Anterolateral approach using tibial tubercle osteotomy for total knee arthroplasty: can we predict failure?

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Abstract

Purpose The purpose of this study was to identify predictive factors for the occurrence of complications in a consecutive series of patients who underwent step-cut tibial tubercle osteotomy (TTO) and subsequent screw refixation in primary total knee arthroplasty (TKA).

Methods Using standardised conventional radiographs, critical parameters including TTO length and depth, proximal abutment width (OT), and orientation and placement of fixation screws were measured in 422 patients (mean age of 71 years and a follow-up time range of one to five years) with two screw fixations.

Results Medial spatial orientation in the distal screw (11 %, $p=0.046$), the TTO length (<55.4 mm, $p=0.013$), the OT width (<14 mm, $p=0.002$) and the distance of the distal refixation screw from the TKA (<51.7 mm, $p=0.003$) were significant factors for the occurrence of complications.

Conclusions Age, gender, comorbidities, height, weight and/or the body mass index had no significant influence on the occurrence of complications. The TTO-related complication rate was 3 %. Consideration of these key surgical factors leads to improved outcomes.

Introduction

Tibial tubercle osteotomy (TTO) is considered to be a clinically valuable adjunct to the orthopaedic surgeon's armamentarium [1–17]. In particular, for revision surgery the advantages of improved exposure [1] and preservation of the medial blood supply to the patella have been highlighted [4, 9, 12–14, 16–18]. However, most surgeons consider TTO to be a technically demanding procedure [7, 11, 16, 17]. A number of clinically significant complications such as skin necrosis, haematoma, compartment syndrome, proximal dislocation of the osteotomised bone, fractures and insufficient consolidation have been reported [1–3, 5–8, 10–14, 16, 17, 19–21]. Some surgeons emphasised a number of important surgical key factors to avoid these aforementioned complications [4, 9, 12–14, 16–18]. The importance of the proximal abutment, the size and depth of the TTO, type of refixation material and the number of screws as well as their direction was highlighted [7, 11, 16, 17]. However, to the best of our knowledge there is no clinical study investigating the size, shape and type of TTO as predictive factors for the occurrence of complications.

The purpose of this study was to investigate a consecutive series of patients after TTO and consequent screw refixation in primary total knee arthroplasty (TKA) and to identify predictive factors for the occurrence of complications.

Material and methods

A consecutive series of patients ($n=500$) having undergone primary TKA from 2001 to 2009 was retrieved from the hospital archives and reviewed for inclusion in this study. A total of 438 patients who had undergone primary TKA using the anterolateral approach combined with a TTO were considered for inclusion. The refixation was performed using one to three 3.5-mm lag screws. The detailed surgical

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technique has been described previously [7, 17]. For the sake of consistency only patients with two fixation screws were considered for statistical analysis in this study; therefore, 14 patients were excluded due to the number of fixation screws (i.e. one or three screws). For refixation of the TTO, two screws were used in 424, one screw in six and three screws in eight patients. Furthermore, two patients were excluded due to missing radiographic data. Finally 422 patients were included in this study. The study was approved by the Institutional Review Board at our institution.

Age, gender, comorbidities such as diabetes mellitus and bone diseases (e.g. osteoporosis, hyperparathyroidism) were noted from the surgical reports. The occurrence and type of any complication related to the TTO were noted from surgical reports, hospital notes, outpatient clinic notes and radiological reports.

Standardised anteroposterior and lateral weight-bearing radiographs were used. All measurements were performed on a PACS (Picture Archiving and Communication System, Netherlands). The length and depth of the TTO as well as the size of the proximal abutment were measured. In addition, the number of screws used for refixation, the localisation and orientation (e.g. medial, lateral, mediocranial etc.) of the screws and distances between these were noted. The tibial and femoral TKA component positions (varus-valgus, flexion-extension, see Fig. 3) were determined according to Ewald [22].

