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The evolution from ultrasonic dental scaling to bone surgery

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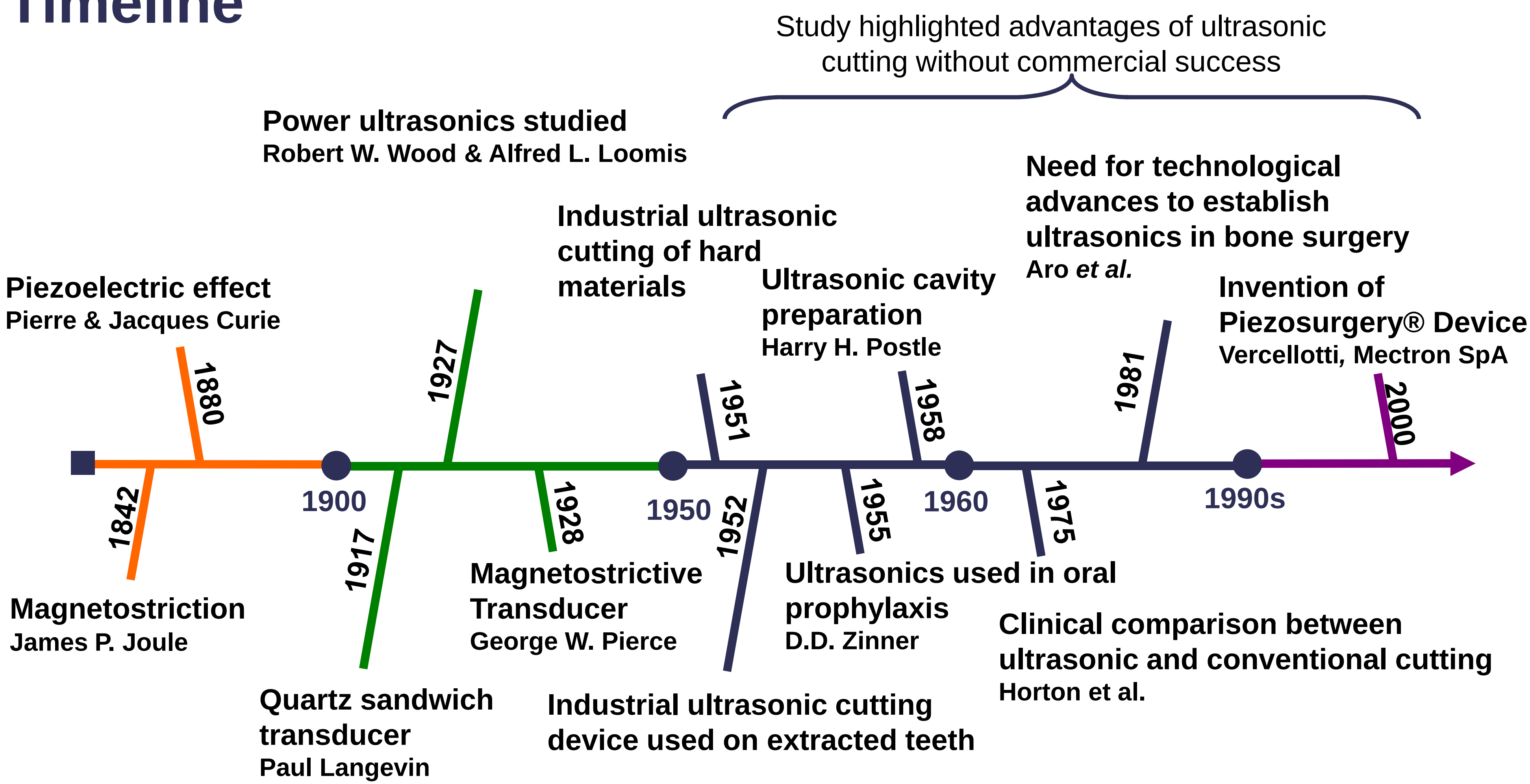
Timeline


Study highlighted advantages of ultrasonic cutting without commercial success
Piezoelectric effect
Pierre & Jacques Curie
1880
1842
Magnetostriction
James P. Joule
1900
Power ultrasonics studied
Robert W. Wood & Alfred L. Loomis
1927
1917
Quartz sandwich transducer
Paul Langevin
1928
Magnetostrictive Transducer
George W. Pierce
Industrial ultrasonic cutting of hard materials
1951
1950
1952
Industrial ultrasonic cutting device used on extracted teeth
Ultrasonic cavity preparation
Harry H. Postle
1958
1955
Ultrasonics used in oral prophylaxis
D.D. Zinner
1960
1975
Clinical comparison between ultrasonic and conventional cutting
Horton et al.
Need for technological advances to establish ultrasonics in bone surgery
Aro et al.
1981
1990s
Invention of Piezosurgery® Device
Vercellotti, Mectron SpA
2000

Dental prophylaxis

→ Commonly known as dental scaling

→ Remove plaque and calculus

- can lead to tooth gingivitis, periodontal disease and tooth loss

→ Traditionally a manual hand instrument is used

→ Advent of ultrasonic devices in 1950s

- Scaling tips vibrating in a resonance mode
- Quicker at removing plaque and calculus deposits
- Enhanced patient comfort

