritis (OA) is an important subtype of temporomandibular disorders (TMD). Nowadays, computed tomography (CT) imaging is

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going to be useful diagnostic method for TMJ OA, because it has provided more detailed change of component of TMJ than conventional radiographic methods. Especially, Single-Photon Emission Computed Tomography/Computed Tomography (SPECT/CT), a hybrid imaging technique, represents the most recent advance in nuclear imaging for OA.

There are two quantitative methods to evaluate SPECT/CT. First, the Hounsfield unit (HU) is CT's relatively quantitative measurement of radio-density and provide quantitative assessment of bone density at the time of diagnosis and make it possible to evaluate quality of bone objectively. Second, standard uptake value (SUV) is rate of metabolic activity of the skeleton which is calculated by the rate of bone remodeling including bone resorption or new bone formation. The purpose of this retrospective study was to assess the bony change of TMJ OA patient's condyle using SPECT/CT with quantitative value such as HU and SUV and examine features of TMJ OA.

50 patients with unilateral TMJ OA were included. In SPECT/CT, SUV max and the HU was calculated and reported by department of nuclear medicine in Gangnam Severance Hospital. And the HU of condyle was analyzed through Centricity Dicom Viewer (GE Healthcare, Chicago, Illinois, United States). Patients were classified according to the period of their initial visit to clinic after TMJ OA related symptoms onset among their chief complaint in Electronic Medical Record (EMR) of Gangnam Severance Hospital. There were three stages, 'Short' (within 1 year), 'Intermediate' (between 1 year and 3 years) and 'Long' (over 3 years).

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SUV max of the condyle with OA was significantly greater the than the condyle without OA (P < 0.05). However, there was no significant difference of SUV max according to progression of TMJ OA. Both the cortical and medullary bone of the condyle with OA had tendency of lower HU than condyle without OA in the group ‘Short’ (p < 0.001). In contrast, the condyle affected by TMJ OA in the group ‘Intermediate’ and ‘Long’ showed tendency of higher HU (P < 0.001). As TMJ OA progressed, tendency of higher HU was observed (P < 0.05).

From this study, significant association between objective values (SUV max and HU) from SPECT/CT and TMJ OA was observed. First, SUV max from SPECT is useful to diagnose TMJ OA in patients who had changes in the structure of the condyle or patient’s symptom. Second, HU from CT may be useful to diagnose TMJ OA objectively and determine progression of TMJ OA.

Key word: SPECT CT, Temporomandibular joint, Osteoarthritis, Hounsfield unit, Standardized uptake value

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Hounsfield Unit and Maximum Standardized Uptake Value of Temporomandibular Joint Osteoarthritis in SPECT/CT

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I. INTRODUCTION

Temporomandibular joint (TMJ) is a synovial joint that performs the most complicated movement in the human body. TMJ differs from the other joints because a layer of

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fibrocartilage, and not hyaline cartilage, covers it. The bone of the mandibular condyle is located just beneath the fibro-cartilage, making it particularly vulnerable to inflammatory damage and a valuable model for studying arthritic bony changes. Therefore, TMJ osteoarthritis (OA) is one of the most common diseases of TMJ (L.H.S. Cevidanes et al., 2014). Patients with TMJ OA may complain of mouth opening limitation, jaw stiffness with pain, or progressively increasing anterior open bite. TMJ OA produces degenerative changes in the articular cartilage, bone marrow, fibrous connective tissue, and disc within the joint, resulting in joint deformity; the advanced stage is characterized by proliferation of new bony tissue at the margin of the joint surface, known as marginal osteophytes, lipping, or spurs (X.D. Wang et al., 2015).

Once TMJ develops degenerative osteoarthritic changes, various nonoperative and operative approaches can be taken to relieve the symptoms. These treatments include conservative therapy such as physical therapy, trigger point injections, medication, lifestyle modifications, fabrication of splints, arthrocentesis and surgery such as arthroplasty. However, current treatment modalities have limited patient satisfaction (Schiffman et al. 2014). Therefore, understanding the disease etiology is critical for the early detection and prevention of TMJ OA. But, the etiology of the majority of TMJ OA cases is unclear and multifactorial (X.D. Wang et al., 2015). Furthermore, no comprehensive research examined the closely associated factors of TMJ OA, especially the association between condylar bone quality and TMJ OA (Shi. J. et al., 2017).

Nowadays, Computed tomography (CT) is going to be useful diagnostic method for TMJ

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OA, because it has provided an advantageous view of osseous changes by allowing visualization of the bony structure in multiple dimensions with superior reliability and accuracy compared to panoramic radiographs and conventional tomography (Song H., et al., 2020). Among various types of CT, Single-Photon Emission Computed Tomography/Computed Tomography (SPECT/CT), a hybrid imaging technique, represents the most recent advance in nuclear imaging for OA (Bailey D. L. et al., 2013). Adding high resolution CT images to SPECT enables the accurate co-registration of nuclear signals with anatomical information. Therefore, more accurate identification of bone lesions with nuclear imaging has been realized (Kim J. et al. 2017). In addition, SPECT/CT offered quantitative value, Standard Uptake Value (SUV) max or mean from SPECT and the Hounsfield unit (HU) in bone or joint area from CT (Cachovan M. et al., 2013).

