Contradictions in the treatment of traumatic dental injuries and ways to proceed in dental trauma research.

Almost all treatment procedures used for dental traumas are still today not evidence-based, a fact, which makes it difficult to analyze the long-term outcome of healing and its relationship to treatment. (Andreasen et al. 2010)

In case of root fractures with dislocation, fast and optimal repositioning and rigid long-term splinting (i.e. 3 months) have been considered the principle of treatment. A recent clinical study has shown that short-term splinting with a semi-rigid splint appears to optimize fracture healing. (Andreasen et al. 2010)

Ideally, randomized clinical studies are needed in the future for selected trauma types. For ethical reasons, it will be difficult to perform randomized studies on trauma victims! We will therefore be forced in the future to rely on experimental animal studies supported by clinical observational studies. (Andreasen et al. 2010)

"Prevention" Minimize additional PDL damage Limit initial inflammatory response Stimulate cemental healing

Emergency Treatment

Prevalence and Incidence of Dental Trauma

"Almost all treatment procedures used for dental traumas are still today not evidence-based, a fact, which makes it difficult to analyze the long-term outcome of healing and its relationship to treatment." (Andreasen et al. 2010)

Luxation Injuries

Lateral, Extrusive Luxation

- Displacement/displacement of the Apex
- Reaction to percussion
- Negative sensibility

? Fracture of root or alveolar process

Luxation Injuries

Lateral Luxation Apical translocation?

Two possibilities:
- Apex in its original location
- Apex moved facially

Luxation Injuries

Treatment inside the office:
1. Radiographs at least 3 vertical angles.
2. Reposition.
3. Functional splint.
**Luxation Injuries**

Apical translocation:

- Force

**Traumatic Injuries**

Extrusion and Lateral Luxation

- Treatment:
  - Anesthesia
  - Reposition the tooth into normal position.
  - Confirm the position with radiograph.
  - S talent for 7-21 days if needed.
  - Follow-up 7-14 days, 3 & 6 weeks, 3, 6, & 12 months.
  - Initiate root canal therapy as soon as symptoms indicate
  - In case of apical translocation and closed apex after 7 to 14 days.

**Early History of Avulsion and Replantation**

- 1583: Pare (as reported by Kupfer and others) Replanted three teeth.
- 1700's: Fauchard: Replanted teeth.
- 1800's: Bourdet: Removed abscessed tooth and replanted it.
- 1933: Wigner: Used cast splint.
- 1959: Soder et al.: Demonstrated that replantation only temporary due to root resorption.

**Modern History of Avulsion and Replantation**

1966 Andreasen: 50% of avulsed teeth could be retained if replanted within 30 min.
1973 Cvek: Pulp removal necessary in order to prevent root resorption.
1974: Wet storage of avulsed teeth in saline or saliva improves healing of replanted teeth.
1975 Andreasen: Showed semi-rigid fixation caused less ankylosis than rigid fixation.
1977 Soder et al.: Demonstrated that the key to retention of avulsed teeth was maintaining periodontal ligament viability.

**Avulsion**

- Known Factors Affecting Prognosis:
  - Time out of the socket
  - Storage condition
  - Splinting technique and time
  - Condition of the alveolus
  - Stage of root development

- Time out of the Socket:
  - 90% of teeth replanted within 30 minutes were without root resorption
  - 43% of teeth replanted 31-90 minutes were without root resorption
  - 7% of teeth replanted after 90 minutes were without root resorption

(Andreasen and Sjögren, 1980)
Avulsed tooth Success rate vs. Extraoral Dry Time

PDL cell Death vs. Extraoral Dry Time

Avulsion
Consequences:
- Attachment damage
- Pulpal necrosis
- Bacteria contamination

Emergency Management Objectives
Minimize or Treat
- Attachment Damage Inflammation
- Pulp Space Infection

Emergency Management Outside the dental office
Place in appropriate storage medium
- specialized media
- milk
- saline
- vestibule of mouth
- ((water))

Milk is Good
- Has physiological osmolarity (230-270mOsm/kg).
- pH is in physiological range (6.5 – 6.9).
- Can provide some nutrients to cells
- Pasteurized milk has very low bacterial count.

