Root Resorption: What we know and how it affects our clinical practice.

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Root resorption
- a physiologic or pathologic process occurring as a result of changes seen in the tooth or surrounding periradicular tissues
- characterized by loss of tooth structure over the root surface

Type
- Physiologic root resorption: occurring on deciduous teeth during eruption of permanent teeth
- Pathologic: occurring on permanent roots

Location
- Internal
- External

External Root resorption
1) Trauma/pulp space infection
2) Ectopic teeth
   Pressure from tumors / cysts
3) Orthodontic treatment

Trauma/pulp space infection
Pulpal infection: Radiolucencies in bone
Radiolucencies in bone And root resorption
Ectopic Canine

A) Buccally impacted canine
B) Resolution of canine impaction
C) Deband
D) 5-8yrs post treatment

Pressure from tumors

Orthodontically Induced Inflammatory Root Resorption (OIIRR)

Maxillary incisors are most commonly affected

Pre-Treatment

Post-Treatment

How do orthodontic treatment factors influence root resorption?

- **Orthodontically induced inflammatory root resorption (OIIRR)**
  - External Apical Root Resorption (EARR)
  - Cervical Root resorption
  - Root resorption (RR): microscopic areas of resorption are rare visualized with histological techniques (Hartsfield et al. 2004)
Orthodontic force

Compression of the PDL

Hylinization and inflammation

Activation of osteoclasts

Removal of superficial surface or cementum

Removal of hyaline material

Root resorption

Three types OIIRR

1) Surface resorption:

Only the outer cemental layers are resorbed, and later fully regenerated/remodeled when the etiologic factor is removed.

Three types OIIRR

2) Deep resorption:

The cementum and the outer layers of the dentin are resorbed and usually repaired with cementum material.

The final shape of the root may or may not be identical to the original form.

Three types OIIRR

3) Circumferential apical root resorption:

Tridimensional resorption of the hard tissue components of the root apex occurs, and root shortening is evident.

When the root loses apical material beneath the cementum, no regeneration is possible and the resorption is irreversible.

Why investigate OIIRR?

- Root resorption is undesirable because it can affect the long-term viability of the dentition.
  - Unfavorable crown:root ratio
  - 3mm apical loss = 1mm crestal bone loss

- It is important to elucidate which orthodontic treatment factors contribute to root resorption so that the detrimental effects can be minimized.

Methods of identifying root resorption

- Human and animal studies
- Histological (SEM, Light microscope)
- Radiographic (Pan, Cephal, Periapical)
- Volumetric (Micro-CT, Cone Beam)
Histological illustration: varying degrees of repair in OIIRR

A) Normal root surface
B) Undermined RR – no repair
C) Partial repair with acellular cementum (AC)
D) Partial repair with cellular cementum (CC)
E) Total repair with CC – root contour has been altered
F) Total repair with AC – root contour was re-established

(Özkan-Hell, F. (1995b))

SEM – varying severity of RR in intruded teeth

Minor RR
Severe RR

(Han G, et al. 2005)

Panoramic radiograph - initial

Panoramic radiograph - progress

Root Resorption Severity

No RR mild moderate severe extreme


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Cone Beam - CT

A No resorption
B Mild resorption
C Moderate resorption
D Severe resorption


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Periapical X-rays

Panoramic X-ray

Deband

Deband
Mean absorbed doses (μGy) to various tissues for each unit

<table>
<thead>
<tr>
<th>Tissue</th>
<th>NewTom 9000</th>
<th>i-CAT</th>
<th>Panoramic/Linear cephalometric</th>
<th>Multi-slice CT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bone marrow</td>
<td>648.9</td>
<td>748.0</td>
<td>62.8</td>
<td>7025.6</td>
</tr>
<tr>
<td>Third cervical vertebra</td>
<td>1244.7</td>
<td>1282.9</td>
<td>603.4</td>
<td>9300.4</td>
</tr>
<tr>
<td>Mandibular ramus</td>
<td>316.1</td>
<td>746.0</td>
<td>30.2</td>
<td>1488.9</td>
</tr>
<tr>
<td>Brain</td>
<td>472.0</td>
<td>1228.2</td>
<td>45.8</td>
<td>862.8</td>
</tr>
<tr>
<td>Eye</td>
<td>1426.7</td>
<td>1394.1</td>
<td>131.1</td>
<td>1417.7</td>
</tr>
<tr>
<td>Thyroid gland</td>
<td>1237.5</td>
<td>1414.9</td>
<td>25.3</td>
<td>1279.6</td>
</tr>
<tr>
<td>Parotid</td>
<td>1480.4</td>
<td>1510.9</td>
<td>563.7</td>
<td>14729.4</td>
</tr>
<tr>
<td>Skin</td>
<td>451.2</td>
<td>1068.9</td>
<td>32.4</td>
<td>1000.8</td>
</tr>
</tbody>
</table>

Silva 2008

Biological Markers to detect OIIRR?

