



Increased in vivo patellofemoral loading after total knee arthroplasty in resurfaced patellae

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Received: 25 July 2017 / Accepted: 10 November 2017 / Published online: 29 November 2017
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Abstract

Purpose The primary purpose of the study was to investigate if and how patellar bone tracer uptake (BTU) distribution in SPECT/CT is influenced by patellar resurfacing and the position of femoral and tibial TKA component position.

Methods A total of 104 knees of 103 consecutive patients who underwent primary TKA were prospectively investigated. Primary patellar resurfacing was done in 40 knees while 64 had a TKA without patellar resurfacing. All patients underwent clinical assessment using the knee society score (KSS) and standardized radiographs and Tc-99m-HDP-SPECT/CT before and 12 and 24 months after TKA. Measurements of BTU including intensity and anatomical distribution pattern in eight different patellar regions were performed. Tibial and femoral TKA component position was assessed from 3D reconstructed CT data. Patellar height, thickness and tilt were measured and the distance between the tibial tuberosity and the trochlear groove (TT–TG) was measured. Univariate analysis was performed to identify differences between the two groups ($p < 0.05$).

Results Significantly higher BTU was found in the anterior, non-articular, areas of the patella in patients who underwent patellar resurfacing ($p < 0.05$). The BTU pattern was similar between the groups, as the maximal uptake in both groups was seen in the superior posterior parts and the minimal uptake was seen in the inferior anterior parts. The mean postoperative KSS was significantly higher in the unresurfaced group after 12 months ($p < 0.05$), but with no significant difference after 24 months.

Conclusions Based on the findings of the present study, patellar resurfacing is related to significantly higher BTU in the anterior parts of the patella and lower clinical outcomes. In light of these results, routine patellar resurfacing as part of a primary TKA might be reevaluated. SPECT/CT enables a precise localization of the BTU and might be considered as the ideal imaging modality for evaluation and investigation of patellofemoral disorders after TKA

Keywords Total knee arthroplasty · Total knee replacement · TKA · TKR · Patellar resurfacing · In vivo loading · Patella

Introduction

The importance of the patellofemoral joint for outcome in TKA is well established. However, whether the patella should be resurfaced routinely remains highly controversial [8, 23, 32]. Although there is a considerable number of studies including large RCT and meta-analyses the question if a patella should be resurfaced remains unanswered [2, 6, 10, 28, 30]. A primary patellar resurfacing has a considerably low complication rate, however, still higher than primarily non-resurfacing of the patella [26]. The incidence of anterior knee pain after TKA is higher in patients with unresurfaced patellae, mainly because of residual or progressing osteoarthritis, patellar maltracking or patellofemoral overloading [27, 29]. Hence, a selective primary patellar resurfacing has become a popular approach among knee surgeons. A more

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profound understanding of patellofemoral biomechanics and kinematics might aid in the decision-making process. Hybrid SPECT/CT, which combines the strengths of 3D bone scan (SPECT) and CT, has been highlighted as an important tool for evaluating patients after TKA [3, 9, 13, 15–19]. In these studies, SPECT/CT was particularly helpful in identifying patellofemoral problems such as maltracking, overloading or progression of osteoarthritis [19]. It is the combined assessment of mechanical, structural and functional information, which offers a richer source for establishment of the correct diagnosis [9, 13, 20].

The primary purpose of the study was to investigate if and how patellar BTU distribution in SPECT/CT is influenced by patellar resurfacing and the position of femoral and tibial TKA component position. The secondary purpose of the study was to investigate if patellar height, patellar thickness, patellar tilt as well as TT–TG distance influence postoperative BTU pattern and if outcome correlates with BTU pattern. It was the hypothesis that there exists a significant difference in BTU pattern between resurfaced and unresurfaced patellae after TKA.

