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ORIGINAL STUDY

Are lesions of the posterior cruciate ligament predictable before knee arthroplasty ?

A histological study of 434 ligaments in osteoarthritic knees

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Despite the number of publications which have dealt with posterior cruciate ligament (PCL) retaining total knee arthroplasty, few studies have addressed the histology of the PCL. Based on these, the use of some predictive factors for lesions of the PCL has been suggested, as a decisive argument to substitute the ligament or not. The objective of this study was to assess the value of some predictive factors, based on objective findings.

We performed histological analysis of 434 PCLs removed during total knee arthroplasty for osteoarthritis. Fifty-eight percent of these ligaments presented histological lesions. The degree of preoperative knee deformity, the intra-operative appearance of both cruciate ligaments, and gender were found to correlate with the severity of the microscopic lesions of the PCL. No such correlation was found with age nor with the type of knee deformity. Calcium pyrophosphate deposits were a frequent and potentially pejorative finding in the PCLs from osteoarthritic knees. Due to their poor sensitivity and specificity, the criteria suggested in previous studies to decide on preserving or substituting the PCL appeared fairly unreliable.

Keywords : posterior cruciate ligament ; histology ; knee arthroplasty.

INTRODUCTION

The issue of the posterior cruciate ligament (PCL) in total knee arthroplasty (TKA) has been widely debated. Some surgeons advocate its excision and substitution while others recommend its preservation, selectively or systematically, arguing better outcomes. In fact, similar long term clinical results have been reported with PCL substitution and preservation (*11,16,19,21-23*).

The theoretical advantage of a more physiological femoral rollback and better range of motion (*4,5*) with PCL retaining implants, has been contradicted by *in vivo* dynamic fluoroscopy studies (*7,9,13,23*), suggesting that the PCL does not function normally.

Surprisingly, among the numerous publications about PCL retaining prostheses, only a few studies, carried out on limited numbers of patients, have been published about the histology of the PCL in

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the OA knee (*1-3,10,14,20*). These studies have shown that the PCL is affected by OA-related microscopic changes that may be macroscopically undetected.

Since undetected microscopic lesions may affect the function of the retained PCL, the value of some clinical and intra-operative criteria in predicting the microscopic status of the PCL before deciding on its possible substitution has also been investigated. Some authors have stated the predictive value of the preoperative knee deformity (*2*) or of the macroscopic appearance of the anterior cruciate ligament (ACL) (*3*). On the other hand the correlation between the severity of microscopic lesions and factors such as patient age, gender, type of knee deformity and intra-operative gross assessment of the PCL has not been statistically demonstrated. Even though microscopic analysis cannot directly inform on the biomechanical alterations of the PCL, we found it of interest to compare our observations to previous studies and to assess the value of the predictive factors suggested in those studies. The purpose of the current study is to enhance this complex debate through evidence based arguments.

MATERIAL AND METHODS

Patients

This study involved 434 PCLs from 390 consecutive patients with degenerative OA, who underwent elective total knee arthroplasty between May 1998 and August 2006 in our institution. The average age at time of surgery was 73 (± 6.5) years. Three hundred thirthy five PCLs were from female and 99 from male patients. All patients were operated by the same surgeon (JPF). A PCL-substituting prosthesis was implanted in all cases and all surgical procedures followed a standard operative protocol. Ligaments from patients with a history of unicompartmental or patellofemoral knee arthroplasty were excluded, since previous surgery could have induced secondary lesions.

Methods

Before resection of the PCL, intraoperative macroscopic assessment of the ACL and when fully exposed, of the PCL, was performed by the surgeon. Three grades of macroscopic alterations were identified as described by Allain *et al* (*3*) : grade 0, normal ; grade 1, abnormal (thinner than normal, cystic, frayed or ruptured) and grade 2, severely damaged or absent ligament. Histological examination of the ligaments was routinely performed by two pathologists (FF and PVE). A sample of the ligament was obtained at the site of any grossly detected lesion. In addition a complete longitudinal section of each ligament was submitted to microscopic examination. Samples were fixed in formalin, embedded in paraffin, haematoxylin-eosin stained and observed by light microscopy. Special histochemical stains were not used. Histological evaluations were performed according to the available criteria for describing the different lesions (*2,10*). Oedema, myxoid/cystic degeneration, and fibrosis with disruption of the collagen bundles were semiquantitatively evaluated (fig 1).

