Original Article

CHONDROMALACIA PATELLAE: COMPARISON OF HIGH-FIELD STRENGTH VERSUS LOW-FIELD STRENGTH MRI FINDINGS*

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Abstract

OBJECTIVE: To compare the performance of low-field-strength and high-field-strength magnetic resonance imaging equipment for evaluation of the patella articular cartilage. MATERIALS AND METHODS: The study was developed using GRE 2D, GRE 3D, FSE T2, STIR sequences (low-field) and TSE T2 SPIR sequences. Each sequence has been separately analyzed for evaluation of the cartilage without knowledge of other sequences results or any patients data; the lesion was assigned a grade from 0 to 3 and had its location defined. Agreement and disagreement results were analyzed by Kappa and McNemar tests. RESULTS: Medial facet has presented low agreement index and disagreements showed

to be significantly overestimated. Lateral facet has presented a reasonable agreement index and disagreement index was not significant. Medial ridge has presented a reasonable agreement index and disagreement index has showed to be underestimated. CONCLUSION: The STIR sequence versus TSE T2 SPIR sequence has presented the higher agreement index. High-grade lesions are better characterized by low-field-strength magnetic resonance imaging equipment sequences. Areas of increased signal intensity make difficult the study of the patella medial facet cartilage in low-field-strength equipment.
Keywords: Magnetic resonance imaging; Skeletal – appendicular; Knee; Comparative study; Equipments; Imaging sequences.

INTRODUCTION

Chondromalacia patellae is a term applied to the loss of cartilage involving one or more portions of patella. Its incidence in the population is very high, increasing with age, and is more frequent in overweight female[1].

Chondromalacia causes include instability, direct trauma, fracture, patellar subluxation, increase in the quadriceps angle (Q angle), inefficient vastus medialis muscle, post-traumatic malalignment, excessive lateral pressure syndrome and posterior cruciate ligament injury[2].

Two types of alterations may occur in the chondromalacia patellae genesis: age dependent superficial degeneration (middle and old-aged people) and basal degeneration (teenagers)[1].

In young patients, cartilage lesions, unless diagnosed and treated, may result in early osteoarthrosis[3].

With plain X-ray and computed tomography it is possible to indirectly diagnose chondral lesions by the presence of osteophytes, cysts and subchondral sclerosis, and articular space narrowing[4] and, in a combination with intra-articular contrast injection, it is possible to directly demonstrate chondral lesions, especially by means of computed tomography[5].

The magnetic resonance imaging, due its excellent soft tissues contrast resolution, is the best imaging technique available for cartilage lesions assessment[3].

According to their strength of the main magnetic field, MRI devices are divided into ultra-low-field (< 0.1 T), low-field (0.1 to 0.3 T)[6], middle-field (between 0.3 and 1.0 T)[7], high-field (between 1.0 and 2.0 T)[8] and ultra-high-field (> 2,0 T)[9].

The advantages of low-field devices in comparison with high-field devices are purchase, installation and maintenance lower costs[6], quite reduced magnetic susceptibility and chemical shift artifacts [8] and possibility of using open magnet, allowing claustrophobic patients examination[10].

Technical disadvantages include lower intrinsic signal-noise ratio, demanding more excitations, resulting in longer acquisition times[6], and the impossibility of using frequency-selective fat suppression.

Low-field devices depend on STIR sequence for suppressing the fat signal in a delayed sequence and low signal-noise ratio[8].

The FSE T2 sequence is a quite accurate technique for detection of cartilage lesions, due its arthrographic effect[11] and medullar bone edema high signal intensity[3,12], also with a good correlation between the grade of the cartilage lesion and the arthroscopy[13–15].

The low-field devices accuracy for evaluating the hyalin cartilage depends on the sequence utilized. James & Buirski[16] utilizing spin eco T1 and T2 sequences, have detected high-grade chondral lesions; Parizel *et al*.[6], utilizing spin echo T1 and echo 3D gradient sequences, have obtained images with quality similar to the quality of the high-field device images; Kladny *et al*.[17], utilizing the echo 3D gradient sequence, could not evaluate the different grades of lesion; Ahn *et al*.[18] have concluded that high-grade cartilage lesions can be reliably evaluated by means of echo 2D gradient and echo 3D gradient sequences.

The present study objective was to compare the diagnostic efficacy of low-field and high-field magnetic resonance devices for evaluation of patella articular cartilage utilizing GRE 2D, GRE 3D, FSE T2 and STIR (low-field) and TSE T2 SPIR. sequences.

