ORIGINAL ARTICLE

Functional outcome of knee arthroplasty is dependent upon the evaluation method employed

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Abstract It is becoming increasingly important to evaluate surgical procedures beyond pain relief and implant survival. Patient satisfaction and objective functional assessment is now as relevant. The aim of this study was to establish the functional differences and patient perceptions between unicompartmental knee replacement (UKR) and total knee replacement (TKR). In a prospective study 52 TKR patients were compared to 24 UKR (at preoperative, 3, 6 months and 1 year postoperative). The disease specific KSS and Womac (pain and function subscores), the generic SF36 (pain, function and patient perception subscores) and the Dynaport®Knee Test, a validated performance-based knee test using accelerometers to score function during activities of daily living, was utilized. Preoperative UKR patients had significantly higher KSS function and the Dynaport®Knee Test ($P < 0.05$), but despite being younger, with different indication, they were not different to TKR with regards to function and pain subscores of Womac and SF36. Regarding preoperative perception, UKR patients reported better physical and social function but subjectively felt worse than TKR patients regarding health, emotion and mental status (n.s.). At one year, postoperative perception scores for both groups increased significantly, with UKR retaining functional lead and UKR patients also felt superior regarding health, emotion and mental status (n.s.). Postoperative recovery regarding KSS, Womac, and SF36-pain was steep only during the first 3 months with near equal values for both TKR and UKR. It was found that SF36-Function recovery was not significant, but UKR also scored higher than TKR. Only functional scores by the Dynaport®Knee Test showed continued improvement and maintained the functional advantage of UKR patients throughout recovery. UKR and TKR patients have different age demographics, indications and perceptions, but clinical outcome scores do not equally capture these differences, especially with regards to function. Postoperative functional benefits of UKR seem to be due mainly to the superior preoperative conditions. Appreciation of recovery with generic, disease specific and functional measurements appears invaluable.

Keywords Knee replacement · Gait analysis · Clinimetrics · Functional outcome

Introduction

Traditionally, the success of (knee) arthroplasty is reported by studying the longevity of the prosthesis with revision as an end point. However, such a technical success from the surgeon's point of view may not necessarily implicate a similar outcome to the patient's standpoint, so from the patient's perspective the outcome could be deemed a failure. This can be reflected in the method that is utilized to study the outcome, and these can be divided as patient related measurements, joint related parameters, functional tests, disease specific scores and generic scores (Fig. 1).

Outcome studies enhance the surgeon's appreciation of the value of joint replacement from the patient's perspective. Patients can provide reliable and valid judgements of health status and the benefits of treatment. The use of patient questionnaires enables the patient to answer standard questions and to score pain (for example) without the

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Fig. 1 Outcome measurements
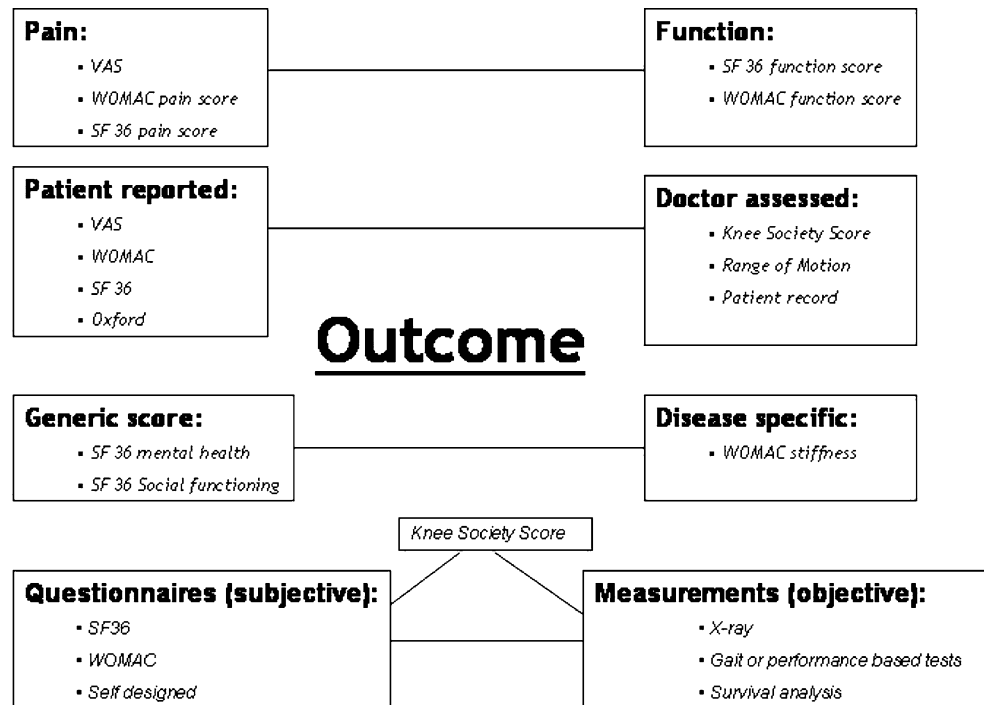
interpretation of an assessor and its bias. The functional outcome as measured by performance-based tests can be influenced only marginally by either the doctor or the patient. It therefore can be considered as a valuable addition to existing assessment tools as indicated by Barr et al. [3].

