In the name of GOD
Periodontal ligament and bone response to sustained orthodontic force

Presented by:
Dr Somayeh Heidari
Orthodontist
Reference:

Contemporary Orthodontics

Chapter 8

Sustained force against the teeth

Heavy force

- rapidly developing *pain*
- *necrosis* of PDL cellular elements
- *undermining* resorption

Light force

- *survival* of cells
- *frontal* resorption
Two major theories of orthodontic tooth movement:

- **Bioelectric theory**
  
  relates tooth movement to changes in bone metabolism controlled by the electric signals that produced when alveolar bone flexes and bends.

- **Pressure-tension theory**
  
  relates tooth movement to cellular changes produced by chemical messengers that generated by alteration in blood flow.
The two theories are neither incompatible nor mutually exclusive.

It appears that both mechanisms may play a part in the biologic control of tooth movement.
Bioelectric theory
Electric signals that might initiate tooth movement, thought to be **Piezoelectric**.

**Piezoelectricity**:

- observed in many **crystalline** materials
- deformation of the crystal structure $\rightarrow$ **electrons** displacement
- flow of **electric current**

in both **inorganic** (bone mineral) and **organic** (collagen) crystals
Two unusual characteristics of piezoelectric signals:

- quick decay rate

- equivalent, opposite direction signal, when the force released

Both explained by the electrons migration
Piezoelectric Crystals

Compression

Tension
Rhythmic activity would produce a constant interplay of electric signals, whereas occasional application and release of force would produce only occasional electric signals.
Ions in the fluids that bathe living bone interact with the complex electric field generated when the bends, causing temperature changes as well as electric signals.

The small voltages that are observed are called streaming potential.

These voltages have rapid onset and alteration, as changing stress are placed on the bone.
Application of an electric field can cause a crystal to deform and produce force.

Reverse piezoelectricity has no place in natural control systems.

Using external electric fields may promote bone healing and regeneration after injury.
Stress generated signals are important in the general maintenance of the skeleton.

Without such signals, bone mineral is lost and general skeletal atrophy ensues.

Alveolar bone bending during normal chewing has an important role in bone maintenance.
**Sustained force** of the type used to induce orthodontic tooth movement does not produce prominent stress generated signals.

Does application of vibrating pressure is effective in orthodontics?
A second type of endogenous electric signal is called **bioelectric potential**:

- in bone that is not being stressed
- metabolically **active** bone or connective tissue cells: **electronegative**
- **inactive** cells and areas: **neutral**

Cellular activity can be modified by **exogenous** electric signals.
The external electric signals probably affect cell membrane receptors, membrane permeability, or both.

Low voltage direct current

Modifying bioelectric potential

Faster tooth movement
Electromagnetic fields:

• Affect cell membrane potential and permeability
• Change cellular activity
• Increased tooth movement by shortening the initial lag phase
• Enhanced bone healing
• Reduced pain and mobility are not approved
Even though stress generated electric signals do not explain tooth movement, electric and electromagnetic influences can modify bone remodeling on which tooth movement depends and may yet prove useful therapeutically.
Pressure-tension theory
✓ The classic theory of tooth movement, relies on chemical rather than electric signals for cellular differentiation and ultimately tooth movement.

sustained pressure

tooth shift within the PDL

compression the ligament in some areas while stretching in the others
Blood flow is decreased where the PDL is compressed.

This alterations quickly create changes in the chemical environment:

- oxygen level, etc
The heavier the sustained pressure, the greater reduction in blood flow
Up to the point that the vessels are totally collapsed and no further blood flows
Blood flow is **maintained** or **increased** where the PDL is under **tension**.

If regions of the PDL are **overstretched**, blood flow may **decrease** **transiently**.
## Light – Prolonged force

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1 sec</td>
<td>PDL fluid <em>incompressible</em>, alveolar bone bends, piezoelectric signal generated</td>
</tr>
<tr>
<td>1-2 sec</td>
<td>PDL fluid <em>expressed</em>, tooth <em>moves</em> within PDL space</td>
</tr>
<tr>
<td>3-5 sec</td>
<td>PDL blood vessels partially <em>compressed</em> on pressure side, <em>dilated</em> on tension side, PDL fibers and cells mechanically <em>distorted</em></td>
</tr>
<tr>
<td>Minutes</td>
<td>Blood flow altered, oxygen tension begins to change, <em>prostaglandins</em> and <em>cytokines</em> released</td>
</tr>
<tr>
<td>Hours</td>
<td>Metabolic changes occurring, <em>chemical messengers</em> affect cellular activity, enzyme levels change</td>
</tr>
<tr>
<td>~ 4 hours</td>
<td>Increased cAMP levels detectable, cellular <em>differentiation</em> begins within PDL</td>
</tr>
<tr>
<td>~ 2 days</td>
<td>Tooth movement beginning as <em>osteoclasts</em>/<em>osteoblasts</em> remodel bony socket</td>
</tr>
</tbody>
</table>
Mechanically deformed cells

