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Ultrasonics in Dentistry

Damien Walmsley

UIA 2011

Objectives

- *Background of dental ultrasonics*
- *How they work*
- *How they are used in dentistry*
- *Future directions*

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Frequency of Ultrasound

Ultrasonic scalers

25 to 40 kHz

Sonic scalers

2 to 6 kHz

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Ultrasonic Scalers

1950 - 1955

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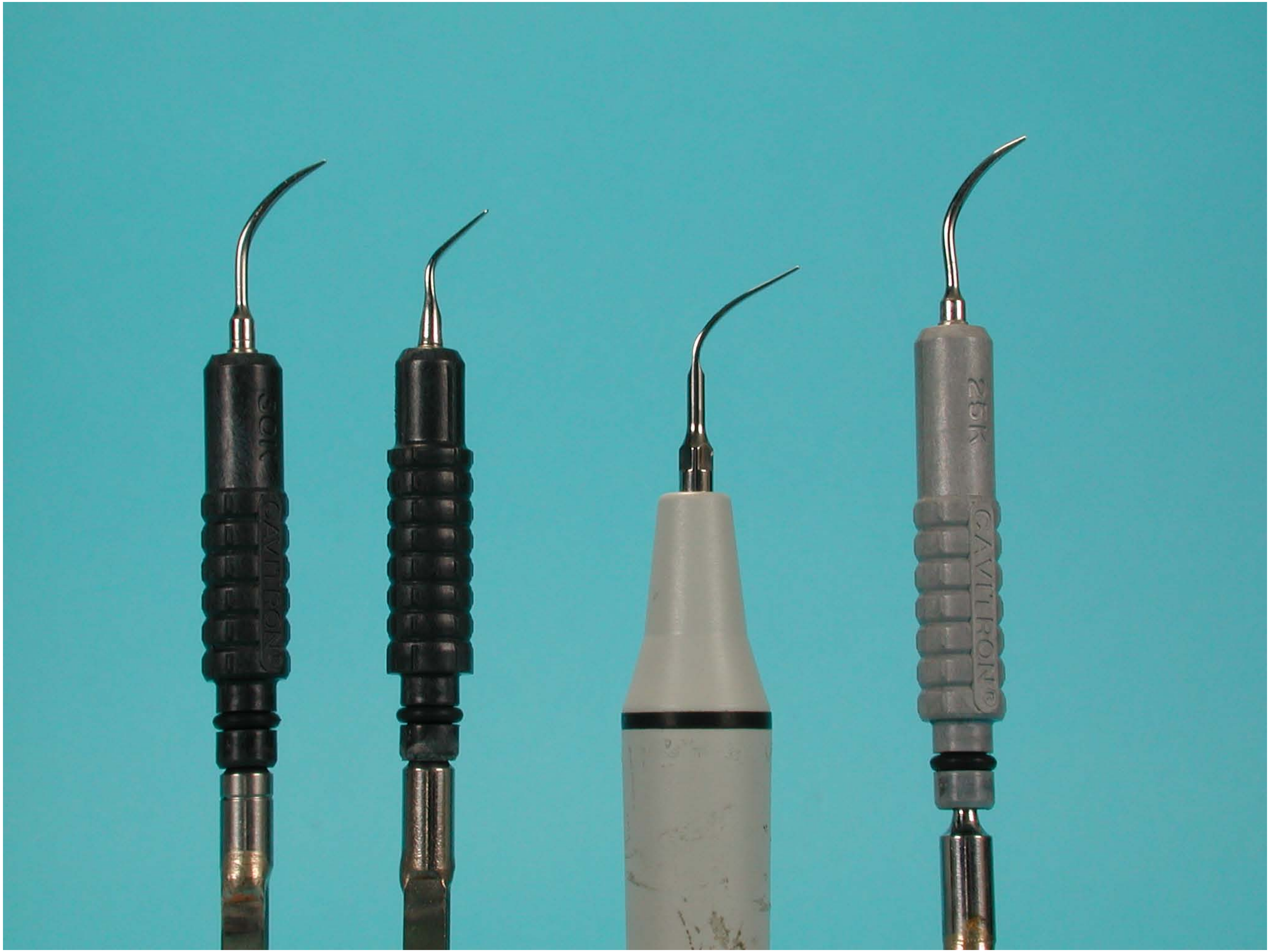

30K
CAVITRON
25K
CAVITRON®

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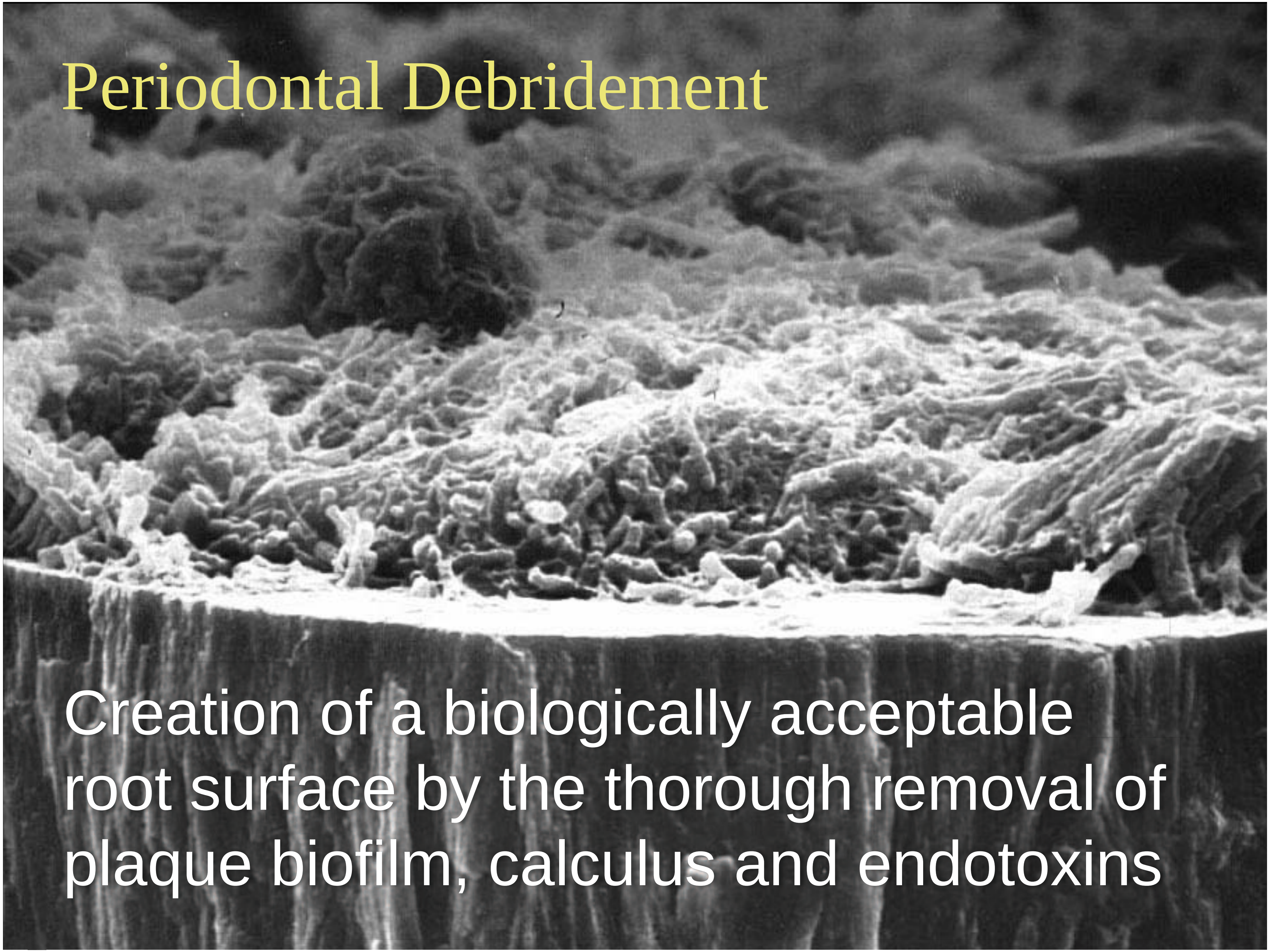
Bacterial Biofilm
Removal of Calculus/Cementum

Periodontal Debridement



Creation of a biologically acceptable root surface by the thorough removal of plaque biofilm, calculus and endotoxins

Successful Debridement

In teeth - thorough Instrumentation

- Ability to contact root surface
- Efficacy of deposit removal
- Efficiency of deposit removal
- Effect on root surface
- Patient comfort
- Ergonomic

Then …..

1957

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…. NOW !!!

2010

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Ultrasonic Technologies

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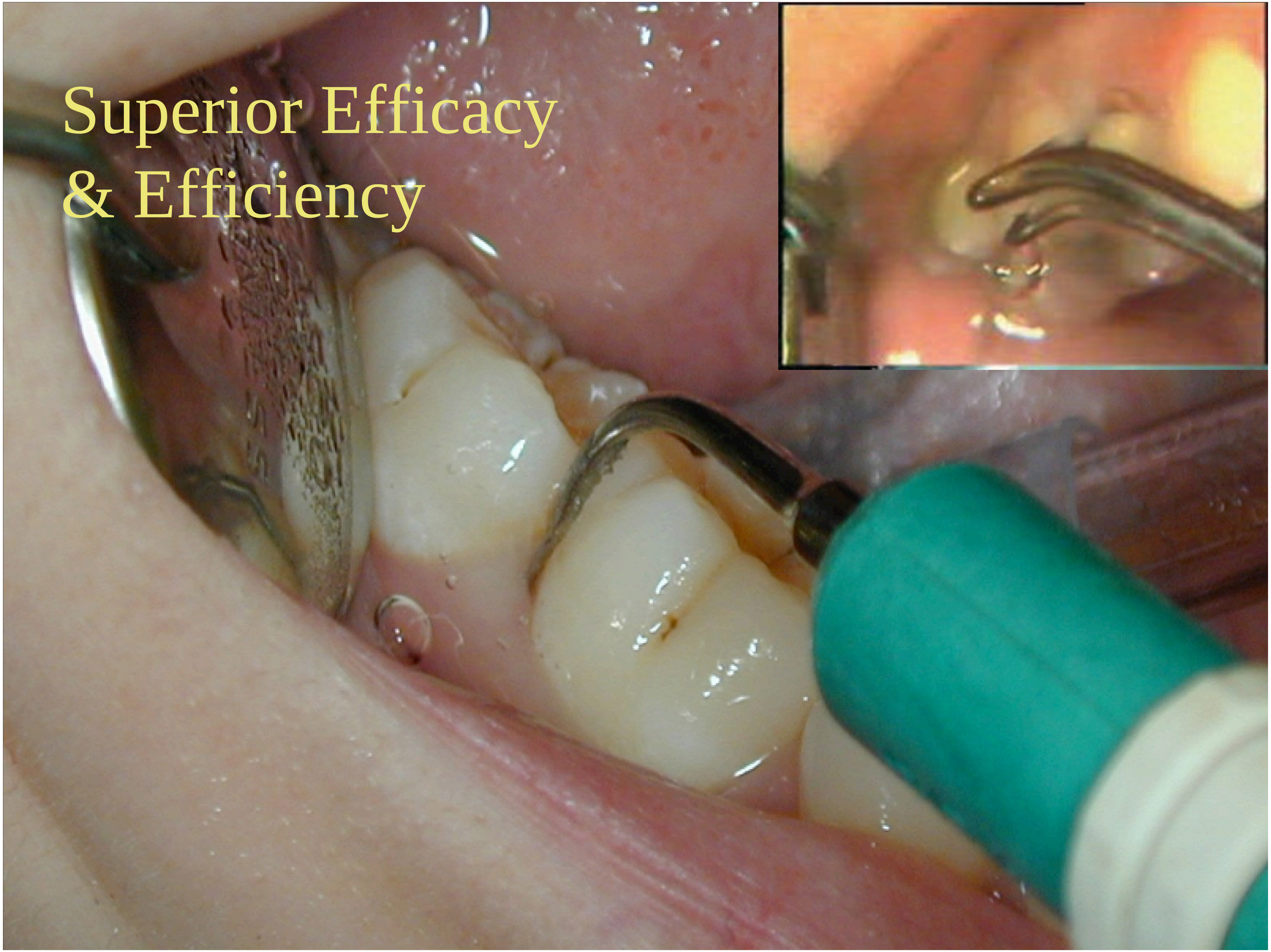
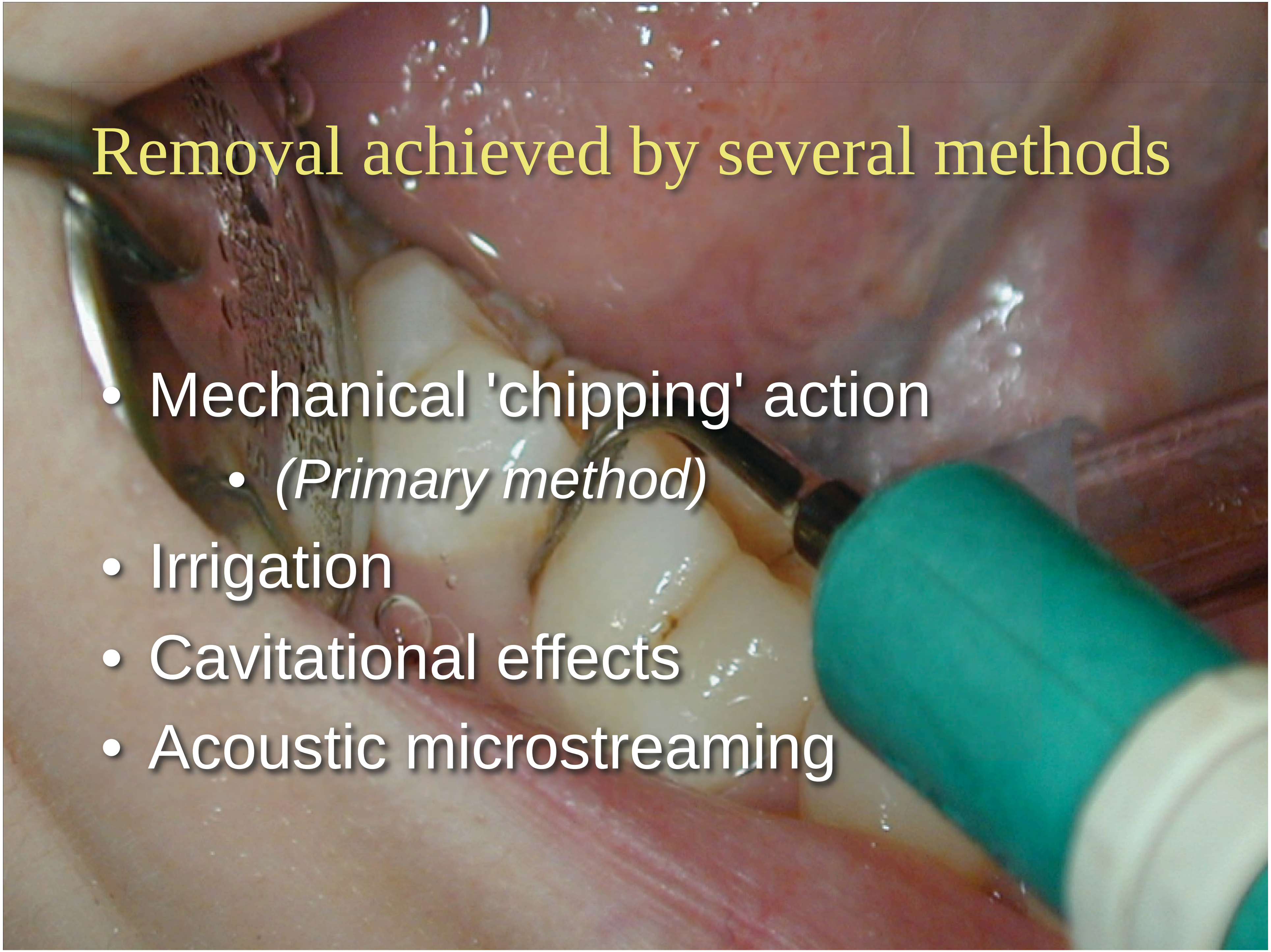

Superior Efficacy
& Efficiency

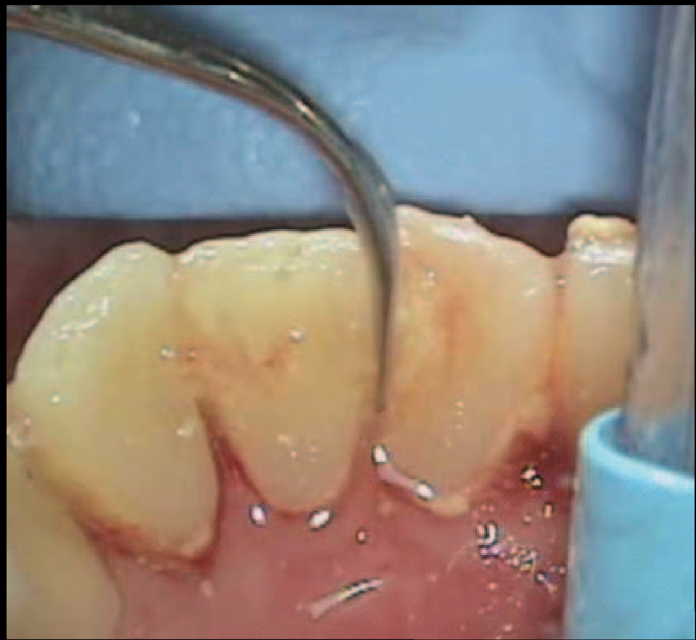


Removal achieved by several methods

- Mechanical 'chipping' action
  - *(Primary method)*
- Irrigation
- Cavitational effects
- Acoustic microstreaming

Mechanical

Predominant mode of cleaning is the sweeping action of oscillating tip over tooth surface



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A common misconception

- Magnetostrictive scalers produce ***elliptical*** motion at the tip
- Piezoelectric scalers produce ***linear*** motion at the tip

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Tip motion

- magnetostrictive AND piezoelectric tips are ELLIPTICAL

  – *Lea SC, Felver B, Landini G & Walmsley AD.*
  Three dimensional ultrasonic scaler probe oscillations.
  J Clin Periodontol 2009; 36, 44-50.

  – *Lea SC, Landini G.*
  Reconstruction of dental ultrasonic scaler 3D vibration patterns from phase-related data.
  Med Eng Phys, 2010 (doi:10.1016/j.medengphy.2010.02.010).

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Impact of tip motion
➡ impacts on tooth surfaces!

- All scaler tips show lateral oscillation
- Impact into tooth surfaces during usage
- Differences in tooth surface defects is due to tip shape and cross-section

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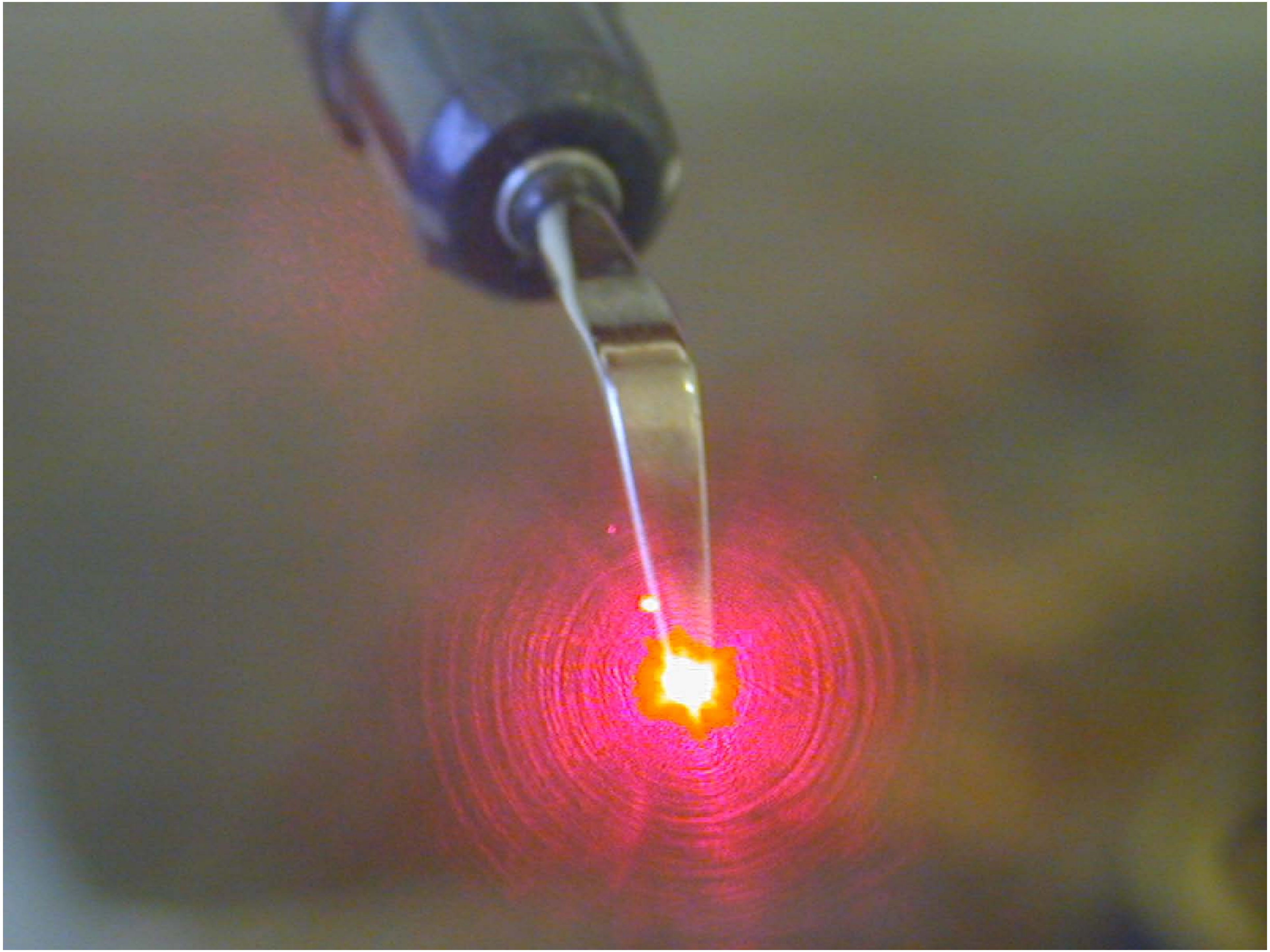
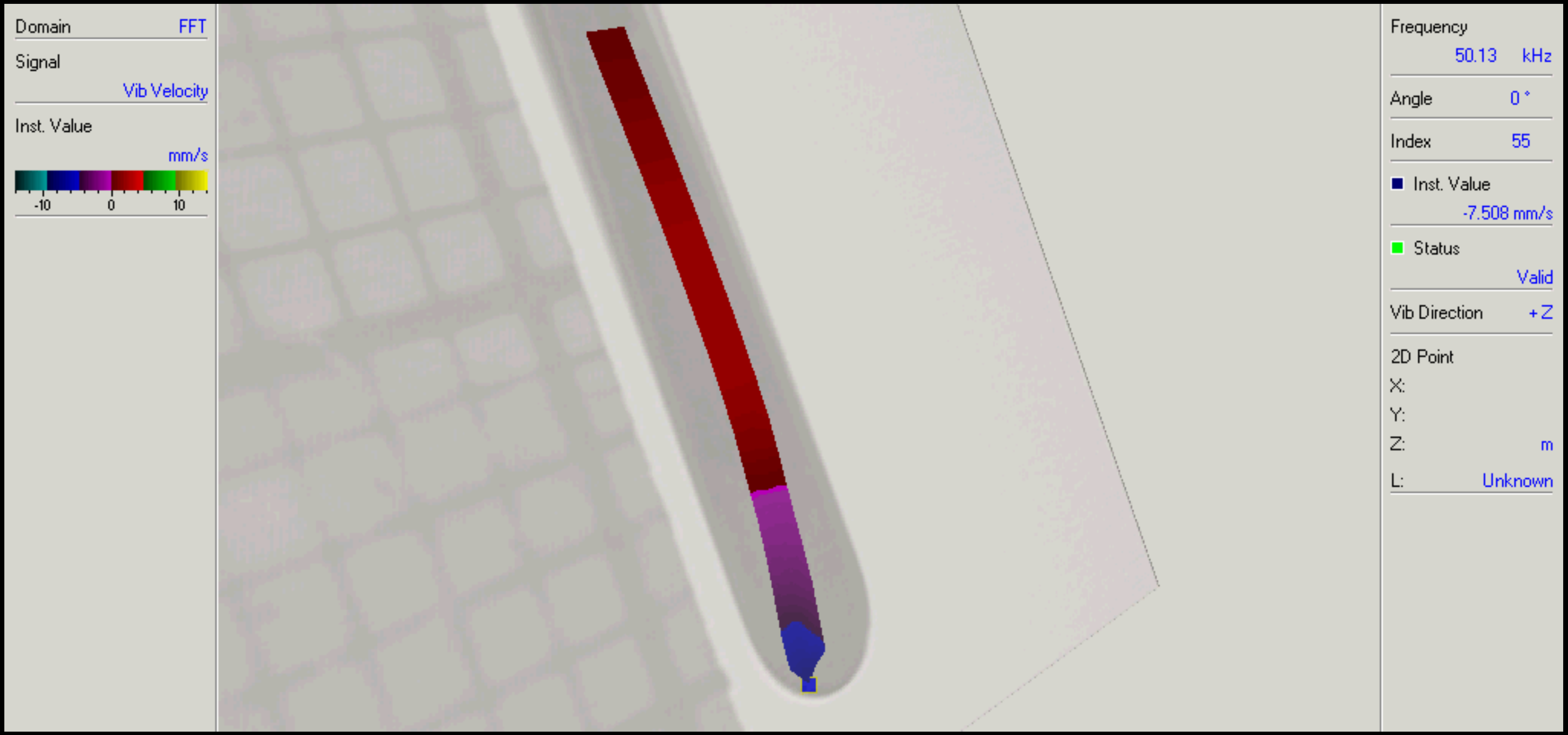
Scanning Laser
Vibrometry



