ORIGINAL ARTICLE

Incision Length in Small Incision Total Knee Arthroplasty: How Long of an Incision Is Needed?

Edward J. McPherson MD, FACS*; Brian Czarkowski, MS*; Matthew V. Dipane, BA*; Sherif M. Sherif, MD*

Abstract

This prospective review studied incision length with a small incision TKA technique and compared measured incision lengths to various anatomic and clinical parameters. We prospectively reviewed 357 cases of primary total knee arthroplasty using a small paramedial incision and utilizing small incision instrumentation. By using linear regression analysis, we found that incision length was generally related to the width of the distal cut femur and the width of the proximal cut tibia. Incision length was not related to height, weight, BMI, or femoral implant width. Clinically based upon our data, a reasonable starting incision for small incision TKA (as measured in knee extension) is a length that is 1.6 times the measured width of the distal femur. The surgeon should always extend the incision if he/she encounters difficulty in exposure and/or placement of instrumentation.

Keywords: Incision Length, Small Incision, Less Invasive, Total Knee Arthroplasty, Primary TKA, Surgical Technique

Level of Evidence: AAOS Therapeutic Study Level III

Introduction

Total knee arthroplasty (TKA) is a well accepted treatment for symptomatic end stage gonarthrosis. [12,19,30] Third generation designs have provided good functional results in the intermediate term. [32] Furthermore, polyethylene bearing technology continues to improve allowing longer term survival of implants before bearing changes are required. [13]

In the new millennium, the TKA procedure itself has been adapted to accommodate the shifting parameters in healthcare. Economic pressures on the healthcare system have prompted surgeons to seek methods to reduce hospital length of stay and lower the amount of post-operative visits for rehabilitation. [21] Along with better perioperative pain management techniques and coordinated “total

joint care,” surgeons have evolved the procedure utilizing “less invasive” surgical techniques. [6,7,8] The less invasive TKA procedure utilizes a smaller skin incision with a smaller arthrotomy. Additionally, instrumentation has been adapted to accommodate the smaller incision technique. [35,37]

Several variants of the small incision TKA technique have been described. [3,10] Interestingly, the starting incision length employed with the small incision technique has not been precisely described. Some surgeons report start-

* LA Orthopedic Institute, 201 S. Alvarado Street, Suite 501, Los Angeles, CA 90057 USA

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ing at an absolute length of 9-10cm and extending the incision as needed. Others report using landmarks starting adjacent to the tibial tubercle and extending just above the patella. There are no clear common guidelines dictating the starting length and the final working length needed for primary TKA.

This study was undertaken to examine our small incision primary total knee TKA technique. We believe that incision length at the knee is dictated by anatomic dimensions of the distal femur. Our focus of this study is to determine whether clinical landmarks can be utilized to provide a clinical guideline as to the proper starting incision length when utilizing a small incision technique for TKA.

Materials and Methods

Between November 2007 and December 2013, 415 primary TKA procedures were performed at a single institution by the senior author (ejm). Patients who were excluded from the study group include the following:

- 1) Patients who had a prior medial or lateral incision that was used and modified for surgical approach (n=9)
- 2) Patients with post-traumatic arthritis who had retained hardware requiring an extended exposure for removal (n=7)
- 3) Patients with severe deformity requiring use of a revision constrained TKA or a salvage hinge TKA (n=42)

This left 357 TKA procedures for study review. The surgical technique remained consistent throughout the study period (see Surgical Technique). A small incision surgical technique was utilized for all procedures.

A small incision with a small paramedial arthrotomy (a.k.a., less invasive technique) was utilized for all procedures. Anthropometric parameters were measured and recorded for each case. This included height and weight. The width of the distal femur was measured after the distal femoral cut was made (Figure 1). The sizes of the femoral component and tibial component were recorded. Finally, after the closure the knee incision was measured with the knee in full extension with a flexible ruler (Figure 2) and the length was recorded.

