The Knee 23 (2016) 511–516

Contents lists available at ScienceDirect

The Knee

Range of movement correlates with the Oxford knee score after total knee replacement: A prediction model and validation

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ARTICLE INFO

Article history:
Received 16 December 2014
Received in revised form 17 December 2015
Accepted 11 January 2016

Keywords:
Oxford knee score
Range of motion
Total knee replacement

ABSTRACT

Background: Patient reported outcome measures are widely used in the evaluation of outcomes after Total Knee Replacement (TKR) in joint registries and large studies. The aim of this study was to assess the relationship between the Oxford knee score (OKS) and range of motion (ROM) after TKR, and to construct and validate prediction models of ROM from the measured OKS.

Methods: Eight hundred sixty patients reviewed five years postoperatively and 273 patients reviewed nine to 10 years postoperatively completed an OKS. Of these, 808 (94%) and 226 (83%) patients, respectively, had a complete dataset (knee extension and ROM) and formed the study cohort.

Results: Regression analysis demonstrated a significant correlation between the OKS and ROM ($r = 0.38$, $p < 0.001$) after adjusting for other confounding variables (age, sex, body mass index, and knee extension). A prediction model was constructed and validated using a second cohort of 226 patients at nine to 10 years after their TKR. Intraclass correlation demonstrated good reliability ($r = 0.60$, 95% CI 0.47 to 0.69) between predicted and actual measured ROM for this group. However, when the OKS is used in isolation the reliability of the predicted ROM is diminished (intraclass correlation $r = 0.41$, 95% CI 0.24 to 0.55).

Conclusions: The OKS is an independent predictor of ROM after TKR. It is also possible to predict ROM from the OKS, but the reliability of this is improved when other independent predictors such as age, gender, body mass index (BMI) and degree of knee extension are also acknowledged.

1. Introduction

Total knee replacement (TKR) is an effective procedure for end stage osteoarthritis of the knee, with approximately 64,000 performed each year in the UK [1]. The rate of TKR continues to increase as a result of an ageing society with greater functional demands [2]. Approximately one in five patients undergoing TKR is not satisfied with their knee replacement post-operatively [3] and the satisfaction rate can be influenced by multiple factors, including patient age, gender, and comorbidity [4,5,6]. The rate of patient satisfaction has been shown to correlate with range of movement (ROM) of the knee postoperatively, with increasing ROM resulting in a greater rate of satisfaction [7,8]. However, it appears that TKR designed specifically to increase the ROM do not provide better outcomes [9].

Patient reported outcome measures (PROMs) are now routinely collected for National Health Service (NHS) patients in the UK to assess whether they perceive their surgery as successful [10]. The PROM of choice to evaluate TKR in England and Wales is the Oxford knee score (OKS) [11], which has been approved for audit and performance assessment purposes [12]. Despite collecting these data, it is not clear how this should be interpreted or what a given score means for the patient.

The OKS has been demonstrated to correlate with achievement of patient expectations and satisfaction after TKR [13,14]. However, there is conflicting evidence regarding the correlation between PROMs and ROM. Padua et al. [15] demonstrated a significant correlation between ROM and the OKS in their study of 48 patients, but the strength of this correlation was not stated. Park et al. [16] in their larger study of 333 TKR only demonstrated a weak correlation between the short form SF-36, American Knee Society (AKS), and Western Ontario McMaster Universities Osteoarthritis index scores and ROM. More recently, Soon et al. [17] demonstrated that there was no correlation between the OKS, SF-36, or AKS scores with postoperative ROM after they adjusted for confounding variables such as age, gender and body mass index (BMI). If a correlation between ROM and the OKS after TKR was established, a prediction model could be used to estimate the associated ROM for a given OKS and this would aid interpretation of what a given score means to a patient.

The primary aim of this study was to assess whether the OKS correlated with ROM after TKR. Our secondary aim, if such a correlation was established, was to construct and validate a prediction model of ROM from the measured OKS.

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http://dx.doi.org/10.1016/j.knee.2016.01.009
0968-0160/

Table 1
Case-mix variables according to group.

Case-mix variables		Group 1 (n = 808)	Group 2 (n = 226)	Difference/odds ratio	95% Confidence Interval		p-Value*
					Lower	Upper	
Age (years: mean, SD)		74.1 (8.8)	75.0 (8.2)	0.9	−0.4	2.2	0.17
Gender (M/F) (n, % of group)	Male	380 (47)	120 (53)	0.78	0.58	*1.05*	0.11**
	Female	428 (53)	106 (47)				
BMI (kg/m^2: mean, SD)		30.2 (5.1)	29.9 (4.7)	0.3	−0.5	1.0	0.14
Extension (degrees: mean, SD)		1.2 (3.7)	1.4 (3.7)	0.1	−0.3	0.7	0.63
ROM (degrees: mean, SD)		97 (16)	95 (18)	1.9	−0.5	4.4	0.12
Oxford Knee Score (mean, SD)		32.8 (10.7)	32.4 (10.8)	0.4	−1.2	2.0	0.40

*t-test unless otherwise stated **chi square test.