Avulsion
Consequences:
- Attachment damage
- Pulpal necrosis
- Bacteria contamination

Root Resorptions
Definition:
“Resorption—A condition associated with either a physiologic or a pathologic process resulting in a loss of dentin, cementum and/or bone.”
The 2003 edition of the Glossary of Endodontic Terms, AAE
Consequences of Tooth Avulsion

Pathologic root resorption due to dental injuries is always (at least initially) inflammatory in origin. It is either:

- **Self-limiting**: if the only stimulus for the resorption is the injury itself.
- **Progressive**: if after the initial injury an additional stimulus is present or there is a severe damage to the protective layer.

**Root Resorption**

**External Root Resorption**

- Localized injury to PDL and/or cementum
- No significant inflammatory changes in PDL
- Self-limited
- Spontaneous repair with cementum
- Not related to contents of root canal
- Hard to detect on radiograph

**Surface Resorption**

- Localized injury to PDL and/or cementum
- No significant inflammatory changes in PDL
- Self-limited
- Spontaneous repair with cementum
- Not related to contents of root canal
- Hard to detect on radiograph

**Surface Root Resorption**

- Fusion of alveolar bone with root surface
- Absence of vital PDL
- Continuous replacement of tooth substance
- No cementum repair
- No direct relationship with content of root canal
- Tooth structure fuse with bone on radiograph

**Replacement Root Resorption**

- Fusion of alveolar bone with root surface
- Absence of vital PDL
- Continuous replacement of tooth substance
- No cementum repair
- No direct relationship with content of root canal
- Tooth structure fuse with bone on radiograph

**Infra-Positioned Tooth (Ankylosed)**

- What can be done for a young individual?
  - Root submersion and transplant or osseous implant later.
  - Benefits are preservation of the alveolar bone and possibly vertical growth of the bone!

**Intervention for Treating Traumatized Ankylosed Permanent Front Teeth**

Cochrane Database Syst Rev 2010

**SELECTION CRITERIA:**

- Randomized controlled trials (RCTs)
- Comparing any intervention for treating displaced ankylosed permanent front teeth in individuals any age.
- No language restrictions.

**MAIN RESULTS:**

- The search retrieved 77 references to studies.
- None matched the inclusion criteria and therefore all were excluded.

**AUTHORS' CONCLUSIONS:**

"There is no evidence from RCTs about the comparative effectiveness of the different treatment options for ankylosed permanent front teeth."

(de Souza et al 2010)
Submerging the root

Maintains the facio-palatal bone dimension.
Induces the alveolar bone to grow vertically.
Allows for an aesthetic temp restoration.
Preserves bone for later implant placement.

(Based on Dr. B. Malmgren)

Root Resorption

External Root Resorption

Inflammatory Resorption

> Injury to PDL and cementum
> Significant inflammation of PDL
> Continuous replacement of tooth substance
> No cementum repair
> Direct relationship with content of root canal
> Tooth structure and bone loss on radiograph

Inflammatory Root Resorption

Quantitative radiographic evaluation of periapical bone resorption in dog’s teeth contaminated with bacterial endotoxin (LPS) associated or not with calcium hydroxide.

Dog model, 60 teeth, pulp removed, radiographic evaluation:

- LPS: average lesion 8.44 mm²
- LPS + Ca(OH)₂: lamina dura intact.
- Saline: lamina dura intact.
- Open canals: average lesion 3.02 mm².

(Tonstad, et al. 1981)

Calcium Hydroxide-Ca(OH)₂

• Alkaline (Tronstad, et al 1981)
• Antibacterial (Byström, et al 1985)
• Proteolytic (Andersen, et al 1992)

Current recommendations include instrumentation and placement of Ca(OH)₂ into the root canal space within 7-21 days following replantation.

When to place the Ca(OH)₂?

"Effect of immediate calcium hydroxide treatment and permanent root filling on periodontal healing in contaminated replanted teeth".

A lesser shift from inflammatory resorption to ankylosis, and higher incidence of "healed" periodontium occurred after permanent root filling than after treatment with calcium hydroxide.

