Objectives

Background of dental ultrasonics

How they work

How they are used in dentistry

Future directions
Frequency of Ultrasound

Ultrasonic scalers
25 to 40 kHz

Sonic scalers
2 to 6 kHz
Ultrasonic Scalers

1950 - 1955

UNIVERSITY OF BIRMINGHAM
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 .....
…. NOW !!!

2010

UNIVERSITY OF BIRMINGHAM
Ultrasonic Technologies
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
A common misconception

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

magnetostrictive AND piezoelectric tips are ELLIPTICAL


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
Scanning Laser Vibrometry
Motion of the scaling tip
Longitudinal movement
Shows the longitudinal movement (front face-on)
Shows the longitudinal movement (tip end-on)
Ultrasonic Adaptation
Clinical Relevance?
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
Even the generators!
Measurements during tooth contact
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
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
3D measurements
Max. displacement amplitude
25.58µm ± 4.19µm
Clinical Impact

Tooth Contact
Subgingival Adaptation

- Position insert like a probe
- “Vertical”
- **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
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

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
Lavage

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

Lavage – created by H₂O supply

Coolant
Removes Biofilm
Flushes debris from pocket
Contributes to cavitation & acoustic microstreaming
Mist with Droplets

- Increased power
- Decreased area of biofilm removal
Lavage Options

Water
Cetylpyridinium Chloride
Hydrogen Peroxide, 3%
Povidone Iodine, 10%
Essential Oils
Chlorhexidine Gluconate 0.12%
Saline
Sodium Fluoride
Lavage Options

No evidence anything is better than water
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
Effect on Microflora

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

*Baehni et al*
1987, 1992
Ultrasonic scaler removal – no water
Ultrasonic scaler removal
–water present
Streaming around ultrasonic scaler
Luminescence around probe
Acoustic Turbulence around Scaler operated in water
Non-Contacting
Acoustic Turbulence around Scaler operated in water

Contacting the tooth
Endosonics - ultrasonic
View of File Movement
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
Inertial cavitation - Endosonic Files
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

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
Results 1 – 27mm files

#10 file – 27mm length – power setting 1
Results 3 – 27mm files

#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
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
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.
New tips

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

- 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

Peri-implantitis – the clinical view
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*
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
Treating Peri-implantitis

Ultrasonics


environment allows tenacious adherence of a biofilm → implant failure

damage minimised using plastic coated ultrasonic scaler probes?
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

Methodology

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

Scaler inserts oscillated with an elliptical vibration pattern

metal scaler probe

plastic scaler insert and probe
SofTip unloaded vibration characteristics (displacement amplitude)
Implant insert

SofTip loaded vibration characteristics (displacement amplitude)
Defect depth

laser profilometer measured defect depth & width
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
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

No Gold Standard

Research Needed!
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
Phase 1

Unloaded
- Cortical
- Spongyous

10 Scans
± Water Flow
- 30ml/minute

SLV measured oscillation
Phase 2

Bovine Bone
  – Cortical Surfaces x5
  – Spongious Surfaces x5
Loads
  – 50g, 100g, 200g
Time
  – 10 seconds
Water Flow
  – 30ml/minute
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 $p=0.05$
Phase 1

Maximum oscillation at tip of probe

<table>
<thead>
<tr>
<th>Longitudinal Vibrations</th>
<th>- Water</th>
<th>+ Water</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cortical</td>
<td>14.6µm</td>
</tr>
<tr>
<td></td>
<td>Spongingous</td>
<td>12.6µm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No Significant Difference (p=0.064)</td>
</tr>
<tr>
<td></td>
<td>Cortical</td>
<td>11.7µm</td>
</tr>
<tr>
<td></td>
<td>Spongingous</td>
<td>11.3µm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No Significant Difference (p=0.942)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lateral Vibrations</th>
<th>± Water</th>
<th>No Significant Difference (p ≥ 0.918)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cortical &amp; Spongious</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

But ……

system designed to contact bone
Phase 2

Cortical
– Average max displacement amplitudes

Longitudinal
– 50g - 11.4µm
– 100g - 10.0µm
– 200g - 2.9µm

No sig diff (p=0.266)

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

Sig.Diff p<0.0001
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≥0.474)
• 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
Probe Motion 3D

As load increased, tip retains elliptical oscillation pattern

![Graph showing longitudinal and lateral vibrations with different load levels.](attachment:graph.png)
Phase 3

scanning laser profilometry
average defect depths
- 50g     -  0.12mm
- 100g    -  0.36mm
- 200g    -  0.33mm
Phase 3

![Graph showing the relationship between load (grams) and vibration displacement amplitude (microns) and defect depth (mm). The graph includes data points for displacement amplitude (diamonds) and defect depth (crosses).]
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.
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.
Further Work

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

Simon Lea
Gareth Price
Tim Donley
Malvern Mann
Dipesh Parmer
Marie George
Clemens Walter

Dentsply
EPSRC (EP/F020090)