Incision length data was compiled and compared to anthropometric data using Microsoft Excel® spreadsheets (Microsoft Corporation, Redmond, WA). Statistical measurements were also calculated using Excel. We utilized linear regression analysis to determine the relationships between incision length and various measured parameters including height, weight, body mass index, femoral width,

Figure 1. Measurement of distal femur width. Photograph showing the end of the distal femur which has been cut at 5 degrees of valgus. The width is measured with a metallic caliper. For consistency, we measured the distal femur at the freshly cut edges, rather than the epicondyles.

Figure 2. Measurement of knee incision at closure. Photograph demonstrating the measurement of incision length which was measured at the completion of the TKA procedure using a flexible ruler. We used a flexible ruler as our incisions were curved around the patella. We measured skin incisions in full extension with the wound completely closed. Prior to starting our study, we determined that measurement of skin incision in extension with a completely closed wound reduced measurement variability compared to measurements in the flexed position and with the wound partially closed.

tibial implant size, and femoral implant size. The R-value coefficients were reviewed for significance. [34]

All patients in this study were followed for a minimum of one year. Functional performance was graded using the Knee Society Score (KSS). [15,26] All charts were re-

viewed for complications and implant failures. Complications were defined as requiring re-operation for any reason. Failures were defined as requiring implant removal for any reason.

Surgical Technique

All TKA's were preformed with a small skin incision and small arthrotomy employing a paramedial incision with a medial parapatellar arthrotomy. [8,22] The incision was made long enough to allow for comfortable access and exposure to the knee. The Vanguard Total Knee System™ (Biomet, Inc., Warsaw, IN) was used in all cases (Figures 3a & 3b). A cruciate retaining femur was inserted in all cases. Three polyethylene tibial bearing designs were used: a flat design, a dished posterior design, or an anterior stabilized (also known as "ultracongruent") bearing. [27] The anterior stabilized bearing had an extended anterior lip which was of a similar height to the Vanguard posterior stabilized post. Additionally, the posterior lip was extended 50% more than the dished tibial insert. The selection of each bearing design depended upon the flexion stability of the knee. An anterior stabilized bearing was used whenever the PCL was deficient or released significantly.

An intramedullary guide was used to cut the distal femur at a 5° valgus cut angle. Rotation of the femur was based upon the Anterior-Posterior axis as described by Whiteside. [9,38,39] Sizing of the femur was measured using a posterior reference technique. The proximal tibial bone cut was made using an extramedullary guide system. A bone block around the PCL was not used. A posterior slope was cut in all cases parallel to the medial compartment slope. [1,2,4,5,14,17,20] Coronal and sagittal plane balancing was performed utilizing a modified spacer block technique. Specifically, a trial femur was inserted along with a tibial trial sans a keel. Rotation of the tibia was set to provide congruent femoral-tibial mating in deep flexion. All patellae were resurfaced with a 3 peg polyethylene reduced thickness implant (Biomet, Inc., Warsaw, IN), a subset of implants that are 15% thinner than the standard patellar implant. All implants were cemented using Cobalt cement (Biomet, Inc., Warsaw, IN) without antibiotics. All surgeries were performed with body exhaust suits (Stryker Corporation, Kalamazoo, MI) in non-laminar flow rooms. Anesthesia consisted of a general anesthetic combined with spinal anesthesia with low-dose intrathecal preservative free morphine sulfate (0.1 mg).

Figures 3a & 3b. Intraoperative photographs of small incision TKA procedure using the Vanguard Knee System.

Figure 3a. Demonstrates exposure of right knee using small incision technique. The arthrotomy was extended proximally just enough to allow the patella to fall into the lateral gutter without force. Retractors protect medial and lateral ligamentous structures.

Figure 3b. Taken after placement of TKA implants. In this case, a Vitamin E infused anterior stabilized polyethylene bearing was used. The femoral width of this patient measured 75mm. His incision length was 12cm. In this case, the incision length was 1.6x the femoral width.

