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The Prevalence and Severity of Incidental Temporomandibular Joint Osteoarthritic Changes in Implant Patients: A Cone Beam CT Study

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The Prevalence and Severity of Incidental Temporomandibular Joint Osteoarthritic Changes in Implant Patients: A Cone Beam CT Study

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بسم الله الرحمن الرحيم

وَقُلْ رَبِّ زِدْنِي عِلْماً

To mom and dad

To my best friend and the love of my life, Fadwa

To my son, Haitham

Acknowledgments

I am very grateful to the Almighty God for the good health, wellbeing, and all the blessings in my life that were necessary to complete this journey.

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Abstract

Osteoarthritis (OA) is one of the most common pathological conditions that affect the temporomandibular joints (TMJs). The diagnosis relies heavily on radiographic examination. Some of the osteoarthritic changes that can be seen in a TMJ affected by OA include flattening, sclerosis, osteophyte formation, erosion of the articular surfaces, subchondral cysts and reduction of the joint space. Cone beam CT (CBCT) is a useful tool for TMJ imaging since it provide 3D images with high spatial resolution and relatively low radiation dose compared to multi-detector CT.

The objective of this study is report the prevalence and severity of osteoarthritic changes incidentally observed in CBCT exams of patients referred for dental implant therapy. The criteria of the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) was used to determine if a TMJ has OA. The severity of the osteoarthritic changes was scored for each joint based on the method that was used by Alexiou et al.

Female subjects showed higher prevalence (almost 80% of females) of osteoarthritis compared to males. Condylar head flattening was the most common finding in our study (87%). Osteophyte formation and erosion were present in 57% and 41% of cases, respectively. Regarding subchondral cyst and condylar sclerosis and resorption, these changes were present in 8%, 12% and 7% of joints, respectively, and they were observed in subjects over the age of 40 years. Subchondral cyst, sclerosis, and the severity of osteophyte formation and erosion showed a statistically significant linear association with age. The mandibular fossa and articular eminence

showed a prevalence of 22% and 26% of erosion and sclerosis, respectively. Furthermore, there was a statistically significant correlation between age and sclerosis as well as erosion.

In conclusion, the results of this study are in accordance with previous studies about osteoarthritis of the temporomandibular joint in that osteoarthritis is more common in females and older individuals. In addition, the frequency and severity of the osteoarthritic changes observed in the TMJ increase with age.

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Introduction

The temporomandibular joint (TMJ) is a synovial joint where the mandible articulates with the temporal bone of the cranium. It is one of the most complex joints in the body.[1–4] It is considered a *ginglymoarthrodial* joint due to its ability to have hinging (ginglymoid) and gliding (arthrodial) movements. (Figure 1)

The part of the mandible that articulates with the cranium is the condyle. It has medial and lateral poles when viewed from the front. In the axial plane, a line connecting the medial a lateral pole will generally extend in the medioposterior direction toward the anterior margin of foramen magnum.[3] The condylar articular surface extends both anteriorly and posteriorly to the most superior aspect of the condyle and it is quite convex in the sagittal plane with slight convexity in the coronal plane.[3]

The mandibular condyle fits into a concavity at the squamous portion of the temporal bone. This concavity is called the mandibular, articular or glenoid fossa. Anterior to the glenoid fossa is a prominent convex dense bony ridge called the articular eminence. It is tilted down at approximately 25° to the occlusal plane and it forms most of the articular surface of the glenoid fossa.[1] It is convex anteroposteriorly and slightly concave mediolaterally. The lateral aspect of the articular eminence is the articular tubercle that provides attachment for the capsule and lateral temporomandibular ligament. The roof of the glenoid fossa is thin, indicating that this area of the joint is not a major load-bearing area.[1,3] The posterior wall is formed by the tympanic plate, which also forms the anterior wall of the external acoustic meatus.

The articular disk separates the mandibular condyle and the glenoid fossa from direct contact. It also divides the TMJ into the superior and inferior joint spaces, or compartments. Both spaces are filled with synovial fluid, which facilitates movement within the joint and also serves as a medium for the transportation of nutrients to and waste products from articular surfaces.[4] The articular portion of the disc is composed of avascular and aneural dense fibrous connective tissue. [2,4] On the other hand, peripheral areas of the disk are vascularized and innervated where the load-bearing is minimal.[2] Normally, the disk has biconcave configuration in the sagittal plane, with the anterior and posterior thicker parts of the disk, respectively, referred to as the anterior and posterior bands.[5] In the normal joint, the posterior band is located over the condyle, and the central thin zone is located between the condyle and the posterior part of the articular tubercle. The anterior band is located under the articular tubercle. In the coronal plane, the disk is crescent shaped.[5] The disk is attached to the condyle both medially and laterally by the collateral ligaments.[4] Anteriorly, it is attached to the joint capsule, and in the anteromedial portion of the joint the disk merges with the upper head of the lateral pterygoid muscle. Posteriorly, the disk is attached to the temporal bone and to the condyle by the posterior disk attachment. This attachment is called the retrodiscal tissue. It is also referred to as the bilaminar zone because initial histological studies suggested that the upper part was elastic tissue and the lower part consists more of connective tissue; however, more recent histologic studies have failed to confirm this.[5] Nonetheless, the term bilaminar zone is still being used both clinically and scientifically.

