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The Rising Moon sign is specific and sensitive in the diagnosis of bucket handle tears of the medial meniscus

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Abstract

Purpose Bucket handle tears of the meniscus are common and can lead to locking, extension deficit and functional impairment. The diagnosis is determined by a combination of physical examination and imaging, but in some cases the diagnosis may be challenging since specific clinical tests are lacking. The aim of the present study was to assess the value of a new clinical test, the elective pain at the anterior aspect of the joint line (defined as the “Rising Moon sign”) in the diagnosis of bucket handle tears of the medial meniscus.

Methods Forty patients treated for a bucket handle of the medial meniscus were enrolled as the study group and were compared to a matched group of 40 patients with a posterior horn tear of the medial meniscus and 50 healthy subjects. The following aspects were investigated in the groups: body mass index, extension deficit, pain at the posterior aspect of the joint line (PPJL), at the middle joint line (PMJL), at the anterior joint line (PAJL) and at combined hyperflexion of the knee and external rotation of the foot (PHE). Pain at the anterior joint line (PAJL) was defined as the Rising Moon sign.

Results In the bucket handle group the average flexion contracture was 12° (0–30°). The average PPJL was one (0–2), the average PMJL was 1.6 (0–3), PAJL was 2.5 (1–3) and PHE was 1.6 (1–2). In the posterior horn tear group the average flexion contracture was 0.9° (– 10 to 5°). The average PPJL was 2.2 (1–3), the average PMJL was 1.4 (0–3), PAJL was 0.6 (0–2) and PHE was 2.5 (1–3). The rising moon showed 95% sensitivity and 98% specificity in the diagnosis of bucket handle tears. In addition it showed a positive predictive value of 97.4% and negative predictive value of 96%. Finally it also demonstrated high inter-observer reliability (0.905).

Conclusions The “Rising Moon” sign has shown to be highly predictive for bucket handle tears of the medial meniscus with very high specificity and sensitivity. In addition it is easy to perform with very high inter-observer reliability.

Level of evidence Level IV.

Keywords Bucket handle · Medial meniscus · Rising Moon sign · Joint line pain · Knee

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Introduction

Bucket handle tears of the meniscus are commonly encountered. They consist of displaced longitudinal tears, most commonly observed in the medial meniscus. Their incidence among all meniscus tears is around 10% [13, 19]. Bucket handle meniscal tears are commonly seen in young adults after trauma [17]. Both the inferior and superior surfaces of the meniscus are disrupted in these type of tears. The medial portion is usually displaced into the intercondylar notch causing pain and locking of the knee [11]. The diagnosis of meniscal tears usually results from a combination of patient history, physical examination and imaging. However, the clinical diagnosis of a meniscal tear can be challenging as several clinical tests are available and the positive (PPV)

and negative predictive values (NPV) of these tests depend on the prevalence of meniscal tears, which varies according to age [3]. Joint line tenderness is often described as the most sensitive finding for diagnosing a meniscal tear; however, joint line tenderness alone is not very specific [4]. Although specific clinical tests are useful in the diagnosis of posterior horn meniscal lesions they are less effective in case of bucket handle tears [2]. Snapping and catching especially in deep flexion and limited range of motion may be present in up to 80% of cases and are associated with more complex meniscal tears [12].

Given the limitations of clinical examination alone, advanced imaging is mandatory for a correct diagnosis. Magnetic resonance imaging (MRI) gives valuable information in bucket handle tears especially when more than one classic radiologic sign (absent bow tie, fragment in intercondylar notch, coronal truncation sign, anterior flipped meniscus sign and double PCL) is considered. In fact, although the sensitivity of MRI historically ranges between 45 and 98%, the sensitivity is much higher (94.4%) when more than one radiologic sign is present [10]. Arthroscopy still remains the gold standard in the diagnosis of bucket handle tears [12]. According to current literature it is clear that the diagnosis of a bucket handle meniscal tear should be based on a combination of the history, physical examination and diagnostic imaging, with arthroscopy as the last diagnostic tool and treatment option of choice. The aim of the present study was to analyze the positive (PPV) and negative predictive values (NPV), sensitivity and specificity of a new clinical sign (Rising Moon sign) in the diagnosis of medial meniscus bucket handle tears and to compare them to a matched cohort of patients with a posterior horn tear of the medial meniscus. It was hypothesized the Rising Moon sign was a reliable and effective in the diagnosis of bucket handle tears of the medial meniscus.

