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RESEARCH ARTICLE

Improvement of bone-erosive temporomandibular joint (TMJ) abnormalities in adolescents undergoing non-surgical treatment: a longitudinal study

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Objectives: To investigate the longitudinal changes of the imaging temporomandibular joint (TMJ) characteristics in young patients with TMJ-related symptoms and treated with non-surgical methods. The severity of self-reported symptoms at follow-up was also investigated.
Methods: A cone beam CT (CBCT)/CT follow-up examination [median follow-up 4.1 (1.3–6.4) years] was performed in 22 patients with erosive TMJ abnormalities [baseline median age 16 (12–18) years]. Imaging characteristics were analyzed and the changes between the examinations were categorized as (A) improvement, (B) no change, or (C) worsening. Severity of follow-up symptoms was evaluated using Jaw Functional Limitation Scale (JFLS-8) and Graded Chronic Pain Scale (Grade 0–IV). Analyses were performed separately for left and right TMJ. Findings at baseline and follow-up were compared using McNemar test to account for dependencies. Changes in proportions of hard tissue findings between examinations were assessed using Wilcoxon signed ranks test.
Results: A significant reduction in the proportion of patients with erosive abnormalities was found [59.1%, 95% CI (36.4–79.3) %]. Baseline erosions improved in 9/12 (75%) right and 14/15 (93%) left TMJs. About half repaired; developed an intact cortical outline. Number of joints with osteophytes increased (right: $p < 0.04$, left: $p < 0.003$). New osteophytes were mostly found in joints with erosive findings. Low or no limitation of jaw function (Jaw Functional Limitation Scale) was found in 12/22 (55%) and no or low intensity of pain (Graded Chronic Pain Scale Grade 0 or I) in 19/22 (86%) at follow-up.
Conclusion: We found a high potential for repair of erosive TMJ abnormalities. However, the patient series was small. The majority of patients assessed their symptom severity at follow-up as low.
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Introduction

Osteoarthritis (OA) like abnormalities of the temporomandibular joint (TMJ) in adolescents have been recognized for a long time. In recent years, frequencies ranging from 27 to 41% have been reported in individuals with TMJ-related symptoms referred for diagnostic imaging.[1,2]

Such abnormalities, whether they represent one entity with different forms of severity or different entities, may be characterized by bone-destructive imaging features.[2–5] Destructive TMJ abnormalities in young patients should be taken seriously. They might represent

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a progressive condition such as idiopathic condylar resorption or juvenile idiopathic arthritis.[5,6] The literature has almost entirely focused on the progressive nature of such abnormalities, and the management of the related facial deformities that may occur. Surgical interventions with injections have also been performed, in particular on adolescents with juvenile idiopathic arthritis (JIA).[7] However, longitudinal studies that demonstrate progressive bone-destructive TMJ changes are scarce.

Evaluation of the bony structures in young, growing individuals is challenging. The condylar surface may have a delicate cortical outline, being partially present or, in early age, not present at all.[8] CT or cone beam CT (CBCT) are accepted as the most reliable methods to assess the bony articular surfaces of this joint.[9,10] CT proved to be superior to MRI in a comprehensive study on adults.[9] CBCT is preferable since the diagnostic accuracy is similar and the radiation exposure is lower compared to CT.[10] However, ionizing radiation should be used with caution in the examination of young individuals.

Many adolescents/young adults with TMJ-related symptoms have myalgia and clinical symptoms of disc displacement.[11] With regard to the joint diagnosis, focus is frequently on soft-tissue abnormalities. MRI and not CBCT is then the method of choice if it is necessary for patient management to confirm the diagnosis by imaging. In our research, we focus on the bony structures, using the most superior imaging modality for that purpose.[12]

We conducted a longitudinal study of adolescents with TMJ-related symptoms and bone-erosive TMJ abnormalities, without evident facial deformities, undergoing non-surgical (conservative) treatment. The aim was to investigate the changes of the imaging TMJ characteristics from baseline (first visit) to a follow-up (second visit). The severity of TMJ-related symptoms at follow-up was also investigated.

Methods and materials

This observational study was approved by the Regional Ethics Committee of Norway (reference 2016/1975). Written informed consent was provided by the participants, or by their parents when younger than 16 years.

All participants had initially been referred to, and were examined at the Department of Maxillofacial Radiology, University of Oslo in the period October 2011 to May 2016. They were selected if they met the following criteria: (1) were referred for radiological examination due to TMJ-related pain (pain in the TMJ and surrounding structures), (2) were younger than 19 years of age, and (3) demonstrated bone-erosive TMJ abnormalities at CT/CBCT. In total, 42 eligible patients were identified and invited to participate in a follow-up examination. Exclusion criteria were: clinically evident facial growth disturbances (micrognathia or facial asymmetry) registered at the baseline, congenital syndromes, and inflammatory joint disease. Patients who had received irreversible or surgical treatment (TMJ injection or surgery, or orthognathic surgery) before or after the baseline examination, were also excluded. 20 patients were either excluded, declined to participate, or did not show up at the follow-up (Figure 1). The final sample comprised of 22 adolescents (44 TMJs).