The presence and the severity of other alterations such as inflammation, iron, amyloid and calcium pyrophosphate (CPPD) deposits (*2,18*), were also recorded. CPPD disease was histologically defined according to the current microscopic criteria (fig 2) (*6*). Because the clinical relevance of CPPD remains unclear (*17*), we have separately compared the PCL macroscopic and microscopic categorizations in subgroups of patients with and without CPPD.

For this study the original surgical pathology reports were reviewed and the ligaments were retrospectively categorized in three microscopic grades, according to the severity of their histological alterations (*10,20*) : grade 0, normal ; grade 1, slight to moderate (i.e. focal or diffuse but not confluent alterations) ; grade 2 : marked (i.e. confluent alterations).

We evaluated in the entire series the correlation between the intraoperative macroscopic categorization of both cruciate ligaments and the results of the PCL microscopic examination. The patient age and gender, the radiological type and degree of preoperative knee deformity measured on a full-length standing radiograph of the lower limb were also compared to the microscopic status of the PCL.

The kappa coefficient ($\varkappa$) and McNemar's chi-squared test were respectively used to analyze the agreement and the discrepancies between the micro- and macroscopic assessments of the ligaments, after pooling pathological grades. The chi-square statistical method was also used to test the homogeneity of occurrence of lesions with the characteristics of patients and ligaments. A p-value $\leq$ 0.05 was regarded as statistically significant. The effect of age adjusted for the knee deformity was evaluated by logistic regression, after pooling pathologic PCL microscopic grades. Finally, the sensitivity and the specificity of each statistically significant factor, predictive of a

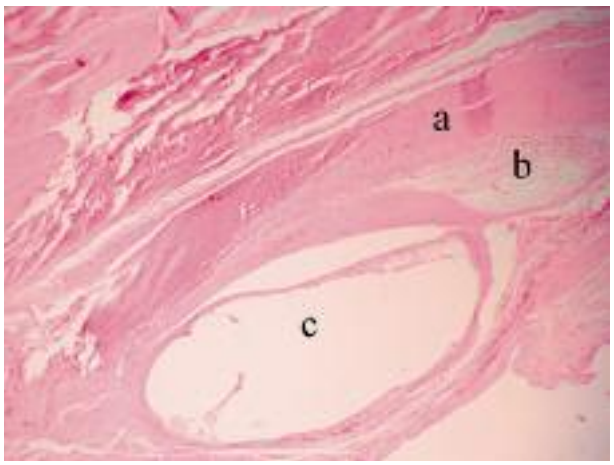

Fig. 1. — Photomicrograph of histological grade 2 PCL (haematoxylin and eosin, original magnification × 100). Thin fibrous dense collagen strands (a) are dissected by loose, myxoid and clear tissue matrix (b) and by an area of cystic degeneration (c). Myxoid lesions contain active fibroblasts and muccopolysaccharidal ground substance whilst cysts only contain ground substance.

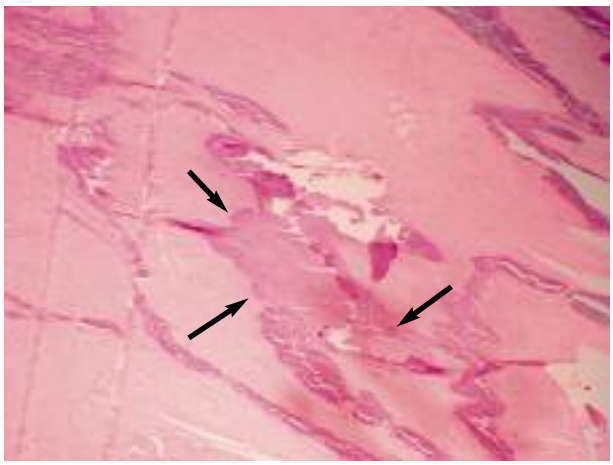

Fig. 2. — Photomicrographs of a histological grade 2 PCL (haematoxylin and eosin, original magnification × 100) showing CPPD replacing the normal dense fibrous connective tissue.

