Development and Characterization of a Novel Ultrasonic Cutting Tool for Osteotomy

Oskar F. Okaya

Supervisor: Dr. Martin Hofmann
Institution: University of Bern, School of Biomedical and Precision Engineering
Examiners: Dr. Martin Hofmann, Prof. Dr. Jürgen Burger

Introduction

Ultrasonic systems for osteotomy make use of the piezoelectric effect to drive a cutting tool at ultrasonic frequency. Due to the high frequency but low amplitude, ultrasonic cutting tools for osteotomy are tissue selective and do not affect soft tissue [1]. This makes them an attractive alternative to traditional osteotomy tools, especially for spine surgeries in proximity to the dura mater. The drawbacks of most ultrasonic cutting tools are thermally induced osteonecrosis due to elevated temperatures during cutting [1, 2], and an excessive bone tissue loss due to comparatively thick cutting blades. The aim of this project was to assess the feasibility of an internally cooled cutting blade and investigate the influence of blade design on cutting performance. Furthermore, a state-of-the-art ultrasonic cutting tool (Misonix MXB-25, Bioventus, USA) was characterized to provide a benchmark for future blade design.

Materials and Methods

Seven different types of cutting tools have been designed and 3D-printed from 316L stainless steel using selective laser melting (Fig. 1). After inspecting the manufacturing quality microscopically, the prototypes were electromechanically characterized using impedance analysis and laser Doppler vibrometry, along with an irrigation flow rate test. In addition, thermal performance and cutting speed were evaluated using infrared imaging and free-hand cuts on synthetic bone tissue.

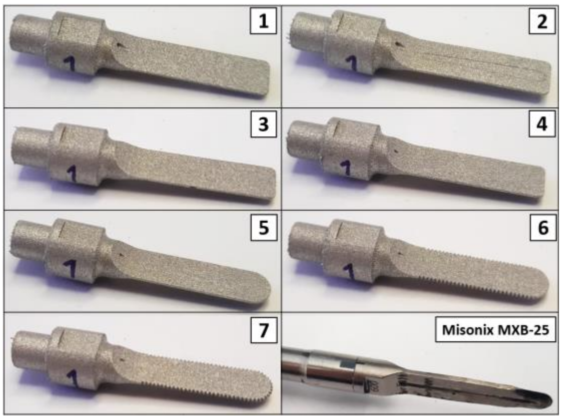

Fig. 1 3D-printed 316L stainless steel cutting tool prototypes (1-7) and Misonix MXB-25 cutting tool.

Results

A functional cooling channel (H: 0.2 mm) spanning the entire length of a 0.5 mm thick cutting tool blade was manufactured (Fig. 2). Testing the prototypes with lateral and longitudinal cuts in 42PCF *SynBone* samples (Fig. 2) revealed no significant differences in cutting speed or thermal performance. Average cutting speeds were about three times slower in longitudinal and only half as fast in lateral cutting direction compared to the Misonix MXB-25.

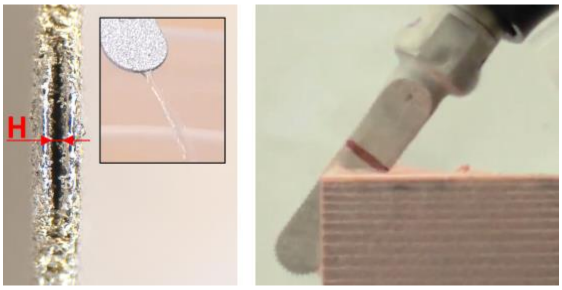

Fig. 2 Internal cooling channel (left) and cutting of 42PCF SynBone sample with the manufactured prototypes (right).

Discussion

The reduced blade thickness by factor two compared to the Misonix MXB-25 contributes to a considerable reduction in bone tissue loss and the internal cooling channels open up new possibilities to counter thermally-induced osteonecrosis. The cutting and thermal performance tests may be improved by implementing force controlled cutting and bone-sample-embedded thermocouples. Despite the slower cutting speeds, the manufactured prototypes are a valuable proof-of-concept for future cutting tool research.

References

[1] Hu X. et al. *Use of an ultrasonic osteotome device in spine surgery: experience from the first 128 patients*. Eur Spine J. 2013 Dec;22(12):2845-9. doi: 10.1007/s00586-013-2780-y.

[2] Tarazi N. et al. *Comparison of thermal spread with the use of an ultrasonic osteotomy device: Sonopet ultrasonic aspirator versus misonix bonescalpel in spinal surgery*. J Craniovert Jun Spine 2018;9:68-72. doi: 10.4103/jcvjs.JCVJS_16_18.

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