To date, several studies have analyzed the bony changes of TMJ using CT analyses (Boeddinghaus et al., 2013; Tsiklakis et al., 2014; Pahwa et al., 2015). Clinical evaluation of the condyle with TMJ OA coupled with appropriate radiographic interpretation with quantitative value would be critical for the accurate diagnosis of TMJ OA and meaningful in early detection of TMJ OA. Nevertheless, few studies have explored the association between condylar bone quantification and TMJ OA (Shi. J. et al., 2017).

There was study which reported that in the early stage of TMJ OA, plain radiography or CT might show degenerative change of condyle such as erosion or resorption and in the advanced stages, radiography might reveal osteophyte formation or condylar sclerosis,

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condylar sclerosis, suggestive of dysfunctional change (Shi. J. et al., 2017). Based on the previous studies, the authors established two hypotheses. First, HU would decrease due to active bone metabolism, such as bone erosion or resorption in initial TMJ OA and as TMJ OA progressed, HU would increase due to bone remodeling such as osteosclerosis, osteophyte formation, etc. Second, SUV would initially increase due to active bone metabolism and decrease as TMJ OA progressed because of weakened bone metabolism.

The purpose of this study was to evaluate the diagnostic effectiveness of the quantitative parameter HU and SUV on SPECT/CT for the evaluation of TMJ OA with different duration.

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II. PATIENTS AND METHODS

1. Patient selection

This retrospective study was conducted after receiving approval from Gangnam Severance Hospital's institutional review board (IRB No.: 3-2022-0570), the need for informed consent was waived. All procedures were conducted in accordance with the Helsinki Declaration of 1975 (2000 revision).

From January 2018 to August 2022, the patients who visited the Department of Oral and Maxillofacial Surgery at Gangnam Severance Dental Hospital with suspected TMJ OA which showed actual bony change (ex. erosion, resorption, flattening, osteophyte, etc.) of the condyle with mouth opening limitation or TMJ pain, etc. and underwent SPECT/CT using technetium-99m (TC-99m) hydroxy-methylene diphosphonate (HDP) were selected for study. SPECT/CT were acquired by SPECT/CT scanner, NM/CT670 (GE Healthcare, Pittsburgh, United States).

Inclusion criteria were patients with unilateral increased bone uptake sign in SPECT/CT and who complained symptoms of TMJ OA and showed actual bony change in unilateral condyle. Exclusion criteria were patients whose age was under 18 or over 80 years, who showed morphologic change of bilateral condyles, had history of trauma or surgery on oro-maxillofacial (ex. fracture, orthognathic surgery, plastic surgery, etc.), radiation therapy on head and neck area or past medical history of rheumatoid arthritis or osteoporosis. Patients

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were classified according to the period of their initial visit to clinic after TMJ OA related symptoms onset among their chief complaint in Electronic Medical Record (EMR) of Gangnam Severance Hospital. There were three stages, ‘Short’ (within 1 year), ‘Intermediate’ (between 1 year and 3 years) and ‘Long’ (over 3 years).

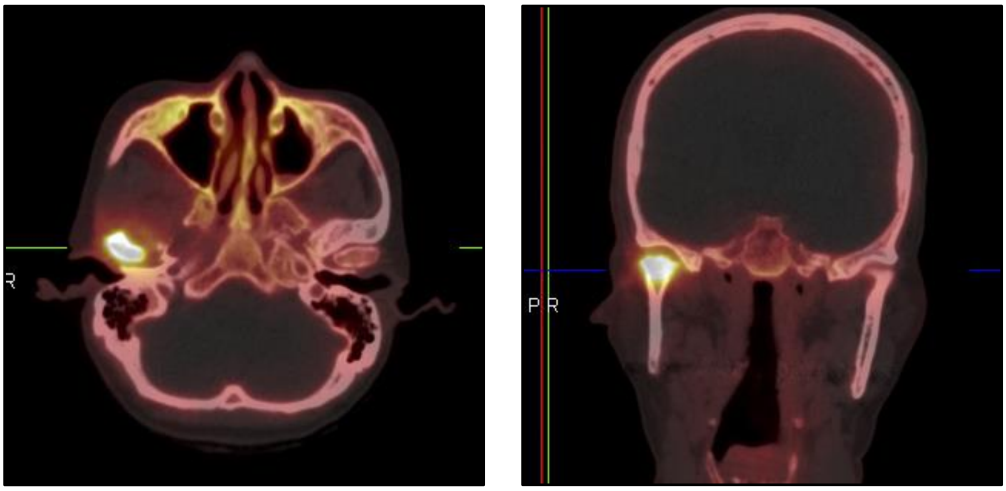

Figure 1. Increased bone uptake of the unilateral condyle in bone scintigraphy

2. Measurement of SUV max

SUV max in SPECT/CT was calculated and reported by the specialist in the department of nuclear medicine in Gangnam Severance Hospital. SUV was calculated using the vendor-provided quantitative software (Q. Metrix; GE Healthcare). SUV calculation required information on the radioactivity before injection and measurement time, the residual radioactivity post-injection and measurement time, the time of injection, body weight, and system sensitivity (10,176 counts/s/mCi). SPECT/CT images were displayed