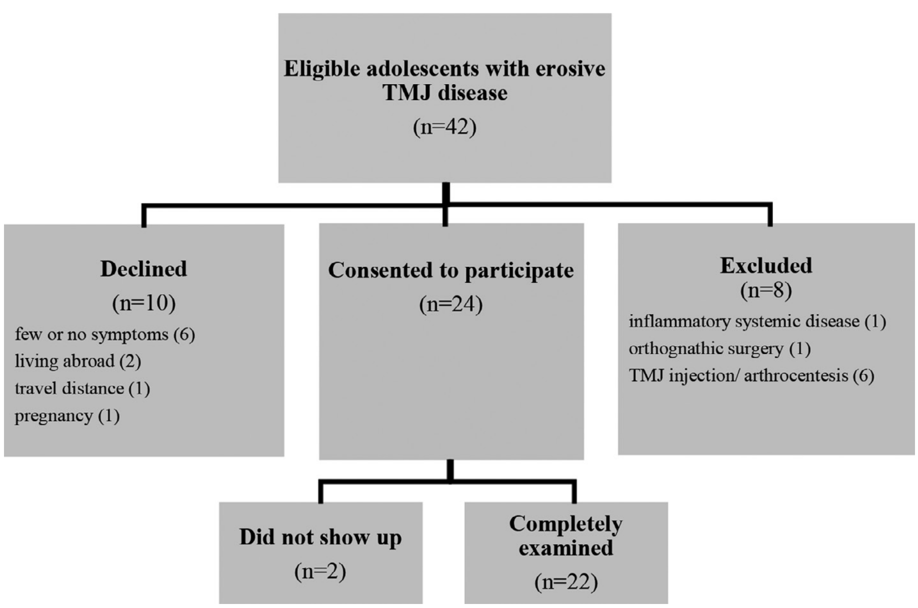

Figure 1 Flow-chart showing inclusion and detailing the reason for decline or exclusion in a CBCT follow-up of symptomatic adolescents with erosive TMJ findings. CBCT, cone beam CT; TMJ, temporomandibular joint

Clinical recordings and questionnaires

Indications for the radiological examination of each participant at baseline were retrieved from clinical records.

In the follow-up assessment, the participants were interviewed about previous TMJ-related treatment (counselling, masticatory muscle exercises, occlusal appliance, analgesics, physical therapy, acupuncture, intramuscular injections with botulinum toxin, cognitive therapy, general relaxation exercises or others) before or after baseline (yes/no) and within the last six mouths (yes/no), symptoms from other joints (pain/swelling/reduced movement) (yes/no), and traumas against jaw or face/head (yes/no, before/after baseline examination).

For the follow-up assessment, the Norwegian versions of Jaw Functional Limitation Scale (JFLS-8) and Graded Chronic Pain Scale (GCPS) from Diagnostic Criteria for Temporomandibular Disorder (DC/TMD) axis II were used to map the functional status of the masticatory system, and the pain-intensity and disability status. The JFLS-8 was used to assess global jaw functional limitation of the masticatory system.[13] Eight items related to jaw function during the previous month were rated on a 0–10 scale (no limitation to severe limitation) and a mean value was calculated. The scores were categorized as follows: (0) no limitation (1–4) low limitation and ($\geq$ 5) significant limitation.[14] The GCPS severity scale was used to assess pain-intensity and disability.[15] Seven questions concerning pain intensity, interference with activities and disability days yielded a 0–IV scale score. Grade 0 was defined as no TMD pain, Grade I as TMD pain of low-intensity and Grade II as high-intensity pain. Grades III and IV reflected moderate to significant pain-related psychosocial disability regardless of pain level.[15,16] JFLS-8 and GCPS were scored and interpreted according to the Scoring Manual from the RDC-TMD international.[17]

Imaging

At the baseline visit, the 22 patients had been examined with CT or CBCT. At the follow-up examination, only CBCT was used. The clinical routine for young patients with bone-destructive findings also included a referral for an MR examination of the TMJs. Recently performed MRIs were retrieved. Due to practical reasons and limited access to MRI facilities, examinations from 18 patients were collected.

The baseline examinations were performed with a CT LightSpeed Ultra scanner (GE Medical Systems, Milwaukee, WI) (120 kVp, 50–90 mA, bone window, spatial resolution 0.625 mm) or a ProMax Mid 3D CBCT unit (Planmeca Oy, Helsinki, Finland) [field of view (FOV) 200 mm X 60 mm, 85–95 kVp, 4–10 mA, spatial resolution 0.2–0.5 mm].

The MR examinations were performed with a 1.5 T magnet. Oblique sagittal proton images were obtained to evaluate the disc position at closed and open mouth. The MRI examination of one joint was excluded due to suboptimal image quality; leaving 35 joints for analysis. The MRI examinations were performed with a median time of 21 days after the CT/CBCT examination at baseline (between 97 days before, and 384 days after). Seven patients had MRI within 3 days after the CBCT examination and four patients had more than 100 days between the examinations.

The follow-up examinations were performed with a CBCT machine; Accuitomo 170 (J. Morita Corp, Kyoto, Japan) (FOV 140 X 50 mm, 85 kVp, 7.5 or 8 mA, spatial resolution 0.2 mm). All CT/CBCT examinations were performed at the Department of Maxillofacial Radiology, University of Oslo.

Image analysis

Reconstructed (baseline and follow-up) images in axial, oblique sagittal and oblique coronal planes were analysed in Sectra PACS viewer IDS seven version (Sectra, Linköping, Sweden) on Eizo FlexScan GS320 (20-inch, color, 1536 × 2048, 32 bit) monitors. The examinations were interpreted by two maxillofacial radiologists (LZA, TAL), with more than 15 years' and 40 years' experience of interpreting TMJ images.

The CT diagnostic criteria by Ahmad et al were used to evaluate the hard tissues.[9] Author-based criteria for evaluating bone destruction or erosion in growing joints were developed: (1) 'Surface destruction', defined as a defect of the articular surface involving the underlying bone and (2) 'Surface irregularity', defined as a minor defect or an irregularity of the articular surface, not involving the underlying bone. We also added 'beaking' and defined this feature as an angular formation on the anterior aspect of the condyle without presence of subcortical sclerosis, in order to differentiate this feature from an osteophyte with presence of subcortical sclerosis.

