RESEARCH ARTICLE

Temporomandibular joint involvement in childhood arthritis: comparison of ultrasonography-assessed capsular width and MRI-assessed synovitis

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Objectives: Ultrasonography is an effective, low-cost, low-threshold and convenient diagnostic tool in childhood arthritis, but its value in temporomandibular joint (TMJ) involvement is not clear. The purpose of our study was to explore the reliability of ultrasonography to assess TMJ inflammation using contrast-enhanced MRI as reference standard, in order to deduce cut-off values for TMJ capsular width to detect enhanced synovial thickening (synovitis).

Methods: 124 ultrasonography and MRI examinations in 55 patients [mean age 12.4 ± 3.5 years ($\pm$ standard deviation)], the majority obtained within 1 day, were scored for subcondylar and condylar capsular width (ultrasonography images) and amount of synovitis (MR images). The correlations of these findings were calculated. A receiver operating characteristic (ROC) curve analysis, with MRI findings as reference standard, was obtained.

Results: The correlation between ultrasonography-assessed capsular width and MRI-assessed amount of synovitis was moderate both at the subcondylar and condylar level [Spearman's ρ (ρ): 0.483; $p < 0.001$ and 0.347; $p < 0.001$ respectively]. The ROC curve indicated the best discriminatory ability at the subcondylar level with an area under the curve of 0.77 (95% confidence interval 0.69–0.85) and a cut-off value of 1.2 mm (sensitivity 72%, specificity 70%) for the capsular width.

Conclusions: A moderate correlation between ultrasonography-assessed capsular width and MRI-assessed synovitis was found in childhood arthritis with the best discriminatory ability at the subcondylar level. This indicates that ultrasonography may be a valuable diagnostic tool in the initial assessment of TMJ inflammation.

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Introduction

The temporomandibular joint (TMJ) may be involved in juvenile idiopathic arthritis (JIA) and a number of

rare paediatric rheumatic diseases such as juvenile dermatomyositis, mixed connective tissue disease, scleroderma, Sjögren syndrome and systemic lupus erythematosus.^{1–5} It is generally accepted that diagnostic imaging is necessary to assess the inflammatory activity in this joint, and MRI has proved particularly valuable

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for this purpose.^{6–9} However, the method is expensive, is time consuming and may require the use of an intravenous contrast medium. Additionally, general anaesthesia may be necessary in young patients. Children with silent TMJ arthritis will therefore rarely be examined by MRI. Thus, it would be valuable in the clinical management of these young patients to have a more convenient and fast method to assess TMJ inflammation. Ultrasonography is routinely used to assess inflammation in a large number of paediatric joints,¹⁰ but its value in the assessment of TMJ arthritis has been seriously questioned.^{9,11} However, a previous study using ultrasonography to assess destructive TMJ changes and disc dislocations in children with JIA concluded that the method “was interesting for use as a diagnostic screening method”.¹² TMJ effusion/synovitis was, however, not investigated. A more recent study concluded that ultrasonography could become “one of the leading instruments” for the evaluation of TMJ involvement in JIA.¹³ In adults, ultrasonography of other TMJ-related diagnoses, mostly disc displacement and degenerative joint disease, have been promising.^{14,15}

The purpose of our study was to explore the ability of ultrasonography to detect inflammatory activity in the TMJ in children with rheumatic disease compared with MRI.

Methods and materials

This study was approved as a quality study by the Data Protection Officer at Oslo University Hospital representing the ethical committee in quality assurance studies. From our picture archiving and communication system, ultrasonography and MRI examinations of TMJs, obtained within 1 week, were collected. The patients, younger than 18 years, had been referred from the Department of Rheumatology at Oslo University Hospital during the period 2005–12. The reasons for referral to diagnostic imaging were symptoms or clinical findings suspicious of TMJ arthritis.

55 patients (13 boys) were included. There was no control group. 7 patients had 2 sets of examinations, thus 62 ultrasonography and MRI examinations were studied. 53 (85%) of the 62 ultrasonography and MRI examinations were performed within 1 day.