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on a dedicated workstation (Xeleris 3.1; GE Healthcare) using the quantitative software. Rectangular volumes of interest (VOIs) were drawn over the medial, lateral, and patellofemoral compartments. Intercondylar eminences were excluded from the analyses. SUV max was calculated (with a voxel volume of 3.2×10^{-3} ml), as follows:

$$\text{SUV max} = \frac{Maximum\ radioactivity/Voxel\ volume}{Injected\ radioactivity/Body\ weight}$$

3. Measurement of HU

The HU of condyle in SPECT/CT was analyzed through Centricity Dicom Viewer (GE Healthcare, Chicago, Illinois, United States). All HU were measured with ROI tool on the coronal view where the largest condyle was selected. First, we set up region of interest (ROI) of the condyle ('Cortical + Medulla') from the top point to the condylar neck which was defined as the narrowest portion of the condylar process (Shi. J. et al., 2017) (Figure 2). In addition, we measured the cortical bone ('Cortical') and medullary bone ('Medulla') of bilateral condyle, respectively (Figure 3). The HU was automatically calculated by Centricity Dicom Viewer. For more accurate measurement, the HU of the condyles was measured twice and the interval between 1st measurement and 2nd measurement was 1week.

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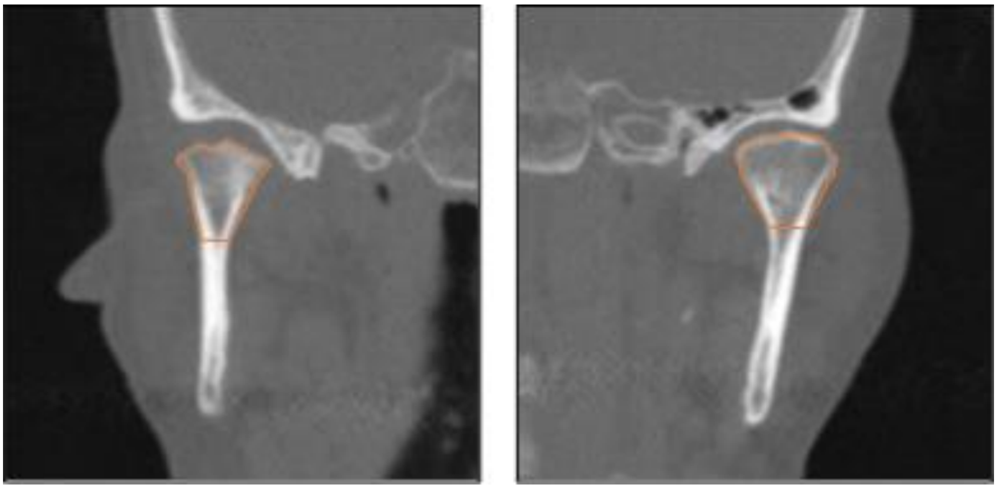

Figure 2. ROI of the condyle on coronal section of SPECT/CT

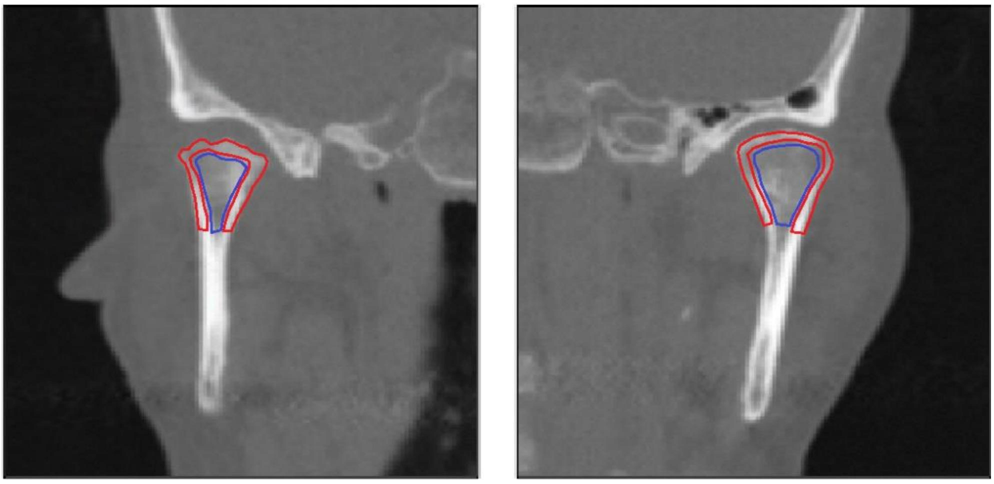

Figure 3. ROI of cortical (red line) and medullary (blue line) bone of the condyle on coronal section of SPECT/CT