For evaluation of the disc position on closed and open mouth MRI, the diagnostic criteria by Ahmad et al[9] and Drace and Enzmann[18] were used to classify the joint in the categories normal disc position, anterior disc displacement with reduction (DDwR), and anterior disc displacement without reduction (DDwoR). A disc was defined as anteriorly displaced at closed mouth in the oblique sagittal view when, relative to the superior aspect of the condyle, the border between the low signal of the disc and the high signal of the retrodiscal tissue was located anterior to the 11:30 clock position.[9,18] The disc position was determined in all sections throughout the joint. If a disc was displaced in all sections, it was defined as completely displaced according to Larheim et al.[19] Further, if a disc was located with its intermediate zone and posterior band caudally to the apex of the articular eminence at closed mouth, it was defined as severely displaced. All severely displaced discs were non-reducing. Therefore, the few joints with severe disc displacement on closed mouth MRI, but with uncertain outline of the disc on open mouth MRI, were categorized as DDwoR.

After calibration, each radiologist interpreted all baseline and follow-up examinations separately and independently. They were blinded to clinical information except for age and could adjust the brightness and contrast settings for best display. Disagreements between the observers were discussed until consensus was met during a second evaluation, in which baseline and follow-up images were viewed simultaneously. In this session, the radiologists in consensus also classified each joint, based on the erosive changes between baseline and follow-up, in three categories: (A) improvement (B) no change or (C) worsening. The longitudinal changes of the erosive findings were evaluated based on the extent of the erosive finding/abnormality and the integrity of the cortical outline. Improvement was defined as a decrease in the extent of the erosive findings and/or a more intact cortical outline/articular surface. Repair was defined as a completion of the corticated outline. Worsening was defined as an increase in the extent of the erosive findings and/or a less intact cortical outline/articular surface.

Statistical analyses

Data were described as counts and proportions (percentages) for categorical data and mean with standard deviation (SD) or median with range for continuous variables when appropriate. Analyses were performed separately for left and right TMJ.

Proportions of patients with erosive findings (surface destruction and surface irregularity) at baseline and at follow-up were compared with McNemar test to account for dependencies as all patients were assessed twice and these analyses were stratified by side (right or left). When assessing changes in the proportion of patients with different types of hard tissue findings (regardless of left or right joints), Wilcoxon signed ranks test was used.

Proportions were presented as percentages with 95% confidence intervals (CIs) constructed using the binomial distribution approximation. p-values < 0.05 were considered statistically significant. As our study was considered exploratory, no correction for multiple testing was made. Analysis was preformed using IBM SPSS v. 24.0 (Statistical Package for Social Services, Chicago, IL).

Results

21 females and 1 male were included in the present study and the median (range) follow-up time was 4.1 (1.3–6.4) years. The median age (range) was 16.2 (11.8–18.8) years at baseline and 20.6 (13.2–23.5) years at follow-up.

Clinical recordings and questionnaires

The indications for radiological examination at baseline were: pain in TMJ and surrounding structures 4/22 (18 %), pain and reduced jaw function 10/22 (45 %) and pain and jaw locking problems 8/22 (37 %).

TMJ-related management was reported by all but one patient: counselling 21/22 (95%), masticatory muscle exercises 18/22 (82%), occlusal appliance 16/22 (73%), analgesics 12/22 (55%), physical treatment 8/22 (36%) and acupuncture 1/22 (4%). None had received irreversible treatment, intramuscular injections with botulinum toxin, cognitive therapy or general relaxation exercises. 12 patients (55%) had received treatment or performed exercises the last 6 months. None reported symptoms from other joints. Trauma to the face before baseline examination was reported by 3/22 (14 %) and in the time between baseline and follow-up examination by one participant.

In the follow-up assessment, 12 patients (55%) were found to have low or no limitation of the jaw function (JFLS activities < 5). Mean JFLS (SD) was 0.7 (0.87). The frequencies of the pain severity grades (GCPS) were Grade 0: 5/22 (23%), I: 14/22 (64%), II: 2/22 (9%), III: 0/22 (0%), and IV: 1/22 (4%).

Imaging findings

The 22 patients with erosive TMJ abnormalities (17 unilateral and 5 bilateral) were reduced to 9 (7 unilateral and 2 bilateral) at follow-up. Our data revealed a statistically significant reduction in the proportion of patients with erosive findings, 59.1%, 95% CI (36.4 to 79.3).

In the 44 joints, there was a statistically significant reduction in joints with destruction between baseline and follow-up (right TMJ: $p < 0.034$, left TMJ: $p < 0.002$). The longitudinal changes of erosive findings are shown in Table 1. Improvement was a dominant feature and was found in 9/12 (75%) right and in 14/15 (93%) left TMJs. Repair of the erosive findings, that is, development of an intact cortical outline, was observed in 6/12 (50%) right and in 9/15 (60%) left TMJs (Figure 2). Worsening of the erosive findings and new erosions in previously non-erosive joints were rare (Figure 3).

In the 44 TMJs, no significant change was found in the additional hard tissue findings between baseline and follow-up, except for osteophytes that increased significantly (right TMJ: $p < 0.046$, left TMJ: $p < 0.003$). At follow-up, the osteophytes were mostly found in joints that were erosive at both examinations (right TMJ: 3/5, left TMJ: 4/6). They were also found in erosive joints that repaired (right TMJ: 0/6, left TMJ: 3/9) and in joints that were non-erosive at baseline (right TMJ: 1/10, left TMJ: 3/7) (Figure 4). Of the joints with osteophytes at follow-up about half of them (right 3/4, left 6/10) showed beaking at baseline (Figure 5). The baseline beaking was stable or had disappeared in the other joints.

