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ORIGINAL ARTICLE

Temporomandibular joint in juvenile idiopathic arthritis: magnetic resonance imaging measurements and their correlation with imaging findings

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Abstract

Objective The aim of this study was to investigate the TMJ components in patients with juvenile idiopathic arthritis (JIA) and to compare them with a control group based on magnetic resonance imaging (MRI) measurements.

Methods This study comprised an assessment of MRI measurements of 96 temporomandibular joints (TMJ) following classification criteria set by the International League of Associations for Rheumatology (ILAR). Three measurements were considered for study: condyle excursion angle (CEA), height of articular eminence (HAE) and inclination of articular eminence (IAE). All TMJs were assessed by linear measurements made by using the OnDemand 3D software. The comparison between the groups was performed by using Mann–Whitney's test.

Results Lower measurement values were found for IAE, HAE and CEA in JIA patients (P-values < 0.001, 0.005 and < 0.001, respectively).

Conclusion The study showed the differences in MRI measurements between JIA patients and controls, with the former with the lowest indices.

Keywords Head and neck · Osteoarthritis · Temporomandibular joint assessment · Magnetic resonance imaging · Synovitis

Introduction

Juvenile idiopathic arthritis (JIA) is a broad term that refers to a clinical heterogeneous group of unknown cause conditions with onset before the age of 16 years old [1, 2]. The etiology and pathogenesis of JIA are still poorly understood. It is considered a multifactorial disease, in which genetically predisposed individuals can develop the disease depending on environmental, immunological and hormonal disease [3]. Therefore, genetically susceptible individuals with JIA stimulated by environmental factors and mediated by the immune system can trigger an inflammatory response and develop the pathology [4].

Temporomandibular joint (TMJ) is affected by arthritis in 40–96% of the cases of JIA. Children with JIA have a higher prevalence of jaw dysfunction and neck pain than the healthy ones. Considering that TMJ abnormalities have been associated with a significant morbidity in JIA patients, an increased interest has arisen regarding their pathological aspects for clinical guidance [5, 6].

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The bony changes on the TMJ in JIA patients range from small bone erosions to complete destruction of the condyle. This involvement appears to be asymmetric in the early stages, but changes tend to become symmetric as the disease progresses [7].

The accurate assessment of pathological TMJ is considerably challenging because it is clinically hindered by the low sensitivity of joint pain and poor detection of arthritic sequelae with computed tomography and plain radiography [8]. Magnetic resonance imaging (MRI) remains as the gold standard diagnostic method, providing high precision visualization of anatomical details without exposing the patient to ionizing radiation or biological risks. Therefore, MRI is the complementary exam of choice for diagnosis of temporomandibular disorders, in which it is possible to visualize the morphology of the disc in sections taken in the sagittal, axial and coronal planes, including its adjacent structures [9, 10]. MRI is essential for visualization of joint structures and presence of bone marrow edema, effusion, synovitis, condylar flattening and erosions [10].

It was observed that during clinical examinations, the patients did not complain of TMJ pain or discomfort and there was neither a clinical correlation with MRI findings. This highlighted the need for usefulness of MRI for early detection of TMJ dysfunctions to avoid irreversible orofacial changes [11].

Recent studies revealed subtle findings regarding MRI scan data. Stoll and colleagues [6] pointed out that MRI scans of non-arthritic children showed presence of joint effusion, a condition consistent with TMJ arthritis. This fact has led to efforts to identify features which can improve differentiation between mild TMJ arthritis and normal TMJs or to establish reference measurements for pathological TMJs, since there might be imaging similarities regardless of the JIA condition [6].

The mandibular growth is particularly vulnerable to arthritis changes, eventually resulting in retrognathia and facial asymmetry. This happens because the primary growth center of the mandible is located in the condyle [12]. Studies have already demonstrated the correlation between facial asymmetry and emotional and physiological distress [13], highlighting once again the multidisciplinary aspects of this theme. Considering this, it is important to develop means to improve the diagnosis of TMJ arthritis for a more proper treatment guidance, especially because there are few prospective data on medical therapy regarding TMJ. Retrospective studies have suggested that TMJ response to medical therapy may lag behind that of other joints, thus leading to the use of intra-articular (IA) therapy [12]. Therefore, an accurate diagnosis may provide an early effective treatment for JIA patients, aiding to increase their quality of life.