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4. Evaluation of the bone pattern

In addition, to identify the association between the duration of TMJ OA and the aspect of bony change, the bone pattern of the condyle with OA was evaluated. The bone pattern was analyzed by one researcher and classified into 'Erosion', 'Resorption', 'Osteosclerosis', 'Osteophyte', 'Subchondral bone cyst' and 'Fibrous ankylosis'. (Figure 4)

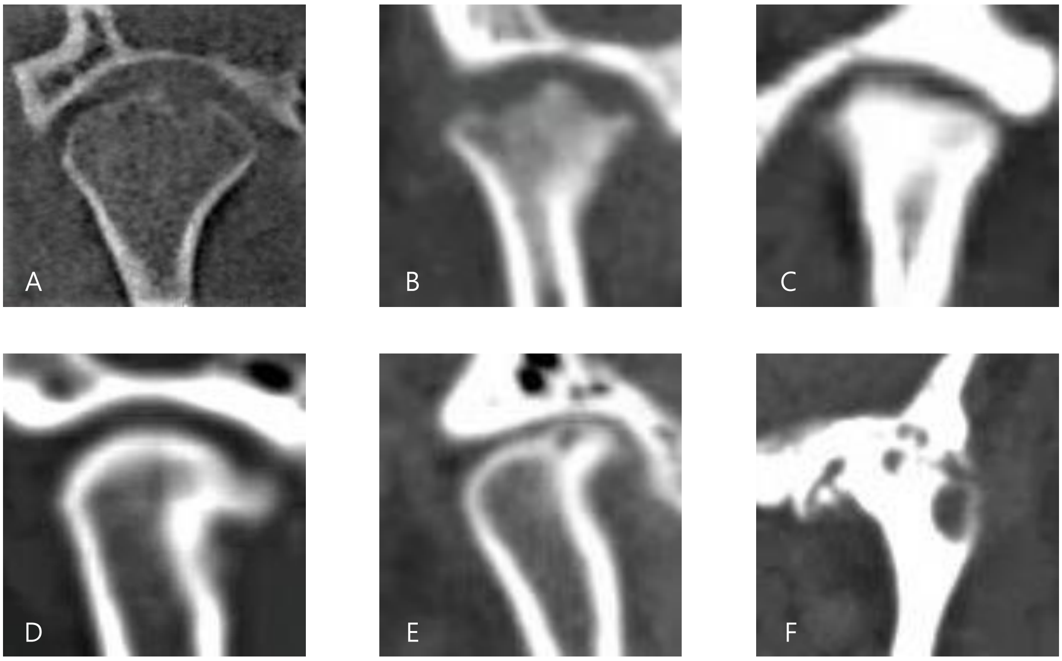

Figure 4. Bone pattern of the condyle with OA. A. Erosion. B. Resorption. C. Osteosclerosis. D. Osteophyte. E. Subchondral bone cyst. F. Fibrous ankylosis.

'Erosion' was peri-inflammatory destructive bone lesion that radiologically refers to a break in cortical bone with destruction of the natural barrier between the extra-skeletal tissue and the bone marrow compartment (Schett. et al., 2012). 'Resorption' was lysis of bone and appeared radiographically as radiolucency which was result in changes in bone

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contour (Mair, et al. 2013). ‘Osteosclerosis’ was thickening of trabecular (spongy, cancellous) bone (Goldman, et al. 2019). ‘Osteophyte’ was fibrocartilage-capped bony outgrowth (Wong, S. H. J., et al. 2016.). ‘Subchondral bone cyst’ was isolated round or irregular shaped cavity within the subchondral bone with or without connection with the joint space encased by subchondral bone sclerosis (Gao, L, et al., 2020). ‘Fibrous ankylosis’ was fibrous and osseous adhesions between the articular surfaces combined with severe mouth opening limitation (Brennan, P., et al. 2016).

5. Statistical analysis

SPSS 25.0 (SPSS INC., Chicago, IL., USA) was used to perform statistical analysis. Intraclass correlation coefficient analysis was performed to confirm the agreement of the ROI setting and Measurement of HU at the 2 time points. Kolmogorov-Smirnov test and Shapiro-Wilk test were done to approve a normal distribution in data of HU and SUV max. The differences of SUV max and the HU between condyle with OA without respectively by paired T-test. Lastly, the difference of SUV max and the HU at 3 stages (‘Short’, ‘Intermediate’, ‘Long’) were evaluated by one way ANOVA test. P value less than 0.05 was considered to indicate a significant difference.