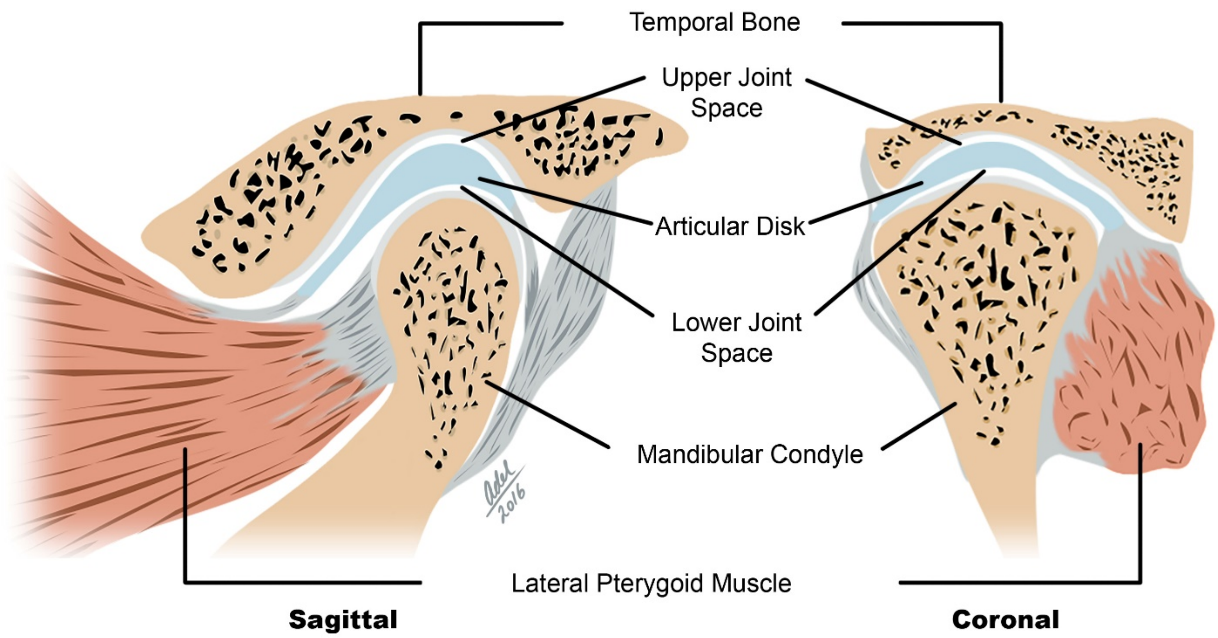

Figure 1: Important anatomical structures of the TMJ

The TMJ is unique because is the only load-bearing joint that is connected to its contralateral counterpart by a single bone, the mandible. Furthermore, unlike other synovial joints in the body, which have hyaline cartilage covering the articular surfaces, the TMJ articular surfaces are lined by fibrocartilage. Fibrocartilage has several advantages over hyaline cartilage. It has lower susceptibility to the effects of aging compared to hyaline cartilage and therefore it is more resistant to break down and degeneration over time. In addition, it has a greater repair capacity than hyaline cartilage.[1,3,6]

While it is probably impossible to measure the pressure developed on the articular surfaces of the human TMJ when biting; direct measurement of loads across the joint in animals has demonstrated significant intermittent loading during mastication.[1,7–9] Other experimental and

analytical studies, although they are all simulations performed on data from human cadavers, have shown that TMJ is a weight-bearing joint during masticatory function.[10–13]

Various terms have been used over the years to describe and identify functional disturbances of the masticatory system. Dr. Weldon E. Bell in the early 1980s suggested the term *temporomandibular disorders* (TMD) which became widely popular and was adopted by the American Dental Association.[14] It is an umbrella term that describes the musculoskeletal disorders affecting the masticatory system. Several epidemiologic studies have examined the prevalence of TMDs in given populations. These studies indicated that signs and symptoms of TMDs are quite common with an average of 41% of these populations reporting at least one symptom related to TMD and 56% showing at least one clinical sign.[15]

For years, there have been many classifications of TMDs. A recent taxonomic classification for TMD[16] developed by consensus by multiple dental and medical experts classifies the disorders into four broad categories: temporomandibular joint disorders, masticatory muscle disorders, headache disorders, and disorders affecting associated structures. One of the TMJ disorders is degenerative joint disease. According to the expanded taxonomy, it was divided into two subclasses: osteoarthritis and osteoarthrosis.[16] However, in the medical literature the terms osteoarthrosis and osteoarthritis are often used interchangeably, with osteoarthritis the more prevalent and common term.[17,18] Ahmad et al.[19] used the term osteoarthritis in developing comprehensive radiographic criteria for the Research Diagnostic Criteria For Temporomandibular Disorders (RDC/TMD) Validation Project. This could explain

why there was a significant discussion regarding the nomenclature among the participants in the expanded taxonomy.[16]

Osteoarthritis (OA) is the most common type of arthritis. It is estimated that among US adults, nearly 27 million have clinical osteoarthritis.[20] The incidence of OA increases with age and has a female preponderance.[21–23] Pain is reported in only 10% of the population.[22,23] Overloading of the joint articular surfaces is the most common etiologic factor for osteoarthritis.[24] While loading on of the joint surfaces is normal and important to maintain the health of the articular tissue by enabling the entrance of the nutrients into the cartilage cells and the exit of waste, there must be a balance between healthy loading and overloading. When there is too much load on the cartilaginous tissue, degradation of cells can occur over time. The proteoglycans and collagen responsible for maintaining the extracellular matrix will be disrupted due to overloading. Eventually, more load will be applied to the subarticular bone. Cytokines along with inflammatory mediators will invade the area, and an arthritic condition is going to develop.[24,25]

Clinical examination alone is not sufficient for diagnosing pathological conditions of the TMJ. In fact, radiographic examination is usually the decisive method for diagnosing TMJ pathology.[26–28] There are several osteoarthritic changes observed in the osseous components of the TMJ that can be detected in radiographic examination including flattening, sclerosis, osteophyte formation, erosion of the articular surfaces, subchondral cysts, and reduction of the joint space.[23,27–34]

Numerous imaging modalities including panoramic radiography, conventional tomography, arthrography, magnetic resonance imaging (MRI), and computed tomography (CT) have been used for the evaluation of the TMJ.[23,35–37] Since the introduction of cone beam CT (CBCT), it has been very useful for imaging bone components of the TMJ, mainly because it offers images with high spatial resolution and diagnostic accuracy of the TMJ hard tissues, comparable or superior to multi-detector CT (MDCT) but with lower radiation dose.[38,39]

The Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD), which is a widely used diagnostic system for TMD, was revised recently.[19] The authors developed comprehensive image analysis criteria for different imaging modalities, which can be used for OA assessment. After evaluating the TMJ hard tissues, the diagnosis can be one of the following: a) no osteoarthritis, b) indeterminate for osteoarthritis, or c) osteoarthritis. Though the RDC/TMD is a very reliable and comprehensive system for assessing OA, it does not offer scoring options for its severity. Other methods reported in the literature offer scales for severity of TMD changes but not specifically for OA.[40–42]

Since there is an increased demand for CBCT exams for various indications, clinicians, and more importantly oral and maxillofacial radiologists, must be familiar with osteoarthritic changes affecting the TMJ and the severity of these changes.

Hypothesis

CBCT can reliably detect and help in quantifying the severity of osteoarthritic changes associated with the TMJs.

Objectives

The purpose of this study is to retrospectively evaluate CBCT exams of patients referred for dental implant therapy to:

1- Assess the prevalence of osteoarthritis using the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) image analysis system.
2- Determine the prevalence and severity of incidental the osteoarthritic changes affecting the TMJ.

Materials and Methods

Sample Description and Study Design

This is a retrospective study of existing de-identified Cone Beam CT exams of 200 patients who were imaged for dental implant therapy between August 2011 and August 2015. All acquisitions were assigned a random study number prior to evaluation. The study protocol qualified for an exemption from the Institutional Review Board (IRB) at the University of Connecticut Health Center.

To be included in the study, at least one TMJ must be completely included and clearly visualized in the field of view. Exclusion criteria consisted of subjects with incomplete imaging of both TMJs, motion artifact, known history of TMJ or jaw trauma, TMJ surgery, condylar fracture, and systemic arthritis such as rheumatoid arthritis.

