RADIOGRAPHIC ASSESSMENT OF THE FEMORAL INSERTION OF THE POSTERIOR CRUCIATE LIGAMENT

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ABSTRACT

Objective: To establish the radiographic images of the femoral insertion of the posterior cruciate ligament (PCL), in order to assist the creation of anatomical femoral tunnels during surgeries, and to be used as parameters in postoperative evaluation of the location of these tunnels. Methods: Thirty adult cadaver knees were used. The PCL anterolateral (AL) and posteromedial (PM) bundles' center was marked with a metallic marker. Radiographs were taken and a grid system was established to locate the position of bundles insertion. The percentile in which the projection of each bundle's center was in relation to the Blumensaat line was also determined. Results: In the anteroposterior view, AL and PM bundles' centers were on average, on the 42.5% and 38.18% percentiles of Blumensaat's line, respectively. In lateral views, the AL and PM bundles' centers corresponded to the 72.94% and 55.56% percentiles of the line, respectively. In 73.33% of the knees the AL bundle center was on the 3D quadrant and in 70% of samples the PM bundle center was in quadrant 2D. Conclusions: We established an X-ray pattern of femoral insertion of PCL that may be of interest for intraoperative control, before tunnel drilling, and also for post-operative evaluation of tunnel location. ***Controlled Laboratory Study.***

Keywords: Femur. Posterior cruciate ligament. Radiography.

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INTRODUCTION

The success of surgical reconstructions of the posterior cruciate ligament (PCL) depends on the accurate restoration of its anatomy.[1] For accurate reproduction of the normal function of PCL the anatomic reconstruction of its anterolateral (AL) and posteromedial (PM) bands should be considered.[2-4] Another condition to obtain a good result in PCL reconstruction is the anatomical location of the graft.[5-7] The improper placement of the tunnels can lead to shortening or enlargement of the graft in flexion and subsequent failure.[8] One of the most critical factors influencing clinical outcomes of PCL reconstructions with dual band is the correct placement of the femoral tunnels.[9]

The exact description of the anatomical insertions of AL and PM bands of the PCL and its corresponding radiographic images can contribute and make surgical reconstructions more precise.[10-12] Interference screws or other metal artifacts used in graft fixation may lead to a less effective MRI to evaluate the position of the tunels.[11]

The aim of our study was to delimit the central points of the femoral insertions of AL and PM PCL bands and determine their corresponding radiographic images so they may serve as intraoperative reference of the ideal place to create anatomic femoral tunnels and for the evaluation of postoperative location of these tunnels in PCL reconstructions.

METHODS

The radiographic study of the femoral insertion of the PCL was done in 30 anatomic adult cadaver knees, 16 of them right and 14 left unpaired knees without identification of gender or age. No piece showed signs of arthrosis and all possessed the anterior and posterior cruciate ligaments intact. The specimens were fixed in 10% formaldehyde and kept in a mixture of 2.5% phenol, 2.5% formaldehyde and 1% sodium chloride. Before dissection, specimens were kept in liquid glycerin for 60 days. We started with dissection of the posterior aspect of the knee. We identified and isolated the AL and AM PCL bands in its femoral insertion, then submitted them to resection and demarcated the centers of the bands with a metallic marker of a different format for each band, directly glued to the bone, with special glue. For the AL band we used a circular marker, 3x3 mm diameter, and for the PM band we used a 1 mm^2 square marker. The inserting center of the bands was determined by the intersection of the height and width diameters. (Figure 1) We did not divide the distal femur in the sagittal plane to keep the natural anatomical references. We performed anteroposterior (AP) incidence digital radiographs of the extended knee and actual profile, where there is an overlap between the medial and lateral femoral condyles,

All the authors declare that there is no potential conflict of interest referring to this article.

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at 30° flexion. The technical standardization to make radiographs was: voltage 48 KV, dosage 5 mA and distance from tube to specimen 120 cm. Radiographs were taken in actual size and the program accurately reported the measurement scale.

In radiographs obtained in the AP incidence we established a grid system that divided the distal femur in quadrants contained in a rectangular space formed by a baseline tangent distally the femoral condyles, by the medial and lateral ends of the medial and lateral femoral condyles and the most proximal region the medial femoral condyle (MFC), parallel to the line tangent to the most distal region of the femoral condyles.

