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The patello-femoral joint in total knee arthroplasty: is the design of the trochlea the critical factor?

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Abstract We report the outcome after 10 years of a prospective study of two cohorts of patients undergoing total knee reconstruction treated with patellar replacement (centre A, *n*=124) or without (centre B, *n*=143). The same tibio-femoral components were used in all knees. The cohorts were demographically similar. The clinical outcome and the patello-femoral revision rates were the same in the two cohorts. Analgesia was required for anterior knee pain in one patient with replacement and in one without. In the replacement group patello-femoral survival on a best-case scenario was 100% at 10 years, and on a worst-case scenario 96%; one of the nonreplaced patellae had been resurfaced for pain by 10 years. In view of the satisfactory and similar outcomes with and without replacement the authors suggest that an appropriate design for the prosthetic trochlea, rather than the replacement or otherwise of the patella, is the main determinant of patello-femoral outcome in total knee reconstruction. Thus patella replacement may be optional. Desirable trochlea design features are described.

Keywords Total knee reconstruction outcome · Patella · Trochlea

Introduction

Ten years ago total knee arthroplasty suffered from a relatively high incidence of complications associated with the patello-femoral joint [13, 14]. This disappointing feature of what was otherwise a successful procedure led to debate as to whether the articular surface of the patella should be replaced and, in the event of replacement, exactly how this should be performed. The present study compared the outcome of patellar replacement versus no replacement using the same tibio-femoral prosthesis. Additionally (and not as planned at the outset) the results form a basis for suggestions as to how the trochlear surface might best be designed.

Material and methods

The prosthesis

The Freeman-Samuelson prosthesis (Sulzer Orthopaedics, Switzerland) was designed as a modification of the Imperial College London Hospital prosthesis in 1980. The floor of the trochlear surface is circular as viewed from the side and inset into the antero-distal femur. Proximally the anterior flange of the prosthesis and the medial and lateral shoulders are extended sufficiently to engage (even) a patella alta in full extension. The floor is continued posteriorly to roof the intercondylar notch as far as possible, commensurate with permitting access through the remaining notch to extract cement from the posterior femur. These design considerations have been discussed elsewhere [8, 9] and are illustrated in Fig. 1.

The patellar prosthesis is reciprocal in shape to that of the trochlea and is therefore saddle-shaped, providing area contact with the femoral component save in full extension. The prosthesis is designed to be inset and has been fixed either with or without cement [8].

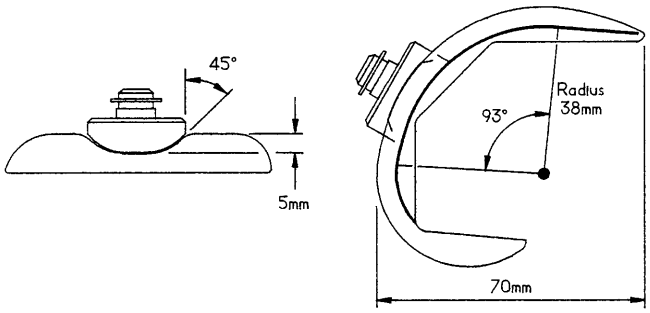

Fig. 1 In sagittal section the antero-distal trochlear floor is circular (radius 38 mm, arc 93E) and inset to replicate the location of the floor of the natural trochlea. Proximally the floor is extended to articulate with even the highest patella. Distally the floor covers the anterior half of the natural intercondylar notch. In profile the lateral wall of the trochlea is 5 mm high and inclined 45E to the vertical. The patella is saddle-shaped to mate with the circular part of the trochlea

Patients

This study was based on 332 consecutive uninfected patients undergoing Freeman-Samuelson total knee replacement between January 1982 and March 1987. These knees have a potential 10- to 15-year follow-up and were reviewed, if available, at 10 years.

The patients were operated upon in either of two hospitals: the Royal London Hospital, United Kingdom (centre A) and Hospital Malalties Reumatiques, Barcelona, Spain (centre B). At centre A the routine clinical policy was to resurface the patella. In this hospital 148 knees in 132 patients were operated upon, 124 of which patellae underwent replacement using a component fixed without cement (Table 1). The component was cemented in a further 12 knees because the state of the prepared patella (e.g. the presence of a cyst in the cavity prepared in the patella) made cementless fixation uncertain. The patella was not resurfaced in 12 knees since the bone was judged to be too thin. At centre B the routine clinical policy was not to resurface the patella. Osteophytes were removed until the bone was a reasonable fit for the trochlea. Here there were 143 knees treated in this fashion, with 41 patellae being replaced, 6 with cement and 35 without because the patella was too thin to be shaped to fit the trochlea. Thus there are two cohorts for comparison: 124 knees in which the patella underwent cementless replacement at centre A and 143 knees in which the patella was not replaced at centre B.

