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Which Are the Most Reliable Methods of Predicting the Meniscal Size for Transplantation?

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Background: Although the size of the meniscal allograft is crucial during meniscal transplantation, the accuracy of meniscal measurement methods is still under debate. A number of methods based on radiographic and magnetic resonance imaging (MRI) data as well as on anthropometric data have been proposed, but their reproducibility and reliability are still unclear.

Purpose: To compare meniscal length and width as measured by different techniques (anthropometric and plain radiographic) to establish which of these 2 methods is more reliable and cost-effective for determining the meniscal size in comparison to MRI.

Study Design: Cohort study (diagnosis); Level of evidence, 2.

Methods: The MRI scans and plain radiographic films of 22 patients (44 knees) from a single institution were studied. The width and length of the medial and lateral menisci were measured using specific techniques. Data on sex, age, body weight, and height were used to develop a regression formula for meniscal measurements (comparing both imaging methods) to establish meniscal dimensions. Data validation was achieved using the Pearson correlation, the intraclass correlation coefficient, and the Wilcoxon nonparametric test for all variables, with a significance level established at 95%. Accuracy was established as a 10% measure discrepancy from the gold standard (MRI) and was considered an average between the right and left knees.

Results: No statistically significant difference was observed between the right and left knees on radiographic and MRI measurements. The Pollard technique of radiographic measurement overestimated the width of the lateral meniscus when compared with anthropometric measurements ($P < .001$), considering MRI as the gold standard. The same was observed for MRI measurements of the length of the lateral meniscus in which not only anthropometric but also plain radiographic measurements using the Yoon technique were significantly smaller than those values found with the Pollard technique ($P < .001$). The anthropometric method underestimated the width and length of the medial meniscus with an accuracy of 68.2% and 63.6%, respectively. The radiographic method was comparable with MRI in establishing all medial meniscal measurements with an accuracy of 93.2% for length and 77.3% for width.

Conclusion: Some viable alternatives to MRI have been suggested. For the lateral meniscus, anthropometric data are an alternative for width, and the Yoon method can be used to assess length. For the medial meniscus, the Pollard method is considered a satisfactory alternative. This study emphasized the importance of measuring the width and length of the meniscus independently during preoperative sizing for a meniscal allograft transplantation procedure. Using MRI as a gold standard, the study also proposed other less costly and satisfactory methods of obtaining such measurements.

Keywords: meniscal allograft transplantation; width; length; radiographic measurement; magnetic resonance imaging

A significant increase in medical knowledge on the functions of the meniscus and on the management of meniscal injuries has occurred in recent years.[8] The meniscus plays a key role in maintaining the function of the human knee by transmitting and distributing the weight load, by absorbing impact, and by lubricating and stabilizing the joint, especially when submitted to rotational forces.[7,8]

Meniscal lesions are very common and are usually treated arthroscopically with partial meniscectomy.[8] Total meniscectomies are rarely performed, although indicated for complex and extensive meniscal lesions.[8] However, it

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is known that the absence of the meniscus causes biomechanical abnormalities of the knee joint in which the severity of degeneration of the joint cartilage is proportional to the extension of the meniscal resection.[9] Therefore, every effort must be made to preserve meniscal tissue when treating complex meniscal lesions; nonetheless, there are cases where total or subtotal meniscectomies cannot be avoided.[7-9] Furthermore, meniscal artificial implants have been developed as an alternative treatment for patients with a preserved meniscal rim, but indications are limited, treatment is costly, and implants are not widely available, although the recent literature reports promising results.[5,13,14] Schüttler et al[13,14] demonstrated an improvement in outcomes after implantation of a novel polyurethane meniscal scaffold for the treatment of chronic, segmental medial meniscal deficiency, achieving sustainable midterm results, after 48 months, regarding pain and knee function. A systematic review of 23 studies in the literature on 2 scaffolds also documented good clinical results in 613 patients after implantation, mainly in young men affected by symptomatic chronic lesions.[5]

Patients considered ideal candidates for meniscal transplantation are young patients with a history of meniscectomy who have pain localized to the meniscus-deficient compartment, a stable joint, no malalignment, and articular cartilage with only minor evidence of osteochondral degenerative changes. In such situations, human meniscal transplantation is an efficient method of attempting meniscal function recovery.[1,7] This method may reduce knee pain and prevent degeneration of the joint cartilage after subtotal or total meniscectomy in patients younger than 50 years and with no evidence of advanced joint degeneration.[1,7-9] The success of human meniscal transplantation depends on accurate measurements to match the donor and recipient knees.[9,15,16]

