Morphological Characteristics of the Infrapatellar Fat Pad

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Research Article

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Abstract

Background: The purpose of this study was to clarify the morphological characteristics of the infrapatellar fat pad (IFP) in Japanese cadavers and to elucidate the relationship between morphological characteristics of the IFP and degeneration of the patellofemoral joint.

Methods: This investigation examined 41 legs from 25 Japanese cadavers. Morphological measurement was performed by one examiner, and the proximal IFP, IFP body length, width, and IFP volume were measured. The morphological characteristics of IFP proximal were used to categorize three types of IFP: Type I, IFP proximal located on medial and lateral sides of the patella; Type II, IFP proximal only located medially; and Type III, absence of IFP proximal medially and laterally. Articular surfaces were graded as macroscopically intact or mildly altered (Grade I), moderately altered (if fissuring or fibrillation was observed; Grade II), or severely altered (if eburnation was present; Grade III).

Results: Type I was identified in 36.6%, Type II in 48.8%, and Type III in 14.6%. IFP medial proximal was seen in 85%, IFP lateral proximal in 36.6%, and loop type was 2.4%. Grade II was significantly more frequent than Grades I or III in Type II, and Grade III was significantly more frequent than Grades I or II in Type III. In addition, IFP volume was significantly larger in Type I than in Types II or III.

Conclusion: Causal relationships remain unclear, but the deformation of patellofemoral joint may be related to decreased IFP volume (atrophy).

Introduction

The infrapatellar fat pad (IFP), also known as Hoffa's fat pad [1], fills the space in the knee joint, providing lubrication for the joint and ensuring that the space is maintained [2]. The IFP is an intracapsular, extrasynovial structure [3–5]. Histological investigation of the IFP has led to the suggestion that this structure acts as a pressure absorber during knee articulation and that the relatively high density of nerves within the IFP may indicate a mechanoreceptor/proprioceptor role for the IFP [6]. Furthermore, together with the plica of the knee, the IFP has been suggested to provide internal support for the patella, mirroring the support given by the external retinacula [7]. The IFP contains free nerve terminals and pain transmitters, and so is considered one cause of knee joint pain [8].

The morphological characteristics of the IFP, in terms of exact size, shape and volume, appear highly variable. Previous anatomical studies have been performed on a small number of cadavers [1, 3, 5, 9], using magnetic resonance imaging [10–15], ultrasonography [16], and arthroscopy [17]. Focusing on gross anatomical research, Gallagher et al. [5] reported that the IFP attaches to the infrapatellar pole, patellar tendon, meniscus, and anterior tibia. In recent years, the existence of the IFP proximal located on the medial and lateral sides of the patella has been reported. In a report examining 36 knees from fresh cadavers [18], IFP medial proximal was present in 100%, IFP lateral proximal in 83%, and a loop-type IFP in 11%. In a report using 43 knees from formalin-fixed bodies [3], IFP medial proximal was present in 81%, IFP lateral proximal in 65%, and loop type in 9.3%. Mean IFP volume has been reported as 24 ml (range: 12–36 ml) [5], 26.86 ± 6.82 ml [9], and 29.2 ± 6.1 ml [18]. Thus, the morphological characteristics of the IFP have yet to be fully investigated.

In recent years, the IFP has been suggested to play an important role in the initiation and progression of knee osteoarthritis (OA) [19, 20]. Biochemically, the IFP can produce various pro-inflammatory cytokines and adipokines, which may be deleterious to the knee joint [21, 22]. Pathological examination of IFP tissue obtained from patients with severe OA revealed the presence of vascular neoformations, fibrosis, and chronic inflammation in these specimens [23]. In another study, individuals with abnormal signal intensity in the IFP and/or greater volume of effusion synovitis in the absence of radiographic OA knee were suggested to be at greater risk of accelerated OA knee, which may be characterized by local inflammation [24]. However, the relationship between the morphological characteristics of IFP and joint deformity has yet to be fully elucidated.

The purpose of this study was to clarify the morphological characteristics of IFP in Japanese cadavers and to identify the relationships between morphological characteristics of the IFP and degeneration of the patellofemoral joint.

Methods

Cadavers

This investigation examined 41 legs from 25 Japanese cadavers (mean age at death, 80 ± 12 years; range, 47–96 years; 18 sides from men, 23 from women; 20 right sides, 21 left sides) that had been switched to alcohol after placement in 10% formalin. No knees showed any signs of previous major surgery around the knee or any relevant deformities, and no obvious degeneration was apparent in any specimens. This study was approved by the ethics committee at our institution (approval number: 18071).

