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AI AND RADIOLOGIST ASSESSMENTS ON THE PREVALENCE OF TMJ OSTEOARTHRITIS USING RADIOGRAPHIC IMAGES: A COMPARATIVE STUDY

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Objectives: This study aims to address the significant discomfort and functional impairment associated with temporomandibular joint osteoarthritis (TMJ OA), which negatively impacts the quality of life. It emphasizes the importance of prompt diagnosis and explores the potential of an Artificial Intelligence (AI) system to enhance TMJ OA diagnosis.

Methods: The prevalence of TMJ OA was evaluated using 3 diagnostic tools: the gold standard, the AI model, and an examiner. In total, 132 patients who performed 190 cone-beam computed tomography (CBCT) images were included.

Results: The prevalence of TMJ OA was 62.11% using the gold standard, 63.68% using the AI model, and 58.42% when assessed by the examiner. No gender variation in TMJ OA diagnosis was reported (p-value>0.05). Age variations were reported with the gold standard and the examiner diagnosis. When compared to the gold standard, the AI model had remarkable sensitivity (97.46%) and specificity (91.67%).

Conclusions: The AI model shows promise in enhancing the accuracy of TMJ OA diagnosis, offering potential benefits for early detection and improved patient outcomes.

Keywords: Artificial Intelligence, Temporomandibular Joint, Osteoarthritis, Diagnosis

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The authors declare no conflicts of interest.

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ÉVALUATIONS DE L'IA ET DES RADIOLOGUES SUR LA PRÉVALENCE DE L'ARTHROSE DES ATM À L'AIDE D'IMAGES RADIOGRAPHIQUES: UNE ÉTUDE COMPARATIVE.

Objectifs: Cette étude vise à aborder l'inconfort important et la déficience fonctionnelle associés à l'arthrose de l'articulation temporo-mandibulaire (A ATM), qui a un impact négatif sur la qualité de vie. Il souligne l'importance d'un diagnostic rapide et explore le potentiel d'un système d'intelligence artificielle (IA) pour améliorer le diagnostic de l'A ATM.

Méthodes: La prévalence de l'arthrose des ATM a été évaluée à l'aide de 3 outils de diagnostic : l'étalon-or, le modèle d'IA et un examinateur. Au total, 132 patients ayant réalisé 190 images de tomodensitométrie à faisceau conique (CBCT) ont été inclus.

Résultats: La prévalence de l'arthrose des ATM était de 62,11 % en utilisant l'étalon-or, de 63,68 % en utilisant le modèle d'IA et de 58,42 % lorsqu'elle était évaluée par l'examinateur. Aucune variation selon le sexe dans le diagnostic d'arthrose des ATM n'a été signalée (valeur $p > 0{,}05$). Des variations selon l'âge ont été rapportées avec l'étalon-or et le diagnostic de l'examinateur. Comparé à l'étalon-or, le modèle d'IA présentait une sensibilité (97,46 %) et une spécificité (91,67 %) remarquables.

Conclusions: Le modèle d'IA est prometteur pour améliorer la précision du diagnostic de l'A ATM, offrant des avantages potentiels pour la détection précoce et l'amélioration des résultats pour les patients.

Mots clés: Intelligence Artificielle, Articulation temporomandibulaire, Arthrose, Diagnostic

Introduction

Osteoarthritis (OA) refers to the chronic degeneration of soft and hard tissues surrounding the joint, thereby resulting in anatomical alterations in the joint along with joint pain [1]. The most commonly affected joints in the body are those that are stress-bearing like the fingers, spine, knee, and hip; yet OA can also affect other joints like the ankle, wrist, shoulder, and temporomandibular joint (TMJ) [2]. TMJ is among the most frequently used joints in the human body, and it is a unique and complex joint that links the mandibular condyle to the articular surface of the temporal bone to allow sliding, hinge, compression, and spinning movements [3].

TMJ OA is characterized by chronic pain, condylar bone remodeling, cartilage breakdown, and synovitis [4]. TMJ OA onset and progression are due to mechanical factors like injuries, amplified friction, parafunctional activities, functional overload, and malocclusion. Aging, hormonal imbalances, metabolic diseases, female sex, inadequate dietary intake, autoimmune diseases, and a predisposed genetic profile are considered systematic TMJ OA risk factors [5-7]. As OA starts progressing, the signs and symptoms of TMJ OA start manifesting and could exacerbate with function. The most common symptoms include pain/aching, reduction in the ability to move the jaw, joint tenderness, and crepitus [8].