MATERIALS AND METHODS

Individuals

The present study has been approved by the Ethics Committee of the Universidade Federal de São Paulo.

This study has prospectively evaluated two patients groups. Group 1 included 15 patients presenting patellofemoral pain and group 2 included 10 asymptomatic volunteers. Therefore, 25 individuals were included in the study, 13 female, 12 male. Ages ranged between 19 and 49 years (average 30.8 years). Examinations were performed in 40 knees, 20 symptomatic and 20 asymptomatic.

Patients and volunteers who had previously undergone surgery or traumatic lesion were excluded.

Examinations

All individuals were submitted to magnetic resonance imaging in 1.5 tesla high-field (Gyroscan T15; Philips) device and 0.2 tesla low-field (Profile; General Electric Medical Systems) device, utilizing QD knee coil.

Patellas transversal (axial) slices of were obtained with patients in supine position, using turbo spin echo T2 with selective presaturation inversion recovery (TSE T2 SPIR) sequence in high-field and gradient echo 2D (GRE 2D), gradient echo 3D (GRE 3D), fast spin echo T2" (FSE T2) and short tau inversion recovery (STIR) sequences in low-field (Table 1). Each sequence was printed on a separate film.

Analysis of imaging findings

Both groups were joined in a group corresponding to 40 studies (160 low-field sequences and 40 high-field sequences)[19].

Each sequence was separately analyzed by a five-year experienced radiologist specialized in musculoskeletal radiology, without knowledge on patients data or other sequences results.

Based on studies by Bredella *et al*.[12] and McCauley & Disler[20], criteria adopted for patellar cartilage analysis were signal or cartilage contour alteration and subchondral bone exposure and alteration (Figure 1). The chondral lesions site also was described: medial facet, lateral facet and apex.

Statistical analysis

Kappa and McNemar tests were applied to evaluate concordances and discordance between sequences obtained in low-field device and the TSE T2 SPIR (high-field) sequence.

RESULTS

Individuals' characteristics are shown in Table 2.

Chondral lesions frequencies are described in Tables 3, 4, 5, 6 and 7.

Medial facets presented low concordances and discordances below the concordance diagonal were significant (Table 8).

Lateral facets presented good concordances and discordances were not significant (Table 9).

Apex presented good concordances and discordances above the concordance diagonal were significant (Table 10).

DISCUSSION

The Kappa test on the medial facet revealed low concordance between low-field sequences and the TSE T2 SPIR (high-field) sequence. The McNemar test demonstrated statistically significant discordance for all the sequences, with overestimation of all the low-field sequences. The main reason for this discordance is related to areas of increase in signal intensity inside the cartilage, probably of artifactual nature (Figure 2), maybe by effect of magic angle[8,21], which, in certain situations, associated with the lower spatial resolution of the low-field devices, has made difficult the rating of the lesions; this also has been observed by James & Buirski[16] and by Ahn *et al*.[18].

The Kappa test on the lateral facet revealed good concordance between sequences in low-field device and the TSE T2 SPIR sequence. The McNemar test demonstrated statistically non-significant discordance for all the sequences.

The Kappa test on apex revealed good concordance between sequences in low-field device and the TSE T2 SPIR sequence. The McNemar test demonstrated statistically significant discordance for all the

sequences, with underestimation of all the low-field sequences. In our opinion, the main reason for this discordance may be related to the TSE T2 SPIR sequence better spatial resolution[10] and, consequently, better anatomical and lesions delimitation, or may be related to the difficulty in exactly defining the apex because it is the region that separates the patella facets and there is no defined anatomical point between them (Figure 3).

The STIR sequence presented the best results in all sites, the GRE 3D sequence obtaining the same results on the apex.

The fact that the STIR sequence has presented the best concordances with the TSE T2 SPIR sequence is related to the significance of the fat signal suppression for the articular cartilage analysis[11,15,22,23] (Figure 4).

The best concordances occurred with grade 3 lesions, as previously observed by Ahn *et al*.[18] (Figure 5).

Our study has presented the following limitations:

1. The number of examinations was limited; however, it should be remembered that prospective and comparative studies require time, are expensive and depend on the individuals who will be evaluated.

2. We have not used other slice planes: the transversal (axial) slices are the best for the patellar cartilage study, but in practice sagittal slices can contribute for a better characterization of lesions or just for a more accurate localization of alterations in the transversal slice plane.

3. The slices have not been obtained in exactly the same localization in high- and low-field devices. Although the slices thicknesses were similar, the number of slices was equivalent and the slices programming was discerning, some variation was expected since the examinations were performed in different devices and on different dates.