Fifty-five scans were excluded; 48 did not have either of the TMJs completely imaged in the field of view, and 7 scans had significant motion artifact. A total of 145 scans were included in the study. Ten scans included only the left TMJ, 19 showed only the right, and the remaining 116 had both TMJs clearly visualized. Each joint was evaluated separately in scans where both joints were included; meaning the total number of joints that were analyzed was 261. The age ranged from 17 years to 84 years and the mean age was 58.01 years. Ninety-one (62.76%) patients were females, with a mean age of 59.73 years, and 54 (37.24%) were males, with a mean age of 55.1 years. Table 1 and Table 2 show the distribution of gender and age, respectively.

Table 1: Gender distribution of patients

Gender	**Frequency**	**Percent**
Female	91	62.76
Male	54	37.24

Table 2: Sample age distribution

Age (years)	**10-19**	**20-29**	**30-39**	**40-49**	**50-59**	**60-69**	**70-79**	**80-89**	**Total**
Frequency	6	6	4	18	43	40	24	4	145
Percent	4.14	4.14	2.76	12.41	29.66	27.59	16.55	2.76	100

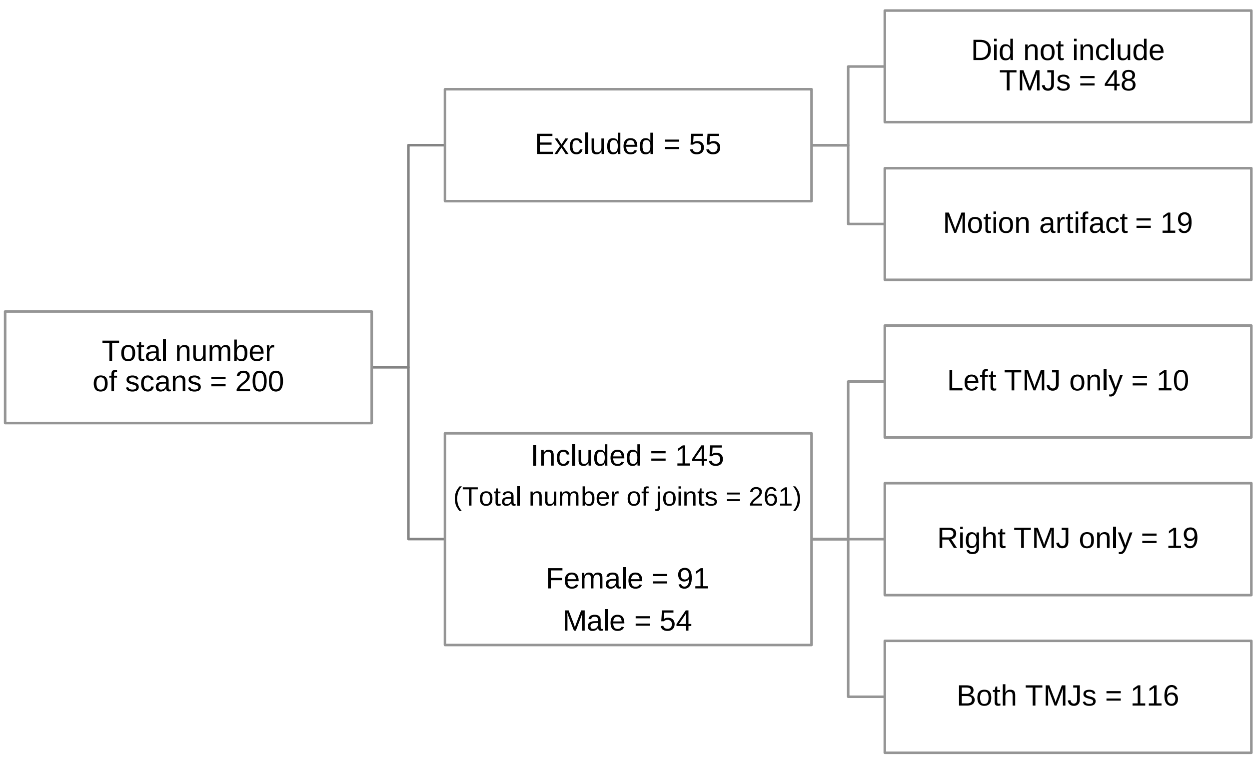

Figure 2: Diagram illustrating the number of excluded and included cases

Osteoarthritis (OA) Status

The criteria of Ahmad et al.[19] was used to determine if the TMJ was affected by OA. These criteria included:

a) No osteoarthritis – normal relative size of the condylar head, no subcortical sclerosis or surface flattening and no deformation due to subchondral cyst, surface erosion, osteophyte or generalized sclerosis.

b) Indeterminate for osteoarthritis - normal relative size of the condylar head, subcortical sclerosis with/without articular surface flattening or articular surface flattening with/without subcortical sclerosis and no deformation due to subchondral cyst, surface erosion, osteophytes or generalized sclerosis.

c) Osteoarthritis - deformation due to subchondral cyst, surface erosion, osteophyte, or generalized sclerosis.

The Severity of the Osteoarthritic Changes

The prevalence and severity of the osteoarthritic changes was scored for each joint based on the method of Alexiou et al.[40] as follows:

a) Osseous changes of the condyles:

   1. Flattening: the condyle will have a flat contour instead of convex (Figure 3):
      - 0: absence
      - 1: presence

Figure 3: Flattening

2. Erosion: an area of decreased density of the cortical bone and the adjacent subcortical bone. The severity of erosion was scaled as follows (Figure 4):
   - 0: absence of erosion
   - 1: slight erosion, when decreased density is observed only in the cortical bone
   - 2: moderate erosion, when decreased density is observed in the cortical bone and extends to the upper layers of the adjacent subcortical bone
   - 3: extensive erosion, when decreased density is observed in the cortical bone and extends below the upper layers of the adjacent subcortical bone

Figure 4: Condylar erosion

3. Osteophyte formation: a marginal bony outgrowth on the condyle. The severity of osteophyte formation was scaled as follows (Figure 5):

   - 0: absence
   - 1: slight, when marginal bony outgrowth on the condyle was less than 1 mm
   - 2: moderate, when marginal bony outgrowth on the condyle was 1–2 mm
   - 3: extensive, when marginal bony outgrowth on the condyle was more than 2 mm

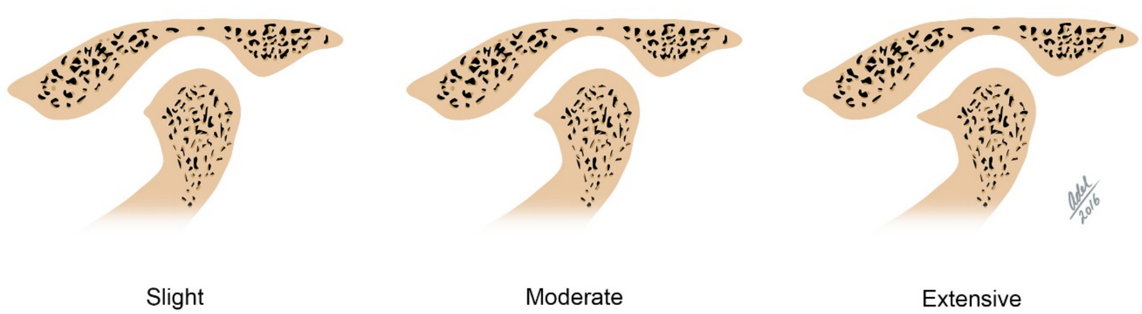

Figure 5: Osteophyte formation

4. Sclerosis: an increased cortical and cancellous bone density of cortical bone (Figure 6):
   - 0: presence
   - 1: absence

Figure 6: Condylar sclerosis.