It has been reported that TMJ OA occurs in 8-16% of the population according to clinical evidence; yet radiographic evidence signifies that it occurs in as much as 14-44% in asymptomatic individuals [9-11]. Since the pathology of TMJ OA is complex, no consensus treatment has been established that ensures full remission. Treatment rather focuses on pain relief and enhancement of TMJ function [12]. Conventional clinical treatment involves psychotherapy, arthrocentesis, medication, occlusal stabilization splints, physical therapy and other non-surgical options whereas the surgery is applied to those suffering from severe symptoms [13]. As such, early and correct diagnosis is crucial at the onset of the disease so that the patient receives the necessary help before it progresses to the severe state [14]. Any undiagnosed dysfunction in TMJ could harm the entire masticatory system and the treatment approach for TMJ OA is considered interdisciplinary as it involves the coordination between gnathologists, physiotherapists, orthodontists, and rheumatologists as well as prosthodontists and maxillofacial surgeons [6].

There are no particular laboratory tests that can be used to definitively diagnose TMJ OA, so it is principally based on clinical examinations and medical history [15]. As such, practitioners should be well trained to differentiate TMJ OA from other temporomandibular disorders (TMDs) and conditions causing orofacial pain [16]. The Research Diagnostic Criteria for TMDs (RDC/TMD) was first developed as a classification system for TMDs to have consistent clinical diagnoses. Its criteria got revised by an interprofessional consortium leading to the Diagnostic Criteria for TMDs (DC/TMD) with enhanced specificity, sensitivity, reliability and validity [17, 18]. DC/TMD is a standardized tool for the classification of TMD based on the observed impairments and function limitations in the patients, and its diagnostic algorithm consists of 2 Axes: Axis-I relies on physical examination of the muscle and joint to assess any structural or functional impairments, while Axis-II relies on psychosocial examination to assess the psychological condition of the patient [19]. Imaging tools like magnetic resonance imaging (MRI) and cone-beam computed tomography (CBCT) are often used as an adjunct to the clinical examination in the classification of TMDs and the diagnosis of TMJ OA as they show signs of pre-existent condylar damage (osteophytes, sclerosis, subcortical cysts, or surface erosions), but they remain subject to bias from the assessing clinical practitioners and researchers [20, 21].

Accordingly, there is a direct need to develop advanced tools that reduce human error and bias in the diagnosis of TMJ OA. Probabilistic modeling, robotics, machine learning, and big data analytics are being widely applied in the medical field to diagnose diseases [22, 23]. Promising results of early prediction and precise categorization of knee OA were reported using machine learning algorithms [24]. In prior research, we developed an AI system for diagnosing TMJ OA using CBCT images. This model was based on a convolutional neural network (CNN) architecture, specifically trained to identify patterns and features characteristic of TMJ OA from the CBCT images. The AI model was rigorously trained and validated using a large dataset of annotated images, allowing it to learn and improve its diagnostic accuracy over time. This system ultimately aligned more closely with the gold standard (DC/TMD) than evaluations from an expert oral radiologist [25].

However, this study sets itself apart by focusing on the application of a novel AI model specifically designed for TMJ OA diagnosis, highlighting its potential advantages over traditional methods. The introduction of this AI model represents a significant advancement in the field, as prior studies have not fully explored its capabilities in the context of TMJ OA.

This current study aims to determine the prevalence of temporomandibular joint osteoarthritis (TMJ OA) based on radiographic images assessed by a previously developed artificial intelligence model compared to an experienced radiologist, using the DC/TMD golden diagnostic tool as a reference. Additionally, the study sought to examine age and gender variations across the diagnostic tools. The null hypothesis for this study posits that there is no significant difference in the diagnostic accuracy of TMJ OA between the AI model and the expert radiologist when using the DC/TMD criteria as the gold standard.

Materials and Methods

Ethical Considerations

Prior to proceeding with this study, approval from the Ethics Committee at Sharjah University was obtained [20-09-21-01]. Confidentiality was respected as patients' identities were kept anonymous and their records were securely stored with access only permitted to enrolled researchers. Informed consent was a critical component of this study. All partaking patients were provided with detailed data about the study, counting its purpose, the procedures included, potential risks, and the expected benefits. The data was communicated in a clear and reasonable way, permitting members to make an informed choice about their inclusion. Patients were also educated of their right to withdraw from the study at any point without any repercussions. To document consent, written forms were gotten from all members, with each patient getting a copy for their records. To ensure persistent privacy and guarantee data privacy, several measures were actualized. Patient identities were anonymized utilizing unique identification codes to anticipate any direct affiliation between the information and individual members. The records, counting both the CBCT images and any related medical data, were safely stored in a password-protected digital database. Access to this database was entirely limited to the analysts directly involved within the study, and all information dealing with procedures complied with relevant data protection controls, counting encryption of data during storage and transmission. Moreover, regular audits were conducted to guarantee that the information management protocols were entirely adhered to throughout the study. These reviews helped in maintaining the integrity of the information and further guaranteed that patient secrecy was maintained at all times.

