# Sonographic Evaluation of the Degree of Medial Meniscal Extrusion During Thessaly Test in Healthy Knees

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**Research**

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# Abstract

Objective

The Thessaly test is a commonly used orthopedic test for meniscus tear evaluation. The study's objective is to evaluate the degree of medial meniscal extrusion during different loading phases of the Thessaly test.

Methods

A convenience sample of 60 healthy knees (35 participants) was examined. Sonographic measurement of the degree of physiologic extrusion of the medial meniscus deep to the medial collateral ligament was taken by two examiners at six different loading phases: supine, standing, 5° knee-flexion with internal (IR)/external (ER) rotation and 20° knee-flexion with IR/ER. The difference in meniscal extrusion by knee position was compared with ANOVA. Interrater reliability assessment was analyzed using intraclass correlation coefficient.

Results

The mean meniscal extrusion for each position was - supine: 2.3±0.5mm, standing: 2.8±0.8mm, 5° IR: 2.3±0.9mm, 5° ER: 2.4±0.7mm, 20° IR: 1.9±0.8mm, and 20° ER: 2.3±0.7mm. Significant increase in extrusion was observed from supine to standing ($p<0.05$) and from 20° IR to 20° ER ($p=0.015$). Significant decreased measurement was observed from standing to 5° IR ($p<0.05$), 5° ER ($p<0.05$), 20° IR ($p<0.05$) and 20° ER ($p<0.05$). There is no significant change between 5° IR and 5° ER ($p=1.0$). Interrater reliability of the measurements across the six positions was poor to moderate (0.35-0.57, $p<0.05$).

Conclusion

Our study's novel findings showed clear dynamic changes during Thessaly test, which implies increase in compressive stress across the medial meniscus and a potential mechanism for pain generation during this test. Further testing is needed to address the poor-moderate reliability and confirm findings.


# Background

Meniscal injury is common, with the incidence of injury resulting in meniscectomy of 61 per 100,000 persons [1]. Meniscal extrusion is described as external meniscal displacement and has been regarded as an indirect sign of meniscal injuries such as meniscal tear, meniscal maceration, cartilage damage, and knee malalignment; however, the exact cause of extrusion is not well understood [2–4]. Medial meniscal extrusion (MME) of > 2mm [5] and > 3mm [4] have been proposed as significant findings with associated meniscal injuries and/or osteoarthrosis. Although various meniscal injuries are known inducers of MME, the degree of normal, or physiological MME in healthy knees, has only been recently investigated [6].

For diagnosing intra-articular knee lesions, MR imaging is the gold standard after arthroscopic knee surgery [7]. When assessing morphologic changes of the meniscus, dynamic capability of sonographic evaluation allows visual assessment of the meniscus while exerting different loading stresses across the knee. Compared to MR imaging as the reference standard, reliability of sonographic assessment for MME seems promising [8].

The Thessaly test is a clinical test for detecting meniscal tear, first described in 2005 at the University of Thessaly in Greece[9]. Since its inception, numerous studies investigated diagnostic ability of the Thessaly test. For instance, Harrison et al. examined 116 patients undergoing knee arthroscopic examination for suspected meniscal tear where the Thessaly test demonstrated 90.3% sensitivity, 97.7% specificity, and 88.8% diagnostic accuracy [12]. In another study of 86 patients comparing diagnostic accuracy of clinical examination (using McMurray's, Apley's and Thessaly's test at 20° flexion) versus MRI and the gold standard arthroscopy, MRI demonstrated the highest diagnostic power, followed by the Thessaly test [13].

Contrarily, there are studies which repudiate these results. In a prospective diagnostic accuracy study of a cluster of physical examination tests (Thessaly's, Apley's, McMurray's and joint line tenderness) versus MRI in 292 patients with knee pathology, the Thessaly test demonstrated only 59% diagnostic accuracy [14]. Similar conclusions derived from other authors have challenged the diagnostic accuracy as too low to be considered as routine clinical value [15,16].