Measurement conditions

In the dissection procedure, an isolated knee specimen was prepared by cutting the distal one-third of the femur and the central part of the tibia, and the skin, subcutaneous tissue, and tensor fasciae lateral were removed. For the IFP body, the synovium and meniscus were incised along the anterior edges of the medial collateral ligament (MCL) and lateral collateral ligament (LCL) (Fig. 1A, 1B). Then, in a position of knee flexion, the quadriceps femoris and patella were inverted from proximally to distally, and the ligamentum mucosum was incised (Fig. 1C). The IFP was detached from the anterior surface of the tibia, and the patellar tendon was resected with the patellar tendon attached to the patella and part of the rough surface of the tibia. The meniscus and transverse knee ligament attached to the IFP were then carefully removed. The presence or absence of the IFP proximal was confirmed between the insertional tendons of the vastus medialis/vastus lateralis, the patellar retinaculum, and the synovium (Fig. 2). Regarding the removal of the synovium, only synovium that was not adherent to the IFP proximal and IFP body was carefully removed (Fig. 2A). Quadriceps muscle fiber bundles were removed along the shape of the IFP proximal (Fig. 2B). Part of the tibial tuberosity was carefully removed from the posterior part to remove the most distal end of the IFP body. After measuring the IFP proximal and IFP body, the IFP was removed from the patella, patellar tendon, and patellar retinaculum for IFP volume measurement.

Morphological measurement was performed by one examiner, and the IFP proximal, IFP body length, width, and IFP volume were measured (Fig. 3). The specimen was photographed from behind using a digital camera (Finepix F600EXR; Fujifilm, Tokyo, Japan) with the patella joint surface facing forward without tilting. At the time of measurement, perpendicular lines were drawn in the following parts: the upper end of the patellar articular surface; the most end of the IFP medial and lateral proximal, the lower end of the patellar articular surface, the horizon passing through the distal end of the IFP body, and the medial and lateral ends of the IFP body. IFP proximal length was measured as the distance between the horizontal line passing through the upper end of the patellar joint surface and the horizontal line passing through the lower end of the patellar joint surface when the IFP was connected to the suprapatellar fat pad (SFP). When the IPF did not bind to the SFP, this distance was taken as the distance between the horizontal line passing through the most end of the IFP proximal and the horizontal line passing through the lower end of the patellar articular surface (Fig. 3A). IFP proximal width was measured at the distance of the horizontal line connecting the medial and lateral ends of the IFP proximal length and was measured at three points of the IFP proximal length (Fig. 3B). IFP body length was measured as the distance between the horizontal line passing through the lower end of the patellar joint surface and the horizontal line passing through the most distal end of the IFP body. The IFP body width is the distance of the line connecting the perpendicular lines passing through the inner and outer ends of the IFP body. Image analysis software (Image J; NIH, Bethesda, MD, USA) was used for the measurement, and the mean ± standard deviation from three measurements was calculated. Before measuring volume, the IFP was soaked in a preservation solution for 10 min to prevent the IFP from drying out. For the IFP volume, a 500-ml cylinder (SANPLATEC, Osaka, Japan) was used, and water displacement was recorded in 2.5-ml intervals, and the mean ± standard deviation from three measurements was calculated. When the IFP proximal and SFP were connected, the SFP was removed at the upper end of the patellar joint surface. To prevent a decrease in IFP volume due to drying of the IFP, specimens were immersed in the preservation solution at 30-min intervals for 10 min, and the entire experiment was performed within 3 h.

Knees were classified into 3 types by the morphological characteristics of IFP proximal. Type I was an IFP proximal located on the medial and lateral sides of the patella (Fig. 4A, 4a). Type II was an IFP proximal located only on the medial side of the patella (Fig. 4B, 4b). Type III was absence of the IFP on both medial and lateral sides (Fig. 4C, 4c).

The articular surfaces were graded [25] as macroscopically intact or mildly altered (Grade I) (Fig. 5A), moderately altered (if fissuring or fibrillation was observed, Grade II) (Fig. 5B), or severely altered (if eburnation was present, Grade III) (Fig. 5C).

Statistical analysis

Fisher’s exact test was used for comparisons of classifications of the IFP by sex and laterality, and to compare differences in degenerative grade of the articular surface for each type of category. Multiple comparisons were performed using the Ryan nominal level for post hoc testing. Comparisons of IFP proximal medial length, width (distal, intermediate, proximal) between Types I and II were made using unpaired t-tests. Comparisons of IFP body length, width, and IFP volume in each type were made with one-way repeated-measures analysis of variance, and Tukey's method. Comparisons of IFP proximal medial and lateral length, width (distal, intermediate, proximal) among Type I were made with paired t-tests. Statistical analyses were performed using SPSS version 26.0 software (SPSS Japan, Tokyo, Japan). The level of significance was $p < .05$.