Although many surgeons utilize functional scoring systems such as the American based Knee Society Score (KSS) [7] to evaluate outcome, it is likely that the criteria for a successful knee arthroplasty differ between the patient and the surgeon. This was evident in a report by Bullens et al. [5], who concluded that surgeons are more satisfied with the results of total knee arthroplasty than are their patients. In addition to concerns about long-term functional outcome, Trousdale et al. [22] showed that patients' major concerns were postoperative pain and the time required for recovery. Still there are patients who remain unsatisfied with the results of surgery, despite technical successes. Of patients with a Knee Society Score of> 90 points after total knee arthroplasty, only 35% of patients stated that they had no limitations, suggesting a certain unreliability as reported by Konig et al. [8]. This was highlighted in a study by Dickstein et al. [6], who found that one-third of the elderly patients who underwent knee replacement were unhappy with the outcome at 6 and 12 months postoperatively.

It would be expected that outcome measurements of two different procedures with different indications and patient characteristics produce different findings. But clearly the success of a knee replacement procedure can be appreciated in different manners. In this view, it is of interest to highlight the acclaimed differences between unicompartmental knee replacement (UKR) and total knee replacement (TKR) using both subjective and objective tools.

A limited number of studies in the literature have addressed the clinical outcome and recovery of unicompartmental and total knee replacement in a comparison [10, 16, 20, 25]. Newman et al. [16] presented a randomized study comparing unicompartmental replacement to total knee replacement, showing a greater range of motion following unicompartmental replacement. Weale et al. [25] suggested a superior result in rehabilitation and cost, beneficial to unicompartmental knee replacement. This difference was not shown to be statistically significant however. Weale et al. [25] report on superior functional recovery after unicompartmental knee replacement over total knee replacement. Kort [9] describes superior recovery and knee function, beneficial to unicompartmental knee replacement.

It was the goal of this study to assess surgical outcome on two different knee arthroplasty procedures and investigate if claimed outcome differences between patient and procedure can be measured using various assessment tools. It is hypothesized that outcome of knee arthroplasty is dependent upon the evaluation method employed.

Materials and methods

For this study a retrospective analysis of a prospective studied cohort of 52 total knee replacements, Anatomic

Graduated Component (AGC) (Biomet, Dordrecht, The Netherlands), and 24 meniscal bearing unicompartmental replacements, Oxford Knee (Biomet, Dordrecht, The Netherlands) was performed. Of both total knee replacement as well as unicompartmental knee replacement long term follow up is well established [18, 27]. Standard time points for measurements were set on preoperative and on 3, 6 and 12 months postoperative and data were acquired in a prospective design. Preoperative measurements were acquired the within 2 weeks prior to surgery. Post operative rehabilitation program was equal for both groups and was followed outpatient in most cases. All operations were performed by the senior author (WM) or under his supervision.