Oscillating scalers

Sonic

- Frequency range: 2.5 to 16 kHz
- Compressed air drives a turbine

Ultrasonic

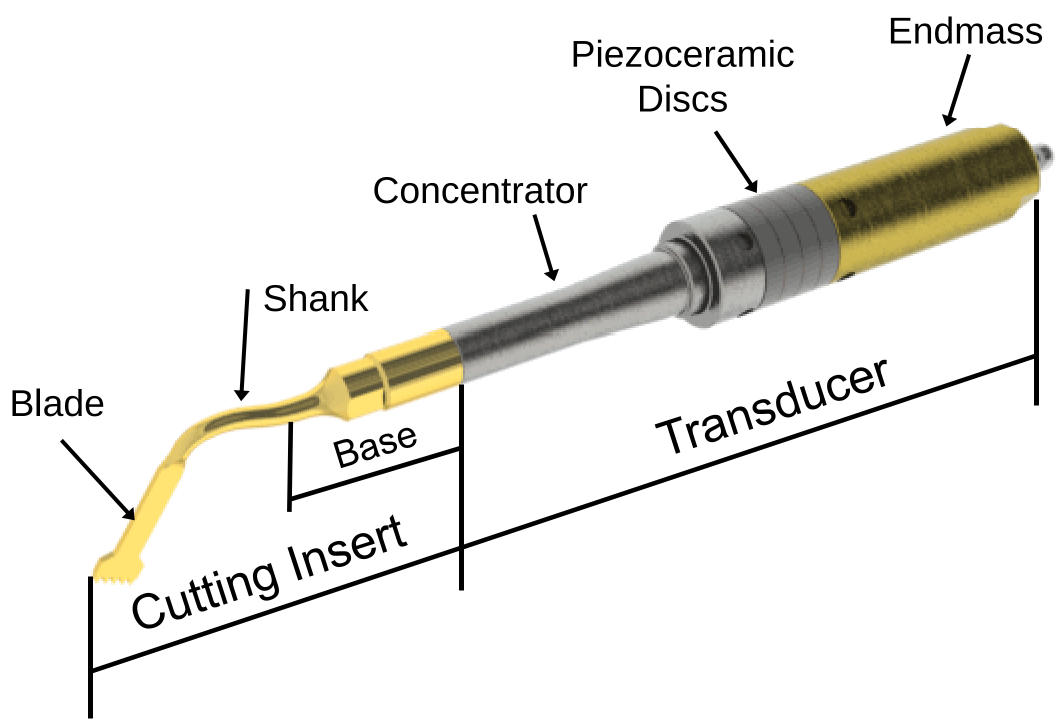
Piezoelectric effect

- Frequency range: 20 to 45 kHz
- Standing waves are generated through an AC voltage applied to a piezoelectric stack
- PZT (Lead Zirconate Titanate)

Magnetostrictive effect

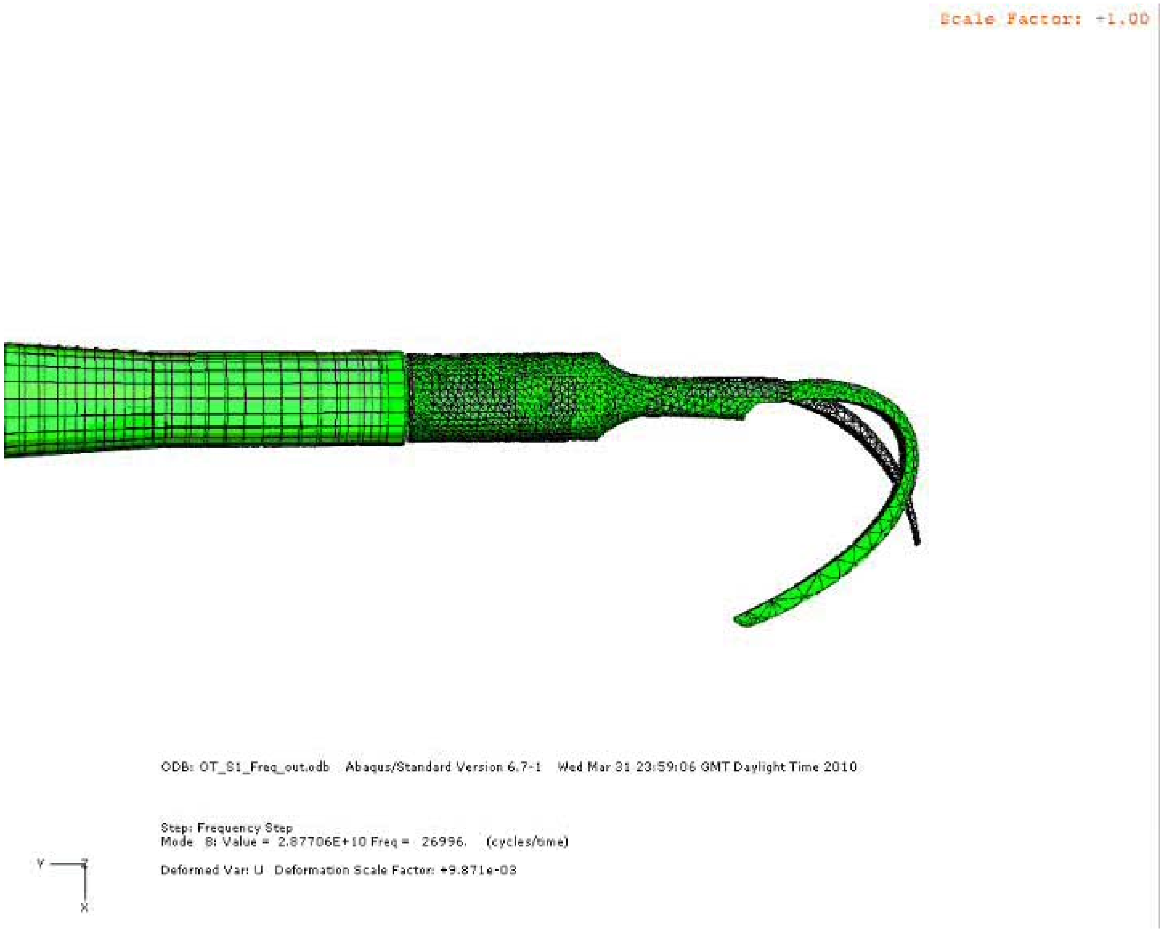
- Frequency range: 20 to 45kHz
- Changing magnetic field induces dimension changes in ferromagnetic material
- Iron, cobalt, nickel

Tuned transducer and insert assembly



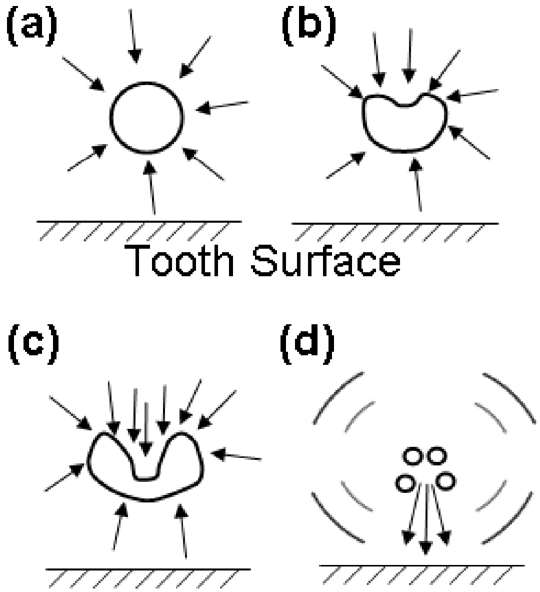
Finite element (FE) analysis:

Motion of ultrasonic scaler



Ultrasonic cleaning process

- Mechanically dislodged through deformation of tip
- Heating of insert and tooth surface
  → Coolant solution required
- Fluid washes away dislodged particles
- Microstreaming and cavitation are present