Results

Classification of the IFP

Type I was seen in 15 knees (36.6%), Type II in 20 knees (48.8%), and Type III in 6 knees (14.6%). Loop type was present in 1 knee (2.4%) in Type I. In determining differences between left and right legs, we were able to measure both legs from 16 cadavers (32 legs). No significant differences were apparent between males and females or between left and right sides (Table 1).

Table 1
Comparison of FPI classifications by sex and laterality

	Type I	Type II	Type III
Male (n = 18)	6 (14.6)	9 (22.0)	3 (7.3)
Female (n = 23)	9 (22.0)	11 (26.8)	3 (7.3)
Total	15 (36.6)	20 (48.8)	6 (14.6)
Right (n = 16)	4 (12.5)	10 (31.2)	1 (3.1)
Left (n = 16)	7 (21.9)	6 (18.8)	4 (12.5)
Total	11 (34.4)	16 (50.0)	5 (15.6)
Values are reported as number of specimens (%).			

Morphological characteristics of the IFP

IFP proximal medial length was significantly longer than IFP proximal lateral length in Type I ($p = 0.002$). IFP proximal medial distal width was significantly longer than IFP proximal lateral distal width in Type I ($p < 0.001$). IFP volume was significantly higher in Type I than in Type II ($p = 0.017$) or Type III ($p = 0.030$) (Table 2).

Table 2
Morphological characteristics of the IFP

	IFP proximal medial				IFP proximal lateral				IFP body		IFP volume
	Length	Width			Length	Width			Length	Width	
		distal	intermediate	proximal		distal	intermediate	proximal			
Type I	33.0 ± 12.0 [a]	16.5 ± 5.6 [b]	11.1 ± 2.9	23.3 ± 5.8	15.4 ± 10.9	5.7 ± 1.8	11.9 ± 3.7	25.0 ± 5.9	46.3 ± 8.8	82.8 ± 11.5	24.2 ± 5.7 [c, d]
Type II	36.1 ± 9.8	17.9 ± 6.5	10.3 ± 2.2	23.3 ± 6.1					50.3 ± 7.4	75.3 ± 9.0	19.4 ± 4.7
Type III									41.7 ± 6.2	75.5 ± 7.0	17.9 ± 2.5

Values represent mean ± standard deviation.

[a]p=0.002 vs. length of IFP proximal lateral; [b]p<0.001 vs. distal width of IFP proximal lateral; [c]p=0.017 vs. IFP volume of Type II

[d]p=0.030 vs. IFP volume of Type III

Relationship between degenerative grade of the articular surface and IFP

In Type I, Grade I was seen in 9 knees (22.0%), Grade II in 1 knee (2.4%), and Grade III in 5 knees (12.2%). In Type II, Grade I was seen in 7 knees (17.1%), Grade II in 10 knees (24.4%), and Grade III in 3 knees (7.3%). In Type III, Grade I was seen in 1 knee (2.4%), Grade II in 0 knees (0.0%), and Grade III in 5 knees (12.2%). In Type I, there were significantly lower in Grade II than in Grades I and III (p = 0.003). In Type II, there were significantly higher in Grade II than in Grades I and III (p = 0.003). In Type III, there were significantly higher in Grade III than in Grades I and II (p = 0.003) (Table 3).

Table 3
Relationship between degenerative grade of articular surface and IFP

	Type I	Type II	Type III
Grade I	9 (22.0)	7 (17.1)	1 (2.4)
Grade II	1 (2.4) [a]	10 (24.4) [b]	0 (0.0)
Grade III	5 (12.2)	3 (7.3)	5 (12.2) [c]
Total	15 (36.6)	20 (48.8)	6 (14.6)

Values represent number of specimens (%).

[a]p=0.003 vs. grade I and grade III.

[b]p=0.003 vs. grade I and grade III.

[c]p=0.003 vs. grade I and grade II.

Discussion

This study intended to clarify the morphological characteristics of IFP in Japanese cadavers and the relationship between morphological characteristics of IFP and degeneration of the patellofemoral joint. To the best of our knowledge, no detailed anatomical studies of the relationship between morphological characteristics of the IFP and degeneration of the patellofemoral joint have been reported previously.

