Endodontiske materialer

Avd endodonti, UiO
2015 01 16
Table I. Dental Endodontic Sealers Tested in the Current Study

<table>
<thead>
<tr>
<th>Material (Manufacturer)</th>
<th>Code</th>
<th>Lot Number</th>
<th>Composition (from Manufacturer)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epiphany® (Pentron Clinical Technologies, LLCC. Wallingford, CT)</td>
<td>EPH</td>
<td>149468</td>
<td><em>Resins</em>: Bis-GMA, UDMA, PEGDMA, EBPADMA <em>Fillers</em>: barium sulfate, bismuth oxychloride, calcium hydroxide, silica, silane-treated barium boroaluminosilicate glass (with a small amount of aluminum oxide); coloring pigment; <em>Dual-cured initiators</em>: cumene hydroperoxide, thiosinamine, camphorquinone. <em>Stabilizer</em>: butylated hydroxytoluene (2,6-di-tert-butyl-4-methylphenol)</td>
</tr>
<tr>
<td>EndoRez® (Ultradent Products, Inc. South Jordan, UT)</td>
<td>ER</td>
<td>102104</td>
<td>Urethane dimethacrylate resin as a matrix, zinc oxide, barium sulfate, resins, pigments.</td>
</tr>
<tr>
<td>Guttaflow® Coltène Whaledent, Switzerland</td>
<td>GF</td>
<td>D-89122</td>
<td>Polydimethylsiloxane, gutta-percha powder, zinc oxide, zirconium dioxide, nano-silver, paraffin-based oil, hexachloroplatinic acid, silicic acid</td>
</tr>
<tr>
<td>InnoEndo® Heraeus-Kulzer, Armonk, NY</td>
<td>IN</td>
<td>40001987</td>
<td>Resins: Bis-GMA, UDMA, PEGDMA, EBPADMA Fillers: barium sulfate, bismuth oxychloride, calcium hydroxide, silica, silane-treated barium boroaluminosilicate glass; <em>Dual-cured initiators</em>: cumene hydroperoxide, thiosinamine, camphorquinone Stabilizer: butylated hydroxytoluene (2,6-di-tert-butyl-4-methylphenol); Pigment: Red #40 (CAS no. 25997–17–3)</td>
</tr>
</tbody>
</table>
This artist’s impression shows the yellow hypergiant star HR 5171. This is a very rare type of star with only a dozen known in our galaxy. Credit: ESO

Root canal sealers
in part from Tyagi et al 2013

• ZOE
• Epoxy
• Ca(OH)2
• Silicone
• MTA
• Ca-Si-P
• Methacrylate
• Ca-P

• PCS, Grossman, TubliSeal
• AH26, AHplus
• Apexit, Sealapex
• RoekoSeal, GuttaFlow
• ProRoot, Fillapex
• Endosequence, Totalfill, Bioaggregate
• EndoRez, RealSeal, Smartseal
• Capseal
Endodontics is:

Prevention or treatment of apical periodontitis which in practice means

*Protection against or elimination of root canal infection*

Irrigation, medication and *root filling* are all means towards this end

Ørstavik 1988
Root filling

Protection against or elimination of root canal infection

1. Stop coronal leakage
2. Entomb surviving microbes
3. Block influx of water and nutrients

Figure courtesy of Eldeniz et al.

guttapercha $\rightarrow$ sealer $\rightarrow$ dentin
Acroseal
Septodont

Composition
Base: Glycyrrhetic acid (enoxolone) [licorice], methenamine, radiopaque excipient.
Catalyst: Calcium hydroxide, DGEBA [(diglycidyl ethers bisphenol-A)], radiopaque excipient.

AH26

A variant of Ahplus; Company website
Silicone-Based Endodontic Sealers

- (Lee Endofil)
- RoekoSeal
- GuttaFlow

Coltène-Whaledent
Silicon-based sealers

Silicone-plugs penetrating dentinal tubules and curling back up when torn from surface
Silicon-based sealers (GuttaFlow)

• Pros
  – Very good documentation
  – Clinically tested
  – Good tissue tolerance

• Cons
  – No antimicrobial effect?
  – Silver added to GF
  – Low mechanical strength
Composition of GuttaFlow:
Guttapercha finely ground
Sealer:

- Polydimethylsiloxane
- Silicone oil
- Paraffin-base oil
- Hexachloroplatinic acid (catalytic agent)
- Zirconium dioxide (radiopacity)
- Silver (conservation agent)
- Color pigments

http://www.wou.edu/has/physci/ch462/BouncingPutty.htm
Finely ground gutta percha in silicone: GuttaFlow
GuttaFlow

Cortesy M.J. Roggendorf
Resin-based sealers

• Pros
  – Known technology
  – Known bioeffects

• Cons
  – No antimicrobial effect?
  – Long term seal?
  – Disintegration?
"EndoREZ™ is a UDMA resin-based, root canal sealer with hydrophilic properties that improve sealing ability even in canals that are moist with water."