Motion of the scaling tip



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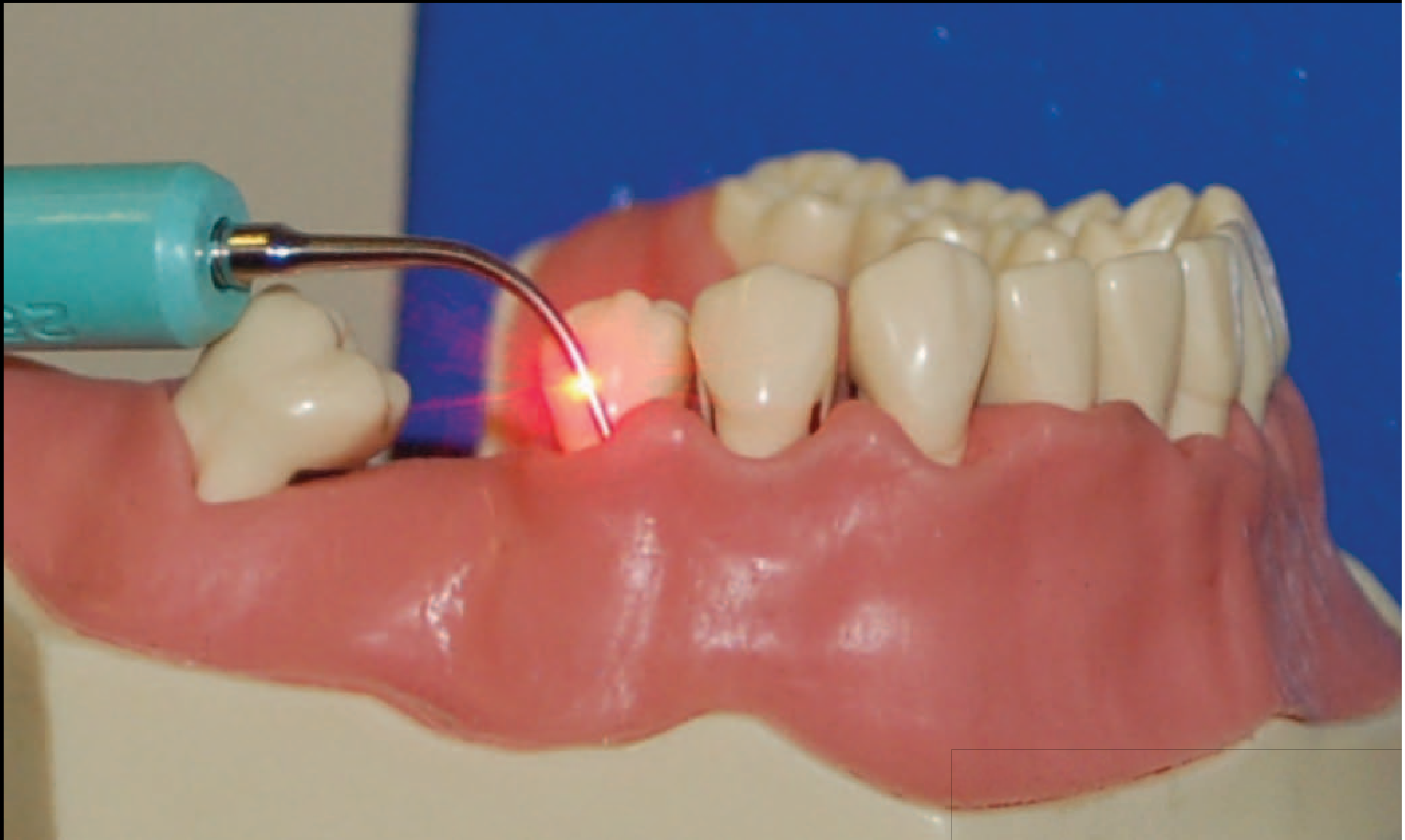
Longitudinal movement



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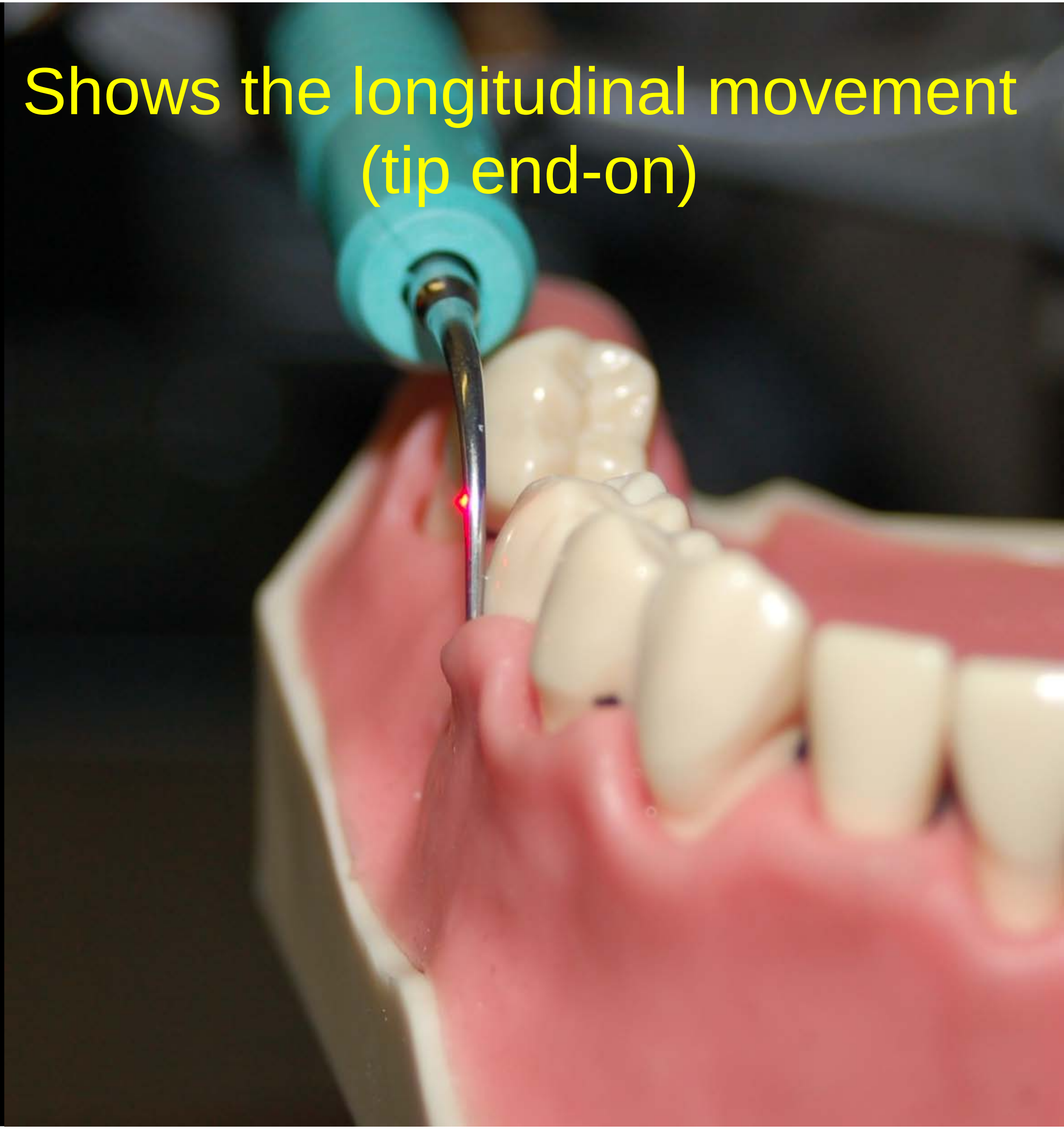
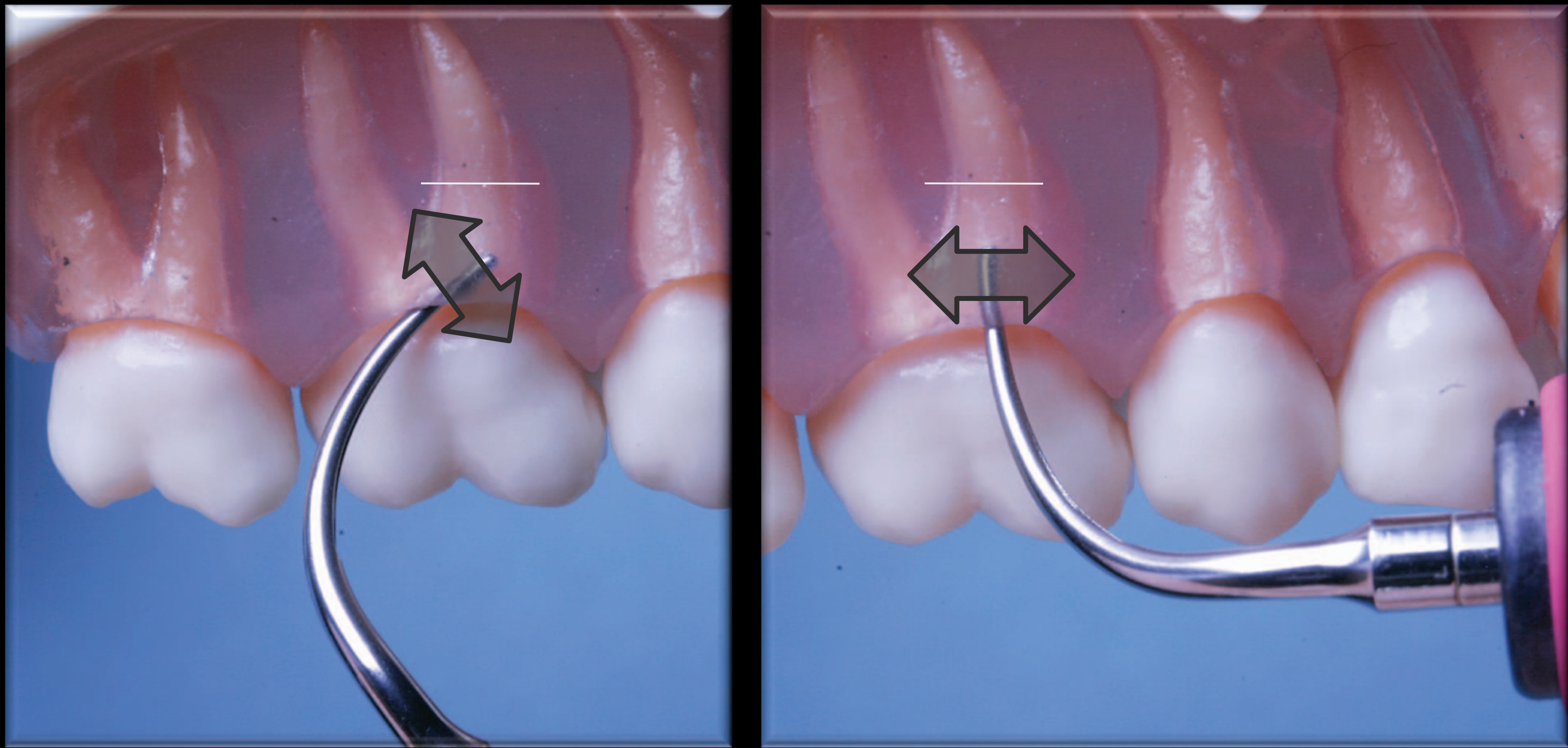
Shows the longitudinal movement (front face-on)

Shows the longitudinal movement (tip end-on)



Ultrasonic Adaptation



Clinical Relevance ?

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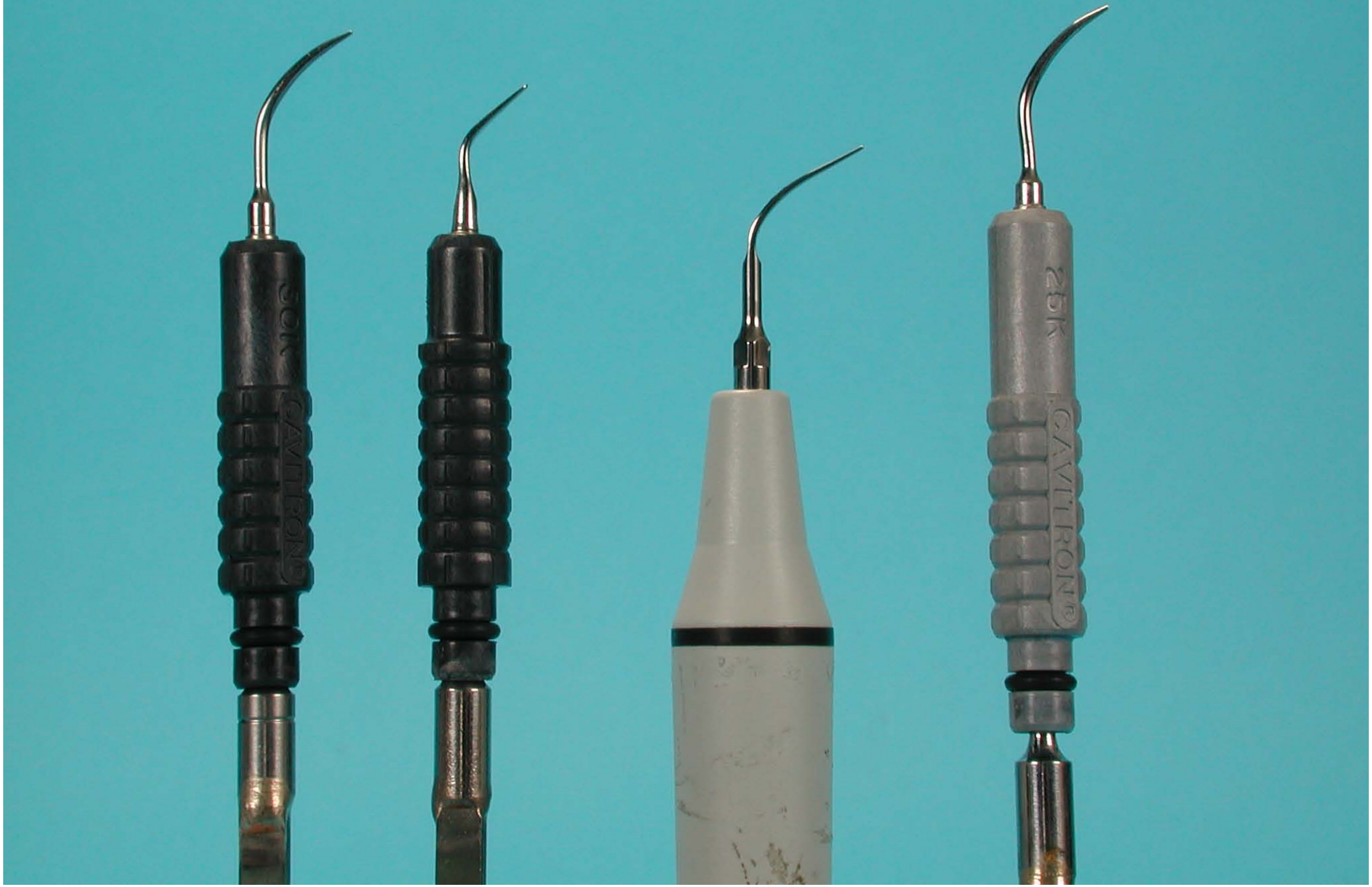
All work differently



Unloaded situation

- Variability between tips
- Poor standardisation

The displacement amplitude of ultrasonic scaler inserts
Lea SC, Landini G & Walmsley AD
J Clin Perio 2003; 30:505-10

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Even the generators !

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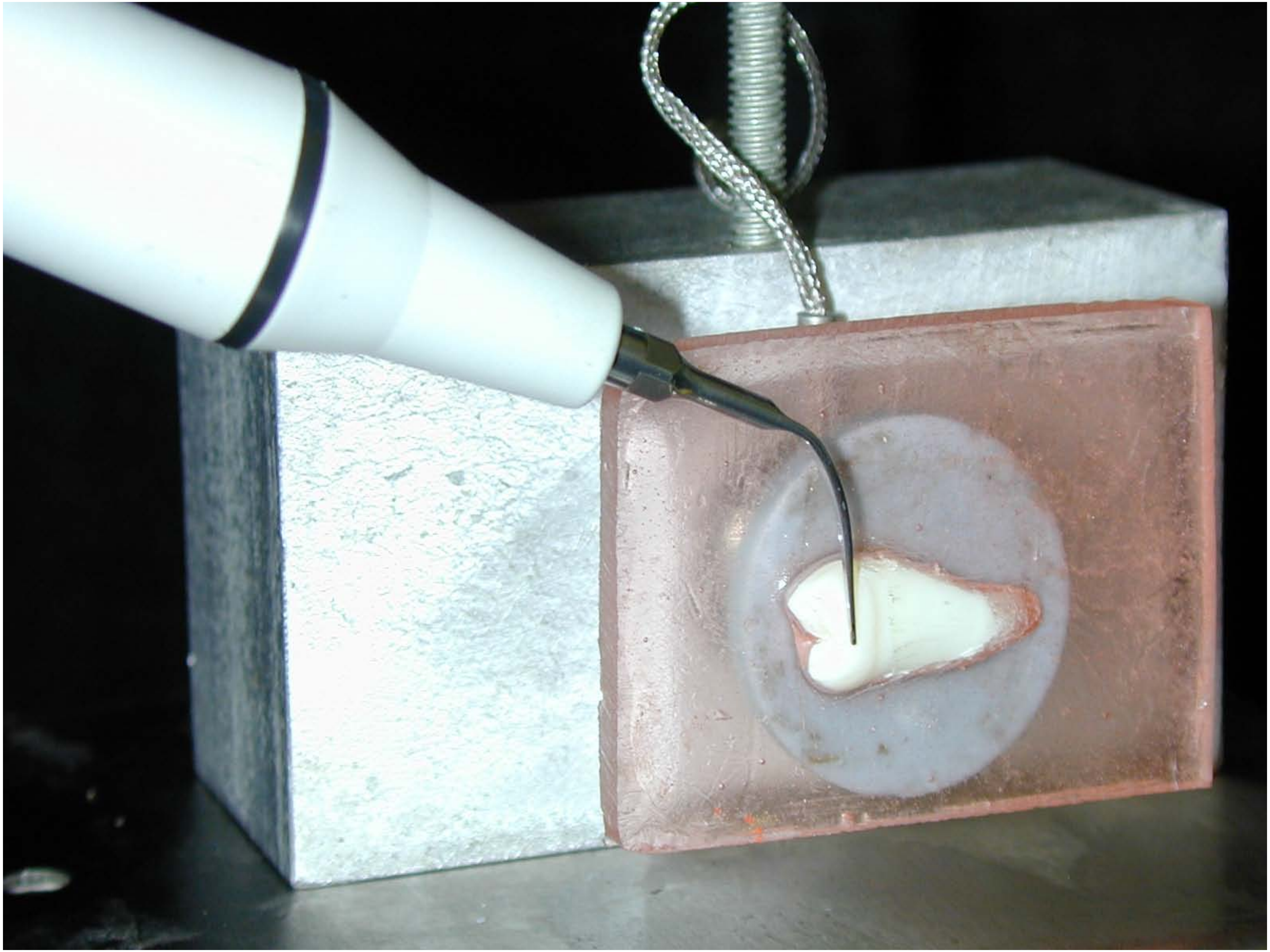
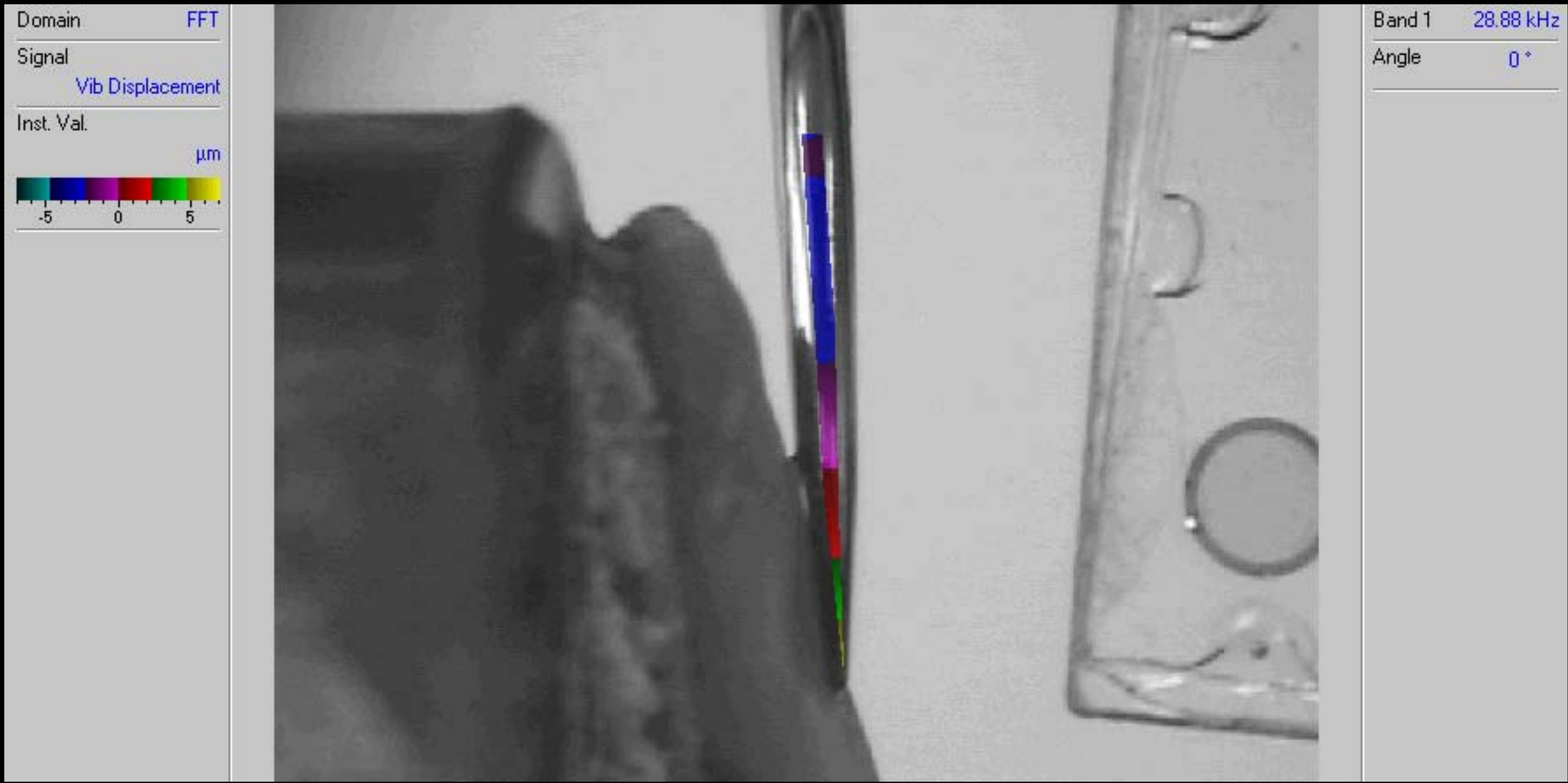


Measurements during tooth contact



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Loaded situation

- Tip movement significantly different from each other at all loads
- Significant difference in tip response from the unloaded situation and also between loads

Ultrasonic scaler tip performance under various load conditions
Lea SC, Landini G & Walmsley AD
J Clin Periodontol 2003; 30: 876-81

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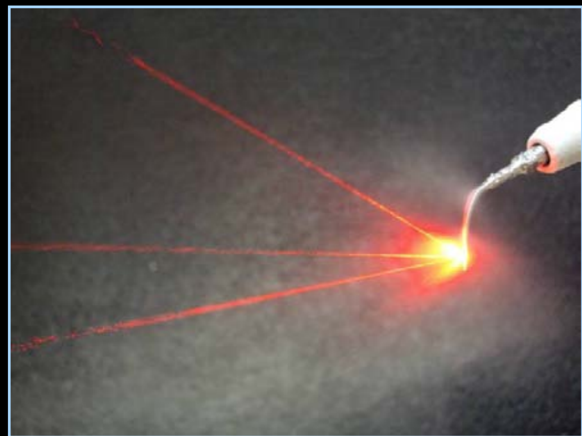
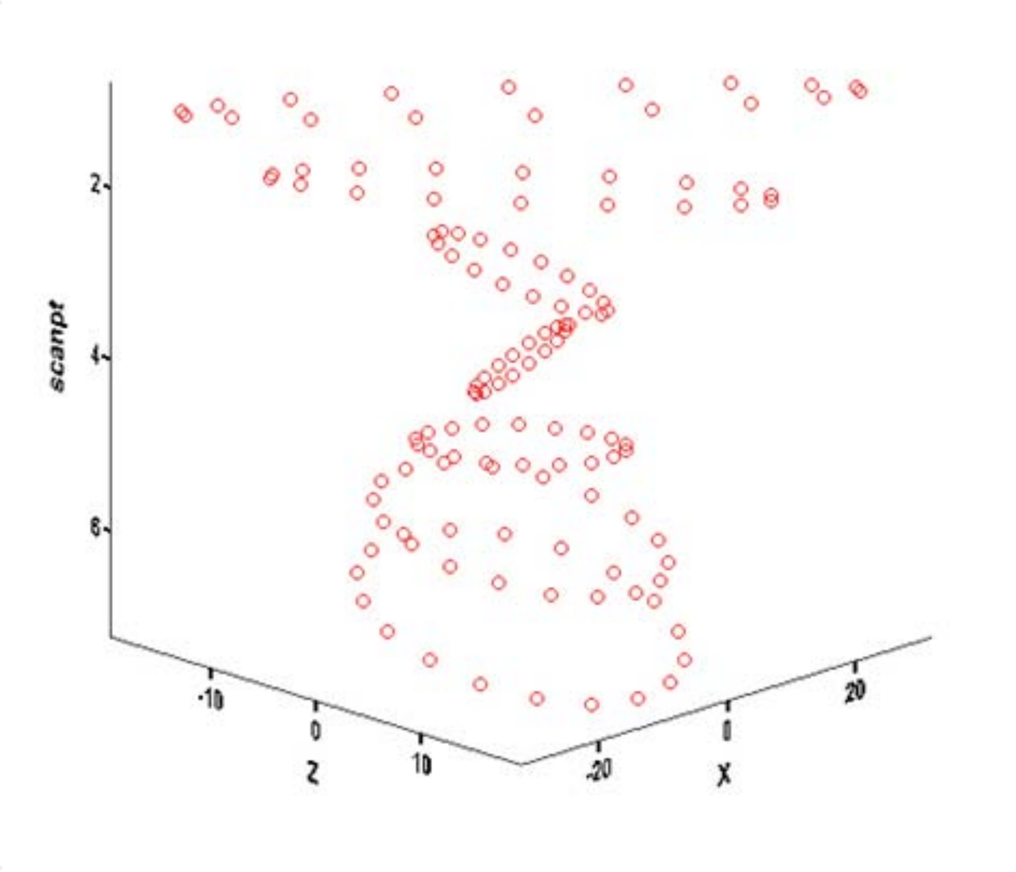
The 3D SLV