Materials and methods

A prospective analysis of all patients undergoing knee arthroscopy from 2015 to 2018 was performed. All patients diagnosed a bucket handle tear of the medial meniscus at our institution were enrolled as the study group. All patients had confirmation of a bucket handle tear of the medial meniscus at the time of arthroscopy. During arthroscopy, a concomitant anterior or posterior cruciate ligament injury or traumatic cartilage lesion was assessed. Both of these situations were considered as exclusion criteria as well as collateral ligaments involvement and previous surgeries on the index knee. Patients' history was evaluated to assess the onset of the symptoms, number of episodes of knee locking and delay between initial diagnosis and surgery. Additionally, all patients diagnosed with a posterior horn tear of the

medial meniscus at the time of arthroscopy were prospectively evaluated as a comparison group. The onset (traumatic or not) of symptoms was investigated as well as the delay between the onset and surgery for the comparison group. The physical examination was carried out in the same way in the two groups and was performed in the ward the day of the surgery in all cases by an experienced surgeon (blinded with the aim of the study). For the purpose of the study, a group of healthy controls (50 knees) was also recruited from the outpatient clinics. These subjects had no knee symptoms or history of knee disorders. They had attended the outpatient clinics for the treatment of shoulder disorders, and a diagnostic MRI of shoulder was indicated for all them. Following consultation and the signing of a consent form, all patients agreed to undergo a knee examination and to have an additional MRI of the knee. The patients in the three groups were similar with regard to age, gender, body weight, and the knee being tested. In the three groups physical examination was focused on the following clinical aspects: body mass index (BMI), extension deficit (ED), pain at the palpation of the posterior aspect of the joint line (PPJL) which corresponds to the posterior horn of the medial meniscus, pain at the middle joint line (PMJL) which corresponds to the body of the meniscus and pain at the anterior joint line (PAJL), which corresponds to the anterior horn of the meniscus. All these trigger points were investigated with the knee at 90° of flexion and the foot in neutral rotation. Elective positive PAJL was defined as the Rising Moon sign. Pain at the posterior aspect of the joint line with combined hyperflexion of the knee and external rotation of the foot was also evaluated (PHE). This specific manoeuvre was similar to the McMurray sign. However, in the McMurray sign, starting from a fully flexed position, the knee is brought in extension while applying a valgus pressure and external rotation of the foot [14]. An elective pain or more specifically a palpable or even audible click on extension of the knee defines a positive test.

The pain level at these trigger points was classified in grade 0: no pain [0 of the visual analogue scale (VAS)], grade one light pain (1–3 of the VAS scale), grade two mild pain (4–6 of the VAS scale) and grade three severe pain (7–10 of the VAS scale). The cut-off score for a positive test was set to the grade ≥ 2 of the scoring system. In addition, the official radiology MRI report of the affected knee was available in all cases. It should be noted that MRI was performed at an outside facility in the majority of the cases and it is unclear of the reading radiologist was a musculoskeletal trained radiologist. Additionally, all intraoperative meniscal and chondral findings were recorded.

Statistical analysis

Descriptive analysis (means and standard deviation, numbers and percentages) was used to describe the outcome

variables. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of the clinical and imaging test for the diagnosis of meniscal tears were calculated.