4. Arthroscopy has not been utilized to confirm chondral lesions. This is not out of our scope, i.e., to compare magnetic resonance devices.

5. Studies were oriented towards evaluation of the patellar cartilage, leading the observer maybe to a more discerning cartilage analysis than it would be in a routine examination.

CONCLUSIONS

1. The STIR sequence had the best concordance with TSE T2 SPIR sequence.

2. The high-grade lesions are better characterized by sequences in low-field devices.

3. Areas of increase in signal difficult the evaluation of the patella medial facet cartilage in low-field device.

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CONDROMALÁCIA DE PATELA

Figuras e Tabelas

Table 1 Sequence technical parameters.

Device	High-field	Low-field			
Sequence	TSE T2 SPIR	GRE 2D	GRE 3D	FSE T2	STIR
TR (ms)	3,507	550	60	3,850	3,650
TE (ms)	85	16	16	94.5	32
TF/TI/FA	TF: 10	FA: 75º	FA: 45º	TF: 10	TF: 6/TI:75
Thickness (mm)	4	4	3	4	3.5
FOV (cm)	18 × 18	24 × 18	22 × 16,5	24 × 24	24 × 18
Matrix (pixels)	256 × 256	256 × 160	192 × 160	256 × 160	256 × 160
No. of acquisitions	3	4	1	3	4
Time (min.)	2:45	4:27	3:54	3:34	5:21

TR, repetition time; TE, echo time; TF, turbo factor or "echo train"; TI, inversion time; FA, "flip angle"; FOV, field of view.

Table 2 Asymptomatic and symptomatic individuals by sex and age (years).

	Symptomatic		Asymptomatic	
	Male	Female	Male	Female
Ages (years)	19 25 39 40 49	20 22 25 25 27 34 39 41 46 49	25 26 27 27 28 29 31	25 28 42
Mean ages	34.4	32.8	27.6	31.7
Mean ages (male + female)	33.3		28.8	

Table 3 Asymptomatic and symptomatic individuals, site and grade of lesion detected by the TSE T2 SPIR (high-field) sequence reading.

Site	Lesion grade	Asymptomatic		Symptomatic		Total	
		N	%	N	%	N	%
Medial facet	0	13	65	9	45	22	55
	1	1	5	8	40	9	22.5
	2	4	20	1	5	5	12.5
	3	2	10	2	10	4	10
	Total	20	100	20	100	40	100
Lateral facet	0	10	50	16	80	26	65
	1	3	15	2	10	5	12.5
	2	3	15	0	0	3	7.5
	3	4	20	2	10	6	15
	Total	20	100	20	100	40	100
Apex	0	12	60	16	80	28	70
	1	1	5	0	0	1	2.5
	2	4	20	0	0	4	10
	3	3	15	4	20	7	17.5
	Total	20	100	20	100	40	100

Table 4 Asymptomatic and symptomatic individuals, site and grade of lesion detected by GRE 2D (low-field) sequence reading.

Site	Lesion grade	Asymptomatic		Symptomatic		Total	
		N	%	N	%	N	%
Medial facet	0	0	0	0	0	0	0
	1	13	65	12	60	25	62.5
	2	5	25	6	30	11	27.5
	3	2	10	2	10	4	10
	Total	20	100	20	100	40	100
Lateral facet	0	12	60	12	60	24	60
	1	3	15	6	30	9	22.5
	2	4	20	2	10	6	15
	3	1	5	0	0	1	2.5
	Total	20	100	20	100	40	100
Apex	0	19	95	20	100	39	97.5
	1	0	0	0	0	0	0
	2	1	5	0	0	1	2.5
	3	0	0	0	0	0	0
	Total	20	100	20	100	40	100

Table 5 Asymptomatic and symptomatic individuals, site and grade of lesion detected by GRE 3D (low-field) sequence reading.

Site	Lesion degree	Asymptomatic		Symptomatic		Total	
		N	%	N	%	N	%
Medial facet	0	1	5	2	10	3	7.5
	1	12	60	13	65	25	62.5
	2	0	0	0	0	0	0
	3	7	35	5	25	12	30
	Total	20	100	20	100	40	100
Lateral facet	0	11	55	15	75	26	65
	1	5	25	3	15	8	20
	2	2	10	1	5	3	7.5
	3	2	10	1	5	3	7.5
	Total	20	100	20	100	40	100
Apex	0	18	90	19	95	37	92.5
	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	2	10	1	5	3	7.5
	Total	20	100	20	100	40	100

Table 6 Asymptomatic and symptomatic individuals, site and grade of lesion detected by FSE T2 (low-field) sequence reading.