- Measure for 1st time in 3D
- He-Ne laser beams operated in 3 scanning heads of SLV
- Builds up a vibration picture

From: Polytec



3D measurements



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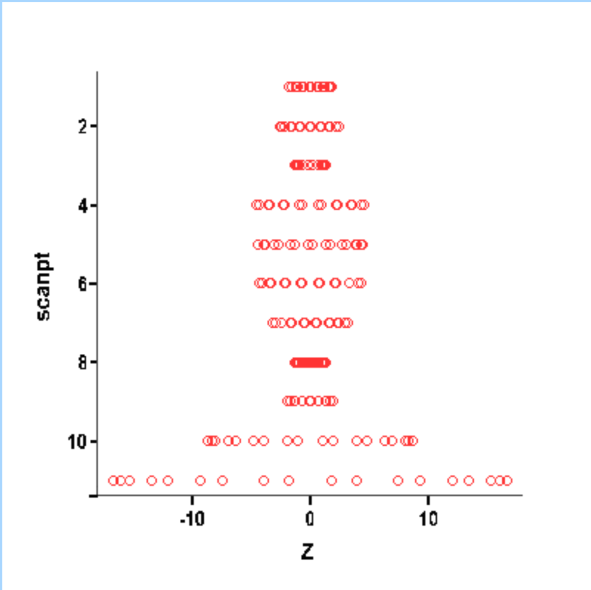
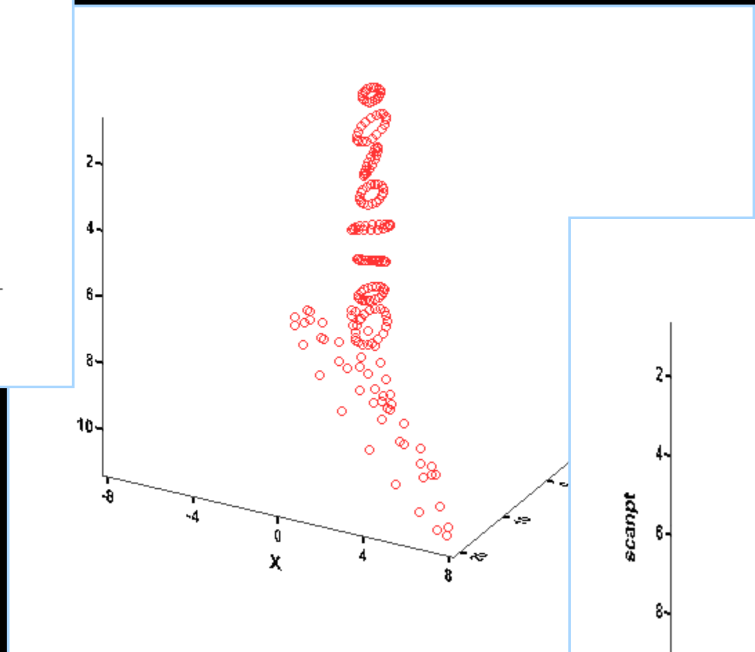
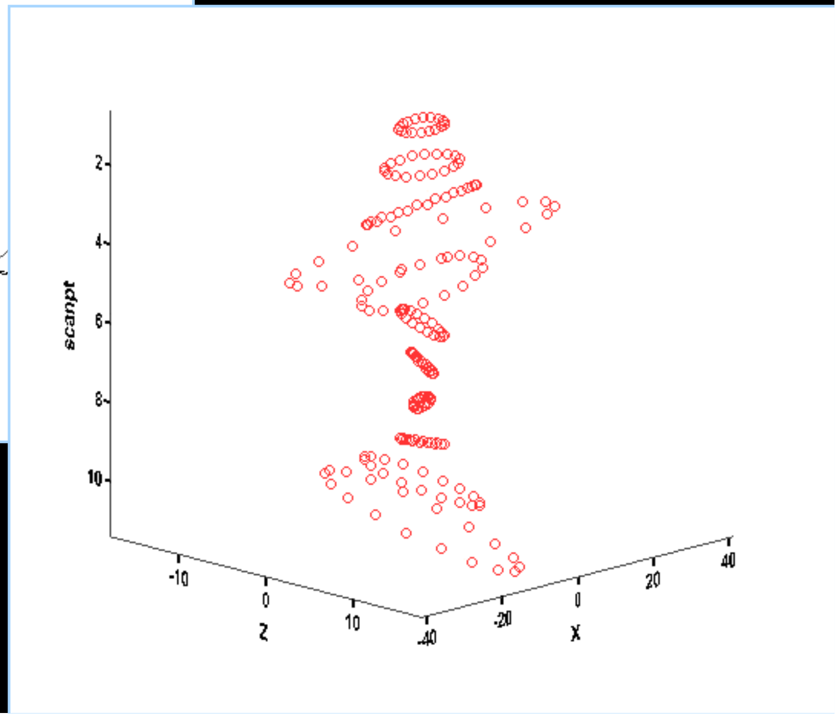
Results (P - high power)







- Max. displacement amplitude 25.58µm ± 4.19µm

Clinical Impact

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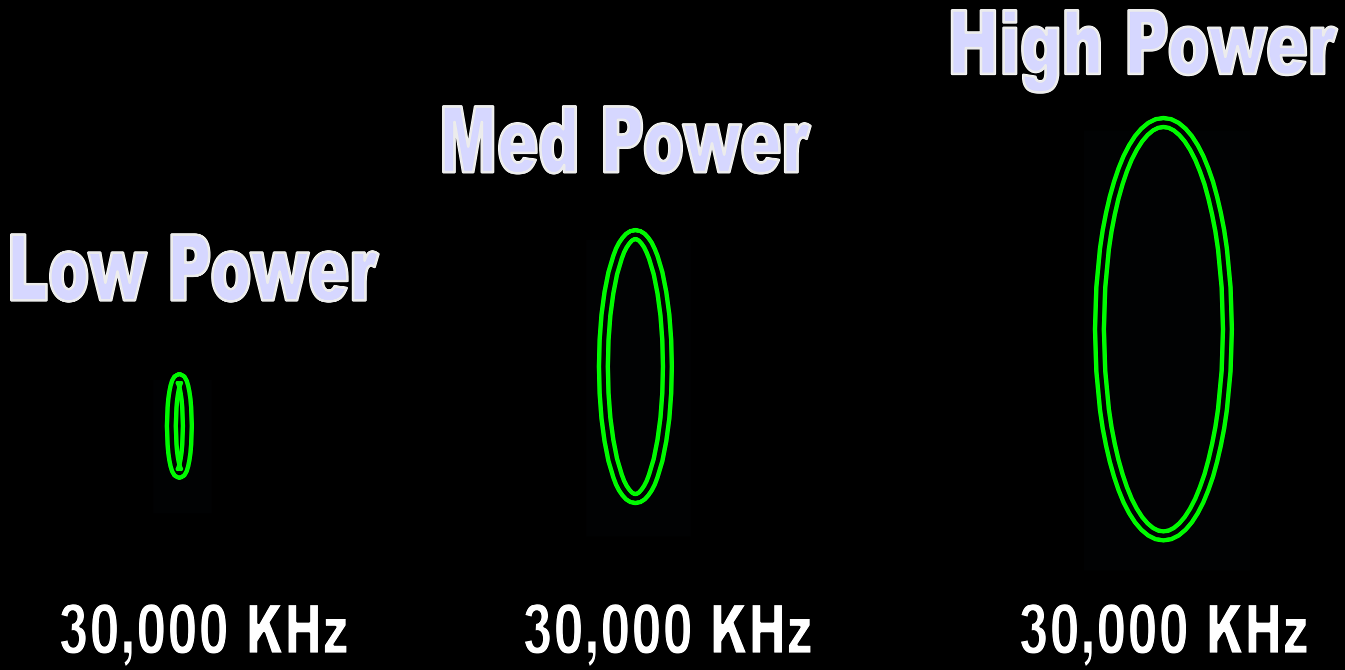
Subgingival Adaptation

- Position insert like a probe
- “Vertical”


Low Power
Med Power
High Power
30,000 KHz
30,000 KHz
30,000 KHz

- Lower: shorter, less powerful stroke
  - Less lateral motion
  - Light deposit, biofilm, endotoxin removal

- Higher: longer, more powerful stroke
  - Greater lateral motion
  - Moderate – heavy calculus removal

Another wrong

Higher power level will remove more deposit, resulting in a better clinical outcome

- Evidence:

Low-medium power level was just as effective in obtaining periodontal health

Chapple IL, Walmsley AD, Saxby MS, Moscrop H. Effect of instrument power setting during ultrasonic scaling upon treatment outcome. J Periodontol. 1995;66:756-60.

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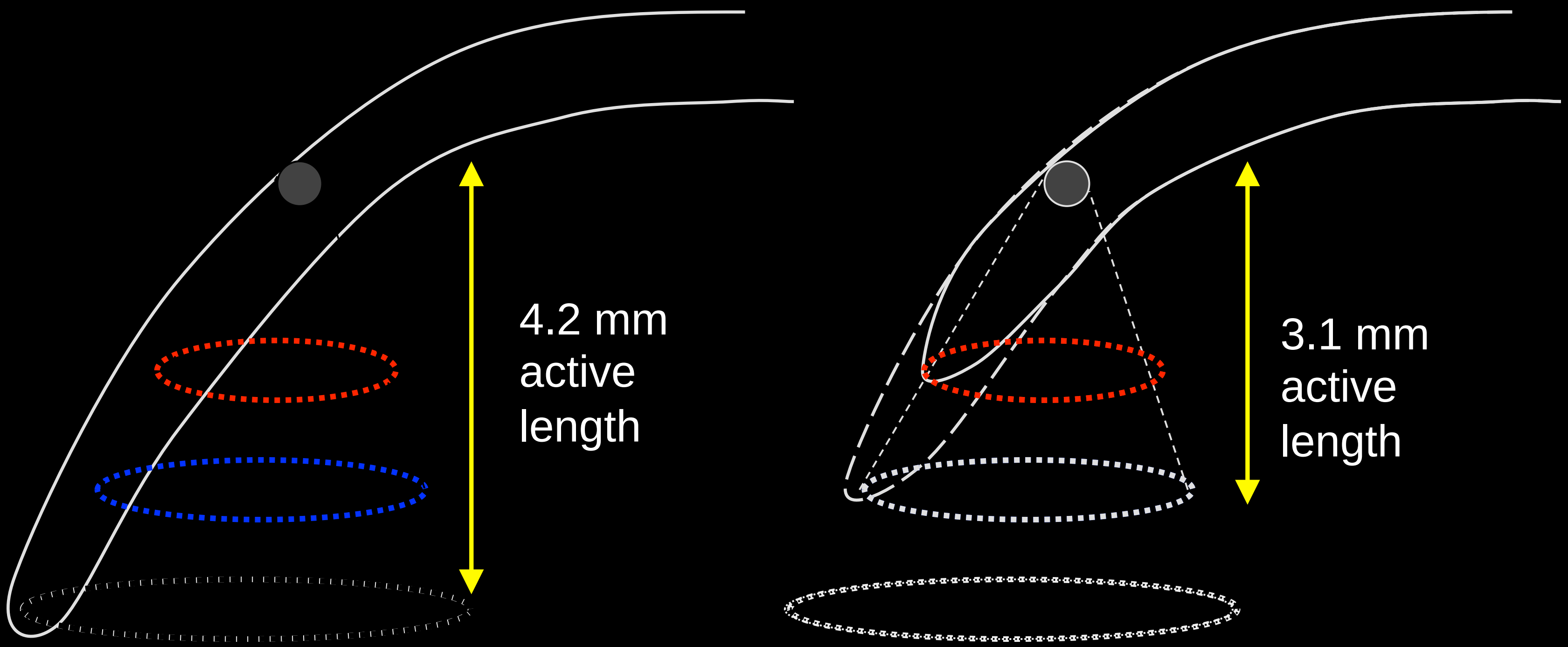
Tip wear reduces efficiency



New Insert
Active Length = 4.2mm
Efficiency is 100%

Worn Insert 25% (Blue Line)
Active Length = 3.1 mm
Efficiency is 75%

Lea SC, Landini G, Walmsley AD. The effect of wear on ultrasonic scaler tip displacement amplitude
J Clin Periodontol 2006; 33: 37-41

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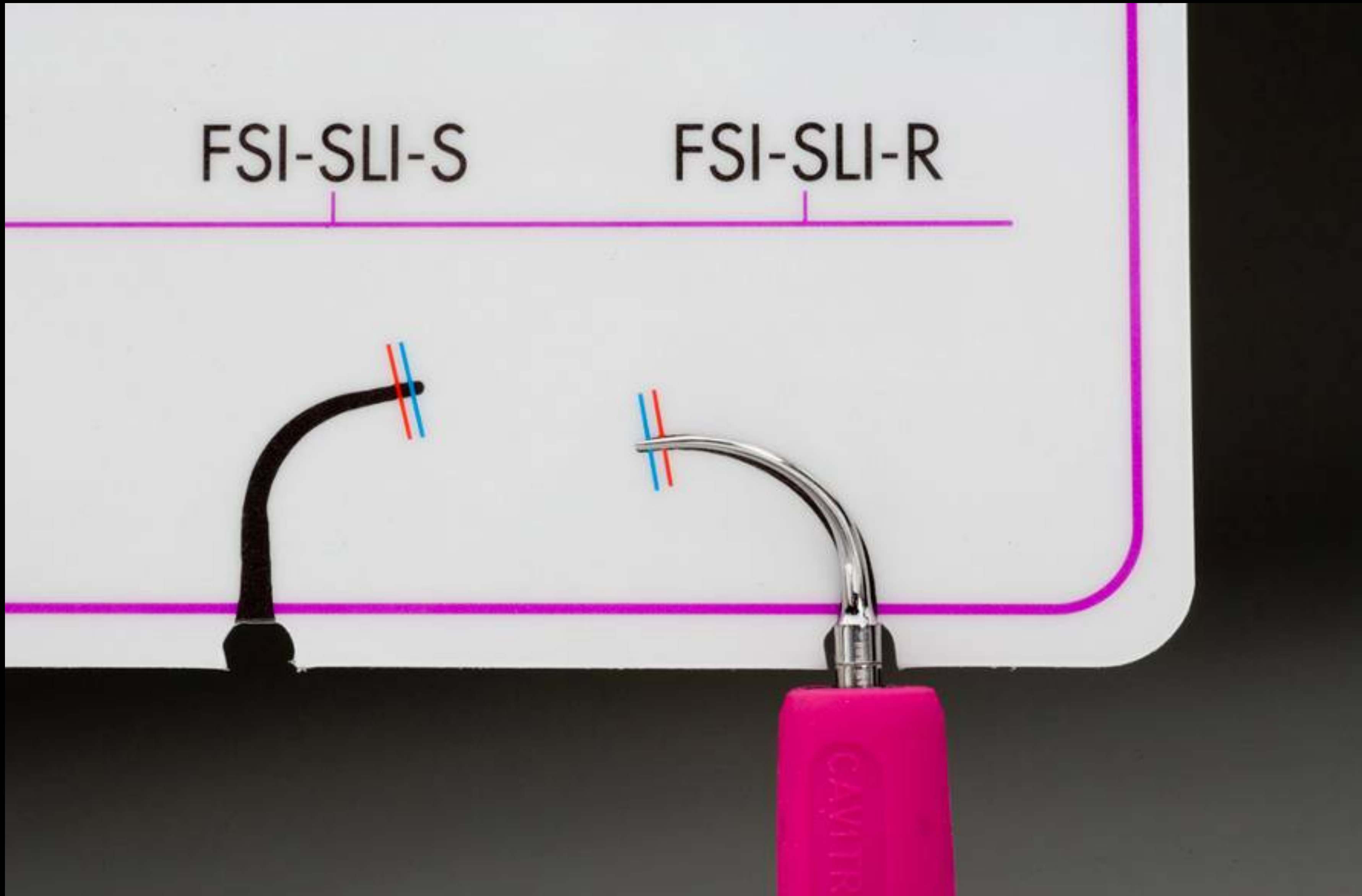

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Lavage

- Cools handpiece and insert / tip
- Adjustable flow rate allows user to select optimal flow

Irrigation

Lavage – created by H_2O supply

- Coolant
- Removes Biofilm
- Flushes debris from pocket
- Contributes to cavitation & acoustic microstreaming

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Mist with Droplets

- Increased power
- Decreased area of biofilm removal

Lavage Options

- Water
- Cetylpyrdinium Chloride
- Hydrogen Peroxide, 3%
- Povidone Iodine, 10%
- Essential Oils
- Chlorhexidine Gluconate 0.12%
- Saline
- Sodium Fluoride

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Lavage Options

No evidence anything is better than water

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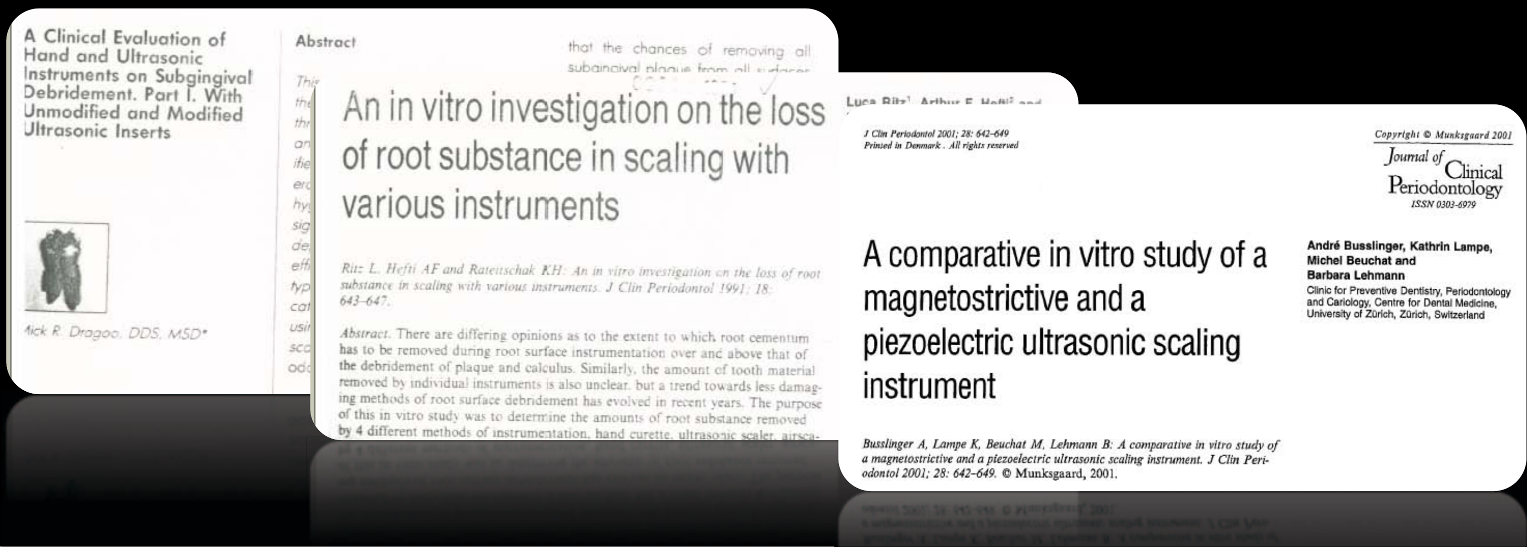
Effect on Root Surface

Ritz et al 1991
Dragoo et al 1992
Jacobson et al 1994
Rees et al 1999
Busslinger et al 2001
Schmidlin et al 2001

- Ultrasonic instrumentation may result in less damage to the root surface than hand instrumentation



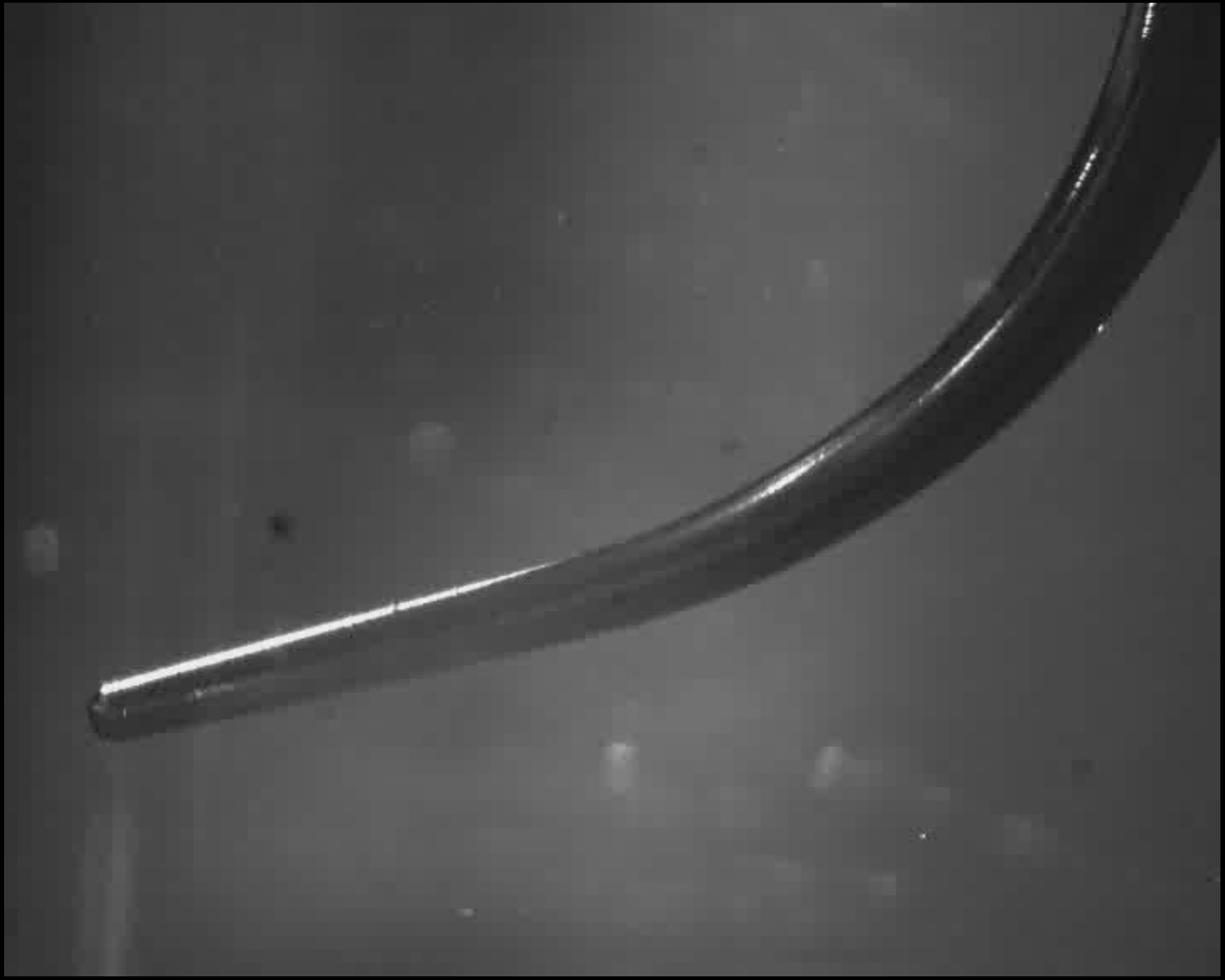
Cavitation

- Bubbles collapse inward, releasing energy
- Potential to disrupt bacterial cell walls

Cavitation

- *Walmsley et al 1984, 1986*
- *Laird &Walmsley 1991*
- *Lea et al 2005*
- *Parini et al 2005*
- *Parini & Pitt 2005*
- *Pitt 2005*
- *Felver et al 2009*

- Potential even to damage scaler tip!