- Dentin sialophosphoprotein (DPP) was higher in proximity to resorbing primary and permanent tooth roots (Mah 2004)
- ELISA combined with electrochemistry is a reliable and sensitive method to detect DPP in gingival crevicular fluid (Sha 2014)

American Academy of Oral and Maxillofacial Radiology

Position statement guidelines for CBCT use in orthodontic practice (2013):

1. Image appropriately according to clinical condition
2. Assess the radiation dose risk
3. Minimize patient radiation exposure
4. Maintain professional competency in performing and interpreting CBCT studies

ALARA principle
as low as reasonably achievable (Mountford & Temperton 1992)

Incidence/Prevalence of EARR and Orthodontic Treatment

- Histological studies: 90% prevalence of RR in orthodontically treated teeth (Shear et al. 1975, Harry MR 1992)
- EARR defined as greater than 4mm or 1/3 of the root length (severe): Incidence is reduced to 0.5-5% in the post orthodontic treatment group (Linge 1983, Levander 1988, Levander 1998; Lupi 1996; Janson 1999; McNab 1999; Kiliany 2002; Sehr 2011).
Etiology of OIIRR

- The etiological factors are complex and multifactorial, resulting from a combination of:
  - individual biological variability and
  - the effect of mechanical factors

Systemic Risk Factors for Orthodontically Induced Inflammatory Root Resorption

<table>
<thead>
<tr>
<th>Likely Risk Factors</th>
<th>Unclear Risk Relationship</th>
<th>Unlikely Risk Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>History of previous Root Resorption</td>
<td>Biphosphonates</td>
<td>Nabumetone (Likely Protective)</td>
</tr>
<tr>
<td>Previous trauma resulting in Root Resorption</td>
<td>Hormone deficiency</td>
<td>Paracetamol (acetaminophen)</td>
</tr>
<tr>
<td>Genetics</td>
<td>Asthma</td>
<td>Tooth/Root morphology</td>
</tr>
<tr>
<td>TNF-RSF1A gene*</td>
<td>Chronic alcoholism</td>
<td>Previous trauma without Root Resorption</td>
</tr>
<tr>
<td>Root proximity to cortical bone</td>
<td>Severity/type of malocclusion</td>
<td>Endodontic treatment</td>
</tr>
<tr>
<td>Age</td>
<td>Gender</td>
<td>Alveolar bone density</td>
</tr>
</tbody>
</table>

*Other factors to be identified but evidence supports a link between genetics and OIIRR, estimated to be over 50%.

Orthodontic Risk Factors for OIRR

- Treatment Duration
- Magnitude of Force – Heavy/Light
- Direction of tooth movement
- Amount of Apical displacement
- Method of force application
  - Continuous vs. Intermittent force
  - Appliance Type
  - Treatment technique (Bracket prescription, self-ligating, archwire sequence etc.)

Reviewing the data on Root resorption

Materials and Methods

Structured question using PICO format

- Population: patients with no history of root resorption
- Intervention: comprehensive orthodontics
- Control/comparison: people who have not had orthodontics / teeth that were not moved orthodontically
- Outcome: external root resorption

Null Hypothesis

1) There is no difference in the incidence and severity of root resorption between patients, with no history of RR, undergoing comprehensive orthodontic treatment and an untreated group.
2) There is no difference in the incidence and severity of root resorption between patients, with no history of RR, undergoing comprehensive orthodontic treatment who receive tooth movement with different techniques.
Inclusion and Exclusion Criteria

Inclusion:
- Randomized controlled trials (RCTs), published or unpublished, that evaluated root length before and after treatment in human subjects.
- Patients of any age, gender or ethnicity who underwent comprehensive orthodontic treatment with full fixed appliances.

Exclusion:
- Animal studies, studies including autotransplanted teeth, and duplicate publications.