Previous studies have indicated that some specific measurements of TMJ components have relationships with clinical and imaging diagnosis of the joint [14, 15]. Changes in the condyle lengths reflect either mandibular growth or pathological processes [16, 17].

Therefore, the study of morphometric values in imaging exams can be valuable and the principal benefits of measurements in MRI for assessing the target structures is a well-defined image of the hard and soft tissues [14, 18]. Standard measures of the joint can help to understand the disease progress and subsequently to establish of successful of the treatment strategies, following the condition of the joint and quantitatively evaluating the pathological changes.

The aim of this study was to assess measurements of TMJ, namely, condyle excursion angle (CEA), height of articular eminence (HAE) and inclination of the articular eminence (IAE) in JIA patients by means of MRI and compare them with a healthy control group to propose standardized measurements for these patients.

Materials and methods

This study was approved by the local institutional review board according to protocol number 1607783 and is in accordance with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. All subjects and their parents or caretakers signed an informed consent form.

Study population

This retrospective study was carried out with the aid of MRI images of 24 JIA patients aged between 7 and 19 years old, with a sample consisting of four males and 20 females. The patients were diagnosed according to the International League Association for Rheumatology (ILAR) criteria [19]. This classification identifies seven JIA subtypes according to clinical and biochemical markers: enthesitis-related arthritis; oligoarthritis; Rheumatoid-factor-negative polyarthritis; Rheumatoid factor-positive polyarthritis; Psoriatic arthritis; systemic arthritis and undifferentiated.

All MRI images were acquired between July 2016 and October 2017. The disease onset occurred before the age of 16 and the patients were followed up at the pediatric rheumatology outpatient clinic of the State University of Campinas (UNICAMP) Clinic Hospital.

The patients had an average time of 6 years from the diagnosis of JIA to MRI scan. In the evaluation period, all the patients were with clinical remission off medication.

All information regarding personal data, age and diagnosis were carefully reviewed from medical records. The healthy control group consisted of 24 volunteers (9 males and 15 females) with no history of autoimmune disease in the family, undergoing routine dental treatment at the dental clinic of Dental Department of Clinic Hospital, and matched by age and socioeconomic status.

The inclusion criteria were the following: patients diagnosed with JIA according to the criteria established by the ILAR and routinely followed up at the pediatric rheumatology outpatient clinic of the UNICAMP Clinic Hospital, patients with disease onset age ≤ 16 years for JIA, and patients who had at least 6 months of follow-up.

The following exclusion criteria were used: presence of congenital/acquired facial anomalies, the history of fractures or trauma to the TMJ, orthodontic treatment in the last 12 months and movement artifact.

Clinical diagnosis of TMJ

The subjects participated in a standardized clinical examination [20] performed by a TMJ specialist with 18 years of experience in TMJ pathology. The examination consisted of an evaluation of mandibular range of motion, pain on assisted mandibular opening, presence or absence of joint sounds, joint and muscle pain on palpation.

MRI acquisition

All individuals underwent standard MRI for TMJ evaluation by using a 1.5-T MRI scanner (Signa CV/I Achieva, Philips Medical Systems, Best, The Netherlands) with bi-specific, 3-inch diameter flexible coils. Parasagittal images were obtained in occlusal position and mouth opening position in proton density-weighted sequence (RT = 1880 ms, TE = 25 ms) with thicknesses of 2.5 mm and field of view (FOV) of 100 mm in an array of 168 × 156 pixels. T2 weighted (TR = 2290 ms, TE = 50 ms) sequence was obtained in the sagittal plane with thicknesses of 2.5 mm and FOV of 100 mm in an array of 168 × 156 pixels, only closed-mouth views were obtained. The files were recorded on CD in Digital Imaging and Communication in Medicine (DICOM) format.