(a) Bubble is subjected to high pressures caused through dynamic loading

(b)-(c) Bubble deforms due to pressures

(d) Bubble implodes releasing shock wave and water jet

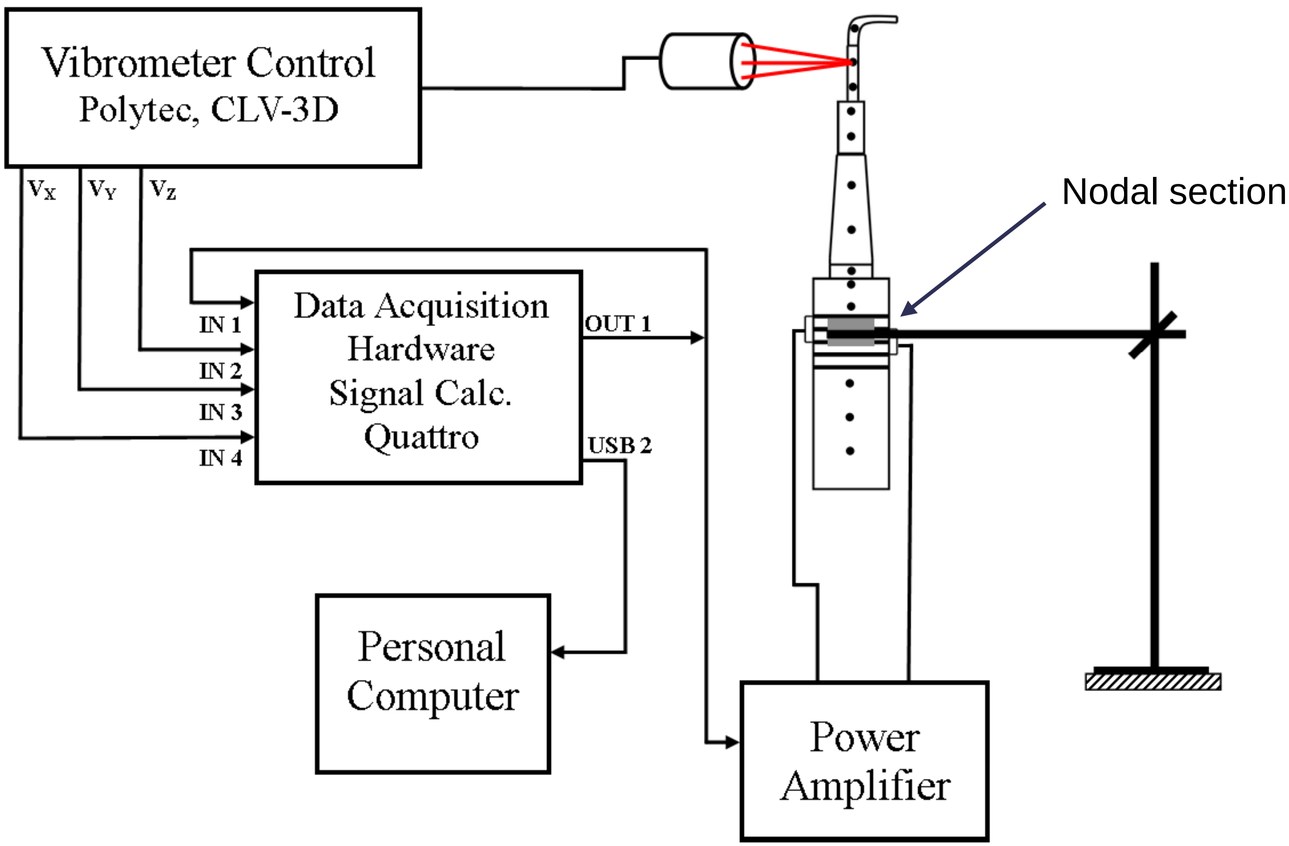
Modified from Laird and Walmsley J. Dent. 19, pp14-17, 1991.

Mectron scaling inserts

- semi-circular cross-section: designed to work on large tooth areas
- triangular cross-section and rounded surface: designed for interproximal scaling

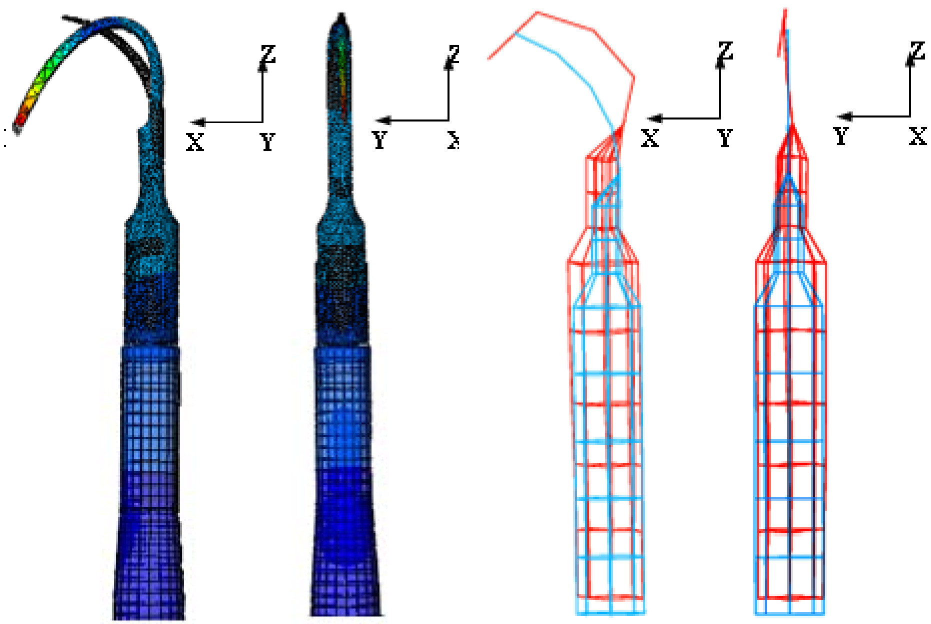
Experimental modal analysis (EMA)