Databases of published trials included in the systematic review (14)
- Cochrane Central Register of Controlled Trials (CENTRAL) AND Database of Systematic Reviews
- MEDLINE
- PubMed
- EMBASE
- Web of Science
- EBM Reviews (DARE)
- Computer Retrieval of Information on Scientific Project
- LILACS, PAHO, BBO, WHOLis, CEPS, etc...

Databases of Unpublished literature included in the systematic review (7)
- Databases of Dissertations and Conference proceedings:
  - Conference Materials, CENTRAL, ProQuest Dissertation Abstracts and Thesis database
- Databases of research registers:
  - TrialCentral, National Research Register (UK), www.Clinicaltrials.gov
- Grey Literature:
  - SIGLE

Additional search methods
- Requests were sent to relevant professional organizations in an attempt to identify unpublished or ongoing studies.
- Hand searching of relevant journals
- Searching through reference lists of relevant articles

Search Strategy (October 2008)
The search strategy developed for MEDLINE via OVID is displayed below. (MeSH terms: in UPPER CASE. Free text terms: in lower case)

#1 ORTHODONTIC*: ME
#2 "braces"
#3 (#1 or #2)
#4 ROOT RESORPTION*: ME
#5 "external apical root resorption"
#6 "root erosion"
#7 "root blunting"
#8 "root shortening"
#9 "tooth-root resorption"
#10 "orthodontically induced inflammatory root resorption"
#11 (#4 or #5 or #6 or #7 or #8 or #9 or #10)
#12 (#3 and #11)
#13 HUMAN*: ME
#14 (#12 and #13)

Major Quality Criteria of included studies
- A. Method of randomization
- B. Allocation concealment
- C. Blinding of outcome assessors
- D. Completeness to follow-up

A,C,D adequate = Low risk of bias
2 criteria adequate= Moderate risk of bias
<2 adequate = High risk of bias
Minor Quality Criteria of included studies

A. Baseline similarities of the groups
B. Reporting of eligibility criteria
C. Measure of variability of primary outcome
D. Sample size calculation

Results

- Of the 921 studies found in this field only 11 trials were considered appropriate for inclusion in this review.
- Protocols were too variable to proceed with meta-analysis (quantitative evaluation).

Quality Assessment

<table>
<thead>
<tr>
<th>Study</th>
<th>Randomisation</th>
<th>Allocation concealment</th>
<th>Blinding: Assessing risk of bias</th>
<th>Drop-out</th>
<th>Risk of bias</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acar 1999</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>High</td>
</tr>
<tr>
<td>Bangsbo 2001</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Moderate</td>
</tr>
<tr>
<td>Bus 2003</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Low, uncertain</td>
</tr>
<tr>
<td>Chan 2004</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Moderate</td>
</tr>
<tr>
<td>Chan 2006</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Moderate</td>
</tr>
<tr>
<td>Han 2005</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Low</td>
</tr>
<tr>
<td>Kavtrong 2006</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Low</td>
</tr>
<tr>
<td>Lombard 1994</td>
<td>Yes</td>
<td>Open</td>
<td>Yes</td>
<td>Yes</td>
<td>Moderate</td>
</tr>
<tr>
<td>Mardai 2000</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Low</td>
</tr>
<tr>
<td>Redford 1991</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Low</td>
</tr>
<tr>
<td>Scott 2008</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Low</td>
</tr>
</tbody>
</table>

The QUOROM statement flow diagram of the citations retrieved by reviewing titles and abstracts, and trials that were evaluated in full text.

Comparison of the Split-Mouth Studies

- 6 of the 11 studies were Split-Mouth
- Limited validity
  - Small sample sizes
  - Premolars
  - Moderate risk of bias
    - Exception: Han 2005 - Low risk of bias
    - Acar 1999 – High risk of bias
  - None of the studies lasted longer than 9 weeks.
  - Orthodontic force applied to teeth over a short period can produce resorption lacunae in the absence of EARR (Kvam 1972).
  - Heavy force application produced significantly more root resorption than light force application or control (Chan 2004; Chan 2006; Harris 2006; Barbagallo 2008).
  - Weak evidence: continuous force produced significantly more root resorption than interrupted force application (Acar 1999).
Comparison of the Split-Mouth Studies

3) Limited evidence that both light forces and forces from thermoplastic appliances result in similar root resorption, both significantly more than seen in controls (Barbagallo 2008).