In the early 1980s a technique of cementless press-fit tibio-femoral fixation was under evaluation at both hospitals. This technique failed [1, 2, 10] and was abandoned. Sixteen of the knees at centre A and 15 at centre B in which the tibio-femoral components had been fixed in this way failed as a consequence of aseptic loosening and required revision. None of these revisions were carried out as a direct consequence of patello-femoral failure, but (obviously) the presence of tibio-femoral loosening made a precise evaluation of patello-femoral function impossible. One knee at centre B was revised for anterior knee pain (see below). At centre A two knees were lost to follow-up, and ten patients died within 10 years. At centre B four knees were lost to follow-up, and eight patients died. Thus 96 knees at centre A and 115 knees at centre B remained for review at 10 years in which patello-femoral function could be assessed. The demographic data for the patients in the two centres who were available for review are presented in Table 2. It can be seen that the two groups are similar with respect to diagnosis, gender and age.

Table 1 The structure of the trial

	Patella replaced (*n*=124)	Patella unreplaced (*n*=143)
Revised for loose uncemented tibio-femoral prosthesis	16	15 (+1 revised for anterior pain)
Died	10	8
Lost	2	4
Reviewed (10 years)	96	115

Table 2 Demographic data in the patients reviewed (*RA* rheumatoid arthritis, *OA* osteoarthritis)

	Patella replaced	Patella unreplaced
RA:OA	34:62	36:79
Male:female	31:65	25:90
Age 30–59:>60 (years)	20:76	34:81

All knees were followed prospectively, both clinically and radiologically (in principle) 1, 2, 3, 4, 5, 7 and 10 years after surgery using standard protocols. Clinical and radiological examinations were conducted and reviewed by surgeons independently of the operating surgeons. Patello-femoral function was assessed clinically by reference to anterior knee pain and the range of flexion. Radiological assessment was made on lateral and skyline views noting the presence of fractures, tracking and osteolysis or migration of the component (in the case of replaced patellae) or sclerosis and bone changes (in nonreplaced patellae). Anterior migration of the component within the patella was determined by measuring the distance between the anterior patellar cortex and the radio-opaque sphere in the patellar component. Survival analysis for the patellar prosthesis in knees treated without cement at centre A was performed using the life tables method as described by Armitage [3] and later developed by Dobbs [4] and Tew and Waugh [15] and Tew et al. [16]. In the absence of a prosthesis, survival was not calculated for centre B.

Results

Clinical results

Anterior pain present at rest and unrelieved by analgesia was noted in one knee in the replacement group. Radiographic examination in this knee showed no abnormality, and no explanation was found for the pain. No treatment was given. One patient in the nonresurfaced group had similar severe pain and 18 months after operation underwent a patellar resurfacing but without pain relief. Nineteen patients (19 knees) complained of anterior pain not requiring analgesia. Seven (7%) of these were in the resurfaced group and 12 (10%) in the nonresurfaced group This difference is not statistically significant. The mean range of flexion pre-operatively in the resurfaced group was 85° as against 100° in the nonresurfaced group. The post-operative range at 1 year in the resurfaced group was 98° and in the nonresurfaced group 99°.

Radiological results

One patella in the resurfaced group and two in the non-resurfaced group made contact with the lateral side wall of the prosthetic trochlea, not with the floor. All other prostheses made contact with the floor of the trochlea. The presence or absence of tilt amongst those prostheses (or patellae) contacting the floor of the trochlea could not be accurately assessed because the appearances changed from radiograph to radiograph (perhaps because sky-line radiography was performed slightly different degrees of flexion). In the nonreplacement group no clear reference line could be established whilst the absence of radio-opaque cement in the replacement group made it difficult to establish the attitude of the prosthesis relative to the femur. In the replacement group one patella sustained a fracture at 12 years. Three patellae sustained fractures between years 1 and 4 in the nonreplacement group. All four fractures were treated conservatively leaving the patient with functioning extensor mechanisms and without a significant gap in the bone. One prosthesis migrated anteriorly within the patella accompanied by osteolysis at 7 years. The knee was symptomless but remains under review. No other patella displayed osteolysis. Twelve patellae (10%) displayed increasing lateral sclerosis, suggesting the possibility of increased pressure between the lateral shoulder of the prosthesis and the patella. No symptoms were seen to be associated with this change.