Materials and methods

A total of 104 knees of 103 consecutive patients who underwent primary TKA between 2011 and 2013 were prospectively investigated. Primary patellar resurfacing was done in 40 knees (mean age \pm standard deviation 68 ± 10 , range 45–83 years, male to female ratio 18:23) while 64 knees (mean age \pm standard deviation 66 ± 11 , range 23–87 years, male to female ratio 30:34) had TKA without patellar resurfacing. The mean preoperative KSS score was 124 ± 27 in the unresurfaced group and 123 ± 31 in the resurfaced group. All patients underwent clinical and radiological examination in a specialized knee clinic, including standardised radiographs (anterior–posterior and lateral weight bearing, patellar skyline view) and Tc-99m-HDP-SPECT/CT before and 12 and 24 months after TKA. Tc-99m-HDP-SPECT/CT was performed using a hybrid system (Symbia T16, Siemens, Erlangen, Germany) which consists of a pair of low-energy, high-resolution collimators and a dual-head gamma camera and an integrated 16×0.75 -mm slice-thickness CT. All patients received a commercial 500–700 MBq Tc-99m-HDP injection (CIS Bio International Sur Yvette, France). Planar scintigraphic images were taken in the perfusion phase (immediately after injection), the soft tissue phase (1 to 5 min after injection) and the delayed metabolic phase (2 h after injection). SPECT/CT was performed with a matrix size of 128×128 , an angle step of 32, and a time per frame of 25 s 2 h after injection. SPECT/CT images were analysed on 3-D reconstructed images. Rotational (internal–external rotation), sagittal (flexion–extension, anterior–posterior

slope) and coronal (varus–valgus) position of the tibial and femoral TKA components were assessed using a customized analysis software (OrthoExpert©, London, UK). Measurements of BTU including intensity and anatomical distribution pattern in eight different patellar surface regions were also performed from 3D data [31]. BTU intensity was measured in 3D for each anatomical area, as reflected by a previously validated localization scheme (Fig. 1). Maximum intensity values were recorded as well as ratios between the respective value in the measured area and the background tracer activities (proximal midshaft of the femur) were calculated. The patellar height, according to the modified Insall-Salvati index and the Caton-Deschamps index, and the patella thickness, were measured using lateral knee radiographs in 30° flexion. The patellar tilt was measured in a “skyline view” using the Sasaki index. The distance between the tibial tuberosity and the trochlear groove (TT–TG) was measured using axial images from the CT scan. Ethical approval was obtained from the Ethics Committee of Northwestern and Central Switzerland (EKNZ 2016-01890). All procedures performed were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

Statistical analysis

All data were analysed by an independent professional statistician using SPSS version 17.0 (SPSS, Chicago, IL, USA). Continuous variables were described using means and standard deviations or medians and ranges. Categorical variables were tabulated with absolute and relative frequencies. Univariate analysis (Chi-square test, Pearson’s correlation and *t* test for independent samples) was performed to identify the difference between the two groups. For all analysis, $p < 0.05$ was considered statistically significant. A post hoc analysis using G*Power, version 3.1.9 (University of Kiel, Germany), showed that with the given $N = 104$ and the given allocation ratio (64/40) an effect size $d = 0.57$ can be shown with a power of 80%.

Results

No significant differences between the groups were found in pre- and postoperative patellar thickness and height on lateral radiographs and in TT–TG distance in the CT scan (Table 1). Mean TKA alignment measurements and measurements of patellar thickness, patellar height, patellar tilt and TT–TG distance are shown in Table 1. Significantly higher BTU was found in the anterior, non-articular, areas

Fig. 1 3D SPECT/CT tracer uptake analysis in the coronal, sagittal and axial planes using a customized software (OrthoExpert[®], London, UK). The quantification of the maximum, minimum and mean uptake values was done in eight different anatomical areas of the patella