Site	Lesion degree	Asymptomatic		Symptomatic		Total	
		N	%	N	%	N	%
Medial facet	0	2	10	0	0	2	5
	1	7	35	13	65	20	50
	2	10	50	7	35	17	42.5
	3	1	5	0	0	1	2.5
	Total	20	100	20	100	40	100
Lateral facet	0	13	65	11	55	24	60
	1	4	20	6	30	10	25
	2	2	10	2	10	4	10
	3	1	5	1	5	2	5
	Total	20	100	20	100	40	100
Apex	0	17	85	17	85	34	85
	1	0	0	0	0	0	0
	2	3	15	3	15	6	15
	3	0	0	0	0	0	0
	Total	20	100	20	100	40	100

Table 7 Asymptomatic and symptomatic individuals, site and grade of lesion detected by the STIR sequence reading.

Site	Lesion grade	Asymptomatic		Symptomatic		Total	
		N	%	N	%	N	%
Medial facet	0	4	20	3	15	7	17.5
	1	7	35	12	60	19	47.5
	2	7	35	5	25	12	30
	3	2	10	0	0	2	5
	Total	20	100	20	100	40	100
Lateral facet	0	12	60	10	50	22	55
	1	6	30	7	35	13	32.5
	2	0	0	1	5	1	2.5
	3	2	10	2	10	4	10
	Total	20	100	20	100	40	100
Apex	0	18	90	19	95	37	92.5
	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	2	10	1	5	3	7.5
	Total	20	100	20	100	40	100

Table 8 Comparison between findings of MRI TSE T2 SPIR and GRE 2D, GRE 3D, FSE T2 and STIR sequences in medial facet by Kappa test supplemented by McNemar test, aiming at demonstrating discordances above and below the concordance diagonal and concordance.

Sequence	Kappa test				McNemar test			
	Concordance	*Kw*	*z* calculated	*p*	Discordance above	Discordance below	χ^2 calculated	*p*
GRE 2D	25%	0.182	1.42	NS	10%	65%	16.13*	0.001
GRE 3D	30%	0.175	1.77	NS	10%	60%	14.29*	0.001
FSE T2	35%	0.209	2.99*	0.001	12.5%	52.5%	9.85*	0.01
STIR	**45%**	**0.312**	**3.39***	**0.001**	**10%**	**45%**	**8.91***	**0.01**

Table 9 Comparison between findings of MRI TSE T2 SPIR and GRE 2D, GRE 3D, FSE T2 and STIR sequences in lateral facet by Kappa test supplemented by McNemar test, aiming at demonstrating discordances above and below the concordance diagonal and concordance.

Sequence	Kappa test				McNemar test			
	Concordance	*Kw*	*z* calculated	*p*	Discordance above	Discordance below	χ^2 calculated	*p*
GRE 2D	66.67%	0.33	2.58*	0.01	11.11%	22.22%	1.33	NS
GRE 3D	65%	0.534	3.39*	0.001	20%	15%	0.29	NS
FSE T2	62.5%	0.455	3.38*	0.001	17.5%	20%	0.07	NS
STIR	**67.5%**	**0.549**	**4.46***	**0.001**	**12.5%**	**20%**	**0.69**	**NS**

Table 10 Comparison between findings of MRI TSE T2 SPIR and GRE 2D, GRE 3D, FSE T2 and STIR sequences in the apex by Kappa test supplemented by McNemar test, aiming at demonstrating discordances above and below the concordance diagonal and concordance.

Sequence	Kappa test				McNemar test			
	Concordance	*Kw*	*z* calculated	*p*	Discordance above	Discordance below	χ^2 calculated	*p*
GRE 2D	72.5%	0.092	2.44*	0.01	27,5%	0%	11*	0.001
GRE 3D	**72.5%**	**0.217**	**1.99***	**< 0.05**	**25%**	**2.5%**	**7.36***	**0.01**
FSET2	65%	0.259	1.07	NS	30%	5%	7.14*	0.01
STIR	**72.5%**	**0.217**	**1.99***	**< 0.05**	**25%**	**2.5%**	**7.36***	**0.01**

