Management of the open apex

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What is an “open” apex?

• Wide canal
• Lack of apical stop due to failure of completion of root development

What does a “normal” apex look like?

• Cvek’s classification of root formation (according to root length and apical opening)

What does a “normal’ apex look like?

• Dummer et al 1984
  • 270 fully formed teeth analysed

• Closure of apex occurs up to 3 years after eruption
• This process can be interrupted due to
  • Trauma
  • Infection (caries, dens in/evaginatus)
  • Physical interferences such as surgery or over instrumentation
• Apexogenesis
  - Vital pulp therapies performed in teeth with some vital tissue to encourage formation of the root end (Wigler et al. 2013)

• Apexification
  - Formation of a calcific barrier in a tooth with open apex (Weine 2004)
Vital pulp therapy

- “Review”
- Pulp capping
  - Direct and indirect
- Pulpotomy
  - Cvek, “full” pulpotomy

Reimplantation allowing apexogenesis

- 8 year old
- 21 avulsion
- 4 year review

 Courtesy – Dr Luke Maloney

Pulp capping allowing apexogenesis

Immature permanent tooth

- Vital tooth
- Non-vital tooth
- Apexogenesis
- Apexification
- Review only
- Pulp capping
- Ca(OH)₂ apexification
- MTA apexification

Apexification before 1960s

- Before 1966 – surgical approach to place an apical seal
- Custom fit GP cones
Ca(OH)$_2$ apexification

- Introduced in 1960s
- Removal of necrotic pulp
- Placement of Ca(OH)$_2$
- Multiple visits to change dressing
- 6-18 months for apical barrier formation
- GP and sealer root filling

- Multiple treatment appointments
- Weakens dentine
- Leaves tooth susceptible to fracture - interim/long term

Andreasen et al 2002, Kaiser 1964

12/08/15
MTA apexification

• Introduced in 1990s
• A lot of “hype” with this material
• Most researched dental material
• Single visit
• MTA plug (6mm)
• Back fill with GP and sealer

MTA apexification

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most researched material</td>
<td>Difficult to mix</td>
</tr>
<tr>
<td>Single visit apexification</td>
<td>Difficult to apply particularly in thin canals</td>
</tr>
<tr>
<td>Maintains the integrity of the root</td>
<td>Stains teeth</td>
</tr>
<tr>
<td>Provides an excellent seal</td>
<td>Long setting time</td>
</tr>
<tr>
<td>Retrieval option limited</td>
<td>Does not strengthen tooth</td>
</tr>
</tbody>
</table>

Bioceramics in endodontics

• What is bioceramics?
  • Materials (eg calcium phosphates, alumina, hydroxyapatites) which are present in the human body making them biocompatible
  • MTA was the first bioceramic material in dentistry
  • MTA Angelus, BioAggregate, Biodentin, Root repair material

Bioceramics in endodontics

• New BC materials seem to show improvement
  • Staining
  • Setting time
  • Ease of mixing
  • Application
  • High pH
  • Biocompatible
  • Good seal
  • Different packaging and application

Most studies report on MTA hence can ASSUME that BC materials will perform comparably to MTA

Trope et al 2015
Immature permanent tooth

Vital tooth
Apexogenesis

Non-vital tooth
Apexification

Review only
Pulp capping
Ca(OH)₂ apexification
MTA apexification

Revascularisation
Regeneration
Revitalisation
Terminology

- Revascularisation
  - No certainty of nature of tissue. But it has a blood supply (Trope 2008)
- Regeneration
  - Argued that revascularisation is applied to dental trauma cases (Huang & Lin 2008)
- Revitalisation
  - Non-specific vital tissue (Lenzi & Trope 2012)
- Maturogenesis
  - Complete development of tooth not localised to the apex

What is regenerative endodontics?

"biologically based procedures designed to predictably replace damaged, diseased or missing structures including cells of pulp-dentine complex, dentine and root structure with live viable tissues, preferably of the same origin that restore the normal physiological functions of the pulp-dentine complex"

Hargreaves et al. 2007

What is regenerative endodontics?

AAE 2015
Goals of regeneration techniques

- Eliminate symptoms
- Space maintenance
- Bony healing
- Increase in root wall thickness
- Increase in root length
- Positive response to vitality tests

Can we re-grow the pulp?

The role of blood clot in pulpal healing

47 patients
- Pulp tissue removed
- Over-instrumentation to induce bleeding
- Obturated canals short of the apex
- 3 years later extraction and histological examination

Recognised that pulp like tissue can grow into the canal and a blood clot is essential for apical healing

Nygaard Østby & Hjortdal (1961, 1971)
The role of bacteria in pulpal healing

Without bacteria, the pulp is able to heal and repair itself.

Can we re-grow the pulp?
Yes
How?

The re-birth of pulpal regeneration

Hoshino et al 1993, 1996
• Took dentine samples from infected teeth
• Incubated on agar plates with various combinations of antibiotics, metronidazole
• Looked at the efficacy of a combination of antibiotics/Hoshino's paste

The effects of surgical exposures of dental pulps in germ-free and conventional laboratory rats

Kakehashi et al 1965

Germ (bacteria) free rats
Conventional lab rats
Pulpal exposure
Pulpal histology
Iwaya et al. 2001

- Tooth 45 – immature with a draining sinus
  - Visit 1
    - Open and drain (left open)
  - Visit 2
    - Vital tissue noted apically, irrigation, dressing of metronidazole and ciprofloxacin placed for 4 weeks
  - Visit 3
    - Ca(OH)₂, followed by GIC restoration

Banchs et al. 2004

- Tooth 45 – immature with draining sinus
  - Visit 1
    - Access, necrotic tissue noted, irrigated, dressing of minocycline, ciprofloxacin, metronidazole
  - Visit 2
    - Bleeding induced, sealed with MTA