5. Resorption: partial loss of condylar head (Figure 7):
   - 0: presence
   - 1: absence

Figure 7: Condylar resorption

6. Subchondral cyst: a well-defined round low density lesion in the periarticular surface (Figure 8):
   - 0: presence
   - 1: absence

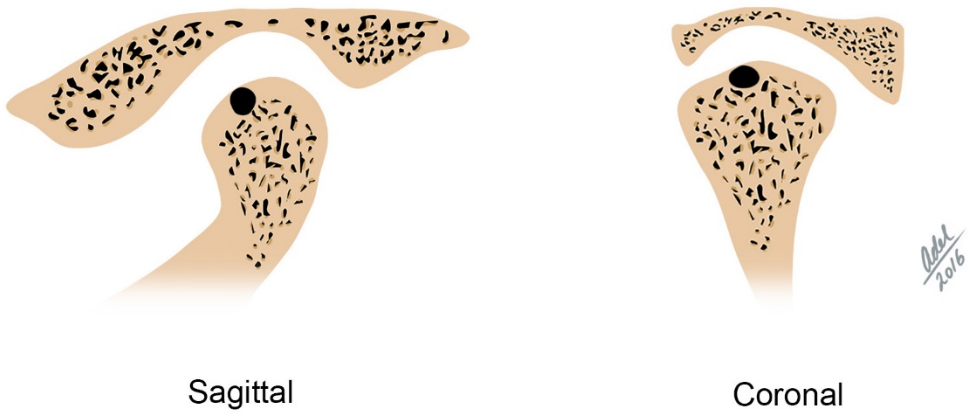

Figure 8: Subchondral cyst

b) Osseous changes of the mandibular fossa and articular eminence:

1. Erosion (Figure 9):

   - 0: presence
   - 1: absence

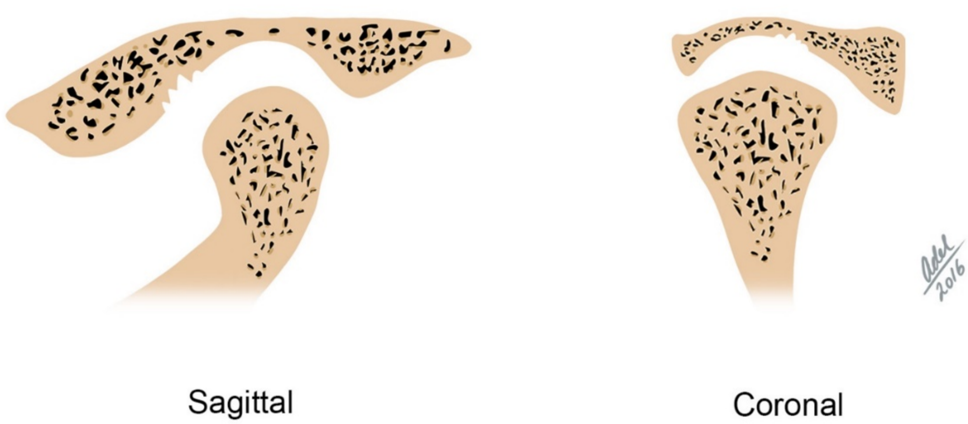

Figure 9: Erosion of the mandibular fossa

2. Sclerosis (Figure 10):

- 0: presence
- 1: absence

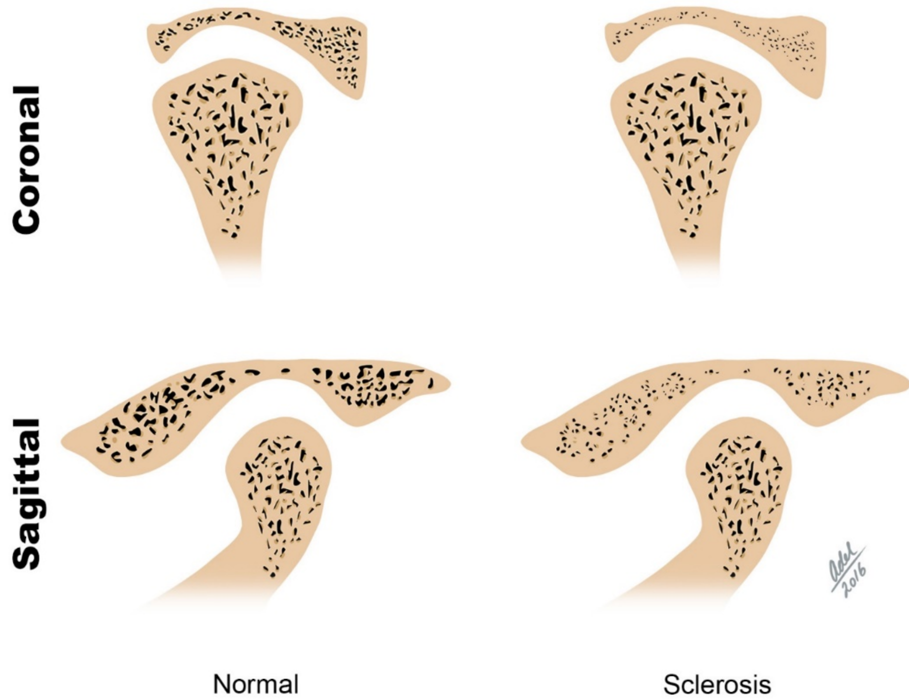

Figure 10: Sclerosis of the mandibular fossa

3. Resorption (Figure 11):

- 0: presence
- 1: absence

Figure 11: Resorption of the articular eminence

The Excel (Microsoft, Redmond, WA) spreadsheet was designed for scoring each variable in consultation with individuals in the Department of Statistics at the University of Connecticut.

3D Image Analysis

The DICOM (Digital Imaging and Communication in Medicine) files of each scan were exported into an external storage device (Western Digital 3TB My Passport Ultra Portable External Hard Drive). The author, a diplomate of the American Board of Oral and Maxillofacial Radiology, evaluated the DICOM files of each scan using InVivoDental software version 5.3.1 (Anatomage Inc., San Jose, CA). Images were projected on 3 monitors of the picture archiving and communication system (PACS) workstation in the reading room of the Oral and Maxillofacial Radiology clinic in the University of Connecticut School of Dental Medicine. Table 3 shows the specifications of the PACS workstation.