Two oral radiologists (investigators 1 and 2) with a 15-year experience in evaluating MRI scans of TMJ, reviewed and performed in consensus all the diagnoses by using the previously established criteria [21]: using sagittal images in proton density-weighted sequence in closed and open mouth position to evaluate disc reduction; joint effusion was identified as an area of high signal intensity in the region of the upper and lower joint spaces on T2 weighted images; bone marrow edema was described as a lesion within the trabecular bone with poorly defined margins and signal appearance of increased water content on T2 weighted images.

The exclusion criteria were the following: impaired visualization of the temporal and masseter muscles and condyle; impaired visualization of details; low sharpness images resulting from patient movement during scanning and presence of metallic prostheses and accessories.

Image analysis

All MRI images were viewed on a 17-inch LCD monitor under dim light conditions in a quiet room. In total, 96 TMJs were assessed in occlusal and maximum mouth opening positions in which linear measurements were performed with the software OnDemand 3D Dental, version 1.0. (www.ondemand3d.com).

The linear measurements were performed in the parasagittal plane in proton density-weighted sequence for selection of the most central slice. The occlusal position was used as reference to determine the height of articular eminence (HAE) and inclination of articular eminence (IAE). Condyle excursion angle (CEA) was determined by subtracting the angle formed by the glenoid fossa, articular eminence and condyle in occlusal position from that formed by the maximum mouth opening position in the parasagittal slices.

The linear measurements were performed by a trained oral radiologist (investigator 3, with 6 years of MRI experience of TMJ) according to parameters adapted from Rabelo et al. [14]:

HAE

To obtain the value of HAE, a rectangle was drawn by tracing an upper line to the deepest point of the glenoid fossa in parallel to the Frankfurt horizontal plane and a lower line to the protruding point of the articular eminence. From this rectangle, another independent line was tangentially drawn from the deepest point of the glenoid fossa to the most protruding point of the articular eminence. The distance in millimeters between the two horizontal lines of the rectangle corresponds to the value of HAE (Fig. 1).

IAE

From the rectangle drawn to determine the HAE, a tangent line was drawn from the deepest point of the glenoid fossa to the most protruding point of the articular eminence, reaching the outermost part of the posterior inclination of the articular eminence. The angle formed by the intersection between eminence-fossa line and lower line of the rectangle was used to determine the value of IAE (Fig. 1).

CEA

This measurement was based on the angle formed by glenoid fossa, articular eminence and condyle in occlusal and maximum mouth opening positions. To measure this angle, three landmarks were determined:

