

ORIGINAL RESEARCH ARTICLE

Topographic evaluation of sacroiliac joints by magnetic resonance imaging in patients with axial spondyloarthritis

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ABSTRACT

Objective: To evaluate the imaging features of spondyloarthritis on magnetic resonance imaging (MRI) of the sacroiliac (SI) joints in terms of topography (in thirds) and affected margin, since this aspect is rarely addressed in the literature. **Methods:** Cross-sectional study with MRI (1.5 T) evaluation of the SI in 16 patients with diagnosis of axial spondyloarthritis regarding the presence of acute (subchondral bone edema, enthesitis, synovitis and capsulitis) and chronic changes (erosions, subchondral bone sclerosis, bone bridging and fatty replacement), performed by two radiologists, blinded to clinical data. MRI findings were correlated with clinical data including age, disease duration, medications, HLA-B27, BASDAI, ASDAS-VHS and ASDAS-PCR, BASMI, BASFI, and mSASSS. **Results:** Bone edema pattern and erosions showed predominance in the upper third of SI ($p = 0.050$, $p = 0.0014$, respectively). There was a correlation between the time of disease and structural changes by affected third ($p = 0.028-0.037$), as well as the presence of bone bridges with BASMI ($p = 0.028$) and mSASSS ($p = 0.014$). Patients with osteitis of the lower third had higher ASDAS values (ESRV: $p = 0.011$ and CRP: $p = 0.017$). **Conclusion:** Chronic inflammatory changes and the pattern of bone edema predominated in the upper third of the SI, but there was also concomitant involvement of the middle or lower thirds of the joint. The localization of involvement in the upper third of the SI was insufficient to differentiate between degeneration and inflammation.

Keywords: Magnetic Resonance Imaging; Sacroiliac Joints; Spondyloarthritis; Sacroiliitis; Topographic Evaluation

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1. Introduction

Spondyloarthritis (SpA) represents a group of diseases with a prevalence of 0.5 to 1.9% and encompasses ankylosing spondylitis, psoriatic arthritis, arthritis associated with inflammatory bowel disease, reactive arthritis and undifferentiated forms. In addition, they have a genetic association with the human leukocyte antigen (HLA) B27 and overlapping clinical forms may occur in the same patient or in first-degree relatives^[1,2]. Conventional radiography (Rx) is inadequate to diagnose the disease in its early stage, especially before the appearance of structural lesions, since it does not detect acute inflammatory lesions and may delay the diagnosis by 8 to 11 years on average^[1,3].

Due to the diagnostic difficulties caused by overlapping clinical pictures of mechanical and inflammatory sacroiliitis, the topographic

study of the SpA by magnetic resonance imaging (MRI) may help to clarify this gap in the literature. The purpose of this study was to describe the topographic characteristics of sacroiliac joint involvement using MRI to help differentiate between inflammatory and mechanical involvement, since these aspects are little covered in the literature, and to correlate clinical and laboratory data with imaging findings.

2. Material and methods

A cross-sectional observational study was carried out involving 16 patients from the Spondyloarthritis Outpatient Clinic of the Universidade Federal de São Paulo (UNIFESP). We included patients diagnosed with axial SpA, according to the classification criteria proposed by the Assessment of Spondyloarthritis International Society (ASAS), and who were referred for MRI of the sacroiliac joints (24 patients). Patients without abnormalities on MRI of the sacroiliac joints and those with incomplete laboratory data were excluded; 16 patients remained. Of these, 12 were diagnosed with ankylosing spondylitis and 4 with non-radiographic axial spondyloarthritis. The exams were analyzed separately by two radiologists from the Department of Imaging Diagnosis (DDI) of UNIFESP, with 5 and 15 years of experience in musculoskeletal specialization (MRC and EAF), blinded to clinical data, and the cases in which there was disagreement were decided by consensus.

MRI scans were performed at DDI-UNIFESP, in 1.5 T, Siemens (Siemens Medical Solutions, Erlangen, Germany) and Philips (Gyrosan; Philips, Eindhoven, The Netherlands) scanners, with matrix ranging from 320×70 to 320×90 . All acquisitions were made at 4 mm thickness. Image evaluation was performed on a standard video monitor with 1024×768 pixel, 32-bit resolution.