The rectangular space was divided into 25 quadrants, designated by letters from "A" to "E" and a numeral from "1" to "5". The division of the rectangle of letters and numbers had as a point of origin the most proximal and medial of MFC. The letters correspond to the five vertical divisions of the rectangle and the numbers their horizontal division. (Figure 2)

We then determine in which quadrant each inserting centers of the bands were located. In radiographs made at AP incidence we also measured the distance between the centers of the AL and PM bands, the angle formed between a line joining these centers and the line tangential to the distal femur which we called the AP baseline), the height of each center in relation to that line, the distance to the center of a line representing the lateral MFC wall (which was called the lateral femoral condylar line), (Figure 3) the distance between the center of each projection at baseline and medial initiation as well as the percentage representation of such distance in relation to the total length of the baseline (what we call percentile band center).

In the AP radiograph, the lateral condylar line was considered the ground zero to determine the value of the distance from the inserting centers of the bands. If the center of the band was laterally positioned in relation to the femoral condylar line, the distance was considered positive, if it was medial to femoral condylar line, although within the limits of their own MFC, this distance was considered negative. In lateral view radiographs, we create a rectangular system, in quadrants, similar to Bernard's *et al.*,[13] but in a simplified form, using as limits the Blumensaat line, two perpendicular lines to the proximal and distal ends and the limit of distal femur.

This rectangular space was divided into 25 quadrants. Taking as starting point the top and back of this rectangle, we called letters "A" through " E" the five divisions of his height and a number from "1 to 5" the divisions of his depth. (Figure 4) We also verified the location of the inserting center of AL and PM bands in these quadrants.

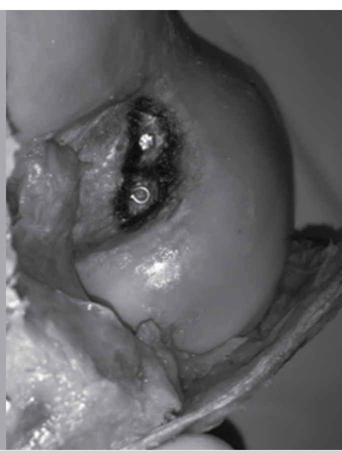

Figure 1. Inserting center of anterolateral band where it can be seen the circular metallic marc and inserting center of posteromedial band, with squared shape metallic marc.

Figure 3. Lateral condylar line, corresponding to the lateral wall of the medial femoral condyle.

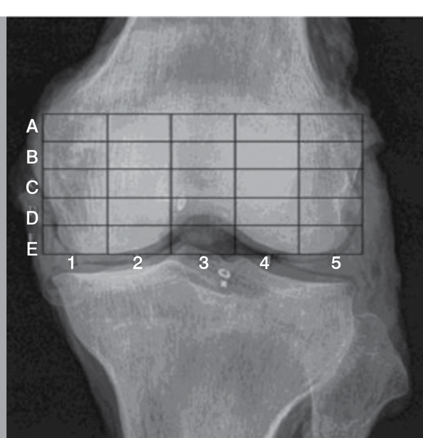

Figure 2. Division of the rectangle, in AP view, into 25 quadrants named by a letter from "A" to "E" and by a numeral, from "1" to "5".

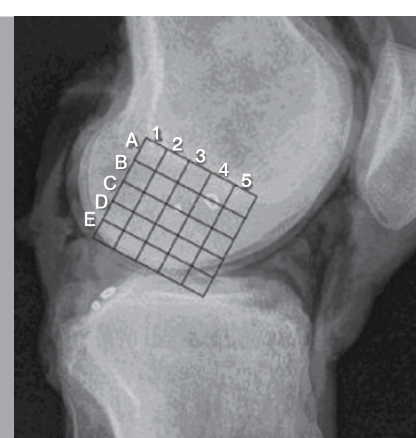

Figure 4. Division of the rectangle, in profile view, into 25 quadrants named by a letter from "A" to "E" and by a numeral, from "1" to "5".

In profile radiographs we also measured the distance between the inserting centers of AL and PM bands, the angle between a line that united these centers and the Blumensaat line, the height of each center to this line, the percentile in which the projection of each center was in relation to the Blumensaat line (where 0% would be the more proximal and posterior end, whereas 100% would be the most distal and anterior extreme).

RESULTS

In the AP incidence, the average distance between the centers of the AL and PM bands was 4.29 ± 1.61 mm. The center of the PM band was proximal to the center of the AL band in 63.33% of the knees. The heights of the centers of the bands in relation to the base line tangential to the distal femoral condyles was 12.67 ± 1.54 and 13.58 mm ± 1.89 mm for AL and PM bands, respectively.