Chart reviews were performed, and the patients with JIA were classified according to the criteria of the International League of Associations for Rheumatology for JIA.¹⁶ Laboratory test results, the number of active joints and medication were registered. Assessments of active joints were carried out using the 71-joint count where active joints were defined as swollen joints, or mobility restricted plus tender or painful joints.¹⁷ The patients' characteristics at the time of the examinations are shown in Table 1.

Ultrasonography examinations were performed on Philips HDI 5000 (Philips, Eindhoven, Netherlands), Philips iU22 (Philips) or Siemens S3000™ (Siemens,

Table 1 Clinical characteristics of 55 children with rheumatic disease at the time of the MRI and ultrasonography examination of their temporomandibular joints (TMJs)

Variable	Values
Age at examination, years, mean $\pm$ SD (range)	12.4 $\pm$ 3.5 (5–17)
Males (%)	13 (24)
Age at symptom onset, years, mean $\pm$ SD (range)	5.9 $\pm$ 4.8 (0–16)
Age at disease onset; doctor's diagnosis, years, mean $\pm$ SD (range)	6.7 $\pm$ 5.0 (0–16)
Disease duration, months, mean $\pm$ SD (range)	71 $\pm$ 59 (14–110,5)
ESR (mm h ⁻¹ , reference value: 3–16), mean $\pm$ SD (range)	11 $\pm$ 11 (2–66)
CRP (mg dl ⁻¹ , reference value: <5), mean $\pm$ SD (range)	4 $\pm$ 8 (1–43)
Number of active joints ^a ; median (IQR) (range)	2 (0–4) (0–28)
Number of active joints with LROM, median (IQR) (range)	2 (1–4) (0–21)
Number of patients on medication (%)	46 (84)
NSAIDs	16 (29)
DMARDs	35 (64)
Prednisolone	5 (9)
Biological medication	18 (33)
JIA, ILAR subtypes	48
Systemic arthritis	1
Oligoarthritis, persistent	19
Oligoarthritis, extended	2
Polyarthritis, rheumatoid factor negative	16
Polyarthritis, rheumatoid factor positive	5
Psoriasis arthritis	1
Enthesitis-related arthritis	2
Undifferentiated arthritis	2
Other paediatric inflammatory rheumatic diseases	7
Juvenile dermatomyositis	1
Mixed connective tissue disease	3
Scleroderma	1
Sjögren's syndrome	1
Systemic lupus erythematosus	1

CRP, C-reactive protein; DMARDs, disease-modifying anti-rheumatic drugs; ESR, erythrocyte sedimentation rate; ILAR, International League of Associations for Rheumatology classifications;¹⁶ IQR, interquartile range; JIA, juvenile idiopathic arthritis; LROM, limited range of motion; NSAIDs, non-steroidal anti-inflammatory drugs; SD, standard deviation.

^aActive joints were swollen joints, or mobility restricted plus tender or painful joints.¹⁷

Erlangen, Germany) with high-frequency linear probes (12–18 MHz). Two experienced musculoskeletal radiologists (EK and RBG), aware of age and gender, analyzed the ultrasonography images separately, blinded to the MRI observations. 25 cases were reassessed by the same two observers for evaluation of intraobserver variation. The data set was selected randomly and was not fully balanced but included all findings. Only the scoring of one of the radiologists (EK) was used in further analysis. As part of our routine examination, a standardized longitudinal (oblique coronal) ultrasonography image of the TMJ with closed mouth was obtained. This image was retrospectively evaluated, and the capsular width was measured as an indirect measurement of synovitis. The width was measured in millimetres from the lateral cortical contour of the condyle

to the lateral contour of the capsule both at the subcondylar level and the condylar level (Figures 1–3). The evaluation of the mandibular condyle shape was also part of our routine ultrasonography examination but was not further explored.