Study Population

Patients admitted to the Emergency and Diagnosis Clinics at Sharjah Dental Hospital from November 2020 to November 2022, who underwent CBCT imaging and had known gender and age profiles, were included in this study. The study population comprised 132 patients, resulting in a total of 190 CBCT images.

Inclusion Criteria

- Patients aged between 18 and 75 years.
- Patients who underwent CBCT imaging as part of their diagnostic evaluation.
- Patients with known gender and age profiles.
- Patients who exhibited clinical signs and symptoms of temporomandibular joint osteoarthritis (TMJ OA) based on the DC/TMD guidelines.
- Patients who were deemed eligible for CBCT imaging due to severe or acute dysfunction symptoms, as per Helkimo's clinical dysfunction index (Di) [26].

Exclusion Criteria

- Patients who had previously received treatment for TMJ OA.
- Pregnant women, due to the potential risks associated with radiation exposure from CBCT imaging.
- Patients with a history of systemic conditions or other joint disorders that could confound the diagnosis of TMJ OA.
- Patients with incomplete clinical or demographic data.

For each patient, a single CBCT scan was performed. However, each CBCT image contained multiple sections and slices (e.g., cross-sectional, tangential) that were utilized to train the neural networks. This approach allowed the AI model to analyze various aspects of the temporomandibular joint, enhancing its ability to accurately diagnose TMJ OA.

Upon admission to the hospital, patients underwent a clinical evaluation for TMJ OA following the DC/TMD guidelines. Those exhibiting symptoms indicative of osteoarthritis, particularly those with severe or acute dysfunction, were selected for CBCT imaging in accordance with Helkimo's clinical dysfunction index (Di) [26].

Data Collection and Study Design

Gathered information encompassed patient demographics (age and gender) and their corresponding CBCT records (both left and right sides). Using cross-sectional CBCT visuals, we identified flattening, subcortical cysts, and surface erosions. For osteophytes allocation, tangential images were employed. The same CBCT images underwent evaluation through varied diagnostic methods: 1) the golden reference, known as the DC/TMD diagnostic instrument, 2) the AI model previously established [25], and 3) a reviewer.

For the golden reference, CBCT records were examined independently by 2 highly experienced evaluators based on the DC/TMD criteria. The evaluators were an oral and maxillofacial surgeon with at least 20 years of experience in TMD management and an oral radiologist with at least 25 years of experience.

The assessments were executed twice on a 1-week interval, and an additional round was applied in cases of disagreement to achieve a consensus. CBCT images were evaluated by the AI model that was developed as previously published [25]. In essence, the AI model utilized the "You Only Look Once" (YOLO) framework, which leverages a singular convolutional network in conjunction with a single regression model for object identification. This AI system underwent training and validation against 2,737 CBCT images sourced from 943 patients, comprising 792 OA joints and 1,094 standard joints. For the third diagnostic method, an oral radiologist with a 15-year clinical background evaluated the CBCT images. The training process included extensive information augmentation and cross-validation to improve accuracy. Performance measurements, such as precision, recall, and F1-score, were detailed to illustrate the model's reliability. This AI model is noteworthy within the setting of existing research for its capacity to perform accurate, mechanized TMJ OA diagnosis, possibly decreasing diagnostic time and variability. An experienced oral radiologist with 15 years of clinical involvement provided a third diagnostic method for comparison.

The occurrence of TMJ OA was gauged using the three diagnostic techniques mentioned previously. The accuracy of both the AI system and the oral radiologist in pinpointing TMJ OA from CBCT visuals was gauged against the established gold standard. Metrics evaluated included sensitivity, specificity, positive predictive values (PPV), and negative predictive values (NPV). Sensitivity captures the percentage of actual positives accurately identified by a diagnostic mechanism (Sensitivity = true positives / (true positives + false negatives)). Specificity represents the percentage of actual negatives correctly pinpointed by a diagnostic tool (Specificity = true negatives / (true negatives + false positives)). PPV denotes the fraction of patients accurately diagnosed as positive from all those with positive test results (PPV = true positives / (true positives + false positives)). Conversely, NPV denotes the fraction of patients accurately diagnosed as negative from all those with negative test results (NPV = true negatives / (true negatives + false negatives)).

Data Analysis

Collected data was statistically analyzed using SPSS software, version 20. A descriptive analysis was used in which variables were presented according to their type: categorical variables were presented as frequency and proportion (percent), while continuous variables were presented as mean, standard deviation, and minimum and maximum values. Categorical variables were compared using Chi-square test or Fisher exact test, specifically chosen when sample sizes were small or when expected cell frequencies were low, ensuring the reliability of the results. For continuous variables, the Student t-test was applied when the data followed a normal distribution, while the Mann-Whitney test was used as a non-parametric alternative for non-normally distributed data. These tests were chosen based on the dissemination and nature of the information, providing a strong analysis and minimizing the risk of biased results. To address potential biases, the study utilized well-defined inclusion and exclusion criteria, standardized information collection strategies, and adjustments for confounders such as age and gender. These measures helped guarantee that the study's findings were solid and reflective of true associations instead of artifacts of sampling or measurement error. A p-value of less than 0.05 was considered factually significant for all tests, adjusting the chance of type I and type II errors and contributing to the overall validity of the study's conclusions.