A number of measurement techniques for the meniscus has been described based on plain radiographic, 3-dimensional computed tomography, magnetic resonance imaging (MRI), and anthropometric data.[6,10,18] Meniscal measurements obtained from plain anteroposterior (AP) and lateral radiographic films, as proposed by Pollard et al,[10] are the most widely used. This method employs mathematical formulas to establish corrective factors of measurements taken from specific bone landmarks on the tibial plateau to estimate the width and length of the meniscus.[10] A number of more recent studies using MRI have tried to establish a more geometrically accurate allograft size based on specific meniscal measurements.[4,6,17] Van Thiel et al[18] proposed a multivariate regression formula using anthropometric data such as sex, height, and weight to estimate meniscal measurements.

Increasing the reliability of preoperative meniscal measurements is of utmost importance for allograft transplantation success. The objective of the current study was to compare meniscal length and width, measured by different techniques (anthropometric and plain radiographic), to try to establish which of these 2 methods was more reliable for determining the meniscal size in comparison to MRI.

METHODS

After approval was obtained from an institutional review board for research in humans, a total of 22 adults scheduled to undergo radiography and MRI of the knee because of chronic anterior knee pain secondary to patellofemoral pain syndrome were selected from the orthopaedics knee outpatient clinic of a tertiary teaching hospital. All patients signed an informed consent form to enter the study. Patients with skeletal immaturity, a history of surgery to the knees, and lesions of the meniscus or knee ligaments, as well as a discoid meniscus and tibiofemoral joint arthritis were excluded from the study.

Both knees were studied in all patients; thus, a total of 44 knees were studied. The mean age of the studied population was 28.9 years (range, 18-41 years); 12 were male, and 10 were female. Comparisons between right and left knee measurements were made for all the studied variables.

Anthropometric Data

All the participants had their weight (kg) and height (cm) measured. The anthropometric measurements of the meniscus were made based on the methodology established by Van Thiel et al,[18] as follows:

$$\begin{aligned} \textit{Meniscus size} &= [\textit{constant coefficient}] \\ &+ [\textit{coefficient of height} \times \textit{height}] \\ &+ [\textit{coefficient of weight} \times \textit{weight}]. \end{aligned}$$

The equation above was published in inches. Because our measurements were made in centimeters, we performed the same conversion method proposed by the same authors in which the height coefficient is divided by 2.54.[18]

Radiographic Measurements

Measurements were taken from plain AP and lateral radiographic films with the ampoule placed 1 m distant from the knee using calibrators for the correction of magnification (Optimus 50 X-ray Generator; Philips USA) (Figure 1). The measurements of meniscal length and width were taken based on the methods proposed by Pollard et al.[10] According to Pollard et al,[10] the width of the meniscus is measured in the AP view by establishing the distance between 2 vertical lines perpendicular to the joint line: one of them tangent to the margin of the tibial metaphysis, and the other one between the medial and lateral tibial eminences in both knees (Figure 1A). The length of the meniscus is then measured in the lateral view by establishing the size of the tibial plateau, and then a line is drawn at the level of the articular line between the anterior surface of the tibia above the tuberosity and a parallel line that is tangent to the posterior margin of the tibial plateau (Figure 1B). The medial meniscus corresponds to 80% and the lateral meniscus to 70% of the measurement of the tibial plateau in the sagittal plane.[10]