All MRIs were performed at 1.5-T units (Magnetom® Avanto, Magnetom Symphony or Magnetom Sonata; Siemens) with either surface coils or phased-array head coils. Examinations were performed according to our routine protocol. Pre-contrast oblique sagittal T_1 weighted [repetition time (TR) 400–471 ms, echo time (TE) 12–15 ms] spin echo and oblique sagittal proton density/ T_2 weighted (TR 2080–3090 ms, TE 14–16/82–98 ms) turbo spin echo images with or without fat suppression (frequency-selective saturation), and then post-contrast oblique sagittal and oblique coronal T_1 weighted images with or without fat suppression (frequency-selective saturation) were obtained with the mouth closed. Post-contrast oblique sagittal T_2^* weighted gradient echo images (TR 125–133 ms, TE 10.8–11.0 ms, flip angle 30°) with the mouth open by the use of an occlusal step wedge were also obtained. The slice thickness was 3 mm. The in-plane resolution was 0.273×0.273 mm. The contrast media used were 0.1 mmol kg^{-1} of either gadopentetate dimeglumine (Magnevist®; Bayer, Berlin, Germany) or gadoterate meglumine (Dotarem®; Guerbet, Paris, France). The post-contrast imaging started immediately after contrast medium injection. There were no sedations. Two experienced maxillofacial radiologists (TAL and LZA), aware of age and gender, analyzed the MR images in consensus, blinded to the ultrasonography observations. 25 cases were reassessed by the same 2 observers in consensus for evaluation of intraobserver variation. The data set was selected randomly and was not fully balanced but included all findings. MRI finding of synovitis was defined as post-gadolinium enhancement

(signal increase) in thickened synovium on T_1 weighted images compared with pre-contrast T_1 weighted images. The amount of synovitis was registered using a one to three grading scale: grade 1 (slight synovitis): slight synovial thickening more than dots or lines; grade 2 (moderate synovitis): moderate band-like thickening including slight distension of the joint space; and grade 3 (extensive synovitis): extensive thickening with extensive distension of the joint space.¹⁸

The continuous variables age at examination, age at symptom onset, age at disease onset (doctor's diagnosis), disease duration and ultrasonography capsular width were normally distributed and described by mean and standard deviation (SD). Numbers of active joints were described by median and quartiles. Categorical data were described as frequency and percentage. Each joint was considered separately.

Spearman's correlation test was used to determine the correlation between ultrasonography-assessed capsular width and MRI-assessed amount of synovitis. One-way ANOVA test with Bonferroni corrections was used to evaluate correlation between capsular width and amount of synovitis.

To assess cut-off levels of pathological ultrasonography-assessed capsular width using MRI as reference standard, receiver operating characteristic (ROC) curves were constructed. MRI findings were dichotomized as either no synovitis (grade 0) or synovitis (grade 1–3). Sensitivity and specificity and cut-off levels were derived from the ROC curves.

Intraclass correlation coefficient (ICC) for continuous data and kappa statistic for categorical data were used to determine consistency among the raters.

Significance level was set to $p < 0.05$. All statistical analyses were performed by IBM SPSS® statistics v. 20.0 (IBM Corp., New York, NY; formerly SPSS Inc., Chicago, IL).

Figure 1 Temporomandibular joint with no arthritis in a 5-year-old female with juvenile idiopathic arthritis. Ultrasonography-assessed (a) subcondylar capsular width is 0.8 mm (thick line) and condylar capsular width is 1.0 mm (thin line). Oblique sagittal (b) and oblique coronal (c) contrast-enhanced T_1 weighted MR images show no synovitis.

Figure 2 Temporomandibular joint arthritis in a 16-year-old female with juvenile idiopathic arthritis. Ultrasonography-assessed (a) subcondylar capsular width (thick line) and condylar capsular width (thin line) are both 2.4 mm. Oblique sagittal (b) and oblique coronal (c) contrast-enhanced T_1 weighted MR images show moderate synovitis (degree 2) (asterisks).

Results

Figures 1–3 illustrate ultrasonography and MRI findings in corresponding images. The mean ultrasonography-assessed TMJ capsular width at the subcondylar level was 1.4 ± 0.8 mm (SD) (range 0.4–4.9 mm), and at the condylar level 1.3 ± 0.67 mm (SD) (range 0.4–3.4 mm). The interobserver and intraobserver agreements were excellent at the subcondylar level {ICC 0.84 [95% confidence interval (CI) 0.77–0.88] and 0.85 (95% CI 0.74–0.91), respectively}, and at the condylar level [ICC 0.80 (95% CI 0.72–0.85) and 0.82 (95% CI 0.70–0.90), respectively].