The Thessaly test is performed by moving the femur through internal and external rotation on the tibia in different knee angles (5° and 20° of flexion) as a means of placing the meniscus under dynamic stress [9].The amount of load applied to the medial meniscus is indirectly assessed under ultrasound through measuring the degree of MME. We hypothesized that if the Thessaly test stresses the knee joint, increase in MME would be observed. It is also hypothesized that the largest degree of MME will be noted at 20° of knee flexion. To the best of our knowledge, this is the first study investigating sonographic characteristics of the medial meniscus under various loading phases of the Thessaly test.

# Methods

This was a repeated measures design with students and employees at our institution as a convenience sample. Signed informed consent was obtained from all participants. Ethical approval was received by our Institutional Review Board (IRB Protocol# A- 00181).

The inclusion criterion was to have asymptomatic knees without any of the following factors: 1) history of knee surgery, 2) known osteoarthritis of the knee and/or 3) injury to the knee that resulted in physician consultation for evaluation and/or therapy. Exclusion criterion was a positive orthopedic examination (i.e., McMurray's test, Anterior and posterior drawer test).

Diagnostic ultrasound (Mindray M5; Shenzhen, China) using a 7–12 MHz linear array transducer was used to measure degree of physiological MME (in millimeter) of the medial meniscus at six different loading phases: 1) supine, 2) standing, 3) 5° knee flexion with internal rotation (IR), 4) 5° knee flexion with external rotation (ER), 5) 20° knee flexion with IR and 6) at 20° flexion with ER. The medial meniscus was scanned with the transducer parallel to the medial collateral ligament (MCL) to assure consistency between the examiners and the loading phases. This site of measurement was previously used by other investigators[10,11]. For the measurement, an initial line was drawn connecting the free edges of the medial tibial cortex to the medial femoral cortex. A second line was drawn tangential to the apex of the medial meniscus from which a measurement was drawn to the initial line for MME (Fig. 2). All images were saved on the ultrasound unit (without the measurements). For the interexaminer reliability assessment, each examiner, JC and LT (10 years and 1 year experience in musculoskeletal ultrasound, respectively) acquired their own set of images for measurements. Each loading phase was measured 3 times then averaged. A digital goniometer was used to bring the knee into 5° and 20° flexion.

Statistical analyses were conducted using the IBM SPSS Statistics 19 software (Chicago, IL). Intraclass correlation coefficient (ICC) was used to analyze the results of the interrater reliability assessment. A univariate one-way repeated measures ANOVA with pairwise comparisons was used to analyze the effect of knee position on MME. ICC estimates and their 95% confidence intervals were calculated based on a single-rating, consistency, 2-way random effects model. To test the assumption of normality, the Kolmogorov-Smirnov test was used and revealed a deviation from normality ($p = 0.48$) for the 5° ER position. The histogram of the dependent variable in the five ER position appeared symmetrical; thus, the violation of normality was deemed minor and within tolerance for parametric testing. Boxplot assessment of the dependent variable according to the levels of the independent variable revealed outliers present in the five ER and twenty ER positions. They were determined to not have a significant effect on the result and thus were left in place. No extreme values were detected. No data were missing in the analyses. Post-hoc power analysis was carried out using G*Power 3.1.9.2 software.

# Results

A total of 60 healthy knees were scanned (mean age = 29; age range = 21–39); there were no exclusions for a positive orthopedic examination. Post-hoc power analysis with an effect size f(V) of .51 (determined according to partial $\eta 2 = .205$), $\alpha$ of 0.05, and with the sample size of 60 revealed 81% power.

Descriptive statistics of MME are reported in Table 1 with the maximum amount of extrusion being with standing (2.8 mm (SD: 0.8); See Fig. 2) and minimum amount with 20° flexion IR (1.9 mm (SD:0.8); See Fig. 3). Significant change in MME during various positions are reported in Table 2. There was a statistically significant increase in MME in the supine to the standing position, as well as in the 20° flexion IR position to the 20° flexion ER position. Significant decreases in MME were noted between several different positions: 1) standing to 5° IR, 2) standing to 5° ER, 3) 5° IR to 20° IR, 4) 5° ER to 20° IR, 5) standing to 20° ER, and 6) standing to 20° IR. As shown in Fig. 1, the inter-examiner reliability of the MME measurements across the six different positions was poor to moderate (0.35–0.57, $p < 0.05$).