The most common hard tissue findings at baseline and follow-up in the 27 TMJs that were erosive at baseline, are shown in Table 2.

The disc position in relation to the bone erosive findings at baseline is shown in Table 3. Of the 35 joints evaluated with MRI, disc displacement was found in

Table 1 Condylar changes of erosive CT/CBCT findings from baseline to follow-up in 22 adolescents/young adults (n = 44 TMJs)

	Right TMJs n = *22 joints*		*Left TMJs* n = *22 joints*	
Baseline:	Erosive n = 12	Non-erosive n = 10	Erosive n = 15	Non-erosive n = 7
Follow-up: Improvement	9 [a]	0	14 [b]	0
No change	2	9	1	6
Worsening	1	1	0	1

CBCT, cone beam CTTMJ, temporomandibular joint.

[a]Six developed an intact cortical outline.
[b]Nine developed an intact cortical outline.

14/17 right TMJs and 16/18 left TMJs. The majority had DDwoR and all of those showed a completely displaced disc. With one exception, severe disc displacement was found in all TMJs with DDwoR (Figure 4). Erosive findings at baseline were mainly found in joints with DDwoR (right TMJ: 9/11, left TMJ: 12/12). In TMJs with a normal disc position, erosive findings were not observed. At follow-up, about half of the joints with erosive findings and DDwoR at baseline had repaired (right TMJ: 4/9, left TMJ: 7/12).

Discussion

The dominant feature in the present study was the improvement of the osseous status of the TMJ from baseline to follow-up. Worsening of the erosive findings was uncommon, although it should be emphasized that the patient series is small. At follow-up, repair, that is development of an intact cortical outline, was found in over half of the joints with erosive findings at baseline.

Figure 2 Three females, 13- (a), 15- (c), and 18- (e) yrs at baseline, with 4.4- (b), 6.4- (d), and 4.8- (f) yrs follow-up. Surface destruction (arrows) has repaired with an intact cortical outline, more evident in the two older patients (c, d and e, f) than in the youngest one (a, b). The condyle has normalized in shape in the first patient (a, b), shows some articular surface flattening with similar shape at baseline and follow-up in the second (c, d), and shows more severe surface flattening (also of fossa/eminence) in the third patient (e, f) The first patient had been managed with counselling and analgesics, the second with counselling, and the third patient with counselling, masticatory muscle exercises, occlusal appliance, and analgesics.

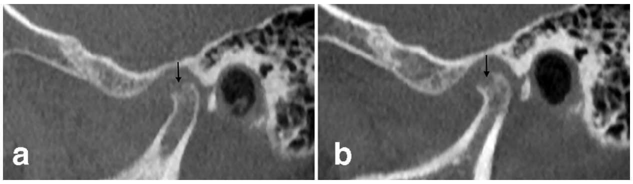

Figure 3 Female, 11 years at baseline (a) with 1.3 years follow-up (b). Condylar destruction (arrow) (a) shows progression (arrow) (b). The patient had been managed with counselling, masticatory muscle exercises, and occlusal appliance.

Remarkably, the majority of the repaired joints showed no other bone abnormalities. The regeneration capacity of the mandibular condyle is well known particularly in young individuals, for instance after fracture. Very few studies have however investigated and documented this phenomenon in adolescents with TMJ-related symptoms.

To our best knowledge, there are only two radiological follow-up studies on erosive TMJ abnormalities.[20,21] A case report documented three patients with erosive findings that developed into articular surface flattening with an intact cortical outline.[20] Condylar repair of erosive findings was also shown in a recent study of adolescents followed for 6–12 months.[21]

Our observation of the osseous improvement is important since most studies of erosive TMJ disease, although they usually are not longitudinal, often indicate the opposite. The reason for the improvement will, however, remain unknown. To investigate any causal relationships would require a much larger sample and was beyond the scope of this study. Regarding treatment, all but one patient reported some kind of previous or present non-surgical treatment. The majority of the patients had received counseling, performed masticatory muscle exercises and used occlusal appliances (most often in different combinations and time periods). Future studies should investigate whether type of treatment, degree of condylar development, patient age and length of follow-up time, have an impact on the osseous status.

In the present study, condylar surface flattening and subcortical sclerosis had similar frequencies both at baseline and follow-up. In contrast, the frequency of osteophytes increased significantly, and they were mostly found in joints with erosive findings at follow-up. These findings are in accordance with a review of joints in general, stating that osteophyte formation is strongly associated with cartilage damage.[22] However, the review also states that osteophytes may occur without such damage, bringing up the discussion whether osteophytes are a pathological phenomenon or a functional adaptation. The authors conclude on one hand that osteophytosis is a common feature of OA and can result in clinically relevant symptoms. On the other hand, they also conclude that osteophytes can be present without negative effects or even have positive effects by increasing the joint surface. In line with these statements, the osteophyte formation that also developed in TMJs without baseline erosions, was considered a functional remodeling in the present sample. The change of the condylar shape seems to have started at baseline when the majority of those joints showed condylar beaking. It should be emphasized though, that it could be challenging to distinguish between a small osteophyte and beaking.