Results

Descriptive Statistics:

In total, 132 patients who underwent 190 CBCT scans were included in this study. Gender data was available for 75 patients, 49 of whom were males (65.33%). Data concerning age was available for 74 patients. Studied patients had a mean age of 46.67±16.36 years with the youngest being 13.09 years old and the eldest being 75.63 years old (Table 1).

Among the 190 CBCT images, 90 (47.37%) were performed for the left side and 100 (52.63%) for the right side. According to the DC/TMD gold standard diagnosis, TMJ OA was detected in 118 CBCT images (62.11%) with condylar flattening being identified in 17.37%, subcortical cysts in 25.26%, surface erosion is 1.58%, and osteophyte in 21.05%. Following the AI diagnosis, 63.68% of the images were indicative for TMJ OA diagnosis. The AI model detected condylar flattening in 31 images (16.32%), and osteophyte in 45 images (23.68%). In accordance with the DC/TMD gold standard, the AI model detected subcortical cysts and surface erosion in 25.26% and 1.58% of the images respectively. When the examiner assessed the CBCT images for the prevalence of TMJ OA, it was only diagnosed in 111 images (58.42%). The examiner detected condylar flattening in 14.74%, subcortical cysts in 22.63%, surface erosion is 1.05%, and osteophyte in 23.16%. It is noteworthy that all diagnosed surface erosion cases were observed in the CBCT images taken for the right side. The detailed descriptive statistics are presented in Table 2.

Sensitivity and Specificity Analysis

When compared to the DC/TMD gold standard diagnosis, the AI model showed equal sensitivity and NPV for the TMJ OA diagnosis of the CBCT images of the right side. It also showed a high sensitivity (97.46%) yet low specificity (91.67%) regarding the overall examined CBCT images (Table 3).

When compared to the DC/TMD gold standard diagnosis, the examiner diagnosis showed low sensitivity (88.98%) and specificity (91.67%) (Table 4).

Table 1. Demographic characteristics of the studied patients

Criteria		Overall
Gender	Valid answers Male	75 49 (65.33)
N(%)	Female	26 (34.67)
Age (years)	Valid answers	74
	Mean ± SD	46.67 ± 16.36
	Median	43.55
	Min – Max	13.09 - 75.63

Relation of Diagnostic Tools and Demographic Characteristics

Gender and age data were only available for 75 and 74 patients respectively. Accordingly, the below relations were based on these patients.

Results showed that TMJ OA was reported in 27 males (55.10%) and 11 females (42.31%) following the DC/TMD gold standard diagnosis; in 30 males (61.22%) and 12 females (46.15%) following the AI diagnosis; and in 29 males (59.18%) and 12 females (46.15%) following the examiner diagnosis. Positively diagnosed patients only showed signs of osteophyte. Prevalence of TMJ OA and signs of pre-existent condylar damage did not vary based on gender in any of the diagnostic tools (Tabe 5).

Out of the 74 patients whose age was available, the examiner diagnosed 41 patients with TMJ OA and 33 patients to be normal with respect to TMJ OA. Patients with TMJ OA were significantly older than those who were normal with respective mean ages of 50.32±15.44 years and 42.12±16.57 years (p-value = 0.027). On the other hand, the DC/TMD gold standard diagnosis and the AI diagnosis showed no significant variation with respect to age (Table 6).

Moreover, out of the 46 patients who had images for the right side, 25 patients were diagnosed with TMJ OA following the DC/TMD gold standard and all 25 showed signs of osteophyte. Those patients were significantly older than the patients being normal for TMJ OA (mean ages of 50.78±16.87 and 40.61±14.47 years, respectively; p-value=0.039). Also, the examiner diagnosed 25 patients with TMJ OA with all showing signs of osteophyte. OA patients were significantly older (mean age of 51.33±16.11 years) than those who were normal for OA (39.95 ± 14.99 years, p-value=0.017). On the other hand, the AI diagnosis showed no significant variation with respect to age. No significant variation between age and any diagnostic tool was observed for the left side (Table 7 and Table 8).