(Langerman, et al. 1995)

Effect of Ca(OH)₂ on Strength of the Tooth

Root canals were filled with Ca(OH)₂ (Calasept) and sealed with IRM(R) cement, and stored in saline at room temperature for 0.5, 1, 2, 3, 6, 9, or 12 months.

All teeth were tested for fracture strength in an Instron testing machine.

The results showed a marked decrease in fracture strength with increasing storage time for the calcium hydroxide dressing group.

(Andreasen et al. 2002)

Effect of Ca(OH)₂ on Fracture Resistance of Human Root Dentin Exposed to Intracanal Calcium Hydroxide

- No difference in fracture of the disks at 30 d.
- Significant difference for slurry Ca(OH)₂ compared to 30 days and 180 d. of the other two.

(Doyon, GS et al 2005)
Prevention of Resorption

Calcium Hydroxide-Ca(OH)\textsubscript{2}
No direct anti-inflammatory action provided.

Hypothesis

If the inflammatory response could be minimized, resorption could then be decreased?

Corticosteroids
Block production of inflammatory stimulators including prostaglandins and leukotrienes, produced by cyclooxygenase and lipoxygenase pathways.

Prevention of Resorption

Ledermix\textsuperscript{\textregistered} Paste

- 1% Triamcinolone - Corticosteroid
- 3% Demeclocycline - Broad spectrum antibiotic

Purpose

To evaluate the usefulness of Ca(OH)\textsubscript{2} and Ledermix in attenuating or arresting external root resorption secondary to avulsion in a dog dental trauma model.

Histology

Tooth root: Alveolar interface evaluated for presence of:

- Favorable Healing
  - Cemental Healing, Surface Resorption
- Poor Healing
  - Osseous Replacement, Inflammatory Resorption

Results 60 min Dry time

<table>
<thead>
<tr>
<th></th>
<th>Favorable Healing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ledermix\textsuperscript{\textregistered}</td>
<td>16.7</td>
</tr>
<tr>
<td>Ca(OH)\textsubscript{2}</td>
<td>13.8</td>
</tr>
</tbody>
</table>

\( p=0.004 \)

(From Bryson et al. 2002)
**Results 60 min Drytime**

<table>
<thead>
<tr>
<th>Ledermix®</th>
<th>Ca(OH)$_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintained 81% of root cross-sectional surface area</td>
<td>Maintained 13% of root cross-sectional surface area</td>
</tr>
</tbody>
</table>

Values determined from 0-6 scale of remaining root structure

(Dr. Bryson et al. 2002)

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**Results**

Results indicate that Ledermix®:

- Significantly increases healing compared to Ca(OH)$_2$ after 60 min dry time.
- Decreases inflammation-induced pathology at root:alveolus interface.

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**The effect of intracanal anti-inflammatory medicaments on external root resorption of replanted dog teeth after extended extra-oral dry time**

**Dog Study:**
- The canals were filled with:
  - Ledermix®
  - Triamcinolone
  - Demeclocycline
- Replanted after 60 min dry time.

(Chan et al. 2006)

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**The effect of intracanal anti-inflammatory medicaments on external root resorption of replanted dog teeth after extended extra-oral dry time**

Dog Study:
- The effect of intracanal anti-inflammatory medicaments on external root resorption of replanted dog teeth after extended extra-oral dry time
- Corticosteroids were as effective as Ledermix at inhibiting external root resorption!

(Chan et al. 2006)

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**The effect of potent intracanal corticosteroids on periodontal healing of replanted avulsed teeth.**

Dog Study:
- The effect of potent intracanal corticosteroids on periodontal healing of replanted avulsed teeth.
- (0.05% clobetasol and 0.05% fluocinonide)
- Systemic absorption of these corticosteroids.

(Kirakozova, et al. 2009)

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**Effect of Intracanal Corticosteroids on Healing of Replanted Dog Teeth after Extended Dry Times**

Dog Study:
- After 4 months, roots were evaluated histologically for signs of periodontal healing.
- Roots treated with clobetasol and fluocinonide healed more favorably than roots filled with gutta-percha and were different from each other at 60 minutes.