Tissue engineering 1990s

Recognised the need for
1. Stem cells
2. Growth factors
3. Scaffold for regeneration
Role of the apical papilla in regeneration
- Source of stem cells ("stem cells of the apical papilla"; SCAP)
- Differentiate into dentine forming cells
- These can survive infections BUT survival following trauma is questionable due to damage to PDL and Hertwig's sheath

Role of a blood clot in regeneration
- Forms the scaffold
- Becomes the route to introduce stem cells into the canal
- Intra-canal blood clot has 500 more stem cells than systemic blood

Role of a irrigation in regeneration
- NaOCl
  - Aim of irrigants in regenerative procedures does not only have to have bactericidal properties, but should also allow stem cell survival and proliferation
  - EDTA
    - Removes smear layer
    - Reverses the detrimental effects of NaOCl
    - Exposes collagen and growth factors
    - Growth factors supports cell survival
Role of medication in regeneration

- Tri-antibiotic paste (not FDA approved)
  - 200mg ciprofloxacin
  - 500 mg metronidazole
  - 100 mg minocycline
  - Multiple case reports
  - Allows increase in root canal wall thickness and root length
  - Found to be detrimental towards SCAP survival

- Ca(OH)\(_2\)
  - Also allows root canal wall to thicken and grow in length
  - Found to be non-toxic towards SCAP


Key concepts

- Patient selection
- Treatment protocol
- Measuring success
- Review

Patient selection

- Patient
  - Compliant
  - Healthy
  - Young (8-16 years old)

- Tooth
  - Necrotic canal
  - Immature apex (>0.8mm)
  - Short root
  - Length of time the infection has been present
  - Cause of necrosis (trauma vs. dental anomaly)

- Restorative
  - Pulp space required for post or restoration

Current protocol

Local anaesthesia

Access

Assess the pulp status

Vital tissue apically

Single visit

Irrigate lightly

Irrigate 2mm short

MTA barrier, GIC and composite

Dress with Tri-antibiotic paste OR Ca(OH)\(_2\), and temporise

Recall for up to 2 years

Vital tissue apically

Two visits

Irrigate lightly

MTA barrier, GIC and composite

Dress with Tri-antibiotic paste OR Ca(OH)\(_2\), and temporise

Recall for up to 2 years
Measuring success of regeneration procedure

• Symptoms
• Sensibility testing
  - Lack of pulp response does not indicate lack of vitality
• Radiographs

[Table]

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Year</th>
<th>Cases</th>
<th>Success</th>
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<tbody>
<tr>
<td>Root Filling</td>
<td>2013</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Root Canal Treatment</td>
<td>2012</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Indicate bleeding</td>
<td>2011</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>MTA barrier, GIC, composite</td>
<td>2010</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Local anaesthesia without adrenalin</td>
<td>2009</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

Review

• 3-21 months – apical bony healing
Review for 2 years before condemning a case
• 10-29 months – root development
Can regeneration be applied to trauma cases?

Difficult to attain success due to
- Damage to PDL cells
- Damage to Hertwig’s sheath

Questions to ponder on....
1. Etiology of necrosis – does it matter whether the cause of necrosis is trauma related or dental anomaly?
2. What type of tissue grows in the canal? Is it dentine, cementum, bone or a combination?
3. What are the potential complications?

Nature of tissue occupying the pulp space

Animal studies have identified the 4 types of tissue growing in the pulp space. Pulp is vital to life. It can be divided into 2 main categories, based on the composition of the tissue occupying the canal:
1. Dentine
2. Cementum
3. Bone
4. PDL and Alveolar bone

Table: Success Rates

<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>Cases</th>
<th>Success</th>
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</thead>
<tbody>
<tr>
<td>Study 1</td>
<td>2008</td>
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<tr>
<td>Study 2</td>
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<td>Study 3</td>
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<tr>
<td>Study 4</td>
<td>2011</td>
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<tr>
<td>Study 5</td>
<td>2012</td>
<td>1</td>
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</tbody>
</table>
Complications - discoloration

Complications - treatment failure

Current status

Regenerative Endodontics
Regenerative endodontics is a term referring to endodontic procedures that attempt to reverse the inflammatory-disease response triggered by root canal treatment. This is achieved using a calcium hydroxide paste or a combination of calcium hydroxide and bioactive glass. Calcium hydroxide is a well-known endodontic dressing. It is thought to provide a physical barrier and promote hard tissue formation by activating the body's natural wound healing process. The use of bioactive glass in regenerative endodontics is expected to provide an additional benefit.

Current status:
- $2.5 million towards research
- Regeneration codes introduced 2011-12
- Introduced regenerative endodontics to the curriculum 2014
- Stated that regenerative procedures is part of endodontics
- Clinical consideration for regenerative procedures developed

Complications - discolouration

Courtesy – Dr Kim Dang

Complications - treatment failure

Jan 2008
Jan 2012
May 2012

Courtesy – Dr Kelvin Yapp
“If you are performing regenerative endodontic procedures, please report them in the ASE Regenerative Database to establish a best practice for treatment and future research”

American Society of Endodontology 2015

Future directions

- Prospective randomised clinical trials underway
- Need regulated clinical protocols

Conclusion

- Need an operating microscope
- Familiarity with use of MTA
- Watch the space for newer materials – Bioceramics
- For regenerative procedures, consider the cause of necrosis and be familiar with case selection
- Don’t throw away the MTA and GP (yet!!)

Conclusion

Regeneration
- Allows root growth
- Allows root strengthening

MTA apicification
- Maintains root strength

Ca(OH)₂ apicification
- Weakens root strength