Evidence in root canal filling techniques

11th Endodontic Symposium
Berlin June 2013

Professor William P. Saunders
Professor of Endodontology, University of Dundee
Endodontics

prevention of disease
treat periradicular (apical) periodontitis by

Root canal treatment
Root canal re-treatment
non-surgical
surgical

how good are we at root canal treatment?

epidemiological studies suggest we are not too good!!

| Endodontists | the root canal specialists |

<p>| Saunders et al | 1997 Quality, dental hospital Scotland |
| Weiger et al | 1997 private practice Germany |</p>
<table>
<thead>
<tr>
<th>No. of teeth</th>
<th>% of teeth with radiolucency</th>
<th>% of teeth with RCT</th>
<th>% of RCT teeth with p/r radiolucency</th>
<th>% of untreated teeth with p/r radiolucency</th>
</tr>
</thead>
<tbody>
<tr>
<td>8420</td>
<td>4.9</td>
<td>5.6</td>
<td>52</td>
<td>2.1</td>
</tr>
<tr>
<td>7987</td>
<td>3.0</td>
<td>2.7</td>
<td>61</td>
<td>1.4</td>
</tr>
<tr>
<td>Overall</td>
<td>5.4%</td>
<td>9.6%</td>
<td>35.9%</td>
<td>2.1%</td>
</tr>
</tbody>
</table>
Periapical status and prevalence of endodontic treatment in an adult Dutch population.

De Cleen, M.J., Schuurs, A.H., Wesselink, P.R., Wu, M.K.

<table>
<thead>
<tr>
<th>Year</th>
<th>Sample Size</th>
<th>Radiographs</th>
<th>Root-Filled Teeth</th>
<th>Radiographic Signs</th>
<th>Endodontic Treatments Regarded as Inadequate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>184</td>
<td>panoramic</td>
<td>2.3%</td>
<td>39.2%</td>
<td>50.6%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>radiographs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>178</td>
<td></td>
<td>4.8%</td>
<td>45.7%</td>
<td>55.8%</td>
</tr>
</tbody>
</table>

There was a significant correlation between the presence of periapical pathology and poor / underfilling of the root canal(s).

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**How good are we at root canal treatment?**

*CREOSOTE AND COTTON IN FANG FILLING.*

BY J. FOSTER FRAGO, D. D. S.

Dent Cosmos 1:115-117. 1860
119 articles identified, 63 studies published from 1922 to 2002. 6 randomized trials, 7 cohort studies and 48 retrospective studies. Mean success rates ranged from 31% to 96% based on strict criteria or from 60% to 100% based on loose criteria. 24 factors (patient and operative) had been investigated. Influence of preoperative pulpal and periapical status of the teeth on treatment outcome were most frequently explored, but the influence of treatment technique was poorly investigated.

No improvement in success rates in 60 years.

**Special Investigations**

**The role of radiography**

Detection of periapical bone defects in human jaws using cone beam computed tomography and intraoral radiography

G. Mello Pinto, A. Da Fonseca, F. Menezes, R. Wilkins and T. Pitt Ford

*Department of Endodontics, Faculty of Dentistry, University of Toronto, Toronto, ON, Canada.

Cone-beam computerized tomographic, radiographic, and histologic evaluation of periapical repair in dogs with endodontic treatment

Fernando Wanderley de Oliveira, DDS, MS.

Milene Sant'Ana Júnior, DDS, MS.

Mário Roberto Evangelista, DDS, MS, PhD.

Albinho de Carvalho, DDS, MS, PhD.

A New Periapical Index Based on Cone Beam Computed Tomography

Carla dos Santos, DDS, MS, PhD.

Willei Del Bimbo, DDS, MS.

Rafael Corrêa, DDS, MS, PhD.

Pitouha Ait-Ameur, DDS, MS, PhD.

Jocelyne A. Picone, DDS, MS, PhD.
The prime cause of endodontic disease is infection of the:
- root canal system
- peri radicular tissues
by micro-organisms

many taxa
up to 20 per root canal
strict anaerobes
facultative anaerobes
Bacterial species in infected root canals is diverse and there are complex interactions among species.

Munson et al 2002
Siqueira & Rocas 2004

E. faecalis is not in the top 50!!
In 70% of cases bacteria invade dentinal tubules at apex of tooth.

Removing dentine does not remove all the bacteria.

Root canal treatment

Clean, clean, clean

Shape

Obturate

Restore
Is there any evidence that obturation, root filling techniques and materials affect success in non-surgical root canal treatment???

