Design and Fabrication of Side-cutting Micro Saw for Harvesting Autologous Donor

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Aims: Osteoarthritis (OA), the most common joint disorder, affects 528 million people worldwide [1], primarily damaging limb joints by degrading avascular cartilage, which heals poorly and often requires surgery. Mosaicplasty, an autologous transplantation technique using small cylindrical plugs of bone and cartilage (Fig.1 left), is a common surgical option. Due to limitations in root-side donor cutting, only small plugs that can be cracked out are typically harvested. To overcome this, we developed a root-side bone cutting mechanism capable of harvesting pre-shaped autografts. This work presents the preliminary design and fabrication of a micro saw with transverse blades.

Materials and Methods: Fig. 1 middle shows the micro saw mechanism operating through guide tubes. Key design requirements included: compact size (~1 mm diameter) to fit inside guide tubes, and blades aligned perpendicular to the motion path for root-side bone cutting. The resulting prototype resembles a miniature timing belt with transverse blades oriented perpendicular to the gear teeth.
Fabrication involved electroplating and two-step photolithography on a 3-inch oxidized silicon wafer. An Au/Ti layer was deposited via e-beam evaporation, followed by spin-coating AZ 40XT photoresist at 800 rpm for 30 seconds. The photoresist was soft baked at 75°C, 105°C, and 125°C in sequence and exposed using an EVG aligner, with patterns developed in AZ300MIF.
A nickel seed layer was electro-deposited at 10 mA/cm² for 10 minutes to form a conductive base, followed by nickel plating using a sulfamate solution (pulse current 10 mA/cm², duty cycle 0.5, at 55°C). The photoresist mold was removed with acetone. The same process was used to form the top layer for the driver teeth. Final saw segments were released by etching the Au/Ti layer. The 200-µm-thick nickel micro saw demonstrated sufficient flexibility for curved cuts. Driver components were fabricated using the same method.

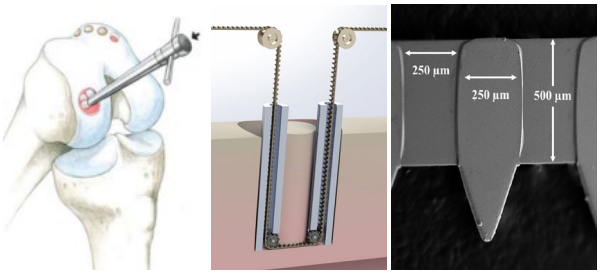

Fig. 1 (left) Mosaicplasty procedure [2], (middle) CAD model illustrating the novel micro saw cutting root side of the profile drilled donor. (right) SEM images of the fabricated micro saw.

Results: A novel nickel micro saw prototype was fabricated using photolithography and electroplating to enable the extraction of customized autografts for osteochondral autologous transplantation. The saw features teeth oriented perpendicularly to its motion axis, allowing effective cutting at the root side of the donor site. With dimensions of approximately 200 µm in thickness and 750 µm in width, the micro saw operates within a narrow drilling path of less than 1 mm.
Scanning electron microscopy (Fig. 1 right) confirmed successful fabrication. Mechanical testing via micro-indentation showed an elastic modulus of 209 ± 2.04 GPa and hardness of 6.39 ± 0.0940 GPa - both significantly exceeding the mechanical properties of human bone. To validate its cutting capability, an in vitro test was conducted on animal bone using a custom-built test rig that incorporated a microcontroller and standard hardware components.

Conclusions: A novel nickel micro saw with integrated driver teeth has been successfully fabricated and validated for bone-cutting applications. Its compact dimensions - 750 µm in width and 200 µm in thickness - enable navigation through guide tubes along donor profiles narrower than 1 mm [3]. The saw operates with rotational or oscillatory motion perpendicular to the cutting direction, enabling precise transverse cuts on the root side of the donor site. This functionality supports the extraction of preoperatively planned bone-cartilage grafts for autologous transplantation, offering a promising solution for the surgical treatment of severe osteoarthritis.

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