MRI-assessed synovitis was present in 62 (50%) joints; 28 (23%) joints with slight synovitis, 27 (22%) joints with moderate synovitis and 7 (6%) joints with

extensive synovitis. The intraobserver agreement was substantial [κ 0.79 (95% CI 0.64–0.94)].

The correlation between ultrasonography-assessed capsular width and MRI-assessed amount of synovitis was moderate both at the subcondylar and at the condylar levels [Spearman's rho (ρ): 0.483; $p < 0.001$ and 0.347; $p < 0.001$, respectively].

Ultrasonography-assessed capsular width according to MRI-assessed amount of synovitis in the TMJs at the subcondylar and at the condylar levels are shown in Figures 4 and 5, respectively.

At the subcondylar level (Figure 4), the median ultrasonography-assessed capsular widths were 0.9 mm (range 0.4–2.5 mm) in MRI grade 0 (no synovitis); 1.4 mm (range 0.4–3.7 mm) in MRI grade 1 (slight synovitis); 1.4 mm (range: 0.6–3.3 mm) in MRI grade 2

Figure 3 Temporomandibular joint arthritis in a 17-year-old female with juvenile idiopathic arthritis. Ultrasonography-assessed (a) subcondylar capsular width is 4.3 mm (thick line) and condylar capsular width (thin line) is 3.0 mm. Oblique sagittal (b) and oblique coronal (c) contrast-enhanced T_1 weighted MR images show extensive synovitis (degree 3) (asterisks).

Figure 4 Boxplots showing median, interquartile distance and range of subcondylar ultrasonography-assessed temporomandibular joint capsular width in MRI-assessed amount of synovitis degrees 0–3. (a) $p \leq 0.010$ vs those with other degrees. (b) $p < 0.004$ vs those with degrees 1 and 2.

(moderate synovitis); and 3.3 mm (range: 0.7–4.9 mm) in MRI grade 3 (extensive synovitis) ($p < 0.001$ for difference between MRI categories by one-way ANOVA). p -values of the *post hoc* tests are given in Figure 4.

At the condylar level (Figure 5), the median ultrasonography-assessed capsular widths were 1.0 mm (range 0.4–2.5 mm) in MRI grade 0 (no synovitis); 1.2 mm (range 0.6–3.2 mm) in MRI grade 1 (slight synovitis); 1.5 mm (range: 0.5–3.2 mm) in MRI grade 2 (moderate synovitis); and 2.3 mm (range: 0.8–3.4 mm) in MRI grade 3 (extensive synovitis) ($p < 0.001$ for

Figure 5 Boxplots showing median, interquartile distance and range of condylar ultrasonography-assessed temporomandibular joint capsular width in MRI-assessed amount of synovitis degrees 0–3. (a) $p \leq 0.011$ vs those with degrees 2 and 3. (b) $p \leq 0.050$ vs those with degrees 1 and 2.

difference between MRI categories by one-way ANOVA). p -values of the *post hoc* tests are given in Figure 5.

The ROC curves illustrate sensitivity and specificity of ultrasonography-assessed capsular width detecting synovitis at the subcondylar and at the condylar levels using MRI as the reference standard (Figure 6). The area under the curve at the subcondylar level was 0.77 (95% CI 0.69–0.86) indicating a fair test and at the condylar level was 0.69 (95% CI 0.59–0.78), indicating a poor test. Derived from the ROC curve, we propose a cut-off value of 1.2 mm (sensitivity 72%, specificity 70%) for the capsular width at the subcondylar level. Because the area under the curve indicated a poor test, no cut-off value was calculated at the condylar level.

Discussion

Even though the surrogates for measuring synovial thickening were quite different, a moderate correlation between ultrasonography and MRI in the assessment of TMJ inflammation in children was found.

The joint capsule with the inner surface lined with synovium, attaches to the lateral and posterior parts of the mandibular neck.¹⁹ In a longitudinal view, synovitis may therefore be indirectly assessed not only at the level of the lateral pole of the condyle, as described by several authors,^{9,11,13,20–23} but also at the subcondylar level. We did both and showed that

Figure 6 Receiver operating characteristic (ROC) curves of ultrasonography-assessed temporomandibular joint capsular widths as a marker of MRI-assessed synovitis at the subcondylar and condylar levels.

ultrasonography evaluation of synovial thickening had better discriminatory ability at the subcondylar level than at the condylar level, indicating that the subcondylar level should be preferred. Ultrasonography-assessed capsular width had a wider range of values at the subcondylar level. This may be part of the reason for the increased discriminatory ability.