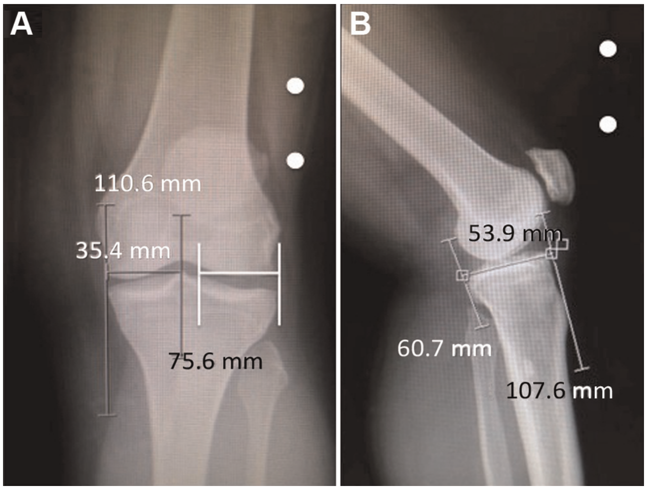

Figure 1. (A) Anteroposterior radiograph of medial and lateral meniscal width (coronal plane). The width is measured from the peak of the medial/lateral tibial eminence to the medial/lateral tibial metaphyseal margin. The markers denote 1-cm calibrations. (B) The lateral radiograph allows for the determination of meniscal length (sagittal plane). A joint line above the tibial plateau measures the distance between a line parallel to the anterior tibia above the tuberosity and another line tangent to the posterior plateau margin perpendicular to the joint line.

The equation proposed by Yoon et al[22] was also used to establish the length of the lateral meniscus, as follows:

$$\textit{Meniscus length} = (0.52 \times \textit{length of the tibia plateau established by the Pollard method}) + 5.2$$

All measurements were taken in centimeters.

All radiographic measurements were tested and retested by 2 experienced orthopaedic knee surgeons (C.C.K., A.S.N.) independently. Interobserver and intraobserver variability were calculated.

MRI Measurements

Meniscal sizing measurements were made through knee MRI based on the method described by Prodromos et al.[11] For better accuracy, an adaptation of the Prodromos method was made by adding axial images where the largest measurements for meniscal length and width were taken. Although a slight change was made to the Prodromos method, it is still considered the gold standard because reference measure points used (the largest distance for each direction) are still the same as for Prodromos et al.[11] These authors validated the method in 2007, when 10 menisci from cadaveric specimens were analyzed by a comparison of MRI and radiography.[11]

MRI was performed using a 1.5-T device (Intera; Philips USA) and a specific 8-channel tube (Philips USA). Proton density–weighted T1 and T2 sequences of the knee in the sagittal, coronal, and axial planes were obtained. An additional T1- and T2-weighted thin-slice proton density sequence was obtained in the axial plane directed to the femorotibial joint spaces (turbo spin echo with fat saturation; 3393-ms repetition time and 60-ms echo time; matrix size [phase × frequency], 200 × 161; field of view, 16 × 16 cm; 1.0-mm cut width; interval, 0.3 mm). This technique allowed manipulation of the plane and width of the MRI slices. Scans were then formatted on a workstation (Extended Brilliance Workspace V3.5.0.2250; Philips USA) by 2 independent radiologists experienced in musculoskeletal MRI, who manipulated the width and plane of orientation of the scans to achieve the best image of the long axis of the meniscus in the longitudinal plane, parallel to the tibial plateau. The objective was to encompass in the same image the insertion roots of the tibia and the borders of the anterior horn, body, and posterior horn of the medial and lateral menisci separately (Figure 2). AP (length) and mediolateral (width) measurements of both menisci were then obtained on reconstructed images. The meniscal length was established by measuring the distance between the most anterior point of the anterior horn and the most posterior point of the posterior horn (Figure 3). The meniscal width was established by first drawing a line that connected the more central points of each meniscal root and then measuring the distance between the external contour and this line, perpendicular to the length line (Figure 4).