In this study, Type I was seen in 15 knees (36.6%), Type II in 20 knees (48.8%), and Type III in 6 knees (14.6%). The IFP medial proximal was seen in 35 knees (85%), IFP lateral proximal in 15 knees (36.6%), and loop type in 1 knee (2.4%). In previous studies, the existence of the IFP proximal located on the medial and lateral sides of the patella has been reported [3, 18]. In a study using 36 knees from fresh cadavers [18], IFP medial proximal was seen in 100%, IFP lateral proximal in 83%, and loop type in 11%. In a study using 43 knees from formalin-fixed bodies [3], IFP medial proximal was seen in 81%, IFP lateral proximal in 65%, and loop type in 9.3%. The result was that the frequencies of IFP lateral proximal and loop type were low. The reason for this might be due to differences in specimens (ethnic background, cadaver fixation method) and methods of dissection.

In recent years, the IFP has been suggested to play an important role in the initiation and progression of knee OA [19, 20]. Biochemically, the IFP can produce various pro-inflammatory cytokines and adipokines, which may be deleterious to the knee joint [21, 22]. Pathological examination of IFPs obtained from patients with severe OA have found vascular neoformations, fibrosis, and chronic inflammation [23]. The present results do not reveal the causal relationships but suggest a relationship to deformation of the patellofemoral joint and a decrease in IFP volume, representing atrophy.

Some limitations should be considered when interpreting the findings from this investigation. First, we investigated the morphological characteristics of the IFP alone, using fixed cadavers. In the future, an in vivo study using ultrasound or MRI examination is needed. Second, as all cadavers were from Japanese individuals, whether the present findings apply to individual from other ethnicities is unclear. Further studies are required to evaluate variations according to ethnic origin.

Conclusion

this study clarified the morphological characteristics of the IFP in Japanese cadavers and the relationship between morphological characteristics of the IFP and degeneration of the patellofemoral joint. In this study, Type I (IFP proximal located on the medial and lateral sides of the patella)was seen in 15 knees (36.6%), Type II (only IFP proximal located on the medial) in 20 knees (48.8%), and Type III (absence of IFP proximal located on the medial and lateral) in 6 knees (14.6%). While the causal relationships remain unclear, but the deformation of patellofemoral joint may be related to decreased IFP volume (atrophy).

Declarations

Ethics approval and consent to participate

All methods were carried out in accordance with the 1964 Declaration of Helsinki, and all cadavers were legally donated for research purposes to the Nippon Dental University, Niigata, Japan. This study was approved by the ethics committee of the Nippon Dental University. Informed consent was obtained from the families of all subjects.

Consent to participate

Consent to publication

Availability of data and materials

The datasets generated and/or analysed during the current study are not publicly available due to limitations of ethical approval involving the patient data and anonymity but are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

None.

Author contributions

ME and OT contributed to the study design and data collection, and drafted the manuscript; HY, RH contributed to the data analysis and made critical revisions to the manuscript; CS, SM made critical revisions to the manuscript; IK supervised the study, contributed to the analysis and interpretation of data, and made critical revisions to the manuscript. All authors read and approved the final manuscript prior to submission.

