NAVIGATED FREEHAND CUTTING (NFC) OF BONE, A FEASIBLE FUNDAMENTALLY LESS-INVASIVE TECHNIQUE FOR TKR

*Barrera, OA; *Sekundiak, TD; *Garvin, KL; O'Brien, BW; Walker, CW; +*Haider, H
+*University of Nebraska Medical Center, Omaha, NE

hhaider@unmc.edu

INTRODUCTION

Previous studies in Pittsburgh [1] and Nebraska [2] introduced the concept of navigated freehand bone cutting (NFC) with Computer Aided Orthopedic Surgery (CAOS). NFC allows surgeons to cut/reshape bone without using cutting blocks (jigs). Instead, the user reshapes/cuts the bone by following graphical guidance from a computer while bones and cutting tools are tracked in space with navigation technology, similar to GPS navigation. While most efforts on minimally invasive arthroplasty have aimed at reducing the size of jigs, NFC aims to fundamentally reduce the size of the incision and simplify the surgical procedure by getting rid of the cutting blocks altogether. However, the quality of the NFC cuts and their speed should at least match the conventional approach to justify use of this novel concept clinically.

An earlier pilot study [4] evaluated preliminary navigated freehand cuts and compared them with conventional jigs in a pseudo-3D manner. This study presents a new and larger set of experiments which evaluates fully in 3D implant fit and alignment due to bone cutting preparation, as well as surface quality of the bone cut by using NFC. The same parameters were evaluated on bones cut with conventional jigs and the results were compared.

MATERIALS and METHODS

An in-house developed CAOS system was used for freehand-navigated cutting. An infrared system (NDI Polaris system, Canada) was chosen for navigation over other alternatives (electromagnetic, ultrasound, mechanical), because of its immunity to ferromagnetic-magnetic materials and its higher spatial and temporal resolution. The system displays in 3D and track in (semi) real time an oscillating saw, a cuts and compared them with conventional jigs in a pseudo-3D manner. This study presents a new and larger set of experiments which evaluates fully in 3D implant fit and alignment due to bone cutting preparation, as well as surface quality of the bone cut by using NFC. The same parameters were evaluated on bones cut with conventional jigs and the results were compared.

Two experienced surgeons (over 200 arthroplasties/year) and a non expert user performed the experiments. Each cut two bones with jigs and four bones with NFC following the graphical guidance of the computer. The cutting of each whole bone was timed (t) till completion of all surface refinements to adjust for implant fit.

All cut bones were digitized (CT based, at 0.39x0.39x0.65mm resolution in x,y and z axes) and reconstructed in 3D. The five cut surfaces were digitally extracted for each bone for further calculation of surface roughness (Arithmetic average roughness Ra and Rtm, which represented the difference between the means of the highest 10 peaks, and the deepest 10 valleys), translational (Pd) and three rotational (Po) deviations from the desired location of that particular surface.

Pd measured the distance from the centroid of the best fitting plane to the surface to the ideal plane. Po measured the rms of the deviation from the ideal in flexion/extension, varus/valgaus, and internal/external rotations. Implant fitlessness error (F) and location/alignment error (L) were measured after cutting each bone with the navigated implant trial. F represented the maximum play which the implant could undergo purely due to the resulting cut bone shape prior to cementation (if any). It was calculated based on the maximum absolute errors in rotation and translation from the ideal position. L index, which expressed the minimum error in rotations and translations that the achieved cuts permitted after insertion, was calculated as the rms of rotation errors - Lmin (in mm) and Lmax (in degrees).

RESULTS

The results (Table 1 and 2) showed 15% saving in time with navigated freehand compared to using conventional jigs. The freehand cutting produced almost 200% rougher surfaces compared to jigs, with higher peaks and valleys. Fit (F) resulted looser with navigated freehand cutting than with jigs, but the best with freehand navigation was slightly better than that of jigs. Implant location (L) was examined through its errors. No medial/lateral errors were reported because, to increase the effective measurement surface the “implant trial”, it did not have a fixation stem, so there was no constraint on medial-lateral translation, and thus no data in ML errors were applicable. The mean of all errors in AP misalignment with navigated freehand cutting were almost 20% less than with jigs. In flexion-extension, varus-valgaus and internal-external rotation, the mean angular errors were all also much lower with navigation than with jigs. The mean of the flexion-extension alignment errors with jigs reached nearly 4° with jigs, but was lower than 0.25° freehand. The superior overall alignment with navigated freehand was not accompanied by any worse outliers compared to jigs.

DISCUSSION

Previous experiments [2] showed freehand cutting to be 35% faster than conventional. The previous saving in time was partly expended in these experiments by the users utilizing extra navigated tools (implant trial and surface monitor) to improve the quality of their cuts, and improvements in quality were indeed achieved. The higher surface roughness of the navigated freehand does not represent a problem for cemented implants, but it is in the limit for acceptance established in the published literature (1 to 2mm). Future work on the technique is needed towards smoother finishes. With many improvements pending on the NFC technique, it confirms its promise to offer a serious alternative for easier and better minimally invasive arthroplasty.

REFERENCES


Table 1: detailed measurements data

Table 2: compact indexes

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