Not much!!!
So what is root canal obturation?

a seal of the root canal system to prevent ingress and egress of micro-organisms and provide an environment to allow predictable healing and prevent further infection of the periradicular tissues

The ideal root filling material?

- easily introduced into the canal
- should seal the canal laterally and apically
- should not shrink after insertion
- should be impervious to moisture
- should be bacteriostatic
- should be radiopaque
- should not stain tooth structure
- should not irritate periradicular tissues
- should be sterile
- should be capable of being removed easily

Factors in obturation that may affect outcome

- materials
- sealer
- bulk
- technique
- apical extent
- apical size
so can we use whatever we like?

**Filling of the root canal system**

The objectives are: to prevent the passage of microorganisms and fluid along the root canal and to fill the whole canal system, not only to block the apical foramina but also the dentinal tubules and accessory canals.

Materials used to fill the root canal system should be: biocompatible, dimensionally stable, able to seal, unaffected by tissue fluids and insoluble, non supportive of bacterial growth, radiopaque, and removable from the canal if retreatment needed.

The root canal filling should consist of a (semi-) solid material in combination with a root canal sealer to fill the voids between the (semi-) solid material and root canal wall. Sealers containing organic materials such as aldehydes are not recommended. Filling should be undertaken after the completion of root canal preparation and when the infection is considered to have been eliminated and the canal can be dried. The prepared root canal should be filled completely unless space is needed for a post. The prepared and filled canal should contain the original canal. No space between canal filling and canal wall should be seen. There should be no canal space visible beyond the end-point of the root canal filling.


**Factors in obturation that may affect outcome**

- **the sealer**
  - should provide intimate sealing contact along all the root canal wall
  - used either alone or in combination with solid core
the sealer

If used in combination with solid core then there should be minimal amounts

Effect of filling technique and root canal area on the percentage of gutta-percha in laterally compacted root fillings

Int Endod J 2009 42 719-726

the sealer

Russian red

N2 Sargent

mutagenic, carcinogenic, toxic
the sealer

which sealer should you use?

zinc-oxide eugenol

used for 90 years
Rickert – added silver
Grossman – added bismuth and barium salts

eugenol is cytotoxic when freshly mixed
antibacterial
breakdown leads to deposits of Zn, Cu, Ca in vital organs
Ca(OH)₂–based sealers

examined physical properties, biocompatibility, leakage, adhesion, solubility, antibacterial properties, periapical healing effect

setting reaction is complex contact with moisture gives a hard surface but deeper parts may be left unset This leaves a relatively weak material

Resin-based sealers

epoxy resin AH 26 and AHPlus

AH26 hydrophilic. releases formaldehyde when freshly mixed after 2 weeks very small amounts. Liquid contains bis phenol A-diglycidyl-ether AH Plus is more compatible

methacrylate Hydron

urethane dimethacrylate Endorez

hydrophilic

poly vinyl Diaket

very acceptable biocompatibility
A polycaprolactone core and sealer filling system

Components were developed to bond with each other and with canal wall to produce a bacteria tight seal with reinforcement of the root

Monoblock

Root canal filling using Resilon: a review

N. J. Shanshan\textsuperscript{1} and H. F. Duncan\textsuperscript{2}

VERIFIABLE CFD PAPER

British Dental Journal Volume 211 No 2 Jul 22 2011

**IN BRIEF**

- Aims to comprehensively review Resilon as a root filling material in practice.
- Highlights that current research although extensive is of limited quality.
- Suggests that prospective clinical studies comparing Resilon to existing materials are required.
- Concludes that Resilon cannot yet be considered an evidence-based replacement to gutta-percha.
Thus until nonshrinking composites are available the pursuit of an ideal monoblock for reinforcing the root canal may be viewed as an ideal goal. The modulus of elasticity of the post, root filling material and accompanying resin cements or sealers have to match that of root dentin so that loading stresses are evenly distributed and borne by all components. These issues become increasingly more complex as additional interfaces are incorporated.

On the basis of the in vitro and in vivo data available to date there appears to be no clear benefit with the use of methacrylate resin-based sealers in conjunction with adhesive root filling materials at this point in their development.

polysiloxane sealers
polydimethyl siloxane Roeko Seal

minimal, if any contraction on setting biocompatible
Ingredients:
- Gutta percha
- Zinc oxide
- Barium sulfate
- Sealer
- Polydimethylsiloxane
- Silicone oil
- Paraffin oil
- Zircon dioxide (radiopacity)
- Platinum catalyst
- Colour pigments
- Nano-Silver

The first “Two in One” fluid cold Filling System

Roeko seal vs Grossmans
lateral compaction
199 teeth in 3 centres
PAI used

Results
52-month control showed healing
no significant difference between sealers