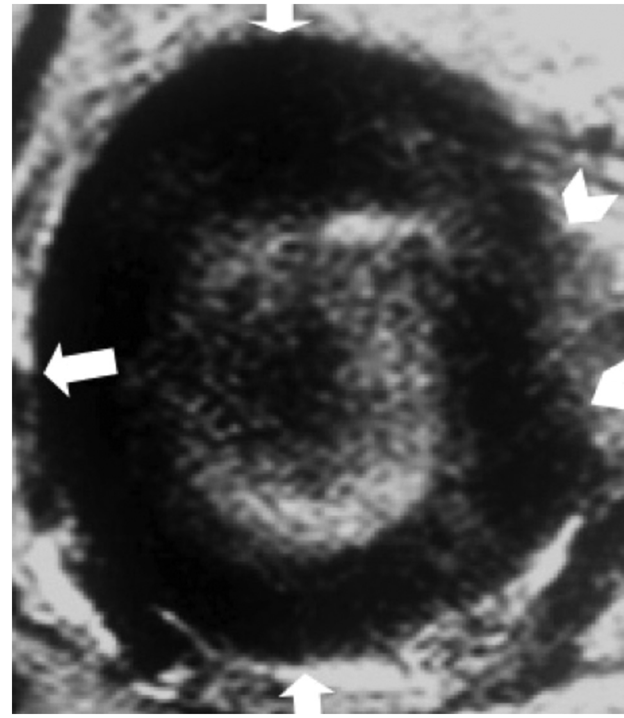

Figure 2. Magnetic resonance imaging scan of the lateral meniscus in the longitudinal plane. Arrowheads indicate meniscal roots; arrows indicate the body extremities and anterior and posterior horns.

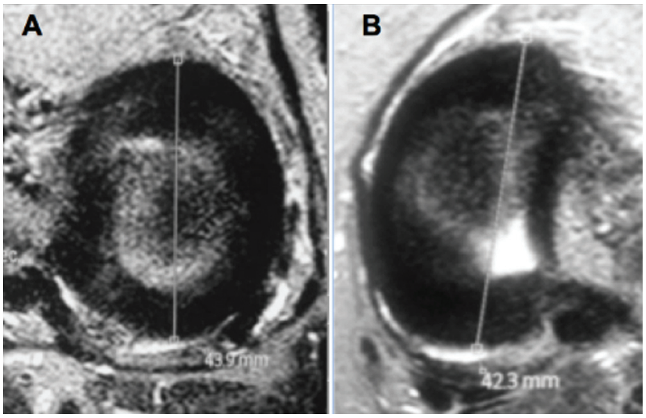

Figure 3. Magnetic resonance imaging scans of meniscal length measured on the anteroposterior cut. (A) Lateral meniscus and (B) medial meniscus.

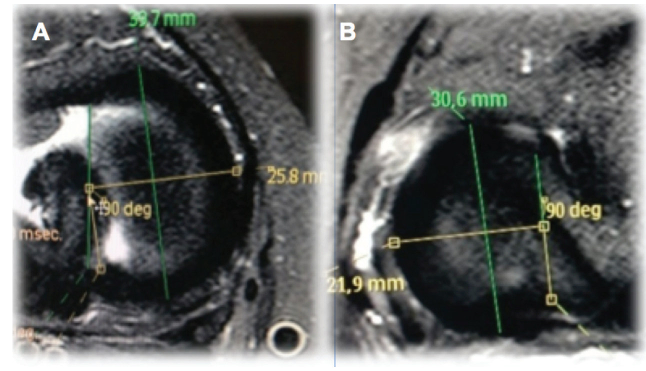

Figure 4. Axial magnetic resonance imaging scans of meniscal length (vertical line) and width (horizontal line). (A) Medial meniscus and (B) lateral meniscus.

All MRI measurements were tested and retested by 2 experienced radiologists (J.C.A.S., M.K.T.) independently. Interobserver and intraobserver variability were calculated.

Statistical Analysis

Statistical analysis was carried out using a commercially available software package (SPSS version 15.0 for Windows; IBM Corp). Validation of data obtained from the plain radiographic films and MRI scans was achieved using 3 distinct methods: the Pearson correlation, the intraclass correlation coefficient, and the nonparametric Wilcoxon test to evaluate interobserver reliability. Qualitative data were analyzed in absolute (n) and relative (%) frequencies. Measurement pairs were compared using the Friedman nonparametric test, and multiple comparisons used the nonparametric Wilcoxon test. The measurement of accuracy was established using MRI as the gold standard, with a 10% discrepancy rate. Statistical significance was established at 95% (α = 5%). Power analysis was performed for sample estimation (Table 1).

RESULTS

Significant and strong correlations ($r > 0.7$) were found for all radiographic and MRI measurements obtained between both examiners with no bias ($P > .05$, Wilcoxon test). Full results are reported in Table 2.

Thus, results were expressed as mean values of all studied variables. MRI was established as the gold standard, and all other results were compared with those obtained by this imaging technique. Table 3 depicts the differences found in the width and length of the meniscus between each of the studied measurement techniques. A significant difference was found between measurements obtained by all 3 methods ($P < .05$, Friedman test). There was no statistically significant difference between the right and left knees for any of the measurements obtained on both plain radiographic films and MRI scans.