Table 1
Mean median meniscal extrusion (MME) across the six loading phases.

| Positions | Mean (mm) | Standard deviation (mm) |
|---|---|---|
| Supine | 2.3 | 0.5 |
| Standing | 2.8* | 0.8 |
| 5° flexion, internal rotation (IR) | 2.3 | 0.9 |
| 5° flexion, external rotation (ER) | 2.4 | 0.7 |
| 20° flexion, internal rotation (IR) | 1.9** | 0.8 |
| 20° flexion, external rotation (ER) | 2.3 | 0.7 |
| *maximum amount of extrusion | | |
| **minimum amount of extrusion | | |

Table 2
Changes in meniscal extrusion during various positions (mm, 95% CI, p value)

| | Supine | Standing | 5° flexion IR | 5° flexion ER | 20° flexion IR | 20° flexion ER |
|---|---|---|---|---|---|---|
| Supine | | **0.5** **(0.2–0.7)^** | -0.05 (-0.27–0.38) | 0.10 (-0.38–0.18) | -0.40 (0.05–0.72) | -0.05 (-0.27–0.36) |
| Standing | | | **0.5** **(0.2–0.8)*** | **0.4** **(0.11–0.65)*** | **0.9** **(0.53–1.21)*** | **0.53** **(0.20–0.90)*** |
| 5° flexion IR | | | | 0.16 (-0.16–0.48) | **0.33** **(0.01–0.65)*** | 0.01 (-0.40-0.38) |
| 5° flexion ER | | | | | **0.49** **(0.19–0.78)*** | -0.15 (-0.43–0.13) |
| 20° flexion IR | | | | | | **0.34** **(0.04–0.63)^** |
| 20° flexion ER | | | | | | |

LEGEND: ER – External Rotation; IR – Internal Rotation

**Bold – Statistically significant**

^ - Statistically significant increase in extrusion.

* - Statistically significant decrease in extrusion.

# Discussion

Although the Thessaly test confronts some challenges, we were compelled to investigate direct morphological variation taking place at the medial meniscus under various loading phases of the Thessaly test and to better understand various degrees of MME. The Thessaly test at 20° of flexion showed highest diagnostic accuracy level of 94% in the diagnosis of medial meniscal tears [9] and our hypothesis was that the greatest degree of MME would be observed at 20° knee flexion.

Our data also showed that the mean MME in healthy normal subjects was 2.3 ± 0.5 mm for the supine and 2.8 ± 0.8 mm for the standing positions. This result conflicts with prior work, where MME of > 3mm[3,4] or > 2mm[5] has shown association with osteoarthrosis, cartilage loss, and medial meniscal tear. Despite prior conclusions of strong associations between MME to various meniscal pathologies, Achtnich and colleagues proposed that the current cut-off value of 3mm for meniscal pathologies be reconsidered [11]. Although they demonstrated normal physiological degrees of MME, there are some measurement differences compared to our current study (Supine: 2.3mm ± 0.5 vs. Achtnich et al. 1.1mm ± 0.5; 20° flexion: 1.9mm ± 0.8 (IR), 2.3mm ± 0.7 (ER) vs. Achtnich et al. 1.9mm ± 0.9). The difference in the measurement is likely due to subtle differences in the measurement reference points and interexaminer variability. In our study, a line was drawn connecting the free edges of the medial tibial cortex to the medial femoral cortex, whereas in Achtnich and colleagues, a tangential line was drawn on the medial tibia without connecting to the femur. Another difference is the addition of internal and external rotation to the 20° flexion position in our study.