The following measurements were performed on the anteroposterior projection (Fig. 1):

- Distance of the screw heads from each other (SS)
- Distance of each screw head from the lower margin of the tibial prosthesis component (ST^1 , ST^2)

Fig. 1 Radiological measurements on the anteroposterior radiograph. ST^1 , ST^2 distance of each screw head from the lower margin of the tibial prosthesis component, SL^1 , SL^2 distance of each screw head from the central perpendicular of the tibial prosthesis component, SS distance of the screw heads from each other

- Distance of each screw head from the central perpendicular of the tibial prosthesis component (SL^1 , SL^2)
- Spatial orientation of the screws (cranial, mediocranial, medial, mediocaudal, caudal, laterocaudal, lateral and laterocranial)

The following measurements were performed on the lateral projection (Fig. 2):

- Length of the osteotomised bone (O)
- Distance of the screw heads from each other measured at the ventral cortical bone (SS')
- Depth of proximal osteotomy (P)
- Depth of the osteotomised bone piece measured at half length of O (Q)
- Width of proximal abutment (OT)
- Angle of each screw (longitudinal axis) to the lower margin of the tibial prosthesis component (ζ^1 , ζ^2)

We hypothesised that surgeons tried to achieve medial measures of TKA positions because extreme values tend to have a negative impact on outcome. We therefore categorised those variables into three groups where the lower and upper portions contain 20 % each and the middle portion 60 % of all patients. We then tested for the influence of those extreme groups on TTO and complications.

Statistical analysis

All data were analysed by an independent statistician using SPSS version 16.0 (SPSS Inc., 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

Fig. 2 Radiological measurements on the lateral radiograph. OT width of proximal abutment, P depth of proximal osteotomy, O length of the osteotomised bone piece, Q maximal depth of the osteotomised bone piece measured at half length of O, SS' distance of the screw heads from each other measured at the ventral cortical bone

analysis was performed to identify any correlations between TTO-related factors and the categorised TKA component positions. Pearson's one-sided chi-square test was used to test whether lower and/or upper portions of TKA positions, compared to the medial portion, had a worse clinical outcome. A linear two-sided chi-square test was used to control for a linear influence of TKA position on outcome. Because of the low number of patients with complications ($n=12$), $p<0.05$ was considered statistically significant and $p<0.1$ as a statistical tendency.

Results

A total of 422 patients were included in this study (male to female ratio 168:254, mean age 71 ± 9). The average weight of all patients was 83 ± 16 kg and the average height 168 ± 9 cm, resulting in an average body mass index (BMI) of 29 ± 5 kg/m². Of the patients, 48 (11.4 %) had a known diabetes mellitus and 99 (23.5 %) a disease which has an influence on bone metabolism such as osteoporosis, prostate carcinoma or hyperparathyroidism. Age, gender, comorbidities, height, weight and/or the BMI had no significant influence on the occurrence of complications.

A clinically significant complication was exhibited by 12/422 (3 %) patients with a two-screw fixation, one out of eight (13 %) patients with a three-screw fixation and three out of six (50 %) patients with a one-screw fixation. Four haematomas, two cases of skin necrosis, six screw displacements and six TTO displacements were noted.

The tibial and femoral TKA component positions (varus-valgus, flexion-extension, Fig. 3) are presented in Table 1.

Table 1 The tibial and femoral TKA component positions according to Ewald [22]

Angle	Femoral TKA position	Angle	Tibial TKA position
α	$4\pm 2^\circ$ valgus	β	$90\pm 2^\circ$
γ	$5\pm 4^\circ$ flexion	δ	$9\pm 3^\circ$ slope