➡ Used to validate finite element methods



FE modelling & EMA validation of scalers

S1 Insert

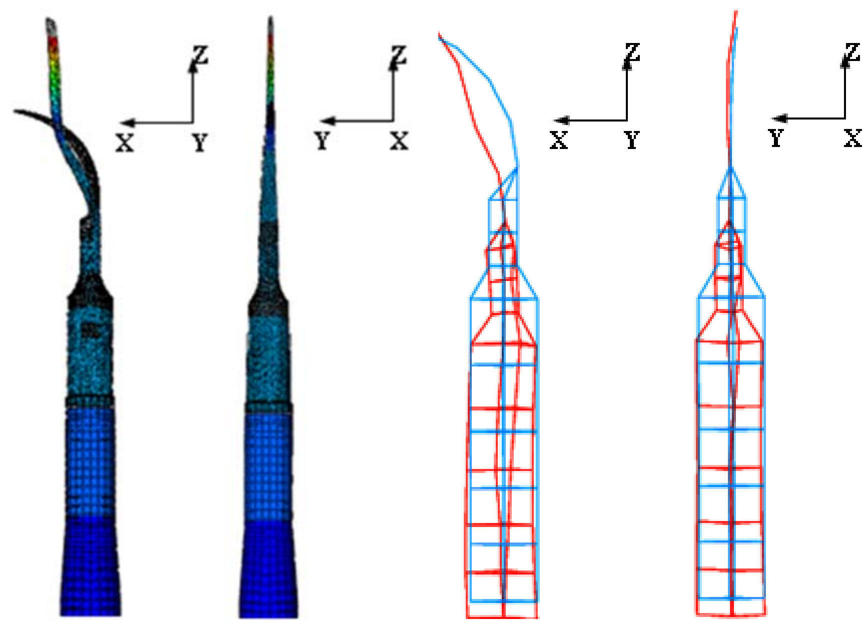


FEA
f_r = 26996Hz

42.5 microns

EMA
f_r = 27257Hz

S2 Insert



FEA
f_r = 27151Hz

51.2 microns

EMA
f_r = 28249Hz

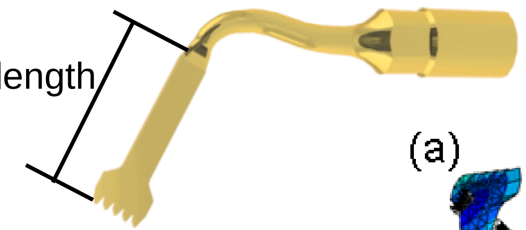
Evolution of Mectron cutting blades

- Scalpel design
- Born out of scaler insert
- Different cuttinng edge design

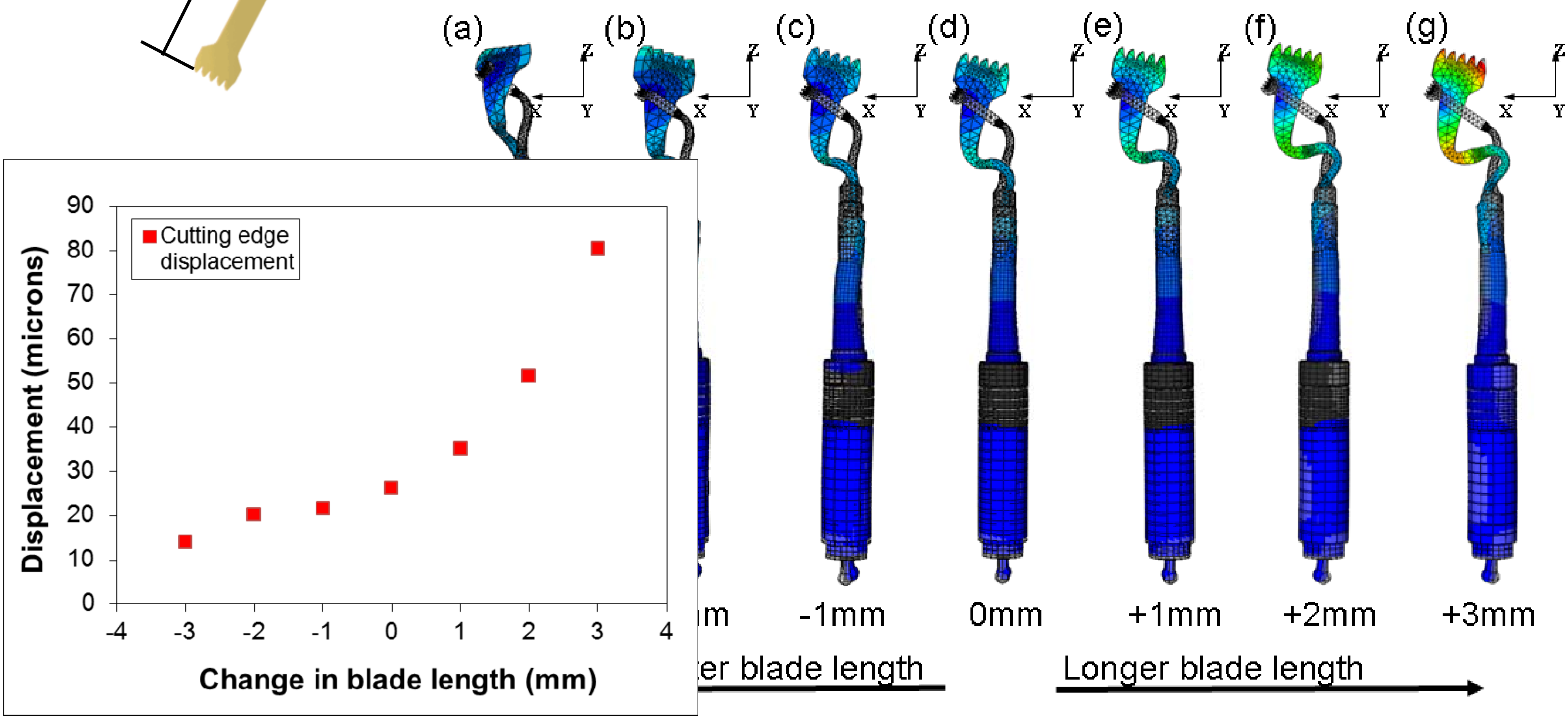
- Modified shank from high amplitude scaler
- Cutting saw edge