Table 2. Descriptive statistics of diagnostic tools for TMJ OA for all study images and by side

		Overall (N=190) (N(%))	Left side (n=90) (N(%))	Right side (n=100) (N(%))
DC/TMD Gold Standard Diagnosis	Normal	72 (37.89)	38 (42.22)	34 (34.00)
	Condylar flattening	33 (17.37)	15 (16.67)	18 (18.00)
	Subcortical cyst	48 (25.26)	24 (26.67)	24 (24.00)
	Surface erosion	3 (1.58)	0 (0.00)	3 (3.00)
	Osteophyte	40 (21.05)	15 (16.67)	25 (25.00)
DC/TMD Gold Standard Diagnosis	Normal	72 (37.89)	38 (42.22)	34 (34.00)
	Osteoarthritis	118 (62.11)	52 (57.78)	66 (66.00)
AI Diagnosis	Normal	69 (36.32)	36 (40.00)	33 (33.00)
	Condylar flattening	31 (16.32)	13 (14.44)	18 (18.00)
	Subcortical cyst	48 (25.26)	24 (26.67)	24 (24.00)
	Surface erosion	3 (1.58)	0 (0.00)	3 (3.00)
	Osteophyte	45 (23.68)	19 (21.11)	26 (26.00)
AI Diagnosis	Normal	69 (36.32)	36 (40.00)	33 (33.00)
	Osteoarthritis	121 (63.68)	54 (60.00)	67 (67.00)
Examiner Diagnosis	Normal	79 (41.58)	40 (44.44)	39 (39.00)
	Condylar flattening	28 (14.74)	12 (13.33)	16 (16.00)
	Subcortical cyst	43 (22.63)	21 (23.33)	22 (22.00)
	Surface erosion	2 (1.05)	0 (0.00)	2 (2.00)
	Osteophyte	44 (23.16)	19 (21.11)	25 (25.00)
Examiner Diagnosis	Normal	79 (41.58)	40 (44.44)	39 (39.00)
	Osteoarthritis	111 (58.42)	50 (55.56)	61 (61.00)

Table 3. Performance measures of AI diagnostic tool for TMJ OA for all study images and by side in reference to the DC/TMD gold standard

AI diagnosis	Overall	Left side	Right side
Sensitivity	97.46%	94.23%	100.00%
Specificity	91.67%	86.84%	97.06%
PPV	95.04%	90.74%	98.51%
NPV	95.65%	91.67%	100.00%

Table 4. Performance measures of the examiner diagnostic tool for TMJ OA for all study images and by side in reference to the DC/TMD gold standard

Examiner diagnosis	Overall	Left side	Right side
Sensitivity	88.98%	86.54%	90.91%
Specificity	91.67%	86.84%	97.06%
PPV	94.59%	90.00%	98.36%
NPV	83.54%	82.50%	84.62%

Table 5. Relation between gender and diagnostic tools in all patients (N=75)

		Gender		
		Male (n=49) (N(%))	Female (n=26) (N(%))	p-value
DC/TMD Gold Standard Diagnosis	Normal	22 (44.90)	15 (57.69)	0.338
	Condylar flattening	0 (0.00)	0 (0.00)	NA
	Subcortical cyst	0 (0.00)	0 (0.00)	NA
	Surface erosion	0 (0.00)	0 (0.00)	NA
	Osteophyte	27 (55.10)	11 (42.31)	0.338
DC/TMD Gold Standard Diagnosis	Normal	22 (44.90)	15 (57.69)	0.338
	Osteoarthritis	27 (55.10)	11 (42.31)	
AI Diagnosis	Normal	19 (38.78)	14 (53.85)	0.232
	Condylar flattening	0 (0.00)	0 (0.00)	NA
	Subcortical cyst	0 (0.00)	0 (0.00)	NA
	Surface erosion	0 (0.00)	0 (0.00)	NA
	Osteophyte	30 (61.22)	12 (46.15)	0.232
AI Diagnosis	Normal	19 (38.78)	14 (53.85)	0.232
	Osteoarthritis	30 (61.22)	12 (46.15)	
Examiner Diagnosis	Normal	20 (40.82)	14 (53.85)	0.334
	Condylar flattening	0 (0.00)	0 (0.00)	NA
	Subcortical cyst	0 (0.00)	0 (0.00)	NA
	Surface erosion	0 (0.00)	0 (0.00)	NA
	Osteophyte	29 (59.18)	12 (46.15)	0.334
Examiner Diagnosis	Normal	20 (40.82)	14 (53.85)	0.334
	Osteoarthritis	29 (59.18)	12 (46.15)	

p-value was calculated using Chi-square test or Fisher exact test
p-value<0.05 was considered as statistically significant

Table 6. Relation between age and diagnostic tools (N=74)