Images were viewed in the axial, coronal and sagittal planes in the software's multiplanar reformatted view. Corrected coronal and sagittal cross sections of the joint were also viewed using the TMJ module in InVivoDental (Figure 12). Deviations in the head position during CBCT acquisition were corrected with the InVivoDental software tools. To avoid misinterpretation, changes had to be found in at least two consecutive sections.[31]

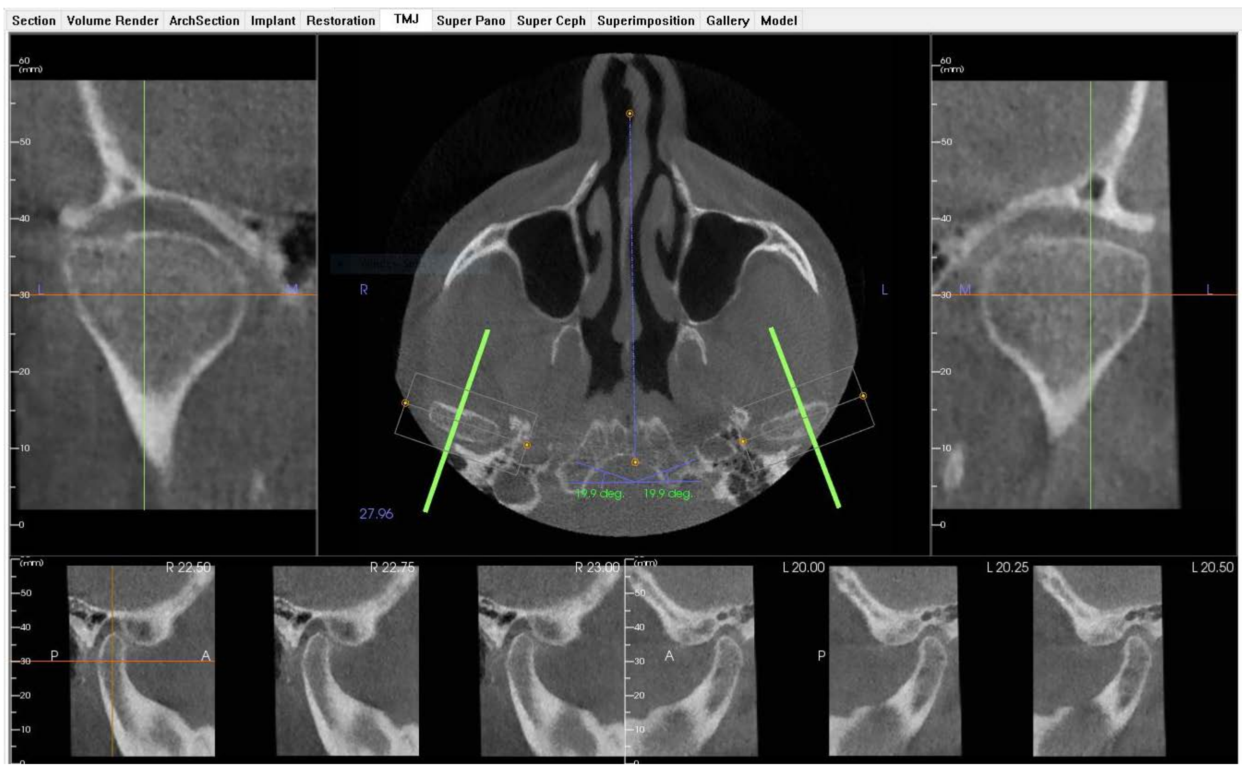

Figure 12: Corrected coronal and sagittal sections

Table 3: PACs workstation specifications

Workstation model	
Name	HP Workstation Z420
Manufacturer	Hewlett-Packard (Palo Alto, CA)
Processor	
Name	Intel(R) Xeon(R) CPU E5-1603 0 @ 2.80GHz
Manufacturer	Intel (Santa Clara, CA)
Speed	2.7GHz
Number of cores	4
Memory	
RAM	8.0 GB
Video Card #1	
Model	NVIDIA Quadro K2000D
Manufacturer	NVIDIA (Santa Clara, CA)
Dedicated Memory	2.0 GB
Total Memory	4.0 GB
Video Card #2	
Model	NVIDIA NVS 315
Manufacturer	NVIDIA (Santa Clara, CA)
Dedicated Memory	1.0 GB
Total Memory	4.0 GB
Operating System	
Name	Microsoft Windows 7
Developer	Microsoft (Redmond, WA)
Architecture	64-bit
Edition	Enterprise
Service Pack	1
Monitor #1	
Model	Planar PX1910M – LCD Monitor
Manufacturer	Planar Systems, Inc. (Beaverton, OR)
Native resolution	1280 x 1024
Size	19”
Monitors #2 and #3	
Model	Planar PX212M – LCD Monitor
Manufacturer	Planar Systems, Inc. (Beaverton, OR)
Native resolution	1600 x 1200 at 60 Hz
Size	21.3”

Statistical Analysis

Statistical analyses were done using SAS 9.4 software (SAS Institute, Cary, NC). Each osseous change was cross tabulated with gender as well as age using contingency tables and chi square test was applied. For cases where both joints where included in the scan, findings were tested to see if there was statistical difference between each joint regarding the presence of osseous changes. McNemar test was used for changes that have two levels (presence or absence), and Bhapkar chi-square and Stuart-Maxwell chi-squared tests were used for changes that had more the 2 levels (severity scale). The Bhapkar chi-square test and Stuart-Maxwell chi square tests were done using MH program (v. 1.2) by John Uebersax (http://john-uebersax.com/stat/mh.htm). A p-value less than 0.05 was considered statistically significant.

Results

In cases where both TMJs were included in the scan, there was no statistical difference in the distribution of the osteoarthritic changes between right and left joints.

OA Status

Based on the image analysis criteria for the RDC/TMD Validation Project, 16 TMJs (6.13%) had no OA, 74 (28.35%) were indeterminate for OA, and 171 joints had OA. Among the female subjects, 72 (79.12) had OA and 15 (16.48%) were indeterminate for OA. On the other hand, 19 (35.19%) of males were indeterminate of OA and 35 (64.81%) had OA. There was a significant correlation between gender and the occurrence of OA ($p < 0.05$), where females had more prevalence of OA. However, there was neither a significant correlation ($p = 0.6649 > 0.05$)

nor a linear association ($p = 0.0564 > 0.05$) between age and OA. Table 4 summarizes the prevalence of OA in the TMJs. Table 5 and Table *6* show the distribution of OA by gender and age groups, respectively.

Condylar Changes

Flattening and sclerosis were observed in 86.59% and 12.26% of cases, respectively, while resorption was observed in 7.28% of the joints. Only 21 (8.05%) of the examined TMJs had subchondral cysts. There was no correlation between gender and these changes ($p > 0.05$). Significant linear association; however, was observed between age and both sclerosis and subchondral cyst ($p < 0.05$). Table 6 - Table 15 demonstrate the prevalence of these changes as well as the gender and age distributions.