Ultradent, company website
EndoREZ Points

”an unusual resin is created by first reacting one of the isocyanato groups of a diisocyanate with the hydroxyl group of a hydroxyl-terminated polybutadiene, as the latter is bondable to hydrophobic polyisoprene. This is followed by the grafting of a hydrophilic methacrylate functional group to the other isocyanate group of the diisocyanate, producing a gutta-percha resin coating that is bondable to a methacrylate-based resin sealer.”

Tay et al 2005
Tay et al. 2005


Gutta-percha

EndoREZ

Sealer

Dentin

Tay et al. 2005
A thermoplastic, synthetic polymer, Resilon™, with Epiphany™ or RealSeal sealer

- The thermoplasticity of Resilon is because of polycaprolactone, a biodegradable polyester with a moderately low melting point, while its bondability is derived from the inclusion of resin with methacryloxy groups. This filling material also contains [bioactive] glass fillers, and barium chloride as fillers, and is capable of coupling to resin sealers, an example of which is Epiphany [or RealSeal]. Epiphany Root Canal Sealant is a dual-curable resin composite containing a new redox catalyst, that enables optimal auto-polymerization under acidic environments.

Tay et al 2005
**Leak-Resistant.** Unlike gutta percha, RealSeal leaves no gap for leakage. Coronal and apical leakage are substantially reduced. [Test results?]

**Strengthening.** Gives the root significant toughness. [Test results?]

**Technique-Compatible.** Works with your current filling method. [OK]

**Retreatable.** With chloroform and/or heat. Like Grossman’s formula, retreatments are easy. [OK]

**Radiopaque.** Just like your current method of obturation, detection is not a problem. [OK]

Dentin

Resilon™ + Epiphany™ sealer monoblock
Physical properties
## Physical properties

<table>
<thead>
<tr>
<th>Sealer</th>
<th>Radiopacity (n=3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AH Plus</td>
<td>9.90±1.56</td>
</tr>
<tr>
<td>Epiphany</td>
<td>9.43±0.15</td>
</tr>
<tr>
<td>Endo-REZ</td>
<td>6.06±0.20</td>
</tr>
<tr>
<td>Roeko Seal</td>
<td>5.37±0.35</td>
</tr>
<tr>
<td>MTA Angelus</td>
<td>4.72±0.45</td>
</tr>
<tr>
<td>Gutta Flow</td>
<td>4.67±0.29</td>
</tr>
<tr>
<td>Apexit</td>
<td>4.60±0.10</td>
</tr>
<tr>
<td>Acroseal</td>
<td>4.50±0.10</td>
</tr>
<tr>
<td>Biodentine</td>
<td>2.80±0.48</td>
</tr>
</tbody>
</table>

Eldeniz et al.

There may be too much or too little: 6mm Aluminum equals dentin, minimum requirement is 3 mm, but that is on the low side clinically.
Investigation of the physical properties of tricalcium silicate cement-based root-end filling materials
L. Grech, B. Mallia, J. Camilleri, Dental Materials 29, Issue 2, February 2013, e20–e28
MTA ProRoot: 27 Mpa after 7 days
Dimensional change

-2
-1
0
1
2
3
4
5
6
7
8
1 12 15 18 24 30 36 42 48 54 60 66

TIME, months
DIM CHNG per cent
AH plus
Apexit
Grossmans sealer
Roeko silicone sealer
GuttaSeal 4

Ørstavik et al. unpublished
Physical properties of 5 root canal sealers.
Zhou HM, Shen Y, Zheng W, Li L, Zheng YF, Haapasalo M.

Table 1.