Table 4 expresses multivariate Wilcoxon test results comparing pairs of measurement techniques. The Pollard technique overestimated the width of the lateral meniscus when compared with anthropometric measurements ($P <$ .001), considering MRI as the gold standard. The same was observed for MRI measurements of the length of the lateral meniscus in which not only anthropometric but also plain radiographic measurements using the Yoon technique were significantly smaller than those values found with the Pollard technique ($P < .001$). Therefore, for the lateral meniscal length, the Yoon technique was more accurate than the Pollard technique and anthropometric data; for the width, anthropometric data had closer measures to MRI.

No statistically significant difference was found between radiographic and MRI measurements of the medial meniscus, except for the right meniscus in which the plain radiographic assessment underestimated its length by 1.5 mm (range, 0.3-2.2 mm) when compared with MRI. Anthropometric data underestimated the width and length of the medial meniscus when compared with the Pollard radiographic measurement and MRI scans. Thus, the Pollard method was the most similar to MRI measures.

The radiographic assessment of the medial meniscal length was 93.2% accurate and the width was 77.3% accurate when compared with the MRI standard. The lateral meniscal width and length assessed by the Pollard method were 47.7% accurate and by the Yoon method were 81.8% accurate. Although anthropometric measurements of meniscal width and length presented median values similar to those of MRI, the accuracy was low. Comparing the anthropometric data with MRI to measure accuracy, for the medial meniscus, the width and length measurements revealed an accuracy of 68.2% and 63.6%, respectively, and for the lateral meniscus, the width and length measurements revealed an accuracy of 72.7% and 75.0%, respectively.

DISCUSSION

A precise correspondence between meniscal allograft measurements and those of the recipient knee is essential to

TABLE 1
Power Analysis[a]

	Mean Measurement, mm[b]					
	Anthropometric	Radiographic	MRI	10% Discrepancy	Power	Type II Error (β)
Medial meniscal width						
Right side	30.7	32.3	32.7			
Left side	30.7	32.6	32.7			
Mean	30.7	32.5	32.7	3.3	0.988	0.012
Medial meniscal length						
Right side	41.4	43.7	45.2			
Left side	41.4	44.2	45.1			
Mean	41.4	44.0	45.1	4.5	1.000	0
Lateral meniscal width						
Right side	30.7	34.8	31.4			
Left side	30.7	34.7	31.7			
Mean	30.7	34.8	31.5	3.2	0.983	0.017
Lateral meniscal length						
Right side	33.3	38.4	35.0			
Left side	33.3	38.5	34.2			
Mean	33.3	38.4	34.6	3.5	0.994	0.006

[a]Analysis performed using paired Student t test. MRI, magnetic resonance imaging.
[b]Standard deviation for all values = 3.5 mm.

TABLE 2
Intraclass Correlation Coefficient and Interobserver Reliability Assessment for MRI and Radiographic Methods[a]

	Pearson Correlation (r)	Intraclass Correlation Coefficient	P Value[b]
Radiographic			
Right side			
Tibial plateau width	0.994	0.993	.767
Lateral meniscal width	0.964	0.965	.926
Lateral meniscal length	0.885	0.883	.614
Medial meniscal width	0.981	0.981	.441
Medial meniscal length	0.969	0.968	.486
Left side			
Tibial plateau width	0.995	0.995	.627
Lateral meniscal width	0.929	0.932	.722
Lateral meniscal length	0.970	0.966	>.999
Medial meniscal width	0.979	0.977	.333
Medial meniscal length	0.739	0.735	.833
MRI			
Right side			
Lateral meniscal width	0.985	0.985	.434
Lateral meniscal length	0.995	0.994	.168
Medial meniscal width	0.984	0.983	.985
Medial meniscal length	0.994	0.993	.550
Left side			
Lateral meniscal width	0.980	0.978	.118
Lateral meniscal length	0.992	0.992	.525
Medial meniscal width	0.989	0.989	.807
Medial meniscal length	0.990	0.990	.454

[a]MRI, magnetic resonance imaging.
[b]Wilcoxon test.

restore meniscal function after transplantation. Some methods are described to provide meniscal length and width measurements. MRI is one of the most reliable methods to acquire them,[6,11] although we suggest some viable alternatives to MRI. For the lateral meniscus, anthropometric data are an alternative for width, and the Yoon method can be used to assess length. For the medial meniscus, the Pollard method is considered a satisfactory alternative.