(Kirakozova, et al. 2009)

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**Root Resorption**

**External Root Resorption**

**Cervical Resorption**

(Subepithelial external inflammation)

- Injury to PDL and cementum
- Lesion located at an attachment level of the tooth
- Cyst-like bony defect associated with the lesion
- No relationship with content of root canal
- Pink spot on crown possible

---

**The effect of intracanal anti-inflammatory medicaments on external root resorption of replanted dog teeth after extended extra-oral dry time**

Dog Study:
- The canals were filled with:
  - Ledermix®
  - Triamcinolone
  - Demeclocycline
- Replanted after 60 min dry time.

(Chan et al. 2006)
Root Resorption

External Root Resorption

Cervical Resorption
(Subepithelial external inflammation)

Histology similar to “classical” inflammatory root resorption except:
- Does usually not penetrate through predentin.
- Does often leave much of the cementum intact.

External Root Resorption

Cervical Resorption
(Subepithelial external inflammation)

Several etiologic factors suggested:
- Dental trauma.
- Orthodontic treatment.
- Intracoronual bleaching.
- Periodontal therapy.
- Idiopathic etiology (e.g. bruxing, restorations, developmental defects, systemic diseases) (Patel et al. 2009)

External Root Resorption

Cervical Resorption
(Subepithelial external inflammation)

Of interest is:
Late onset after ortho (1½ to 33 y) vs. immediate apical blunting after ortho! (Heithersay 1999, Patel et al. 2009)

External Cervical Resorption

Sulcular Infection?*

The pulp plays no role in cervical root resorption and is mostly normal in these cases.
The source of stimulation (infection) is not the pulp, more likely bacteria in the sulcus of the tooth that stimulate and sustain an inflammatory response in the periodontium at the attachment level of the root.

Geristore

Resin-ionomer & Hybrid ionomer Cements Part II

Human clinical and histologic wound healing responses in specific periodontal lesions.

“Clinical and histologic evidence of epithelial and connective tissue adherence to resin-ionomer restorative materials was observed during the healing process.”

Cervical Root Resorption

Human and feline invasive cervical resorptions: the missing link?—Presentation of four cases
- Feline odontoclastic resorptive lesion is common in domestic and wild cats.
- Etiology of this is unknown but has been linked with feline viruses.

Cervical Root Resorption

Human and feline invasive cervical resorptions: the missing link?—Presentation of four cases
- All four cases history of direct or indirect contact with cats.
- All were positive for feline herpes virus type-1 (FeHV-1).

Root Resorptions

Definition:
Internal resorption—A pathologic process initiated within the pulp space with loss of dentin and possible invasion of the cementum; may or may not perforate to the external root surface; effectively managed by removal of the vital pulp and subsequent conventional root canal therapy.
The 2003 edition of the Glossary of Endodontic Terms, AAE
When resorption is present, chronic inflammation is adjacent to areas of internal root where the odontoblastic layer and the predentin are lost or altered. Reasons for the loss of pre-dentin adjacent to the granulation tissue are not obvious. Reasons suggested have been lack or alternations of blood circulation after traumatic injury or extreme heat produced when cutting on dentin without adequate water spray.

Internal Inflammatory Root Resorption

Usually asymptomatic and is first recognized clinically through routine radiographs. For internal resorption to be active, at least part of the pulp must be vital.

Internal Inflammatory Root Resorption

Internal root resorption is treated with the endodontic methods. Pulpectomy removes the blood supply to the granulomatous tissue and the rest of the treatment is concentrated on removing tissue from the irregular resorptive defect and obliterating the space.

Internal Inflammatory Root Resorption

Internal root resorption close to the root fracture site (without any lesion in the bone at the same level) are to be considered part of the normal healing process. And no treatment is needed or should be done!

Internal Inflammatory Root Resorption

Internal root resorption close to the root fracture site (without any lesion in the bone at the same level) are to be considered part of the normal healing process. And no treatment is needed or should be done!

Internal Inflammatory Root Resorption

"Pressure" Root Resorption

Other Possible Reasons for Root Resorption:
Pressure damage can be caused by many sources. Most common causes are orthodontic tooth movement. Presently it is accepted that it is a "sterile" inflammation with all the expected inflammatory cytokines present during active resorption.