Previous studies of ultrasonography of the TMJs use longitudinal scans, similar to those used in our study, or transversal scans measuring the capsular width at the condylar level. Both the scan direction and the level of measurement may be crucial for assessing the capsular width. In adults with normal TMJs, average values of 1.4 mm in longitudinal and 1.6 mm in transverse scans have been reported.²⁰ To discriminate between internal derangement joints with and without effusion, a cut-off value of 1.65 mm was found.²¹ Manfredini *et al*²³ proposed a capsular width cut-off value of 2 mm, assessed at the condylar level in a longitudinal scan, as an indirect marker of TMJ effusion in adults with temporomandibular dysfunction.

In a study of 30 children with JIA (median age 9.8 years), Müller *et al*¹¹ used the same cut-off level as had been applied for adults (2 mm) for the assessment of TMJ effusion/synovitis. This could explain the weak correlation found between ultrasonography and MRI. The authors showed that ultrasonography examinations correctly diagnosed 6 (33%) patients with active TMJ arthritis but misdiagnosed 12 (67%) as having no signs of inflammation.¹¹ An even worse correlation between ultrasonography and MRI was reported by Weiss *et al*.⁹ In a study of 32 patients with JIA (median age 8.6 years), TMJ effusion/synovitis was diagnosed in 75% by MRI but in none by ultrasonography. An incorrect cut-off level may wrongly discredit ultrasonography as a method.

In children, capsular width measurements should probably be age adjusted.²⁴ Melchiorre *et al*²² studied 68 children with JIA (mean age 11 years) and showed that all 40 age- and sex-matched healthy controls without symptoms had TMJ capsular width <1.4 mm. Our results also support that the cut-off level is lower in children than in adults. Derived from the ROC curve, we propose a cut-off-level of 1.2-mm ultrasonography-assessed capsular width at the subcondylar level in children, with acceptable sensitivity and specificity values.

Although it has been suggested that ultrasonography can detect different abnormalities in the TMJ such as condylar erosions, synovial thickening and effusion,¹³ most authors consider the examination to be non-specific. The hypoechoic area between the condyle and the capsule contains fluid, synovium and the disc, and the differentiation between those structures is difficult. Both synovial thickening and effusion are signs of inflammation. In a recent MRI study, no TMJs in children with JIA had effusion without synovial thickening.¹⁸

The ultrasonography image is limited to the lateral part of the joint, and a joint with focal medial synovitis may have a normal capsular width. A laterally or medially displaced disc may result in an altered capsular width at the condylar level.²⁵ Measuring at the subcondylar level may possibly reduce this consequence of disc displacement.

The fact that ultrasonography and MRI examinations were obtained within 1 week, the majority within 1 day, is a strength in our study. Inflammation can fluctuate, and a short time interval is therefore crucial. Comparable studies had time intervals as long as 1 and 2 months.^{9,11}

There are several limitations in our study. Our convenience sample was relatively small and hospital based from a single institution, and the patients had therefore more advanced JIA involvement and a lower frequency of oligoarthritis (44%) than found in epidemiological studies.²⁶ The predictive value of the test could therefore be overestimated. The retrospective design based on a pre-defined single ultrasonography image excluding the real-time examination may also be a limitation. Ultrasonography is an operator-dependent examination method, and images may be difficult to interpret retrospectively. Ideally, future studies should be prospective, real time, include a control group and be performed using the same ultrasonography and MRI equipment for all individuals.

We experienced that ultrasonography examination of the TMJ was well tolerated by the patients, also by the youngest ones. In children without symptoms of TMJ involvement, ultrasonography may be a valuable imaging modality in the decision whether or not an additional MRI is needed. In small children with clinical TMJ symptoms, an evident ultrasonography-assessed synovitis may possibly make MRI redundant. Recently, we showed that 78% of children with JIA and TMJ symptoms had evidence of synovitis on MRI.¹⁸ MRI should be performed prior to injection therapy of the TMJ, since there are obvious pitfalls with the ultrasonography examination.