Results

Between November 2007 and December 2013, we reviewed 415 consecutive primary TKA procedures. 58 were excluded from the study based on study criteria. 9 knees had prior medial or lateral incisions, 7 knees were excluded because a prior standard length arthrotomy was used to remove retained metallic hardware, and 42 knees required a revision or salvage hinge TKA implant system based on prior trauma and/or severe deformity.

The number of knees measured in this study was 357, consisting of 291 patients. There were 214 female cases and 143 male cases. The average age of the study group was 65.5 years (33-91). In the female group the average age was 65.8 years (33-91) and in the male group the average age was 65.2 years (33-85). The average body mass index for the study group was 31.9 (18-57). In females, the average BMI measured 32.3 (18-57). In males, the average BMI measured 31.4 (23-56).

The results of our study are summarized in Tables 1 and 2. In the study group, average incision length measured

11.1cm (7-19). In females, the average incision length measured 10.5cm (7-19). In males, the average incision length measured 11.8cm (8.5-18). The femoral width measured varied considerably. The average width for the study group was 71.1mm (57-88). In females, the average width measured 67.1mm (57-87). In males, the average width measured 76.8mm (58-88).

Femoral implant size in the Vanguard Knee System was labeled based upon the width of the femoral component. The size options for the femoral implant ranged from 55mm to 80mm, increasing in 2.5mm increments. The median femoral implant size for the study group was 62.5mm (55-75). In females, the median femoral implant measured 60mm (55-72.5). In males, the median femoral implant measured 67.5mm (57.5-75). Tibial implant size in the Vanguard Knee System was labeled based upon the width of the tibia. The size options for the tibial implant ranged from 59mm to 91mm, increasing in 4mm increments. The median tibial implant size for the whole group was 71mm (59-83). In females, the median tibial implant measured 67mm (59-83). In males, the median tibial implant measured 75mm (63-83).

We compared incision length to several measured parameters. These parameters were analyzed using linear regression analysis and are summarized in Table 3. The scatter plot graphs are shown in Figures 4a – 4d. Linear regression analysis showed a correlating trend of incision length and femoral width ($R^2=0.17$, $p=0.00065$) as well as tibial implant size ($R^2=0.23$, $p=0.00001$). There was a lesser correlation with femoral implant size, but the p-value was still significant ($R^2=0.12$, $p=0.015933$). There was no correlation with body mass index ($R^2=0.03$, $p=0.255856$).

Using the regression equation for the parameter femoral width, we calculated a ratio of incision length to femoral width in order to determine a typical starting incision length. Beginning with the smallest femoral width measurement (55mm), we calculated the predicted incision length for each 5mm increment (55, 60...) up to 90mm. For each predicted incision length, we then calculated the ratio of predicted incision length to femoral width and then averaged the produced ratios to find one ratio for the study group. The calculated ratio for the entire study group was 1.55 times the width of the distal femur. By 5mm increments, the ratios ranged from 1.65 for the narrowest femoral width to 1.5 for the widest femoral width. From a practical standpoint, we determined that the starting incision length should be 1.6 times the width of the distal femur, measured just above the joint line. From a clinical standpoint, the best way to measure this value is to place the knee at 90° of flexion, palpate the distal end of the femur, and measure this width with a ruler.

Table 1 – Summary of Anthropometric Data

	Incision Length Average	Incision Length Range	Age Average	Age Range	BMI Average	BMI Range
Study	11.1cm	7 - 19	65.5	33 - 91	31.9	18 - 57
Females	10.5cm	7 - 19	65.8	33 - 91	32.3	18 - 57
Males	11.8cm	8.5 - 18	65.1	33 - 85	31.4	23 - 56

Table 2 – Summary of Intra-Operative Knee Measurements

	Femoral Bone Width Average	Femoral Bone Width Range	Femoral Implant Size Median	Femoral Implant Size Range	Tibial Implant Size Median	Tibial Implant Size Range
Study	71.1mm	57 - 88	62.5mm	55 - 75	71mm	59 - 83
Females	67.1mm	57 - 87	60mm	55 - 72.5	67mm	59 - 83
Males	76.8mm	58 - 88	67.5mm	57.5 - 75	75mm	63 - 83

