

The accuracy of bone resections made during computer navigated total knee replacement. Do we resect what the computer plans we resect?

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Abstract

Many studies have shown that computer navigation in total knee arthroplasty aids the surgeon to place the prosthesis in a more accurate overall alignment. Bony resection creates the flexion and extension gaps; important in balancing the knee and implant selection in TKR. The computer plans the bone cuts but has variables that it cannot control: the surgeon, the saw blade thickness and oscillation, the accuracy of the jigs, movement of the pins, and the quality of initial mapping data inputted by the surgeon. The accuracy of computer navigated bone resections are validated on cadavers, but this is the first study to compare the predicted bone cuts to that physically resected during TKR. For 89 patients undergoing primary TKR, the bone cut from the distal femur and proximal tibia was measured using Vernier callipers and compared to the computer calculation of the same. Results show that computer measurement of the physical space left by the resected bone is accurate.

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1. Introduction

Computer navigation is increasingly used to assist the surgeon during total knee replacement (TKR) surgery. It has been shown to result in a more accurate alignment of the prosthesis [1–4]. The accurate cutting of bone to create the flexion and extension gaps is vital for a well functioning balanced TKR. To navigate the knee using an image free system, its bony surfaces and anatomical landmarks must be mapped by the surgeon using a pointer. The computer creates a

reconstruction of the knee using these landmarks and bone resection cuts are based on this reconstruction. The accuracy of the computer measurements of bone resection is evaluated in this study by direct measurement of the resected bone slices using a Vernier calliper.

2. Methods

Eighty nine consecutive patients undergoing posterior stabilized Genesis II TKR (Smith and Nephew, Sydney, Australia) using BrainLab image-free navigation (BrainLab Australia Pty Ltd, Sydney, Australia) were studied. A standard medial parapatellar approach was utilised and the knee exposed in the routine fashion. The highest and lowest points of the tibial plateau and distal femur were marked with a diathermy. The computer navigation points were acquired from these marks with a three-ball acquisition pointer. The pointer takes a reading at the point indicated and the surrounding 6 mm radius. After resection of the bone by the surgeon using a standard saw blade (1.27 mm thick), a broad plate three-ball verification instrument was placed on the cut bone surface, and the computer measured the resection level. The computer calculated how much bone had been removed from the high side of the distal femur

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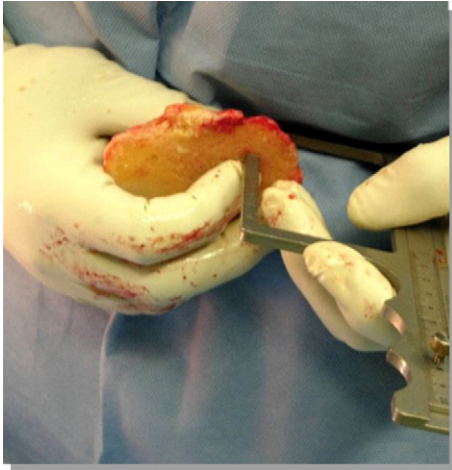


Fig. 1. Calliper measurement of the bone resected from the proximal tibia.

(maximal femoral resection) and the highest and lowest points of the proximal tibial surfaces. The actual resected bone slices were measured by a senior orthopaedic fellow using a Vernier calliper at the diathermy mark for each resected bone slice (Fig. 1). The fellow was blinded to the computer measurement.

The manually measured thickness of the resected bone was then compared to the computer measurements. The mean of the difference for 89 patients was calculated.

3. Results

The results were calculated firstly without consideration of the saw blade thickness. The second calculation allowed for 1.27 mm (the thickness of the saw blade) of bone to have been lost during the cutting process. The results for each patient of the computer measurement of the resection minus the manually verified resection were calculated and a mean of these results is presented in Table 1.

The accuracy of the computer measurement of the physical space left by the bony resection, accounting for the bone lost by the saw blade is within 0.4 mm on average. There were some outlier measurements (Fig. 2a–c), but the majority of data points fell within a range of 1 mm from zero for the distal femoral resection and ‘high side’ of the proximal tibial resection, and 1.5 mm for the ‘low side’ of the proximal tibial resection.

4. Discussion

Pitto et al. [5] have shown *in vitro* with a simulated knee model that an image-free navigation system is accurate to within 1° of rotation. To our knowledge, this is the first study to examine the accuracy of computer calculation of bony cuts *in vivo*. The results show an overall accurate result, however there are a few outliers. This may be due to human measurement error, an intrinsic weakness of the study. The points of the calliper could fall into a small chondral crevice at the point measured. The maximal error may therefore be due to human factors rather than computer inaccuracy in measurement of the same space. Minor inaccuracies in computer navigation may relate to errors in acquisition of the points, such as the probe falling into a cleft at the diathermy mark. Variation of the saw cut within the cutting jig may also result in more or less bone

resection by the surgeon than planned by the computer. The smallest degree of slope in a saw cut can influence computer measurement of the magnitude of resection when the acquisition plate is applied to the cut bony surface.

The accuracy of measurement of the tibial resection was marginally more accurate than that of the femur. Again, this may be an inaccuracy of point acquisition by the computer, or human error. It is possible that there is less accuracy in measuring the maximal extent of the convex surface of the distal femur with a calliper than the deepest concavity of the proximal tibia.

There are many factors which may affect the longevity of total knee replacement prostheses. Three important factors over which the surgeon has influence during the operation are alignment of the implant, balancing bony flexion and extension gaps, and ligament balance.