Indications for total knee replacement

All patients with bicompartmental or tricompartmental osteoarthritis of the knee received total knee replacement. All procedures were performed through a medial parapatellar approach. The monoblock tibial component was used in a cruciate retaining version and patella resurfacing was performed in all cases after routine denervation with cautery and removal of osteophytes.

Indications for unicompartmental replacement

Patients with medial osteoarthritis of the knee were offered unicompartmental replacement and were younger of age than has been reported previously [18]. In all patients, the varus deformity was passively correctable to neutral. The anterior cruciate ligament was observed to be intact intraoperatively and the cartilage of the lateral compartment was considered normal for this age group. The surgical procedure was performed according to the Oxford unicompartmental knee replacement guidelines.

Outcome parameters

The patient demographics of age, sex and body mass index (BMI) were recorded.

Clinical outcome after knee replacement was assessed by the clinician-based American Knee Society Score (KSS). The disease specific Western Ontario and McMaster Universities Index for Osteoarthritis (WOMAC) [4], consisting of subscores pain, function and stiffness, and the generic quality-of-life Short Form 36 (SF 36), which contains subscores of pain, function and satisfaction, were used as self-reported questionnaires. Both were in a validated Dutch-translated version [1, 19] and answers were in a 5-point Likert-scale. The scores of WOMAC were transformed into a 100 point scale (highest is best) as frequently used in literature.
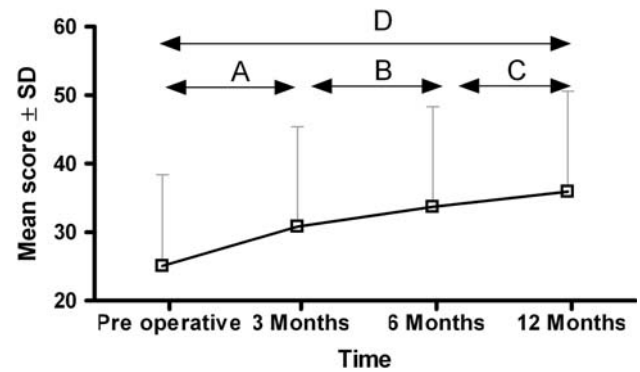

Fig. 2 Division of time periods

In addition to these classic assessment methods, the Dynaport®Knee Test, an accelerometer based system with small movement sensors that are fixed to the patient, was used as a performance based knee test. It assesses functional abilities objectively in a standardized set of tasks, closely related to activities of daily living (ADL). An algorithm programmed by the manufacturer was used to calculate one Dynaport®Knee Score that ranges from 0 to 100 (best). The rationale of the system has been explained [24, 26] and the reliability and construct validity was studied [14, 15].

Improvement was calculated between two time points of each score. Period A was set between preoperative and 3 months, and Period B was between 3 and 6 months. Period C was set between 6 and 12 months, whereas period D was considered the improvement between preoperative and 1 year (Fig. 2).

Statistical analysis

Data analysis was performed using Statistical Package for the Social Science (SPSS) 12.0 (Chicago, IL, USA). Reported values are mean ± standard deviation (SD). For each time period the differences in means of improvement of all scores were analyzed with a two-sided Student's t test in the event of normal data distribution, otherwise a Mann–Whitney test was used for comparison.

Differences in the WOMAC and SF 36 scores among measured time points in each patient group were compared using repeated measures ANOVA. Post hoc comparisons were checked using the Tukey–Kramer Multiple Comparisons Test. Maxwell and Delaney explained that for proper use of repeated measures analysis of variance (ANOVA), the number of observations should be larger than $n + 10$, where n is the number of level of repeated measures. This study was comprised over three scenarios and there were 24 patients in the smallest group. When employing t tests and the sample size is between 16 and 40, a t distribution can be applied if the sampling distribution is moderately

Table 1 Mean age and body mass index of patients after total knee replacement (TKR) and unicompartmental knee replacement (UKR)

	TKR (±SD)	UKR (±SD)	P value
Age	70.6 (8.6)	61.5 (8.4)	0.001*
BMI	30.0 (5.3)	28.6 (4.6)	0.232

The mark '*' is significant

skewed, unimodal, without outliers, which was the case in this study. Therefore, the validity and applicability of the used tests were considered acceptable [13]. Level of significance was set at $P < 0.05$.