Even when assessing the bone with the most superior methods (CT/CBCT), interpretation of the articular

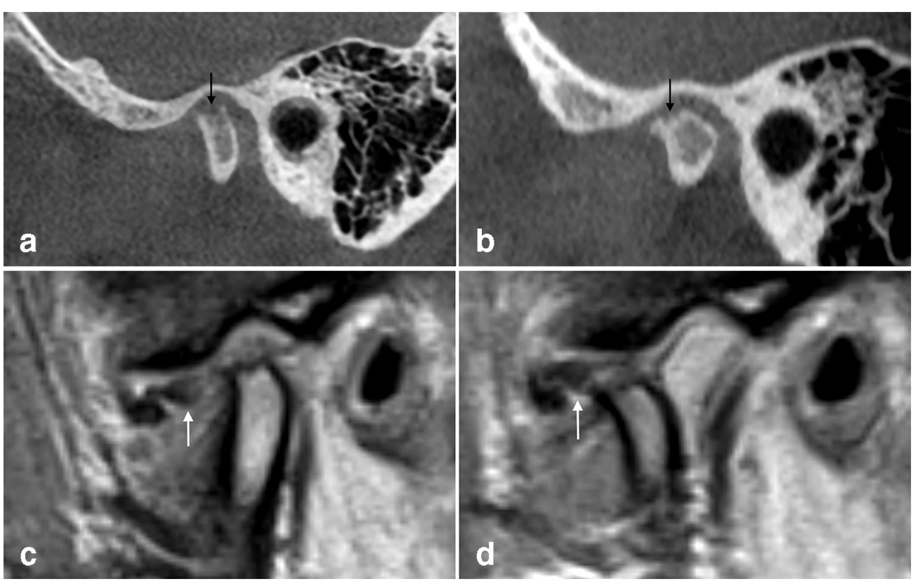

Figure 4 Female, 18 years at baseline (a) with 2.7 years follow-up (b). Surface destruction (arrow) (a) is replaced by irregular cortical outline (arrow) and osteophyte (b). Closed mouth MRI at baseline shows severe disc displacement; disc displaced with its intermediate zone and posterior band (white arrow) located caudally to the eminence (c) and non-reducing disc on open mouth image (white arrow) (d) The patient had been managed with counselling, masticatory muscle exercises, occlusal appliance, physical therapy, and analgesics.

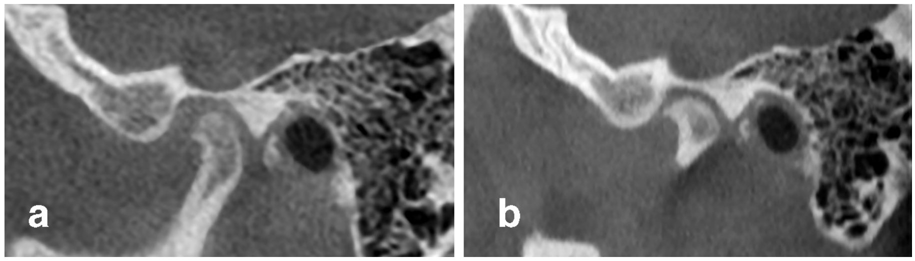

Figure 5 Female, 16 years at baseline (a) with 3.5 years follow-up (b). Condylar beaking (a) has developed into an osteophyte (b). The patient had been managed with counselling, masticatory muscle exercises, occlusal appliance, physical therapy, and analgesics.

surface was challenging. A recent review underlined that the diagnosis of adult OA should be based on evident changes and not on subtle change that may mimic anatomic variation.[12] In children and adolescents, the differentiation between small anatomic variations and pathological signs is even more challenging.[10] In the present study, we used the criteria defined by Ahmad et al,[9] but could not apply the criteria for surface erosion 'loss of continuity of articular cortex', since the cortical layer of the condyle starts to develop at the age 12–14, and is not complete until the age 21–22.[8] Thus, in healthy, growing individuals, the cortical layer is missing or is only partially formed, and surface discontinuities are common. We therefore modified the surface or bone erosion criteria to distinguish between (1) 'surface destruction', a surface defect which involved the underlying bone and (2) 'surface irregularity', a minor surface defect or an irregularity of the articular surface, not involving the underlying bone. The majority of joints had 'surface destruction', an undisputable sign of abnormality.

Of the few available cross-sectional CBCT studies of symptomatic adolescents and young individuals with OA-like TMJ disease, the majority report bone erosive signs as the main TMJ finding.[1,2,23] In contrast, proliferative signs (sclerosis and osteophytes) and surface flattening are reported as the main findings in asymptomatic individuals or non-patients.[1,2,24] The dynamic nature of the TMJ findings as revealed in the present study may explain the apparent discrepancy of the observations in the above-mentioned studies. Our results showed erosive findings at baseline and more proliferative findings at follow-up, indicating that the observed signs will be highly influenced by the stage of development and the adaptation of the joint.

The relationship between DDwoR and OA in the TMJ is frequently discussed, and an association has been reported in adolescents.[23,25] The results from the present study are in line with this finding. Erosive findings were found in the majority of the joints with DDwoR, compared to only in a few joints with DDwR and in no joints with a normal disc position. Whether OA is a consequence of disc displacement, or vice versa, is still debated, and our study cannot contribute to answer this question. What is clear is that almost in all joints with DDwoR the disc was completely displaced, that is displaced in all sections through the joint, definitely a pathological condition.[12,19] Moreover, in those joints the disc displacement was severe, that is the disc was located with its intermediate zone or posterior band caudally to the articular eminence in all sections at closed mouth.

To the best of our knowledge, the present study is the first one with a rather long observation period to demonstrate improvement of erosive findings in such

Table 2 Condylar findings at baseline and at follow-up in 22 adolescents/young adults with joints showing erosive baseline abnormalities (n = 27 TMJs)

		Right TMJ n = *12*		*Left TMJ* n = *15*	
CT/ CBCT findings [a,b]		*Baseline*	*Follow-up*	*Baseline*	*Follow-up*
Erosive findings	Surface destruction	11	3	10	1
	Surface irregularity	1	2	5	5
Articular surface flattening		9	8	13	12
Subcortical sclerosis		4	6	5	2
Beaking		4	1	5	1
Osteophyte		0	3	1	7

CBCT, cone beam CT;
TMJ, temporomandibular joint.
[a]Defined according to Ahmad et al[9] with author based modifications.
[b]At baseline and follow-up, few joints were registered with condyle subcortical cyst, hypoplasia and deviation in form, or fossa/eminence articular surface flattening and subcortical sclerosis. No joints were registered with loose calcified body, bony ankylosis, generalized condylar sclerosis, condylar hypoplasia, and fossae/eminence irregularity or destruction.