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III. RESULTS

From January 1, 2018 to August 31, 2022, a total of 125 patients with suspected TMJ OA had SPECT/CT. 50 patients meet the inclusion criteria for study and 75 patients were excluded. 4 (8.0%) patients were male and 46 (92.0%) patients were female. The age distribution was ranged from 22 – 79 years, and the average age was 49.5 ± 17.1 years. 17 patients belonged to 'Short', 17 patients belonged to 'Intermediate' and 16 patients belonged to 'Long'. (Table 1)

Table 1. Demographic data of the patients

	Short	Intermediate	Long	Total
Male	0 (0.0%)	2 (11.8%)	2 (12.5%)	4 (8.0%)
Female	17 (75.0%)	15 (88.2%)	14 (87.5%)	46 (92.0%)
Age (years)	48.9 ± 14.5	43.3 ± 16.6	55.9 ± 17.4	49.5 ± 17.1

1. Maximum Standardized Uptake Value (SUV Max)

Data of SUV max was approved to follow a normal distribution by Kolmogorov-Smirnov test and Shapiro-Wilk test. The condyles with OA showed increased bone uptake sign on SPECT/CT in all patients. SUV max of the condyle with OA was significantly greater the than the condyle without OA in all stage ($P < 0.05$). There was tendency that SUV max of condyle with or without OA decreased as TMJ OA progressed, but it was not

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statistically significant. (Table 2) (Figure 5)

Table 2. Comparison of SUV max between the condyle with and without OA

	n	OA	Non OA	P value*
Short	17	8.89 ± 3.56	4.31 ± 1.84	< 0.001
Intermediate	17	8.40 ± 3.42	3.52 ± 0.90	< 0.001
Long	16	7.31 ± 3.36	3.19 ± 0.51	< 0.001
P value**		0.471	0.084	
Total	50	8.20 ± 3.51	3.67 ± 1.29	< 0.001

*Paired t-test was done. **one-way ANOVA test was done. Abbreviations: OA, osteoarthritis

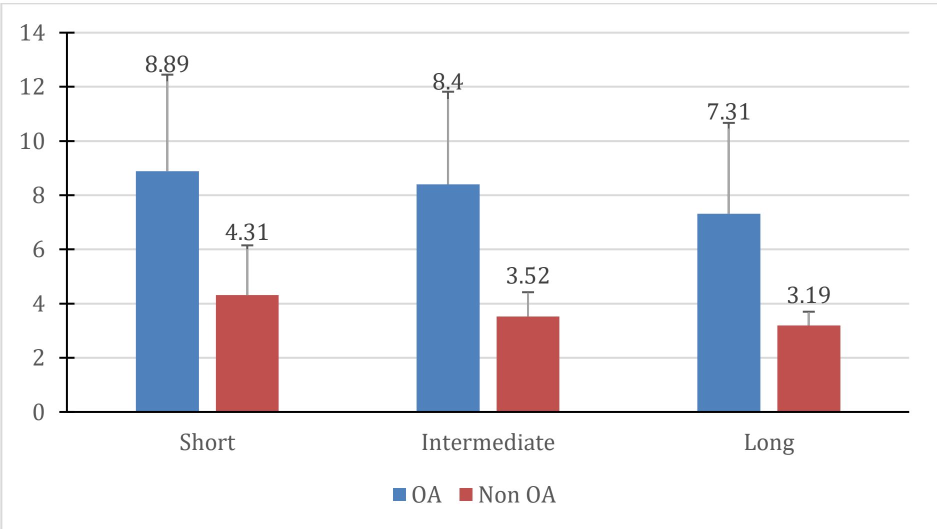

Figure 5. SUV max of the condyle

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2. Hounsfield Unit (HU)

Measurement of HU were not statistically different between first trial of HU measurement (T1) and second trial (T2). The intraclass correlation coefficient was over 0.990 for all variables (Table 3).

Table 3. Interclass correlation coefficient of measurement of HU

		1st measurement	2nd measurement	ICC (95% CI)
Cor	OA	901.01 ± 177.62	906.57 ± 179.07	0.998 (0.996 – 0.999)
	Non OA	815.78 ± 160.67	817.62 ± 158.22	> 0.999
Med	OA	533.84 ± 238.92	538.69 ± 239.03	0.997 (0.995 – 0.998)
	Non OA	394.64 ± 157.20	394.06 ± 156.12	0.994 (0.990 – 0.997)
Cor + Med	OA	720.74 ± 208.61	720.90 ± 209.87	> 0.999
	Non OA	607.96 ± 176.49	607.04 ± 176.77	0.999 (0.999-1.000)

Abbreviations: OA, osteoarthritis; Cor, cortical; Med, medulla

Data of HU was approved to follow a normal distribution by Kolmogorov-Smirnov test and Shapiro-Wilk test. The cortical bone of condyle with OA (787.15 ± 145.03) had tendency of lower HU than the cortical bone of condyle without OA (910.09 ± 163.82) in stage 'Short'. In contrast, the condyle with OA in stage 'Intermediate' (931.62 ± 187.04) and 'Long' (989.84 ± 135.13) showed tendency of higher HU compared to the condyle without OA('Intermediate' 737.56 ± 135.68, 'Long' 804.50 ± 123.78). From the point of view of the medullary bone of the condyle, the same results were observed as in the aspect