Results

The patients in the unicompartmental knee replacement group were significantly younger and the majority of the

patients were female in both groups (Table 1). BMI was higher in the total knee group, but not significantly so (Table 1).

Preoperatively, the KSS was better for the unicompartmental knee replacement than for the total knee replacement (Fig. 3a) and pain and function scores of Womac (Fig. 3c, e) and SF36 (Fig. 3d, f) are similar. The total knee replacement group was slightly better in SF36 health, emotion and mental health, whereas the unicompartmental knee replacement was better in physical and social functioning. These differences did not reach significant levels (Student's t test, P values ranging from 0.343 to 0.935). The Dynaport®Knee Test was significantly higher preoperatively in the unicompartmental knee replacement group (Fig. 3b).

Comparing the steepness of KSS improvement between both groups postoperatively it revealed no significant difference during the one year follow up (Mann–Whitney

Fig. 3 Function and pain scores of total knee replacement (TKR) and unicompartmental knee replacement (UKR). Significant differences are marked *Asterisk*
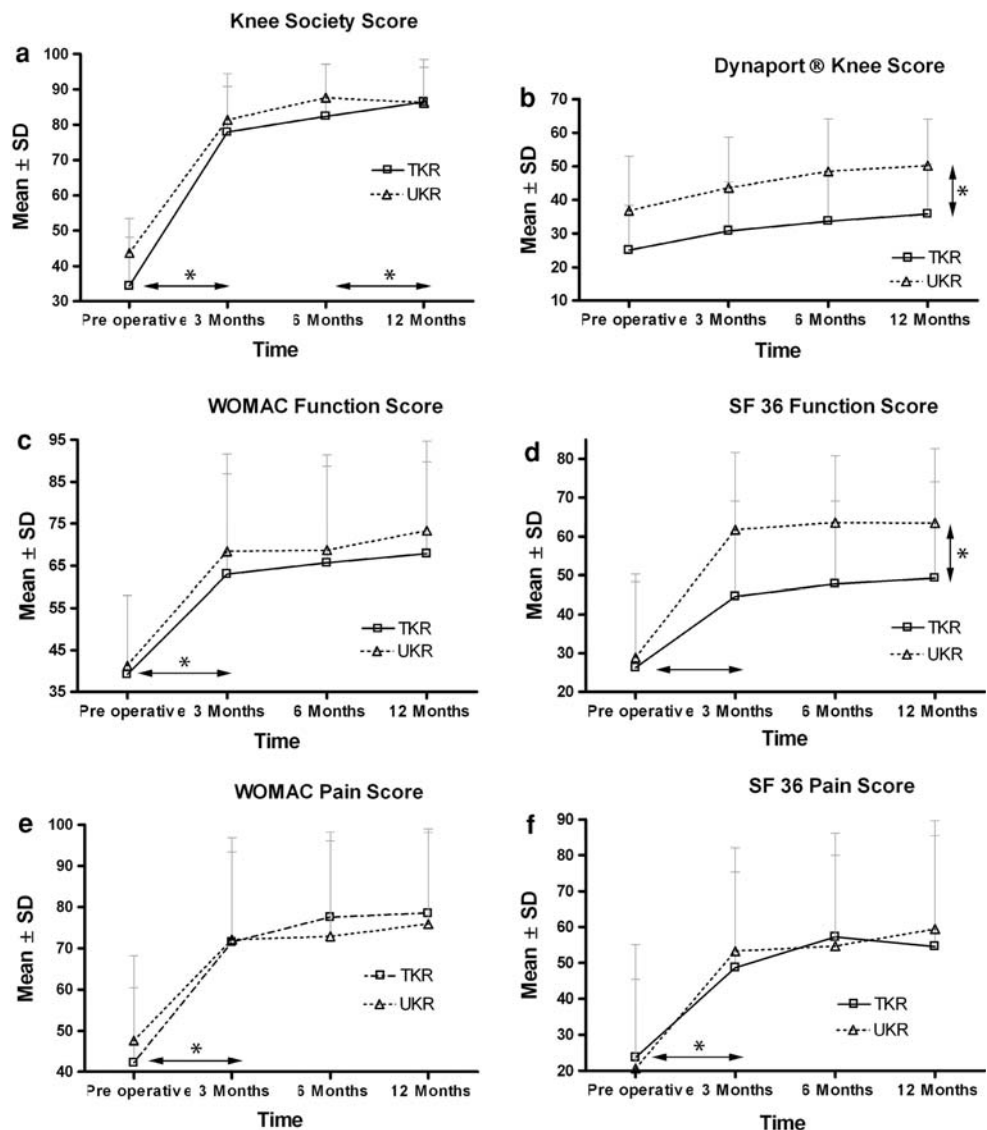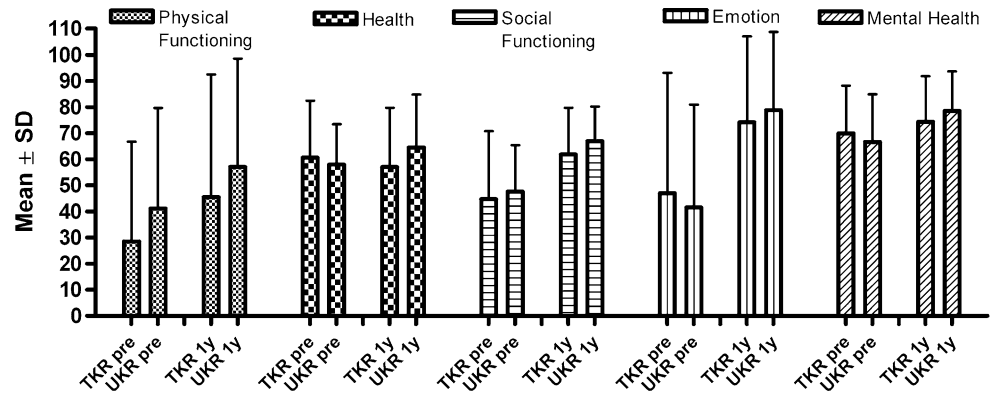
Fig. 4 Patient perceptions