		Valid answers	Mean ± SD	p-value
DC/TMD Gold Standard Diagnosis				
Normal	Yes	36	42.86 ± 15.81	0.055
	No	38	50.27 ± 16.27	
Condylar flattening	Yes	0		NA
	No	74	46.66 ± 16.36	
Subcortical cyst	Yes	0		NA
	No	74	46.66 ± 16.36	
Surface erosion	Yes	0		NA
	No	74	46.66 ± 16.36	
Osteophyte	Yes	38	50.27 ± 16.27	0.055
	No	36	42.86 ± 15.81	
DC/TMD Gold Standard Diagnosis	Osteoarthritis	38	50.27 ± 16.27	0.055
	Normal	36	42.86 ± 15.81	
AI Diagnosis				
Normal	Yes	32	42.74 ± 16.45	0.064
	No	42	49.65 ± 15.84	
Condylar flattening	Yes	0		NA
	No	74	46.66 ± 16.36	
Subcortical cyst	Yes	0		NA
	No	74	46.66 ± 16.36	
Surface erosion	Yes	0		NA
	No	74	46.66 ± 16.36	
Osteophyte	Yes	42	49.65 ± 15.84	0.064
	No	32	42.74 ± 16.45	
AI Diagnosis	Osteoarthritis	42	49.65 ± 15.84	0.064
	Normal	32	42.74 ± 16.45	
Examiner Diagnosis				
Normal	Yes	33	42.12 ± 16.57	0.027
	No	41	50.32 ± 15.44	
Condylar flattening	Yes	0		NA
	No	74	46.66 ± 16.36	
Subcortical cyst	Yes	0		NA
	No	74	46.66 ± 16.36	
Surface erosion	Yes	0		NA
	No	74	46.66 ± 16.36	
Osteophyte	Yes	41	50.32 ± 15.44	0.027
	No	33	42.12 ± 16.57	
Examiner Diagnosis	Osteoarthritis	41	50.32 ± 15.44	0.027
	Normal	33	42.12 ± 16.57	

p-value was calculated using Mann-Whitney test since normality assumption for age was not met
p-value<0.05 was considered as statistically significant

Table 7. Relation between age and diagnostic tools in patients who performed images for right sides (N=46

		Valid answers	Mean ± SD	p-value
DC/TMD Gold Standard Diagnosis				
Normal	Yes	21	40.61 ± 14.47	0.039
	No	25	50.78 ± 16.87	
Condylar flattening	Yes	0		NA
	No	46	46.14 ± 16.47	
Subcortical cyst	Yes	0		NA
	No	46	46.14 ± 16.47	
Surface erosion	Yes	0		NA
	No	46	46.14 ± 16.47	
Osteophyte	Yes	25	50.78 ± 16.87	0.039
	No	21	40.61 ± 14.47	
DC/TMD Gold Standard Diagnosis	Osteoarthritis	25	50.78 ± 16.87	0.039
	Normal	21	40.61 ± 14.47	
AI Diagnosis				
Normal	Yes	20	40.82 ± 14.82	0.057
	No	26	50.22 ± 16.77	
Condylar flattening	Yes	0		NA
	No	46	46.14 ± 16.47	
Subcortical cyst	Yes	0		NA
	No	46	46.14 ± 16.47	
Surface erosion	Yes	0		NA
	No	46	46.14 ± 16.47	
Osteophyte	Yes	26	50.22 ± 16.77	0.057
	No	20	40.82 ± 14.82	
AI Diagnosis	Osteoarthritis	26	50.22 ± 16.77	0.057
	Normal	20	40.82 ± 14.82	
Examiner Diagnosis				
Normal	Yes	21	39.95 ± 14.99	0.017
	No	25	51.33 ± 16.11	
Condylar flattening	Yes	0		NA
	No	46	46.14 ± 16.47	
Subcortical cyst	Yes	0		NA
	No	46	46.14 ± 16.47	
Surface erosion	Yes	0		NA
	No	46	46.14 ± 16.47	
Osteophyte	Yes	25	51.33 ± 16.11	0.017
	No	21	39.95 ± 14.99	
Examiner Diagnosis	Osteoarthritis	25	51.33 ± 16.11	0.017
	Normal	21	39.95 ± 14.99	

p-value was calculated using Mann-Whitney test since normality assumption for age was not met
p-value<0.05 was considered as statistically significant

Table 8. Relation between age and diagnostic tools in patients who performed images for left sides (N=38)