The most noteworthy findings from our study were observed during supine to standing where largest degree of *increase* in mean MME was noted (refer to Fig. 2), while going from standing to 20° of flexion IR resulted in largest degree of *decrease* (refer to Fig. 3). We found that the mean MME at 20° flexion IR demonstrated the smallest degree of MME; initially, least amount at first glance, least amount of stress applied across the meniscus was assumed. However, upon review of the literature [17–21], a reasonable explanation for this paradoxical reduction of the mean MME at 20° of flexion was found. Both medial and lateral menisci are roughly wedge-shaped in their short axis and with a semilunar longitudinal morphology. It is this wedge-shaped meniscal morphology that converts the vertical load to circumferential tensile loads as the shear forces develop within the menisci, deforming it radially [17]. While the knee undergoes flexion, the menisci conforms to the geometry of the femoral condyle[18]. In flexion, the posterior femoral condyle is in contact with the tibial plateau, which structurally has lesser radii of curvature compared to the contact point of the femoral condyle at extension (i.e. standing), resulting in a decreased contact area[18]. Understanding that the stresses are inversely proportional to the contact area, flexion distributes larger stress across the meniscus during flexion. As a result of the different parts of the femoral condyle contacting the tibial plateau during extension and flexion, the medial meniscus withstands posterior displacement while the femoral condyle rolls on the tibial plateau during flexion[18,21] The degree of MME could be an indirect measure of assessing the contact area/force relationship applied at the meniscus. These findings reinforce the reason for significant decrease in the mean MME during 20° of flexion which initially was hypothesized to demonstrate the largest degree of MME from greatest applied stress across the meniscus.

Our study demonstrated physiological variations of the medial meniscus during the Thessaly test. Although it does not assume any further diagnostic ability of the Thessaly test, the largest degree of reduction in MME occurred at 20° flexion with IR, which may implicate that this loading phase places most degree of stress among all loading phases. The degree of the MME varies depending on the dynamic phases of the Thessaly test; therefore, the absolute degrees of the extrusion during different loading phases should be investigated in pathologic knees. Future investigation should consider correlating MME variability between age, weight, and gender differences. Further, natural history of physiologically ‘larger’ MME and its progression to osteoarthrosis or tear is still unknown and future investigation is needed.

One of the limitations of the study is the measurement site for the MME. MCL was used as the sole landmark for measurements, thus the posteriorly displaced meniscus could not have been observed during knee flexion. Another limitation is considerable experience difference between the examiners (10 years vs. 1 year) measuring the MME. Although interexaminer reliability was poor to moderate, the actual difference between the measurement points were less than 1/10mm, which likely has little clinical impact.

# Conclusions

Our study demonstrated various degrees of physiological extrusion of the medial meniscus in asymptomatic knees during the loading phases involved in the Thessaly test. Physiological MME does exist and should not be defaulted to pathologic meniscus as previously described. Finally, greatest reduction of the MME was shown during 20° flexion with IR of the Thessaly test. This paradoxical flattening of the meniscus may be considered an indirect measure of increased stress across the medial meniscus.

# Abbreviations

IR- Internal rotation, ER- External rotation, MCL- Medial collateral ligament, MME- Medial meniscal extrusion

# Declarations

## Ethics approval and consent to participate.

Ethical approval was received by Parker University Institutional Review Board (IRB Protocol# A- 00181)

## Consent for publication

Not applicable.

## Availability of data and materials

The dataset collected and analyzed are available from the corresponding author upon request.

## Competing interests

The authors declare that they have no competing interest.

## Funding

The authors declare there was no funding body in the design of the study and collection, analysis, and interpretation of data and in writing the manuscript.

### Author's contribution

JC and LT initiated the concept development. JC planned the protocol of the study. JC and LT organized and processed data collection. KR analyzed and interpreted the data results. JC carried out the literature search and manuscript writing. All authors read and approved the final manuscript.