test, P value ranging from 0.159 to 0.289). Only period C (6–12 months) showed a decrease in the KSS for unicompartmental knee replacement, while the total knee replacement group continued to improve resulting in a significant difference in recovery rate between both groups (Mann–Whitney test, P = 0.04).

The WOMAC pain and function scores (Fig. 3c, e) were not significantly different during follow up (Student's t test, P values ranging from 0.328 to 0.872). Both the unicompartmental knee replacement group and the total knee group showed a significant improvement in the WOMAC scores up to three months postoperative (Repeated measures ANOVA, p values ranging from 0.035 to 0.047), but ceased to improve thereafter (Repeated measures ANOVA, P > 0.05). The comparison between groups in WOMAC stiffness, WOMAC pain score and WOMAC functioning revealed no significant differences at all time periods post operative (Student's t test, P values ranging from 0.075 to 0.982).

SF 36 (Fig. 3d) showed a similar function score preoperatively (Student's t test, P = 0.675). The comparison between groups in steepness of improvement was in favour of the unicompartmental knee replacement, mainly due to period A (Student's t test, P = 0.040, significant improvement) and Period C (Student's t test, P = 0.069). However, the SF 36 pain score (Fig. 3e, f) showed no significant difference during follow (Student's t test, P value ranging from 0.540 to 0.794).