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Figures

Fig. 1

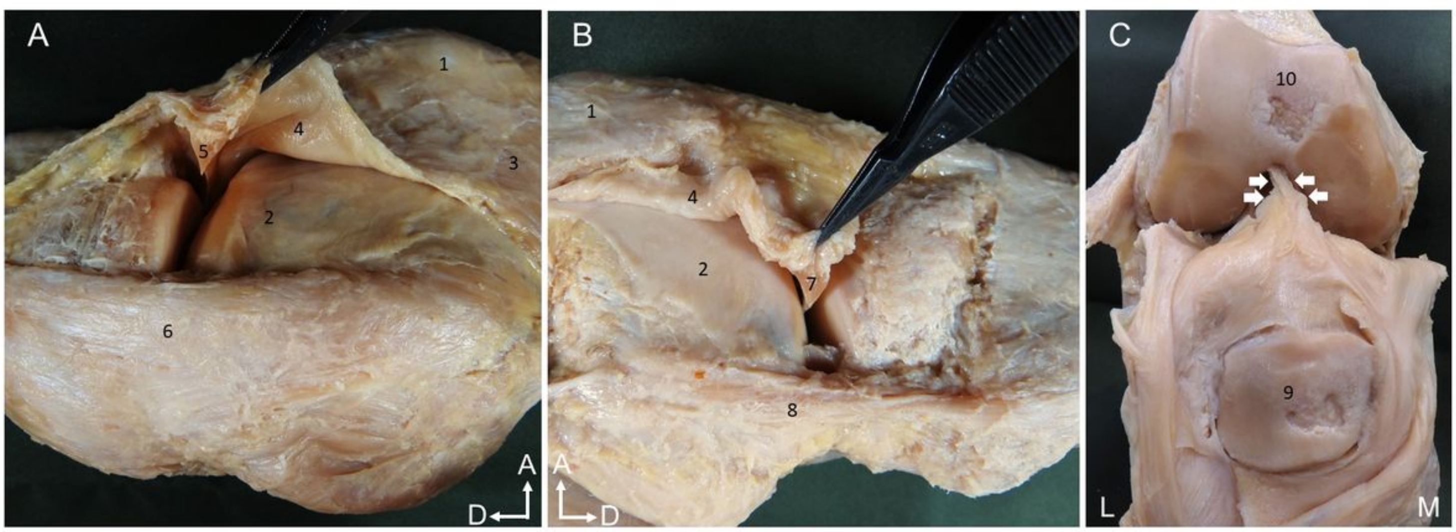

Figure 1

Method of dissection; right knee A) Medial view. The synovium and medial meniscus are incised along the anterior edge of the MCL, and the synovium and meniscus are lifted forward. B) Lateral view. The synovium and lateral meniscus are incised along the anterior edge of the LCL, and the synovium and meniscus are lifted forward. C) Anterior view. Knee flexion position. The quadriceps femoris and patella are inverted from proximal to distal. 1: Articular surface of the patella; 2: femur; 3: vastus medialis; 4: synovitis; 5: medial meniscus; 6: medial collateral ligament; 7: lateral meniscus; 8: lateral collateral ligament; 9: articular surface of the patella; 10: articular surface of the femur. A: Anterior; D: distal; M: medial; L: lateral. White arrow: ligamentum mucosum.