		Valid answers	Mean ± SD	p-value
DC/TMD Gold Standard Diagnosis				
Normal	Yes	23	44.97 ± 15.85	0.343
	No	15	49.96 ± 15.32	
Condylar flattening	Yes	0		NA
	No	38	46.94 ± 15.63	
Subcortical cyst	Yes	0		NA
	No	38	46.94 ± 15.63	
Surface erosion	Yes	0		NA
	No	38	46.94 ± 15.63	
Osteophyte	Yes	15	49.96 ± 15.32	0.343
	No	23	44.97 ± 15.85	
DC/TMD Gold Standard Diagnosis	Osteoarthritis	15	49.96 ± 15.32	0.343
	Normal	23	44.97 ± 15.85	
AI Diagnosis				
Normal	Yes	19	45.49 ± 16.75	0.574
	No	19	48.39 ± 14.73	
Condylar flattening	Yes	0		NA
	No	38	46.94 ± 15.63	
Subcortical cyst	Yes	0		NA
	No	38	46.94 ± 15.63	
Surface erosion	Yes	0		NA
	No	38	46.94 ± 15.63	
Osteophyte	Yes	19	48.39 ± 14.73	0.574
	No	19	45.49 ± 16.75	
AI Diagnosis	Osteoarthritis	19	48.39 ± 14.73	0.574
	Normal	19	45.49 ± 16.75	
Examiner Diagnosis				
Normal	Yes	19	45.49 ± 16.75	0.574
	No	19	48.39 ± 14.73	
Condylar flattening	Yes	0		NA
	No	38	46.94 ± 15.63	
Subcortical cyst	Yes	0		NA
	No	38	46.94 ± 15.63	
Surface erosion	Yes	0		NA
	No	38	46.94 ± 15.63	
Osteophyte	Yes	19	48.39 ± 14.73	0.574
	No	19	45.49 ± 16.75	
Examiner Diagnosis	Osteoarthritis	19	48.39 ± 14.73	0.574
	Normal	19	45.49 ± 16.75	

p-value was calculated using Student t-test since normality assumption for age was met
p-value<0.05 was considered as statistically significant

Discussion

TMJ OA is a common condition, but its exact prevalence is hard to identify as many patients can be asymptomatic [27]. Also, it is clinically challenging to differentiate TMJ OA from other TMDs and early detection is crucial for the implementation of the appropriate prevention [28]. In this study, we relied on 3 diagnostic tools to determine the prevalence of TMJ OA among 132 patients admitted to the Oral Diagnosis and Urgent Care Clinic at the University Dental Hospital Sharjah, UAE, who performed 190 CBCT images. Of those, 52.63% of the images were performed for the right side. According to the DC/TMD gold standard diagnosis, the prevalence of TMJ OA was 62.11%, with the most common sign of pre-existent condylar damage being subcortical cysts (25.26%). The prevalence was higher (63.68%) using the AI model, yet lower (58.42%) when assessed by the examiner. Abrahamsson et al. reported a prevalence of 67% for TMJ OA based on CBCT findings in hand OA patients [29]. It has been reported that similar to other TMDs and OA of other joints, TMJ OA is twice more prevalent in females than in males [2, 30]. This is largely attributed to Estrogen Receptor alpha polymorphism and is possibly related to higher pain susceptibility in female TMJ OA patients [31].

Our findings illustrate that the AI model's performance was comparable to the DC/TMD gold standard in recognizing TMJ OA, especially with a 100% specificity and NPV for diagnosing right-side CBCT images. However, the AI model's performance was less reliable when assessing left-side images, which proposes the need for further optimization of the diagnostic algorithm. Despite this, the AI model outflanked the examiner in ruling out TMJ OA based on structural changes. These discoveries show that while the AI model shows promise in helping TMJ OA diagnosis, it isn't without limitations and requires change to guarantee reliable accuracy over all CBCT images. Imperatively, the AI model did not completely replace the clinical skill of the radiologist, especially given the multidisciplinary nature of TMJ OA determination, which incorporates clinical evaluations and consideration of the patient's psychological status.

In our study, 65.33% of the studied patients were males, of these 55.10% were diagnosed with TMJ OA. Of the females, 42.31% were diagnosed with TMJ OA. Those prevalence values were obtained using the DC/TMD gold standard diagnosis. Prevalence of TMJ OA and signs of pre-existent condylar damage did not vary based on gender in any of the diagnostic tools used in our study. This does not comply with the general trend of higher prevalence in females, but the reason could be the small sample size (75 patients with data regarding gender) in our study and the unequal number of male and female patients. A larger pool of patients is needed for a better evaluation of TMJ OA prevalence across gender.

The mean age of the studied 74 patients was 46.67±16.36 years, and the age range was 13-75 years. Following the DC/TMD gold standard diagnosis, 38 out of the 74 patients were diagnosed with TMJ OA. It has been documented that TMJ OA not only affects adults, but adolescents too, and that its prevalence increases with age [32, 33]. Izawa et al. reported TMJ OA prevalence of 25% in patients aging between 20 and 49 years and as high as 70% in those aging between 73 and 75 years [34]. In our study, a similar positive correlation between TMJ OA diagnosis and age was reported. Patients diagnosed with TMJ OA using overall images following the examiner diagnosis were significantly older than those who were normal for OA (50.32±15.44 years versus 42.12±16.57 years, respectively; p-value=0.027). The same was observed with CBCT images of the right side (51.33±16.11 years versus 39.95±14.99 years, respectively; p-value=0.017). Patients diagnosed with TMJ OA using CBCT images of the right side and following the DC/TMD gold standard diagnosis were significantly older than normal patients (50.78±16.87 versus 40.61±14.47 years, respectively; p-value=0.039). However, no such correlation was observed when assessing images using the AI model. This can also be attributed to the small sample size.