It has been shown by many previous studies that computer navigation during total knee replacement results in better alignment of the implanted prosthesis [6]. Malalignment of greater than 3° results in higher failure rates [2]. The senior author has shown higher contact stress *intra-operatively* using Tek scan when the knee is improperly balanced during knee replacement [7]. This may lead to increased polyethylene wear and earlier failure. In the normal disease-free knee the lateral side of the knee is physiologically more lax than the medial side [8] suggesting that the flexion and extension gaps in normal knees may not be rectangular. After TKR the laxity of the knee on medial and lateral side is more equal [9]; more rectangular flexion and extension gaps. There is no consensus on the optimal varus–valgus laxity of the ligaments in posterior-stabilised TKR. Aiming for restoration of the natural anatomy is one approach. In the diseased knee, the soft tissues may be contracted as a result of long standing deformity and the implanted prosthesis is more symmetrical than the ‘natural’ anatomy of the non-diseased knee. In this situation accurate bone cuts are important. This study has shown that computer navigation is accurate in measurement of bone resection affecting the extension gap. It is likely, although not proven by this study, that the bone resection of the posterior condyles of the knee is also accurate as none of the 89 knees in this study required further bony resection or resizing of the femoral component to balance the flexion gap. The surgeon may have

Table 1

The mean difference between computer and manual measurement of bone resected during TKR

	Mean of computer minus manual measurement of bone resected without consideration of saw blade thickness (mm)	Mean of computer minus manual measurement of bone resected allowing for loss of 1.27 mm of bone by the saw blade (mm)
Distal femur	1.66 (SD 1.4)	0.39
Highest point of the tibial plateau	1.10 (SD 1.4)	−0.17
Lowest point of the tibial plateau	1.36 (SD 1.3)	−0.09

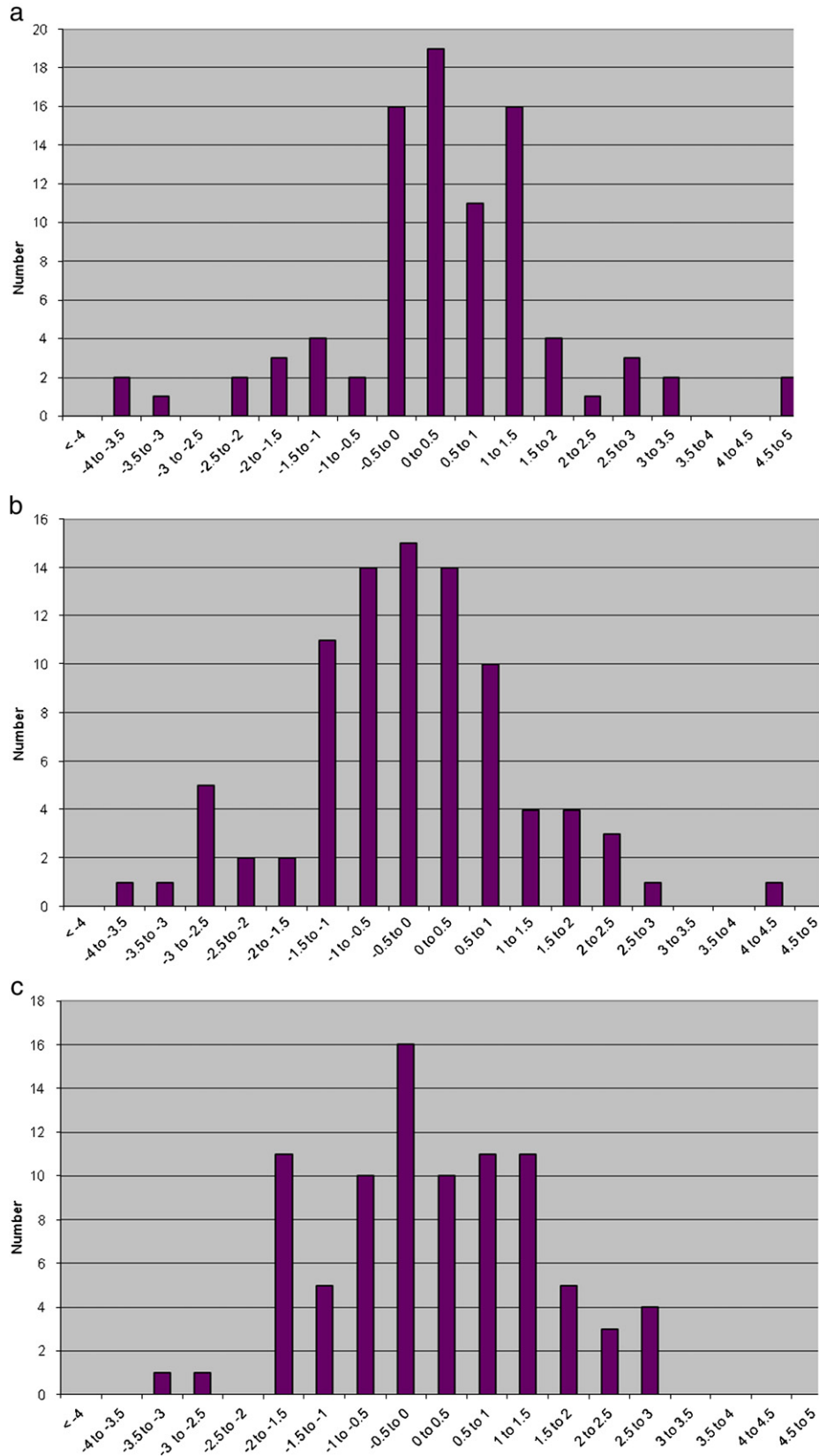


Fig. 2. a) Difference between computer and manual measurement of the maximal distal femoral resection (mm). b) Difference between manual and computer measurement of the ‘high side’ maximal tibial resection (mm). c) Difference between manual and computer measurement of the ‘low side’ minimal tibial resection (mm).

confidence in relying on computer positioning of the jigs for bone resection in TKR.

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