Table 3 Disc position in relation to erosive findings at baseline in 18 adolescents/young adults (*n* = 35 TMJs)

	Right TMJ n = *17*[b]		*Left TMJ* n = *18*	
MRI findings of disc position at baseline[a]	*All*	*Erosive*	*All*	*Erosive*
Normal	3	0	2	0
Anterior displacement with reduction	3	2	4	0
Anterior displacement without reduction	11	9	12	12
Total joints	17	11	18	12

TMJ, temporomandibular joint.
[a]Defined according to the diagnostic criteria by Drace and Enzmann.[18]
[b]One joint could not be evaluated due to suboptimal image quality.

a large proportion of joints with a non-reducing disc. 11 of the 21 joints with erosions and DDwoR (4 right and 7 left) had repaired and developed an intact cortical outline at follow-up. This was an unexpected observation. Traditionally, non-reducing disc displacement is thought of as a severe form of internal derangement and frequently, at least by many, considered to be related to the development of osteoarthritis.

Most terms used to describe the OA-like abnormalities in children and adolescents are similar to those applied for adults: degenerative joint changes,[23] condylar bony changes,[3] condylar degeneration,[26] osteoarthrosis,[2] osteoarthritic changes,[1] and OA.[20,24] A 'juvenile' term, juvenile OA, has been introduced.[10] Another term, arthrosis deformans juvenilis, was introduced in 1966 and was associated with facial growth disturbances.[27] Later, several terms have been proposed: condylar resorption, idiopathic condylar resorption, progressive condylar resorption, adolescent internal condylar resorption, condylysis etc when erosive disease is related to facial deformities.[4]

Erosive TMJ disease in adolescents usually is considered a form of degenerative joint disease and the opinions on whether or not it is inflammatory are divergent.[5] Recently, a study comparing this disease with JIA convincingly demonstrated that both diseases were inflammatory.[6] This is in line with adult OA, being regarded as a low-inflammatory disease both in the TMJ and in other joints.[28–30] JIA is therefore an important differential diagnosis. It frequently involves the TMJ unilaterally in early phase but usually progresses into bilateral involvement.[31] Bone abnormalities can be similar in both disease groups. However, frequently the disc is normally located in JIA,[32] in contrast to erosive TMJ disease in which the disc is usually displaced. When the disc occasionally is displaced in JIA,[33] it may be difficult or impossible to radiologically distinguish JIA from erosive TMJ disease. The imaging signs that may differ between the diseases are a more pronounced inflammation and a more flattened fossa/eminence in JIA.[6] In the present study, none of the patients reported other joints with inflammatory signs (pain/swelling/reduced function) in the follow-up interview. Serologic tests for arthritis are often negative in JIA patients. When there is uncertainty about the diagnosis, the patient should be referred to a pediatric rheumatologist.

Idiopathic condylar resorption (ICR) also needs to be further discussed. Whether this condition is a separate disease entity, or an aggressive form of erosive TMJ disease,[4] is unclear. ICR is usually bilateral and progressive, resulting in facial growth disturbances and malocclusion.[5] In our study, three out of four patients had unilateral affection without clinically evident facial growth disturbances, and frequently the erosive findings improved. However, bilateral erosive findings did occur which could represent an early phase of ICR, before facial deformities are evident. However, also these patients improved. It seems to be impossible to differentiate between ICR and erosive TMJ disease by TMJ imaging findings alone, and they may show similar progression.[5] Occasionally, ICR is unilateral. One 12-year-old patient in the present study showed unilateral progression of the erosive findings during a 1.3 years follow-up period. This might be such a case.

The present study is focusing on the imaging features of OA-like TMJ disease in young patients, but self-experienced symptoms were also recorded. Self-experienced pain seemed quite low for most of the patients in the follow-up assessment. The vast majority (86%), had low-intensity pain without disability (GCPS Grade 1) or no pain at all (GCPS Grade 0). It was, however, challenging to evaluate the results of the jaw functional limitation assessment. Since no cut-offs yet have been provided for the interpretation of JFLS,[17] we considered patients who rated any of the JFLS questions with a score 5 or higher to have significant limitation while the remaining patients were classified as having low or no limitation.[14] Significant limitation was found in as many as 10 (45%), but our mean JFLS (0.7) seemed quite low, especially compared to a Swedish study of adolescent females (16–19 years) with self-reported symptoms and mean JFLS of 5.8.[34] This may indicate that the participants had a significant limitation in a limited number of situations. The GCPS and JFLS were not assessed at baseline and a comparison with the follow-up assessment could not be made. However, we speculate that the symptoms had improved as all patients had TMJ-related pain and most of them also had dysfunction when referred to us at baseline. Although pain and other symptoms have been associated with bone erosions in adolescents,[1] it is known that symptoms may fluctuate and frequently do not correlate with imaging findings.[12] In a short-term follow-up of adults (mean age 26.9 years) with TMJ OA, pain reduction was reported irrespectively of the imaging findings.[35]

Study limitations need mentioning. Dropouts are common in longitudinal studies. Of the 42 invited participants, 12 declined or did not show up for assessments and 6 were excluded. The small sample size limited the statistical analyses and precision of our estimates. Whether the non-participants had more or less severe disease (or symptoms) is unknown, and our findings can therefore only be generalized to a subgroup of adolescents with erosive TMJ findings who experience (and seek help for) TMJ-related pain. Further, as participation was voluntary, we cannot exclude selection bias.