Healing of apical periodontitis after endodontic treatment: a comparison between a silicone-based and a zinc oxide-eugenol-based sealer

Int Endod J 2003, 36, 296-301
## Classification of Calcium Silicate Materials – Dutta and Saunders

### CALCIUM SILICATE MATERIALS:

<table>
<thead>
<tr>
<th>Generation I</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Grey MTA</td>
<td></td>
</tr>
<tr>
<td>• White MTA</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Generation II</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Modifications to MTA</td>
<td></td>
</tr>
<tr>
<td>o To decrease setting time: with calcium chloride, sodium hypochlorite, KY Jelly, calcium nitrate, calcium nitrate + dicalcium formate, sodium phosphate dibasic</td>
<td></td>
</tr>
<tr>
<td>o To improve handling: methyl cellulose</td>
<td></td>
</tr>
<tr>
<td>o Dual functional (faster set &amp; better handling): calcium lactate gluconate</td>
<td></td>
</tr>
<tr>
<td>o Alteration in bismuth oxide concentration</td>
<td></td>
</tr>
<tr>
<td>o Replacement of bismuth oxide with alternative radio-opacifier: zirconium oxide, iodoform, silver-tin alloy, gold, titanium</td>
<td></td>
</tr>
<tr>
<td>• MTA Angelus, MTA Branco &amp; MTA Bio</td>
<td></td>
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</tbody>
</table>

### Classification of Calcium Silicate Materials

<table>
<thead>
<tr>
<th>Generation III</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Modification of Portland Cement: several experimental cements</td>
<td></td>
</tr>
<tr>
<td>• Modification for use as sealer: Endo CPM, ProRoot Endo (with water soluble polymer), MTAS, iRootSP (also retailed as Endosequence BC and SmartPaste Bio), MTA Obtura, Tech Biosealer Endo, experimental fluoride doped cement</td>
<td></td>
</tr>
<tr>
<td>• Calcium silicate materials:</td>
<td></td>
</tr>
<tr>
<td>o Synthesized as a partial-stabilized cement</td>
<td></td>
</tr>
<tr>
<td>o Synthesized via sol-gel method</td>
<td></td>
</tr>
<tr>
<td>o Aluminium-free cement</td>
<td></td>
</tr>
<tr>
<td>o New Endodontic Cement</td>
<td></td>
</tr>
<tr>
<td>o Bioaggregate</td>
<td></td>
</tr>
<tr>
<td>o Tech Biosealer (with accelerator and phyllosilicate plasticizer)</td>
<td></td>
</tr>
<tr>
<td>o Aureoseal</td>
<td></td>
</tr>
<tr>
<td>o Biodentine</td>
<td></td>
</tr>
<tr>
<td>o Experimental Cements:</td>
<td></td>
</tr>
<tr>
<td>o Calcium sulpho-aluminate cement with or without granite</td>
<td></td>
</tr>
<tr>
<td>o Calcium fluoro-aluminate cement with or without granite</td>
<td></td>
</tr>
<tr>
<td>o Additives of Mg, Zn, Fe</td>
<td></td>
</tr>
<tr>
<td>o Calcium aluminate-calcium silicate composite cement</td>
<td></td>
</tr>
<tr>
<td>• Generex A</td>
<td></td>
</tr>
<tr>
<td>• Generex B</td>
<td></td>
</tr>
<tr>
<td>• Ceramicrete-D</td>
<td></td>
</tr>
<tr>
<td>• Capasio</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Generation IV</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Hybrid Cements:</td>
<td></td>
</tr>
<tr>
<td>o Calcium Phosphate/Calcium silicate/Bismuthite Cement</td>
<td></td>
</tr>
<tr>
<td>o NRC (Incorporating HEMA)</td>
<td></td>
</tr>
<tr>
<td>o MTA with 4-META/MMA-TBB</td>
<td></td>
</tr>
<tr>
<td>o Light cured cements</td>
<td></td>
</tr>
</tbody>
</table>
Calcium silicate and bioceramics

dicalcium silicate, tricalcium silicate,
tricalcium aluminate

+  

phosphate in tissue fluid

\[ 10 \text{ Ca}^{+2} + 6(\text{PO}_4)^{2-} + 2(\text{OH})^{-1} \rightarrow \text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2 \]  

hydroxyapatite

Mineral Trioxide Aggregate

MTA

grey

white

tricalcium silicate
tricalcium aluminate
tetracalcium aluminoferrite  
tricalcium oxide  
silicate oxide  
bismuth oxide - radiopacity
MTA mixed with water to form gel 3-stage set

1) dispersion of clinker grain in water.
2) hydration products eat into and grow out from surface of each grain.
3) setting occurs when the different clinker grains join together.