Regarding the SF 36 perception scores (Fig. 4), both groups reported improvement between preoperative and 1 year. The subscore emotion was statistically significant (repeated measures ANOVA, P = 0.041), whereas physical functioning, social functioning, health, mental health, improved at non-significant levels (repeated measures ANOVA P > 0.05). In all postoperative perception measures the patients after unilateral knee replacement scored higher than those after total knee replacement although their preoperative values for general health, mental health and emotion were lower (Student's t test, P > 0.05).

Regarding the performance-based functional measurements with the Dynaport®Knee Test, the preoperative functional advantage of patients, indicated for unilateral knee replacement, remained during recovery as both groups improved at equal rates (Student's t test, P values ranging from 0.195 to 0.979). While other scores levelled off at 3 or 6 months, the Dynaport®Knee score in period C improved.

Discussion

This paper is addresses the recovery after unicompartmental knee replacement in relation to total knee replacement and uses both a knee score, self reported questionnaires and a performance based knee test. It is recognized that both surgical procedures are conducted based on different preoperative indications. However, similar efforts were found in the literature [10, 20, 25, 28]. As it has been established unicompartmental knee replacement has become a solution in itself [9] and not merely a delay for total knee replacement, a true comparison would involve only patients with medial knee involvement. However, when the surgical recovery profiles, and the methodology of outcome measurements, rather than the indications of both procedures are compared, the results are worth discussing.

Based upon the measurements that assess function, patients preoperatively indicated for unicompartmental knee replacement objectively perform better than total knee replacement prior to surgery. Since unicompartmental knee replacement is performed in patients with less extensive arthritis and at a younger age, it could be expected that the unicompartmental knee replacement group would have better preoperative functional status than the total knee arthroplasty group.

This was true in the present study, where it was found that all function-related measurements with objective elements (KSS, The Dynaport®Knee Test) were in favour of unicompartmental knee replacement, although preoperative

differences in subjective function scores of WOMAC and SF 36 questionnaires were not significant. Therefore the magnitude of difference is dependent upon the used evaluation method employed.

However, using the KSS, the unicompartmental knee replacement and total knee replacement level out at the same point. Obviously, a patient that starts with a lower value has a larger range for improvement. The fact that both groups level out after surgery indicates that the KSS does not appear to be responsive enough to detect further differences. This can be illustrated by the maximum value for knee flexion in the KSS, which is set on 120°, whereas patients after unicompartmental knee replacement are in most cases able to reach beyond this ceiling.

In contrast the Dynaport®Knee Test shows a difference between unicompartmental knee replacement and total knee replacement preoperatively and continues to show this difference throughout the postoperative improvement process. It indicates that this test is more responsive to changes due to surgery. Therefore higher preoperative starting values and thus the related joint and patient condition, rather than the type of prosthesis can be considered responsible for a better performance.

A close study of the functional results, postoperatively, was expected to show a more rapid recovery of the unicompartmental group. However, the improvements between both groups in the studied time periods were not significantly different. Since unicompartmental knee replacement is performed less invasive it could be expected that these patients would show a higher magnitude of functional recovery due to better soft tissue condition such as preserved quadriceps muscles.

Comparing functional recovery between groups using the WOMAC and SF36 function score pre-operative values were almost equal with both assessment tools. A much steeper improvement up to 3 months was measured with SF36 function in favour of the unicompartmental knee replacement. This resulted in a functional benefit for unicompartmental knee replacement in comparison to total knee replacement that WOMAC did not capture.

In direct contrast, Parent and Moffet [17] found, using a methodological comparison, that SF 36 was least responsive between pre operative and 3 months. WOMAC proved to be the most responsive outcome. Angst et al. [2] also confirmed that functional improvement was better detected by WOMAC over SF36. The value of SF36 in this report may not reflect true functional gain, and WOMAC is still the more trustworthy test, indicating that improvement is essentially similar. It appears that the more reliable test produces a similarity in results where a difference was hypothesized and the less responsive test result in the acclaimed difference. It is worth noting that the questions in WOMAC which cover the functional aspects appear to

have a larger array than SF36. WOMAC is a disease specific questionnaire, whereas SF36 is regarded as more generic. This would indicate that WOMAC should have picked up changes, if any, but may not be responsive enough and functional differences exists. As Sodermann and Malchau [21] demonstrated high validity and reproducibility of WOMAC, it clearly provokes uncertainties as to which score is superior, and it indicates that using only one score may not reflect true outcome.