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of the cortical bone except 1 case in stage 'Short'. Also, the HU of total condyle ('Cortical + Medulla') showed similar tendency according to stages. (Table 3)

Table 4. The HU of condyle in 'Cortical', 'Medulla' and 'Cortical + Medulla'

	n	Cor			Med			Cor + Med		
		OA	Non OA	P value*	OA	Non OA	P value*	OA	Non OA	P value*
Short	17	787.15 ± 145.03	910.09 ± 163.82	< 0.001	382.76 ± 141.82	397.76 ± 151.65	< 0.001	564.23 ± 146.45	645.94 ± 167.92	0.002
Intermediate	17	931.62[a] ± 187.04	737.56[a] ± 135.68	< 0.001	594.13[a] ± 232.41	368.26[a] ± 146.27	< 0.001	779.63[a] ± 228.56	598.51[a] ± 195.16	0.002
Long	16	989.84[a] ± 135.13	804.50[a] ± 123.78	< 0.001	632.49[a] ± 236.68	412.56[a] ± 162.06	< 0.001	794.98[a] ± 191.83	606.03[a] ± 136.36	0.004
P Value**		0.002	0.068		0.004	0.799		0.001	0.089	

*Paired t-test was done. ** one-way ANOVA test was done. a: Compared with 'Short' ($p < 0.05$)
Abbreviations: OA, osteoarthritis; Cor, cortical; Med, medulla

As there were large variations in the HU of the condyle between patients, subtraction values of HU were used. As TMJ OA progressed 'Short' to 'Long', tendency that subtraction value of HU progressed from positive value to negative value was observed. (Table 4) (Figure 5) There was a statistically significant difference in subtraction value of HU in 'Cortical', 'Medulla' and 'Cortical + Medulla' according to progress of TMJ OA. (Table 5)

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Table 5. Subtraction value of HU between the condyle with OA and without OA in 'Cortical', 'Medulla' and 'Cortical + Medulla'

	n	Cor	Med	Cor + Med
Short	17	122.95 ± 83.24	15.00 ± 126.10	81.61 ± 73.28
Intermediate	17	-194.07[a] ± 101.42	-225.87[a] ± 223.88	-181.11[a] ± 154.68
Long	16	-206.31[a] ± 120.87	-261.59[a] ± 210.27	-192.63[a] ± 190.39
P value		0.003	< 0.001	0.001

One-way ANOVA test was done. a: Compared with 'Short' ($p < 0.05$). Abbreviations: OA, osteoarthritis; Cor, cortical; Med, medulla

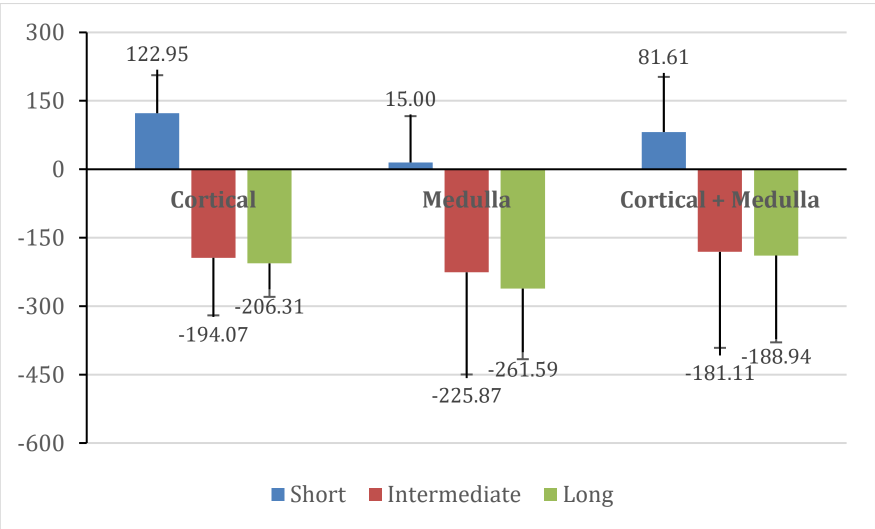

Figure 6. Subtraction value of the HU between the condyle with OA and without OA

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3. Bone pattern

Erosion and resorption of the condyle with OA were significantly appeared only in stage 'Short', 10 cases and 7 cases respectively. There was no bone remodleing reaction such as osteosclerosis, osteophye, etc. in stage 'Short'. The frequency of osteosclerosis, osteophyte, subchondral bone cyst and fibrous ankylosis of the condyle with OA was 15, 2, 1 and 1 respectively in stage 'Intermediate'. Lastly, in stage 'Long', 8 osteosclerosis, 5 osteophyte, 2 subchondral bone cyst and 1 fibro-ankylosis were observed. (Table 6)

Table 6. Bone pattern of the condyle with OA according to the stage

	Short	Intermediate	Long
Erosion	10	0	0
Resorption	7	0	0
Osteosclerosis	0	15	8
Osteophyte	0	2	5
Subchondral bone cyst	0	1	2
Fibrous ankylosis	0	1	1
Total	17	17	16

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IV. DISCUSSION

TMJ OA is the disease of the bone, cartilage, and supporting tissues of the TMJ and results from both mechanical and biological events that destabilize the normal coupling of the degradation and synthesis of the articular cartilage and subchondral bone (S. cömmert Kilic, et al. 2015). It causes not only focal degeneration of the joint cartilage, but also osseous erosion, sclerosis, flattening, and sometimes osteophyte formation occurring at the joint margins (Suh, M. S. et al. 2016).