Small sample sizes often evoke skepticism about whether the collected data can be subjected to a statistical test, as studies have limited statistical power and thus can often suffer Type II error. Our study was sufficiently powered for the main outcome. When conducting the power calculation, we anticipated the proportion of patients experiencing reduction of erosive findings to be at least 50%. Keeping the customary significance level α of 5%, we would need 25 individuals to achieve a level of precision of 10%. To achieve a lower level of precision of ±15%, we would need 12 patients. Thus, with 22 included individuals we consider our study sufficiently powered.

Other weaknesses of this study are that the baseline imaging techniques were not standardized, and that the osseous criteria are not validated for this age group. Future studies are therefore needed. To enhance the validity of the CBCT interpretation, we used two experienced radiologists to render consensus diagnoses, rather than depending on a single radiologist. However, the longitudinal changes of erosive findings from baseline to follow-up were assessed using a side by side comparison, which is a method susceptible to detection bias. Regarding the follow-up questionnaires, they have not been validated in individuals below 18 years of age. However, they are both used in studies in young populations and are considered appropriate and adapted for Scandinavian culture.[34]

Our results should be confirmed with larger studies using validated criteria and symptom registration both at baseline and at follow-up.

Conclusion

Improvement of the bone-erosive TMJ abnormalities was the dominant feature in this series of adolescents with TMJ-related symptoms undergoing non-surgical treatment. Half of the joints with erosive abnormalities repaired, the majority without other radiological abnormalities. Osteophytes were common at follow-up, and most of them were found in joints with erosive abnormalities. At follow-up, the majority of patients assessed their symptom severity as low.

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REFERENCES

1. Cho B-H, Jung Y-H. Osteoarthritic changes and condylar positioning of the temporomandibular joint in Korean children and adolescents. *Imaging Sci Dent* 2012; **42**: 169–74. doi: https://doi.org/10.5624/isd.2012.42.3.169
2. Wang ZH, Jiang L, Zhao YP, Ma X-chen. Investigation on radiographic signs of osteoarthrosis in temporomandibular joint with cone beam computed tomography in adolescents. *Beijing Da Xue Xue Bao Yi Xue Ban* 2013; **45**: 280–5.
3. Nah KS. Condylar bony changes in patients with temporomandibular disorders: a CBCT study. *Imaging Sci Dent* 2012; **42**: 249–53. doi: https://doi.org/10.5624/isd.2012.42.4.249
4. Kristensen KD, Schmidt B, Stoustrup P, Pedersen TK. Idiopathic condylar resorptions: 3-dimensional condylar bony deformation, signs and symptoms. *Am J Orthod Dentofacial Orthop* 2017; **152**: 214–23. doi: https://doi.org/10.1016/j.ajodo.2016.12.020
5. Hatcher DC. Progressive condylar resorption: pathologic processes and imaging considerations. *Semin Orthod* 2013; **19**: 97–105. doi: https://doi.org/10.1053/j.sodo.2012.11.005
6. Kellenberger CJ, Bucheli J, Schroeder-Kohler S, Saurenmann RK, Colombo V, Ettlin DA. Temporomandibular joint magnetic resonance imaging findings in adolescents with anterior disk displacement compared to those with juvenile idiopathic arthritis. *J Oral Rehabil* 2019; **46**: 14–22. doi: https://doi.org/10.1111/joor.12720
7. Moldez MA, Camones VR, Ramos GE, Padilla M, Enciso R. Effectiveness of intra-articular injections of sodium hyaluronate or corticosteroids for intracapsular temporomandibular disorders: a systematic review and meta-analysis. *J Oral Facial Pain Headache* 2018; **32**: 53–66. doi: https://doi.org/10.11607/ofph.1783
8. Lei J, Liu M-Q, Yap AUJ, Fu K-Y. Condylar subchondral formation of cortical bone in adolescents and young adults. *Br J Oral*