The routine protocol used in the sacroiliac region was: three planes localizer, coronal short-tau inversion recovery (STIR), coronal T1, axial T2 with fat-sat, and axial T1. After intravenous (IV) paramagnetic contrast injection, axial and coronal T1-weighted fat-sat sections were performed. On MRI, acute and chronic inflammatory alterations of the sacroiliac joints were studied and divided into

three thirds: the upper third, above the first sacral foramen; the middle third, between the first two sacral foramen; and the lower third, below the second sacral foramen (**Figure 1**).

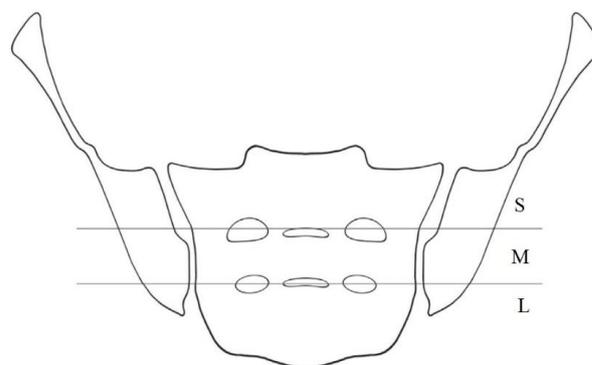


Figure 1. Schematic drawing of the division into thirds made for the evaluation of the imaging findings.
Note: S: upper third; M: middle third; L: lower third.

As regards acute alterations, the presence of osteitis was verified and topographed, characterized by subchondral bone edema (high signal on liquid-sensitive sequences and contrast-enhancement). In addition, signs of capsulitis, enthesitis and synovitis were found which, without associated osteitis, are not sufficient to assure the diagnosis of active sacroiliitis, defined on the basis of the Outcome Measures in Rheumatology Clinical Trials (OMERACT) resolution 10^[4].

(1) Capsulitis: high signal intensity on STIR and/or T1 fat-sat sequence after IV contrast in the anterior or posterior capsule. May show medial and/or lateral extension into the adjacent periosteum.

(2) Enthesitis: high signal on STIR and/or T1 fat-sat after IR contrast at sites where ligaments and tendons insert into bone, including the retroarticular space (interosseous ligaments). The signal change may extend into the bone marrow and adjacent soft tissues.

(3) Synovitis: high signal intensity on T1 fat-sat after IR contrast in the synovial portion of the sacroiliacs (signal intensity similar to that of blood vessels).

Chronic lesions in the sacroiliac joints were characterized by the presence of erosions, subchondral bone sclerosis, bone bridges, and fatty replacement as established by ASAS^[5]. Through the analysis of the medical records, the following clinical data were verified: age, sex, skin color, duration

of disease, continuous use of non-steroidal anti-inflammatory drugs (NSAIDs) and other disease course modifying drugs (DCMDs) such as sulfasalazine and anti-tumor necrosis factor blockers (anti-TNF), HLA-B27 research and specific instruments for the evaluation of disease activity (BASDAI-Bath Ankylosing Spondylitis Disease Activity Index and ASDAS—Ankylosing Spondylitis Disease Activity Score, with PCR—C-reactive protein and ESR—erythrocyte sedimentation rate), mobility (BASMI-Bath Ankylosing Spondylitis Metrology Index) and function (BASFI—Bath Ankylosing Spondylitis Functional Index), as well as structural damage (mSASSS—Modified Stoke Ankylosing Spondylitis Spine Score).

The MRI findings were compared with each other and with the clinical data obtained from the medical record, and data on disease activity (BASDAI, BASFI, ASDAS-VHS and ASDAS-PCR with the acute MRI findings) and time of disease and clinical tests associated with chronicity (BASMI and mSASSS) were correlated with the chronic MRI findings. Chi-square and Fisher's exact tests were used for categorical variables and Student's t-test for independent samples for numerical variables. In order to evaluate concomitantly the association between categorical (use of medication and alterations in the sacroiliac joints on MRI) and numerical variables (duration of disease, BASDAI, ASDAS-PCR, ASDAS-VHS, BASMI, BASFI, mSASSS), cluster analysis was performed using the Student's t-test. The significance level (*p* value) considered was 0.05.