In this study, we used SPECT/CT for quantitative evaluation of the condyle with TMJ OA, because SPECT/CT would provide more accurate information in that SPECT/CT could detect not only structural and quantitative change of bone in 3D image but also metabolic change of bone by evaluating the rate of metabolic activity of the bone with the use of radiopharmaceuticals (A. Coutinho, et al., 2005). Shi. J. et al. reported that according to duration of TMJ OA, there were changes in bone of condyle from erosion to bone remodeling such as osteosclerosis or osteophyte formation (Shi. J. et al., 2017). Unlike previous studies (Barghan et al. 2012; Dos Anjos Pontual et al. 2012), statistical quantification such as HU and SUV was used in place of visual diagnosis to achieve a more objective comparison for this study to investigate how objective values changed according to duration after TMJ OA symptom occurred. There are two reasons why those objective values were used in this study. First, the HU is CT’s relatively quantitative measurement of radio-density and calculated based on a linear transformation of the baseline linear

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attenuation coefficient of the x-ray beam. The HU can provide quantitative assessment of bone density at the time of diagnosis and make it possible to evaluate quality of bone objectively. Second, SUV is rate of metabolic activity of the skeleton which is calculated by concentration of radiopharmaceuticals in the bone depends on the local blood flow, vascular permeability, enzymatic action, amount of mineral component of the bone, and of immature collagen. This concentration is proportional to the rate of the rate of bone remodeling including bone resorption or new bone formation (A. Coutinho, et al. 2005). There were two values in SUV, max and mean. In this study, we used SUV max instead of SUV mean to evaluate condyles. Because there was result in other study about association between SPECT/CT and TMD that SUV max was highly correlated with visual analysis results of planar bone scintigraphy and arthralgic symptoms of TMD whereas SUV mean did not reach the level of SUV max in terms of detection of arthralgic TMJ and correlation with visual grading (Suh, M. S. et al. 2016).

The reason for classifying the stage of TMJ OA was to see the change of HU and SUV in condyles according to the duration after TMJ OA symptom occurred. In results, increased SUV max was significantly high in all TMJ OA affected condyles. In other study, there was similar result that SUV max was significantly greater in arthralgic TMJ than in non-arthralgic TMJ (Suh, M. S. et al. 2016). However, there was no significant difference according to duration after TMJ OA symptom occurred. These results suggested that the SUV max of the condyle from SPECT/CT is helpful in diagnosing TMJ OA, but it is difficult to determine how long TMJ OA has lasted. There was lower HU of the condyle

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with OA than condyle without OA in stage ‘Short’ and higher HU of condyle with OA in stage ‘Intermediate’ and ‘Long’. From the point of view in bone pattern, lower HU of condyle with OA in stage ‘Short’ was due to degenerative changes such as erosion and resorption and higher HU of condyle with OA in stage ‘Intermediate’ and ‘Long’ was due to remodeling of the condyle from inflammatory reaction. According to other study on osteoarthritis in the knee joint, subchondral sclerosis usually appears before any joint space narrowing is observed. In the normal joints, subchondral bone act as passive shock absorber and absorbs up to 50% of the load, and the cartilage absorbs only 1%~3%. In the osteoarthritic joint, sclerotic subchondral bone is able to absorb only about half the load as a normal knee does. Due to mechanical loading, subchondral bone sclerosis in the arthritic joint showed increased bone density than normal joint as OA progress (Angali J, et al. 2012). Other study reported that thickening of the cortex is presumably a response of the subchondral bone to a nonpathological level of pressure (Ko et al., 2013). Also, we can predict that tendency of increasing HU due to pathologic remodeling of condyle of progressed OA was the cause of severe fibrous ankylosis or osteophyte formation in advanced stage of TMJ OA.

According to results, SUV max could be used as predictable value to examine development and existence of TMJ OA, but it has limitations in determining the progression of TMJ OA. In order to compensate for such limitation of SUV max, quantitative assessment of the condyle’s bone density by HU could be used as assessment parameter for progression of TMJ OA. Therefore, HU and SUV max of condyle in

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SPECT/CT may be used together as a potential diagnostic tool for detecting TMJ OA. . In addition, results suggested that condylar bone loss is significantly correlated with the development of TMJ OA. Clinicians should inspect not only the joint but also the condylar bone structure when evaluating patients for TMJ OA, especially those presenting with TMD symptoms (Shi. J. et al., 2017). Even if there may be no notable changes in the bone, clinicians should bear in mind that low HU of condyle is associated with TMJ OA

Limitations of this study were that first, the classification of patients according to period was too patient-dependent and could be imprecise. This is because the degree to which patients feel pain is different, so even if they were affected by TMJ OA, they might not be aware of it and visited clinic after a while. Second, there was no follow-up SPECT/CT of TMJ OA patient. If there was follow up SPECT/CT, there could be much more accurate information about change of HU in TMJ OA condyle.