microscopically altered PCL were separately calculated for the entire series (i.e. all the PCLs) and after excluding those PCLs with lower grade (i.e. grade 1) microscopic lesions.

RESULTS

On intraoperative macroscopic examination 35% of the PCLs (151/434) and 82% (354/434) of the ACLs were considered to be abnormal. No PCL was macroscopic grade 2 on intra-operative inspection. Microscopic examination increased the proportion of abnormal PCLs to 58% (251/434) ($p < 0.001$). In addition microscopic examination generated more severe gradings : 88/434 (20%) PCLs were found to have grade 2 microscopic lesions (table I).

As shown in table II, a slight concordance was found between the macroscopic appearance of the PCL and its microscopic status ($\varkappa = 0.2$). The lesions observed with light microscopy were more severe than expected based on the intra-operative appearance of the ligaments (Mc Nemar : $p < 0.0001$). Almost half (141/283) of the PCLs that were macroscopically unremarkable showed microscopic alterations while no histological changes were observed in 27% (41/151) of the PCLs that were considered macroscopically abnormal (table II). With reference to the microscopic status of the PCL, intraoperative gross examination showed 44% sensitivity and 78% specificity. In the case of grade 2 microscopic lesions only, sensitivity and specificity were respectively 42% and 78%.

As shown in table III, a slight concordance was noted between the intra-operative visual assessment of the ACL and the microscopic grading of the PCL ($\varkappa = 0.13$). There was a significant trend towards observing more severe lesions with the microscopic assessment of the PCL than with the macroscopic examination of the ACL (Mc Nemar : $p < 0.0001$).

Macroscopic assessment of the ACL showed 86% sensitivity and 25% specificity in identifying a microscopically abnormal PCL, both for the entire series and after excluding PCLs with microscopic grade 1 lesions.

The microscopic lesions most frequently observed in the PCL were myxoid/cystic degeneration, which was present in 148 (34%) ligaments, followed by CPPD observed in 89 (21%) PCLs. CPPD was the dominant lesion in 71 (16%) ligaments. These tended to often appear macroscopically abnormal, although microscopic examination showed lower grade alterations ($p = 0.0003$ and 0.19, respectively) (table IV). Other lesions such as

Table I. — Detailed grading of both cruciate ligaments

	Macro ACL*	*Macro PCL*	*Micro** PCL*
Grade 0	80 (18%)	283 (65%)	183 (42%)
Grade 1	268 (62%)	151 (35%)	163 (38%)
Grade 2	86 (20%)	0 (0%)	88 (20%)
Total	434	434	434

* Intra-operative macroscopic grading
** Microscopic histological grading.

Table II. — PCL macroscopic grading compared to PCL microscopy

	n	*Micro PCL 0*	*Micro PCL 1*	*Micro PCL 2*
Macro PCL 0	283	142 (50%)	90 (32%)	51 (18%)
Macro PCL 1	151	41 (27%)	73 (48%)	37 (25%)
Total	434	183	163	88

$\varkappa = 0.2$ and Mc Nemar : $p < 0.001$.

Table III. — ACL macroscopic grading compared to PCL microscopy

	n	*Micro PCL 0*	*Micro PCL 1*	*Micro PCL 2*
Macro ACL 0	80	46 (58%)	22 (28%)	12 (15%)
Macro ACL 1	268	121 (45%)	95 (36%)	52 (19%)
Macro ACL 2	86	16 (19%)	46 (54%)	24 (28%)
Total	434	183	163	88

$\varkappa = 0.13$ and Mc Nemar : $p < 0.0001$.

fibrosis, oedema and microcalcifications were observed in 42 (10%) ligaments, isolated in 32 ligaments or associated with myxoid degeneration or CPPD in 10 ligaments.