4) Both studies examining intrusive force application found significantly increased RR rates to controls (Narins 2006, Han 2005).
   - Root resorption from extrusive force was not significantly different than control (Han 2005).

Comparison of the comprehensive orthodontic treatment RCTs

7) No statistically significant difference was found in the amount of RR between archwire sequences for upper left central incisors.
   - Also, no difference between the proportion of patients with or without root resorption was seen (Mandell 2006).

8) Incisors with clinical signs or patient reports of trauma, but no signs of EARR, had the same prevalence of moderate to severe OIIRR as those without trauma (Brin 2003, Mandell 2006, Levander 1994).

Comparison of the comprehensive orthodontic treatment RCTs

10) No statistical significance between one-phase and two-phase treatment groups when looking at OIIRR prevalence or severity.
   - As treatment time increased, the odds of OIIRR also increased.
   - The odds of a tooth experiencing severe root resorption were greater if a large reduction of overjet occurred during phase 2 (Brin 2003).

Discussion

- Comprehensive orthodontic treatment causes an increase in the incidence and severity of root resorption:
  - Heavy forces are particularly harmful.
- There is no evidence that OIIRR is affected by archwire sequencing, bracket prescription, or self-ligation.
- There is little evidence that previous trauma (with no history of EARR) and unusual tooth morphology play a role in increased OIIRR.
Implications for Clinical Practice

- Best practice is using light forces, especially when engaging in intrusive movements.
- Progress radiographs should be obtained 6-12 months into treatment to detect OIIRR early.
- Once identified, a 2-3 month treatment pause with passive archwires, will lead to a decrease in total root resorption by the end of treatment.

LIPUS?

- Low intensity pulsed ultrasound (Baily 2004)
  - Decreased the number of resorption lacunae
  - Decreased the area or resorption

Non-invasive method to reduce OIIRR in Humans

Management of EARR during Orthodontic Treatment

- Continue with lighter forces / rest periods
- Revise treatment goals – shorten treatment duration
- Follow-up radiographs during and after orthodontic treatment
- If termination of RR does not occur, sequential root canal therapy with calcium hydroxide may be considered
- Retaining the teeth with fixed appliances should be done with caution since occlusal trauma of the fixed teeth or segments might lead to extreme EARR (Brezniak 2002b).

Implications for Research

- More evidence is required to determine risk factors and effective ways to decrease the severity and prevalence of OIIRR.
- Parallel group studies, with appropriate randomization, allocation concealment and masking of outcome assessment are needed.
- Standardized measurement techniques along with proper assessment blinding, error analysis and consensus measures.
- Assessment of patient centered outcomes
  - Quality of life post treatment, and occurrence of further complications such as mobility, and tooth loss.
- Genetic predisposition and systemic factors should also be assessed.

Long Term Prognosis

- Root resorption associated with orthodontic treatment ceases with the termination of active treatment (Remington et al. 1989).
- When post treatment root resorption does occur, it is likely associated with other factors, such as traumatic occlusion and active force-delivering retainers (Copeland & Green 1989).

Long Term Prognosis

- Extensive root resorption does not usually affect the functional capacity or greatly compromise the longevity of the teeth.
- An average sized normally shaped maxillary central incisor that experienced no alveolar bone loss during orthodontic treatment, with a root shortened by 5mm will still have 75% of its periodontal attachment remaining (Kalkwarf et al. 1986).
1) Case Report: Initial Radiographs

18 months into orthodontic treatment

Deband

25 year follow-up

2) 13 year follow-up

3) 15 year follow-up
100 patients with severe resorption were recalled 14 years after orthodontic treatment:
- no incidences of tooth loss
- hypermobility in only 2 cases (Remington et al. 1989).

Patients with severe root resorption (root lengths 5.5-18.1mm), recalled 5-15 years after treatment:
- no teeth had mobility scores greater than 1 on Miller’s index (crown deviates within 1mm of normal)
- no teeth had been lost (Leverd & Malmgren 2000).

Orthodontic Treatment and OIIRR

- How will you discuss the risks of OIIRR with your patients/parents before orthodontic tx.?
- Can you predict how much root resorption will occur?
- What is the average amount of OIIRR to expect with comprehensive orthodontic treatment?
- Which teeth are most at risk?
- How can OIIRR be managed if it occurs during orthodontic treatment?
- What is the prognosis of teeth with OIIRR?

References