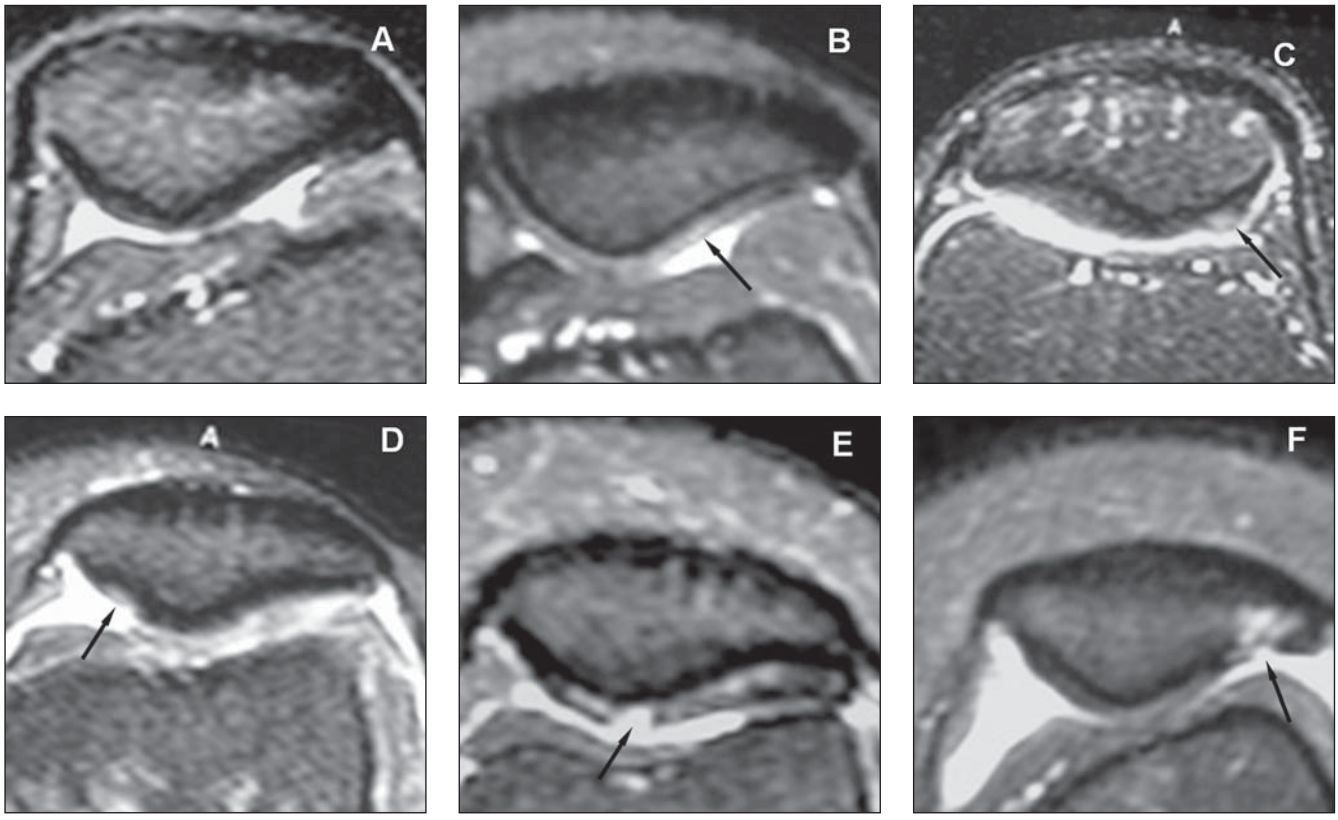

Figure 1. TSE T2 SPIR (high-field) slices image showing the rating applied (arrows). Grade 0: cartilage presenting normal signal and contours (**A**). Grade 1: cartilage presenting abnormal signal (**B**) or cartilage presenting abnormal signal and concave contour, without fissures or erosion (**C**). Grade 2: chondral fissure or erosion without subchondral bone exposure (**D**). Grade 3: chondral fissure or erosion with subchondral bone exposure (**E**) or chondral fissure or erosion with subchondral bone exposure or signal alteration (**F**).