Preoperatively, a varus deformity was present in 283 (65%) and a valgus deformity in 129 (30%) of the 434 knees (table V). We found a significant association between the severity of the deformity and the microscopic alterations recorded in the PCL ($p < 0.001$ and $p = 0.004$, respectively). With a threshold of 8° of deformity, sensitivity was 54% and specificity, 62% for the whole series. After excluding PCLs with microscopic grade 1 lesions, sensitivity was 61% and specificity, 62%.

No correlation was found between age and the presence of microscopic alterations in the PCL ($p = 0.99$).

When compared to female patients, male patients showed a slight but significant trend towards more severe deformity of the knee and also towards more severe microscopic lesions in the PCL ($p = 0.04$) (table VI). Male gender appears as an independent predictive factor for more severe microscopic lesions (ORa = 1.62 with IC95% = [1.00 ; 2.61], $p = 0.05$).

DISCUSSION

The choice of a PCL-retaining knee prosthesis is based on the assumption that the PCL is anatomically and biomechanically normal, or at least more functional than a prosthetic substitution mechanism at the time of arthroplasty and will remain so later on. However it has clearly been suggested that an

Table IV. — PCLs distributed into two groups (i.e. PCL presenting with CPPD without other important lesions versus PCL with other lesions, without CPPD) compared to their respective microscopic and macroscopic grading*

	n	*Micro PCL p = 0.0003*		*Macro PCL p = 0.19*	
		Grade 1	Grade 2	Grade 0	Grade 1
Predominant CPPD	71	61 (86%)	10 (14%)	36 (51%)	35 (49%)
Other lesions, CPPD excluded †	162	101 (62%)	61 (38%)	97 (60%)	65 (40%)
Total	233	162	71	133	100

* 18 PCLs presenting with important myxoid/cystic lesions and associated CPPD were not considered in the present table.

Table V. — Seven categories of knee alignment compared to their respective PCL microscopic grading

Angle (degrees)	*n*	*Microscopic grading of PCL p = 0.004*		
		Grade 0	Grade 1	Grade 2
Varus > 14°	35	9 (26%)	12 (34%)	14 (40%)
Varus 8 – 14°	124	40 (32%)	54 (44%)	30 (24%)
Varus < 8°	124	55 (44%)	48 (39%)	21 (17%)
0	22	14 (64%)	6 (27%)	2 (9%)
Valgus < 8°	83	44 (53%)	28 (34%)	11 (13%)
Valgus 8 – 14°	34	16 (47%)	13 (38%)	5 (15%)
Valgus > 14°	12	5 (42%)	2 (17%)	5 (42%)
Total	434	183	163	88

Table VI. — Gender of the patients compared to PCL microscopy grading and mean amplitude of knee deformity

	n	*Mean deformity (degrees)*	*Micro PCL 0 p = 0.04*	*Micro PCL 1*	*Micro PCL 2*
Men	99	8.54 (SD : 4.97)	32 (32%)	40 (41%)	27 (27%)
Women	335	7.48 (SD : 4.86)	151 (45%)	123 (37%)	61 (18%)

arthritic ligament is less strong and stiff, and that its biomechanical properties depend on the collagen fibrils (*2,15*). Since degenerative histological changes alter the collagen fibrils (fig 1 & 2), they may compromise the mechanical resistance of the affected ligaments intra- and postoperatively.

The current study aimed at assessing the histological lesions of the PCL and determining their predictive value. Our data do not show a formal association between the histology and the function of the PCL at the time of surgery, nor between its function and the long term clinical results of the arthroplasty.

Our analysis confirms that the majority of PCLs (58%) in osteoarthritic knees present microscopic alterations. This proportion is similar to that reported by Allain *et al* (*3*), but is lower than in other observations (73 to 100%) (*1,2,10,14,20*). In these series, the variability in the reported prevalence of the PCL alterations may be explained by the relatively small number of cases in each series and by differences in the sampling techniques as well as in the definition and the grading of the lesions.