2. Materials and methods

A prospectively compiled arthroplasty database has been maintained at the study centre for all patients undergoing total knee arthroplasty. Patients are reviewed pre-admission, six months, 18 months, three, five and nine to 10 years after their TKR. Patient demographics are recorded (age, gender, BMI) and active knee extension (i.e. active extension deficit in degrees) and ROM (i.e. the arc of movement as calculated by the maximal active flexion minus the active extension deficit) was also measured using a goniometer with the patient lying supine by a dedicated team of four specialist arthroplasty nurses, who remained constant during the study period. At these same time points patients were also asked to complete an OKS. All patients underwent primary unilateral TKR with Sigma PFC (DePuy, Johnson & Johnson Professional Inc., Raynham, Massachusetts) fixed bearing prosthesis via a medial parapatellar approach and the patella was not routinely resurfaced. The procedures were carried out by one of six consultant orthopaedic surgeons, by a registrar operating under direct consultant supervision or by an independently practising staff grade surgeon.

There were 860 patients reviewed five years postoperatively and 273 patients reviewed nine to 10 years postoperatively that completed an OKS, however only 808 (94%) and 226 (83%) patients, respectively, had a complete dataset (knee extension and ROM) to enable analysis and inclusion within the study cohort. In order to ensure that these patient groups were representative, a comparison was made with those patients not included in the study. We found no significant differences with respect to age, gender or BMI in those patients that were included in the study cohorts at five and nine to 10 years, compared to those who were not ($p > 0.1$). Patients reviewed at five years were defined as group 1 and those reviewed at nine to 10 years were defined as group 2.

The OKS is a validated joint specific patient reported outcome measure [11]. This score consists of 12 questions assessed on a Likert scale with values from 0 to four. A summative score is then calculated where 48 is the best possible score (least symptomatic) and 0 is the worst possible score (most symptomatic) [18].

The study centre serves a population of approximately 365,000 people [19]. A standardised rehabilitation protocol was used for all patients, with active mobilisation on the first day post-operatively.

Statistical analysis was performed using Statistical Package for Social Sciences version 17.0 (SPSS Inc., Chicago, IL, USA). Student t-tests were used to compare normally distributed continuous data between groups, and Pearson's correlation (PC) was used to assess the relationship between continuous variables. Dichotomous variables were assessed using a chi square test. Multivariate linear regression analysis was used to identify whether the OKS was an independent predictor of ROM after adjusting for confounding variables using data from group 1. Simple linear regression analysis was also used to identify the direct relationship of ROM with OKS, using the slope of the line for change in the OKS according to ROM using data from group 1. Equations were constructed using the multiple and simple linear regression models to predict the ROM according to the included variables. These equations were then validated using the data from group 2. Bland and Altman plots and intraclass correlation coefficients were used to assess the reliability of the equations to predict ROM with the actual measured ROM for group 2 [20]. A p-value of <0.05 was defined as significant.

3. Results

The mean age at time of follow-up for the study cohort was 74.1 (SD 8.9) years in group 1 and 75.0 (SD 8.2) in group 2 ($p = 0.17$). There were 534 (51%) females and 500 (49%) males with a mean preoperative BMI of 30.1 (range 15.8 to 60.8) kg/m^2. Overall there was a mean flexion deformity of one degree with a mean ROM of 97 (range 10 to 130) degrees. The mean OKS was 32.8 (range 0 to 48). There was no significant difference in these case-mix variables between groups 1 and 2 (Table 1).

Univariable and bivariable analyses were used to identify predictors of ROM using data from group 1. Female patients had a mean ROM of 95° (standard deviation (SD) 16, range 10 to 130) and males had a mean ROM of 99° (SD16, range 10 to 130), and this four degree difference was statistically significant (95% confidence interval (CI) 1.8 to 6.3, $p < 0.001$ t-test). Age, BMI, knee extension and OKS were all also demonstrated to be significant predictors of ROM for group 1 (Table 2). Patients with a greater BMI, increasing flexion deformity, and lower (worse) OKS (Figure 1) had a significantly reduced ROM. Interestingly the factor with the greatest correlation with ROM was the OKS, and further correlation analysis of each question with ROM demonstrated variation in the correlation (Table 3) but none were greater than the total OKS (Table 4). Seven patients had patellar resurfacing at the time of TKR and no relationship between patellar resurfacing at ROM was identified ($p = 0.87$).

Multiple variable regression analysis demonstrated age, gender, BMI, the degree of knee extension, and OKS to be independent predictors of ROM using data from group 1 (Table 4). Interestingly older age was associated with a greater ROM. In contrast female gender, increasing BMI and patients with a flexion deformity were independent predictors of a diminished ROM. The OKS was illustrated to be an independent predictor of ROM, with an increasing score (improving function) being associated with an increased ROM. Simple linear regression also demonstrated the OKS to be predictive of ROM, with single point change being associated with a 0.6 degree change in the ROM (Table 5).

Using the multiple regression model (Table 4) from group 1, the predicted ROM for group 2 was calculated and compared to the actual

Table 2
Correlation of linear case-mix variables with ROM for group 1.

Case-mix variables	Correlation coefficient (r)	p-Value[a]
Age	0.11	0.002
BMI	−0.18	<0.001
Extension	−0.34	<0.001
Oxford Knee Score	0.38	<0.001

[a] Pearson's correlation.