Conclusion

A moderate correlation between ultrasonography-assessed capsular width and MRI-assessed synovitis was found in childhood arthritis with the best discriminatory ability at the subcondylar level. This indicates that ultrasonography may be a valuable diagnostic tool in the initial assessment of TMJ inflammation.

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References

- Arabshahi B, Cron RQ. Temporomandibular joint arthritis in juvenile idiopathic arthritis: the forgotten joint. *Curr Opin Rheumatol* 2006; **18**: 490–5. doi: <https://doi.org/10.1097/01.bor.0000240360.24465.4c>
- Arvidsson LZ, Smith HJ, Flatø B, Larheim TA. Temporomandibular joint findings in adults with long-standing juvenile idiopathic arthritis: CT and MR imaging assessment. *Radiology* 2010; **256**: 191–200. doi: <https://doi.org/10.1148/radiol.10091810>
- Tse S, Lubelsky S, Gordon M, Al Mayouf SM, Babyn PS, Laxer RM, et al. The arthritis of inflammatory childhood myositis syndromes. *J Rheumatol* 2001; **28**: 192–7.
- Fain ET, Atkinson GP, Weiser P, Beukelman T, Cron RQ. Temporomandibular joint involvement in pediatric sjogren disease and sarcoidosis. *J Rheumatol* 2011; **38**: 2272–3. doi: <https://doi.org/10.3899/jrheum.110080>
- Aliko A, Ciancaglini R, Alushi A, Tafaj A, Ruci D. Temporomandibular joint involvement in rheumatoid arthritis, systemic lupus erythematosus and systemic sclerosis. *Int J Oral Maxillofac Surg* 2011; **40**: 704–9. doi: <https://doi.org/10.1016/j.ijom.2011.02.026>
- Taylor DB, Babyn P, Blaser S, Smith S, Shore A, Silverman ED, et al. MR evaluation of the temporomandibular joint in juvenile rheumatoid arthritis. *J Comput Assist Tomogr* 1993; **17**: 449–54. doi: <https://doi.org/10.1097/00004728-199305000-00022>
- Küseler A, Pedersen TK, Herlin T, Gelineck J. Contrast enhanced magnetic resonance imaging as a method to diagnose early inflammatory changes in the temporomandibular joint in children with juvenile chronic arthritis. *J Rheumatol* 1998; **25**: 1406–12.
- Küseler A, Pedersen TK, Herlin T, Gelineck J. A 2 year followup study of enhanced magnetic resonance imaging and clinical examination of the temporomandibular joint in children with juvenile idiopathic arthritis. *J Rheumatol* 2005; **32**: 162–9.
- Weiss PF, Arabshahi B, Johnson A, Bilaniuk LT, Zarnow D, Cahill AM, et al. High prevalence of temporomandibular joint arthritis at disease onset in children with juvenile idiopathic arthritis, as detected by magnetic resonance imaging but not by ultrasound. *Arthritis Rheum* 2008; **58**: 1189–96. doi: <https://doi.org/10.1002/art.23401>
- Damasio MB, Malattia C, Martini A, Tomà P. Synovial and inflammatory diseases in childhood: role of new imaging modalities in the assessment of patients with juvenile idiopathic arthritis. *Pediatr Radiol* 2010; **40**: 985–98. doi: <https://doi.org/10.1007/s00247-010-1612-z>
- Müller L, Kellenberger CJ, Cannizzaro E, Ettlin D, Schraner T, Bolt IB, et al. Early diagnosis of temporomandibular joint involvement in juvenile idiopathic arthritis: a pilot study comparing clinical examination and ultrasound to magnetic resonance imaging. *Rheumatology (Oxford)* 2009; **48**: 680–5. doi: <https://doi.org/10.1093/rheumatology/kep068>
- Jank S, Haase S, Strobl H, Michels H, Häfner R, Missmann M, et al. Sonographic investigation of the temporomandibular joint in patients with juvenile idiopathic arthritis: a pilot study. *Arthritis Rheum* 2007; **57**: 213–8. doi: <https://doi.org/10.1002/art.22533>