Finally, hardening occurs with further development of the gel and crystalline particles are disseminated throughout. Chemical expression is called alite and belite phase reaction. Alite with water may be expressed as:

\[ 2\text{Ca}_3\text{SiO}_4 + 6\text{H}_2\text{O} \rightarrow 3\text{CaO}.2\text{SiO}_2.3\text{H}_2\text{O} + \text{3Ca(OH)}_2 \]

Fast reaction and causes setting and strength development in the 1st wks.

The simplified reaction of belite is:

\[ 2\text{Ca}_2\text{SiO}_4 + 4\text{H}_2\text{O} \rightarrow 3\text{CaO}.2\text{SiO}_2.3\text{H}_2\text{O} + \text{Ca(OH)}_2 \]

Relatively slow reaction responsible for gaining strength after 7d.

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**MTA problem!!**

slow setting time 2h 45m

other problems

manipulation – like wet cement
don’t use Ca(OH)$_2$ for long periods!

Andreasen et al 2002
Doyon et al 2005
Rosenberg et al 2007

Recall >1 year  I visit  93.5%
2 visits  90.5%

Do it in 1 visit
followed up for up to 43 months
Cytotoxicity evaluation of Gutta Flow and Endo Sequence BC sealers

Keivan Zareian, DDS, MDS.1 Jin Jiang, DDS, PhD.2 Takashi Konagaya, DDS, MDS, PhD.3 Yu-Hsiung Wang, DMD, PhD.4 Kamyar E. Safavi, DMD, MS.5 and Qiang Zhu, DDS, PhD.1,2 Farmington, Connecticut, and Dallas, Texas

UNIVERSITY OF CONNECTICUT AND BAYLOR COLLEGE OF DENTISTRY

cell culture MTT assay for cytotoxicity

Fig. 1. Cell viability of L929 cells after culture with 1-day eluate of freshly mixed sealers.

Fig. 4. Cell viability of L929 cells after culture with 3-day eluate of set sealers.
which sealer should you use?

zirconium oxide, calcium silicates, calcium phosphate, calcium hydroxide, filler and thickening agents nanoparticles

Factors in obturation that may affect outcome

bulk/core material

silver
gutta-percha
polymers

Factors in obturation that may affect outcome

bulk/core material

silver

solid

fit where they touch
corrode cytotoxic
Factors in obturation that may affect outcome

bulk/core material

gutta-percha
Gutta-percha is a polyterpene, a polymer of isoprene, or polyisoprene, specifically (trans-1,4-polyisoprene).

John Tradescant returned from his travels in the Far East with this material in 1656. A British surgeon, Dr William Montgomerie, was the first person to introduce the Western world to gutta-percha in 1843.

Gutta-percha fulfils many of the objectives of a core material and is very versatile.

- Good wettability
- Good flow
- Tacky
- Melting point 64°C
- Thermal history on heating
- Good wettability
- Good flow
- Tacky
gutta-percha cones

composition

- gutta-percha: 20%
- zinc oxide: 60-75%
- metal sulphates: up to 15%
- waxes: up to 4%

Advantages:

- plastic – adapts relatively well with compaction to canals, especially when heated
- easy to place and remove
- low toxicity
- has withstood the test of time!

latex allergy

allergic reactions to GP
Very rare - only one case has been reported
(Boxer et al. J Allergy Clin Immunol 1994 943-4)

Latex allergy
The immuno cross-reactivity of gutta percha points
- Kang PB et al Dent Mat 2007; 23:380-384
- No cross reactivity to NLR from raw gutta-percha or gp cones

Cross-Reactivity Studies of Gutta-Percha, Gutta-Balata, and Natural Rubber Latex
No cross reactivity to NLR from raw gutta-percha but some reactivity to gutta-balata
**gutta-percha**

Tissue reaction:
milled gutta-percha points implanted in guinea pigs caused chronic foreign body reaction

large particles from points caused little reaction

Tissue reaction to gutta-percha particles of various sizes when implanted subcutaneously in guinea pigs
Sjögren U, Sundqvist G, Nair PN.