Ultrasonic scaler in water
showing cavitation and streaming

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Effect on Microflora

Spirochetes and motile rods were reduced to 0.1% after exposure to ultrasonic vibrations

Baehni et al
1987, 1992

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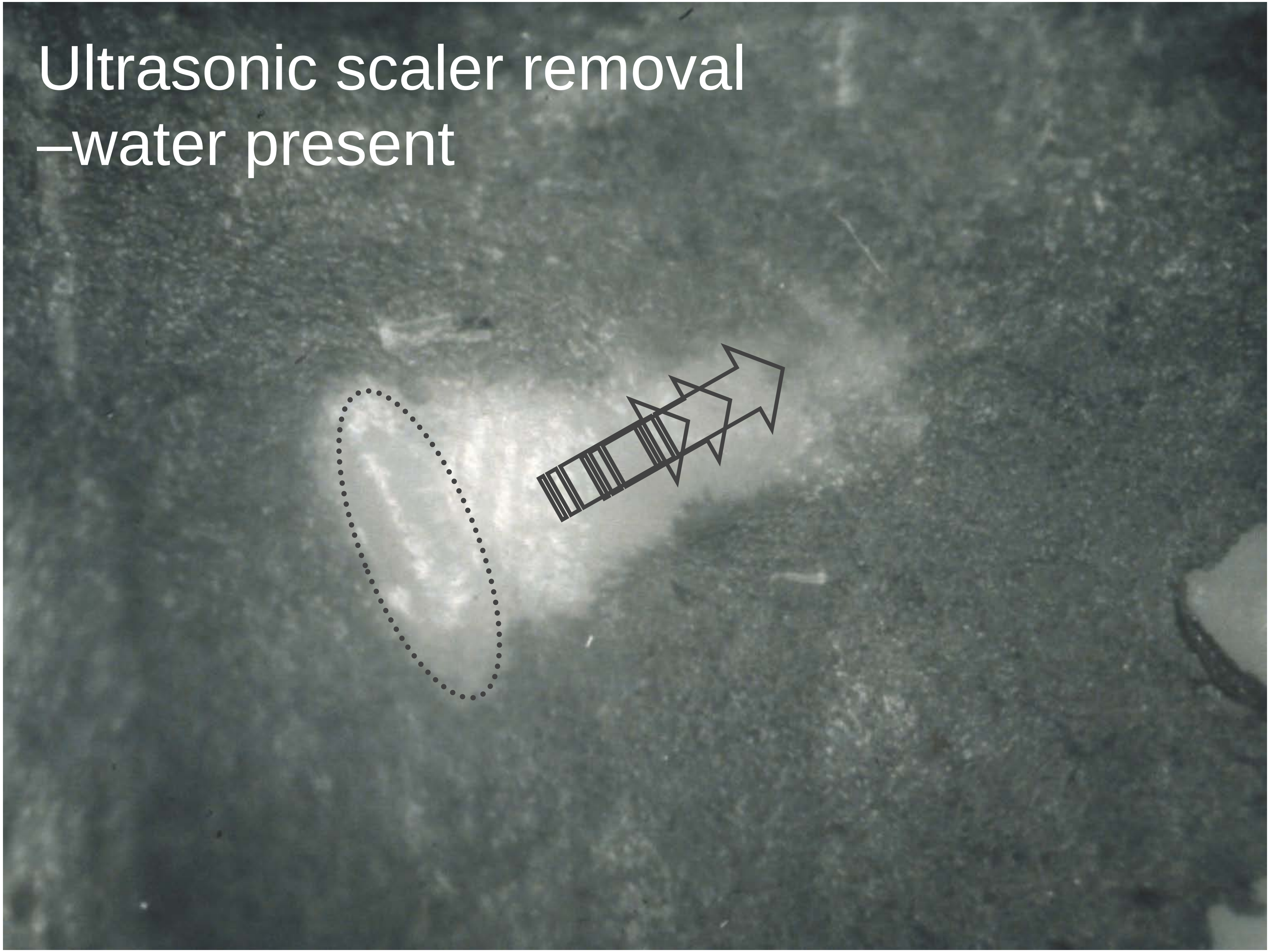
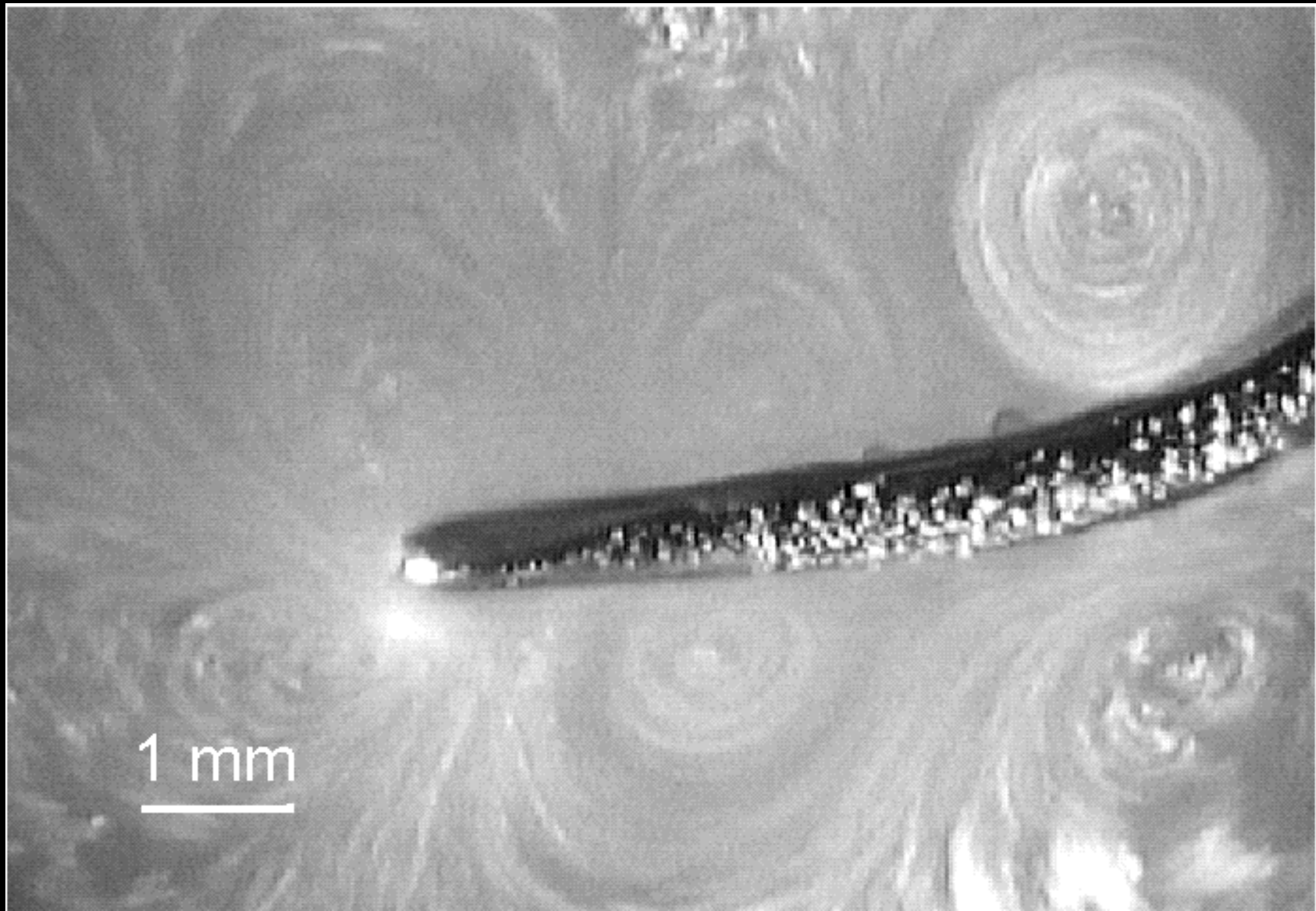
Ultrasonic scaler removal
– no water


Ultrasonic scaler removal
–water present

Streaming around ultrasonic scaler



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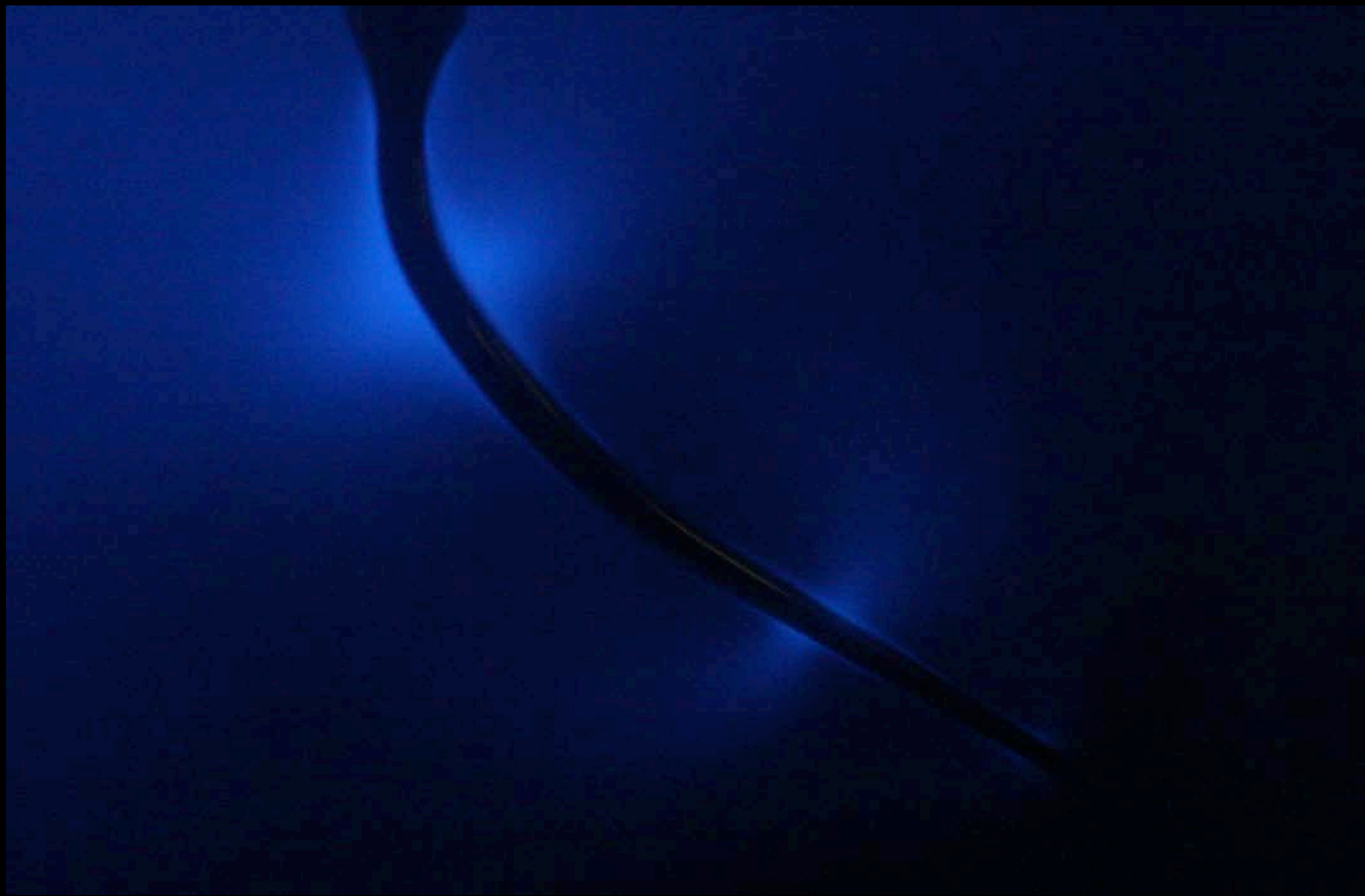
Luminescence around probe



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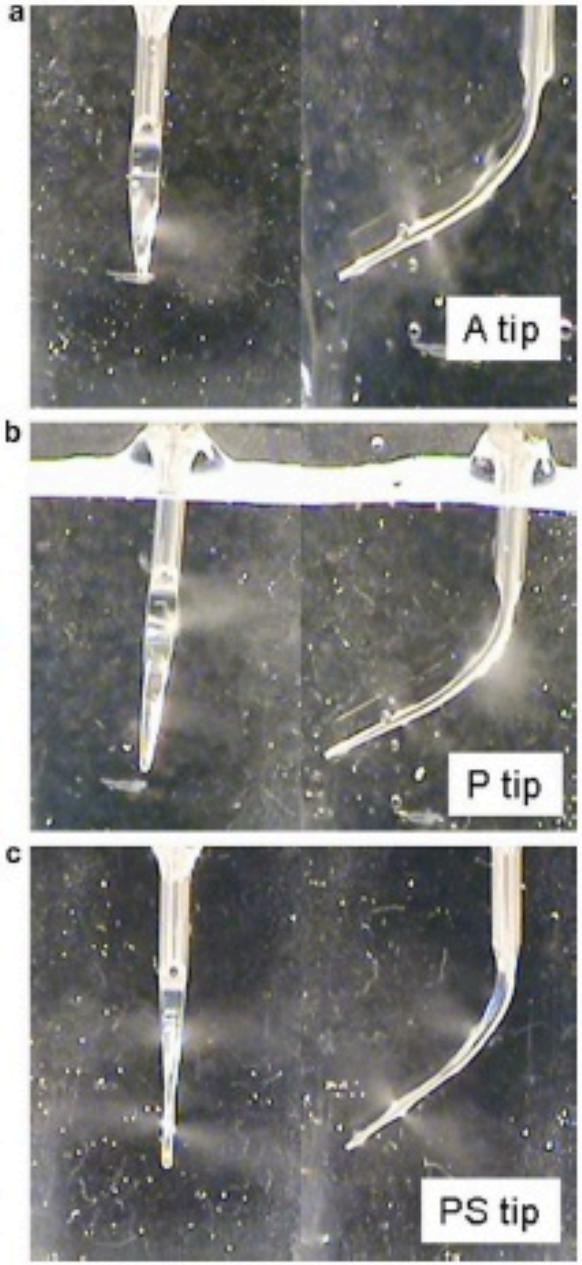

Fig. 5. Photographs of scaler tips in operation at power 10/10. (a) A tip, (b) P tip, (c) PS tip.

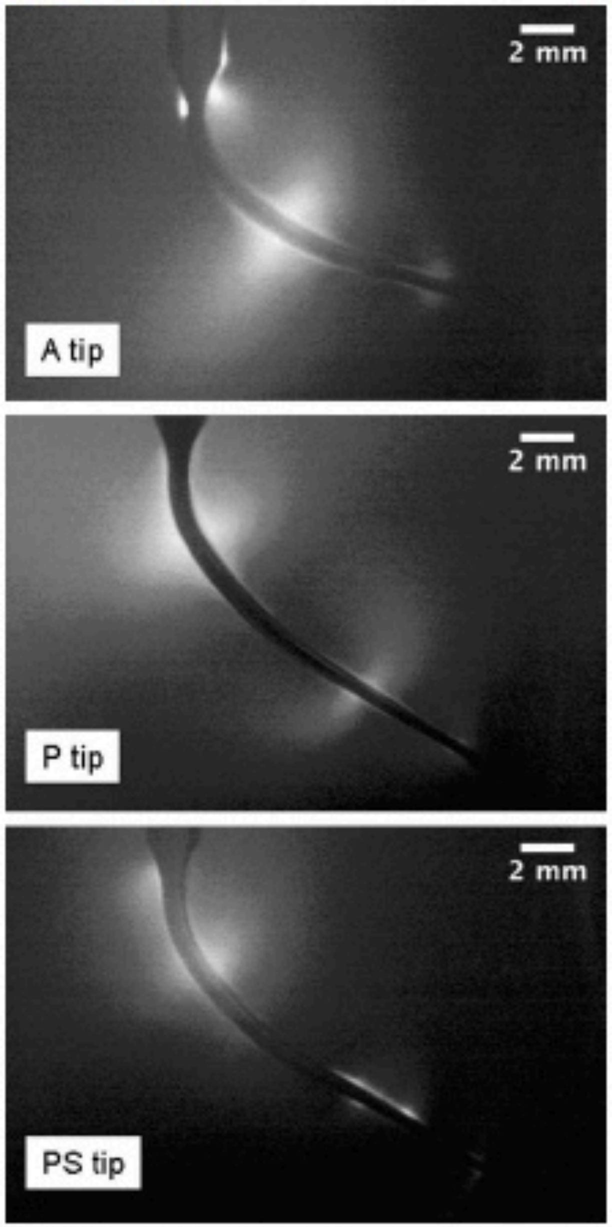

Fig. 6. Luminol photography of A, P and PS tips at power 10/10. Light regions indicate areas of high cavitation activity, with dark regions indicating little or no activity.

Acoustic Turbulence around Scaler operated in water

Non-Contacting

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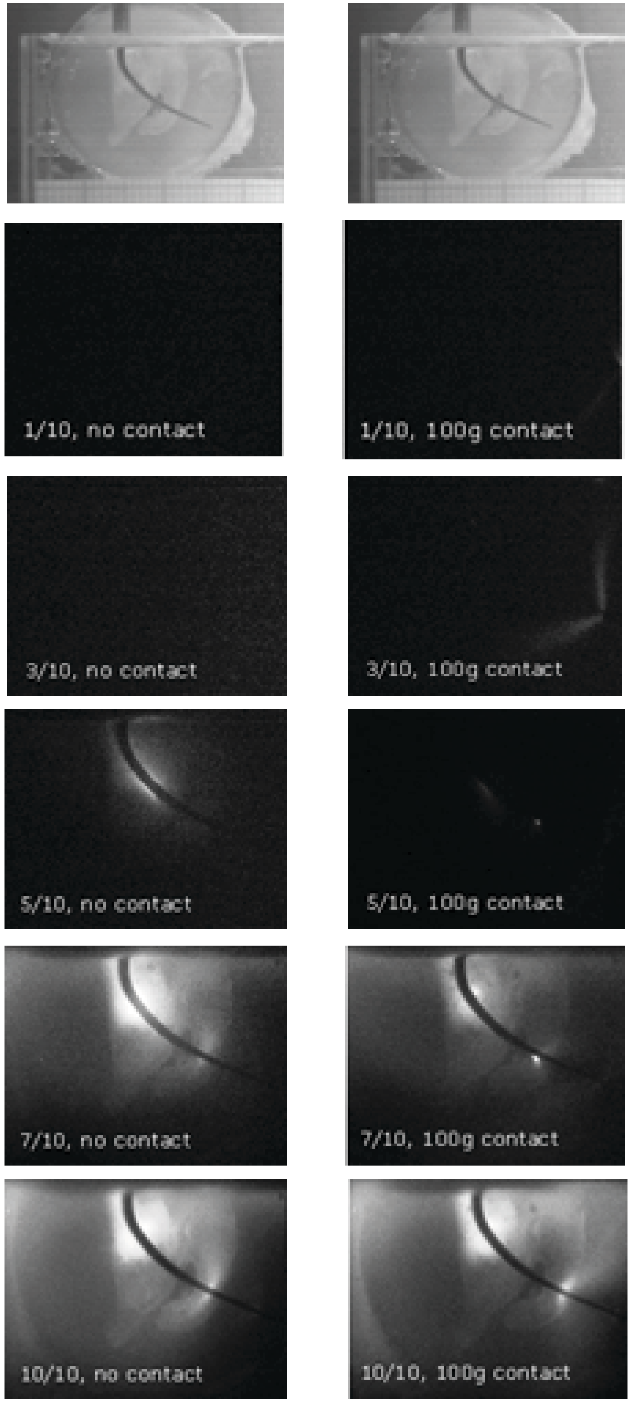

Acoustic Turbulence around Scaler operated in water

Contacting the tooth

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30K
CAVITRON
30K
CAVITRON

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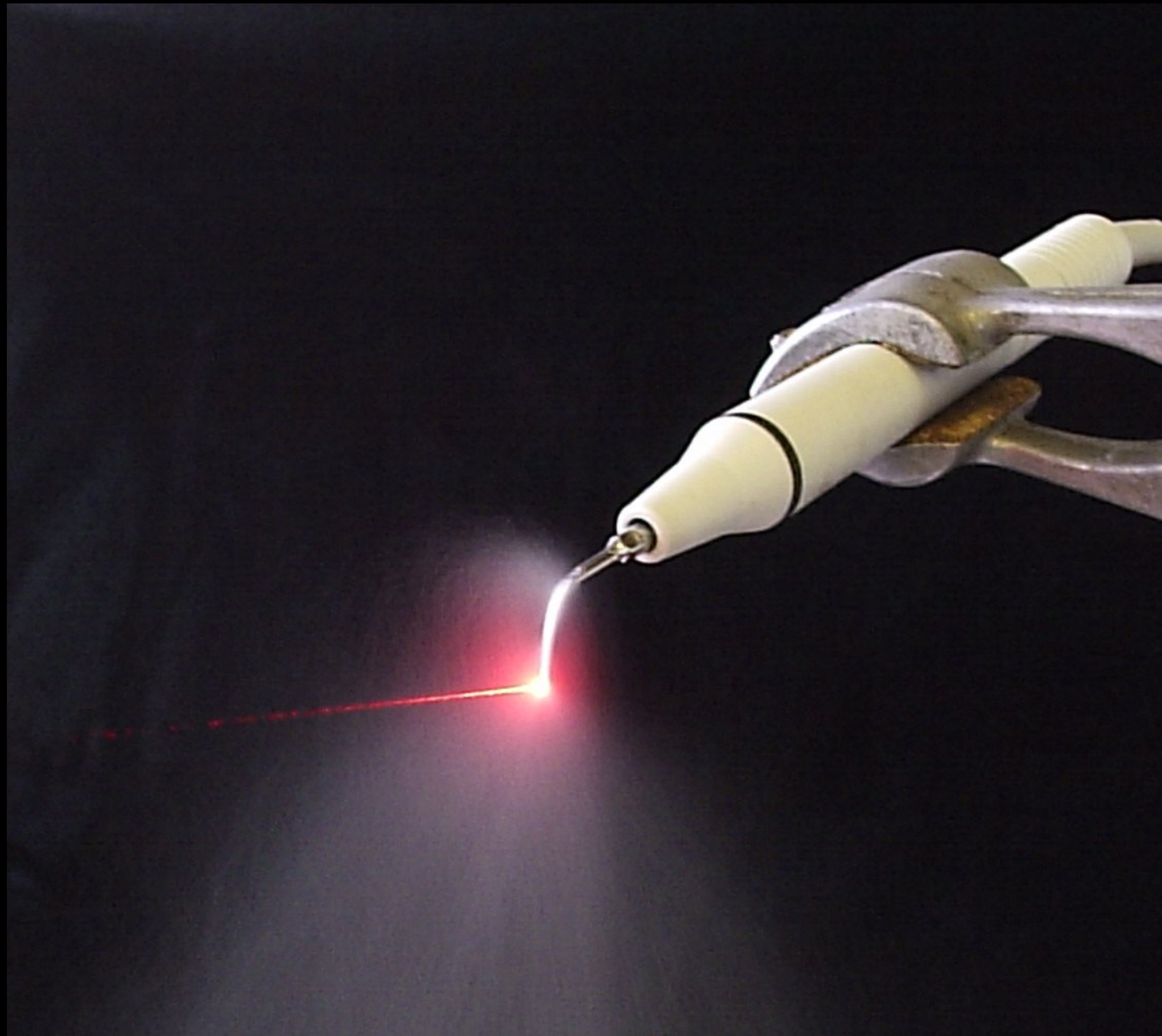
Endosonics - ultrasonic



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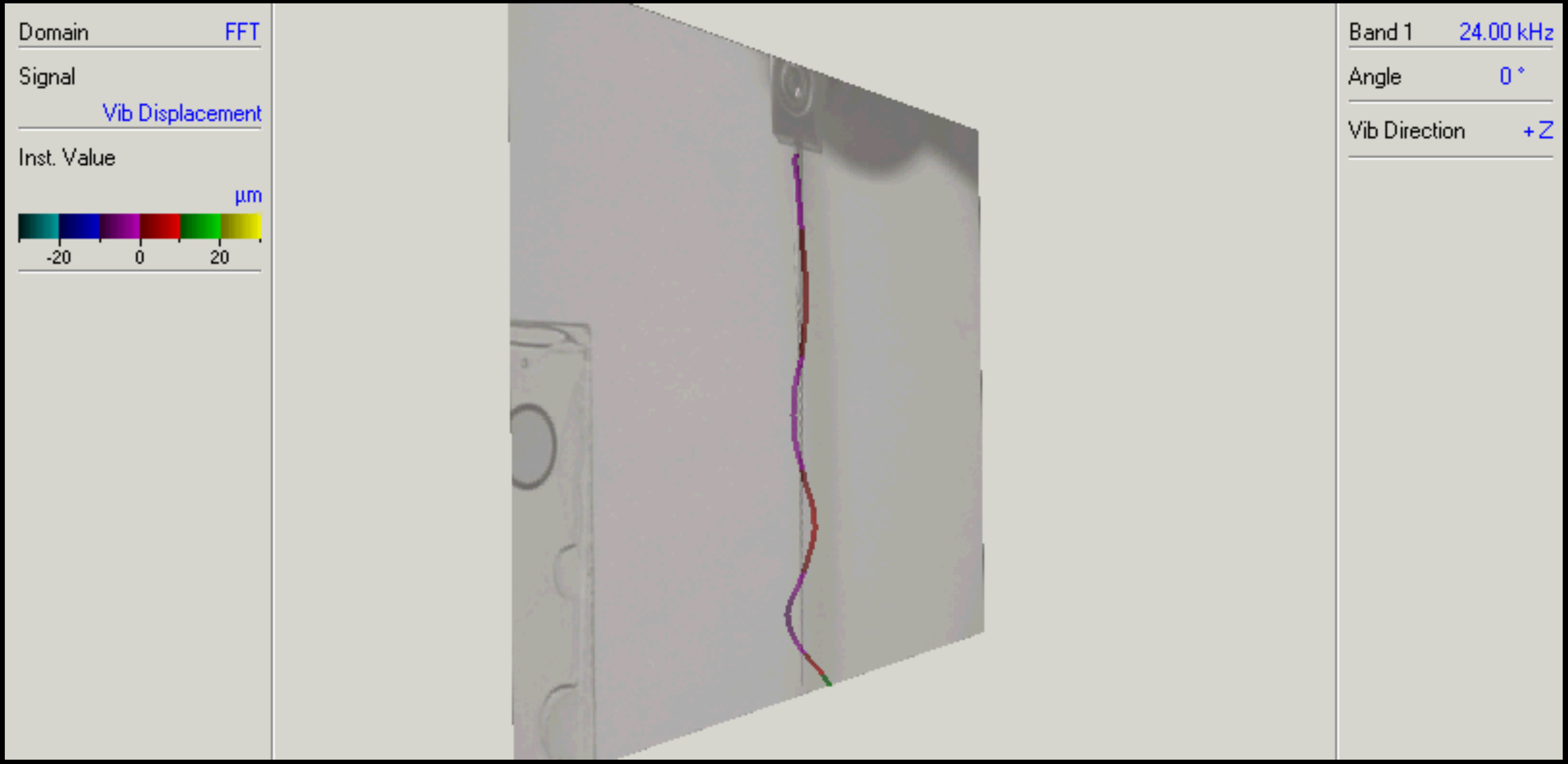
View of File Movement