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# Figures

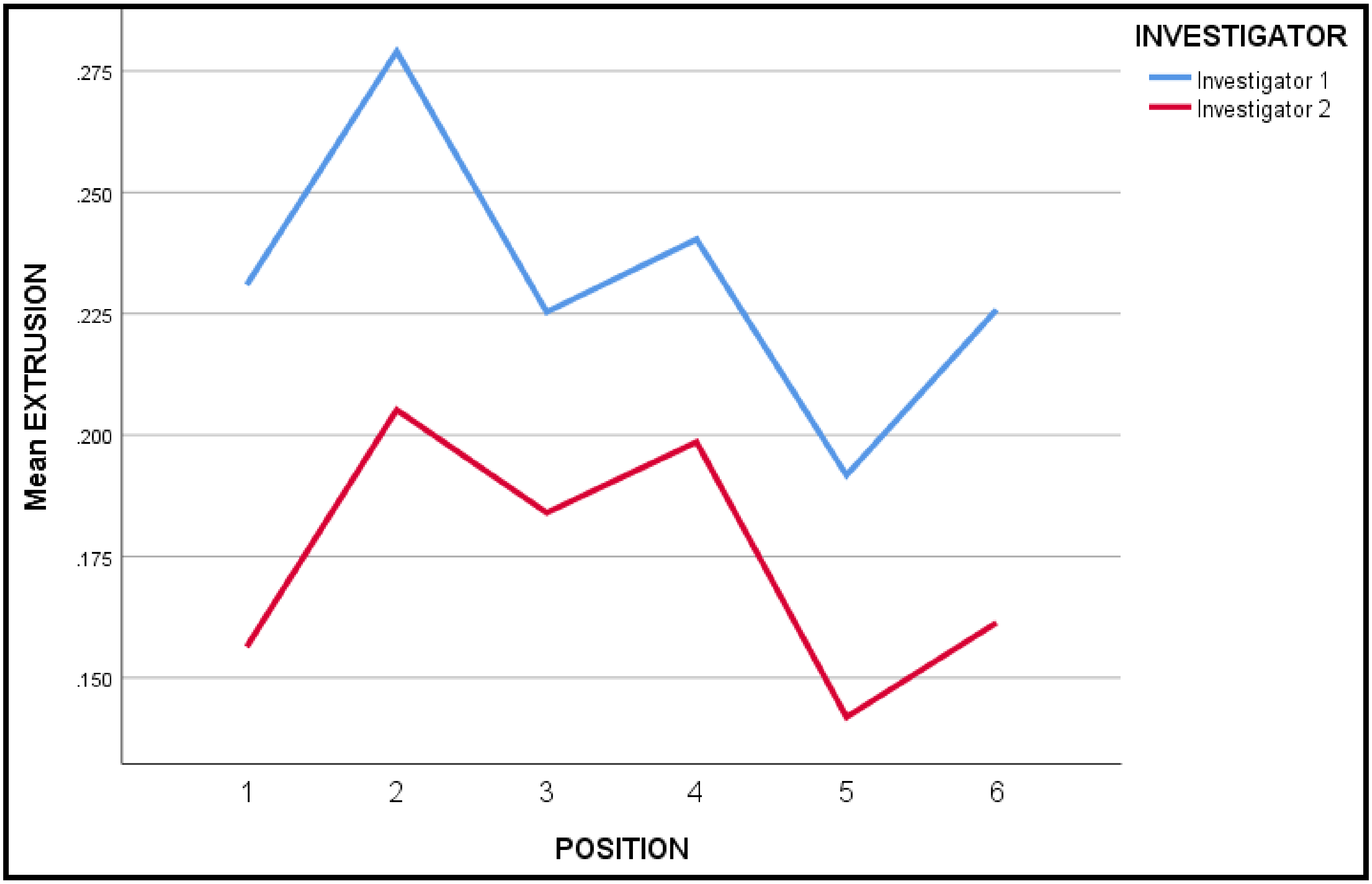


**Figure 1**

Mean (mm) medial meniscal extrusion comparison between the examiners across the six loading phases. Positions 1= Supine, 2=Standing, 3=5∘IR, 4=5∘ER, 5=20∘IR, 6=20∘ER.