The reproducibility of the Rising Moon sign was also assessed. A second physical examination was carried out in the operating room just before anaesthesia by a different surgeon in order to achieve a subgroup of 15 patients in the bucket handle group and 15 patients in the posterior horn group. The intraclass correlation coefficient (ICC) regarding inter-rater (two observes) reliability was assessed. The $P < 0.05$ was regarded as indicating statistical significance. 95% confidence intervals (CIs) were also calculated. All statistical analysis was conducted using SPSS (Statistical Package for the Social Sciences, version 24.0 for Mac; SSPS Inc).

Sample size was calculated considering previous research (G*Power 3 Software). A minimum of 38 patients per group were determined to satisfy medium-large effect

size (Cohen's $f = 0.33$) with 80% power and a statistical significance at an alpha level of 0.05.

Results

Forty patients with bucket handle tears of the medial meniscus were enrolled. Demographic data are summarized in Table 1. MRI radiology reports were available in all patients and according to them the diagnosis of a bucket-handle tear was considered as certain, possible or not given (Table 1). Aetiologies and sports involved in the initial event are summarized in Table 2. The values of clinical tests such as PPJL, PMJL, PAJL and PHE are summarized in Table 3. During arthroscopy the involvement of the medial meniscus was assessed as well as the presence of lateral meniscus tears and the status of the cartilage (wear below stage three according to the Oütherbridge classification) in the medial, lateral and patella-femoral compartments. The integrity of

Table 1 Demographics of the bucket handle, posterior horn and control (healthy subjects) groups

	Num-ber of patients	Male/female	Age	Side R/L	BMI	Locking events	Onset	Delay injury/ surgery (days)	MRI
(Bucket handle)	40	32/8	35.2 (21–55)	23/17	26.5 (22–30)	1.9 (1–9)	Traumatic n.29. Hyperflexion n.7. Atraumatic n.4	20.6 (3–60)	Positive n.31. Negative n.5. Possible n.4
(Posterior horn)	40	28/12	36.4 (20–57)	22/18	25.3 (20–31)	0	Traumatic n.24. Hyperflexion n.7. Atraumatic n.9	90 (10–210)	Positive n.28. Negative n.1. Degenerative n.11
CG (healthy patients)	50	48/32	36.8 (23–55)	47/33	25.5 (22–32)		Na	Na	Negative n. 50

CG control group, Na not applicable

Table 2 Onset by aetiology in the bucket handle and posterior horn groups

	Atraumatic	Soccer	Ski	Tennis	Volley	Basket	Rugby	Gym	Total
(Bucket handle)									
Atraumatic	4								4 (10%)
Traumatic		9	4		5	4	4		26 (65%)
Hyperflexion		2			1			7	10 (25%)
Total	4 (10%)	11 (27.5%)	4 (10%)	0	6 (15%)	4 (10%)	4 (10%)	7 (17.5%)	40
(Posterior horn)									
Atraumatic	9								9 (22.5%)
Traumatic		10	4	5	1	2		1	23 (57.5%)
Hyperflexion		1		1	1			5	8 (20%)
Total	9 (22.5%)	11 (27.5%)	4 (10%)	6 (15%)	2 (5%)	2 (5%)	0	6 (15%)	40

Table 3 Clinics, morphology of meniscal tears and associated lesions in the bucket handle, posterior horn and control (healthy subjects) groups

	Flexion contracture	PPJL	PMJL	PHE	PAJL (Rising Moon)	Morphology	Associated lesions
Bucket handle	12° (0°/30°)	1 (0–2)	1.6 (0–3)	1.6 (1–2)	2.5 (1–3)	Dislocated n.30. Reduced n.10	Isolated n. 24. Associated n.16
Posterior horn	0.9° (5°/– 10°)	2.2 (1–3)	1.4 (0–3)	2.5 (1–3)	0.6 (0–2)	Simple n. 16. Simple + flap n.6. Complex n.18	Isolated n. 21. Associated n.19
CG (healthy patients)	– 3° (5°/– 20°)	0.5 (0–1)	0.7 (0–2)	0.6 (0–1)	0.3 (0–1)	Na	Na