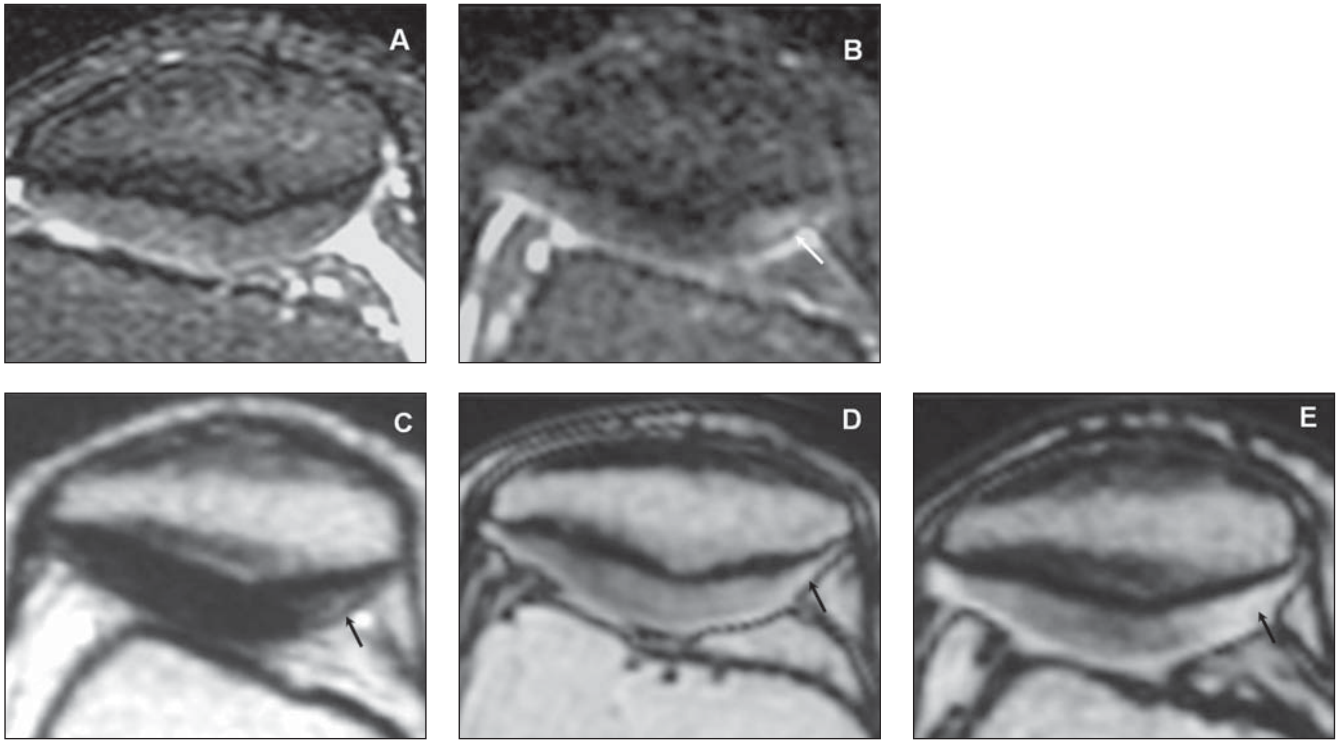

Figure 2. Study rated as grade 0 by TSE T2 SPIR – high-field device – (**A**) and grade 1 in medial facet by STIR (**B**), FSE T2 (**C**), GRE 3D (**D**) and GRE 2D (**E**) (arrows).