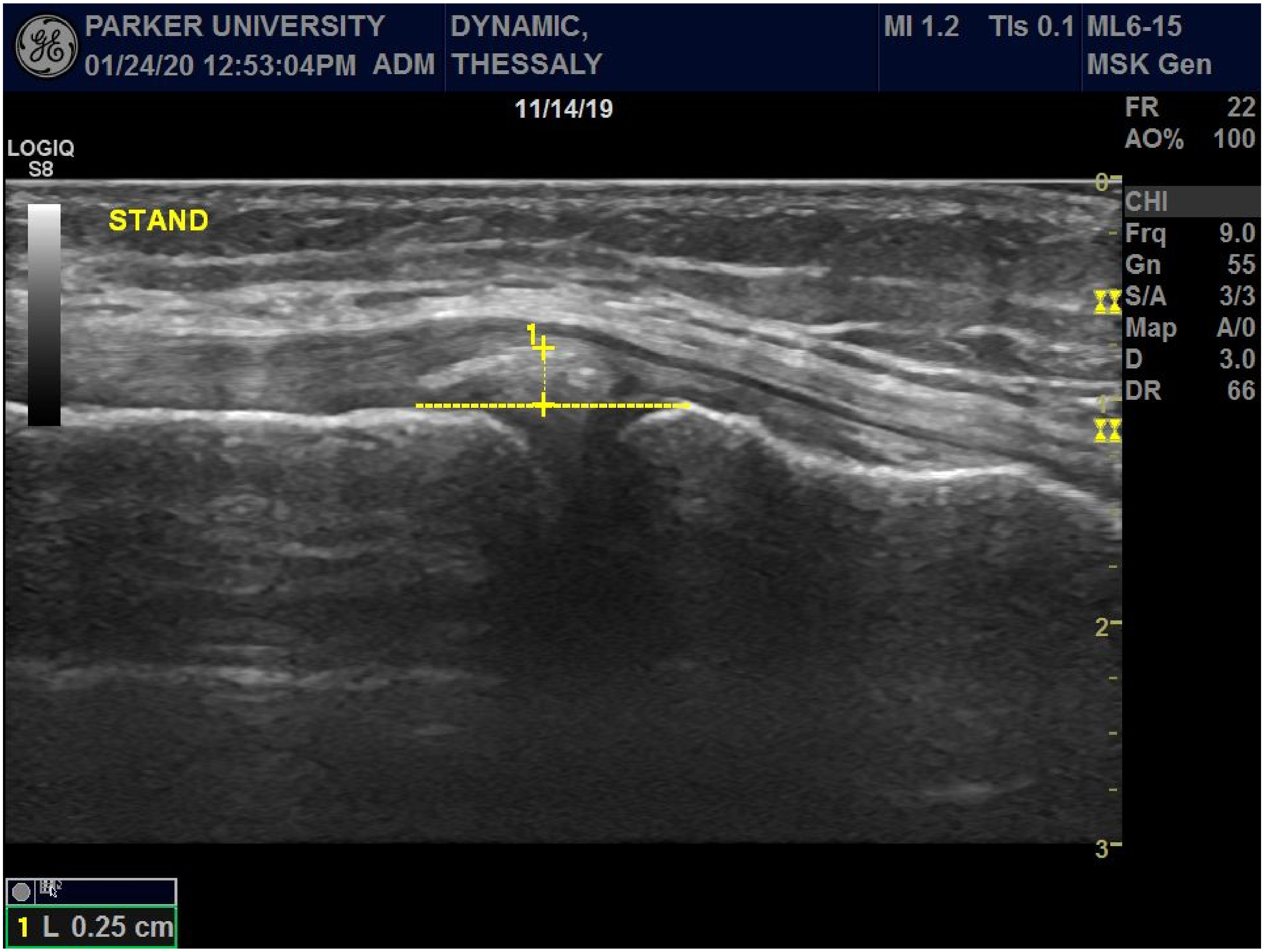


**Figure 2**

Sonography of the medial meniscus deep to the MCL while standing.