Table 3 – Linear Regression Analysis of Incision Length versus Measured Parameters

Factor	Correlation (0-1)	P-value	2-Tailed Probability (<.05 is considered statistically significant)
Tibial Implant Size	0.23023	0.00001	$p < .05$
Femoral Bone Width	0.16937	0.00065	$p < .05$
Femoral Implant Size	0.12754	0.015933	$p < .05$
BMI	0.03484	0.255856	$p > .05$

Note: The R-value is a measure of how closely the data fit onto the regression line. It is a percentage of all response variable variation that is explained by the linear model. Having a low R-value that is statistically significant is still important as one can use this information to draw conclusions about how the fluctuations in the values of these variables are associated with changes in the outcome variable. Statistically significant predictors, regardless of the value of R, still reflect the mean change in the outcome variable for one unit of change in the predictor variable, while holding other variables constant that are in the model.

Figure 4a.

Figure 4b.

Figure 4c.

Figure 4d.

Pre-operatively, the average KSS score for the study group was 32.5 (0-80). Average flexion measured 114° (70-140). At a minimum of one-year follow-up (range 1-7 years), the average KSS score was 93.7 (55-100). Average flexion measured 128° (95-145). There were 17 cases which required manipulation (4.8%). All manipulations were performed between 5 to 7 weeks. There were 7 complications as a result of mild hyperextension that required a modular bearing exchange in all instances. We attribute the hyperextension deformity to cutting too much posterior slope which allowed these knees to develop hyperextension over a period of 1 to 3 years. We have since reduced the extent of our posterior slope cut. There were 6 cases of infection (1.7%) in this series. All infected patients were treated successfully with a 2-stage revision protocol utilizing an interim articulating PROSTALAC arthroplasty (prosthesis with antibiotic-loaded cement).

Discussion

Society in general, including the United States, does place some value on the physical appearance of a surgical incision. Psychologically, a person who has a small incision perceives oneself as less “defective” or “broken.” Actually, a small incision has more importance psychologically than many physicians believe. It is the arrogant surgeon who believes that a large incision does not affect the patient. In our personal reflections of patients who have undergone TKA, we not infrequently encounter patients comparing knee incisions and lamenting that they could also have a smaller incision. In regards to primary TKA, if the surgeon can perform the procedure in a technically proficient fashion and obtain similar clinical results to a larger, more extensive exposure, then it is fair to discuss the application of a small incision approach. We therefore believe there is inherent value in researching small incision technique.

In essence, this study demonstrates that incision length is most directly related to the bone width of the knee. With a wider knee, a longer incision is required to pull the soft tissues medially and laterally to expose the distal femur and proximal tibia. There was considerable variability in the scatter plot of incision lengths for a fixed femoral bone width. In fact the R-values for femoral bone width and tibial width (i.e., tibial implant size) were not strong. However, we feel that there is a correlation with the width of the knee and incision length. The R-values for femoral width and tibial implant size are 0.17 and 0.23, respectively. Although the R-values obtained were low (≥ 0.7 would be preferred), the p-values were highly significant and the

study group as a whole was large. This means that the R-value calculations are still useful, but there is going to be significant variability for each point value measured. This is obvious upon viewing the scatter plot data. To us, this makes sense clinically. Whenever we could not retract the arthrotomy to see the entire width of the distal femur, the incision and arthrotomy were extended to provide effective exposure of the knee.