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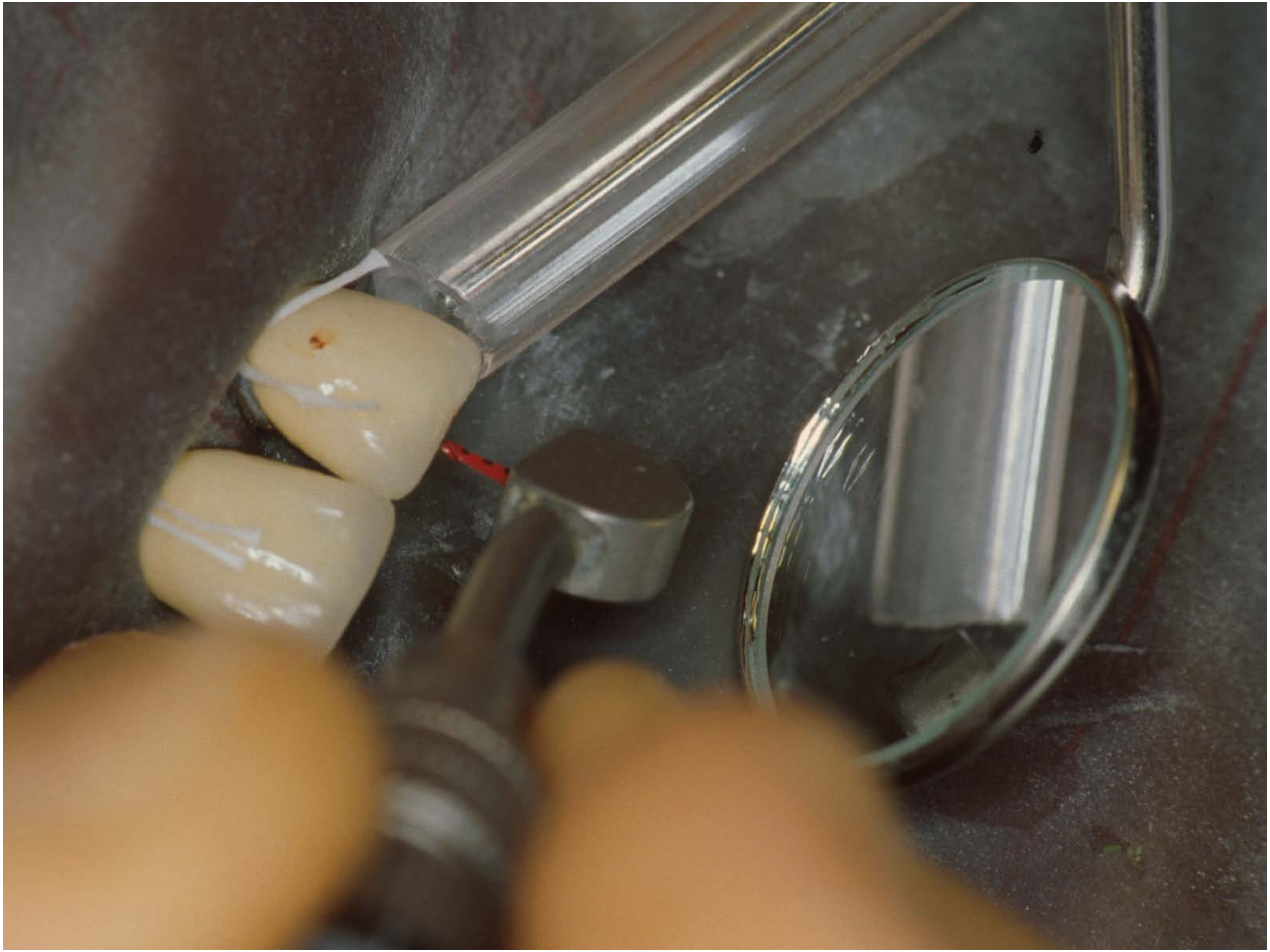
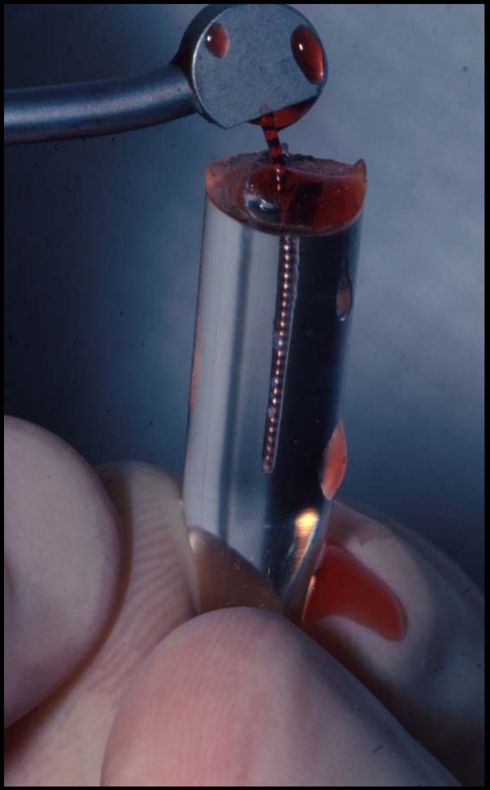


Endosonics



van der Sluis LW, Wu MK, Wesselink
The efficacy of ultrasonic irrigation to remove artificially placed dentine debris from human root canals prepared using instruments of varying taper
Int Endod J. 2005;38:764-8

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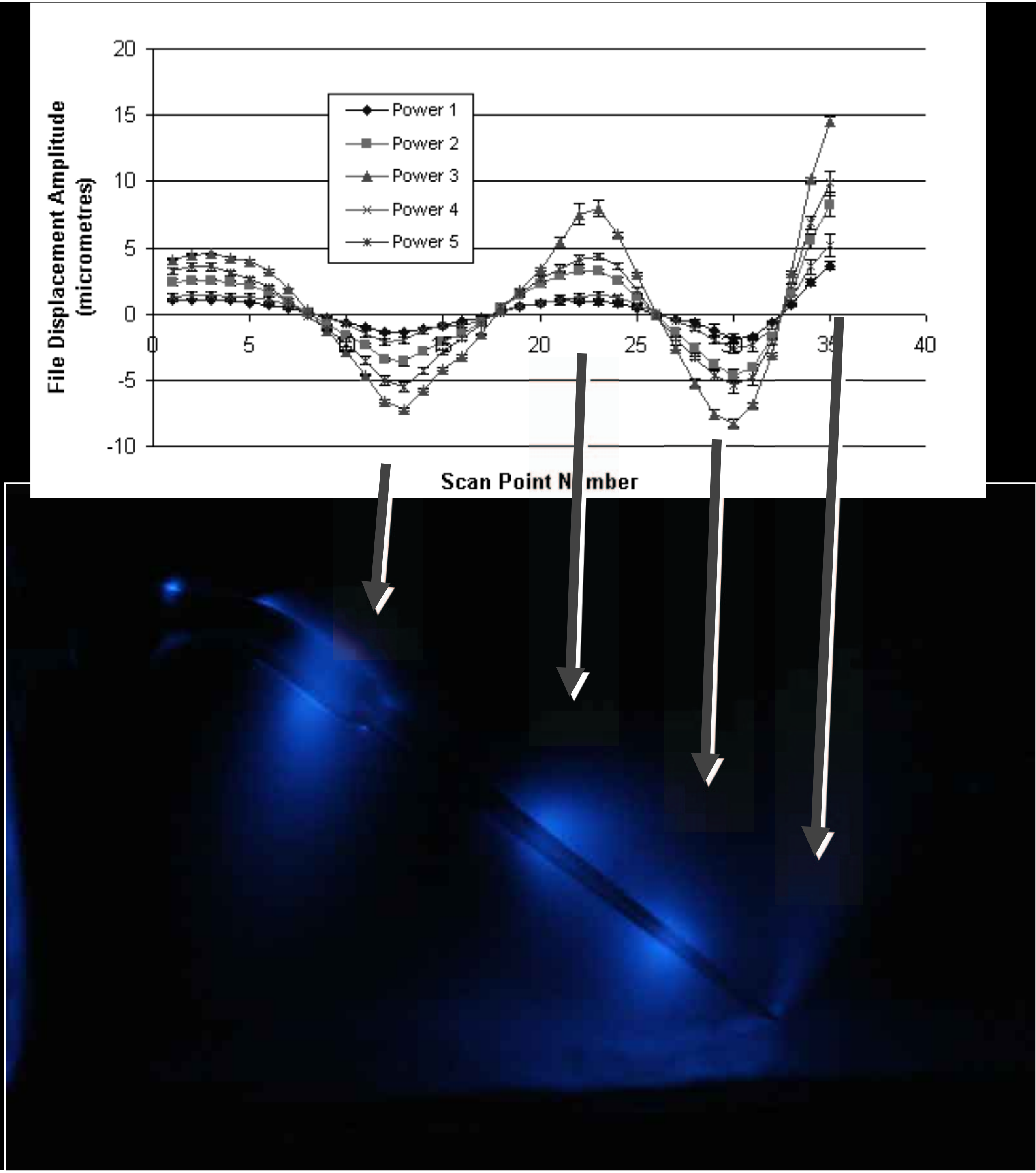
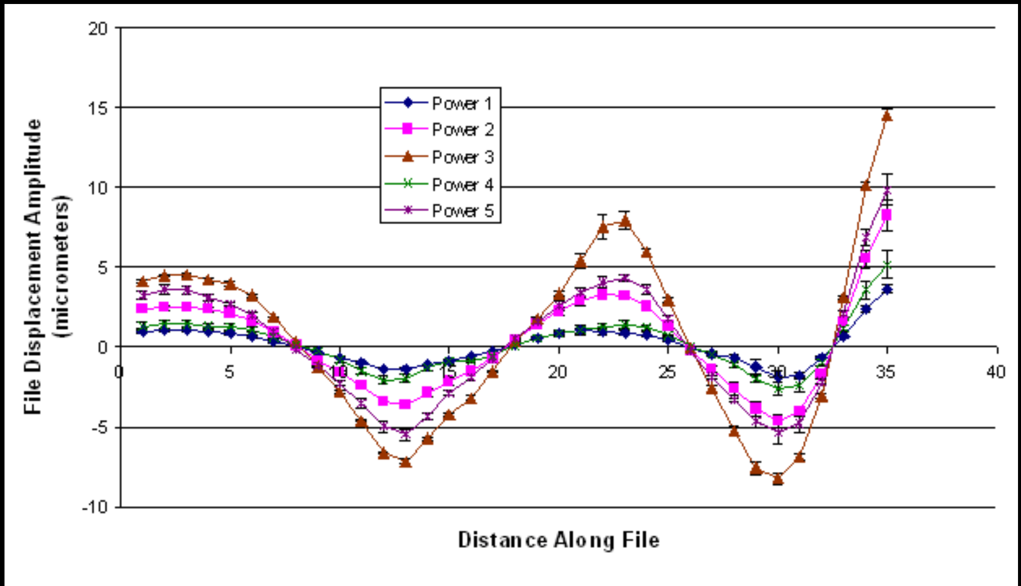
Inertial cavitation - Endosonic Files



File Displacement Amplitude (micrometres)
20
15
10
5
0
-5
-10
Power 1
Power 2
Power 3
Power 4
Power 5
0
5
10
15
20
25
30
35
40
Scan Point Number

File motion assessed using laser vibrometry circa 2004

- Previous work indicated that file motion comprised a series of nodes and antinodes
- Measurements performed in air with flow of water



Lea et al. Phys Med Biol; 2004: 49: 2095-2102.

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Endosonic file evaluation

- #10 and #30 files evaluated (27mm and 31mm)
- 31mm files inserted into file holder to depths of 3mm and 10mm (to colour-band). 27mm files inserted to colour-band
- MiniMaster (EMS) piezoelectric ultrasound system used (30kHz)
  - Generator used on ‘endo’ setting, limiting power to setting 5
- Files inserted into water bath up to file holder (whole file immersed)
- Mirror enables simultaneous lateral / longitudinal data acquisition

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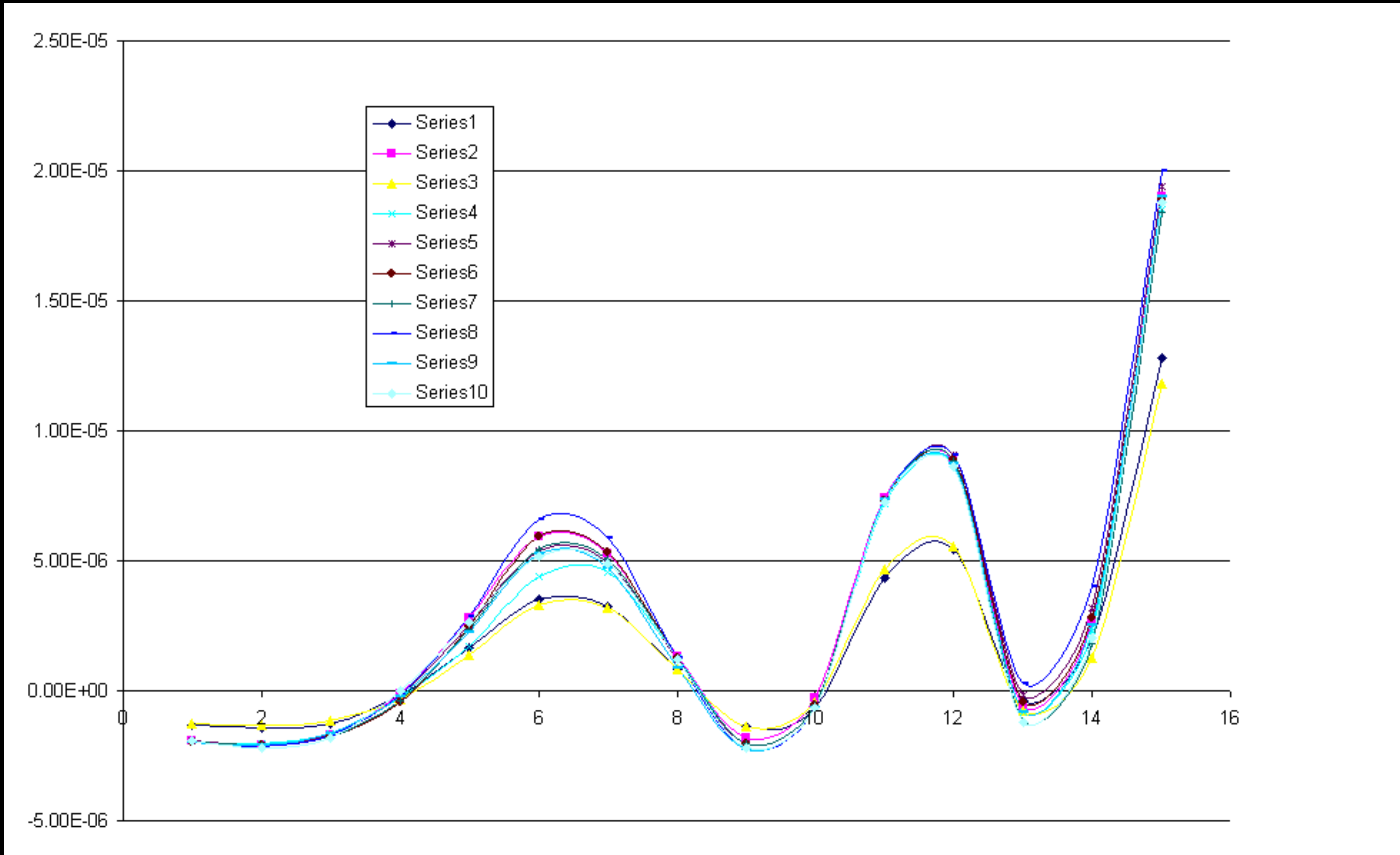
Results 1 – 27mm files



#10 file – 27mm length – power setting 1

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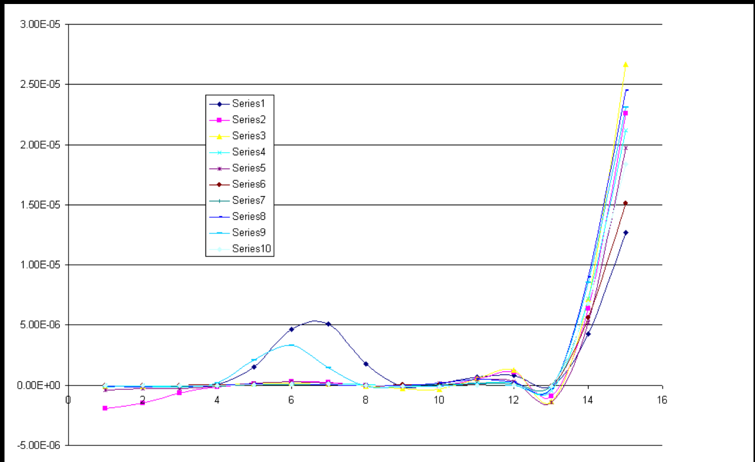
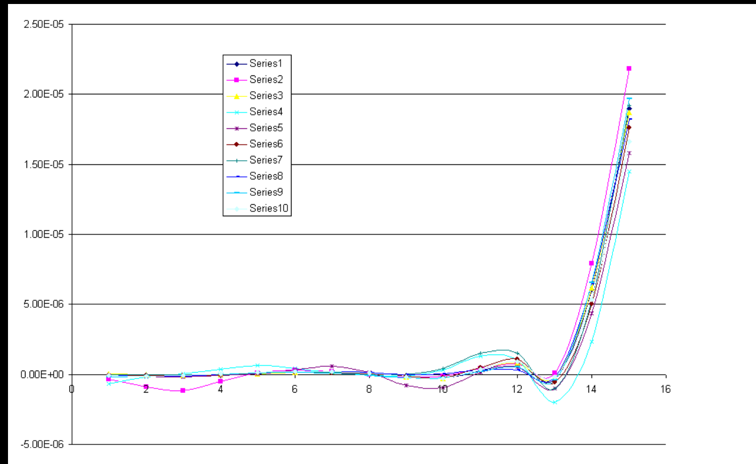
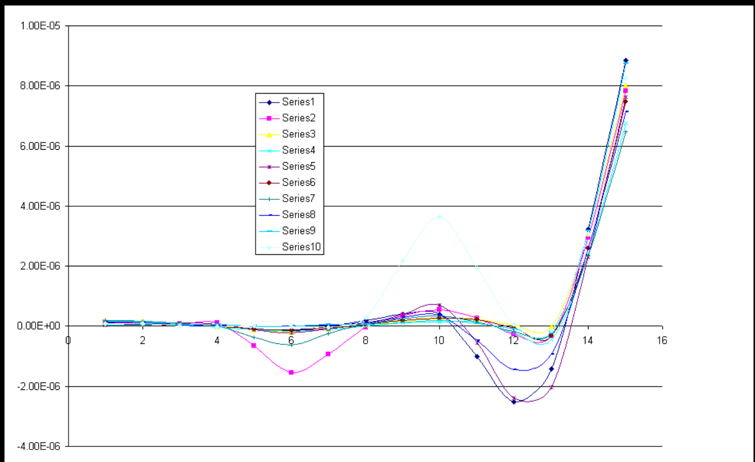
Results 3 – 27mm files



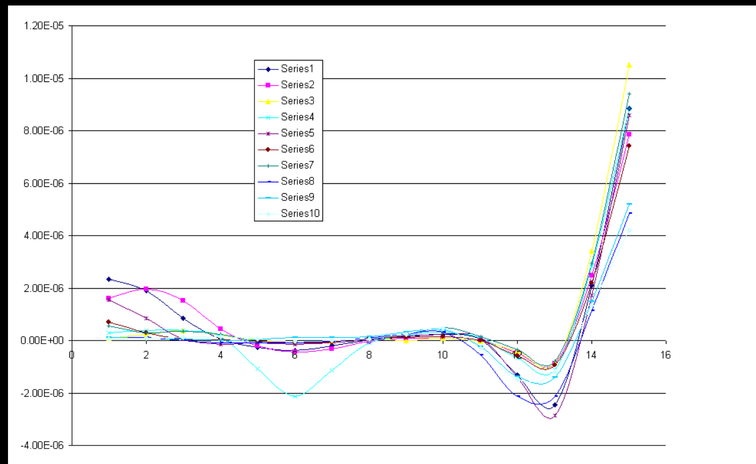
a



b



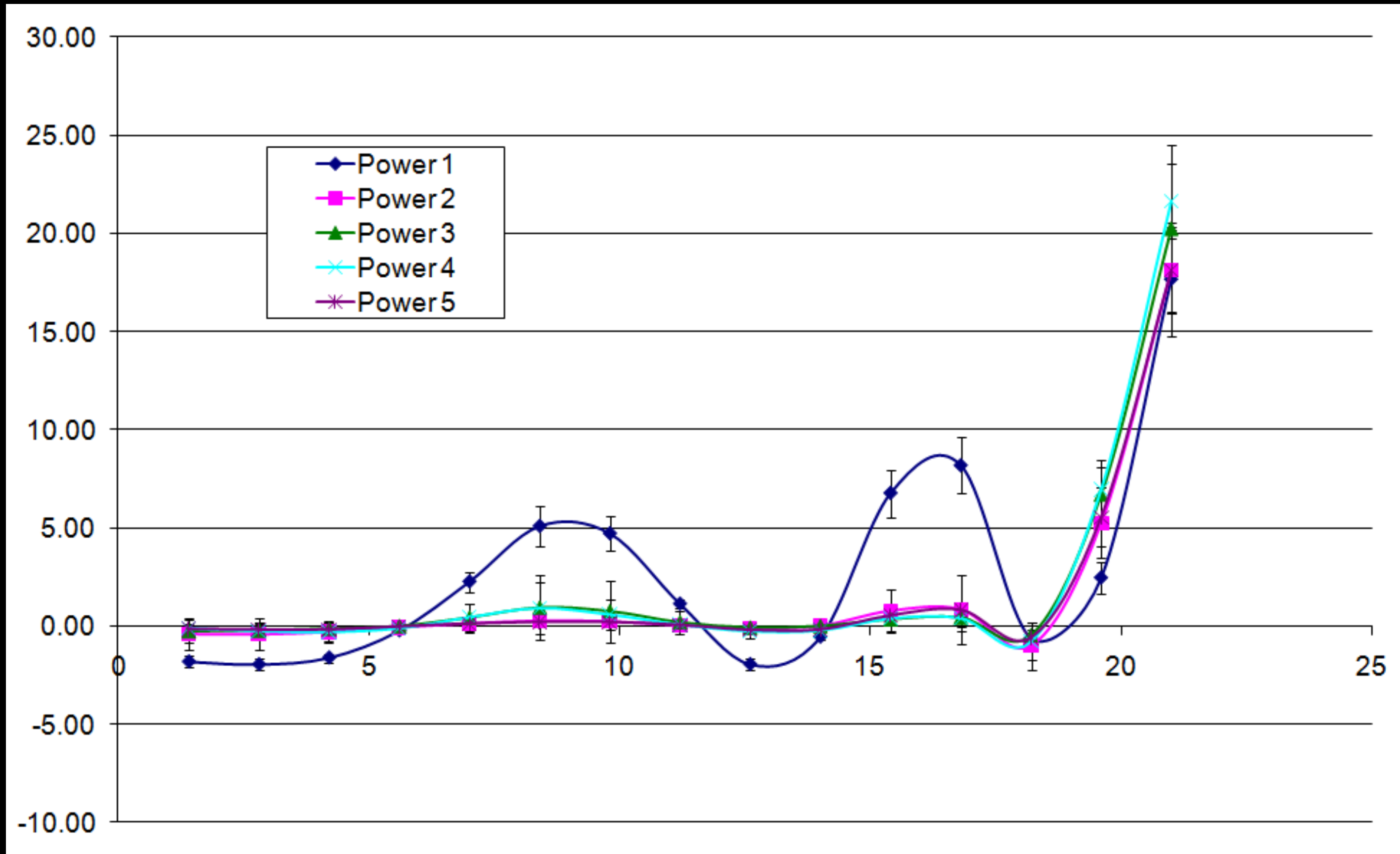
c



d

#10 file - a) power 3, b) power 5. #30 file - c) power 3, d) power 5

Power comparisons



#10 file, 27mm length – all power settings

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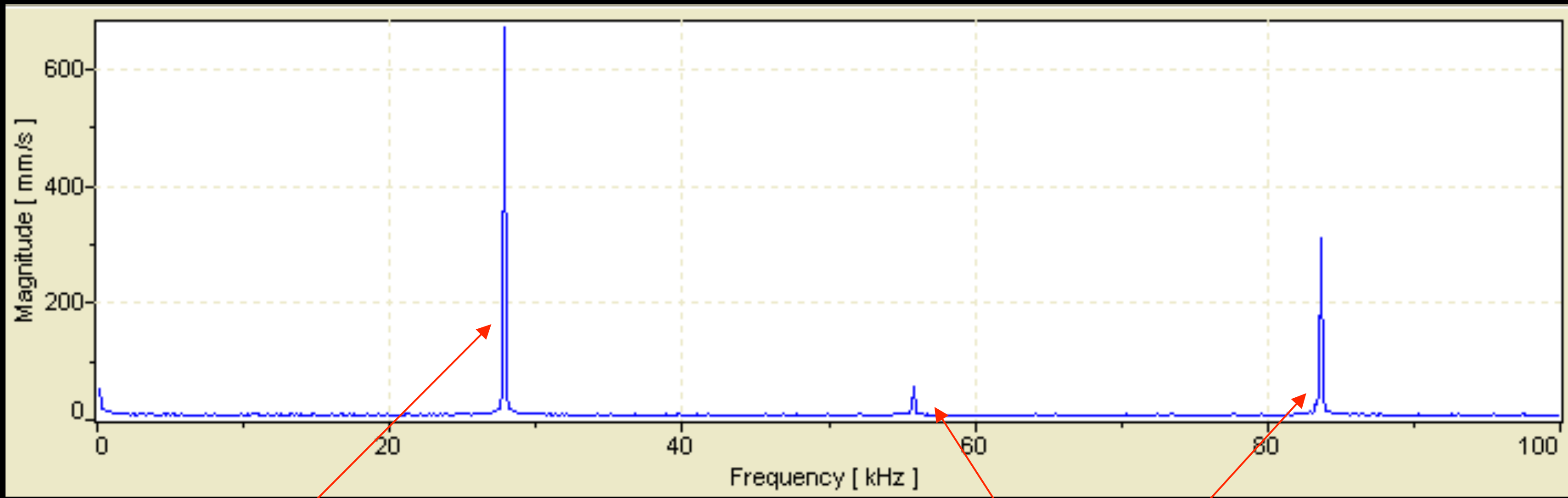
Frequency spectrum at power 1



Fundamental frequency peak with width +/- frequency resolution of scan

Other peaks are also pure with width +/- frequency resolution of scan

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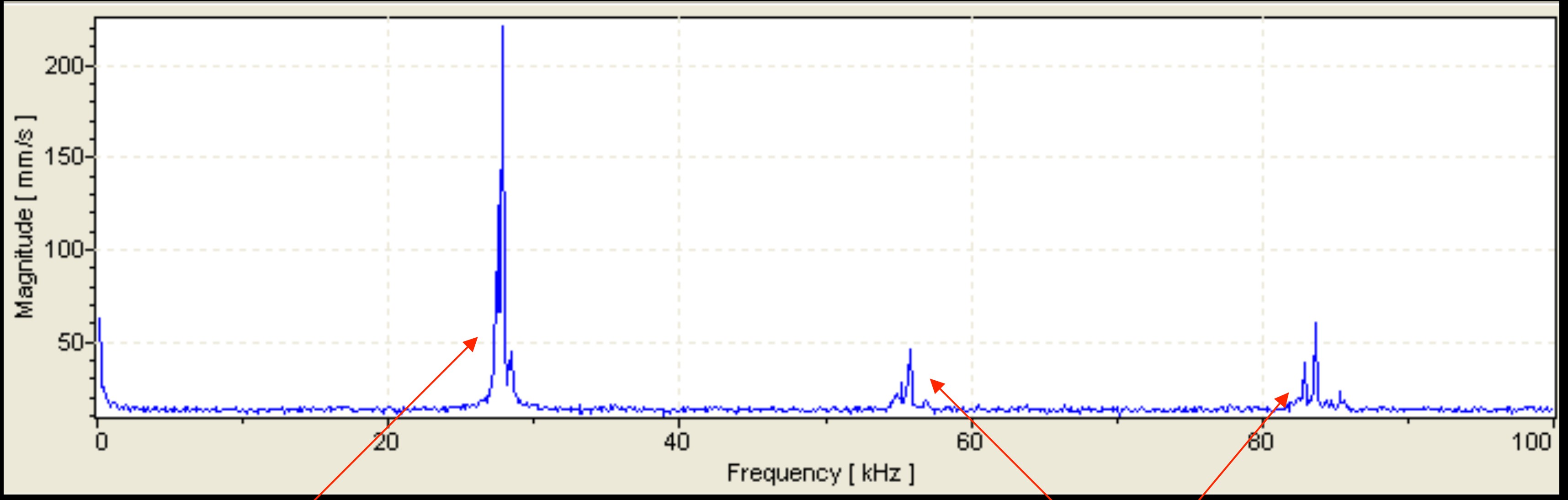
Frequency spectrum at power 5



Fundamental frequency peak with width +/- 3x frequency resolution of scan

Other peaks are also broader than at power 1 and are also comprised of multiple peaks.