Revision surgery

No revision was performed for clinical or radiological patellar loosening in the resurfaced group. One patient with anterior pain in the nonreplacement group (noted above) underwent resurfacing but without relief of symptoms. The cause of this patient's pain remains unclear. Sixteen knees that had undergone a press-fit cementless tibio-femoral fixation at centre A were revised due to aseptic loosening of the tibia and/or femur. Eleven knees with nonreplaced patellae were similarly revised at centre B. Of the 16 replaced patellae the component was found to be rotationally loose (at operation) in three knees and was revised to cemented fixation. There was no radiographic evidence of patellar loosening prior to revision. In 7 knees the patella was not loose but was revised nevertheless, along with the tibial and femoral components. In the remaining 6 knees the patella was not revised; these had a satisfactory patellar outcome at review.

Survival

Survival for the patellar prosthesis fixed without cement at centre A on a best case scenario was 100% using revision for (patellar component loosening) as the end-point (Table 3). Considering loosening (as found in three patellae during revision carried out for aseptic loosening of the tibio-femoral components) as the criterion of failure, survival was 97% (95% confidence interval: 94–100%, standard error 2%). On a worst case scenario (defining two patients who were lost to follow-up, the three patellae that were found to be loose at operation at the time of revision and the one migrated and radiologically loose patellar component that is under review as having failed), the survival after 10 years was 96% (95% confidence interval: 91.6–99.6%, standard error 2%; 99 knees at risk in year 10). Exactly comparable figures cannot be calculated for centre B since the some end-point (revision for patellar component loosening) cannot be used. However, at centre B 143 knees entered the study, one was revised for anterior pain at 18 months, 4 were lost and 115 were at risk in year 10. Using revision for (presumed) patello-femoral complications as the end-point, survival on a best case scenario at centre B at 10 years was 99%. On a worst case scenario (counting the 4 lost knees as failed) it was 95%.

Table 3 Survival analysis for knees with cementless patellar replacement, worst case scenario

Years since operation	Number of patients					Cumulative survival rate (%)	Confidence limits (%)	
	Starting	Failing	Dead	Lost	At risk		Lower	Upper
0–1	124	0	0	0	124	100	100	110
1–2	124	0	0	0	123	100	100	100
2–3	122	1	0	0	121.5	100	100	100
3–4	120	0	0	0	120	99	97.63	100
4–5	120	0	0	0	119	99	97.63	100
5–6	118	1	0	0	116.5	99	97.63	100
6–7	114	2	1	0	112	98	96	100
7–8	108	1	1	0	107.5	97	93.2	99.8
8–9	106	0	2	0	104	96	91.6	99.6
9–10	102	1	6	0	99	96	91.6	99.6

Discussion

The two groups of knees upon which a comparison of patellar replacement versus no replacement might have been based were significantly dissimilar: they were treated by different surgeons in different countries. This fact would have made it difficult for us to have based any conclusions upon this study had the outcome in the two groups been different from each other or unsatisfactory. However, the outcome in the two groups was similar, and that in both was satisfactory compared with some reports in the literature. This finding leads us to the following conclusions. Firstly, with the particular design of trochlear surface which we have used, there is no important difference between the outcome of replacing the patella with an unconventional method (an uncemented high-density polyethylene patella component) and not replacing it at all. Secondly, both outcomes are satisfactory. Thirdly, the outcome may depend not upon the patella surface of the patello-femoral joint but upon the way in which the opposite surface, namely the trochlear surface of the femur, is reconstructed.

In 1982, when the first knees reported in this study were replaced, a technique of cementless fixation in which polyethylene was interfaced with bone was under evaluation by one of the authors. At the tibia this technique failed, and as a consequence 31 knees originally in the groups now reported failed because of tibio-femoral loosening [1, 2, 10]. From the point of view of the patello-femoral joint these knees did not fail and are treated here as if the patient had died. In three of these cases the patellar component was found to be rotationally slightly mobile at re-operation although the pre-revision radiographic appearances were unremarkable. This finding raises the possibility that some of the patellar components in unrevised knees were also "loose" in this way, perhaps causing anterior knee pain. The cementless technique used at centre A for the patella was clinically successful, with only one case of lysis in the patella (an observation which suggests that the relatively constrained patellar component did not rotate against the bone itself and thus become abraded). Nevertheless, we would today recommend that the component be cemented.