- Increased blade length for increased cutting depth

FE optimisation of cutting blade

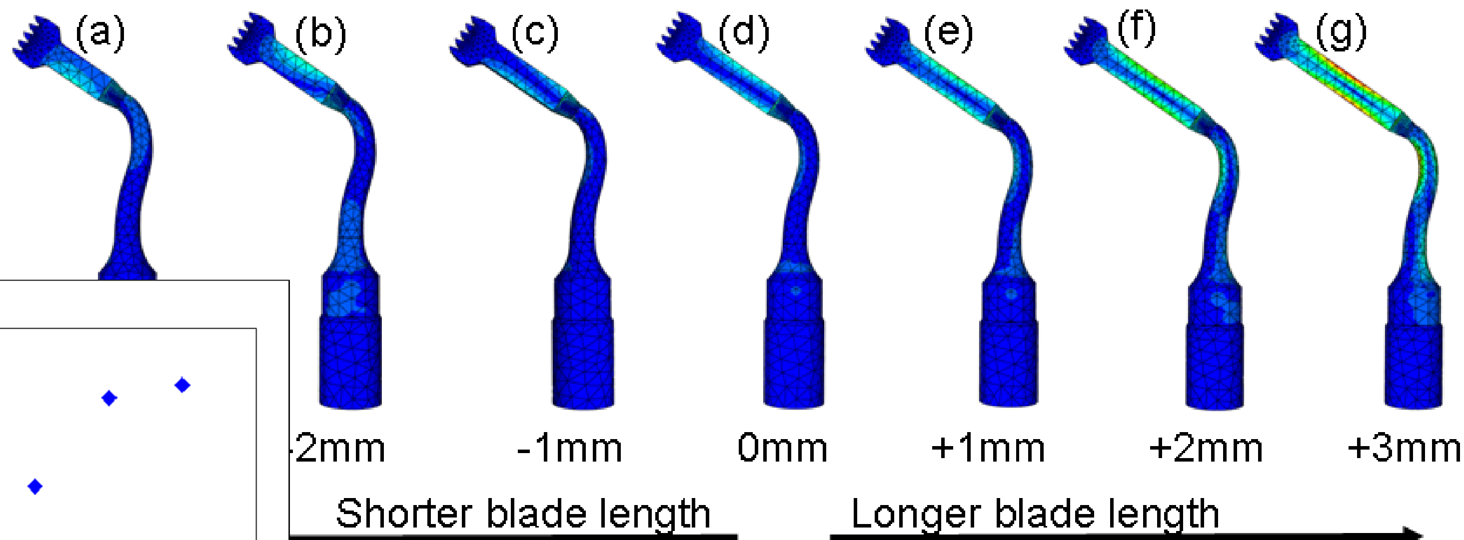


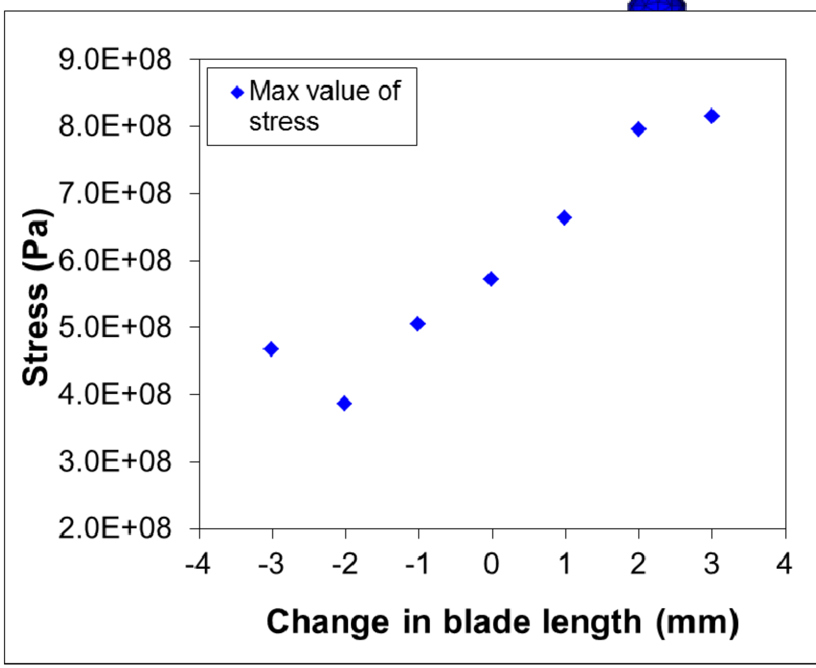
Predicted displacement



FE optimisation of cutting blade

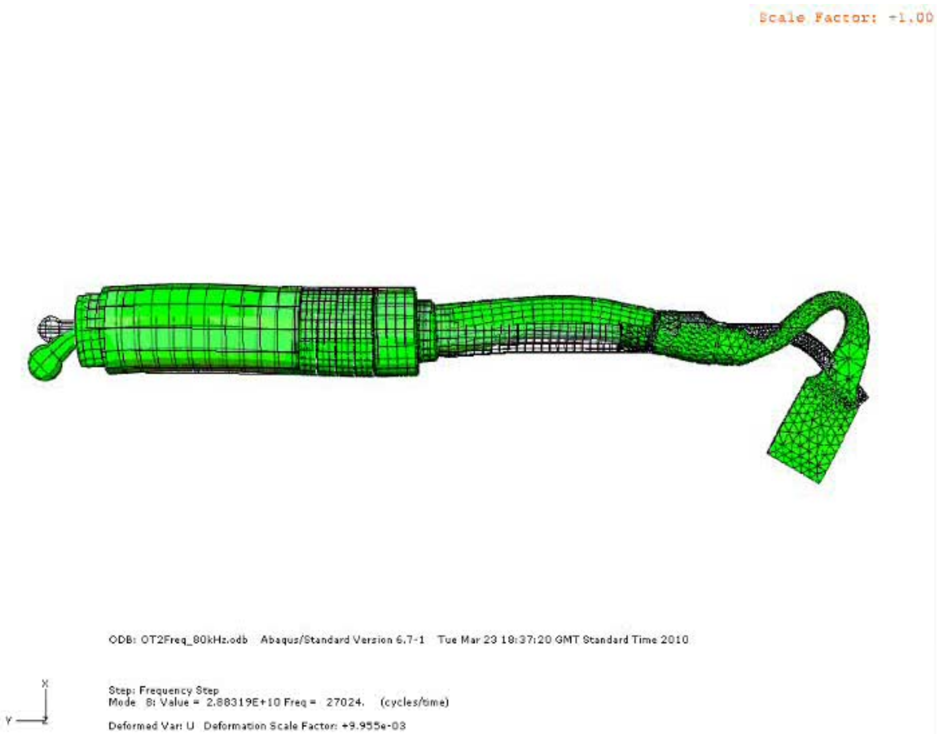
Predicted stress

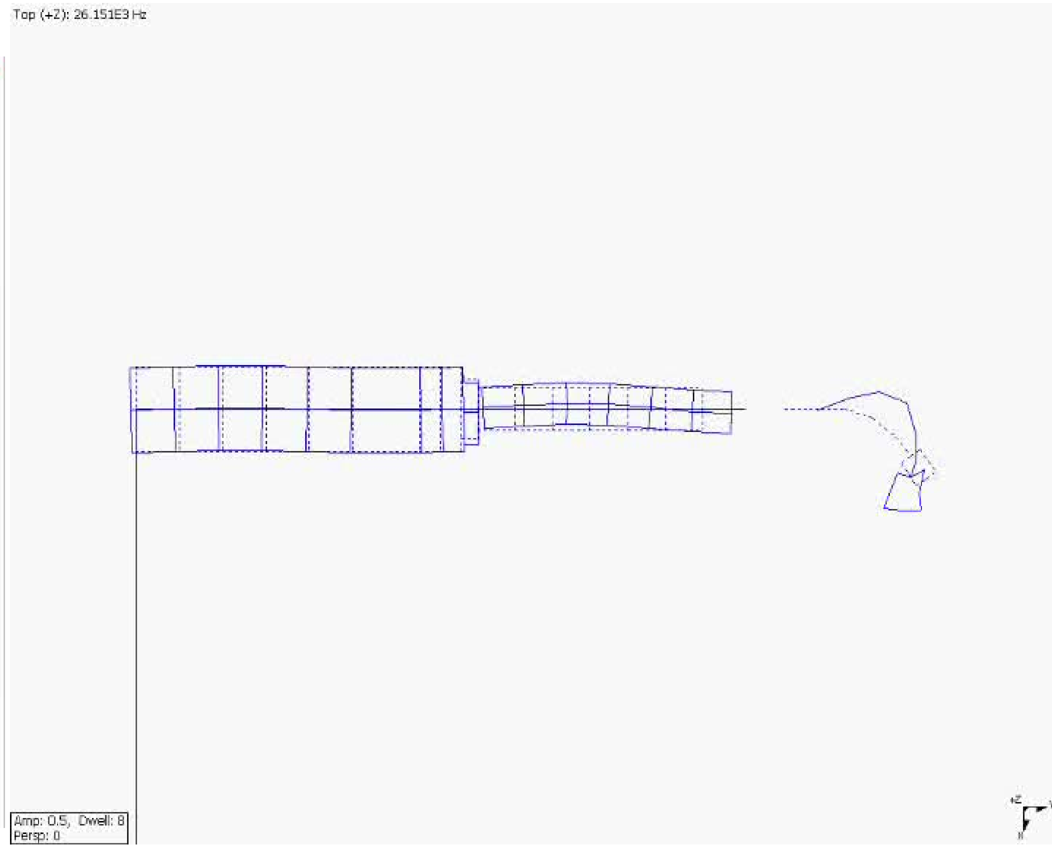




Finite element & experimental modal analysis

Transducer with OT2 insert





FEA

f_r = 26151Hz

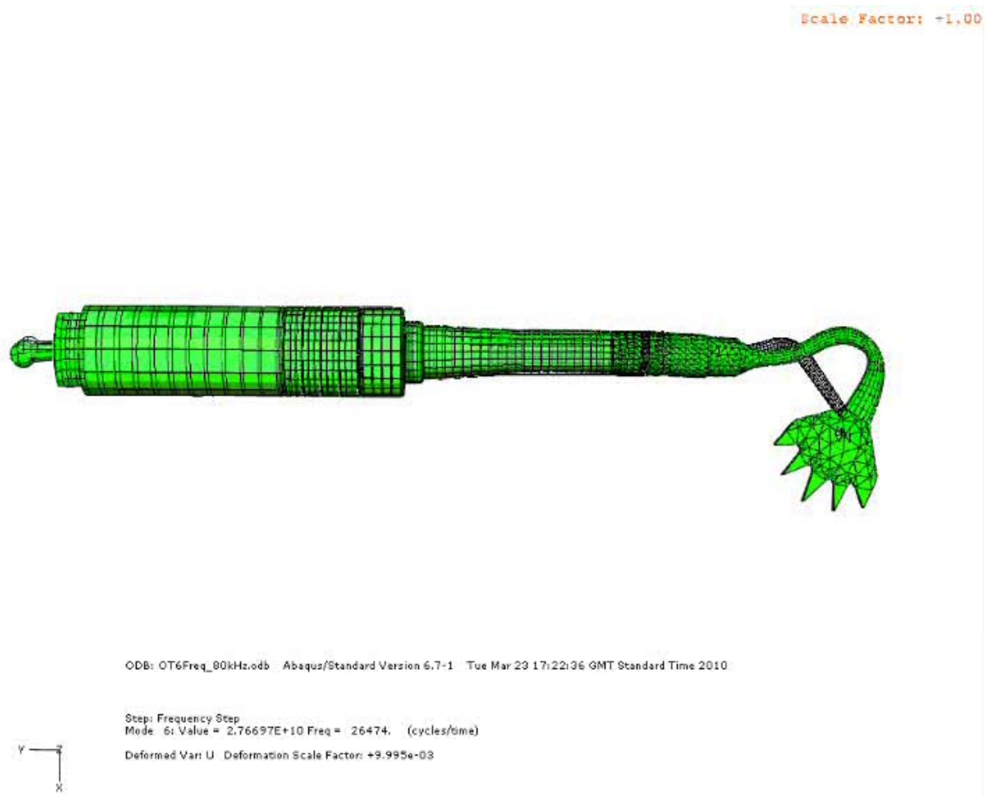
D = 28.6microns

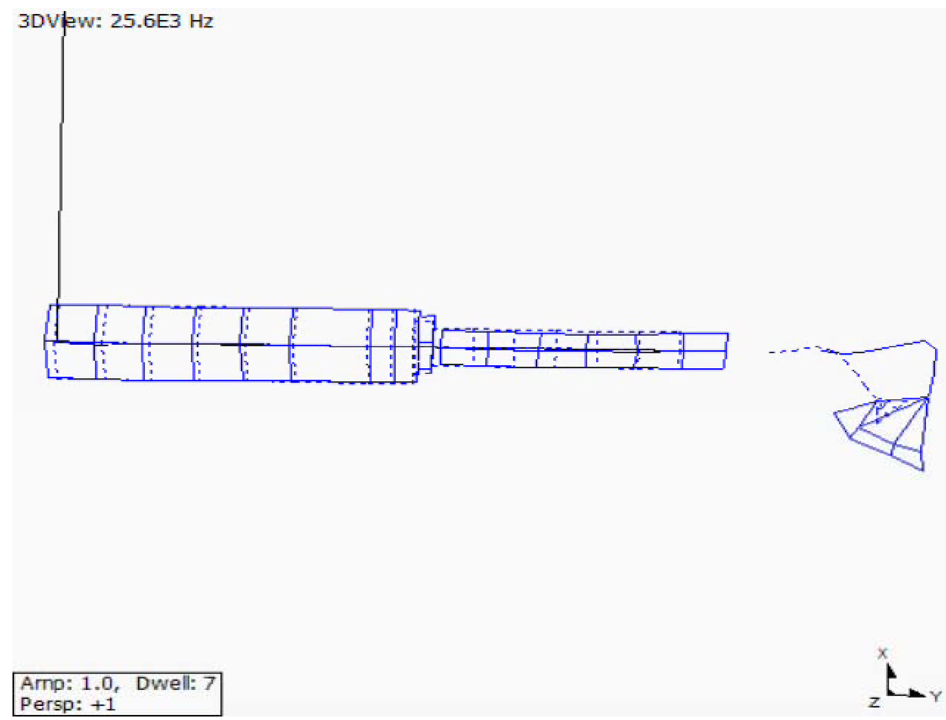
EMA

f_r = 27030Hz

Finite element & experimental modal analysis

Transducer with OT6 insert





FEA

f_r = 26475Hz