3. Results

The group of patients studied was composed of 11 men and five women, with a mean age of 46.4 years and a mean time of illness of 8.6 years. HLA-B27 was positive in nine (56.3%) of the patients, negative in six (37.5%), and unavailable in one (6.3%). Demographic, clinical and laboratory data are presented in **Table 1**.

Regarding the topography of MRI findings, the upper third was the most affected, both for bone edema (*p* = 0.049) and chronic changes (*p* = 0.0014). In the case of acute changes, the second most affected third was the lower third, and in the

Table 1. Demographic, clinical and laboratory characteristics

Evaluated parameters	Values
Age (years), mean ±SD	46.4 ±13.2
Sex, n (%)	
Male	11 (68.8)
Female	5 (31.2)
Skin color, n (%)	
White	11 (68.8)
Not white	5 (31.2)
Time of illness (years), mean ±SD	8.6 ±7.2
Presence of EAM and AM, n (%)	
Uveitis	6 (37.5)
Psoriasis	2 (12.5)
Colitis	0 (0.0)
Urethritis	2 (12.5)
Enthesitis	14 (87.5)
Arthritis	7 (43.8)
Disease activity assessment indices, mean ±SD	
BASDAI	3.9 ±3.0
BASMI	3.3 ±2.2
BASFI	4.3 ±2.3
ASDAS-VHS	3.4 ±1.6
ASDAS-PCR	3.1 ±1.8
mSASSS	7.9 ±6.2
Concomitant medications, n (%)	
Non-steroidal anti-inflammatory drugs	11 (68.8)
TNF blockers	2 (12.5)
Sulfasalazine	4 (25.0)
Did not use	4 (25.0)

Note: SD: standard deviation; AM: peripheral articular manifestations; EAM: extra-articular manifestations.

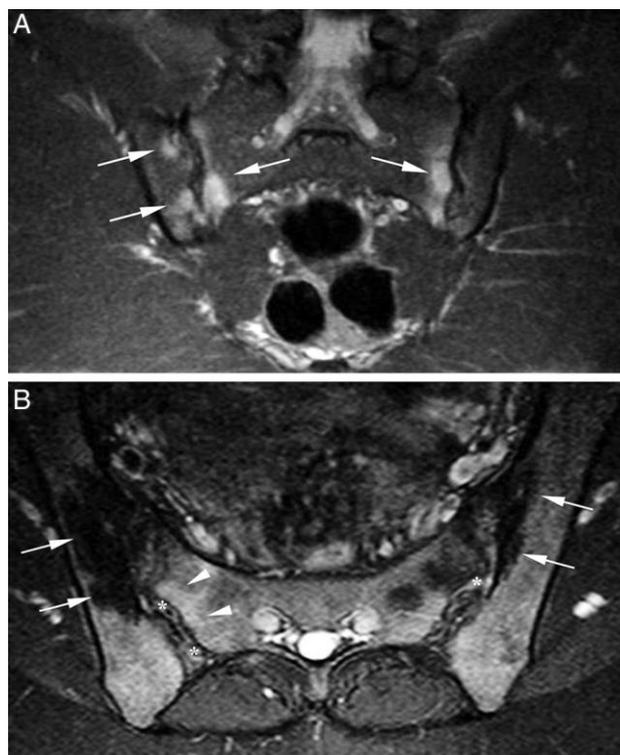


Figure 2. A: Coronal MRI T2-weighted section with fat-signal saturation shows bone marrow edema in the upper and middle thirds of the sacroiliac joints (arrows); B: axial MRI T2-weighted section with fat-signal saturation shows bone sclerosis in the upper third of the sacroiliac joints (arrows). Subchondral edema is observed on the right sacral surface (arrowheads) and bilateral enthesitis (asterisks).

Table 2. Correlation of acute changes and areas of bone edema per third with clinical and laboratory data related to disease activity