In all knees the center of the lateral AL band was located laterally to the center of the PM band and in one knee (3.3%), the centers of these bands were contained within the radiographic limits of the MFC; the center of the PM band was isolated in this condition in 46,67% of the knees.

Thus, the average distance between the centers of AL and PM bands and the lateral femoral condylar line was 3.39 mm ± 2.42 and 0.00 ± 1.98 mm, respectively.

The distance of the centers of the AL and PM bands in relation to the most medial distal femur was 35.41 ± 2.39 mm and 31.76 ± 2.45 mm, respectively. The centers of the AL and PM bands were on average, in a reciprocal mode, in the percentiles 42.48% and 38.14%.

In 73.33% of the knees the center of the AL band was in quadrant 3D and in 70 % of the knees, the PM band was in quadrant 2D. The angle formed between the inserting centers of the bands and the baseline was 32.41°± 26.68°.

On profile radiographs, the average distance between the inserting centers of AL and PM bands was 7.18 ± 1.27 mm and the average height of the inserting centers of AL and PM bands to the Blumensaat line was 5, 52 mm ± 1.85 and 9.92 ± 2.08 mm, respectively. The inserting center of the bands formed an average angle of ± 43.58° ± 16.88° with the Blumensaat line. Taking the Blumensaat line as a reference, the centers of the AL and PM bands corresponded to the percentile 72.86 % and 55.46% respectively. The center of the AL band was mainly located in the quadrant 4B (46.67% of the parts), the center of the PM band showed a more proportionate distribution of its location: in 30% of the parts it was in quadrant 3C and in 26.67% of the knees in quadrant 4B, and 26.6% of the evaluated parts it was in quadrant 3B. The complete results of all measurements taken can be seen in Tables 1 and 2.

DISCUSSION

The anatomical knowledge is critical for knee ligament reconstructions. The use of intraoperative fluoroscopy helps to verify the anatomical points, before the drilling of tunnels.[12]

Radiographs can also be useful for postoperative evaluation of the bone tunnels positions. However, PCL reconstruction is made in three plans and X-rays show only two planes. Computed tomography can show bones in three dimensions, which is very useful for assessing the positioning of the tunnels in the postoperative period, but exposure to radiation and its cost may limit its usefulness.[14]

The evaluation of the location of the tunnels by magnetic resonance imaging may be hampered by the presence of metallic objects used in ligament reconstructions.[11]

Moreover, both tomography and magnetic resonance cannot be used as instruments in intraoperative assessment, therefore, it is essential to establish parameters that correlate anatomy with radiographic information to be used in the reconstruction of the PCL, both the intra-and postoperatively, especially in dual band techniques.

We found in PubMed only two papers[12,15] correlating anatomic insertions of AL and PM bands of the PCL and radiographs of such sites to determine the precise location of the femoral tunnels. As in our work, the studies of Lorenz *et al.*[12] and Osti *et al.*[15] were performed in cadaver knees without description of anthropometric data of the individuals. However, data in those papers are expressed as percentages, which would, not requiring, thus, the absolute height and weight values of individuals. Lorenz *et al.*[12] published a study of 16 human cadaver knees. They kept 7 mm from the femoral insertion and delimited the peripheral edges with four to five 0.8 mm wide by 3 mm long copper wires.

Differently from these authors, we took off the bands through a delicate dissection and marked the inserting centers, which we consider a more accurate way to determine the location of the bone tunnels drilling intraoperatively, and to check the results postoperatively. In profile radiographs the authors determined in a rectangle formed by the Blumensaat line, anterior and posterior edges of the MFC and a tangent line to the distal portion of the CFM. Subsequently, this rectangle divided into a lattice of 100 units and considered as a reference the highest point of this reticle.

The rectangle that we have defined on the same radiographic view was divided into 25 quadrants and had as limits the Blumensaat line, two perpendicular lines to its proximal and distal ends, and the limit of the distal femur. To Lorenz *et al.*[12] to the center of insertion of AL and PM bands were located in the middle percentiles of 62% ± 3% and 51 ± 5% relative to the Blumensaat line, respectively. In our study, the inserting centers of AL and PM bands were located in the average percentiles of 72.86 ± 6.02% and 55.46 ± 9.63%, results which are close to those of Lorenz *et al.*[12] More recently, Osti *et al.*[15] conducted research using 15 cadaver knees. They removed the lateral femoral condyle with oscillating saw and marked the center of AL and PM bands with 2 mm diameter and 4 mm deep radiopaque cannulas. We kept this portion of the femur, so that the X-ray images could be closer to real. We have used circular markers to the center of the AL bands AL and square markers to the center of the AM band, in order to enable radiographic differentiation. We believe that the metal markers can lead to some doubts about the individual identification of the center bands, in AP incidence radiographs. For radiographic analysis of the insertion of the bands, we used a grid system with 16 rectangular zones, superimposed on profile images, where areas, numbered from 1 to 16, started in the anterosuperior corner and ended in the posteroinferior corner. The limits of this grid, which the authors called M2, were identical to those described by Lorenz *et al.*[12] For Osti