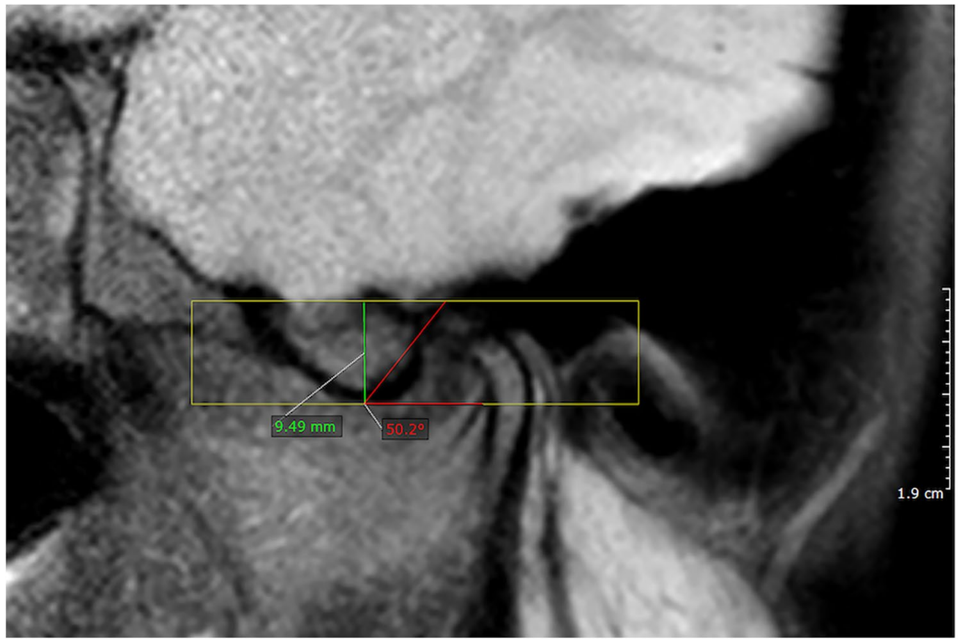


Fig. 1 The distance (in millimeters) between the two horizontal lines of the rectangle (yellow color) corresponds to the value of the height of articular eminence (HAE) (green color). The angle formed by the intersection between the eminence-fossa line and lower line of the rectangle was used to determine the value of the inclination of articular eminence (IAE) (red color)

1. The deepest point of the glenoid fossa.
2. The most prominent point of the articular eminence.
3. The most superior point of the condyle (condyle apex) from the rectangle made for determination of HAE and IAE.

The value of CEA was obtained by subtracting the angle in occlusion position from the angle in maximum mouth opening position (Figs. 2, 3).

The same investigator repeated all of the measurements 15 days after the first evaluation to assess the intraclass correlation coefficient (ICC).

Statistical analysis

Exploratory data analysis was performed by using summary measurements. The comparison between the groups regarding age was performed by using Student *t*-test, whereas Fisher's exact test was used to determine associations between categorical variables. ANOVA models were used with rank transformation for repeated measurements to compare the groups regarding numerical variables measured on the right and left sides.

Non-parametric methods were used in the analysis because some of the variables did not have normal distribution. Statistical analysis was performed by using the R software, version 3.6.0. (The R Foundation for Statistical Computing) at a significance level of 5%.