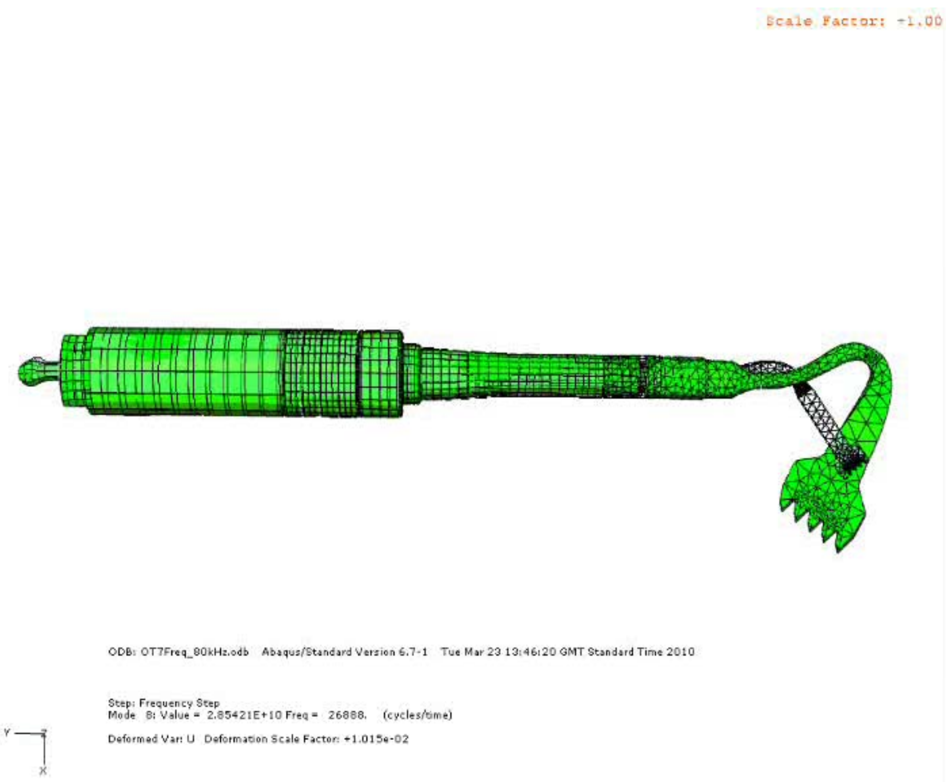
D = 32.2microns

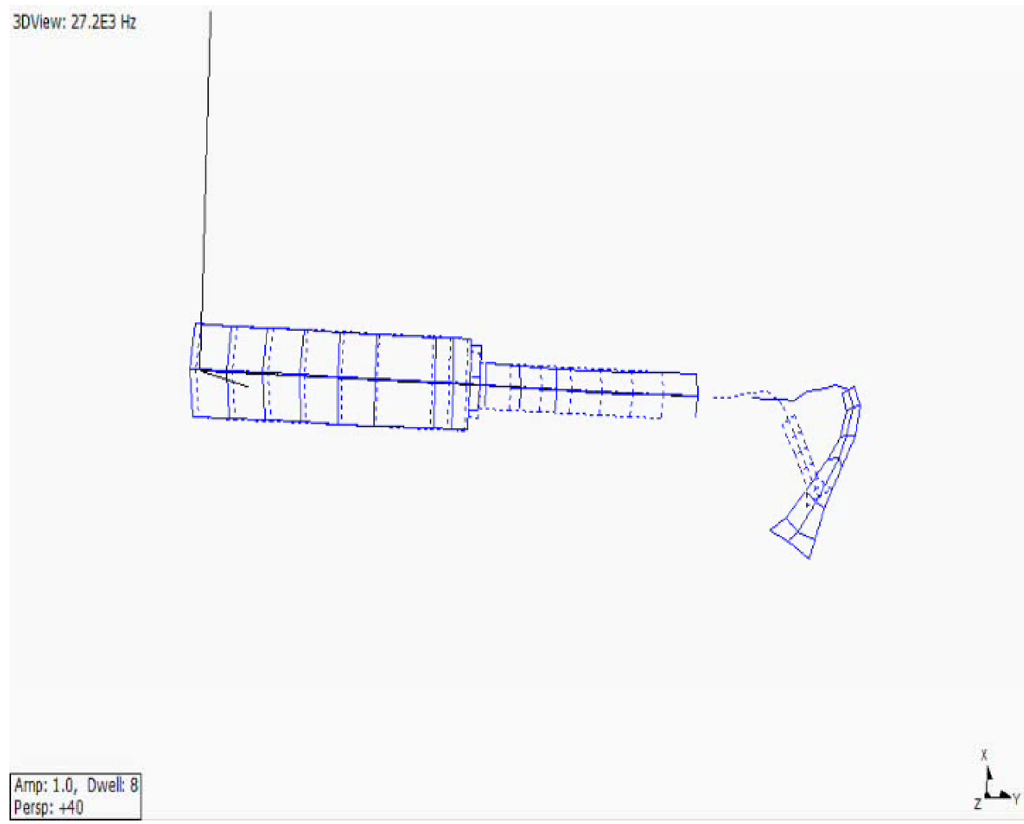
EMA

f_r = 25630Hz

Finite element & experimental modal analysis

Transducer with OT7 insert





FEA

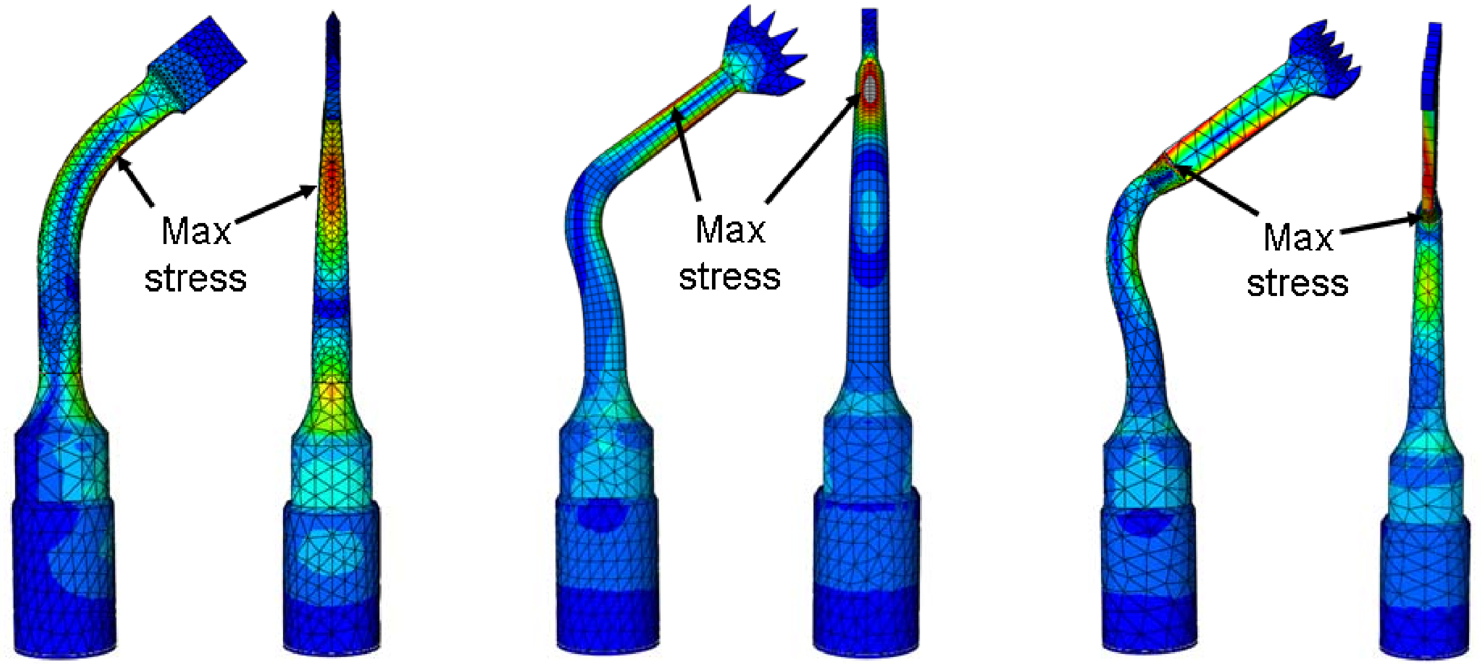
f_r = 26889Hz

D = 31.3microns

EMA

f_r = 27190Hz

Predicted stress in cutting inserts



OT2
Max stress = 223MPa

OT6
Max stress = 274MPa

OT7
Max stress = 573MPa

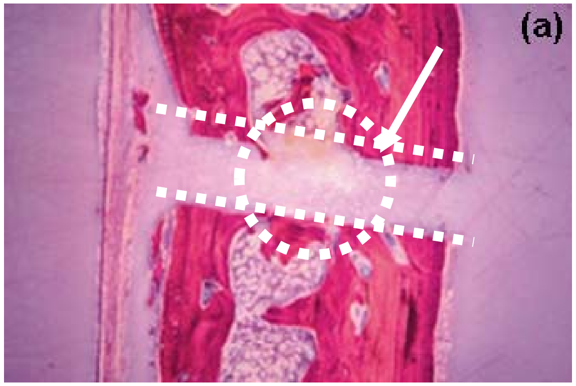
Clinical benefits from Ultrasonic bone cutting

Different methods of cutting bone

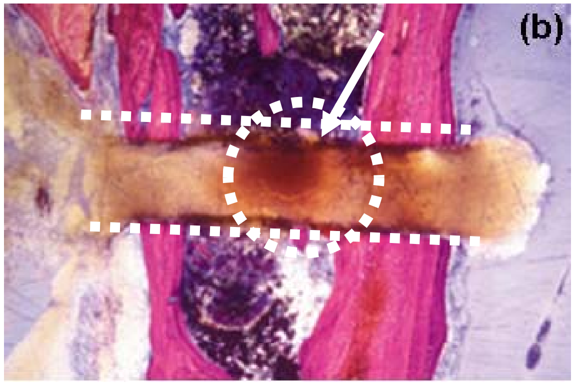
- Bone bur, bone saw, ultrasonically
  → Macrometric vs micrometric vibrations
- Small deformations can not cut soft tissue