Fig. 2

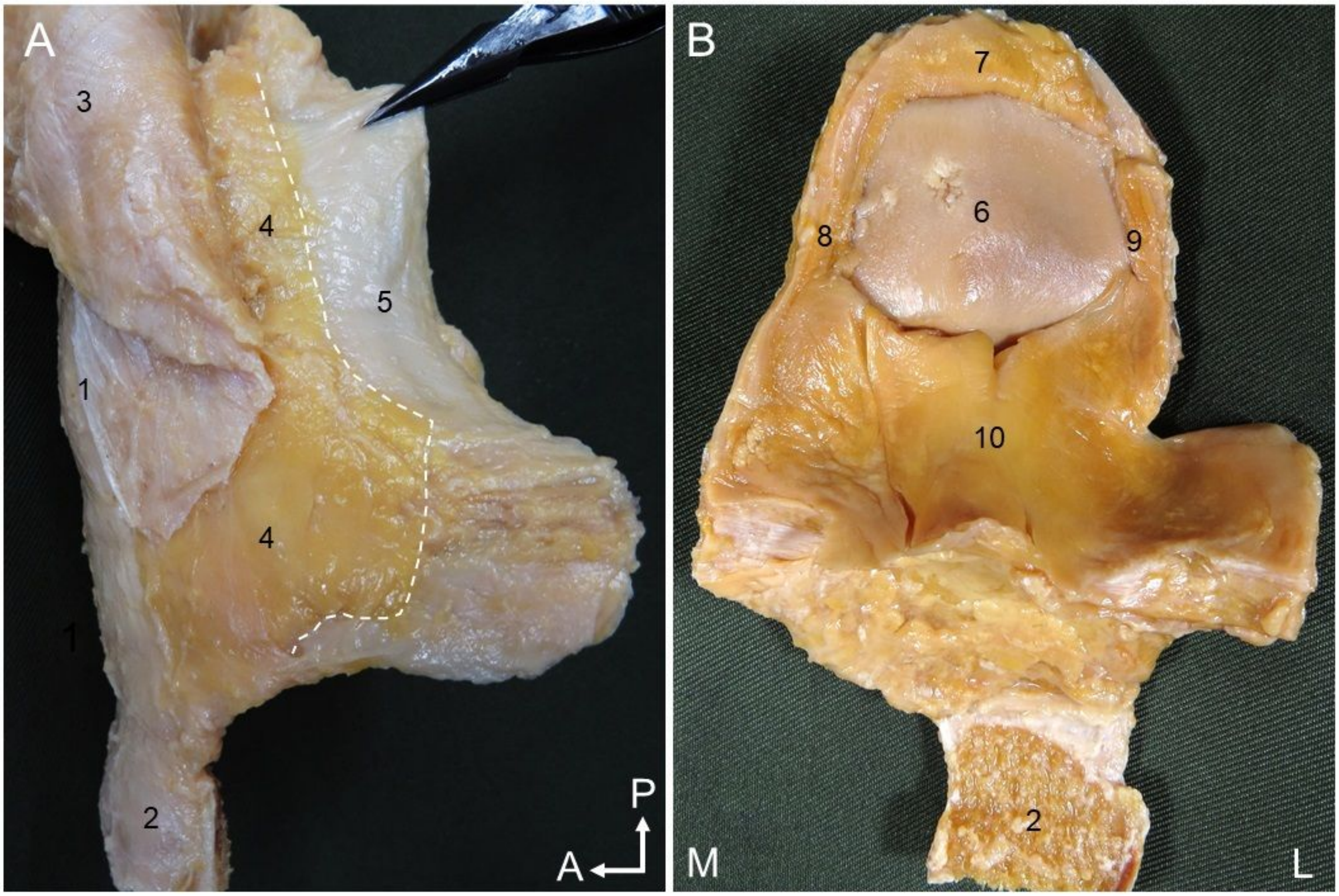

Figure 2

Method for dissection of the infrapatellar fat pad; right knee A) Medial view. The VM is flipped forward and the synovium is gripped with forceps. An incision is made along the white dashed line to remove synovium not adherent to the infrapatellar fat pad. B) Posterior view. The quadriceps femoris is removed along the morphology of the infrapatellar fat pad proximal. 1: Articular surface of the patella; 2: tibial tuberosity; 3: vastus medialis muscle; 4: infrapatellar fat pad; 5: synovitis; 6: articular surface of the patella; 7: suprapatellar fat pad; 8: infrapatellar fat pad medial proximal; 9: infrapatellar fat pad lateral proximal; 10: infrapatellar fat pad body. P: Proximal; A: anterior; M: medial; L: lateral. White dashed line: boundary between Infrapatellar fat pad and synovitis