Osteophyte formation was absent in 112 (42.91%) TMJs. Slight and moderate osteophyte formations were observed in 44 (16.86%) and 66 (25.29%) of the examined joints, respectively. ADEL – specify gender or whatever the 44 and 66 represent in this sentence. Furthermore, 39 (14.94%) of cases showed severe osteophyte formation. There was no age nor gender correlation ($p > 0.05$). However, there was a statistically significant linear association between the severity of osteophyte formation and both gender and age ($p<0.05$). Table 16 summarizes the prevalence of osteophyte formation. Tables 17 and 18 show the distribution by age and gender, respectively.

Erosion was absent in 154 (59%) joints. Thirty-six joints (13.79%) had slight erosion and 30 (11.49%) had moderate erosion. Severe erosion was found in 41 joints (15.71%). Significant correlation was observed between gender and erosion ($p = 0.0009$) where females showed higher

prevalence. In addition, there was a significant linear association between the severity of erosion and age groups ($p = 0.0086$).

Figure 13-Figure17 show CBCT images of some of the osteoarthritic changes observed in the mandibular condyle.

Osseous Changes of the Mandibular Fossa and Articular eminence

Erosion was seen in 58 (22.14%) of cases, while sclerosis and resorption were found in 68 (25.95%) and 16 (6.11%) of the TMJs, respectively. SAME comment – specify that 68 and 16 are. There was no significant correlation between gender and these changes. However, there was a significant correlation between age, sclerosis and resorption, where higher observations were noted in older age groups ($p < 0.05$). Moreover, linear association was found between sclerosis and age ($p < 0.05$). Table 22-Table 28 show the prevalence of these changes as well as the gender and age distributions.

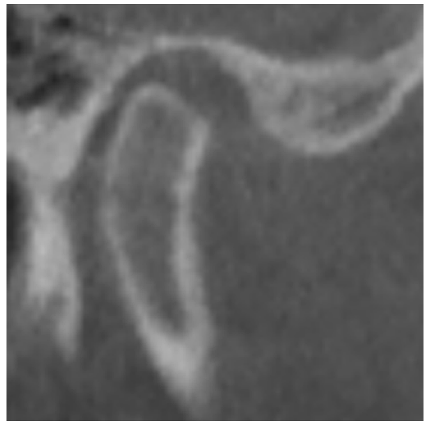

Figure 13: Flattening

Figure 14: Sagittal CBCT images showing severity scale of osteophyte formation

Figure 15: Coronal and sagittal CBCT images showing subchondral cyst (arrows)

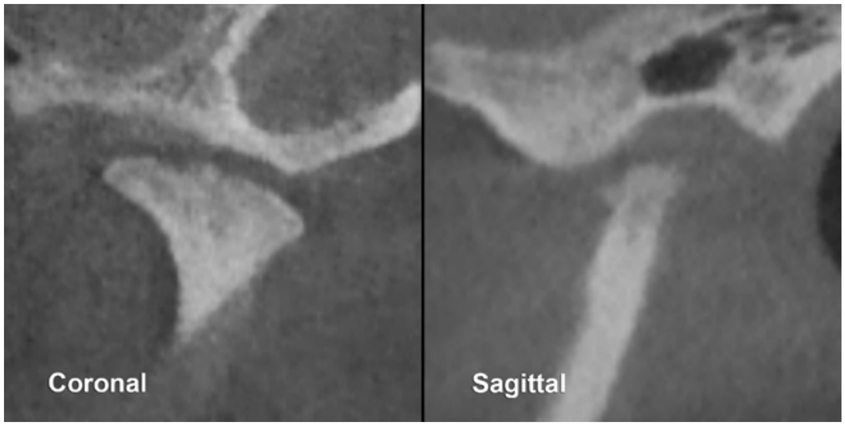

Figure 16: Coronal and sagittal CBCT images showing condylar sclerosis, erosion and resorption

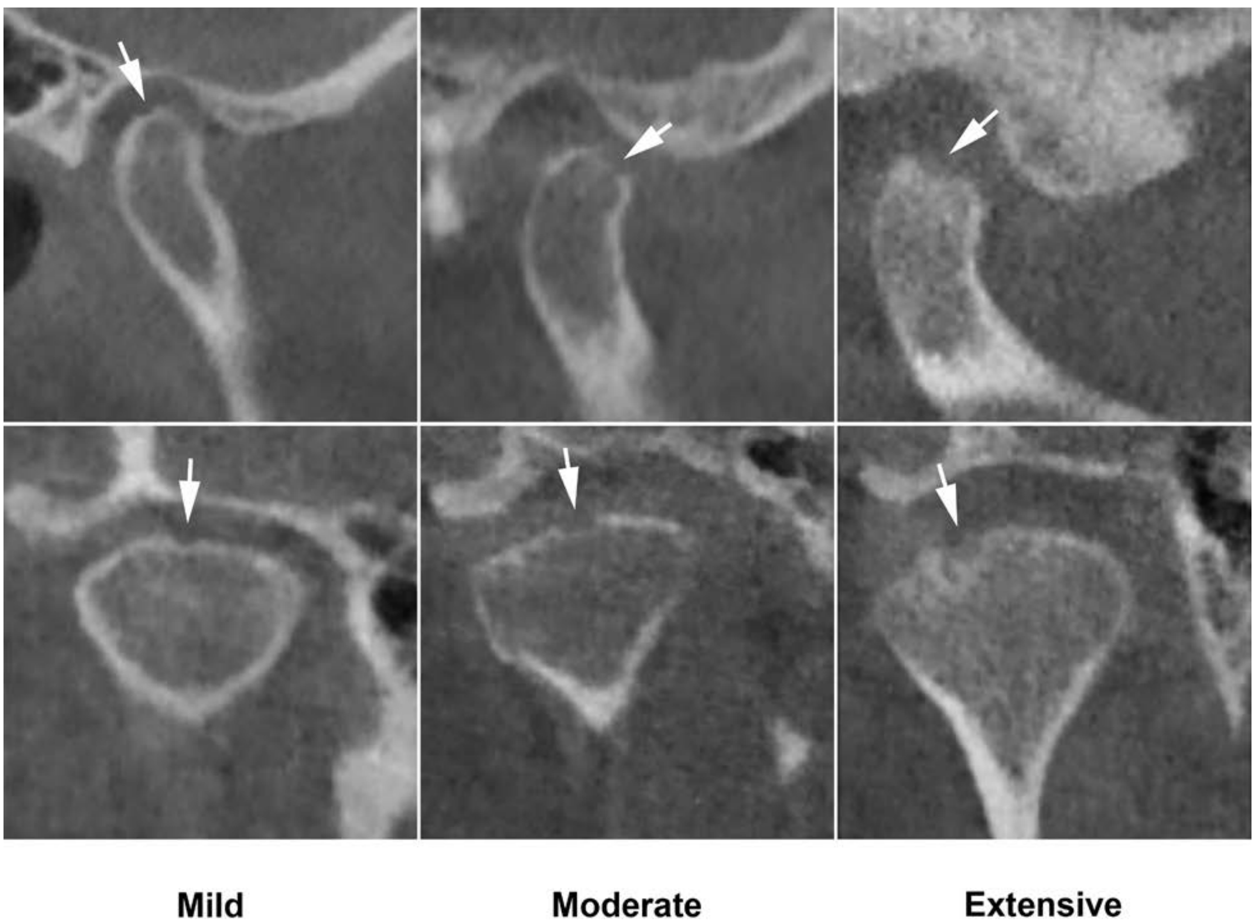

Figure 17: Sagittal (top) and coronal (bottom) CBCT images showing severity scale of condylar erosion