The nature of the histological lesions observed in the OA PCL is similar to that observed in age matched controls. However these changes are more

severe in the OA group (*1,10*). Also ultrastructural examination of the PCL in OA knees showed a trend toward more severe collagen fiber changes, compared to the control group (*1*). It may thus be concluded that the PCL is directly involved in the OA process (*10,20*). In our series 20% of the PCLs showed on microscopic examination marked (grade 2) degenerative changes that were characteristic of the OA knees (*10*). In series smaller than ours and using variable sampling techniques, the prevalence of marked lesions has varied between 31% and 64% (*3,14*). We observed in 38% of the PCLs lower grade (grade 1) lesions, which were reported with similar frequencies in both the OA and the age matched control group (*10*). Whatever their pathogenesis, even less severe changes may interfere with the mechanical resistance of the PCL.

CPPD has been reported in articular hyaline cartilage or fibrocartilage in 33% of the patients undergoing joint replacement (*18*). Alexiades *et al* found CPPD deposits in 21% of the OA PCLs in their series (*2*). They likely participate in articular damage in OA, however, whether they define a subset of patients with more severe disease remains controversial (*17*). In our series CPPD was also present in 21% (89/434) of the cases either as a dominant or an associated finding. Our data suggest that when predominant CPPD is present the PCL is more frequently recognized as pathological on macroscopic examination. Mechanical testing of the retrieved PCL would be interesting in order to confirm a correlation between morphology and function (*1,20*).

When planning TKA, the surgeon can decide whether to retain or to substitute the PCL, taking into account specific pre- and peroperative clinical criteria (*12*).

Stubbs *et al* found a poor correlation between the naked eye appearance of the ACL and the microscopic degenerative changes present in the PCL (*20*). Allain *et al* found that when the ACL was grossly abnormal or ruptured, only 26% of the PCLs were histologically normal (*3*).

We have found that intraoperative macroscopic evaluation of the ACL and PCL is rather inaccurate. The highest sensitivity (86%) is observed when the appearance of the ACL upon inspection is used to predict the microscopic alterations of the PCL (specificity : 25%). We found the highest specificity (78%) when the macroscopic appearance of the PCL was used to predict the absence of microscopic alterations within its substance (sensitivity : 44%). Excluding less severe (grade 1) lesions from our analysis did not improve the accuracy of macroscopic examination.

At variance with the conclusions of Akisue *et al* (*1*) we have found that, as suggested by Alexiades *et al* (*2*), the severity of the knee deformity is significantly correlated with the severity of microscopic lesions of the PCL. However, low sensitivity and specificity again make this conclusion inaccurate in predicting the microscopic status of the PCL. The varus or valgus type of knee deformity is not predictive of a microscopically abnormal PCL.

In our series the age of the patient was not related to the severity of microscopic lesions of the PCL, supporting the idea that these were directly related to the OA process (*10,20*).

Contrary to the results of Alexiades *et al* (*2*) male patients had a significant trend, independent from their more severe knee deformity, toward exhibiting more severe PCL microscopic alterations.

Despite statistically significant associations between the existence of histological lesions in the PCL and both the degree of knee deformity and the intraoperative visual appearance of the two cruciate ligaments, these criteria lack sufficient sensitivity (from 44% to 86%) and specificity (from 25% to 78%) to reliably detect the pathologic ligaments. This holds true when considering the predictive value for only the most severe and potentially more deleterious histological lesions. Additional investigations such as detailed MRI studies specifically focused on OA PCLs are needed to improve the prediction of unexpected microscopic lesions. The MRI data available at the present time appear promising but they were not specifically focused on OA knees (*8*).

The current study confirms the high incidence of lesions of the PCL related to OA, and suggests that the previously described predictive criteria are statistically rather unreliable when used as a decision key to whether or not preserving the OA PCL.

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