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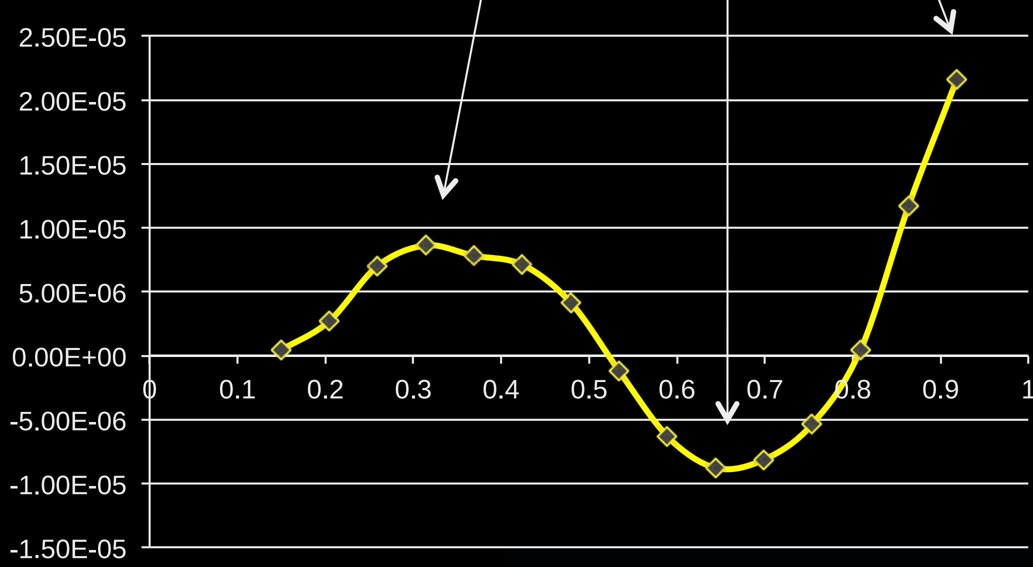
New tips

- Vibrometry of new tips ongoing
- Correlate oscillations with cavitation findings (to be presented by Joyce, Bath University)



Conclusions


Analyzing Endosonic Root Canal File Oscillations: An In Vitro Evaluation

- ❑ Increasing power
  - increase in file displacement
  - ❑ Vibration 'flattening' at higher powers
  - ❑ Vibration spectra highlight problems
  - ❑ Generator power increase may enhance efficacy of PUI
- ❑ Variations in design impact on oscillation

Lea SC, Walmsley AD, Lumley PL. Analysing endosonic root canal file oscillations: an in vitro evaluation. Journal of Endodontics. 2010; 36: 880-883

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Peri-implantitis – the clinical view

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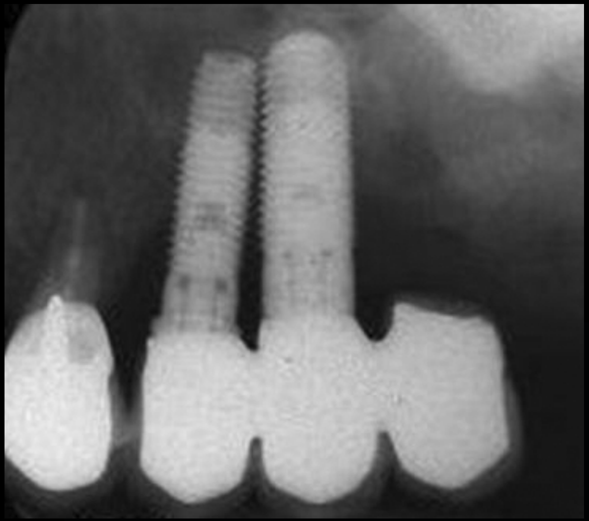
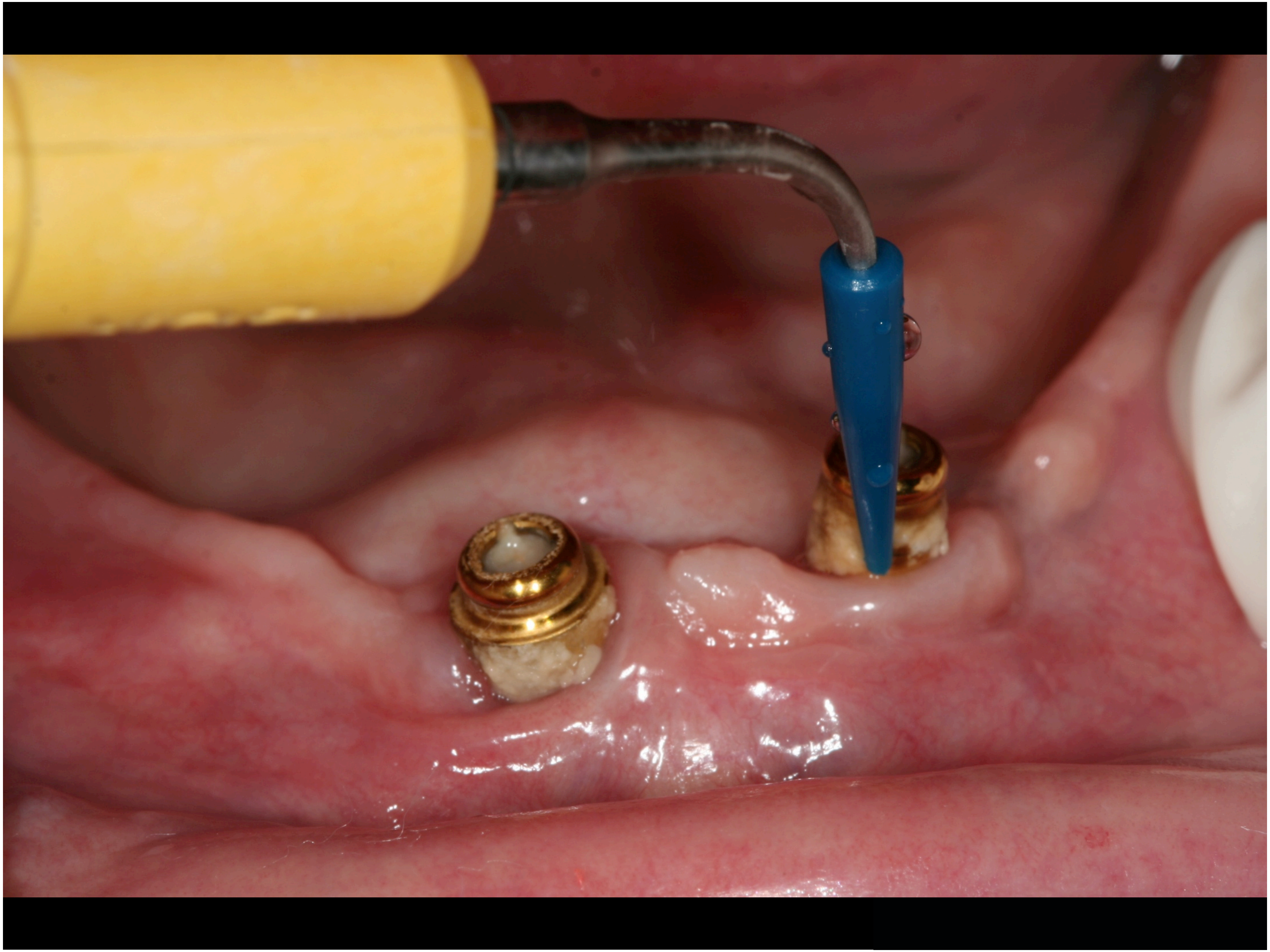
Which instrument to use for cleaning?

- Stainless Steel
- Titanium
- Plastic
- Ultrasonic scaler

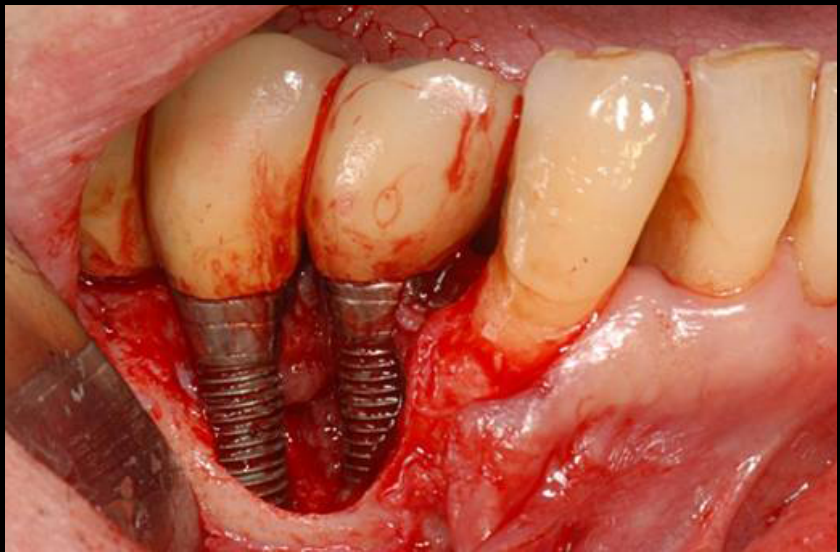


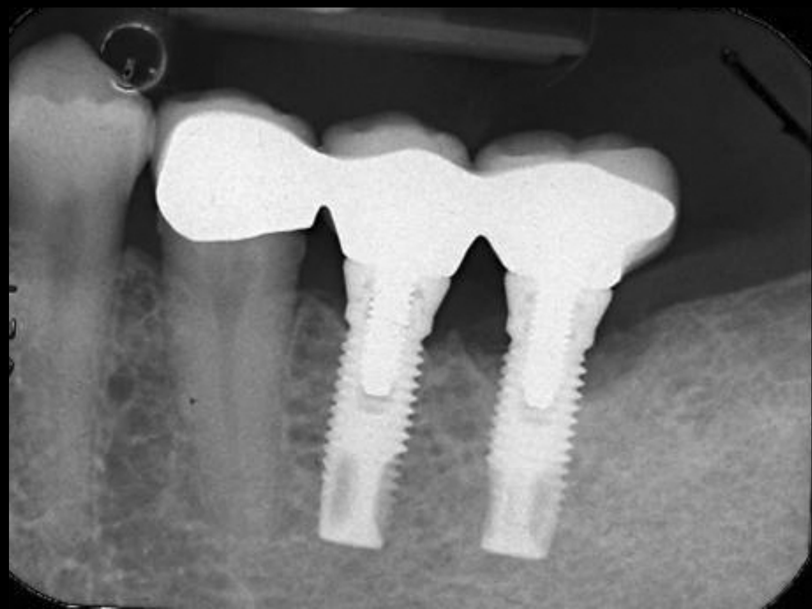
Ultrasonic Scalers



Evidence for treatment?

- Implant infection is a relatively new pathology
- Little scientific evidence to suggest a standard treatment modality





Problem becoming greater

- Increase in number of implants placed
- Implant problems increases with number of years in function

- Management of implant pathology
  - *Major challenge for general practitioner and specialist in near future*

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Treating Implant problems with Ultrasonics

- professional maintenance importance:
  dental implants = natural teeth

- ultrasonic scalers used to remove plaque and calculus from titanium implant surfaces

- damage may be caused by metal probes

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Treating Peri-implantitis
Ultrasonics

- relationship between surface roughness and bacterial colonization - Quiryen et al (1993)
- environment allows tenacious adherence of a biofilm → implant failure
- damage minimised using plastic coated ultrasonic scaler probes ?

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Plastic covered ultrasonic scalers

- investigate vibration patterns of 2 ultrasonic scaler probe designs
  - *traditional metal probe*
  - *new plastic coated probe*

- under various load and power conditions

- correlate findings with damage caused

Mann M, Parmer D, Walmsley AD, Lea SC. Effect of plastic covered ultrasonic scalers on titanium implant surfaces. 2011 Clinical Oral implants Research (In Press)

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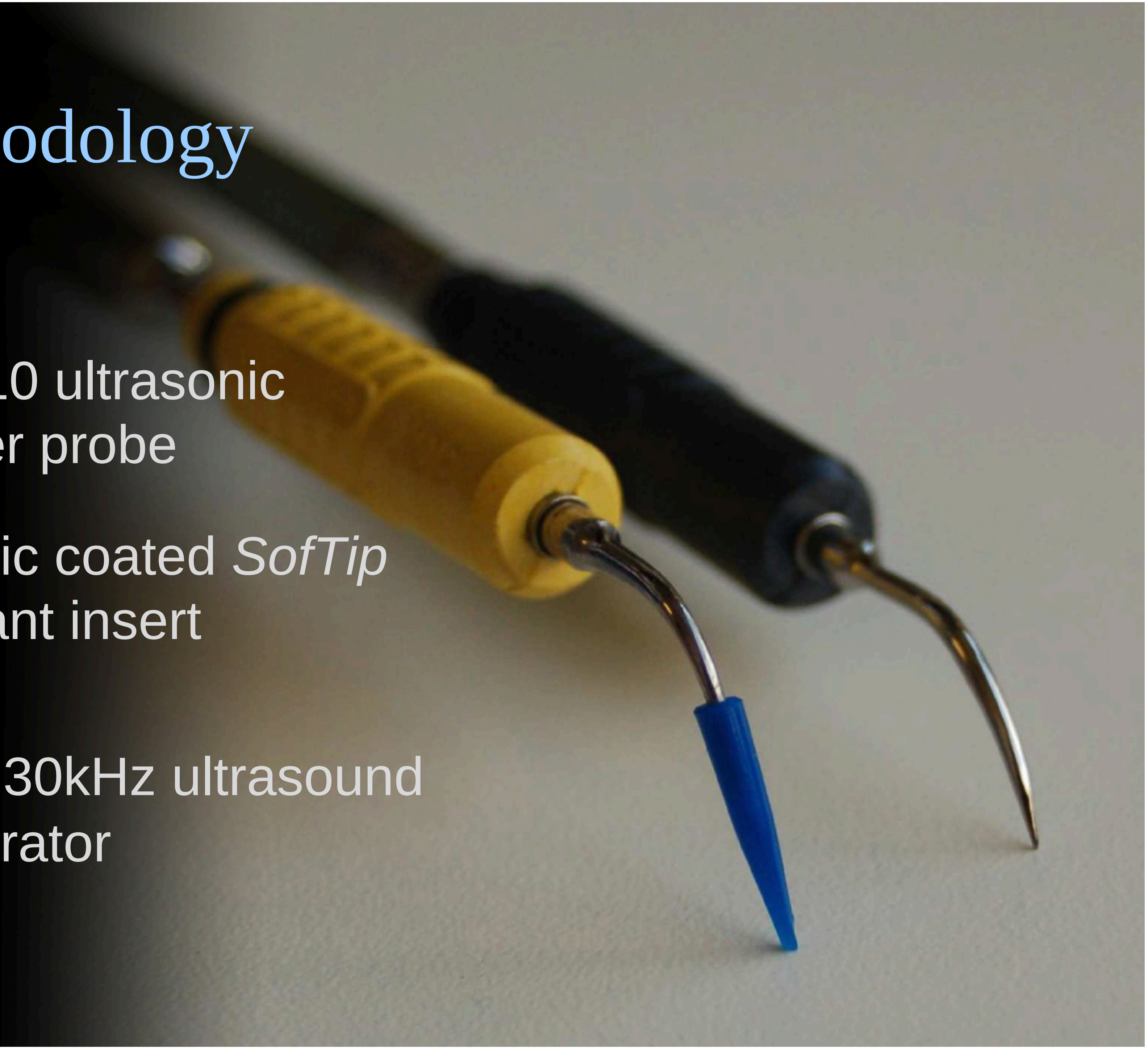
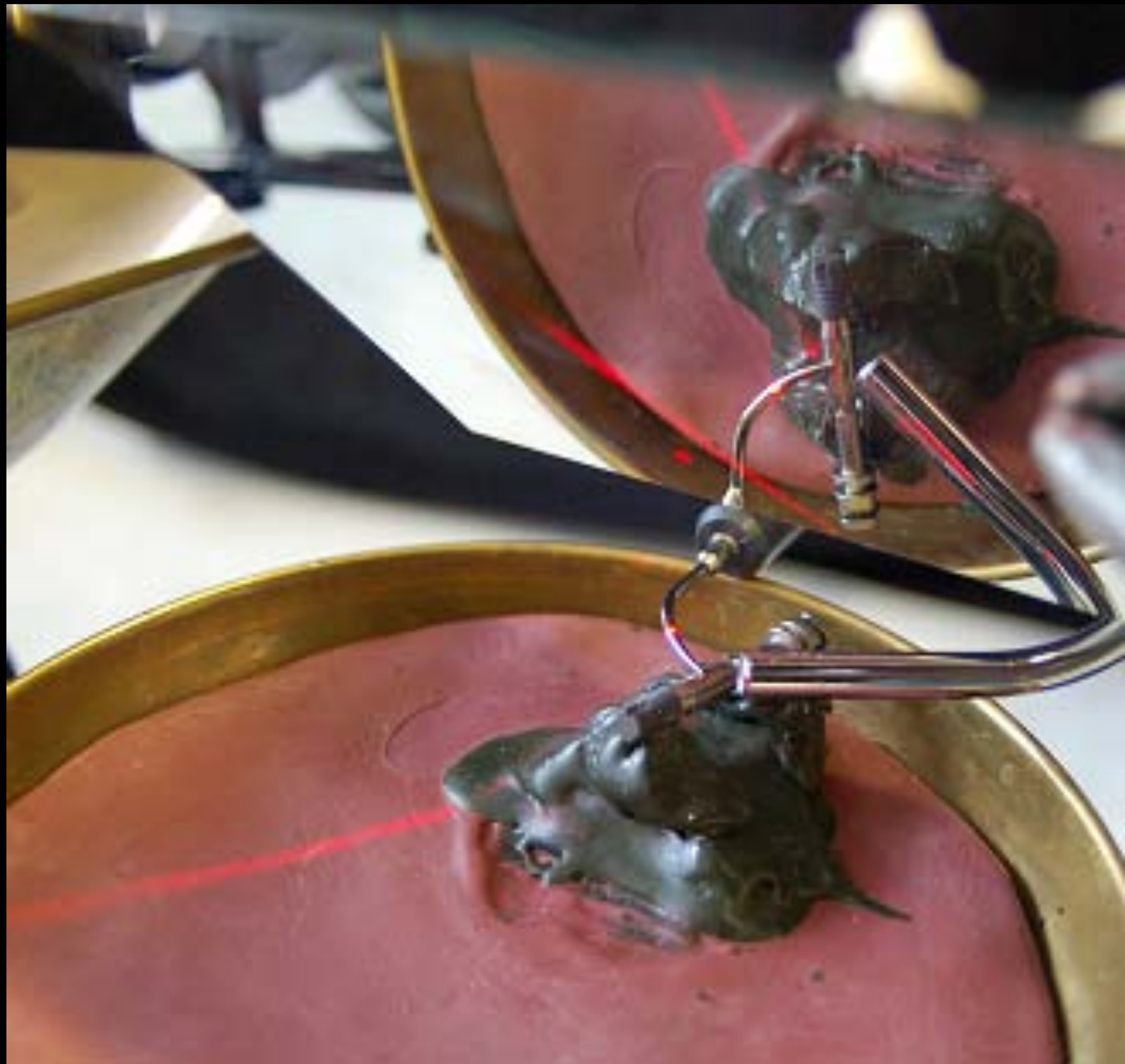
Methodology

- TFI-10 ultrasonic scaler probe
- Plastic coated *SofTip* implant insert
- SPS 30kHz ultrasound generator





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Methodology

- loads - 100g and 200g (high and low power)
- 10 seconds
- water flow rate - 30 ml/min
- repeated 5 times for each condition

- laser vibrometer with mirror
  - 3D vibration + displacement amplitude

- laser profilometer scanned surfaces

- data evaluated using SPSS
  (significance level of $p = 0.05$)

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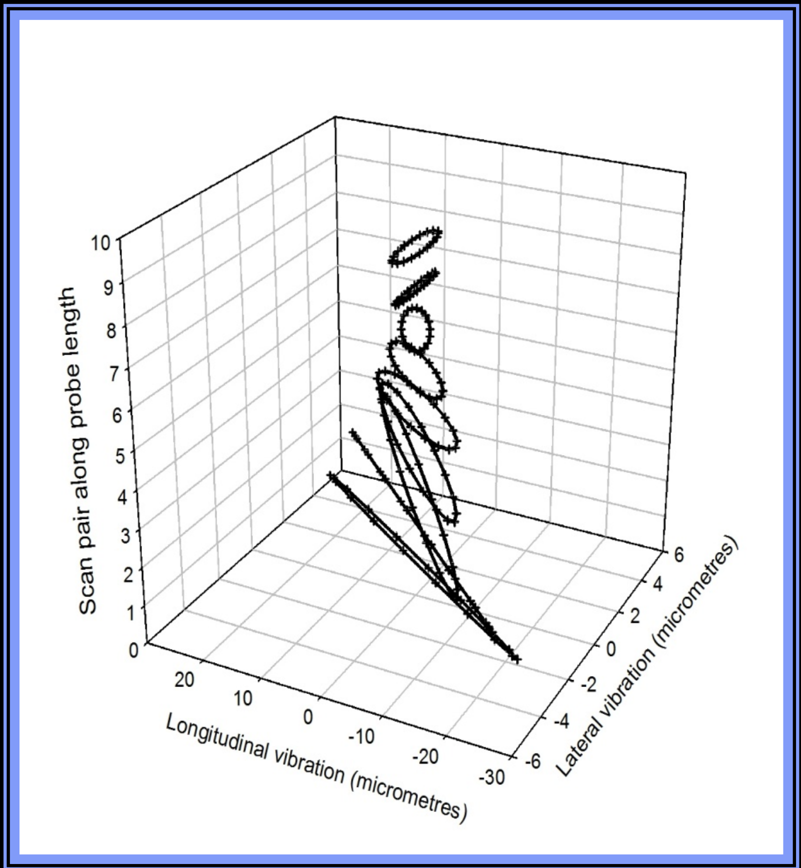
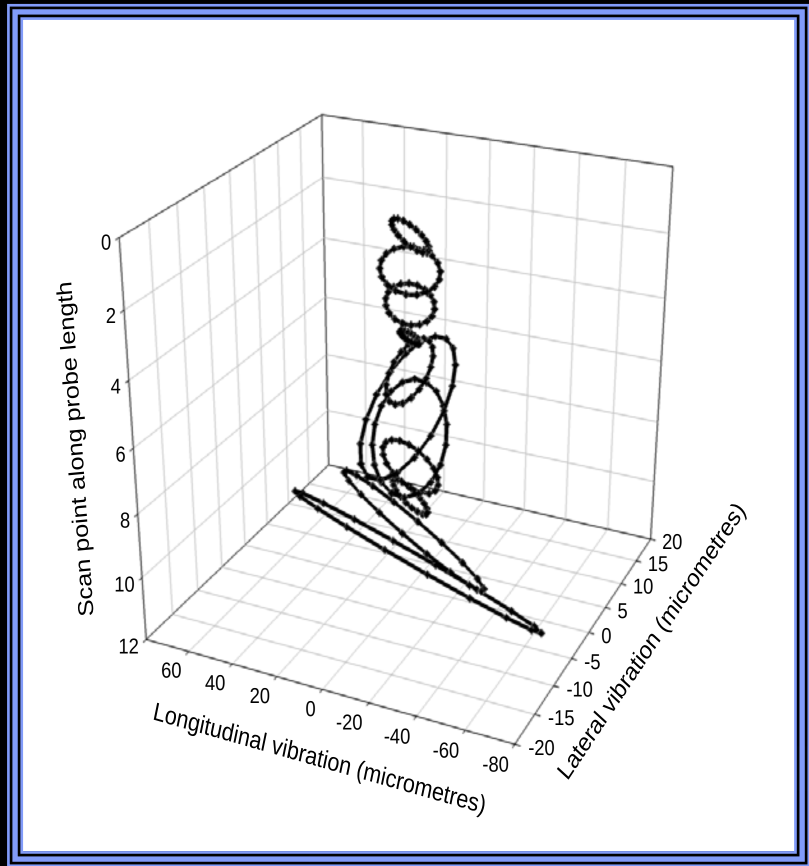
Results