- Assaf AT, Kahl-Nieke B, Feddersen J, Habermann CR. Is high-resolution ultrasonography suitable for the detection of temporomandibular joint involvement in children with juvenile idiopathic arthritis? *Dentomaxillofac Radiol* 2013; **42**: 20110379. doi: <https://doi.org/10.1259/dmfr.20110379>
- Habashi H, Eran A, Blumenfeld I, Gaitini D. Dynamic high-resolution sonography compared to magnetic resonance imaging for diagnosis of temporomandibular joint disk displacement. *J Ultrasound Med* 2015; **34**: 75–82. doi: <https://doi.org/10.7863/ultra.34.1.75>
- Kundu H, Basavaraj P, Kote S, Singla A, Singh S. Assessment of TMJ disorders using ultrasonography as a diagnostic tool: a review. *J Clin Diagn Res* 2013; **7**: 3116–20. doi: <https://doi.org/10.7860/JCDR/2013/6678.3874>
- Petty R, Southwood TR, Manners P, Baum J, Glass DN, Goldenberg J, et al; International League of Associations for Rheumatology. International League of Associations for Rheumatology classification of juvenile idiopathic arthritis: second revision, Edmonton, 2001. *J Rheumatol* 2004; **31**: 390–2.
- Giannini EH, Ruperto N, Ravelli A, Lovell DJ, Felson DT, Martini A. Preliminary definition of improvement in juvenile arthritis. *Arthritis Rheum* 1997; **40**: 1202–9. doi: [https://doi.org/10.1002/1529-0131\(199707\)40:7<1202::AID-ART3>3.0.CO;2-R](https://doi.org/10.1002/1529-0131(199707)40:7<1202::AID-ART3>3.0.CO;2-R)
- Kirkhus E, Arvidsson LZ, Smith HJ, Flatø B, Hetlevik SO, Larheim TA. Disk abnormality coexists with any degree of synovial and osseous abnormality in the temporomandibular joints of children with juvenile idiopathic arthritis. *Pediatr Radiol* 2016; **46**: 331–41. doi: <https://doi.org/10.1007/s00247-015-3493-7>
- Soames RW. Skeletal system. In: Williams PL, ed. *Gray's anatomy*. 38th edn. New York: Churchill Livingstone; 1995. pp. 425–736.
- Elias F, Birman EG, Matsuda CK, Oliveira IR, Jorge WA. Ultrasonographic findings in normal temporomandibular joints. *Braz Oral Res* 2006; **20**: 25–32. doi: <https://doi.org/10.1590/S1806-83242006000100006>
- Bas B, Yılmaz N, Gökce E, Akan H. Ultrasound assessment of increased capsular width in temporomandibular joint internal derangements: relationship with joint pain and magnetic resonance grading of joint effusion. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2011; **112**: 112–7. doi: <https://doi.org/10.1016/j.tripleo.2011.02.020>
- Melchiorre D, Falcini F, Kaloudi O, Bandinelli F, Nacci F, Matucci Cerinic M. Sonographic evaluation of the temporomandibular joints in juvenile idiopathic arthritis(). *J Ultrasound* 2010; **13**: 34–7. doi: <https://doi.org/10.1016/j.jus.2009.09.008>
- Manfredini D, Tognini F, Melchiorre D, Zampa V, Bosco M. Ultrasound assessment of increased capsular width as a predictor of temporomandibular joint effusion. *Dentomaxillofac Radiol* 2003; **32**: 359–64. doi: <https://doi.org/10.1259/dmfr/25091144>
- Tien YC, Yang CY, Chih HW. The normal width of anterior hip synovial recess in children. *J Pediatr Orthop* 2000; **20**: 264–6.
- Hayashi T, Ito J, Koyama J, Yamada K. The accuracy of sonography for evaluation of internal derangement of the temporomandibular joint in asymptomatic elementary school children: comparison with MR and CT. *AJNR Am J Neuroradiol* 2001; **22**: 728–34.
- Berntson L, Andersson Gäre B, Fasth A, Herlin T, Kristinsson J, Lahdenne P, et al. Incidence of juvenile idiopathic arthritis in the nordic countries. A population based study with special reference to the validity of the ILAR and EULAR criteria. *J Rheumatol* 2003; **30**: 2275–82.