Fig. 3

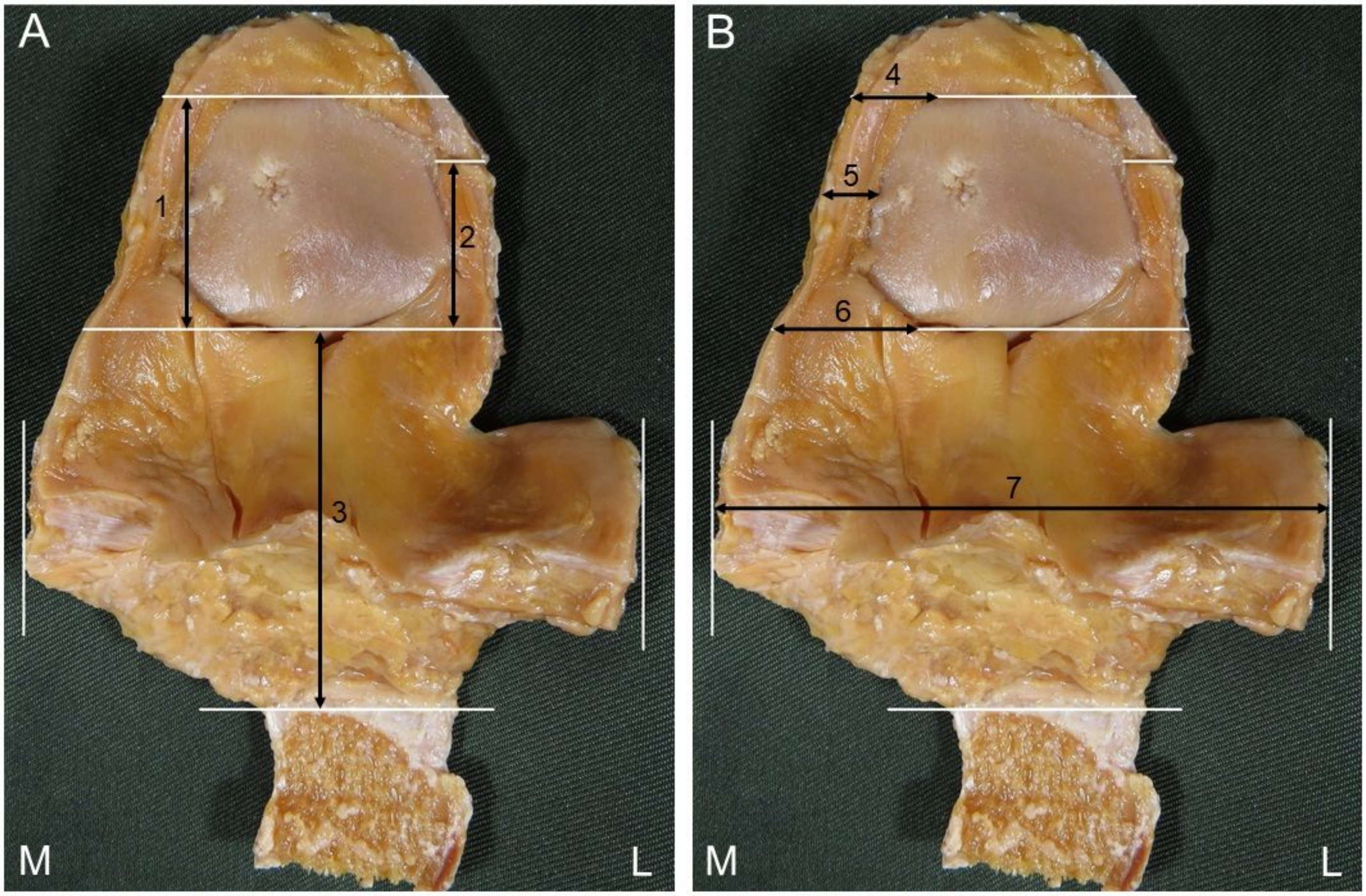

Figure 3

Measurement of the infrapatellar fat pad; right knee, posterior view A) Length of the infrapatellar fat pad proximal, infrapatellar fat pad body B) Width of the infrapatellar fat pad proximal, infrapatellar fat pad body Black arrow 1: In cases with the infrapatellar fat pad proximal connecting to the suprapatellar fat pad. Black arrow 2: In cases with the infrapatellar fat pad proximal not connecting to the suprapatellar fat pad. Black arrow 3: Infrapatellar fat pad body. Black arrow 4: Infrapatellar fat proximal top. Black arrow 5: Infrapatellar fat proximal center. Black arrow 6: Infrapatellar fat proximal end. Black arrow 7: Infrapatellar fat body. White line: Reference line. M: medial; L: lateral.