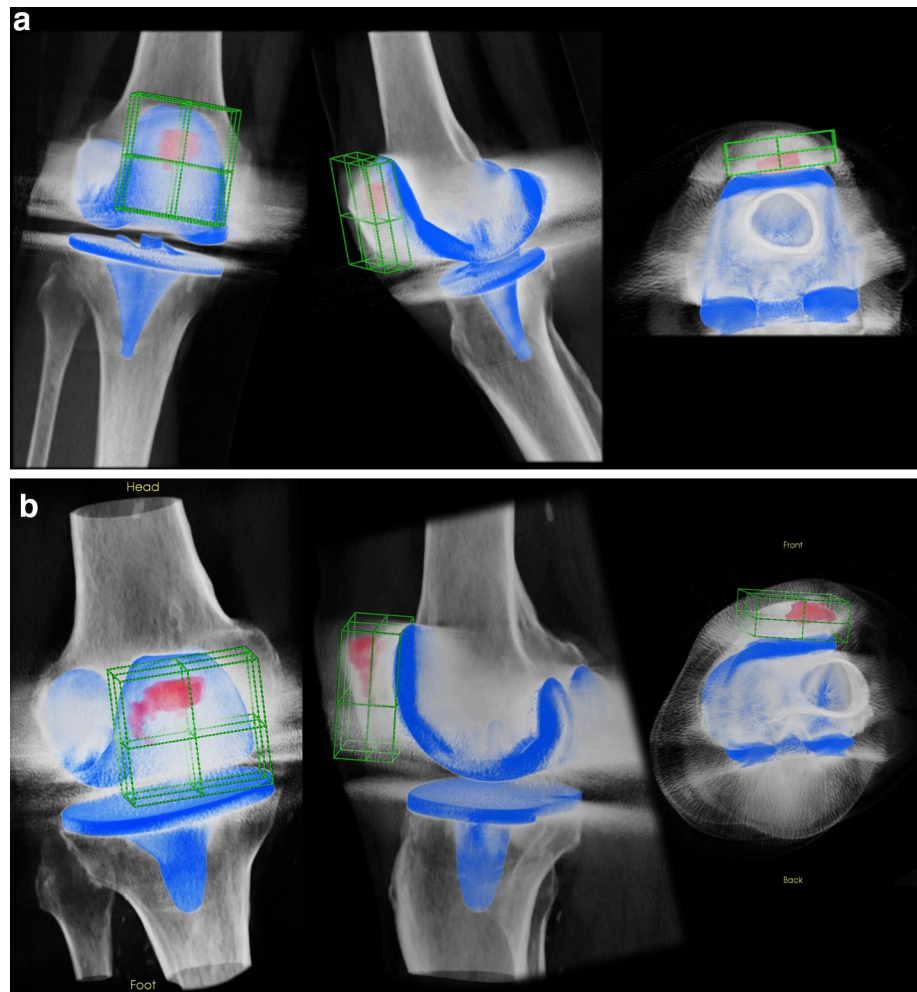


Table 1 Mean TKA component measurements using 3D-reconstructed CT images and patellar measurements including patellar thickness, patellar height and TT–TG distance

	Patellar retention Mean (\pm SD)	Patellar resurfacing Mean (\pm SD)	<i>p</i> value
Rotation femur	2.5 (\pm 3.1)	2.7 (\pm 2.6)	n.s
Coronal femur	– 0.1 (\pm 2.3)	– 0.9 (\pm 3)	n.s
Sagittal femur	7.4 (\pm 3.7)	9.5 (\pm 3.3)	0.006*
Rotation tibia	– 4.8 (\pm 6.7)	– 2.2 (\pm 7.1)	n.s
Coronal tibia	0.4 (\pm 2.5)	1.2 (\pm 2)	n.s
Sagittal tibia	4.0 (\pm 2.6)	1.55 (\pm 4.1)	0.000*
Patellar thickness	25.9 (\pm 3)	26.3 (\pm 2.6)	n.s
Patellar height (modified Insall-Salvati index)	1.6 (\pm 0.2)	1.5 (\pm 0.3)	n.s
Patellar height (Caton-Deschamps index)	0.7 (\pm 0.2)	0.7 (\pm 0.2)	n.s
TT–TG distance	6.7 (\pm 4.3)	6.8 (\pm 5.5)	n.s

of the patella in patients who underwent patellar resurfacing (Table 2). The BTU in the more posterior, articular, regions was higher in the unresurfaced group but did not reach significant statistical difference. The BTU pattern was similar between the groups, as the maximal uptake in both groups was seen in the superior posterior parts and the minimal uptake was seen in the inferior anterior parts. The mean postoperative KSS was significantly higher in the unresurfaced group after 12 months (183.5 vs. 171, $p=0.027$) and non-significantly higher after 24 months (180.1 vs. 174.5, $p=0.42$) (Table 3; Fig. 2).