Given the indication and age demographics in the two patient groups, it is remarkable that expected and objective functional differences are only marginally reflected in the result of the patient questionnaires. The differences in assessing knee function both before and after surgery show that knee function can be reflected differently. This is especially important for the physician in the evaluation of a procedure and it should be considered in the design of a study.

The perceptions of studied patients showed that those preoperatively indicated for unicompartmental knee replacement, with less advanced stage of arthritis and objective function at a higher level, show that they consider themselves better in both physical and social functioning, but scored lower in health, mental health and emotion compared to those indicated for total knee replacement. Thus a less advanced condition could result in more mental deprivation, probably because they still aim for higher activity levels and they are not yet as adapted as those patients in more advanced stages. Postoperatively, patients after unicompartmental knee replacement objectively have not functionally improved in comparison to those having undergone total knee replacement, while they do report so regarding SF 36 function score. Furthermore, they report higher scores in health, mental health and emotion as well as social and physical functioning was better than in the total knee replacement group. Expectations after total knee replacement are likely to be lowered as age increases and the level of activity, although it has been reported these patients are still unhappy with the result of the surgery [6]. Younger patients and those with less advanced stages of arthritis may therefore subjectively benefit more from surgery than objectively can be detected.

Marx et al. [12] have recently demonstrated that WOMAC and SF 36 are responsive and therefore these self-report measures can be considered to likely reflect the patients' perception after total joint surgery. Maly et al. [11] indicated that self-report measures are strongly related to pain, whereas physical performance measures are strongly related to self-efficacy. The patient has primary concerns in terms of pain relief and longevity of rehabilitation [22]. Both the improvement in WOMAC and SF36 pain scores in this study were comparable between both groups. This indicates that patients tend to report rather

their pain relief and its forthcoming satisfaction in preference to the gain of function. However, looking at the results at the measured time points, SF36 pain score favours unicompartmental knee replacement in contrast to WOMAC pain score, which favours the opposite. It can be discussed whether this difference is the influence of the specific questions in SF36 compared to WOMAC, or that the patients reflect their pain differently with the two questionnaires. In this view, where the unicompartmental group is significantly better in objective measurements, it confirms that patients report their pain relief rather than functional gain and it shows that both surgical procedures provide adequate and similar pain relief.

It would be of interest to investigate cases with medial osteoarthritis of the knee receiving both unicompartmental knee replacement and total knee replacement. Only then it can be stated that the treated condition rather than the type of prosthesis is the reason for better performance. However in our opinion it is virtually impossible to perform such in a randomised trial. Random allocation of patients with different indications for surgery and meet different criteria seems rather unethical. When this is pursued a power analysis is necessary, but in this study we have not done so. Therefore the significances could be an item of discussion and subject to a type II error due to potential low power. However, since methods instead of population are compared, we feel this is less of an issue.

Considering the acknowledged differences, this paper was set up to document the expected functional and perceptional differences between unicompartmental and total knee replacement. In this view it can be concluded that patients after unicompartmental knee replacement using performance-based tests are functionally better objectively, which is likely to be due to the favourable preoperative situation.

However, both patient groups show that the objective functional difference are not reflected in the employed questionnaires relating to function, patient perception and the development of postoperative improvement. Knee replacement is appreciated differently by the treating surgeon (KSS), the patient (WOMAC and SF36) and any objective tests (Dynaport). This study raises the impression that patients with different indications show remarkable similarities. It can be concluded that different outcome measurements produce different results, suggesting different capabilities of the tests. In agreement with van den Akker-Scheek et al. [23] it is recommend to utilize generic, disease-specific and performance-based measurements to fully appreciate recovery after knee replacement.

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