PG E

Interleukin 1- β

Focal adhesion kinase (FAK)

Nuclear factor-kappa ligand (RANKL)

Cytokine family

Nitric oxide

Osteoclasts in compression area

Osteoblasts in tension area
After 48 hours

in two waves:

- local cells (first wave)
- distant area via blood flow (larger second wave)

Frontal resorption → fast tooth movement
# Heavy – Prolonged force

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1 sec</td>
<td>PDL fluid <em>incompressible</em>, alveolar bone bends, piezoelectric signal generated</td>
</tr>
<tr>
<td>1-2 sec</td>
<td>PDL <em>fluid expressed</em>, tooth <em>moves</em> within PDL space</td>
</tr>
<tr>
<td>3-5 sec</td>
<td>Blood vessels within PDL <em>occluded</em> on pressure side</td>
</tr>
<tr>
<td>Minutes</td>
<td>Blood flow <em>cut off</em> to compressed PDL area</td>
</tr>
<tr>
<td>Hours</td>
<td><em>Cell death</em> in compressed area</td>
</tr>
<tr>
<td>3-5 days</td>
<td><em>Cell differentiation</em> in adjacent narrow spaces, <em>undermining resorption</em> begins</td>
</tr>
<tr>
<td>7-14 days</td>
<td>Undermining resorption <em>removes lamina dura</em> adjacent to compressed PDL, tooth movement occurs</td>
</tr>
</tbody>
</table>
Totally occlude blood vessels $\rightarrow$ sterile necrosis (hyalinized area)
loss of all cells

remodeling of the necrotic area must be accomplished by cells derived from adjacent undamaged areas.
After a delay of several days, cellular elements begins to invade the hyalinized area.

Osteoclasts appear within the adjacent bone marrow spaces

- Delayed in cell differentiation in marrow spaces
- Considerable thickness of bone must be removed

Undermining resorption

Delayed tooth movement
Frontal resorption vs. undermining resorption
When areas of PDL necrosis are avoided, tooth movement is more efficient and the pain is also lessened.

However, even with light forces, small avascular areas are developed.

In clinical practice, tooth movement usually proceeds in stepwise fashion because of the inevitable areas of undermining resorption.
Drug effects on the response to orthodontic force
drugs that stimulate tooth movement:

**Prostaglandin**
- direct injection into the PDL
- quite painful

**Relaxin**
drugs that **depress** tooth movement:

**Prostaglandin Inhibitors**

corticosteroids and non steroidal anti inflammatory drugs (NSAIDs) especially those that are used in arthritis treatment, like Indomethacin common analgesics (ibuprofen, aspirin) have little or no inhibition effect
drugs that depress tooth movement:

**Bisphosphonates**

Alendronate (Fosamax), Risedronate (Actonel) used in treatment of osteoporosis almost entirely in older adults inhibit osteoclast-mediated bone resorption

**Estrogen therapy** (Evista) prevents loss of bone with little or no orthodontic impact
drugs that *depress* tooth movement:

**Tricyclic antidepressants**
- doxepin, amitriptyline, imipramine

**Anti-arrhythmic agents**
- procaine

**Anti-malarial drugs**
- quinine, quinidine, chloroquine

**Methyl xanthines**

**Anticonvulsant**
- phenytoin

**Tetracyclines**
- doxycycline
Corticotomy and accelerated tooth movement
Regional acceleration of bone remodeling
Modified corticotomy
Other proposed approaches to faster tooth movement:

- **vibration** of the teeth

  - **AcceleDent vibratory system:** high-frequency vibration
    
    30 Hz – 20 minutes per day
  
  - stimulates cell **differentiation** and **maturation**
Other proposed approaches to faster tooth movement:

- Application of light to the alveolar process
  - 800-850 nm wave length (above the visible spectrum)
  - 3% of the light energy penetrates
  - Excite intracellular enzymes and increase cellular activity
  - Increase the rate of bone remodeling and tooth movement
  - Increase blood flow
Other proposed approaches to faster tooth movement:

- application of therapeutic ultrasound to the teeth and adjacent bone
  - increases blood flow in the treated area
  - decrease or eliminate the formation of hyalinized area (in theory)
  - will reduce root resorption and facilitate tooth movement
Thanks for your attention