**gutta-percha**

sealability:
does not seal without the use of a sealer

**gutta-percha**

surface can be coated
calcium hydroxide
chlorhexidine
glass ionomer
gutta-percha surface can be coated and perhaps with other chemicals including bioglasses nanoparticles

Factors in obturation that may affect outcome

bulk/core material

resin

A new thermoplastic synthetic polymer-based root filling material to replace gutta-percha

- Based on polymers of polyester
- Contains Bioactive glass
- Ca(OH)$_2$
- Radiopaque fillers
hydrophilic monomer povidone

Factors in obturation that may affect outcome

Technique

gutta-percha

Techniques of obturation with gutta-percha

cold
- single cone
- lateral compaction
- variations on lateral compaction
- chemically plasticised

warm
- vertical compaction
- sectional compaction
- lateral/vertical compaction
- thermomechanical compaction
- thermoplasticised syringe
- core-based
Obturation Technique

cold lateral compaction

02 tapered points

Protaper points
sizes F1-F5

Canal preparation
continuously flared from apex to coronal

Spreader selection
risk of root fracture with hand spreaders
NiTi penetrate deeper, less stress
spreader depth
Allison DA, Weber CR, Walton RE.
The influence of the method of canal preparation
on the quality of apical and coronal obturation.
J Endod 1979;5:298-304

Accessory cone selection
same size or slightly smaller than spreader

Cone
MUST have friction fit at WL

Sealer
biocompatible, slowish setting
**cold lateral compaction**

fit cone in damp canal
radiograph master cone
dry canal with correct size of paper
points measured to WL

mix sealer and have spreader ready

place master cone with pumping action

watch wind spreader to length
Evaluation of Epoxy Resin Sealer After Three Root Canal Filling Techniques by Confocal Laser Scanning Microscopy

Premolars
Protaper F5
EDTA/ultrasonic
AH Plus/Rhodamine dye
sectioned 4mm from apex

Groups
single cone 21.18%
cold lateral compaction 17.4%
Thermafil 8.09%

100% integrity at wall face for all groups
Thermafil thinner layer
heated gutta-percha techniques

system B

microseal

lateral compaction

Obtura

thermomechanical compaction

Therafil

The single-cone obturation technique enables an easier and faster endodontic obturation. However, regarding to the aspects such as the obturation quality, apical microleakage and bacterial penetration, this technique is similar to or lower than others. Conclusion: This technique has the advantage of saving time during the filling of the root canal. However, further studies are necessary to evaluate its prognosis, especially in canals with complex anatomy.
Thermafil vs lateral compaction 3 year follow up

Factors in obturation that may affect outcome

apical extent
Determining the Optimal Obturation Length: A Meta-Analysis of Literature

4 studies
Harty et al 1970 1025 teeth
Kerekes et al 1979 501
Matsumoto et al 1987 85
Kerekes et al 1978 188

Results demonstrated that obturating materials extruding beyond radiographic apex correlated with a decreased prognosis.

More prospective studies required.

Factors in obturation that may affect outcome

Recall radiographs of 1,007 endodontically treated teeth with 1,770 canals were evaluated for success or failure. Results revealed that 89.66% of 1,770 canals received a successful evaluation. Evaluation of several variables suggests that a lower success rate is associated with overfilled canals, canals with preexisting rarefaction, and teeth not properly restored following completion of root canal therapy. A significantly lower success rate was also found in male patients and mandibular first molars in this study. No significant difference in success rate was found when evaluating age of the patient or type of filling material.

Factors in obturation that may affect outcome

apical extent

J Endod 2005 31 271-4

J Endod 1983 5 198-202
how large should we prepare the apex?

**larger the better**
Shuping et al 2000  
Rollison et al 2002  
Card et al 2002

**small but with taper**
Yared & Bou Dagher 1994  
Siqueira et al 1999  
Lumley 2000  
Coldero et al 2002

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<table>
<thead>
<tr>
<th>Treatment Outcome in Endodontics—The Toronto Study. Phase II: Initial Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No of teeth</strong></td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td>Modified stepback &amp; lateral condensation</td>
</tr>
<tr>
<td>Flared prep vertical compaction</td>
</tr>
</tbody>
</table>

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**Taper**
Albrecht LJ, Baumgartner JG  
Evaluation of apical debris removed using various sizes and tapers of Profile GT files  
J Endod 2004; 30: 425-428

prepared to size 20 or 40

Taper had an important influence

Taper 04, 06 and 08  
Cleaner canals with apical prep of 40

Taper 10  
No significant difference between 20 and 40
So how should we obturate the root canal? Perhaps a single tapered cone and a nanofilled bioceramic.

And protect the obturation.

Coronal leakage as a cause of failure in root canal therapy: a review

Saunders WP, Saunders EM

Endod Dent Traumatol 1993, 10 105-108
obturation is only part of the picture

To make endo work

check restorability
access
glide path
irrigation and slide path
shaping with taper
obturate with coronal seal
restore as soon as possible

Thank you