Maxillofac Surg 2013; **51**: 63–8. doi: https://doi.org/10.1016/j.bjoms.2012.02.006
9. Ahmad M, Hollender L, Anderson Q, Kartha K, Ohrbach R, Truelove EL, et al. Research diagnostic criteria for temporomandibular disorders (RDC/TMD): development of image analysis criteria and examiner reliability for image analysis. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2009; **107**: 844–60. doi: https://doi.org/10.1016/j.tripleo.2009.02.023
10. Larheim TA, Abrahamsson A-K, Kristensen M, Arvidsson LZ. Temporomandibular joint diagnostics using CBCT. *Dentomaxillofac Radiol* 2015; **44**: 20140235. doi: https://doi.org/10.1259/dmfr.20140235
11. da Silva CG, Pachêco-Pereira C, Porporatti AL, Savi MG, Peres MA, Flores-Mir C, et al. Prevalence of clinical signs of intra-articular temporomandibular disorders in children and adolescents: a systematic review and meta-analysis. *J Am Dent Assoc* 2016; **147**: 10–18. doi: https://doi.org/10.1016/j.adaj.2015.07.017
12. Larheim TA, Hol C, Ottersen MK, Mork-Knutsen BB, Arvidsson LZ. The role of imaging in the diagnosis of temporomandibular joint pathology. In: Laskin D. M, Renapurkar S. K, eds. *Current controversies in the managment of temporomandibular disorders 2018/06/06 ed. Oral Maxillofac Surg Clin North Am 302018*. **30**; 2018 08.. pp. 239–49. doi: https://doi.org/10.1016/j.coms.2018.04.001
13. Ohrbach R, Larsson P, List T. The jaw functional limitation scale: development, reliability, and validity of 8-item and 20-item versions. *J Orofac Pain* 2008; **22**: 219–30.
14. Lövgren A, Visscher CM, Häggman-Henrikson B, Lobbezoo F, Marklund S, Wänman A. Validity of three screening questions (3Q/TMD) in relation to the DC/TMD. *J Oral Rehabil* 2016; **43**: 729–36. doi: https://doi.org/10.1111/joor.12428
15. Von Korff M, Ormel J, Keefe FJ, Dworkin SF. Grading the severity of chronic pain. *Pain* 1992; **50**: 133–49. doi: https://doi.org/10.1016/0304-3959(92)90154-4
16. Dworkin SF, Sherman J, Mancl L, Ohrbach R, LeResche L, Truelove E. Reliability, validity, and clinical utility of the research diagnostic criteria for temporomandibular disorders axis II scales: depression, non-specific physical symptoms, and graded chronic pain. *J Orofac Pain* 2002; **16**: 207–20.
17. Ohrbach R, Knibbe W. Diagnostic Criteria for Temporomandibular Disorders: Scoring Manual for Self-Report Instruments. Version 9 January2017 [Assessed on 02/10/17]. Available from: http://www.rdc-tmdinternational.org.
18. Drace JE, Enzmann DR. Defining the normal temporomandibular joint: closed-, partially open-, and open-mouth MR imaging of asymptomatic subjects. *Radiology* 1990; **177**: 67–71. doi: https://doi.org/10.1148/radiology.177.1.2399340
19. Larheim TA, Westesson P, Sano T. Temporomandibular joint disk displacement: comparison in asymptomatic volunteers and patients. *Radiology* 2001; **218**: 428–32. doi: https://doi.org/10.1148/radiology.218.2.r01fe11428
20. Yamada K, Saito I, Hanada K, Hayashi T. Observation of three cases of temporomandibular joint osteoarthritis and mandibular morphology during adolescence using helical CT. *J Oral Rehabil* 2004; **31**: 298–305. doi: https://doi.org/10.1046/j.1365-2842.2003.01246.x
21. Lei J, Yap AU-J, Liu M-Q, Fu K-Y. Condylar repair and regeneration in adolescents/young adults with early-stage degenerative temporomandibular joint disease: a randomised controlled study. *J Oral Rehabil* 2019; **46**: 704–14. doi: https://doi.org/10.1111/joor.12805
22. van der Kraan PM, van den Berg WB. Osteophytes: relevance and biology. *Osteoarthritis Cartilage* 2007; **15**: 237–44. doi: https://doi.org/10.1016/j.joca.2006.11.006
23. Lei J, Han J, Liu M, Zhang Y, Yap AU-J, Fu K-Y. Degenerative temporomandibular joint changes associated with recent-onset disc displacement without reduction in adolescents and young adults. *J Craniomaxillofac Surg* 2017; **45**: 408–13. doi: https://doi.org/10.1016/j.jcms.2016.12.017
24. Krisjane Z, Urtane I, Krumina G, Neimane L, Ragovska I. The prevalence of TMJ osteoarthritis in asymptomatic patients with dentofacial deformities: a cone-beam CT study. *Int J Oral Maxillofac Surg* 2012; **41**: 690–5. doi: https://doi.org/10.1016/j.ijom.2012.03.006
25. Moncada G, Cortés D, Millas R, Marholz C. Relationship between disk position and degenerative bone changes in temporomandibular joints of young subjects with TMD. An MRI study. *J Clin Pediatr Dent* 2014; **38**: 269–76. doi: https://doi.org/10.17796/jcpd.38.3.w43m8474433n7ur2
26. Zhuo Z, Cai X. Results of radiological follow-up of untreated anterior disc displacement without reduction in adolescents. *Br J Oral Maxillofac Surg* 2016; **54**: 203–7. doi: https://doi.org/10.1016/j.bjoms.2015.11.007
27. Nickerson JW,Boering JW. Natural course of osteoarthrosis as it relates to internal derangement of the temporomandibular joint. *Oral Maxillofac Surg Clin North Am* 1989; **1**: 27.-46.
28. Berenbaum F. Osteoarthritis as an inflammatory disease (osteoarthritis is not osteoarthrosis!) *Osteoarthritis Cartilage* 2013; **21**: 16–21. doi: https://doi.org/10.1016/j.joca.2012.11.012
29. Wenham CY, Conaghan PG. New horizons in osteoarthritis. *Age Ageing* 2013; **42**: 272–8. doi: https://doi.org/10.1093/ageing/aft043
30. Wang XD, Zhang JN, Gan YH, Zhou YH. Current understanding of pathogenesis and treatment of TMJ osteoarthritis. *J Dent Res* 2015; **94**: 666–73. doi: https://doi.org/10.1177/0022034515574770
31. Arvidsson LZ, Flatø B, Larheim TA. Radiographic TMJ abnormalities in patients with juvenile idiopathic arthritis followed for 27 years. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2009; **108**: 114–23. doi: https://doi.org/10.1016/j.tripleo.2009.03.012
32. Arvidsson LZ, Smith H-J, 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
33. Kirkhus E, Arvidsson LZ, Smith H-J, 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
34. Nilsson I-M, Drangsholt M, List T. Impact of temporomandibular disorder pain in adolescents: differences by age and gender. *J Orofac Pain* 2009; **23**: 115–22.
35. Lee J-Y, Kim D-J, Lee S-G, Chung J-W. A longitudinal study on the osteoarthritic change of the temporomandibular joint based on 1-year follow-up computed tomography. *J Craniomaxillofac Surg* 2012; **40**: e223–8. doi: https://doi.org/10.1016/j.jcms.2011.10.023