The mean distance of both screws from each other (SS) was 16.3 mm (7.7–42.8 mm). The mean distance of the proximal screw from the lower margin of the tibial prosthesis component (ST¹) was 43.9 mm (21.2–94.2 mm) and 59.2 mm (37.5–100.1 mm) of the distal screw (ST²). The mean distance of the proximal screw from the central perpendicular of the tibial prosthesis component (SL¹) was 9.4 mm (0.2–27.0 mm) and 6.6 mm (0.2–20.8 mm) for the distal screw (SL²). The mean length O of the osteotomised bone piece was 69 mm (41.5–142.3 mm). The mean distance of both screws (SS') from each other was 15.5 mm (1.5–42.5 mm). The mean proximal depth of the osteotomised step-cut bone piece (P) was 11.4 mm (0.0–24.2 mm). The mean depth of the osteotomised bone piece at mid-length (Q) was 9.9 mm (3.3–18.5 mm). The mean length of the proximal abutment (OT) was 17.4 mm (0.0–30.8 mm). The mean angle (ζ) of the proximal screw to the lower margin of the tibial prosthesis component was -4.9° (-18 to 13°) and 6° (-26 to 26°) for the distal screw, respectively.

A medial spatial orientation of the distal screw (11 %, $p=0.046$), a TTO length (O) of <55.4 mm ($p=0.013$), an OT width of <14 mm ($p=0.002$) and a distance of the distal refixation screw from the TKA <51.7 mm ($p=0.003$) significantly correlated with a higher complication rate.

Fig. 3 The Knee Society total knee arthroplasty roentgenographic evaluation and scoring system for evaluation of TKA implant position on radiographs as described by Ewald [22]. α femoral varus-valgus angle, β tibial varus-valgus angle, γ femoral flexion-extension angle, δ tibial slope angle

The univariate correlations are presented in Table 2. Of 16 included categorised TKA positions, seven measurements (ST^2 , SL^1 , valgus α and β , SS^2 , O, OT) show a statistical significance ($p<0.05$) and three measures (SS , ST^1 , Q) a statistical tendency ($p<0.1$) in their influence on clinical outcome. In SS , ST^1 , ST^2 , valgus β , SS^2 , O and OT, especially lower values correlate with a high proportion of negative clinical outcomes whereas in SL^1 , valgus α and Q higher values correlate with a high proportion of negative clinical outcomes.

Discussion

This study investigates the influence of shape and size of the step-cut tibial tubercle osteotomy on the occurrence of complications in primary TKA. The most important findings of this study were fourfold:

Firstly, the length of the TTO is a significant predictive factor for the occurrence of complications related to TTO. Clearly, there is a significantly higher risk for the occurrence of complications if the length of the TTO is shorter than 55.4 mm. This is in agreement with a considerable number of authors who have emphasised the importance of adequate sizing of the TTO based on their clinical experience [3, 7, 11–14, 17]. Ries and Richman [12] and

Whiteside [13] commented on the problem of undersizing of the TTO. Ries and Richman highlighted that the strength of the osteotomised bone is related to its thickness and bone quality and found that the width should be 1.5–2 cm [12]. In our study the depth did not have a significant influence on the occurrence of TTO-related complications.

In 1999 Arnold et al. reported a complication rate $<1\%$ in 702 knees undergoing TKA with the step-cut technique at one institution [17]. Their recommendation was to keep the length of the osteotomy over 5 cm and to choose a proximal width of 1 cm [17]. Burki et al. aim for a 7 cm long and 2–3 cm wide TTO [3]. They found no problem with non-union or displacement of the TTO [3]. Zonnenberg et al. performed a review investigating the results and complications after TTO in patients undergoing TKA [16]. In most of the studies the length of the TTO varied between 7 and 10 cm with the exception of Dolin (4.5 cm) and Wolff et al. (2–9 cm) [6, 21]. All TTO-related fixation failures in the study of Wolff et al. were in osteotomies shorter than 3 cm [21].

