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Novel Robotic Soft Tissue Protecting Cutter for Bone Resections in Total Knee Arthroplasty

S. Herregodts[a,b], M. Verhaeghe[a], S. Gijsels[a], J. Herregodts[a], P. De Baets[b], J. Victor[a]

[a] Department of Orthopaedic Surgery and Traumatology, Ghent University, 9000 Ghent, Belgium

[b] Department of electrical energy, metal, mechanical construction and systems, Ghent University, 9000 Ghent, Belgium

Introduction: Robot systems have been successfully introduced to improve the accuracy and reduce sever iatrogenic soft tissue damage in knee arthroplasty. Unfortunately to perform complete a complete bone cut, the cutting tool has to slightly pass the edge of the bone. In the posterior zones were retractor protection is impossible this will lead to contact between the cutting tool and the soft tissue envelope. Therefore, complete soft tissue preservation cannot be guaranteed with the current commercial systems.

Methods: This study presents an alternative robotic controlled cutting technique to perform the bone resections during TKA by milling a slot with a long slender high-speed milling tool. The design of the device and application to the proximal tibial cut is shown in Figure 1. The system is composed by a long milling tool driven by a high-speed motor and a protector covering the end of the cutter. The protector is rigidly connected to the motor by the support structure next to the mill, which moves behind the mill in the slot created by the cutter. The protector at the end of the cutter has four functions: providing mechanical support for the mill, preventing soft tissue to come into contact with the cutter, sensing the edge of the bone to accurately follow the shape of the bone and releasing the attached soft tissue. The edge of the bone is sensed by force feedback and with the help of a probing motion the adaptive algorithm enables the protector to follow the edge of the bone closely by compensating for small segmentation and registration errors. A pilot test to evaluate the concept was performed on three fresh frozen knees (Figure 2). The flatness of the resection, the iatrogenic soft tissue damage, the cutting time and the efficiency of the bone contour following algorithm was measured.

Results: An *Rq* flatness of 0.10±0.03 mm and the *Rt* flatness of 0.52±0.08 was obtained. The MASTI score for soft tissue damage was 34.11±1.0 resulting in two A scores and one B score. The active contour following algorithm was capable of predicting the physical location of the bone three times more accurate compared to the initial surface based registration (1.51±0.31 mm to 0.44±0.29 mm). The cutting time was 106±7 s.

Discussion: The mean flatness was about three times better compared to the oscillating saw and in line with other active robots using a mill. In contrast to other orthopaedic robotic systems with a rotating cutter, this technique enables performing each resection in TKA in one movement. Therefore the new approach was significantly faster compared to other active robotic systems using a mill. Because of the active shielding of the cutter, only very little superficial soft tissue was observed. Furthermore, the adaptive bone contour approach opens the possibility for imageless active robotic knee arthroplasty.

Conclusion: The promising results of this pilot study demonstrate the potential of the novel soft tissue protecting cutter by combining the accuracy of a cylindrical mill with an active soft tissue protection while reducing the cutting time.

Figures

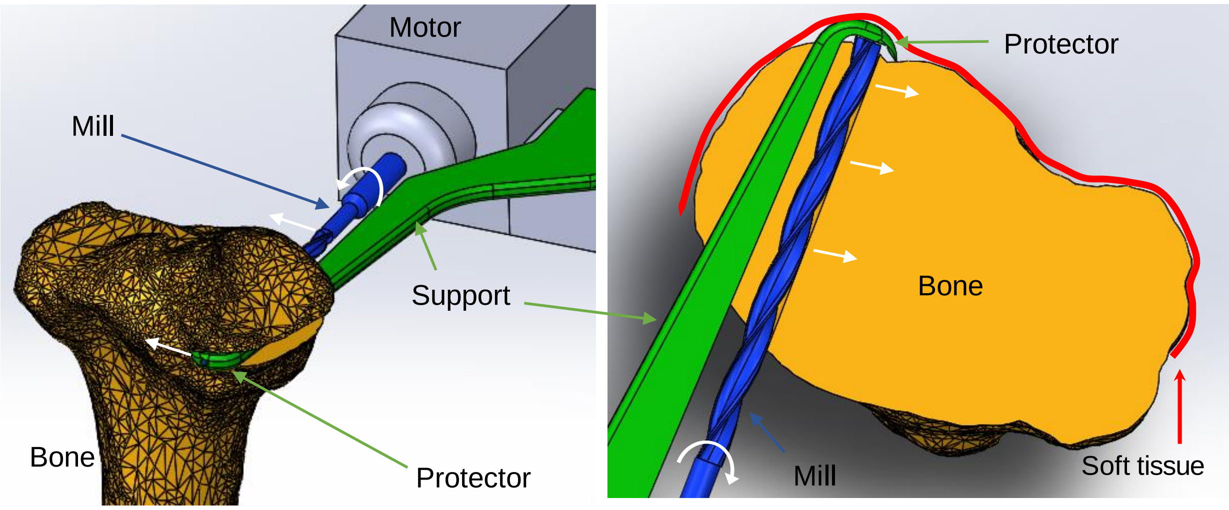

Figure 1. Concept ligament protecting cutter

(a) (b)

Figure 2. (a) cutting tool approach, (b) resection in progress