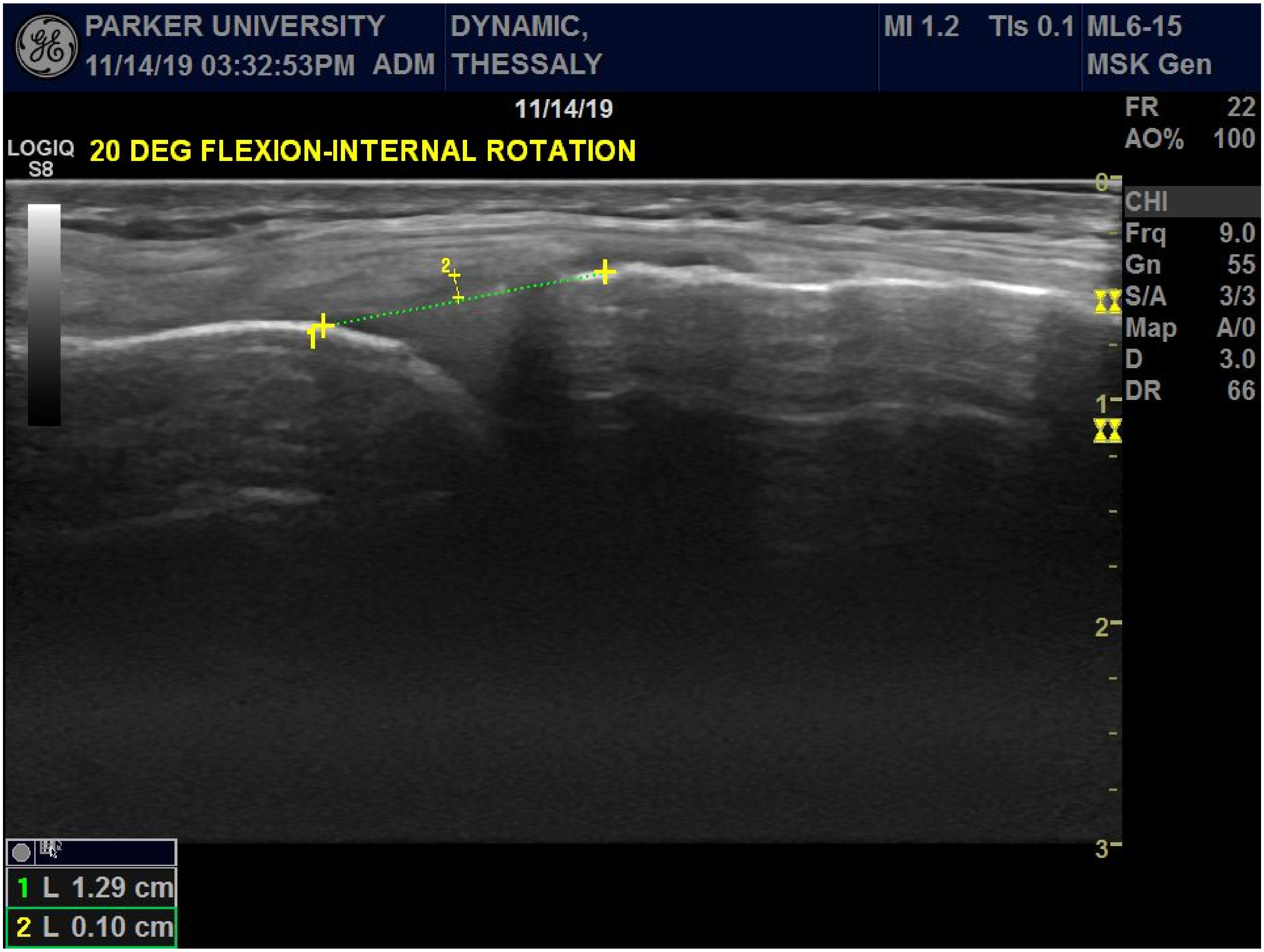


Figure 3

Sonography of the medial meniscus while knee in 20° flexion with internal rotation.