CG control group, PPJL pain at the posterior joint line, PMJL pain at the middle joint line, PHE pain at hyperflexion and external rotation, PAJL pain at the anterior joint line, Na not applicable

Table 4 Intra-articular associated lesions in bucket handle and posterior horn groups

	Associated lesions	lateral meniscus	Cartilage wear (MC)	Cartilage wear (MC+PF)	Cartilage wear (MC+LC)
(Bucket handle)	16	6	8	1	1
(Posterior horn)	19	3	9	4	3

MC medial compartment, LC lateral compartment, PF patello-femoral compartment

the ACL and PCL and the presence of traumatic cartilage lesions were also confirmed. Intraoperative data are summarized in Table 4.

The same evaluation was completed for the posterior horn tear group. Data are summarized in Tables 1, 2, 3, and 4.

Finally the same clinical and imaging evaluation was performed in the control group (healthy subjects). Data are summarized in Tables 1 and 3.

The “Rising Moon” sign was excellent in predicting the presence of a bucket handle tear of the medial meniscus, showing higher results than other clinical tests (Table 5). This test had a sensitivity of 95% and a specificity of 98%. In addition, it showed a PPV of 97.4% and NPV of 96%. The other clinical manoeuvres did not show the same sensitivity and specificity (Table 5).

In addition, the “Rising Moon” sign demonstrated high agreement, for inter-observer reliability [0.905 (95% CI 0.827–0.930)]. Conversely, the “Rising Moon” sign had a sensitivity of 10% and a specificity of 96% in predicting the presence of a posterior horn tear of the medial meniscus. In addition, it showed a PPV of 80% and NPV of 57.1%. In these kind of lesions the PPJL and PHE showed an higher sensitivity and compared to the “Rising Moon sign”.

Table 5 Results of predictors of clinical test for diagnosis of meniscal tears (bucket handle and posterior horn) of the medial meniscus in 130 patients

	True positive (A)	False positive (B)	False negative (C)	True negative (D)	PPV % (A/A+B)	NPV % (D/D+C)	Sensitivity % (A/A+C)	Specificity % (D/D+B)
Bucket handle tear of the medial meniscus (n=40)								
MRI	29	5	6	50	85.2	89.2	82.8	90.9
PPJL	6	0	34	50	100	59.5	15	100
PHE	10	1	30	49	90.9	62	25	98
PMJL	18	3	22	47	85.7	68.1	45	94
Rising Moon (PAJL)	38	1	2	49	97.4	96	95	98
Posterior horn tear of the medial meniscus (n=40)								
MRI	32	4	4	50	88.8	92.5	88.8	92.5
PPJL	40	0	0	50	100	100	100	100
PHE	39	2	1	48	95.1	97.9	97.5	96
PMJL	18	3	22	47	85.7	68.1	60	94
Rising Moon (PAJL)	4	2	36	48	80	57.6	10	96

MRI magnetic resonance imaging, PPJL pain at the posterior joint line, PMJL pain at the middle joint line, PHE pain at hyperflexion and external rotation, PAJL pain at the anterior joint line, PPV positive predictive value, NPV negative predictive value

Discussion

The most important finding of the present study is the strong correlation between the PAJL and the presence of a bucket handle tear of the medial meniscus. The PAJL was defined as the “Rising Moon sign” since it is located at the basis of quarter moon shaped medial meniscus.

The diagnosis of isolated bucket handle tears of the medial meniscus can be challenging. Patients usually present with acute onset after trauma or hyperflexion of the knee underweight bearing conditions. Typically locking and/or permanent flexion (“locked knee”) are often reported as shown in the series by Thoreux et al. (29 out of 33 patients) but subtle episodes may be challenging to diagnose. Metcalf and Barrett in a cohort of 1485 meniscal tear patterns in patients with stable knees found that male gender and loss of extension were associated with peripheral tears while others factors such as age and chronicity of symptoms were not associated [14]. More recently Haviv et al. shown that male gender, locking events and limitation in extension were strong indicators for bucket handle tears of the medial meniscus in stable knees [8].