Most of the papers reporting patello-femoral complications describe the patella and its mode of replacement but do not describe the shape of the trochlea surface in the prosthesis used. As a consequence it is not possible to determine which shapes have and which have not been associated with patella symptoms. In particular the shape of the trochlea in sagittal section is often ignored even though the design is said to be "anatomic" [7, 12]. We believe that the following features are important.

Firstly, a number of patello-femoral joints have been designed with a discontinuity half-way along the floor of the trochlea represented by what is effectively a "corner" facing antero-distally. This feature comes about either because the femoral bone cuts have included a very limited antero-distal shamfer or because the use of a posterior stabilising mechanism has resulted in a box in the femoral component intruding into the trochlea surface antero-distally. If the knee be imagined as a joint in which the femur rotates in a concave surface composed of the patella and tibia in combination (and on this analogy is thus comparable with the femoral head rotating in a concave acetabulum), it seems clear that such a "corner" may interfere with patella tracking; were a similar "corner" to be provided on the femoral head, the effect would obviously be unsatisfactory.

Secondly, the prosthetic trochlea surface has often been terminated proximally at the level of the proximal extent of the articular cartilage on the natural femur. In the normal knee the patella contacts the area of the suprapatella pouch when the quadriceps are contracting in full extension and only just contacts the cartilage surface when the quadriceps relax. Thus a prosthetic reconstruction imitating the natural knee results in a patella (replaced or otherwise) which is not engaged in the femoral prosthesis at the start of extension. The possibility then exists that tracking abnormalities could arise as the patella enters or fails to enter the trochlear groove. This situation mimics that in the natural knee with recurrent patella subluxation. In such knees the defect has been shown to affect the lateral wall of the trochlea in its most proximal extent. It is not that such patellae enter a normal groove and then dislocate, but rather that they do not securely enter the groove as flexion begins [6]. In general, once the patella is in the trochlea groove of the flexed knee it is stable. In contrast, in the fully extended relaxed knee the patella is medio-laterally mobile.

Thirdly, the prosthetic trochlea surface frequently ends at or even proximal to the distal level seen in the natural knee. This comes about either in an effort to provide maximal access through the reconstructed intercondylar notch to enable the surgeon to reach excess posterior cement or because of the use of a posterior stabilising mechanism. In the natural knee in deep flexion the patella tracks onto the medial and lateral shoulders of the intercondylar notch and is carried somewhat away from the femur by the backward displacement of the trochlea relative to the tibia during deeper degrees of flexion. In the prosthetic knee it is hard to replicate the natural tracking mechanism on the shoulders of the intercondylar notch. In addition, if the femur is not adequately stabilised antero-posteriorly, it may sublux forwards and be driven against the patella as it does so. We believe that the best that can be done to meet these difficulties is to extend the floor of the trochlea posteriorly as far as access to the posterior compartment of the knee allows.

In the light of this analysis we believe that four features are essential for a successful prosthetic trochlea surface. Firstly, viewed from the side, the trochlea surface over the loaded part of the flexion/extension range should be circular and inset into the antero-distal femur (as it is in the

normal knee) [5, 11]. Secondly, the surface should be extended proximally sufficiently to enable even the highest patella to articulate with the femur in full extension. This part of the femoral prosthesis should be provided with (at least) a lateral wall and floor so as to ensure that the patella remains in contact with the floor of the trochlea from 0° to 20° of flexion since it is within this arc that the natural patella may dislocate [12]. Thirdly, the floor of the patella groove should be continued posteriorly so as to roof the intercondylar notch, thereby providing a surface against which the patella can articulate in full flexion. Finally, the lateral wall of the trochlea groove should be sufficiently steep to provide a distinct resistance to lateral subluxation. It is not clear that a medial shoulder has any function.

The key to successful reconstruction of the patellofemoral joint is perhaps not so much the management of the patella itself but rather the design of the trochlea surface. With what we believe to be a suitably designed trochlea surface we have shown that satisfactory results may be obtained either with or without replacement of the patella, provided that the patella is not so thick as to make replacement impossible and that the bone can be shaped to fit the trochlea.

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