Fig. 4

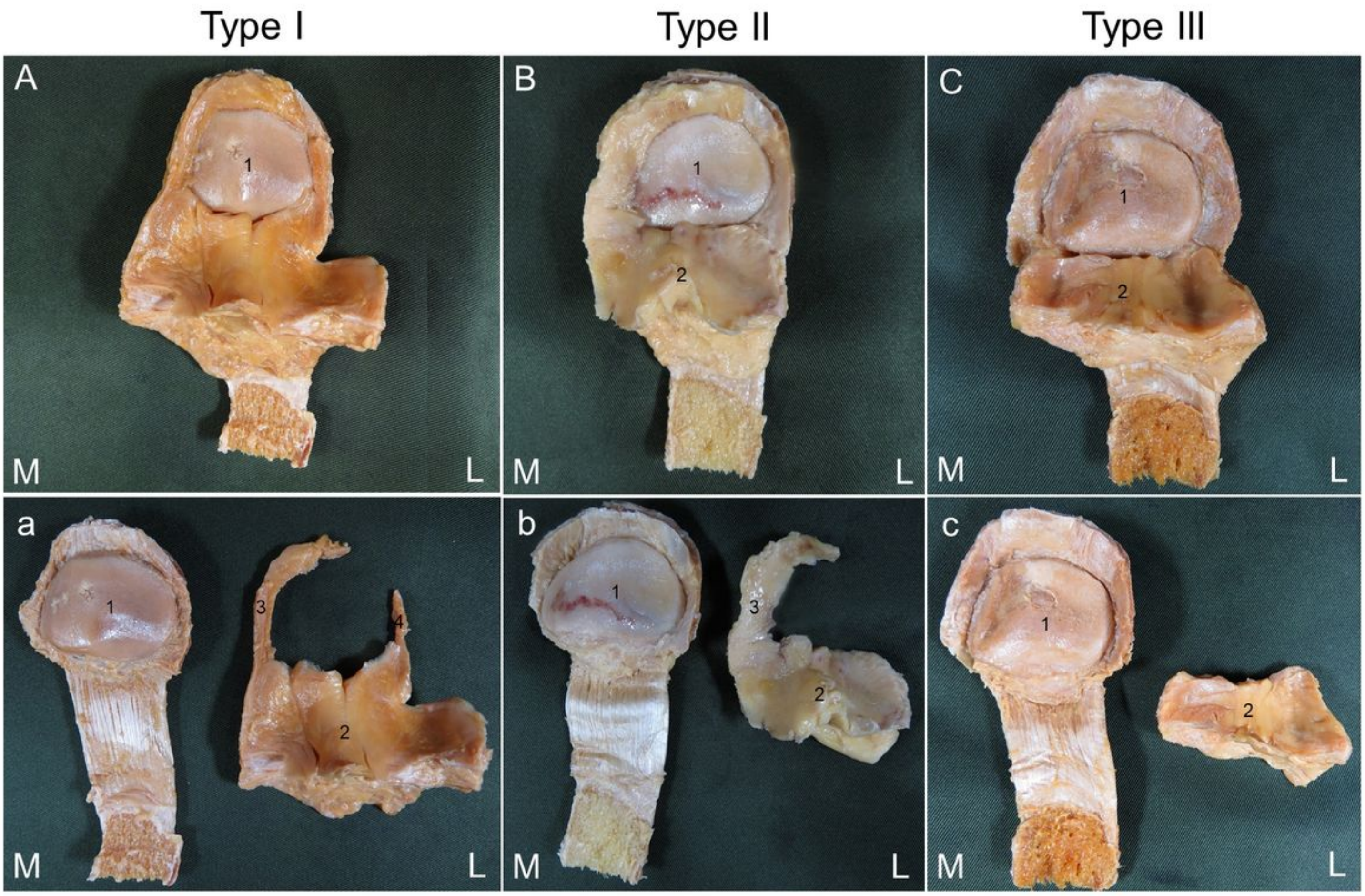

Figure 4

Classification of the IFP A) Type I: IFP proximal located on the medial and lateral sides of the patella. B) Type II: only IFP proximal located on the medial side of the patella. C) Type III: absence of IFP proximal located on the medial and lateral sides of the patella. a, b, c) IFP removed from the patella. 1: Articular surface of the patella; 2: infrapatellar fat pad body; 3: infrapatellar fat pad medial proximal; 4: infrapatellar fat pad lateral proximal. M: Medial; L: lateral.

Fig. 5

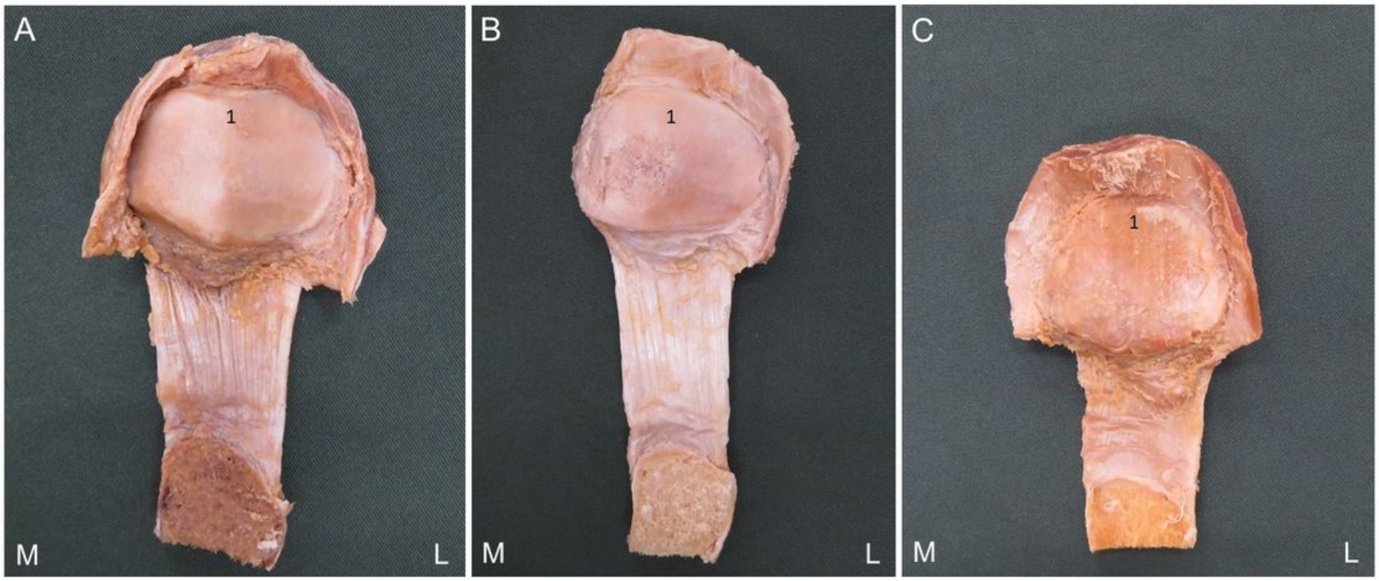

Figure 5

Classification of degenerative grade of the articular surface A) Grade I: macroscopically intact or only mildly altered. B) Grade II: macroscopically moderately altered (if fissuring or fibrillation is observed). C) Grade III: macroscopically severely altered (if eburnation is present). 1: Articular surface of the patella. M: Medial; L: lateral.