Table 1. Radiographic Measurements of centers of AL and PM bands in antero-posterior view.

		Dist. between centers of bands (mm)	Angle bands-baseline (degrees)	Height AL band – baseline (mm)	Height PM band – baseline (mm)	Dist. AL center – lateral face med. condyle (mm)	Dist. PM center – med. condyle lateral face (mm)	Dist. AL center – med. face med. condyle (mm)	Dist. PM center – med. face med. condyle (mm)	Percentile AL center - LL axis (%)	Percentile PM center - LL axis (%)	AL Quadrant	PM Quadrant
1	R	6.10	14.60	11.80	13.20	7.50	1.60	42.00	36.10	45.85	39.41	3D	2D
2	R	5.00	93.20	12.50	18.00	6.10	4.30	37.00	35.40	41.57	39.77	3D	2C
3	R	5.60	71.80	10.70	16.20	2.10	0.90	36.20	34.50	40.71	38.80	3D	2D
4	L	5.20	15.20	14.30	13.20	3.00	-1.80	37.60	32.70	43.61	37.93	3D	2D
5	L	6.20	14.10	12.60	14.20	8.30	2.20	38.40	32.00	45.49	37.91	3D	2D
6	R	6.30	94.80	9.20	15.50	2.80	2.50	34.50	33.90	38.20	37.54	2D	2D
7	L	1.30	28.40	12.00	10.80	-2.70	-3.80	31.90	30.50	39.62	37.88	2D	2D
8	R	3.60	21.40	10.70	11.90	0.40	-2.80	31.00	27.50	45.05	39.97	3D	2D
9	R	6.60	4.80	12.00	12.50	6.20	-0.70	33.60	26.50	44.80	35.33	3D	2D
10	R	3.80	45.10	11.20	13.70	5.10	2.10	33.00	30.20	38.01	34.79	2D	2D
11	R	2.30	14.40	12.00	12.30	1.50	-0.60	34.50	32.30	40.30	37.73	3D	2D
12	L	4.90	18.30	12.00	10.60	1.10	-4.00	37.60	32.90	43.61	38.16	3D	2D
13	L	3.70	90.80	11.80	15.40	0.40	-1.00	34.60	33.00	40.75	38.86	3D	2C
14	L	3.40	20.90	13.00	14.20	2.40	-1.00	35.00	31.60	43.37	39.15	3D	2D
15	L	3.90	33.30	12.50	14.20	6.00	2.80	37.80	34.50	44.26	40.39	3D	3D
16	R	4.50	3.70	11.60	11.70	5.10	0.30	37.70	33.20	42.31	37.26	3D	2D
17	R	3.60	20.50	13.00	11.90	4.20	1.00	35.30	31.70	42.37	38.05	3D	2D
18	R	1.50	51.60	12.80	14.20	2.70	1.50	36.00	35.00	43.42	42.21	3D	3D
19	R	2.90	37.30	11.30	13.10	1.00	-1.40	32.60	30.20	39.90	36.96	2D	2D
20	L	5.20	17.30	13.70	12.20	3.40	-1.50	35.40	30.30	43.59	37.31	3D	2D
21	R	7.50	16.10	12.80	11.00	6.30	-0.90	35.50	28.50	43.61	35.01	3D	2D
22	L	4.70	5.60	16.20	16.90	3.60	-1.20	37.90	33.60	45.49	40.33	3D	3D
23	R	5.30	52.90	13.30	17.20	5.00	1.60	32.50	29.30	41.82	37.70	3D	2C
24	R	5.20	9.30	13.10	14.00	3.90	1.20	34.70	29.40	42.21	35.76	3D	2D
25	L	2.70	16.70	14.90	14.60	1.10	-1.20	37.70	35.40	40.71	38.22	3D	2D
26	R	1.90	67.50	12.20	13.70	1.00	-1.20	31.40	29.10	42.72	39.59	3D	2D
27	R	4.60	22.60	15.00	13.50	3.20	-1.30	34.60	30.10	42.40	36.88	3C	2D
28	L	1.60	15.80	12.20	11.60	2.40	0.80	34.50	32.10	46.37	43.14	3C	3D
29	L	5.40	28.70	16.10	13.60	5.50	1.10	35.50	31.10	40.29	35.30	3C	2C
30	L	4.10	25.60	13.70	12.40	3.20	0.50	36.20	30.30	41.75	36.80	3C	2D
Mean		4.29	32.41	12.67	13.58	3.39	0.00	35.41	31.76	42.48	38.14		
St. Dev.		1.61	26.68	1.54	1.89	2.42	1.95	2.39	2.45	2.24	1.97		