Acute changes	Clinic-laboratory data			
	BASDAI	BASFI	ASDAS-VHS	ASDAS-PCR
Bone edema				
Presence (n = 7)	3.4 ± 3.4	3.5 ± 2.3	3.8 ± 2.0	3.4 ± 2.4
Absence (n = 9)	4.3 ± 2.8	5.0 ± 2.2	3.0 ± 1.2	2.9 ± 1.2
t-test (p)	0.576	0.193	0.299	0.592
Enthesitis				
Presence (n = 4)	5.4 ± 4.6	3.4 ± 2.4	4.4 ± 2.4	3.8 ± 3.1
Absence (n = 12)	3.4 ± 2.3	4.7 ± 2.3	3.0 ± 1.1	2.8 ± 1.2
t-test (p)	0.256	0.346	0.144	0.357
Synovitis				
Presence (n = 5)	5.6 ± 4.0	3.1 ± 2.2	4.0 ± 2.2	3.6 ± 2.7
Absence (n = 11)	3.1 ± 2.2	4.9 ± 2.3	3.1 ± 1.2	2.9 ± 1.3
t-test (p)	0.133	0.167	0.261	0.457
Bone edema per third				
<i>Upper third</i>				
Presence (n = 6)	4.0 ± 3.3	3.7 ± 2.4	3.6 ± 2.0	3.0 ± 2.4
Absence (n = 10)	3.9 ± 3.0	4.7 ± 2.3	3.2 ± 1.3	3.2 ± 1.4
t-test (p)	0.946	0.416	0.680	0.863
<i>Middle Third</i>				
Presence (n = 2)	6.7 ± 4.7	2.8 ± 2.5	5.3 ± 2.7	5.0 ± 3.7
Absence (n = 14)	3.5 ± 2.7	4.6 ± 2.3	3.1 ± 1.3	2.8 ± 1.4
t-test (p)	0.177	0.320	0.060	0.117
<i>Lower third</i>				
Presence (n = 3)	4.4 ± 5.1	2.5 ± 1.8	5.3 ± 1.9	5.2 ± 2.7
Absence (n = 13)	3.8 ± 2.6	4.8 ± 2.3	2.9 ± 1.1	2.6 ± 1.2
t-test (p)	0.752	0.135	0.011	0.017

Table 3. Correlation of structural (chronic) lesions with time of disease, BASMI and mSASSS

Structural injuries	Sick time	BASMI	mSASSS
Fatty substitution			
Presence (n = 5)	12.4 ± 10.9	4.4 ± 2.3	11.8 ± 7.4
Absence (n = 11)	6.8 ± 4.3	2.8 ± 2.0	6.2 ± 5.1
t-test (p)	0.155	0.192	0.096
Bone bridge			
Presence (n = 2)	19.5 ± 16.3	6.4 ± 0.6	17.5 ± 3.5
Absence (n = 14)	7.0 ± 4.2	2.9 ± 1.9	6.6 ± 5.3
t-test (p)	0.015	0.028	0.014
Subchondral sclerosis			
Presence (n = 6)	9.8 ± 2.6	3.2 ± 2.4	7.2 ± 6.0
Absence (n = 10)	7.8 ± 9.0	3.4 ± 2.1	8.4 ± 6.7
t-test (p)	0.601	0.878	0.716
Erosion			
Presence (n = 13)	9.5 ± 7.5	3.2 ± 2.3	7.2 ± 6.3
Absence (n = 3)	4.3 ± 3.5	3.8 ± 2.0	11.0 ± 6.1
t-test (p)	0.272	0.701	0.364
Total structural lesions per thirds			
<i>Upper third</i>			
Presence (n = 14)	9.4 ± 7.3	3.4 ± 2.3	7.8 ± 6.4
Absence (n = 2)	2.5 ± 2.1	2.7 ± 1.0	9.0 ± 7.0
t-test (p)	0.031	0.683	0.807
<i>Middle third</i>			
Presence (n = 9)	11.8 ± 8.0	3.9 ± 2.0	8.9 ± 6.7
Absence (n = 7)	4.4 ± 2.9	2.5 ± 2.3	6.7 ± 5.9
t-test (p)	0.037	0.220	0.509
<i>Lower third</i>			
Presence (n = 5)	14.2 ± 10.0	4.2 ± 2.1	11.8 ± 5.2
Absence (n = 11)	6.0 ± 3.7	2.9 ± 2.2	6.2 ± 6.1
t-test (p)	0.028	0.306	0.096

case of chronic changes, the middle third. There was a statistically significant correlation between the alterations of the upper, middle, and lower thirds in relation to the edema on the iliac side ($p =$

0.050), that is, when the alteration was present in the upper third of the iliac border, it was also present in the middle or lower thirds. The same did not occur regarding the sacral margin edema, in which two patients presented isolated edema in the upper third, or when the iliac and sacral sides were considered together.