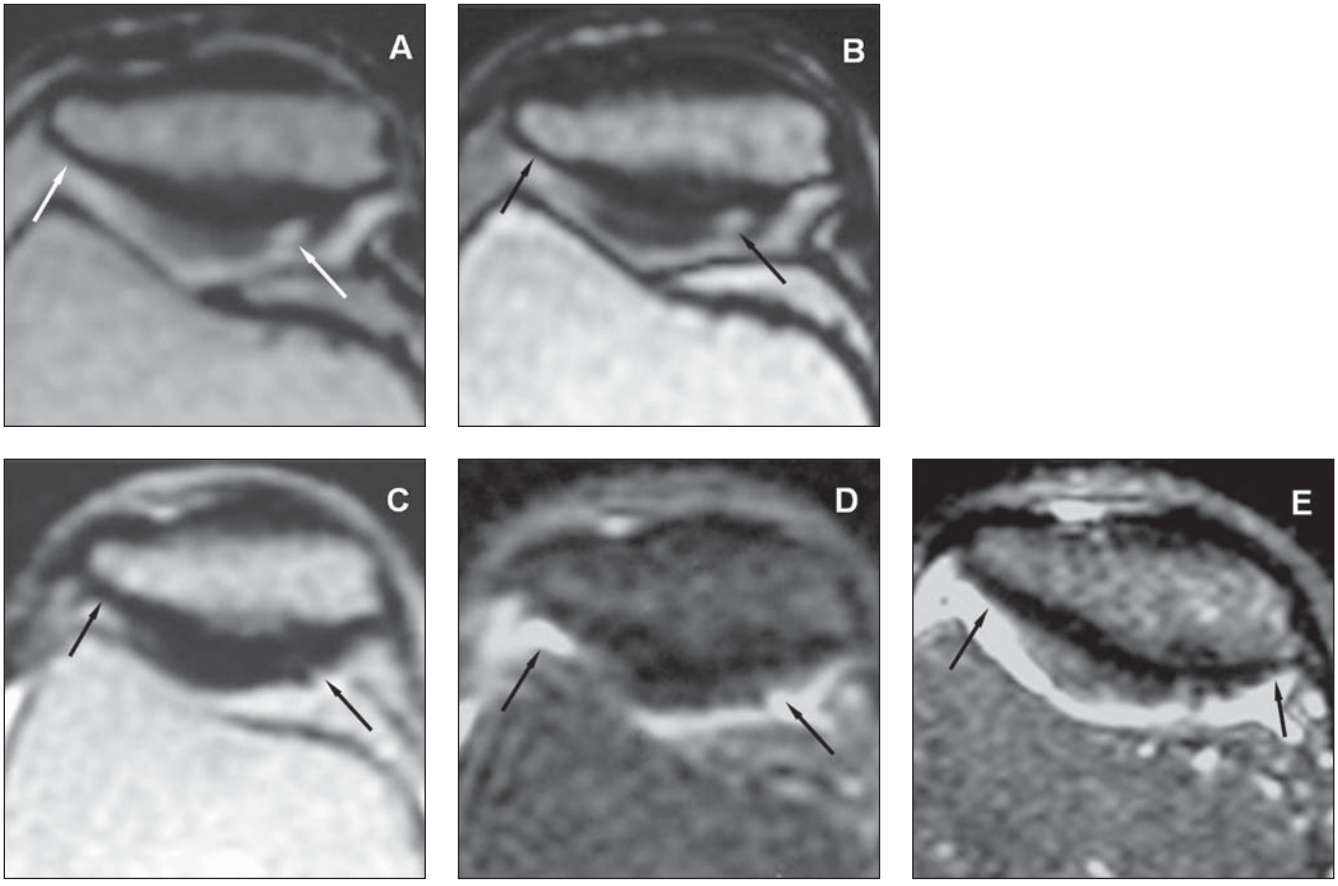

Figure 3. Study rated as grade 2 in facets and apex by TSE T2 SPIR – high-field device – (**A**) and grade 2 in facets by STIR (**B**), FSE T2 (**C**), GRE 3D (**D**) and GRE 2D (**E**) (arrows).