TABLE 3
Results of Anthropometric, Radiographic, and MRI Measurements[a]

	Measurement, mm			
	Mean ± SD	Range	Accuracy, %	P Value[b]
Lateral meniscal width				
Anthropometric method	30.7 ± 3.1	26.9-39.2	72.7	
Pollard radiographic method				
Right side	34.8 ± 3.3	29.3-41.1	36.4	
Left side	34.7 ± 2.9	29.7-41.0	59.1	<.001
MRI				
Right side	31.4 ± 2.9	23.9-37.0		
Left side	31.7 ± 2.9	25.1-38.8		
Lateral meniscal length				
Anthropometric method	33.3 ± 2.3	29.8-37.7	75.0	
Pollard radiographic method				
Right side	38.4 ± 3.2	31.6-46.0	54.5	
Left side	38.5 ± 3.2	32.2-46.7	40.9	
Yoon radiographic method				
Right side	33.7 ± 2.3	28.7-39.6	86.4	<.001
Left side	33.8 ± 2.5	28.8-40.2	77.3	
MRI				
Right side	35.0 ± 4.0	27.8-46.9		
Left side	34.2 ± 3.7	27.6-44.0		
Medial meniscal width				
Anthropometric method	30.7 ± 2.2	27.8-34.9	68.2	
Pollard radiographic method				
Right side	32.3 ± 3.3	26.5-37.8	81.8	
Left side	32.6 ± 3.5	27.2-38.0	72.7	<.003
MRI				
Right side	32.7 ± 3.1	26.2-41.0		
Left side	32.7 ± 3.6	25.0-41.4		
Medial meniscal length				
Anthropometric method	41.4 ± 2.6	37.4-46.8	63.6	
Pollard radiographic method				
Right side	43.7 ± 3.4	36.1-52.6	95.5	
Left side	44.2 ± 3.3	36.8-53.4	90.9	<.001
MRI				
Right side	45.2 ± 3.5	37.2-55.0		
Left side	45.1 ± 3.6	36.6-54.3		

[a]MRI, magnetic resonance imaging.
[b]Friedman test.

Meanwhile, some mismatch can occur. When the graft is too small, forces across the meniscus are increased, and an imbalance in the femoral condyle occurs, resulting in compartment overload.[9] On the other hand, when the meniscal allograft is too large, then it will not bear loads, and forces on the articular cartilage will increase, precipitating early degeneration of the knee joint.[9,12,15,16] Only a small number of studies have focused on the consequences of measurement errors during meniscal allograft transplantation, suggesting that only 5% to 10% of size discrepancies could be well tolerated by the knee.[3,19]

Meniscal allografts should be side and type specific.[15] The width of the meniscus should preferably be obtained independently based on the mediolateral dimension in the coronal plane and its length to the AP measurement in the sagittal plane[10] because one measurement cannot and should not be used to predict the other.[23]

According to Dargel et al,[2] although human knees are not symmetrical, they do show a good correlation between right and left knee morphometric dimensions. Likewise, the current study did not observe significant radiographic or MRI discrepancies between the right and left knees.

Haut et al[6] found that MRI is more accurate than plain radiography in determining meniscal geometry. Prodromos et al[11] confirmed these findings when comparing the measurements taken by plain radiographs of the contralateral (nondiseased) knee to MRI scans, suggesting that MRI should be the gold standard for the assessment of meniscal size. The results of the current study concur with these findings, which lead us to consider MRI findings as our base data for comparisons.

The radiographic method of measuring the meniscus preoperatively was initially proposed by Pollard et al[10] in 1995 by establishing a correlation between standard radiographic

TABLE 4
Results of Anthropometric, Radiographic, and MRI Comparisons[a]

	P Value[b]					
	Pollard × Anthropometric	Pollard × MRI	MRI × Anthropometric	Yoon × Pollard	Yoon × MRI	Yoon × Anthropometric
Medial meniscal width						
Right side	**<.001**	**<.001**	**<.001**	—	—	—
Left side	**<.001**	.149	**<.001**	—	—	—
Medial meniscal length						
Right side	**.002**	.417	**.001**	—	—	—
Left side	**<.001**	.426	**.004**	—	—	—
Lateral meniscal width						
Right side	**<.001**	**<.001**	**.022**	**<.001**	**.024**	.263
Left side	**<.001**	**<.001**	.158	**<.001**	.527	.211
Lateral meniscal length						
Right side	**<.001**	**<.001**	.094	—	—	—
Left side	**<.001**	**<.001**	**.028**	—	—	—