Clinical evaluation may also reveal joint effusion and flexion contracture. These findings may be more evident when the meniscus is dislocated in the notch but may be absent if the bucket handle remains reduced in the anatomic position.

Joint line tenderness is usually present however it is nonspecific and therefore has limited ability to determine a precise diagnosis [5]. Specific tests such as McMurray, Apley and Thessaly tests are useful in the diagnosis of posterior horn tears [6, 7] but are less effective in case of bucket handle tears [2].

Therefore, since both joint line tenderness and specific clinical tests have low diagnostic value when applied individually [16, 17], they should be combined together with the background of clinical history [6]. Imaging should always be performed to confirm the clinical suspect. High-resolution ultrasound has been proposed in the past as an easy to perform tool, however the sensitivity for diagnosing bucket-handle tears of the menisci was only 54% [1].

MRI analysis is critical and should always be performed to plan the treatment course when a bucket handle tear of the medial meniscus is suspected. However, the sensitivity of MRI for the detection of bucket handle tears of the meniscus ranges from ~ 84 to 93% and this pattern of meniscal tear is one of the most commonly missed tear types in MRI [9]. Specific signs such as: absent bow tie, fragment in notch, coronal truncation, anterior flipped meniscus, double PCL, double anterior horn, disproportional posterior horn have been described to increase the sensitivity of the MRI. MRI may be inadequate when these

signs are absent and becomes highly specific only when these classic signs are found in combination. In any case, MRI findings should not completely guide surgeon's decision making at the time of surgery. A recent retrospective analysis of 117 meniscectomies and 106 meniscal repairs, showed an increased risk of disagreement between MRI and surgical procedure in the presence of bucket-handle tears [15].

The results of the present study demonstrated the “Rising Moon” sign was statistically associated with a bucket handle tear of the medial meniscus with a sensitivity of 95% and a specificity of 98%. In addition it was easy to perform with an inter-observer agreement of 0.905. This specific trigger point probably corresponds to the location of the anterior aspect of the bucket-handle, which is usually located in the anterior third of the meniscus. Once a bucket handle tear, has occurred, there is damage of the architecture of the meniscus with a starting point (anterior aspect of the meniscus) and an end point (posterior aspect). At these levels there is an interruption of the horizontal and vertical fibres with a transition zone between the healthy and torn meniscus. During flexion and extension movements there should be increased traction to the capsule-meniscal fibres of the healthy meniscal remnants. This phenomenon could be present even when the bucket handle is reduced and should be more evident in cases of dislocated menisci.

Although the present study has notable findings it does have several limitations that need to be acknowledged. First of all, no power analysis was performed to determine how many patients would be needed to show a statistical difference. In addition, only a specific test has been performed (PHE) and other tests may have led to different results. Moreover, it should be noted that MRI evaluation and clinical evaluation were not performed on the same day. Therefore, displaced bucket handle meniscal tears the day of the MRI may have been reduced prior to the day of the clinical evaluation and vice versa, thus generating potential incongruences between the imaging and clinical evaluation. Finally, it should be highlighted that only the charts of the MRI exams were included in the present study (although the images were evaluated at the time of surgery). The radiologists in charge of the charts were not always completely dedicated to joint pathologies. This may partially explain the lower sensitivity (72.0%) and specificity (75.6%) of the MRI compared to clinical tests.

Conclusions

The diagnosis of bucket handle tears of the medial meniscus may be challenging. Patients' history may not give relevant informations. Specific meniscal tests such as McMurray, Apley and Thessaly tests can be inconclusive regarding these

peculiar tears of the medial meniscus. The “Rising Moon” sign has shown to be highly predictive for bucket handle tears of the medial meniscus with very high specificity and sensitivity. In addition, it is easy to perform with high inter-reliability. It is a useful tool in daily life practice.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

Ethical approval The study was carried out in accordance with the Helsinki declaration principles and approved by the Health Director of the Marrelli Hospital.

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