Discussion

The most important findings of the present study were the following. First, TKAs with patellar resurfacing showed significantly higher BTU in the anterior parts of the patella and inferior clinical outcomes. As no previous study described the patellar BTU after TKA when divided into different regions, the explanation for these findings can

Table 2 Mean BTU measurements of patellar areas in SPECT/CT

		Patellar retention Mean (± SD)	Patellar resurfacing Mean (± SD)	p value	
				T test	Mann–Whitney
Articular areas	Medial superior (2sp)	2.8 (± 1.45)	2.78 (± 1.33)	n.s	n.s
	Lateral superior (1sp)	2.37 (± 1.17)	2.3 (± 1)	n.s	n.s
	Medial inferior (2ip)	1.91 (± 1.35)	1.83 (± 1.17)	n.s	n.s
	Lateral inferior (1ip)	1.43 (± 0.81)	1.63 (± 0.97)	n.s	n.s
Non-articular areas	Medial superior (2sa)	1.74 (± 1.34)	2.2 (± 1.31)	n.s	0.014*
	Lateral superior (1sa)	1.55 (± 0.97)	1.98 (± 0.9)	0.027*	0.006*
	Medial inferior (2ia)	1.05 (± 1.10)	1.24 (± 0.9)	n.s	n.s
	Lateral inferior (1ia)	0.88 (± 0.65)	1.2 (± 0.75)	0.027*	0.013*

Table 3 Pre- and postoperative outcome scoring using KSS

		Patellar retention Mean (± SD)	Patellar resurfacing Mean (± SD)	p value
Preoperative	KSS knee	54.8 (± 14.4)	55.1 (± 15.9)	n.s
	KSS function	69.7 (± 17.7)	67.8 (± 22.3)	n.s
	KSS total	124.5 (± 26.8)	122.8 (± 31)	n.s
12 months postoperative	KSS knee	89.8 (± 9.8)	85.4 (± 16.3)	n.s
	KSS function	93.7 (± 10.1)	85.7 (± 21.2)	0.018*
	KSS total	183.5 (± 16.3)	171 (± 36)	0.027*
24 months postoperative	KSS knee	89.4 (± 12.5)	88.3 (± 14.8)	n.s
	KSS function	90.7 (± 16.3)	86.2 (± 23.6)	n.s
	KSS total	180 (± 25)	174.5 (± 37)	n.s

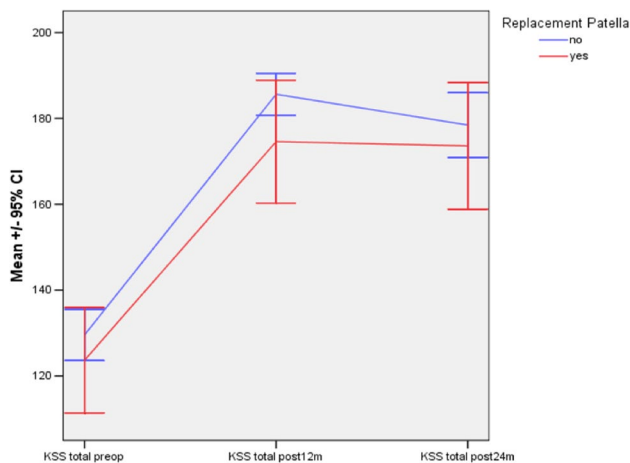


Fig. 2 Pre- and postoperative outcome scoring using KSS

be established on previous biomechanical studies, which examined the various forces that are applied to the patella after TKA. Higher BTU in the anterior regions can represent bony stress reaction, secondary to increase quadriceps forces. As the extensor mechanism plays a major role in the rehabilitation period after TKA and in certain daily activities, any disruption will lead to poorer clinical

outcomes. The finding that alternation in knee kinematics is much more marked with patellar resurfacing than in TKA with patellar retention is in agreement with previous biomechanical studies that demonstrated that the contact stresses did not change significantly after total knee arthroplasty when the patella was not resurfaced, but they increased significantly after the patella was resurfaced [5, 25, 34]. Moreover, the finding that patellar resurfacing is not related to better functional results is consistent with the numerous clinical studies which showed strong support for not routinely resurfacing the patella [2, 4, 8, 10, 21] or to resurface the patella selectively in patients with inflammatory arthritis or severe preoperative patellar pain [11]. Besides the described differences in the BTU, the uptake pattern was similar between the groups, which is probably related to the fact that no significant difference was found between the groups in the postoperative patellar thickness, height and TT–TG distance which are the major factors affecting the patellar tracking.