Secondly, another significant factor in our study, which was related to the occurrence of TTO-associated complications, was the width of the proximal abutment. It should be wider than 14 mm. Clearly, in our experience it provides better resistance against the proximally directed forces generated by the extensor mechanism and thus impairs proximal displacement of the TTO

Table 2 Negative predictive influence on clinical outcome of categorised TKA position

Variable	Medial portion	Proportion of negative clinical outcome (%)			<i>p</i> value of chi-square test ^a	
		Portion			Pearson's one-sided	Linear two-sided
		Lower	Medial	Upper		
SS (mm)	13.2–18.9	4.8	3.1	0.0	<i>0.087</i>	<i>0.069</i>
ST^1 (mm)	37.1–50.2	6.1	2.0	2.4	<i>0.070</i>	0.154
ST^2 (mm)	51.7–65.5	8.3	1.2	2.4	0.001	0.020
SL^1 (mm)	4.6–13.8	3.7	1.6	6.0	0.049	0.365
SL^2 (mm)	2.1–10.8	2.4	2.4	4.8	0.249	0.354
Valgus α (°)	3–6	0.0	2.9	6.4	0.068	0.047
Valgus β (°)	–2 to 1	10.4	2.2	0.0	0.001	0.002
Flexion γ (°)	1–8	4.4	2.9	1.4	0.274	0.274
Slope δ (°)	79–84	1.6	3.3	1.8	0.342	0.912
ζ^1 (°)	–10 to 0	4.1	2.4	3.4	0.359	0.775
ζ^2 (°)	–11 to 2	1.4	2.7	5.7	0.175	0.171
SS^* (mm)	12.2–18.1	6.2	2.7	0.0	0.029	0.017
O (mm)	55.4–80.5	7.2	1.6	1.2	0.006	0.015
P (mm)	9.5–13.4	3.6	3.1	0.0	0.126	0.149
Q (mm)	7.6–11.8	0.0	2.6	4.8	<i>0.086</i>	<i>0.062</i>
OT (mm)	14.0–20.9	8.4	1.2	2.4	0.001	0.019

$p<0.05$ values are indicated in bold while $p<0.10$ values are indicated in italics

^a Pearson's one-sided for lower and/or upper vs medial; linear two-sided for continuous correlation

fragment. Interestingly, we could not find any study investigating the optimal width of the proximal abutment in step-cut TTO [16].

Thirdly, the distance of the refixation screws from the tibial TKA component is a key factor for the occurrence of complications related to the TTO. For the distal screw there is a significantly higher risk when the distance is <51.7 mm. A similar finding was shown for the proximal screw, although it was not statistically significant. In our experience it is also important not to produce any conflict between the fixation screws and the tibial keel.

This study indicates that there is an optimal site to place the screws for refixation of the TTO. Considering an optimal proximal abutment of 10–15 mm and a length of the TTO of 70 mm, the proximal screw should be placed at half the length of the TTO.

Fourthly, the overall complication rate related to the TTO is low in our series (<3 %) when compared to others. Zonnenberg et al. found a complication rate of 9 % in a systematic review including 823 cases undergoing a TTO ($n=762$ medial, $n=61$ lateral) [16]. Proximal migration of the TTO, pain related to the site of the TTO and avulsion fractures of the tibial tubercle were the most frequently reported complications [16].

One could speculate why the rate in our study is lower than in others. It might be related to the meticulously performed surgical technique (use of osteotomes and no oscillating saw, preservation of a medial periosteal flap and the refixation method using two lag screws).

Limitations

The number of complications observed in our patient cohort was smaller than the hypothesised 5 %, which formed the basis for the sample size calculation performed. Hence, it could be considered to be underpowered. The consequence is that only big differences and correlations become statistically significant. Therefore, it might be the case that some of the variables that did not show a significant correlation might become significant in a bigger sample. On the other side, the fact that seven of 16 controlled variables showed a significant influence on negative clinical outcome and three others at least a statistical tendency has to be interpreted as a very strong indication of the importance of a correct TKA position.

The predictive values identified cannot be generalised to any type of TTO and are only valid for the described lateral step-cut TTO using osteotomes, leaving the medial periosteum intact and using one to three screws for refixation.

Every measurement or analysis performed on standardised radiographs has to be questioned with regard to its reliability and measurement error. The measurement

error using the described method on radiographs is 3° and 0.5 cm.

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Conflict of interest The authors declare that they have no conflict of interest.

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