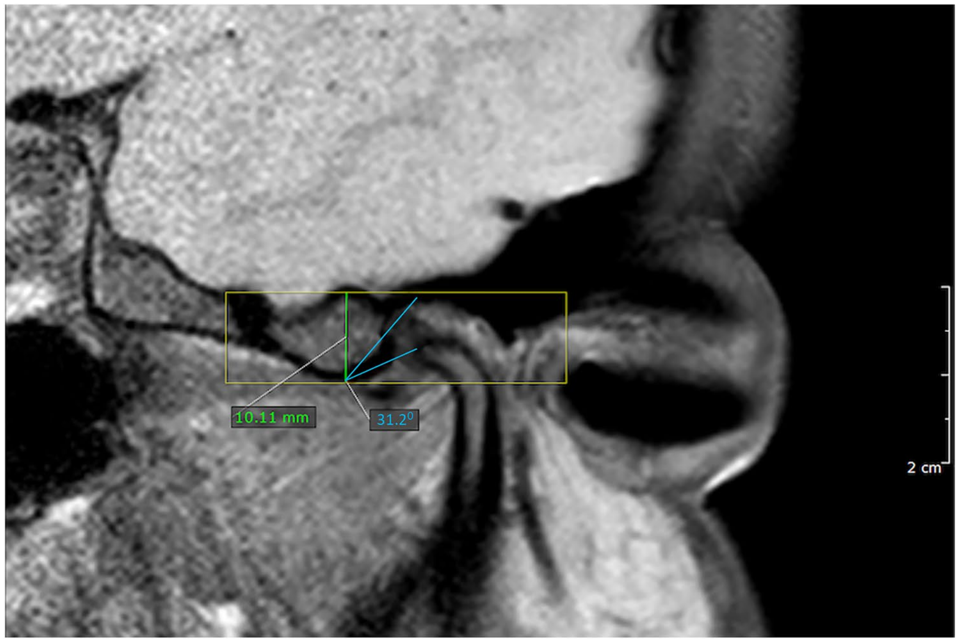
Results

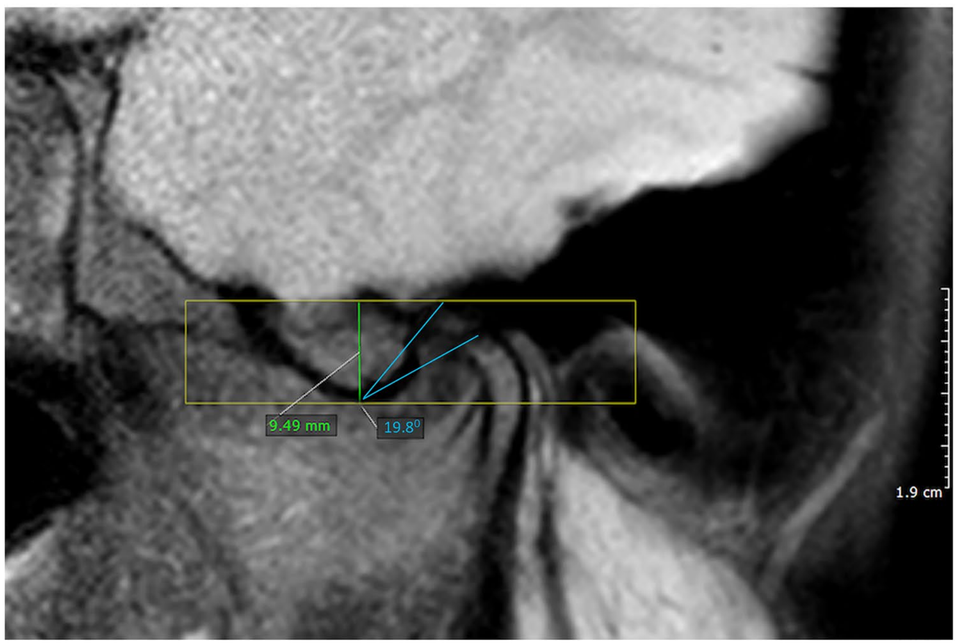
The mean ages of the patients and healthy controls were, respectively, 12 and 13.5 years old. The intra-observer ICC (Table 1) showed a high concordance between the measurements in different assessment (0.99–1.00).

The two groups are homogeneous in terms of age (*P*-value = 0.333) and gender (*P*-value = 0.194). The age of diagnosis in the JIA group ranged between 2 and 11 years, with a mean of 5.5 years and standard deviation of 2.3 years. These results are shown in Table 2.

In patients group, there were statistically significant differences between mandibular range of motion and HAE (*P*-values = 0.0491) and IAE (*P*-values = 0.0061). There was statistical correlation between pain on assisted mandibular opening and HAE (*P*-values = 0.0202) and IAE (*P*-values = 0.0310) No significant differences were observed in joint sounds, joint and muscle pain on palpation and measurements HAE, IAE and CEA.

The variables HAE, IAE and CEA were measured on the right and left sides in the comparison of the groups, whereas ANOVA was used for repeated measurements. There was no significant relationship between side and group for these three measurements (*P*-values = 0.785, 0.210, 0.238 for HAE, IAE and CEA, respectively), showing that the differences between groups are independent of differences between sides. Moreover, if there is a difference between the groups for one side of the mouth,





Figs. 2, 3 Measurement of the condyle excursion angle (CEA) (blue color) was based on the angle formed by glenoid fossa, articular eminence and condyle in occlusal and maximum mouth opening positions. To measure this angle, three landmarks were determined (i.e. the deepest point of the glenoid fossa, the most prominent point of the articular eminence and the most superior point of the condyle—condyle apex) from the rectangle made for determination of the height of articular eminence (HAE) and the inclination of articular eminence (IAE). The value of CEA was obtained by subtracting the angle in occlusal view from the angle in maximum mouth opening position

there is also a difference on the other. It was observed that the JIA individuals have lower values, on average, of HAE (*P*-value < 0.001), IAE (*P*-value = 0.005) and CEA (*P*-value < 0.001).

It was observed that JIA individuals had more bone marrow edema (*P*-value < 0.001), more bilateral bone marrow edema (p-value = 0.049) and more effusion (*P*-value = 0.007).