Scaler inserts oscillated with an elliptical vibration pattern

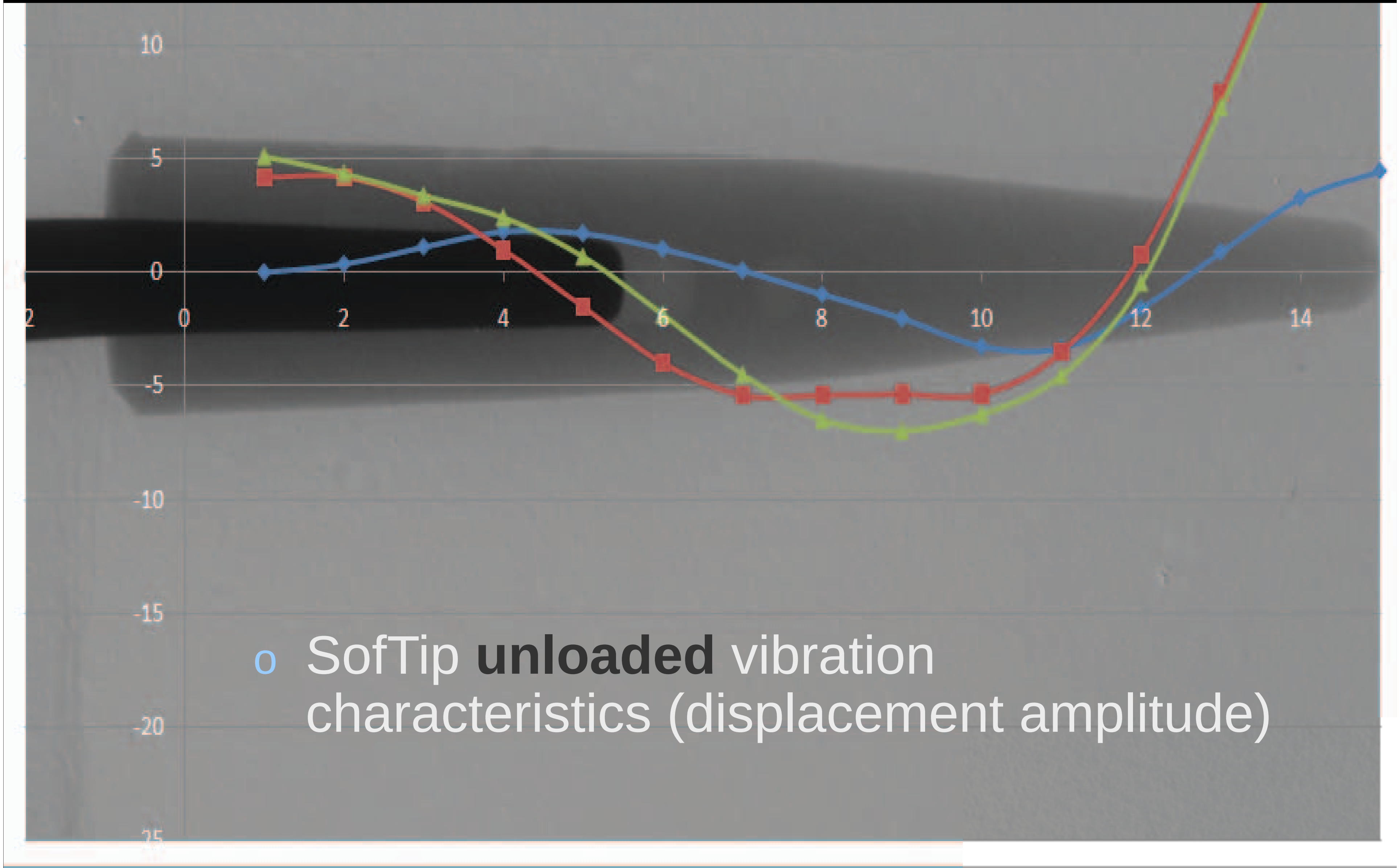


metal scaler probe



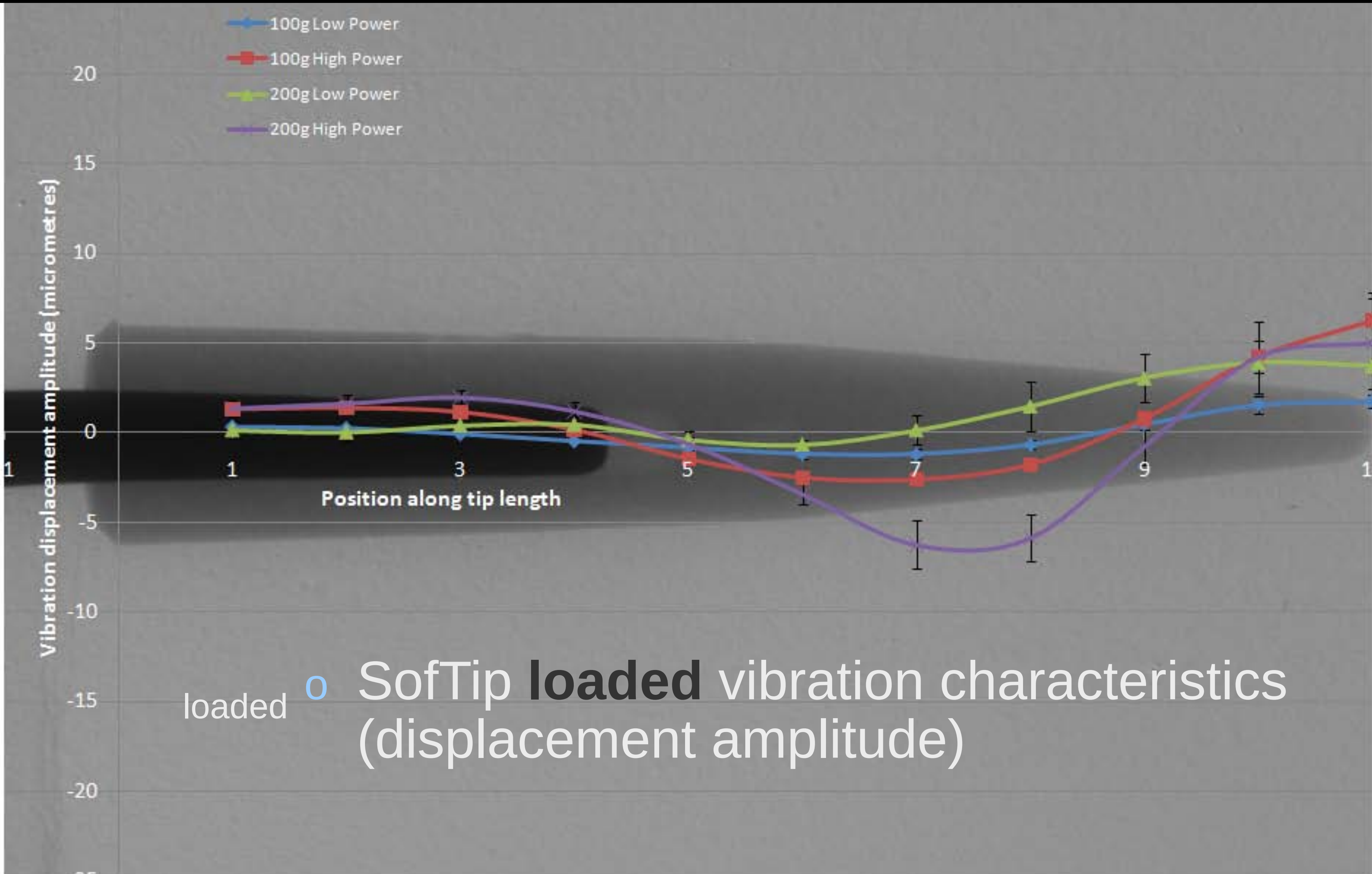
plastic scaler insert and probe

Implant insert



- SofTip **unloaded** vibration characteristics (displacement amplitude)

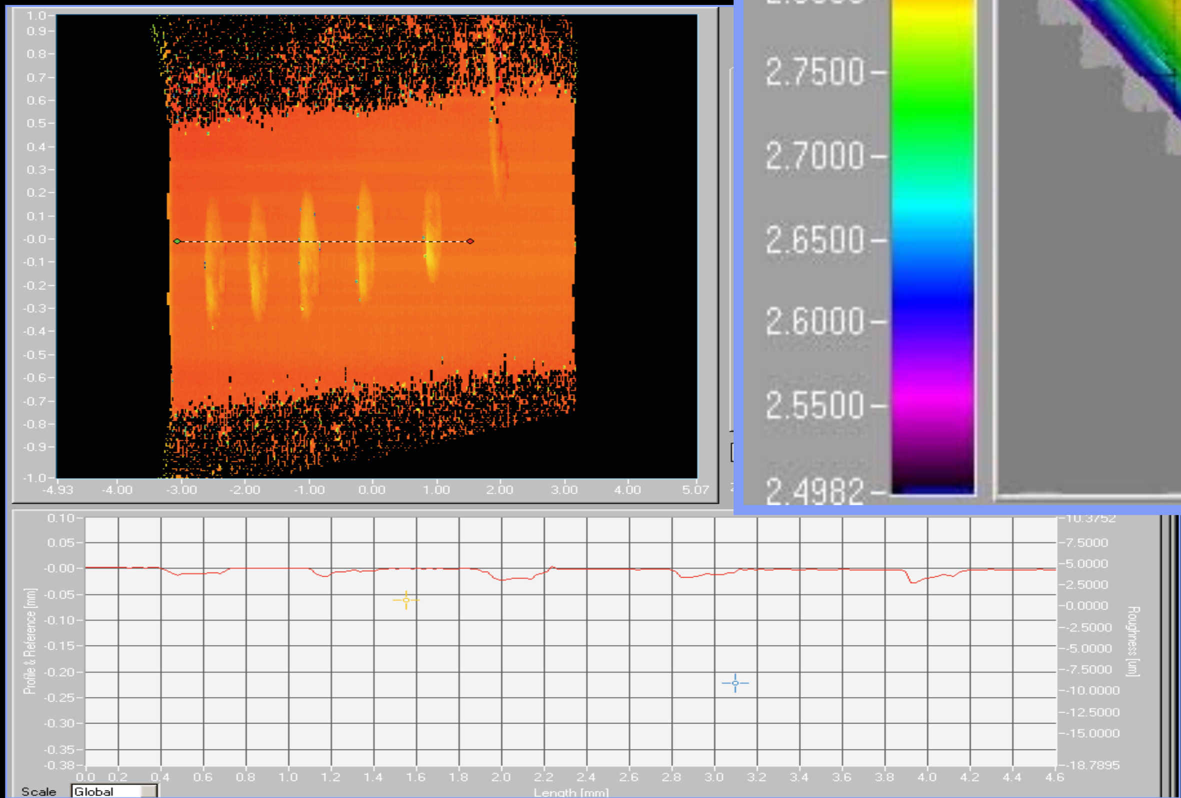
Implant insert

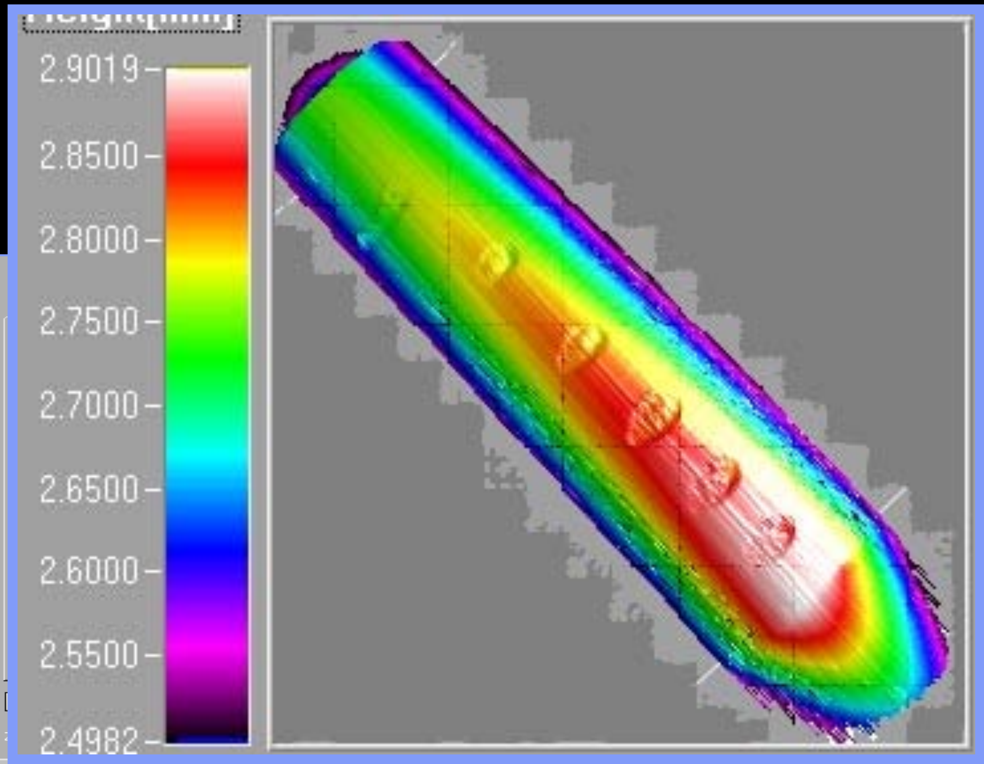


- SofTip **loaded** vibration characteristics (displacement amplitude)

Defect depth

laser profilometer measured defect depth & width





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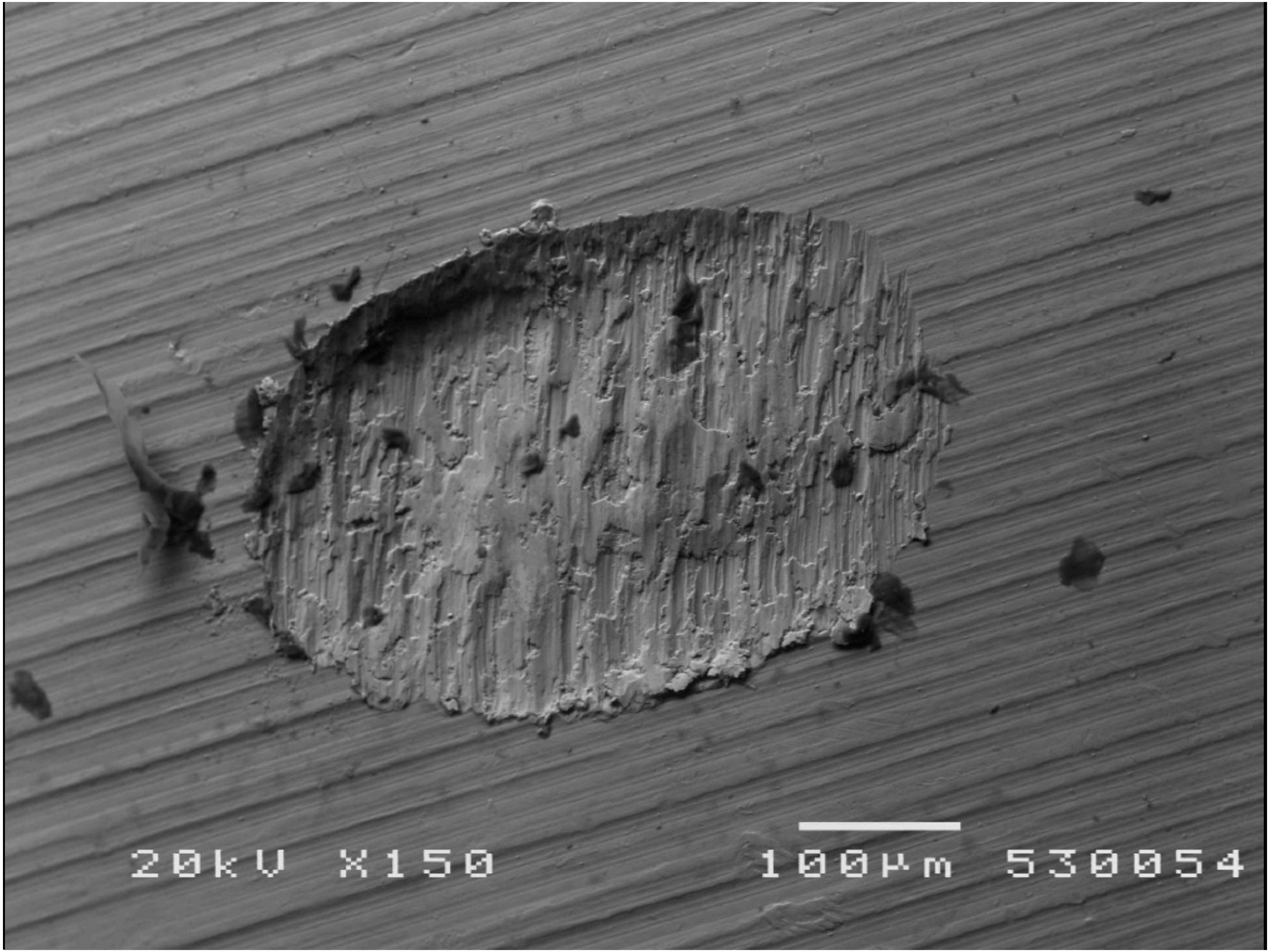
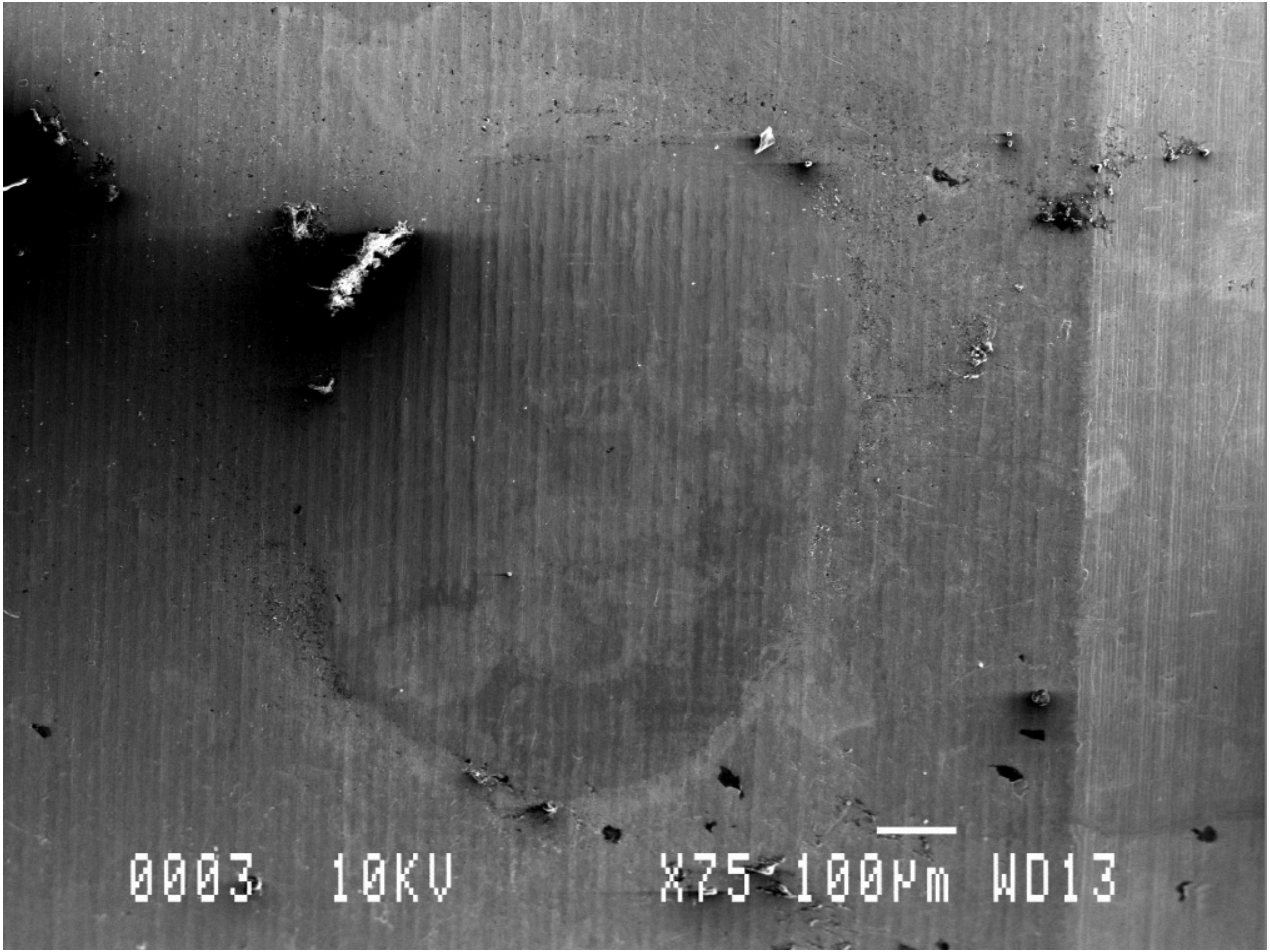

20kV X150
100µm 530054


0003 10KV
X75 100μm WD13

Implant insert

- Debris visible may be removal of superficial layer of titanium surface + plastic coat
- At high power, plastic coat melts at tip
- May create further damage to implant surface

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Summary

- load/power settings - important factors in damage caused to implant surfaces by scaler probes
- provision of plastic coated – minimal damage
- operating at low power ensures efficiency as no visible damage to tip

Mann M, Parmar D, Walmsley AD, Lea SC.
Effect of plastic-covered ultrasonic scalers on titanium implant surfaces.
Clin Oral Implants Res. 2011. doi: 10.1111/j.1600-0501.2011.02186.x.

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No Gold Standard
Research Needed!

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Piezosurgery

Background

- Ultrasonic drill used to cut teeth in 1950s
- Overtaken by high speed rotary drills
- Main use is plaque and calculus removal
- Use in endodontics for debridement
- Now back to cutting bone

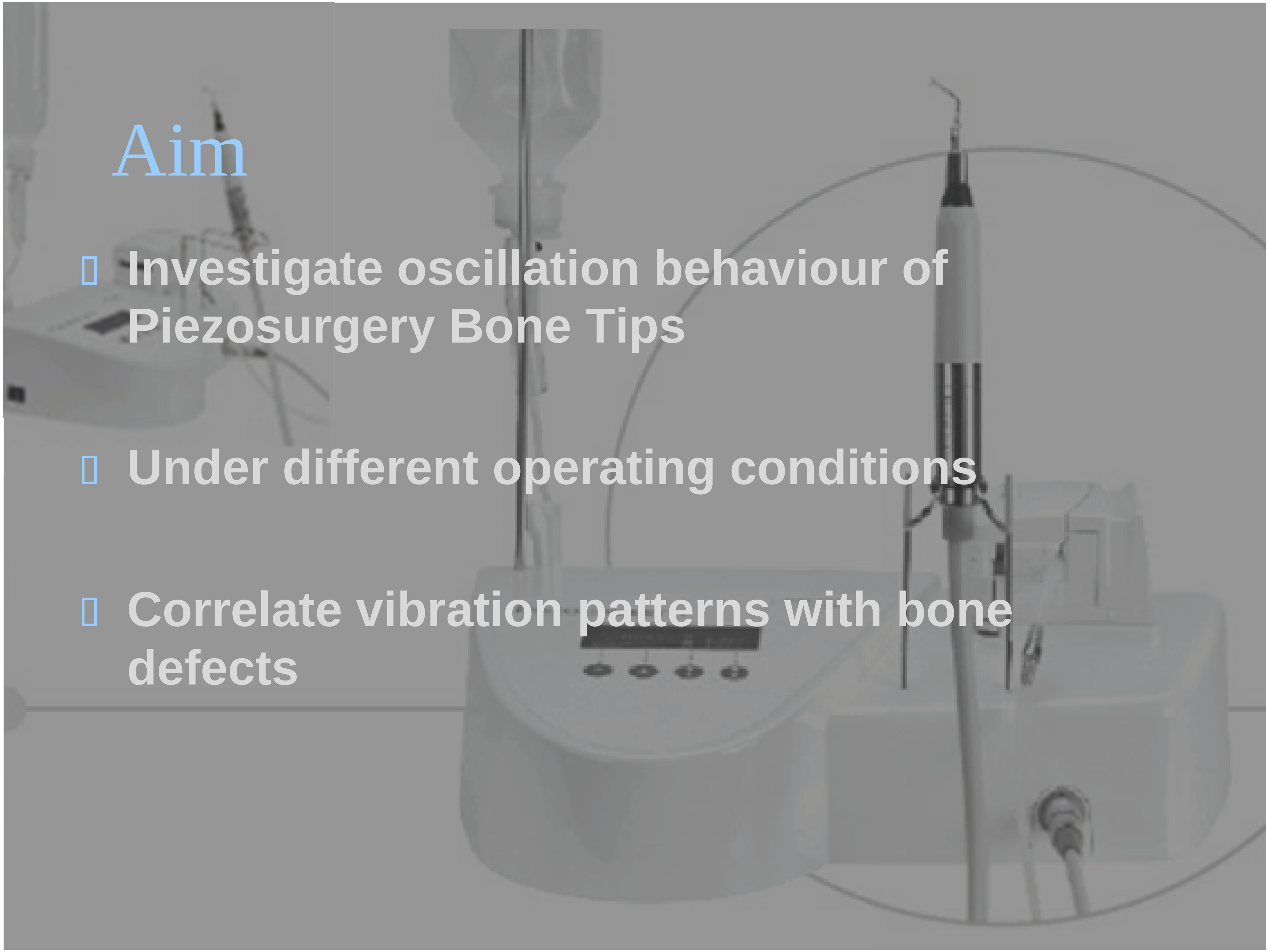
PIEZOSURGERY

Aim

- **Investigate oscillation behaviour of Piezosurgery Bone Tips**

- **Under different operating conditions**

- **Correlate vibration patterns with bone defects**



Method

- Piezosurgery Ultrasound Unit (Mectron, Italy)
- 3 Cutting Modes
  - Cortical
  - Spongious
  - Special
- OT7 Cutting Tip

Method

- 1D Scanning Laser Vibrometer Unit (SLV)

- Anterior surface of probe – Longitudinal
- Side surface of probe – Lateral
- First Surface Reflecting Mirror

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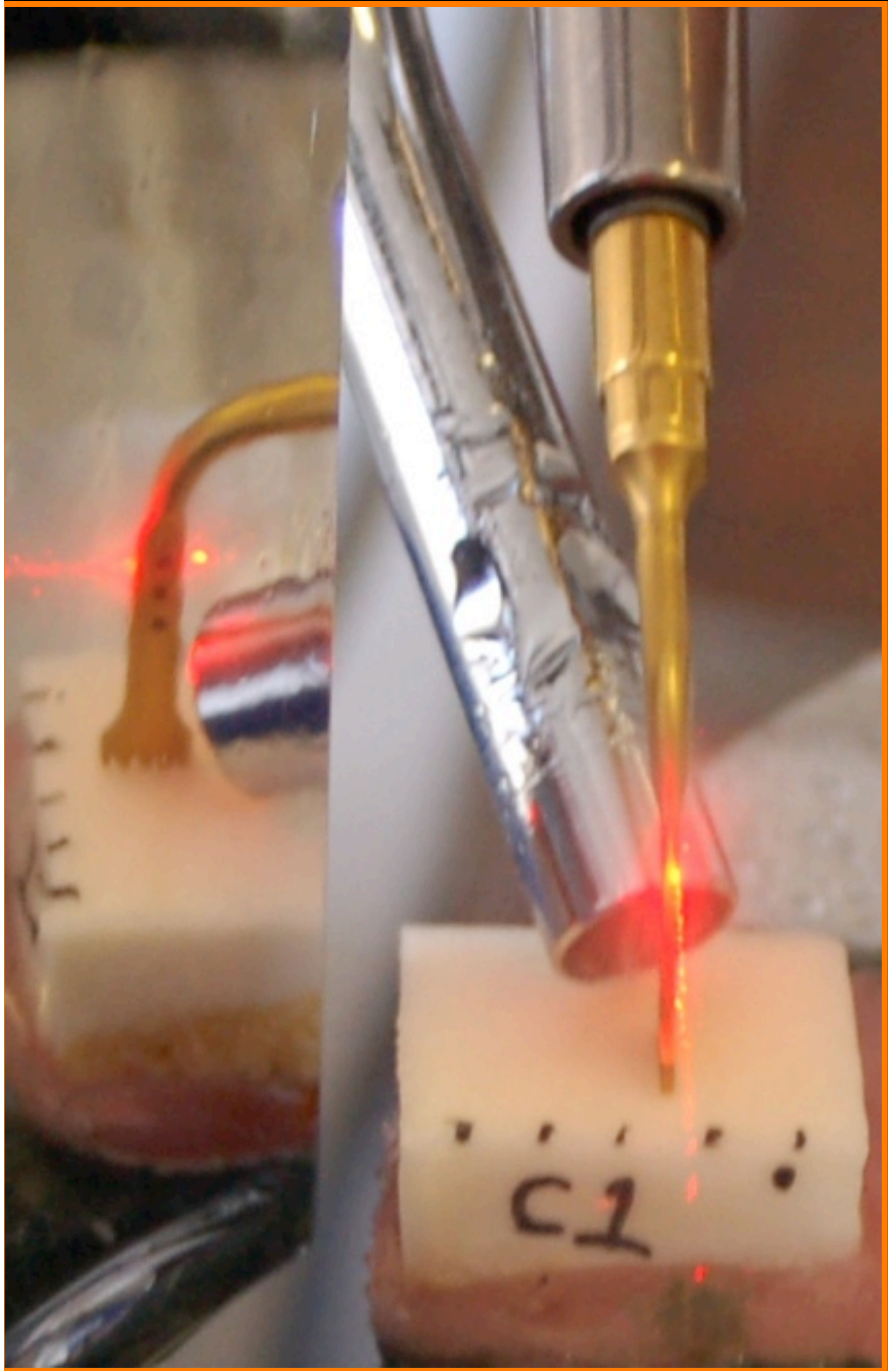