In further study, if the patients consent continuous follow up with SPECT/CT for periodic follow-up, it would be better to conduct research using follow-up data by observing the change of the HU and SUV on TMJ in SPECT/CT. If the circumstances allow, it would be good to conduct research on diagnosing TMJ OA by using Artificial Intelligence (AI) to identify not only structural change of the condyle but also change of the HU and SUV of the condyle on SPECT/CT.

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V. CONCLUSION

From this study, significant association between objective values (SUV max and HU) from SPECT/CT and TMJ OA was observed. First, SUV max from SPECT is useful to diagnose TMJ OA in patients who had changes in the structure of the condyle or TMJ OA symptom. Second, HU from CT may be useful to diagnose TMJ OA objectively and determine progression of TMJ OA.

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국문요약

단일 광자 방출 컴퓨터 전산화 단층촬영을 이용한 측두하악관절 골관절염의 하운스필드 단위 및 표준 흡수 계수율의 분석

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턱관절은 인체에서 가장 복잡한 움직임을 보이는 활액 관절이다. 턱관절 골관절염은 턱관절 질환에 있어 중요한 하위 유형 중 하나이다. 턱관절 골관절염에 이환된 환자는 턱관절 잡음, 통증을 동반한 턱관절 강직, 개구제한 혹은 점진적으로 진행되는 양상의 전치부 개방교합을 보인다. 그리고 방사선학적 소견으로는 초기

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관절염에서는 침습성 흡수 양상, 좀더 진행된 관절염에서는 골경화 혹은 골증식체 형성 등의 양상을 보인다. 오늘날 컴퓨터 전산화단층 촬영은 턱관절 골관절염을 진단하는데 유용한데, 이는 전통적인 방사선 영상들에 비해 턱관절 구성요소들에 대한 좀더 자세한 정보를 제공하기 때문이다.

단일 광자 방출 컴퓨터 전산화 단층촬영을 평가하는 단위에는 2 가지가 있다. 첫째, 하운스필드 단위는 컴퓨터 전산화 단층촬영의 방사선 밀도를 정량적으로 측정한 것으로 영상학적 진단시 골밀도를 정량적으로 평가하여 객관적인 골질 평가를 가능하게 한다. 둘째, 표준 흡수 계수율은 골의 대사 활성 정도로, 골흡수 또는 골형성을 포함한 골재형성의 비율로써 계산된다. 이 후향적 연구의 목적은 단일 광자 방출 컴퓨터 전산화 단층촬영 영상에서 하운스필드 단위 및 표준 흡수 계수율을 사용하여 턱관절 골관절염에 이환된 환자 하악 과두의 골 변화를 평가하고 과두의 골질과 턱관절 골관절염의 연관성을 수치적으로 조사하는 것이다.

편측 턱관절 골관절염에 이환된 50 명의 환자가 연구대상으로 포함되었다. 단일 광자 방출 컴퓨터 전산화 단층촬영 영상에서 표준 흡수 계수율은 강남세브란스병원 핵의학과에 의해 계산되어 기록되었다. 그리고 과두의 하운스필드 단위는 연구에서 설정한 관심 영역에 따라 센트리시티 다이콤 뷰어에서 측정되었다.

턱관절 골관절염에 이환된 과두의 최대 표준 흡수 계수율은 비이환측 과두에 비해 유의성있게 높은 것이 관찰되었다. 턱관절 골관절염에 이환된 과두의 피질골과

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수질골 그리고 피질골과 수질골을, 그룹_이른 시기 에서는 1 명의 환자를 제외하고 비이환측 과두에 비해 유의미하게 낮은 하운스필드 단위가 관찰되었다. 대조적으로, 그룹_진행된 단계 에 속한 턱관절 골관절염에 이환된 과두의 피질골과 수질골은 비이환측에 비해 유의미하게 높은 하운스필드 단위와 관찰되었다.

본 연구를 통해 하운스필드 단위 그리고 표준 흡수 계수율과 턱관절 골관절염의 진행 사이에는 유의미한 연관성이 있다는 것이 관찰되었다. 그러므로 단일 광자 방출 컴퓨터 전산화 단층촬영 영상의 하운스필드 단위와 표준 흡수 계수율을 분석하는 것은 턱관절 골관절염의 정확한 진단에 도움이 될 것으로 사료된다.

핵심되는 말 : 단일 광자 방출 컴퓨터 전산화 단층촬영, 하운스필드 단위, 표준 흡수 계수율, 턱관절, 골관절염