Acute changes were observed in almost 60% of the patients. The most frequent finding was bone edema ($n = 6$; 37.5%; five on the sacral and four on the iliac side) (**Figures 1 and 2**), followed by synovitis ($n = 5$; 31.2%) and enthesitis ($n = 4$; 25%) (**Figure 2**). Capsulitis was not observed. Chronic alterations were observed in the great majority of patients ($n = 14$; 87.5%). The findings in decreasing order of frequency were: erosions ($n = 13$; 81.2%), subchondral sclerosis ($n = 6$; 37.5%) (**Figure 2**), fatty replacement ($n = 5$; 31.2%), and bone bridge ($n = 2$; 12.5%).

Patients with signs of osteitis in the lower third had higher ASDAS-VHS and ASDAS-PCR values ($p = 0.011$ and $p = 0.017$, respectively) (**Table 2**). There was an association between the long-time of disease and the presence of chronic alterations globally and also by third of involvement (upper: $p = 0.031$; middle: $p = 0.037$; lower: $p = 0.028$) (**Table 3**). Furthermore, there was an association be-

tween the presence of bone bridges, regardless of topography, with long disease duration ($p = 0.015$) and higher BASMI ($p = 0.028$) and mSASSS ($p = 0.014$) values.

4. Discussion

MRI constitutes a major advance, not only for the diagnosis but possibly in the clinical management of spondyloarthritis, including differential diagnosis and therapeutic monitoring^[6,7] because of its sensitivity and reliability for the evaluation of signs of active inflammation^[8].

The higher frequency of acute and chronic findings observed in the present study in the upper third of the sacroiliac joints is, to the best of our knowledge, a new finding in the literature. The fact that both bone edema and chronic changes present this behavior suggests that this was one of the sites of disease activity, which has raised questions about justification from the point of view of joint anatomy and also of disease pathophysiology.

4.1 Anatomy of the sacroiliac joints

The sacroiliac joint is considered an “amphiarthrosis”^[9] with a cartilaginous diarticular (synovial) portion (composed of the sacral and iliac auricular surfaces) and another syndesmosis fibrous portion (composed of the interosseous ligaments). Its cartilaginous portion (C-shaped, with the convexity facing anteriorly) has been considered a synovial joint since the 1920s, but it is not a usual synovial joint, given the unique characteristics of the sacroiliac joint. First, the articular facets have a thick hyaline cartilage on the sacral side and a thick hyaline cartilage on the iliac side. In addition, the articular capsule is fibrous and has sites of discontinuity.

In the upper third of the sacroiliac joint, thick bands of membranous tissue with a wide transitional zone composed of fibrocartilage that start from the ventral sacroiliac ligament and insert into the sacral and iliac articular cartilages stand out. Dorsally, in the ligamentous portion of the articulation, tough fibers of ligaments insert into both the bone and the sacral and iliac cartilages^[10].

Puhakka *et al.*^[11] correlating histology of the sacroiliac joint with MRI findings, demonstrated

the absence of synovial tissue in the upper third of the joint in normal individuals within the cartilaginous region and in the joint capsule. Bowen and Cassidy^[10] described that the joint capsule, from the third and fourth decades of life on, becomes more collagenous and less cellular, which could explain the absence of synovial tissue in the anatomopathological study of Puhakka *et al.*^[11] in which the cadavers were between 20 and 45 years old.

4.2 Pathophysiology of spondyloarthritis

In ankylosing spondylitis, the finding of enthesitis is so striking that it is considered the primary lesion of this disease. In the other spondyloarthritides, Benjamin and McGonagle^[12] proposed that synovitis is secondary to the release of inflammatory media from the involvement of the adjacent entheses.

Correlating these data to the fact that the iliac facet is covered by fibrocartilage, since inflammatory activity usually starts and predominates on this facet, these fibrous ligament and cartilage components may be the keys to the antigenic target involved^[13,14]. Perhaps the fibrous component of the fibrocartilage is the preferential target of the inflammatory attack rather than the pure hyaline cartilage present in the sacral aspect of the joint.

There are two types of entheses^[12]: the fibrous and the fibrocartilaginous. The involvement of spondyloarthritis is usually located in the latter and spares the former. Fibrocartilaginous genes are not mere junctions of tendons or ligaments with bones and can be considered complex organs. This complexity is not only observed in the “true” entheses, but also in places of friction with bony surfaces or fibrous structures, called functional entheses. The similarity of this type of entheses with the fibrocartilaginous lining of some articular surfaces in synovial joints, the most striking example of which is the iliac surface of the sacroiliac joint, should also be mentioned.