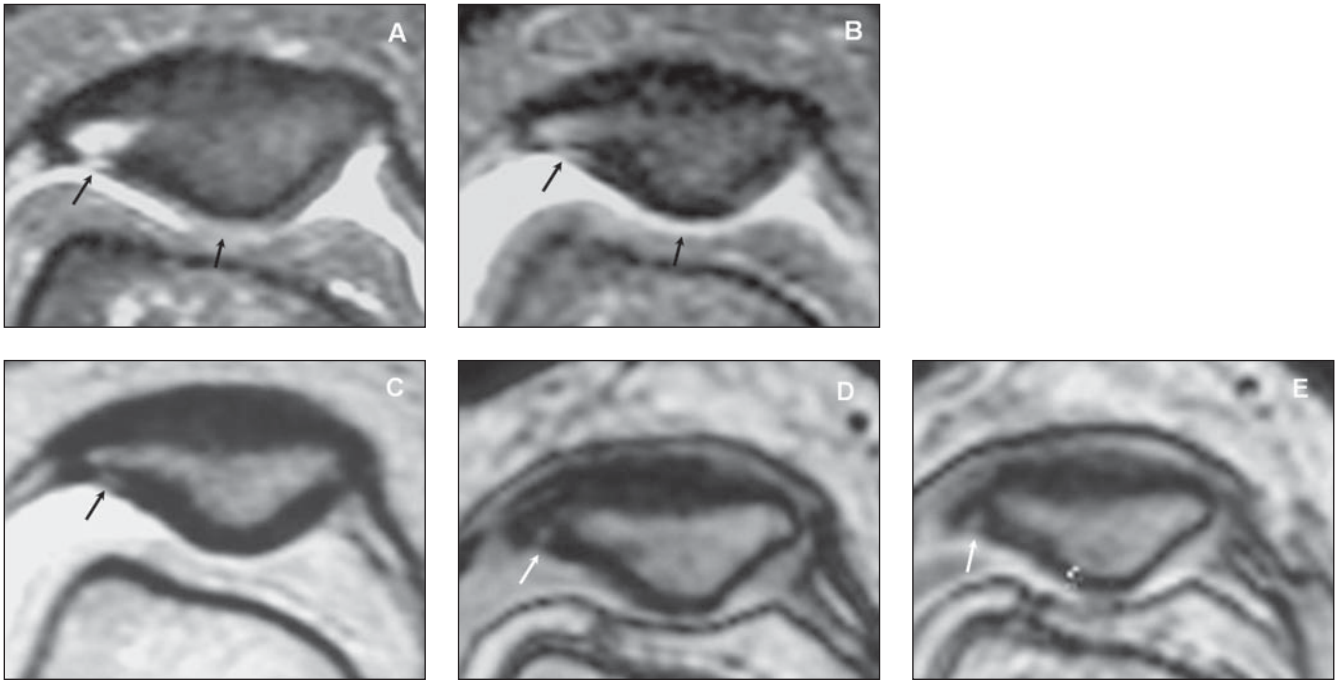

Figure 4. STIR best concordance. Study rated as grade 3 in lateral facet and apex by TSE T2 SPIR – high-field device – (**A**) and by STIR (**B**), and grade 3 in lateral facet by FSE T2 (**C**), GRE 3D (**D**) and GRE 2D (**E**) (arrows).

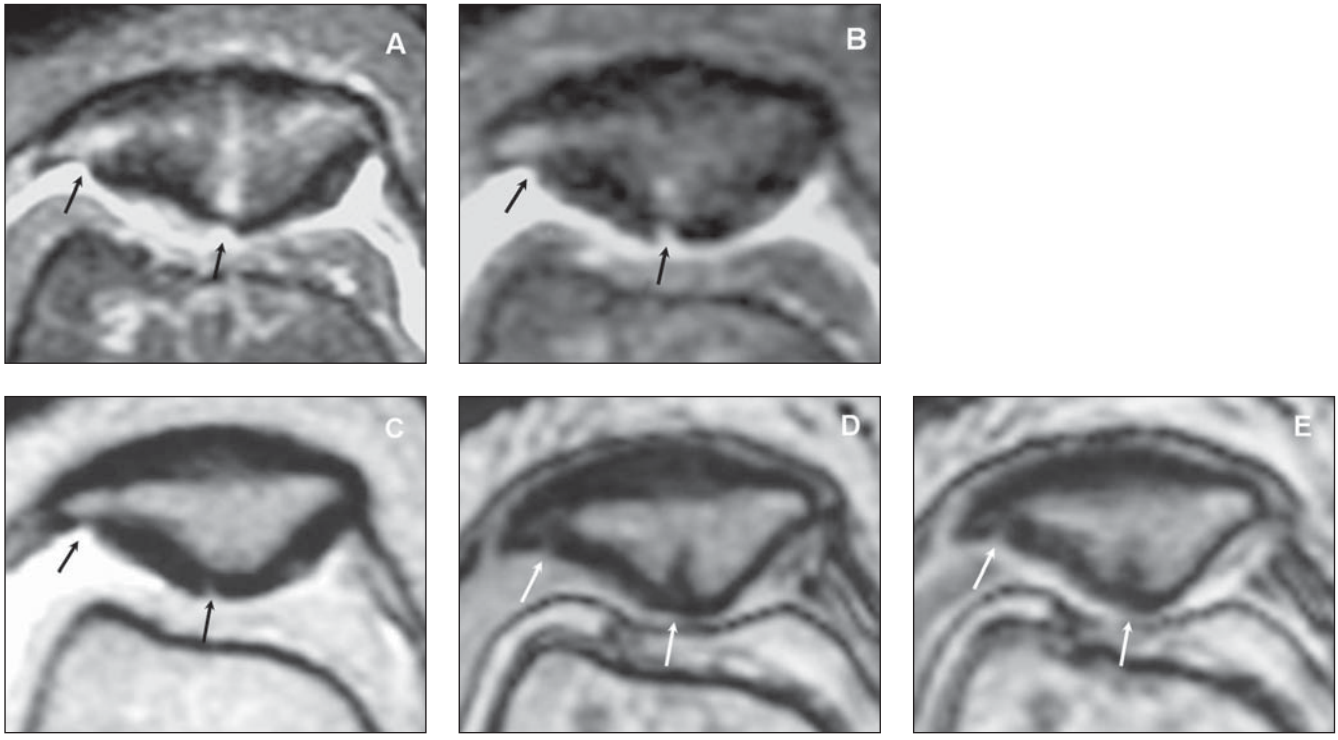

Figure 5. Study rated as grade 3 in lateral facet and apex by TSE T2 SPIR – high-field device – (**A**), STIR (**B**), GRE 3D (**D**) and GRE 2D (**E**), and grade 2 in the apex and grade 3 in lateral facet by FSE T2 (**C**) (arrows).