Table 4: TMJs osteoarthritis status based on image analysis for RDC/TMD system

Osteoarthritis (OA) status	**Frequency**	**Percentage**
No OA	16	6.13
Indeterminate for OA	74	28.35
OA	171	65.52

Table 5: Patients' osteoarthritis status by gender

Gender	**No OA**	**Indeterminate for OA**	**OA**
Female	4 (4.4%)	15 (16.48%)	72 (79.12%)
Male	0 (0.00%)	19 (35.19%)	35 (64.81%)

(Chi-Square p = 0.015)

Table 6: Patients' osteoarthritis status distribution by age

Age (years)	**10-19**	**20-29**	**30-39**	**40-49**	**50-59**	**60-69**	**70-79**	**80-89**
No OA	0	0	0	1	1	1	1	0
Indeterminate for OA	4	2	2	4	9	9	4	0
OA	2	4	2	13	33	30	19	4

(Chi-Square p = 0.66, Mantel-Haneszel Chi-Square p = 0.056)

Table 7: Presence and absence of condylar flattening, sclerosis, resorption and subchondral cysts

Osseous changes	**Present**	**n**	**Percentage**
Flattening	Yes	226	86.59
	No	35	13.41
Sclerosis	Yes	32	12.26
	No	229	87.74
Resorption	Yes	19	7.28
	No	242	92.72
Subchondral	Yes	21	8.05
	No	240	91.95

Table 8: Condylar flattening prevalence by gender

Gender	Absent	Present	Total
Female	7 (7.69%)	84 (92.44%)	91
Male	3 (5.56%)	51 (94.44%)	54

(Chi-Square p = 0.62, Fisher's exact test p = 0.74)

Table 9: Condylar flattening prevalence by age

Age (years)	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89
Absent	0	0	1	1	3	3	2	0
Present	6	6	3	17	40	37	22	4

(Chi-Square p = 0.84, Mantel-Haenzsel Chi-Square p = 0.71)

Table 10: Condylar sclerosis prevalence by gender

Gender	Absent	Present	Total
Female	69 (75.82%)	22 (24.18%)	91
Male	47 (87.04%)	7 (12.96%)	54

(Chi-Square p = 0.10, Fisher's exact test p = 0.13)

Table 11: Condylar sclerosis prevalence by age

Age (years)	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89
Absent	6	6	4	15	35	31	18	1
Present	0	0	0	3	8	9	6	3

(Chi-Square p = 0.09, Mantel-Haenszel Chi-Square p = 0.006*)

Table 12: Condylar resorption prevalence by gender

Gender	Absent	Present	Total
Female	79 (86.81%)	12 (13.19%)	91
Male	49 (90.74%)	5 (9.26%)	54

(Chi-Square p = 0.47, Fisher's exact test p = 0.598)

Table 13: Condylar resorption by age

Age (years)	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89
Absent	6	6	4	16	37	36	21	2
Present	0	0	0	2	6	4	3	2

(Chi-Square p = 0.32, Mantel-Haenszel Chi-Square p = 0.089)

Table 14: Subchondral cyst prevalence by gender

Gender	Absent	Present	Total
Female	77 (84.62%)	14 (15.38%)	91
Male	49 (90.74%)	5 (9.26%)	54

(Chi-Square p = 0.29m Fisher's exact test p = 0.32)

Table 15: Subchondral cyst prevalence by age

Age (years)	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89
Absent	6	6	4	17	39	38	16	0
Present	0	0	0	1	4	2	8	4

(Chi-Square p < 0.0001*, Mantel-Haenszel Chi-Square p < 0.0001*)

Table 16: Prevalence and severity of osteophyte formation among the entire sample

Osteophyte	**Frequency**	**Percentage**
Absent	112	42.91
Slight	44	16.86
Moderate	66	25.29
Extensive	39	14.94

Table 17: Osteophyte formation prevalence and severity by gender

Gender	**Absent**	**Slight**	**Moderate**	**Extensive**	**Total**
Female	29 (31.87%)	11 (12.09%)	28 (30.77%)	23 (25.27%)	91
Male	22 (40.74%)	12 (22.22%)	19 (24.07%)	7 (12.96%)	54

(Chi-Square p = 0.11, Mantel-Haenszel Chi-Square p = 0.04*)

Table 18: Osteophyte formation prevalence and severity by age

Age (years)	**10-19**	**20-29**	**30-39**	**40-49**	**50-59**	**60-69**	**70-79**	**80-89**
Absent	4	3	2	8	12	12	10	0
Slight	1	2	1	2	8	6	3	0
Moderate	1	1	1	5	11	16	4	2
Extensive	0	0	0	3	12	6	7	2

(Chi-Square p = 0.51, Mantel-Haenszel Chi-Square p = 0.01*)

Table 19: Prevalence and severity of erosion in the entire sample

Osteophyte	**Frequency**	**Percentage**
Absent	154	59
Slight	36	13.79
Moderate	30	11.49
Extensive	41	15.71

Table 20: Erosion prevalence and severity by gender

Gender	Absent	Slight	Moderate	Extensive	Total
Female	33 (36.26%)	19 (20.88%)	19 (20.88%)	20 (21.98%)	91
Male	35 (64.81%)	3 (5.56%)	3 (5.56%)	13 (24.07%)	54

(Chi-Square p = 0.0009*, Mantel- Haenszel Chi-Square p = 0.06)

Table 21: Erosion prevalence and severity by age

Age (years)	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89
Absent	5	4	3	7	23	18	8	0
Slight	0	1	0	3	4	10	4	0
Moderate	0	1	1	3	6	6	5	0
Extensive	1	0	0	5	10	6	7	4

(Chi-Square p = 0.11, Mantel-Haenszel Chi-Square p = 0.0086*)

Table 22: Prevalence of osseous changes of the mandibular fossa and articular eminence

Osseous changes	Present	n	Percentage
Erosion	Yes	58	22.14
	No	204	77.84
Sclerosis	Yes	68	25.95
	No	194	74.05
Resorption	Yes	16	6.11
	No	246	93.89

Table 23: Prevalence of the mandibular fossa and articular eminence erosion by gender

Gender	**Absent**	**Present**	**Total**
Female	62 (68.13%)	29 (31.87%)	91
Male	40 (74.07%)	14 (25.93%)	54