Only the constitution of the entheses does not determine their involvement. It was observed that osteitis seems to follow mechanical stress lines and also that functional entheses are affected even though there is no direct contact with the bone component. Thus, it is inferred that biomechanical

influences can initiate and/or perpetuate bone inflammatory changes^[13].

The presence of acute and chronic inflammatory changes prevalent in the upper third of the sacroiliac joints found in the present study is probably related to the anatomical and pathophysiological characteristics commented above, as a reflection of the inflammatory activity in the emphases, which also involves the upper third of the sacroiliac joints. Bone erosions were found predominantly in the upper thirds of the iliac facets. Based on the premise that erosions are the most specific finding^[15] of spondyloarthritis, our findings suggest that the inflammatory activity also occurred in the upper third. However, it is important to note that isolated involvement of the upper sacroiliac third was not observed in any patient.

There is no consensus in the literature regarding the topographical criteria for sclerosis in sacroiliac joints to define degenerative changes. Resnick *et al.*^[16] have evaluated degenerative sacroiliac arthropathy by conventional radiography and found that focal sclerosis was more common in the upper and lower margins of the sacroiliac joint cavity. Shibata *et al.*^[17] performed tomographic evaluation and the finding of (degenerative) sclerosis was most common in the upper and middle portions of the anterior region of the iliac joint facet. Brunner *et al.*^[18] found, in their histological evaluation, a higher frequency of degenerative changes in the medial third. In the present study, the higher frequency of our finding of sclerosis in the upper sacroiliac third could raise the question as to the degenerative origin, considering that more than half of our patients were over 50 years of age and the findings of degenerative arthropathy are described increasingly over the age of 20^[10]. However, given the concomitance with another more specific finding for inflammatory arthropathy (erosion) in the upper third of the sacroiliac joints, we believe that the sclerosis must be related to the chronic structural lesions of spondyloarthritis.

The observation in the present study of a higher frequency of chronic alterations than of acute ones may be justified by the long mean time of disease of the patients, which was considered as from the diagnosis (8.2 years). Considering that the di-

agnosis can be delayed mainly with the evaluation only by conventional radiography^[19], we can infer that the actual time of disease must be even longer than considered.

The long duration of the disease favors that the chronic alterations should alter the load axis of his axial skeleton, due to the change in sagittal balance with rectification of the lumbar lordosis and variable alterations of the thoracic kyphosis. It is known that sacroiliac joint motion occurs by nutation and counter nutation and the pivot of the joint occurs in the iliac tubercle at the level of S2, posterior to the auricular aspect of the joint^[9,18]. Therefore, further studies are needed to assess how structural changes influence sagittal balance and whether this would be related to the topography of the lesions.

4.3 Correlation of MRI findings with clinical and laboratory data

The higher ASDAS-VHS and ASDAS-PCR values in patients with signs of osteitis of the lower third suggest that these areas of bone edema were linked to inflammatory activity. The statistical correlation between chronic findings and duration of disease is corroborated by the long average time of disease of the patients, as well as the possible diagnostic delay inherent to the conventional radiological method. The significant correlation between the presence of bone bridges, regardless of topography, with the BASMI and the mSASSS reinforces the relationship between the structural damage of the sacroiliac joints with those of the spine and the impairment of mobility.

Limitations of the paper included the small sample size and the variable time interval between symptom onset, diagnosis and MRI examination.

5. Conclusions

Chronic inflammatory changes and the pattern of bone marrow edema predominated in the upper third of the sacroiliac joints, but were also observed in the lower 2/3. This suggests that the entire joint may be affected by the inflammatory process of the entosynovial complex in patients with axial SpA. On the other hand, the location does not seem to be sufficient to differentiate inflammatory from degenerative changes.

Furthermore, there was a significant correlation between ASDAS-VHS and ASDAS-PCR with the presence of osteitis in the SI lower third, and between long disease duration and the presence of chronic structural changes, as well as between the clinical assessment instruments BASMI and mSASSS with the presence of sacroiliac bone bridges.

Conflict of interest

The authors declared no conflict of interest.

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