There are several factors we observed that contributed to the wide variability seen in the incision length measurements. One main subjective factor is pliability of the soft tissue envelope. Some patients have remarkably “stretchable” soft tissues compared to others. In those cases with pliable soft tissues, the soft tissue envelope could accommodate additional retraction without risking tearing of adjacent tissues. In contrast, patients with thin, attenuated skin (for example, patients with advanced age, prednisone use, or smoking habituation) were easy to tear. Thus skin incisions were increased in such cases. Another important factor was soft tissue thickness over the patella. Some obese patients with a gynecoid body habitus carry their adipose tissue in their extremities. [11,16,40] A patient who has 5-6cm of adipose tissue overlying the patella certainly requires a longer incision compared to a patient who has 0.5cm of subcutaneous fat above his/her patella. This was definitely a drawback to this study. In retrospect, we should have measured the distance of skin to patella as one of our measured parameters. Even with this deficiency, we still found a generally linear correlation with boney knee width and incision length.

In this study we chose to measure incision length in extension rather than flexion. In a prior study we discovered that at 90° of flexion, incision length increases by approximately 22%, but there was significant variability for multiple factors including soft tissue pliability and subcutaneous thickness. [29] We felt that incision measurements in extension were reasonably consistent and permitted a more accurate comparison to measured anthropometric data.

We also found that there was a correlation with tibial implant width and skin incision. For purposes of this study we chose to not measure the width of the cut tibia. Instead, we recorded tibial implant size out of convenience. In the Vanguard Knee System, the size of the tibial implant is measured in millimeters at its maximal width. Since our surgical technique was employed to maximize coronal rim coverage, we felt that the recorded tibial implant size was a close approximation of tibial width. This is not the case with the width of the femur. The Vanguard femur is considered a universal femur, by which we mean that the implant accommodates both narrow and wide distal femurs. In wide femurs, the implant will have residual underhang.

Therefore, for this study, the width of the distal femur is the more accurate parameter predicting the ultimate incision length. Since tibial implant size increased in 4mm increments, there is probably less accuracy in predicting incision length with this parameter.

There are several potential advantages of utilizing small incision technique for primary TKA. The first is a reduced exposure risk for bacterial inoculation as a small incision reduces the exposed soft tissue area. It is well known that bacteria are present in the air in an operating room. With vortex air currents, these bacteria can land into the wound and potentially cause infection. [24] In this series, our infection rate was 1.7%. We did not use antibiotic-loaded cement. We utilized IV antibiotics pre-operatively for 24 hours adhering to SCIP guidelines. [33] We attribute our reasonably low infection rate to careful technique, but we also feel that a less invasive incision was a helpful factor in keeping the infection rate low. The only way to prove a smaller incision as a factor in reducing infection rates would be to perform a randomized study comparing long and small incision techniques. This, however, would require a large number of patients and would be an arduous study to conduct.

A second advantage of utilizing a less invasive incision is that the arthrotomy length into the suprapatellar pouch is shorter. A limited disruption of the quadriceps mechanism translates to a potentially improved rehabilitation experience. [23,25,28] With the initiation of the Affordable Care Act (ACA), all surgeons have witnessed a significant reduction in the approved number of out-patient visits allowed by Medicare for physiotherapy sessions. [21,31] Those patients who cannot participate in an “accelerated rehabilitation program” will have difficulty obtaining good ultimate knee function. [18,36] In our series, our manipulation rate was reasonable, despite patients having very limited post-operative physiotherapy. Our manipulation rate was 4.8%. Furthermore, 95% of our patients went directly home. We attribute our successful functional outcomes in part to a good perioperative pain management protocol and a small incision technique. Our KSS scores and range of motion after follow-up support this claim. Our KSS scores averaged 93.7 across the study group with a minimum of one-year follow-up.

In summary, when performing a primary TKA, the surgeon should always utilize an incision length that provides him/her comfort and allows him/herself to execute the procedure correctly and efficiently. In our study, the lower limits of incision length were tested. We found that an incision length (measured in extension) that is approximately 1.6 times the width of the distal femur is a reasonable measurement to use for a small incision TKA technique. This

rule would provide a uniform starting point for the surgeon and create consistency in surgical technique. If the surgeon encounters difficulty with exposure (especially with a stiff knee with a thick subcutaneous layer) the incision should always be extended to address the exposure needs of the procedure.

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