The AI model showed high potential in the assessment of CBCT records and in diagnosing TMJ OA. When compared to the gold standard, it showed 100% specificity and 100% NPV for the diagnosis of the CBCT images at the right side, thus mimicking the gold standard as it was able to correctly detect all normal cases as being non-TMJ OA cases. Yet, lower performance measures were calculated for the AI model in assessing CBCT images of the left side. This signifies the need for the optimization of the AI model diagnostic algorithm to enhance its diagnostic performance measures and accuracy. In our previous study [25], we found that the developed AI model matched the diagnostic performance of the human expert in diagnosing TMJ OA. Here on the other hand, we found that it was better in ruling out TMJ OA when assessing CBCT images based on the evaluation of the osseous and structural changes. However, the diagnosis of TMJ OA is multidisciplinary due to its complex pathology and structure [12]. Thus, assessment cannot just rely on CBCT findings; rather, it entails clinical assessments of the symptoms along with the evaluation of the psychological status and behaviors of the patient. The AI model has limitations in this regard and cannot replace completely the human examiner. It is anticipated that AI will not replace physicians but will support them by performing routine parts of their work, granting physicians more time with their patients to improve their human touch [35]. Patients may have concerns regarding the privacy of their medical records, and this should be addressed for future applications. Studies are limited regarding the incorporation of AI models in the diagnosis of TMJ OA in specific and OA in general. Bianchi et al. developed a machine learning model for the early diagnosis of TMJ OA using biomarkers, but this study was based on a cross-sectional design that does not permit the evaluation of disease stages and how they affect the biomarkers [36]. Thus, although the AI model shows great potential, its limitations must be acknowledged. The model's inconsistent performance between right and left-side CBCT images highlights the need for further development. Additionally, the AI model currently lacks the capability to assess clinical symptoms and patient behavior, which are crucial in TMJ OA diagnosis. Future research should focus on integrating AI with clinical assessment tools to create a more comprehensive diagnostic approach. Moreover, while AI can significantly reduce the workload of clinicians by handling routine diagnostics, it should be viewed as a complementary tool rather than a replacement for human expertise.

The study's null hypothesis, which set that there would be no difference within the diagnostic performance of the AI model, the gold standard, and the radiologist, was partially rejected. Whereas the AI model demonstrated high specificity, especially for right-side images, it showed inconstancy in performance compared to the gold standard and the radiologist, demonstrating that it cannot yet completely replace human expertise in TMJ OA determination. These results emphasize the significance of further refinement of AI models to improve their symptomatic consistency over distinctive conditions and imaging scenarios.

Clinically, these discoveries propose that while AI can improve diagnostic precision and effectiveness, especially in imaging, it should be utilized in conjunction with conventional diagnostic strategies to guarantee comprehensive patient care. The AI model might serve as a valuable support tool in clinical settings, possibly decreasing diagnostic time and changeability, but clinicians must stay involved within the diagnostic process to supply multifaceted care that considers the multidimensional nature of TMJ OA. Future research ought to aim to improve AI diagnostic algorithms and investigate how AI can best be integrated into routine clinical practice to support, instead of replace, clinicians.

Conclusion

While the practice of medicine is advancing significantly with the integration of AI methods and machine learning, the role of clinical practitioners remains crucial in the diagnosis of complex diseases such as TMJ OA. Healthcare providers offer a comprehensive evaluation that encompasses clinical, psychological, physical, and mental assessments, which AI alone cannot achieve. Our study demonstrates that while the AI model shows promise in diagnosing TMJ OA, particularly in enhancing diagnostic efficiency and consistency, it should be viewed as a supportive tool rather than a replacement for human expertise.

Key insights incorporate the AI model's high specificity in recognizing TMJ OA in certain scenarios, though it exhibited changeability in execution depending on the imaging side. These discoveries recommend that AI can complement, but not supplant, traditional diagnostic strategies. Clinically, the integration of AI into diagnostic workflows could decrease variability and help in early detection, but clinicians must stay actively involved to guarantee comprehensive care. Future research ought to center on refining AI algorithms to address current limitations and investigating the integration of AI with clinical evaluation tools. This study highlights the need for ongoing evaluation of AI's role in restorative practice and its potential impact on understanding demographics and results.

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