- High precision
- Easy to hold in to position
  → Low loading to working area

Dissected bone: cutting tool comparison

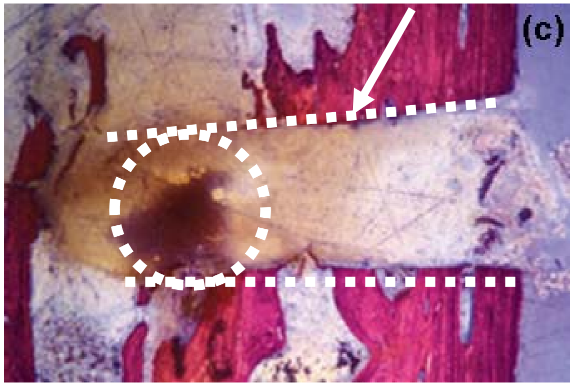
Representative histologic photomicrographs of decalcified specimens characterizing the appearance of the cut edges of osteotomy incisions baseline



Ultrasonic instrument



Bone bur

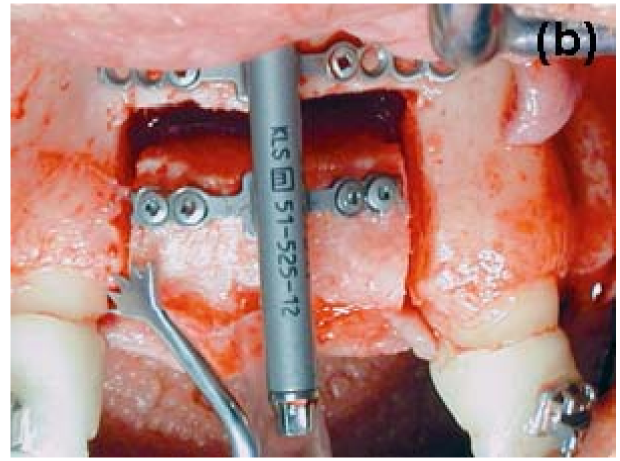


Bone saw

- Precise, clean cut
- Discolouration: Osteonecrosis
- Darkened edges: Reduced vascularisation

Clinical procedures

Sinus lift, window preparation



Osteotomy (cutting) of large bone section

(a) Sinus lift: increases the bone volume in the maxillary (upper jaw bone) sinus

→ **Advantage**: reduced chance of lacerating the Schneiderian membrane.

(b) Osteotomy: Multipiece maxillary osteomies (shortening or lengthening of the upper jaw bone)

→ **Advantage**: increased level of osteoblasts

Summery

- Validation of FE scaling and cutting insert models with experimental modal analysis
- Dimension optimisation of a tuned cutting insert
- Comparison between ultrasonic cutting and convensional methods
- Clinical evidence of procedure enhancement using ultrasonics

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Thank You for listening

Questions?

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