Discussion

The TMJ bone changes accompanying that accompany JIA range from small bone erosions to complete destruction of the condyle [12, 22]. This involvement appears to be asymmetric in the early stages, but the changes tend to become symmetric as the disease progresses [23–26]. Generally,

Table 1 Analysis agreement between the measurements

Variable	Assessment	Mean	SD	Median	ICC (IC 95%)
HAE (left)	1	9.41	1.48	9.90	0.99 (0.995;0.99)
	2	9.41	1.53	10.00	
HAE (right)	1	9.03	1.48	8.91	1.00 (0.99; 1.00)
	2	9.05	1.49	8.93	
IAE (left)	1	40.69	5.58	41.40	1.00 (1.00; 1.00)
	2	40.73	5.59	41.40	
IAE (right)	1	43.59	7.32	41.20	0.99 (0.998; 1.00)
	2	43.63	7.45	41.30	
CEA (left)	1	7.98	4.89	9.70	1.00 (1.00; 1.00)
	2	7.99	4.89	9.73	
CEA (right)	1	5.42	6.49	2.80	1.00 (1.00; 1.00)
	2	5.43	6.50	2.80	

HAE height of articular eminence; *IAE* inclination of articular eminence; *CEA* condyle excursion angle; *SD* standard deviation

Assessment: 1 = first measurements; 2 = second measurements

the characteristic facial morphology of these patients is associated with destruction of the condyle [25, 26].

Despite these morbidities, TMJ arthritis remains one of the least diagnosed and treated conditions in in patients with JIA [23, 27]. The absence of symptoms and the inherent difficulties in examining this joint generally lead to a delay in the diagnosis, allowing for a progression of inflammatory damage to the growing condyle [27, 28].

It is estimated that 40–60% of the children with JIA will continue to have it into adulthood, resulting in progressive and irreversible joint destruction, as 11–39% of the JIA patients are significantly debilitated [29].

This study highlights the statistically significant differences regarding variations in the measurements of HAE, IAE and CEA and their association with imaging signs of JIA. As studies showed that MRI findings in TMJ arthritis can also be found in non-arthritic children [6], the measurements of HAE, IAE and CEA may be an additional way to characterize TMJ abnormalities.

The results found here demonstrate that the strategic measurements of TMJ structures, specifically the angle formed by the intersection between eminence-fossa line and lower line of the rectangle (Fig. 1), can help differentiate the TMJ functionality caused by JIA. These impairments may

Table 2 Comparison between JIA patients and healthy controls regarding MRI parameters and imaging findings

Variable	Control (*N* = 24)		JIA patients (*N* = 24)		*P*-value
	Mean (SD) or *N* (%)	Median [min; max]	Median (SD) or N (%)	Median [min; max]	
Age	12.7 (2.71)	12.0 [9.00;18.0]	13.7 (3.95)	13.5 [7.00;19.0]	0.333
Gender					0.194
Female	15 (62.5%)		20 (83.3%)		
Male	9 (37.5%)		4 (16.7%)		
HAE (left)	11.9 (0.69)	11.8 [10.8;12.8]	9.05 (1.55)	8.91 [5.40;11.2]	**< 0.001**
HAE (right)	11.4 (1.00)	11.1 [10.2;13.6]	8.73 (1.78)	9.04 [3.89;12.5]	
IAE (left)	46.0 (3.20)	46.8 [39.7;50.6]	41.4 (6.38)	43.2 [24.6;53.3]	**0.005**
IAE (right)	44.4 (4.34)	42.7 [39.8;53.9]	42.7 (6.92)	40.8 [30.5;56.5]	
CEA (left)	16.5 (0.84)	16.3 [14.9;18.2]	9.86 (4.69)	11.2 [−0.40;15.1]	**< 0.001**
CEA (right)	16.7 (0.99)	16.8 [14.6;18.5]	8.10 (6.23)	11.1 [−3.40;15.7]	
Bone marrow edema					**< 0.001**
No	24 (100%)		11 (45.8%)		
Yes	0 (0.00%)		13 (54.2%)		
Bilateral bone marrow edema					**0.049**
No	24 (100%)		19 (79.2%)		
Yes	0 (0.00%)		5 (20.8%)		
Effusion					**0.007**
No	20 (83.3%)		10 (41.7%)		
Yes	4 (16.7%)		14 (58.3%)		
Bilateral effusion					1.000
No	21 (87.5%)		20 (83.3%)		
Yes	3 (12.5%)		4 (16.7%)		