Phase 1

- Unloaded
  - Cortical
  - Spongious
- 10 Scans
- ± Water Flow
  - 30ml/minute
- SLV measured oscillation

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Phase 2

- Bovine Bone
  – Cortical Surfaces x5
  – Spongious Surfaces x5
- Loads
  – 50g, 100g, 200g
- Time
  – 10 seconds
- Water Flow
  – 30ml/minute

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Phase 3

- Scanning of bone defects
- TaiCaan Xyris 4000 WL/CL 3D metrology system
- Defect depths measured

- Statistical analysis
  - Univariate Analysis of Variance
  - Significance level p=0.05

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Phase 1

- Maximum oscillation at tip of probe

Longitudinal Vibrations	- Water	Cortical	14.6µm	No Significant Difference (p=0.064)
		Spongious	12.6µm	
	+ Water	Cortical	11.7µm	No Significant Difference (p=0.942)
		Spongious	11.3µm	

Lateral Vibrations	± Water	No Significant Difference ($p \geq 0.918$)
	Cortical & Spongious	

- But ……
  system designed to contact bone

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Phase 2

- Cortical
  - Average max displacement amplitudes
    - Longitudinal
      - 50g - 11.4µm
      - 100g - 10.0µm
      - 200g - 2.9µm

No sig diff (p=0.266) [50g vs 100g]

Sig.Diff p<0.0001 [200g]

    - Lateral
      - 50g - 1.5µm
      - 100g - 0.7µm
      - 200g - 0.6µm

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Phase 2

- Spongious Setting
  - Average Max Displacement Amplitudes
    - Longitudinal
      - 50g - 2.81μm
      - 100g - 3.04μm
      - 200g - 3.53μm
    - Lateral
      - 50g - 1.91μm
      - 100g - 1.48μm
      - 200g - 1.67μm
  - No SD between 50g, 100g and 200g ($p \geq 0.474$)

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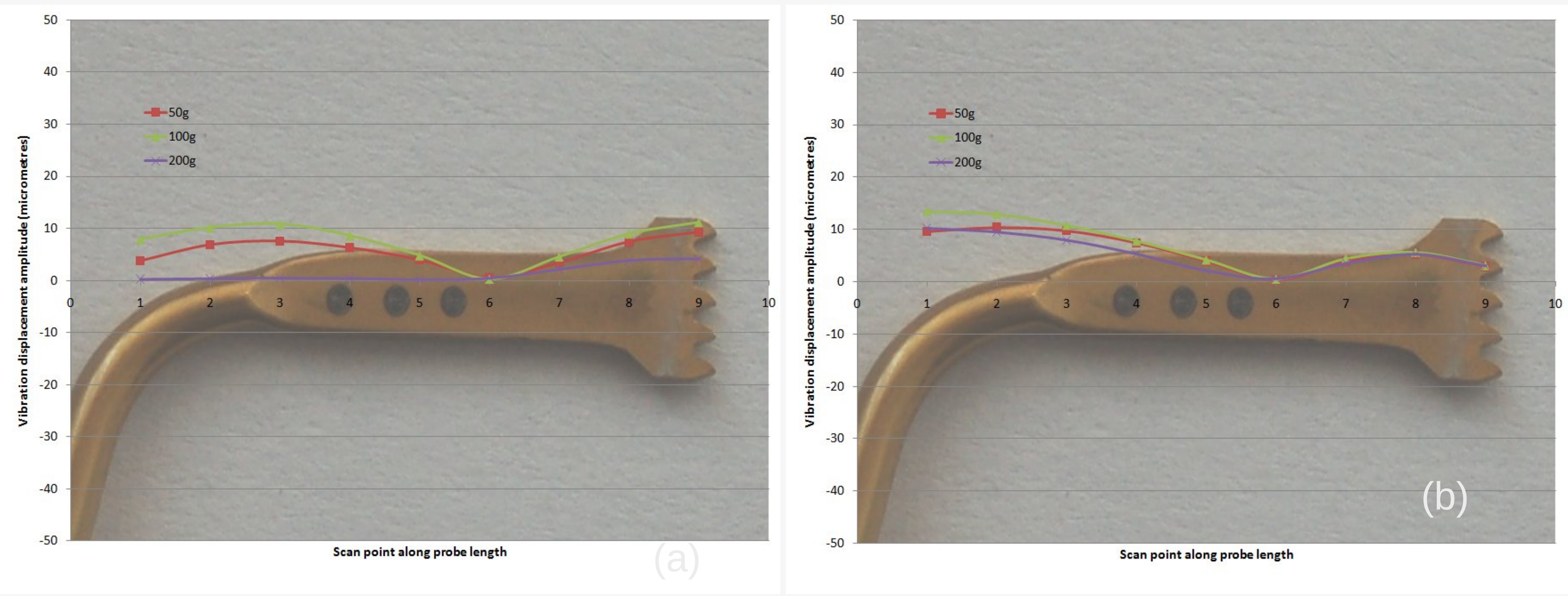

- Max oscillation magnitude, along length of probe,
  both cortical (a) and spongious (b) bone cutting settings (all loads)

- Position of node remains constant for 2 settings,
  mode shapes quite different

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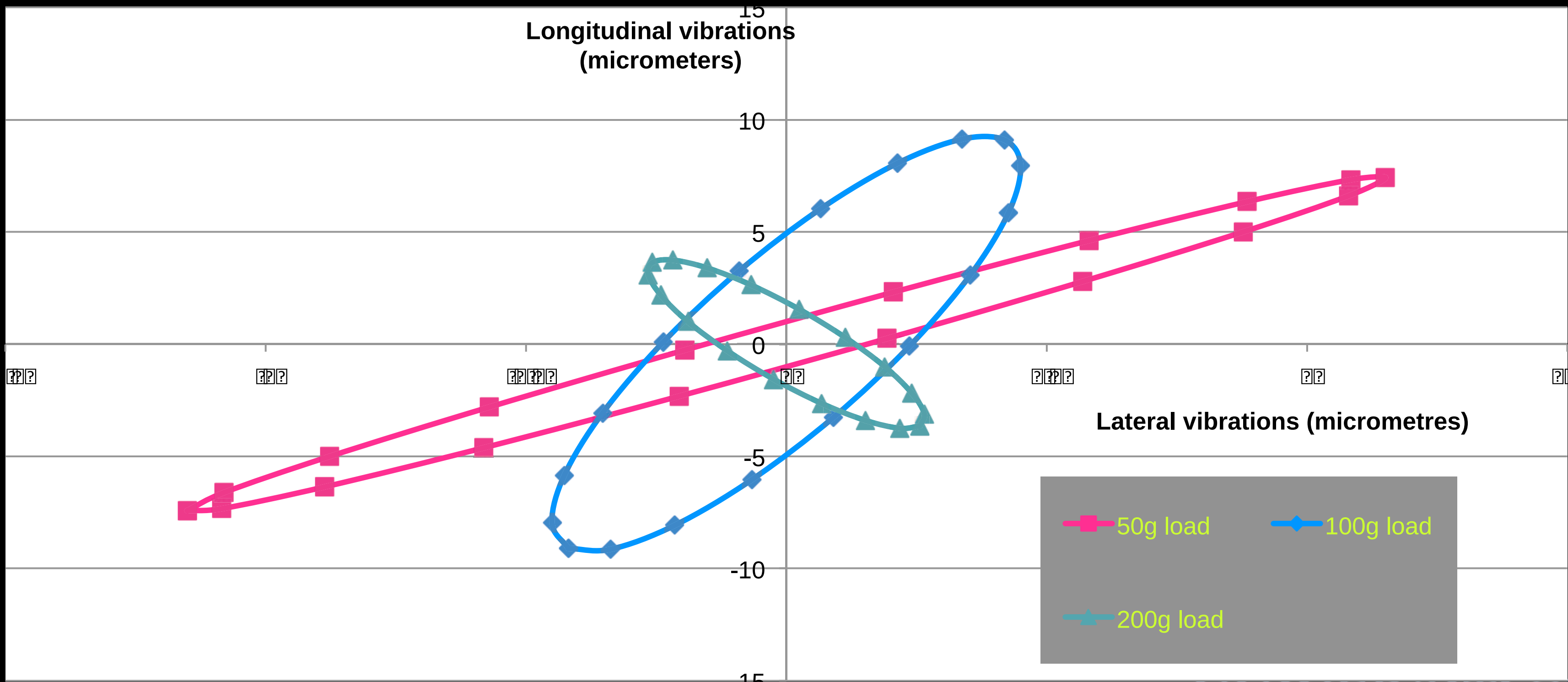
Probe Motion 3D

- As load increased, tip retains elliptical oscillation pattern



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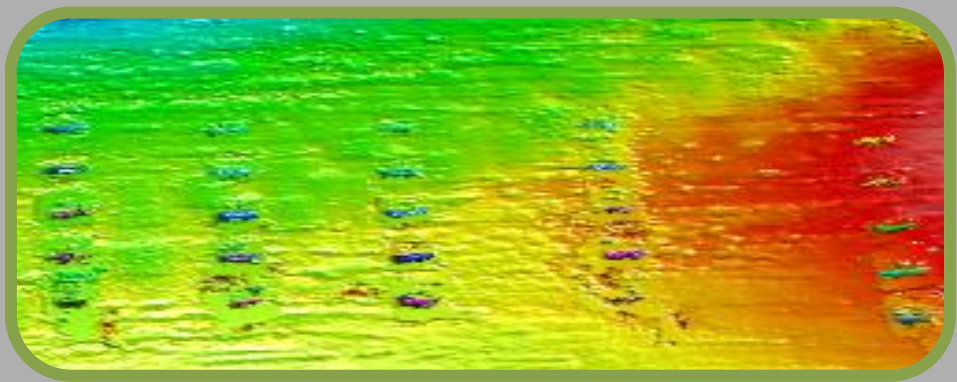
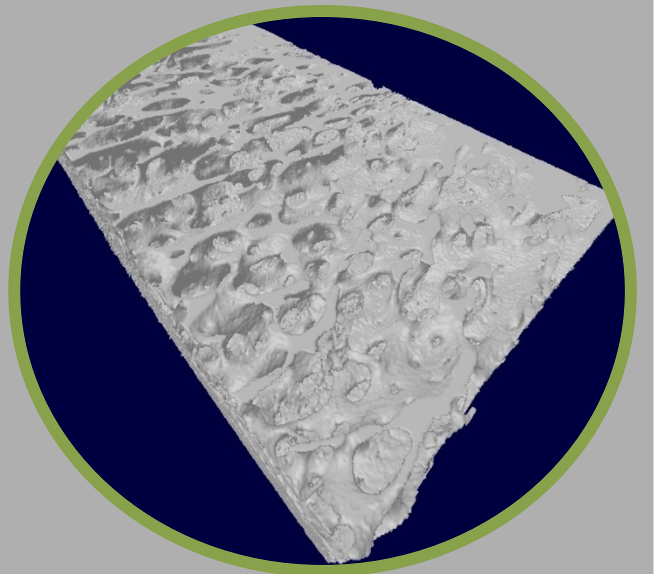
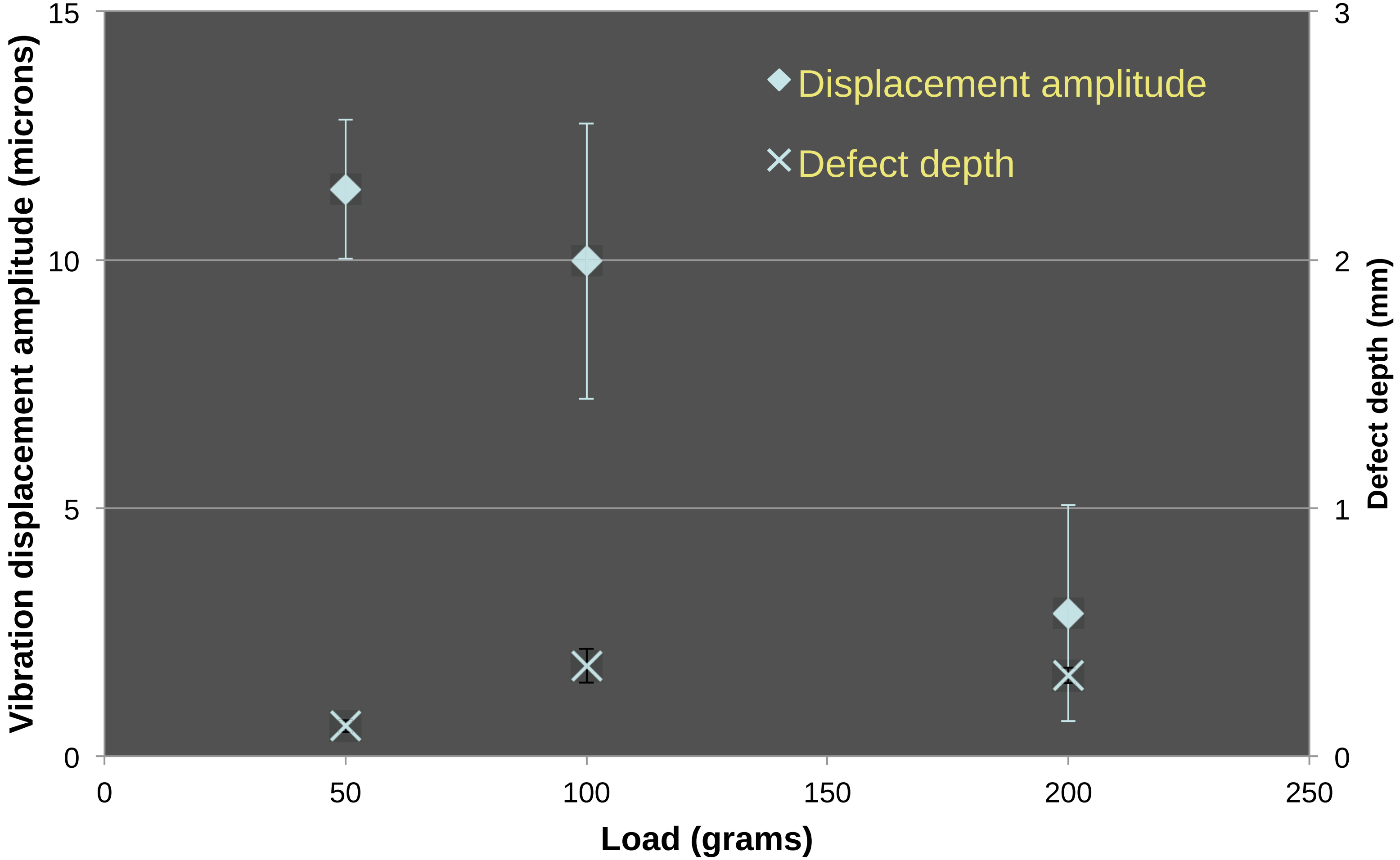
Phase 3

- scanning laser profilometry
- average defect depths
  - 50g - 0.12mm
  - 100g - 0.36mm
  - 200g - 0.33mm





Phase 3



Displacement amplitude
Defect depth
Vibration displacement amplitude (microns)
Defect depth (mm)
Load (grams)
15
10
5
0
3
2
1
0
0
50
100
150
200
250

Conclusion

- More work needed
- Study focussed on OT7 tip
  - Light pressure to maximise bone cutting
  - 200g load may lead to strain
  - Vibration is elliptical
- Bone structure influences cutting process

Parmar D, Mann M, Walmsley AD, Lea SC.
Cutting characteristics of ultrasonic surgical instruments.
Clin Oral Implants Res. 2011 Mar 8. doi: 10.1111/j.1600-0501.2010.02121.x.

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Conclusion

- Surface alters mode shape and oscillation magnitude
- Max depth at 100g contact
- Increasing load reduces oscillation amplitude and depth of cut
- Clinical Relevance
  - Pressure affects cutting efficiency

Parmar D, Mann M, Walmsley AD, Lea SC.
Cutting characteristics of ultrasonic surgical instruments.
Clin Oral Implants Res. 2011 Mar 8. doi: 10.1111/j.1600-0501.2010.02121.x.

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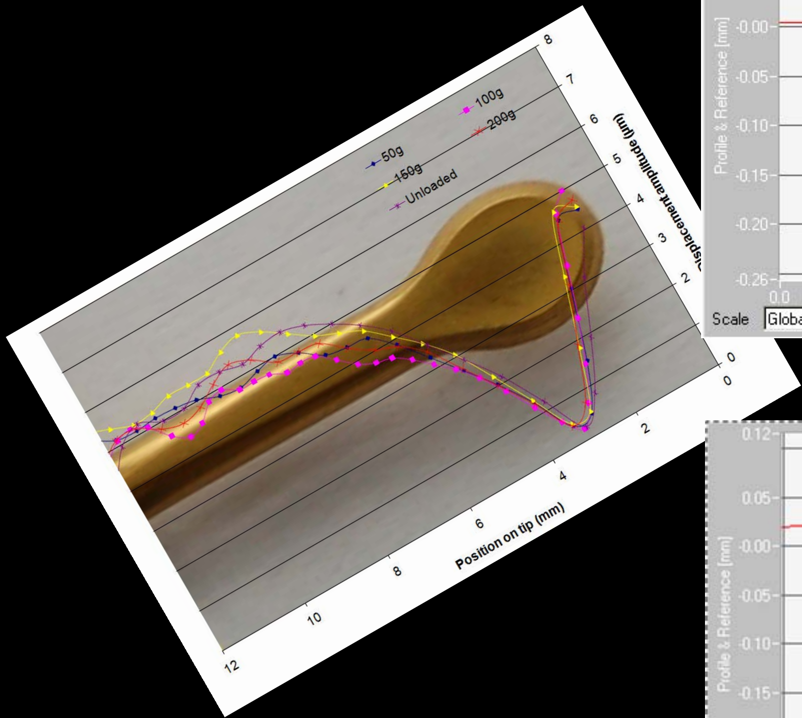
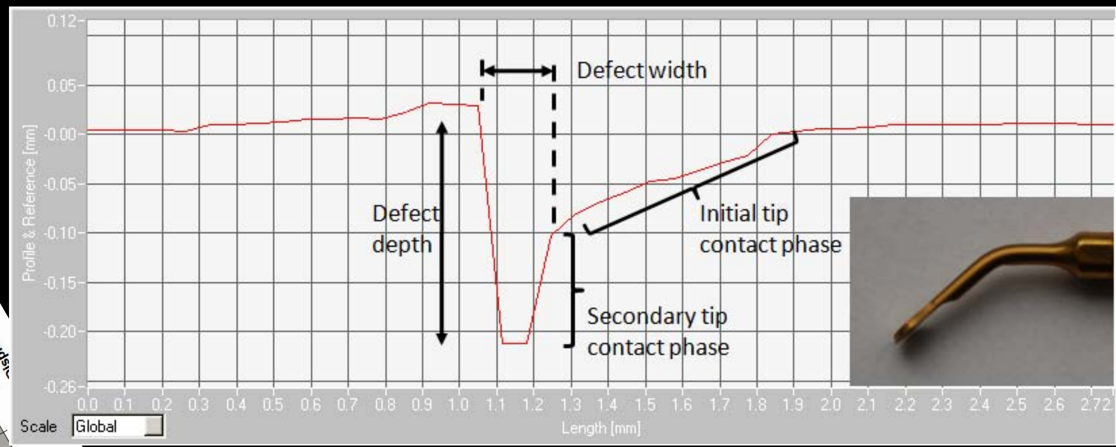
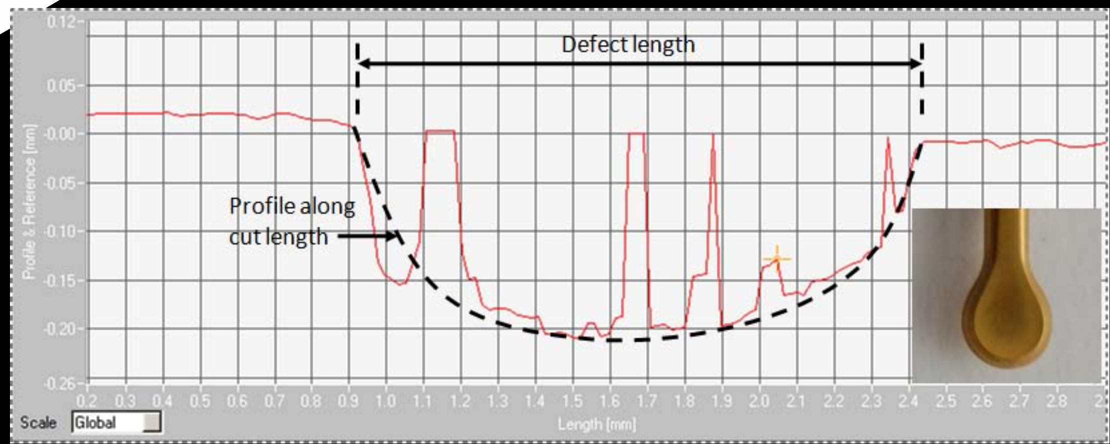
Further Work







Claire S, Lea SC, Walmsley AD.
Characterisation of bone following ultrasonic cutting.
Royal Society Interface (Submitted for publication)

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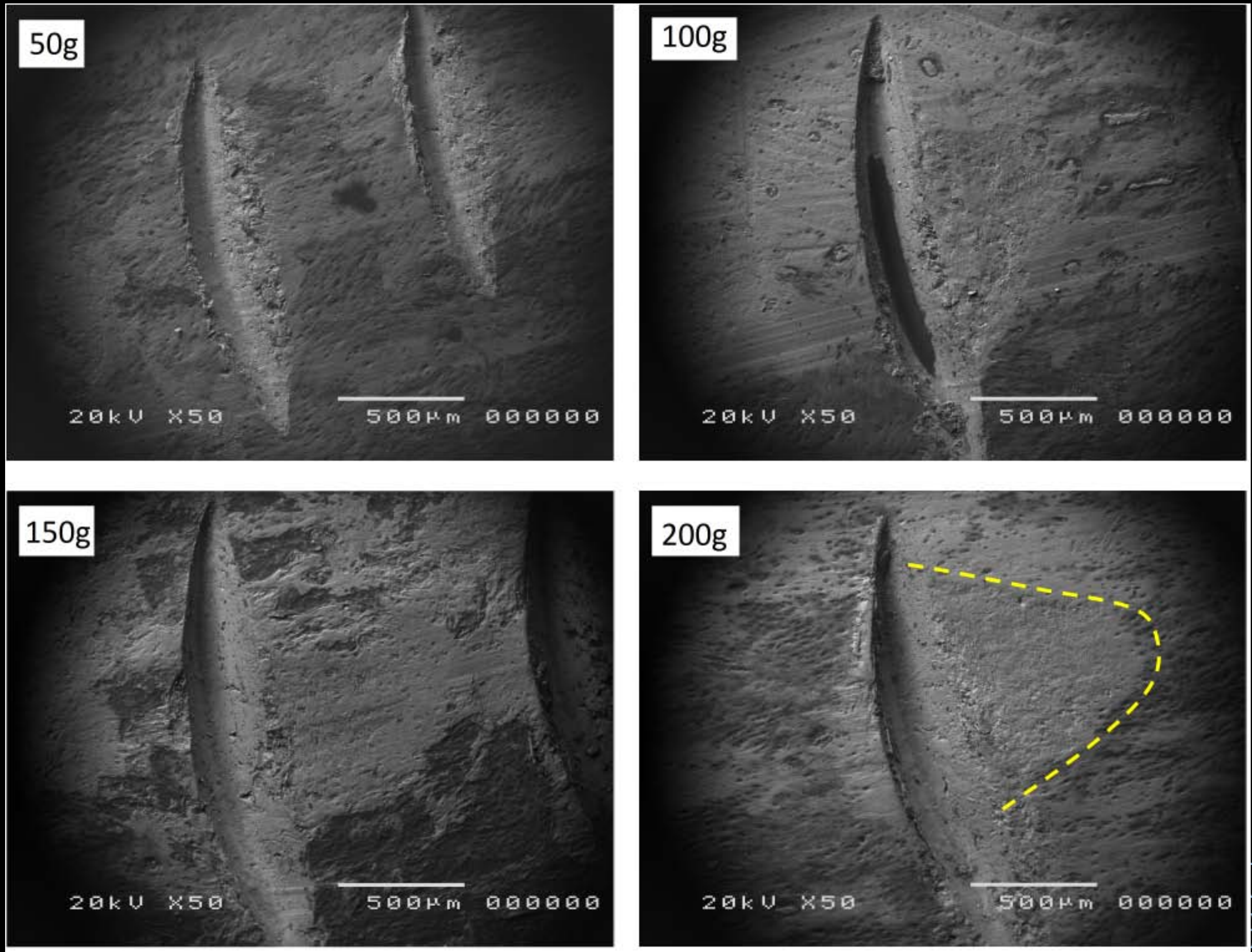
Further Work



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In Summary

- Ultrasonics for dental use
  - Mainly relies on probe – tooth contact
  - Contribution on cavitation and streaming
  - Further research on using such phenomenon to break up bacterial biofilms

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Thank you to

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