[a]Bolded *P* values indicate statistical significance. MRI, magnetic resonance imaging.
[b]Wilcoxon test.

landmarks with meniscal dimensions so that surgeons can order size-specific meniscal allografts. Although this method is still widely used, a number of studies have shown that errors in magnification of the radiographic film, inaccurate determination of the bone landmarks, rotational errors in knee positioning, and difficulties in differentiating the bone–soft tissue interface all contribute to a low accuracy of this method.[15,20,21] Pollard et al[10] reported an error margin of 7.8%; however, other authors have not been able to reproduce these results, especially regarding meniscal length. This was documented by Yoon et al,[22] who proposed a modification to the Pollard method by using a mathematical formula that was supposed to predict this variable, increasing accuracy from 40% to 92%. The current study confirmed these findings for establishing the length of the lateral meniscus (accuracy, 47.7% [Pollard method] vs 81.8% [Yoon method]).

No statistically significant difference was found in the lateral meniscal length measurements obtained by MRI when compared with the Yoon method, but when compared with the Pollard method, the measurement was overestimated by 5 mm. Such an error of 10% could lead to transplantation failure. The Pollard method also overestimated the lateral meniscal width and had a low accuracy of 47.7%. These findings strongly suggest that the Pollard method is not reliable for establishing lateral meniscal dimensions and that the Yoon method can be used to establish its length.

As for the medial meniscus, the Pollard method was as accurate as MRI for establishing all measurements, with the exception of the length of the right medial meniscus. The accuracy for right medial meniscal length was 95.5%. This good accuracy rate may be biased by a relatively small number of participants.

Instead of using imaging studies, Stone et al[16] proposed correlating preoperative meniscal measurements to anthropometric data, such as height, weight, and sex, to minimize technical imperfections of the radiographic methods and decrease costs related to MRI. The authors found that such data are not only easily obtained but also correlates strongly to meniscal size.[16] Van Thiel et al[18] later described a method of establishing the meniscal size for transplantation based solely on anthropometric data. The authors studied the meniscus of 930 donors and developed a regression model based on sex, weight, and height that showed an accuracy slightly higher than that of the radiographic and MRI methods. However, there are potential limitations to this study. The most important is that the donor height and weight were recorded from outside sources and do not represent exact measurements taken using strict criteria. The large sample size does correct for some of this variation, although there is no way to know if the recorded weight represents the actual weight of the donor at the time of harvest.[18] The current series used Van Thiel et al's[18] anthropometric model, finding no statistically significant difference in the measurement of the lateral meniscus when compared with MRI, with an accuracy of 72.7% for width and 75.0% for length. However, the Yoon method was more accurate than Van Thiel et al's[18] model for the lateral meniscus, especially its length, which was significantly underestimated when compared with MRI and revealed a lower accuracy than that of the Pollard method.

We concluded that surgeons should make requests to tissue banks for a meniscal allograft that is sized as similar as possible to the meniscus that will be implanted; contralateral meniscal width and length measurements on MRI is a viable option to minimize size compatibility errors. However, less costly alternatives for meniscal graft size estimation are also available, especially for patients with an injured contralateral knee. The anthropometric data found in our study showed similar accuracy when compared with MRI, suggesting that it can be safely used to establish measurements of the lateral meniscal width and that the Yoon method should be used to establish measurements of the lateral meniscal length. When the medial meniscus is involved, the Pollard radiographic method is comparable with contralateral MRI and is a satisfactory alternative.

There are potential limitations to our study. Ideally, measurements should be compared with meniscus samples from cadaveric specimens as a gold standard. According to our study design and methodology, MRI was the most suitable option to be taken as a gold standard to acquire meniscal measurements, as proposed and validated by Prodromos et al.[11] Also, a greater number of patients would increase our statistical significance. Future studies with larger populations are necessary to confirm these findings and to develop more accurate techniques of establishing meniscal measurements for transplantation.

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