"Pressure" Root Resorption

Pressure: Pressure resorption is always localized to the area of pressure. Treatment is easy in that removal of the source of the pressure will result in cessation of the resorption in the majority of cases.

Dr. IB Bender maintained for many years that in severe ortho resorptions the pulp played a significant role in the patho-physiology of the root resorption: Periapical replacement resorption of permanent, vital, endodontically treated incisors after orthodontic movement: report of two cases. JCO 1997

Severe Ortho Root Resorption

Prevalence and severity of apical root resorption of mandibular anterior teeth in adult orthodontic patients. Ortho treatment of 343 adults: Evaluation of the 39 contralateral pairs of teeth with and without endodontic treatment in 36 of the patients revealed less resorption of the endodontically treated teeth (P < 0.05).

(Minakawa and Aran, 1986)

Consequences of Tooth Avulsion

In summary: In order for root resorption to occur two requirements must be met:
1. A change has to occur in the protective attachment layer (pre-dentin internally or pre-cementum externally) of the root.
2. An inflammatory process must be present and be maintained adjacent to this damaged root surface.*

(* except in replacement root resorption)
Emergency Visit
Root preparation - Mature Tooth
Dry time > 60 minutes
Remove perio ligament

Emergency Visit
Root preparation - Mature Tooth
Dry time > 60 minutes
Soak in - Fluoride

Avulsion
Consequences:
- Attachment damage
- Pulpal necrosis
- Bacteria contamination

Pulpal Necrosis
Pulp revascularization is favored when the apical foramen is not completely formed.
(Öhman, 1965; Seigland and Tonstad, 1981; Kästner and Andreasen, 1984; King et al., 1986; Cvek et al., 1990a)

Pulpal Necrosis
The occurrence of pulp revascularization is enhanced if the apical foramen is more than 1.1 mm wide in humans.
(King et al., 1986)

Pulpal Necrosis
Complete revascularization of the pulp in a tooth with an open apex could be expected to be some where between 18 and 25% - more likely the larger the apical opening is.
(Cvek et al., 1990 and 1990)

Revascularization
The principle factor for failure of revascularization is Bacterial contamination !!!!
(Cvek et al., 1990)

Topical Treatment with Doxycycline before replantation
(1mg/20ml saline)
Increases the incidence of revascularization from 18% to 41% in a monkey model
(Cvek et al., 1990)

Statistical Analysis:
Fisher’s exact test
There was a significant difference between groups with and without doxycycline soak (p<0.024).
- Complete vitality with doxycycline: 60%
- Complete vitality with no doxycycline: 38%
(Tumpo et al., 2010)
**Pulpal Necrosis**

Dry time < 60 min

Open apex

Soak the tooth for 5 min in doxycycline (1mg/20ml saline)

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**Research Question**

Is Minocycline (Arestin or Dentozyne) more effective than Doxycycline in preventing bacterial penetration along the PDL after replantation?

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**Results - Histology**

Minocycline topical treatment: 90.96% Vital pulp + osteoid tissue

Doxycycline topical treatment: 72.73% Vital pulp + osteoid tissue

Saline: 33.33% Vital pulp

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**Necrotic Pulp**

When the pulp in an immature tooth becomes necrotic and the pulpal space infected the success of any endodontic treatment is severely reduced.

- Difficult to treat
- Inadequate strength

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**Where it all started**

Tissue formation in the root canal following pulp removal

Nygaard-Ostby and Hjortdal


Dental pulp regeneration aided by blood and blood substitutes after experimentally induced periapical infection

Myers and Fountain


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**Necrotic and Infected Pulp**

Two main questions:

Is it possible completely disinfect the pulpal space such that revascularization will occur?

Do the pulp progenitor cells necessary for the proliferation of pulp tissue survive the infection?