JIA juvenile idiopathic arthritis; *MRI* magnetic resonance imaging; *HAE* height of articular eminence; *IAE* inclination of articular eminence; *CEA* condyle excursion angle; *SD* standard deviation

Significant *P*-values are indicated in bold be caused by condyle deformation in TMJ arthritis. All the measurements parameters were smaller when compared to the control group showing the tissue degeneration caused by disease progression.

Therefore, linear measurements obtained from the analysis of these variables serve as an additional differential method, including serving as an indicator of a need for specific treatment.

In previous studies, the authors emphasized that the treatment of JIA is focused on controlling the active inflammation to prevent further joint damage [15]. By preventing joint damage, it is possible to preserve a normal mandibular growth. The results of this study propose that measurements of HAE, IAE and CEA in the articular eminence of TMJ can serve as a method to increase the awareness of its potential involvement in JIA patients as these variables are significantly different from those of healthy individuals.

In this work, bone marrow edema was found at a higher frequency in JIA patients (45.8%) compared to other studies (i.e. 12–21%) [30, 31]. With regard to bone marrow edema, the results are in accordance with Kellemberg et al. [15], who reported a substantially higher frequency for it. According to their study, only bone marrow edema was less common in patients with anterior disc displacement compared to those with JIA. This fact reinforces the need for reliable differential diagnostic criteria.

The importance of TMJ measurements was also shown in a recent study, in which glenoid fossa depth and inclination angle were within the normal range (i.e. 90%) in individuals with disc displacement, but below the normal range (72–50%) in JIA patients [15].

Moreover, this work provides an important insight into a possible standardization of measurements in JIA patients, which can contribute to a framework for further studies. Imaging protocols and standardized examination contribute to establishing an early intervention strategy, besides providing additional information on craniofacial growth and progression of signs and symptoms in patients suffering from TMJ arthritis [32].

The development of a standardized protocol to differentiate ordinary TMJ impairments from TMJ arthritis caused by JIA is fundamental for a primary diagnosis. As emphasized by some authors [33, 34], JIA patients may have no painful symptoms. In addition, TMJ injuries may be the first or even the only sign of JIA, which reinforces the need for an accurate differential diagnosis for treatment guidance.

This study has shown a significant difference between JIA patients and healthy controls regarding bone marrow edema (P-value < 0.001) and effusion (P-value < 0.007). These results are similar to those found by Hemke et al. [35], who showed that these two imaging findings are related to condylar deterioration. Abramowics et al. [36] reported that joint effusion is an indicator of abnormal condyle morphology and one of the most common side effects in JIA patients, which concurs with the results here.

It was noted that there was a positive correlation between HAE and IAE mandibular range of motion and pain on assisted mandibular opening in patients group. Rabelo et al. [14] reported that IAE can have an impact in the range of the condyle's excursion movement. Subjects with accentuated articular eminences has wider condyle/disc movement during function, and this amplified movement can lead to higher risk of temporomandibular disorders [14, 18].

A limitation of the study is MRI slice selection. The selection of MRI slice for the measurements depends on imaging experience of the operator. In general the central slice, the largest diameter of the condyle, is chosen. However, if the operator chooses more anterior or posterior slices, the measurements will be altered.

Conclusion

This study has revealed a significant difference between metric measurements of the condyle of JIA patients and healthy controls. The HAE, IAE and CEA parameters are valuable tools and may allow a more targeted diagnostic in TMJ of JIA patients.

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Declarations

Conflict of interest All authors of this work declare no conflict of interest.

Ethics approval The study was approved by the Institutional Review Board of UNICAMP, according to protocol number 2.093.884. All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008.

Informed consent Written informed consent was obtained from the guardian of each participant, after informed about the study. Informed consent was obtained from all patients for being included in the study.

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