Table 2. Radiographic Measurements of centers of AL and PM bands in profile view.

		Dist. center of bands (mm)	Angle bands – Blumensaat line (degrees)	Height AL band – Blumensaat line (mm)	Height PM band – Blumensaat line (mm)	Percentile center AL – Blumensaat line (%)	Percentile center PM – Blumensaat line (%)
1	R	7.60	34.40	3.90	8.20	74.43	51.77
2	R	5.40	6.30	6.40	6.10	69.36	53.75
3	R	9.00	21.20	5.70	9.10	81.01	54.11
4	L	6.20	62.40	3.10	8.80	73.55	63.04
5	L	6.00	48.10	6.50	10.70	77.55	62.92
6	R	5.50	21.80	8.40	6.40	77.84	61.23
7	L	6.20	49.30	2.40	7.20	74.51	59.07
8	R	6.40	41.20	5.60	9.70	79.08	61.59
9	R	6.20	47.40	4.50	9.00	73.85	56.84
10	R	8.30	28.90	7.80	11.70	59.54	36.89
11	R	6.30	39.50	7.20	11.30	80.60	61.59
12	L	7.40	62.70	6.50	13.30	73.29	62.61
13	L	6.50	10.70	9.80	10.90	61.24	38.06
14	L	7.60	39.20	6.70	11.10	67.69	47.07
15	L	7.20	31.70	4.60	8.40	76.82	57.61
16	R	9.00	48.30	5.00	11.70	77.66	54.98
17	R	6.50	57.20	3.50	9.20	78.43	67.64
18	R	9.30	37.40	7.70	13.10	66.21	42.22
19	R	9.30	42.30	7.10	13.30	76.95	54.25
20	L	8.90	61.20	4.40	11.50	66.66	52.77
21	R	4.10	87.40	2.60	6.50	83.60	83.60
22	L	6.60	53.50	3.50	6.40	77.34	65.69
23	R	8.20	26.90	7.30	11.10	67.84	42.40
24	R	7.80	44.30	6.00	11.50	69.78	49.64
25	L	6.50	55.40	3.40	9.00	72.91	61.67
26	R	7.40	35.30	7.30	11.50	66.79	43.62
27	R	6.60	58.90	4.10	9.50	63.07	50.38
28	L	7.60	49.90	5.20	10.80	73.57	54.64
29	L	8.40	57.40	4.50	11.50	74.14	59.50
30	L	7.50	47.20	4.80	9.20	70.34	52.63
Mean		7.18	43.58	5.52	9.92	72.86	55.46
St. Dev.		1.27	16.88	1.85	2.08	6.02	9.63

et al.[15] the height of inserting center of AL and PM bands, relative to Blumensaat line was 3.27 ± 1.22mm and 9.27±2.43mm, respectively. Our results for this parameter were: height of inserting center of the AL band 5.52 ± 1.85 mm, and 9.92 ± 2.08 mm for the PM band, also very similar to results from Osti *et al.*[15] In our sample we studied the inserting of PCL bands in 30 knees, a larger number of samples than Lorenz' *et al.*[12] study who evaluated 16 knees and Osti's *et al.*[15] who studied 15 knees. Thus, our results have a lower statistical chance of errors. However, comparable results were very similar. We believe that our evaluation system is simpler and can be easily reproduced with the possibility of practical application in surgical reconstruction of the PCL.

CONCLUSION

In our study we were able to establish a radiographic pattern of anatomical insertions of AL and PM bands of the anteroposterior and lateral PCL. The data may be useful for intraoperative control of the anatomical location of the tunnels by fluoroscopy prior to their perforation. The knowledge from our research can also be applied to the postoperative evaluation of the correct location of the tunnels.

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