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**Where it all started**

Sterilization of infected non-canal dentine by topical application of a mixture of ciprofloxacin, metronidazole and minocycline in situ

Sato, Ando-Kurihara, Kota, Iwaku, Hoshino


In-vitro antibacterial susceptibility of bacteria taken from infected root dentine to a 0.5-mg mixture of ciprofloxacin, metronidazole and minocycline

Hoshino, Kurihara-Ando, Sato, Uematsu, Sato, Kota, Iwaku


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**Sato et al. 1996**

Confirmed that in extracted teeth there was penetration of the antibiotic paste through dentine.

And the mix had the antibacterial efficacy expected against bacteria infecting the dentine.
Sato et al. 1996

Hoshino et al. 1996

Studied the antibacterial effect of a mixture of: ciprofloxacin, metronidazole minocycline, on bacteria taken from infected dentine of extracted root canal walls under strict anaerobic conditions. The combination of all three consistently killed all bacteria, single antibiotic not!

Three Mix Antibiotic

Some kind of a scaffold for the in-growing tissue seems to be essential.

Previous case reports used a blood clot to serve as a scaffold. However it is rather difficult control and to maintain during restoration.

Application of Tissue Engineering Concepts to Regenerative Endodontics

So Where Are We Going?

Application of Tissue Engineering Concepts to Regenerative Endodontics

The first component of tissue engineering is a cell source.

- Odontoblasts are of mesenchymal origin, under appropriate conditions, cells from dental pulp, the apical papilla, and possibly other tissues can form odontoblast-like cells.

- To date, the precise cell source(s) supporting the continued root development are unknown. (Hargraves et al. 2008)

Application of Tissue Engineering Concepts to Regenerative Endodontics

The second component of tissue engineering is a physical scaffold.

- Tissues are 3-dimensional structures, and an appropriate scaffold is needed to promote cell growth and differentiation.

- It is known that extracellular matrix molecules can control the differentiation of stem cells and an appropriate scaffold might selectively bind and localize cells, it contains contain growth factors etc. (Hargraves et al. 2008)

Application of Tissue Engineering Concepts to Regenerative Endodontics

The third component of tissue engineering to consider is signaling molecules.

- It is likely that the signaling molecules play major roles in guiding the development of cells in the regenerating tissue.

(Hargraves et al. 2008)

Treatment Protocol

Protocol

The root canal system is thoroughly irrigated with NaOCl BUT minimally instrumented.

Two layers of bonding agent is cured on the inside of the access preparation close to the CEJ.

Canals dried with paper points.

The three antibiotics, ciprofloxacin, metronidazole and minocycline are mixed together in equal portions and then a paste is created with adding saline OR...

(M Trope, J Endodon 2008)

Treatment Protocol

OR.

Make a carrier by mixing together in equal portions

Macrogol ointment Propylene glycol

Separate out small portion of 3Mix and mix with the carrier:

1:5 (carrier 3Mix) for creamy mixture

1:7 (carrier 3Mix) for standard, that smears easily but does not crumble

(M Trope, J Endodon 2008)
**Treatment Protocol**

The paste is pipetted into the canal and 2/3 of the canal filled with the paste.

Care is to be taken to not leave ANY of the paste in the coronal portion of the tooth because the mix will seriously stain the crown.

**Treatment Protocol**

After three weeks the patient is recalled and the paste irrigated out with saline.

Bleeding is created in the canal space with a sterile endo explorer and files.

Effort is made to have the blood fill the whole canal space.

This blood should be allowed to begin its initial clotting prior to closing the access.

**Treatment Protocol**

Protocol

After the blood had started to coagulate; as dense filling as possible is created.

(White) MTA is used as the initial barrier between the blood clot and the coronal access and then the remainder of the access filled later with bonded resin filling.

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**So the Future? Or What is Next with Tri-mix Antibiotics?**

- So far limited animal research.
- Only case reports or small case review papers.
- AAE has established online web collection of cases.
- Some more elaborated studies are on their way BUT much more needed.
- To date no but one human histological evaluations.

**So the Future? Or What is Next with Tri-mix Antibiotics?**

- Another issue is the BIG question:
- Is the antibiotic mixture needed at all?
- The key seems to be disinfection below tolerable threshold of new growth of tissue! Therefore technically good irrigation with NaOCl could be enough! (da Silva et al. 2010)