Second, it is interesting that patients showed improved outcomes 12 and 24 months after patellar resurfacing. However, the BTU was higher in the lateral areas of the patellar resurfacing group. A fact, which represents increased bony stress, which could be due to increased in vivo loading at the lateral patellar facet or due to bone remodelling.

Third, the proposed SPECT/CT algorithm enables a precise localization of the BTU and distinction between, at least, eight different regions, even in a small surface area as the patella. The standardized SPECT/CT algorithm for monitoring the results of knee surgeries, and especially TKA, was presented and introduced into clinical practice by Hirschmann et al. [20]. This algorithm includes localization and quantification of the bone tracer activity in the patella into eight different regions. So far, two clinical studies, which assessed the patella BTU using this novel diagnostic strategy, were published. The first study, which assessed the patellar BTU pattern in native knees, demonstrated that a lower patella position (patella baja) correlates with higher tracer uptake in all patellar regions, higher patellofemoral tilt angle correlates with higher uptake in the superior and inferior regions and mechanical varus alignment of the knee correlates with increase uptake in the medial regions while mechanical valgus alignment correlates with higher tracer uptake in the lateral regions [33]. The second study, which assessed the patellar BTU after TKA with patellar retention, demonstrated that valgus alignment of the femoral TKA component was significantly correlated with increased BTU in the patella, in particular in the lateral patellar areas [35]. In previous studies, which described the clinical signification of patellar uptake in native knees [12, 22, 24], the bony uptake was referred only as “normal” or “increased” when assessing patellofemoral pain. Moreover, when assessing anterior knee pain after TKA, the increase uptake in the patella was described as the “hot patella” sign, which is defined as greater BTU in the patella than in the ipsilateral distal femur or the proximal tibia [22], which is a rather rough and broad assessment of patella BTU. The use of three-dimensional reconstruction imaging for localization of the BTU using SPECT/CT offers more realistic and detailed window into the bone homeostasis [14, 15, 20, 31]. However, when the patellar bone is divided into several different areas, BTU evaluation in 3D might be helpful for assessing the patellofemoral in vivo loading after total knee arthroplasty. Furthermore, new insights regarding whether the patella should be resurfaced during primary TKA can be gained and to refine the indications for selectively resurfacing the patella. This SPECT/CT algorithm might be considered as the ideal imaging modality for evaluation and for follow-up of patients with patellofemoral disorders after TKA [33].

The present study bears a considerable number of limitations. As the discussion whether to resurface routinely the patella during primary TKA focusses on the incidence of anterior knee pain, there is a great importance for precise assessment of the patellofemoral joint. In the present study, as the joint line after TKA with patellar resurfacing is composed of polyethylene, on the patellar side, and the femur prosthesis, assessing the bony uptake might not be

accurate enough. A clear mismatch is existing between the groups when comparing the joint line BTU as the joint line in the patellar retention group is composed of bone to bone interaction. Nevertheless, as previous studies showed clear correlation between quadriceps tension and patellar forces [1, 7], we can assume that although a statically higher BTU was found in the patellar-resurfaced group only in the anterior regions, there are also higher compressive forces around the patellar component. In addition, the patients investigated were not specifically evaluated for anterior knee pain, which would allow more clinically relevant understanding of the abnormal BTU pattern. In this study the clinical assessment was based only on the KSS, which is not a patellofemoral-specific outcome instrument. Furthermore, increased patellar BTU might not only be due to the factors investigated, but also due to other reasons such as residual patellar osteoarthritis.

The small but significant difference in sagittal alignment of femoral TKA component might have influenced patellar BTU. However, the difference of 3° is rather not clinically relevant.

Conclusion

The results of the in vivo assessment of the patellofemoral loading after primary total knee arthroplasty using SPECT/CT demonstrated that patella resurfacing is related to significantly higher BTU in the anterior parts of the patella and lower clinical outcomes. In light of these results, we cannot support routine patellar resurfacing as part of primary TKA. Using SPECT/CT after primary TKA enables a precise localization of the BTU and might be considered as the ideal imaging modality for evaluation and for follow-up of patients with patellofemoral disorders.

Compliance with ethical standards

Conflict of interest All authors declare that there is no conflict of interest.

Funding There was no financial conflict of interest with regards to this study.

Ethical approval Ethical approval was obtained from the Ethikkommission Nordwest- und Zentralschweiz (EKNZ, Basel). All procedures performed were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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