(Chi-Square p = 0.45, Fisher's exact test p = 0.57)

Table 24: Prevalence of the mandibular fossa and articular eminence erosion by age

Age (years)	**10-19**	**20-29**	**30-39**	**40-49**	**50-59**	**60-69**	**70-79**	**80-89**
Absent	6	5	3	12	32	26	16	2
Present	0	1	1	6	11	14	8	2

(Chi-Square p = 0.66, Mantel-Haenszel Chi-Square p = 0.07)

Table 25: Prevalence of the mandibular fossa and articular eminence sclerosis by gender

Gender	**Absent**	**Present**	**Total**
Female	61 (67.03%)	30 (32.97%)	91
Male	41 (75.93%)	13 (24.07%)	54

(Chi-Square p = 0.26, Fisher's exact test p = 0.35)

Table 26: Prevalence of the mandibular fossa and articular eminence sclerosis by age

Age (years)	**10-19**	**20-29**	**30-39**	**40-49**	**50-59**	**60-69**	**70-79**	**80-89**
Absent	6	6	4	13	27	28	17	1
Present	0	0	0	5	16	12	7	3

(Chi-Square p = 0.026*, Mantel-Haenszel Chi-Square p = 0.01*)

Table 27: Prevalence of the mandibular fossa and articular eminence resorption by gender

Gender	**Absent**	**Present**	**Total**
Female	83 (91.21%)	8 (8.79%)	91
Male	49 (90.74%)	5 (9.26%)	54

(Chi-Square p = 0.92, Fisher's exact test p = 1.00)

Table 28: Prevalence of the mandibular fossa and articular eminence resorption by age

Age (years)	**10-19**	**20-29**	**30-39**	**40-49**	**50-59**	**60-69**	**70-79**	**80-89**
Absent	6	5	4	18	38	39	20	2
Present	0	1	0	0	5	1	4	2

(Chi-Square p = 0.029*, Mantel-Haenszel Chi-Square p = 0.088)

Discussion

CBCT was introduced to dentistry in the late 1990s.[43] Often similar in appearance to a panoramic unit, a CBCT scanner has an x-ray source and a detector 180° apart. During acquisition, the x-ray source and the detector will rotate synchronously around the patient's head and multiple sequential 2-dimensional projections are captured. The computer will reconstruct the acquired data using specific algorithms.

A CBCT unit is substantially less expensive and smaller than a MDCT scanner. In addition, CBCT provides high-resolution images and smaller radiation doses compared to MDCT. However, the dose of CBCT is variable. The dose associated with CBCT varies according to many factors, such as the size of the field of view, the area of the maxillofacial complex imaged, the spatial resolution selected, the number of basis projections acquired, and the use of continuous versus pulse-beam exposure.[35] CBCT is considered reliable in evaluating the bony structures of the TMJ. Its effectiveness and reliability has been previously reported in the literature.[44,45]

Osteoarthritis is a degenerative inflammatory disease that is more frequent in older individuals and has female preponderance.[21–23] In this study, female subjects showed higher prevalence (almost 80% of females) of osteoarthritis compared to males. According to the literature, approximately 40% of patients affected by TMJ osteoarthritis are older than 40 years. Alexiou et al. reported that the mean age of patients with TMJ osteoarthritis is 48.17 years.[40] The results of the present study showed a mean age of 59.9 years. This difference in the mean age could be explained by the nature of the study population. The patients in the present study

were not imaged for TMJ problems; rather they were imaged for implant treatment planning. The vast majority of patients that require replacement of teeth are the elderly[46], thus skewing the population of the present study towards older individuals.

Condylar head flattening was the most common finding in our study. In approximately 28% of the cases of flattening, there were no other osseous changes associated with condyle. This suggests that the presence of flattening alone is not a reliable indicator for OA. The RDC/TMD image analysis criteria considered flattening with absence of other changes as a sign of remodeling and graded the joints with flattening only as indeterminate for OA.[19] It has been suggested that remodeling, particularly condylar flattening, should be considered as functional adaption.[47]

The second most common osseous change in the present study was osteophyte formation. According to Alexiou el al., osteophyte formation was present in 56% of their cases, which is in almost an exact agreement with the results of our study where 57% of joints showed osteophyte formation. Others; however, reported higher prevalence of osteophyte formantion.[48] There was a statistically significant correlation between age and the presence, as well as the severity, of osteophytes in Alexiou et al. study and other reports.[40] Our study did not show a correlation between age and the occurrence of osteophyte formation; however, there was a linear association between age and the severity of osteophyte indicating an increase of the severity of osteophyte with aging.

Erosion was present in 41% of cases and, similar to osteophyte, there was a linear association between age and the severity of erosion. This finding is in accordance with previous reports.[40,49,50]

Condylar sclerosis and subchondral cyst were present in 12% and 8% of the examined TMJs, respectively. This is relatively consistent with studies performed by Cömert Kiliç et and Al-Ekrish et al.[48,51] Resorption of the condyle was observed in 7% of cases. Other studies reported higher rates of condylar resorption. [40,48] All of these changes were seen in subjects over the age of 40 years in our sample.

It has been reported in previous studies that the mandibular fossa and articular eminence commonly show osseous changes as a result of osteoarthritis and joint remodeling.[40,52,53] Results from the present study showed a prevalence of 22% and 26% of erosion and sclerosis, respectively. Furthermore, there was a statistically significant correlation between age and sclerosis as well as erosion.

Internal derangement of the TMJ is one the most common conditions affecting the TMJ. It refers to the abnormal position of the articular disk in relation to the osseous components of the TMJ. It is classified into disk displacement with reduction and disk displacement without reduction. While CBCT is used for examining the osseous structures, MRI is the imaging modality of choice for evaluation of position, morphology, and integrity of the disk.[36] A group in Japan conducted a study where they investigated the association between TMJ soft tissue pathology observed in MRI and osteoarthritic changes confirmed by CBCT.[54] They found a

significant association between the presence of osseous abnormalities and disc deformity as well as anterior disk displacement without reduction.

A limitation of this study is lack of clinical information regarding the patient symptomology. All of the observed changes were considered incidental because the indication for the CBCT scans was implant treatment planning. Correlation between pain and the osseous changes observed in the TMJs could not be assessed. Other studies have reported poor correlation between the radiographic findings and clinical signs and symptoms.[36,55–57]

Conclusion

The results of this study are in accordance with previous studies concerning osteoarthritis of the temporomandibular joint in that osteoarthritis is more common in females and in older individuals. In addition, the frequency and severity of the osteoarthritic changes observed in the TMJ increase with age.

Future Directions

Partially edentulous patients' with TMJ osteoarthritis should be evaluated using advanced imaging before and after receiving dental implants to determine whether there is progression, stasis or regression of the of osteoarthritic changes. In addition, correlation of clinical signs and symptom with radiographic findings before and after implant placement should be investigated.

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