<table>
<thead>
<tr>
<th>Physical Properties</th>
<th>Endosequence BC sealer</th>
<th>MTA Fillapex (Angelus)</th>
<th>AH Plus (epoxy, Dentsply)</th>
<th>ThermaSeal (epoxy, Dentsply)</th>
<th>PCS (zeug)</th>
<th>GuttaFlow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow (mm)</td>
<td>23.1 ± 0.69</td>
<td>24.9 ± 0.54</td>
<td>21.2 ± 0.27</td>
<td>21.3 ± 0.47</td>
<td>23.1 ± 1.21</td>
<td>20.5 ± 0.32</td>
</tr>
<tr>
<td>Film thickness (μm)</td>
<td>22 ± 4.58</td>
<td>23.92 ± 7.05</td>
<td>16.07 ± 4.5</td>
<td>16.6 ± 5.26</td>
<td>13.35 ± 2.8</td>
<td>15.67 ± 1.4</td>
</tr>
<tr>
<td>Working time (min)</td>
<td>&gt;1440</td>
<td>45 ± 15</td>
<td>240 ± 40</td>
<td>300 ± 40</td>
<td>453 ± 31</td>
<td>15 ± 5</td>
</tr>
<tr>
<td>Setting time (h)</td>
<td>2.7 ± 0.3</td>
<td>2.5 ± 0.3</td>
<td>11.5 ± 1.5</td>
<td>23.0 ± 1.5</td>
<td>26.3 ± 2.5</td>
<td>0.7 ± 0.1</td>
</tr>
<tr>
<td>Solubility* (%)</td>
<td>2.9 ± 0.5</td>
<td>1.10 ± 0.15</td>
<td>0.06 ± 0.04</td>
<td>0.0015 ± 0.07</td>
<td>0.07 ± 0.03</td>
<td>0.02 ± 0.001</td>
</tr>
<tr>
<td>Dimensional change† (%)</td>
<td>0.087 ± 0.04</td>
<td>~0.67 ± 0.01</td>
<td>~0.034 ± 0.01</td>
<td>0.04 ± 0.02</td>
<td>~0.86 ± 0.03</td>
<td>0.037 ± 0.02</td>
</tr>
</tbody>
</table>


Physical Properties of the Sealers (mean ± standard deviation)
Hoop stress - (tension)
Radial stress - (pressure)

Ørstavik et al. 2003
E moduli: Calciumsilicate (CHS) ca 250 GPa, Composite ca 15 Gpa, elastomer ca 1 MPa

From Ørstavik et al. 2001
Smear layer and adhesion; cohesive and adhesive fracture

Dentin cleared: adhesive fracture

Guttapercha cleared: adhesive fracture

Saleh et al. Seldom cohesive fracture of sealer
Smear layer and adhesion

Saleh et al.: removal of smear layer did NOT increase adhesion
Fracture resistance of roots endodontically treated with a new resin filling material

**Teixeira et al 2004**: slightly stronger teeth after root filling with Resilon

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<table>
<thead>
<tr>
<th>GROUP</th>
<th>MEAN*</th>
<th>STANDARD DEVIATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Control—No Obturation</td>
<td>465.39&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>76.85</td>
</tr>
<tr>
<td>2 Lateral Gutta-percha</td>
<td>391.51&lt;sup&gt;a&lt;/sup&gt;</td>
<td>146.79</td>
</tr>
<tr>
<td>3 Vertical Gutta-percha</td>
<td>392.37&lt;sup&gt;a&lt;/sup&gt;</td>
<td>77.03</td>
</tr>
<tr>
<td>4 Lateral Resilon†</td>
<td>504.22&lt;sup&gt;b&lt;/sup&gt;</td>
<td>195.94</td>
</tr>
<tr>
<td>5 Vertical Resilon</td>
<td>498.23&lt;sup&gt;b&lt;/sup&gt;</td>
<td>135.32</td>
</tr>
</tbody>
</table>

* Superscript letters a and b represent statistically significant differences (*P* < .05).
† Resilon is manufactured by Resilon Research, North Branford, Conn.
Fracture resistance of roots obturated with three different materials.

Mean, standard deviation, and minimum and maximum values of forces for experimental groups (in Newtons)

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (AH26 + gutta-percha)</td>
<td>15</td>
<td>1021.04</td>
<td>226.74</td>
<td>684.31</td>
<td>1365.01</td>
</tr>
<tr>
<td>2 (Resilon + Epiphany)</td>
<td>15</td>
<td>886.33</td>
<td>175.15</td>
<td>600.00</td>
<td>1223.96</td>
</tr>
<tr>
<td>3 (Ketac-Endo Aplicap + gutta-percha)</td>
<td>15</td>
<td>741.38</td>
<td>175.46</td>
<td>426.73</td>
<td>1053.56</td>
</tr>
<tr>
<td>4 (No obturation)</td>
<td>15</td>
<td>831.40</td>
<td>163.07</td>
<td>598.00</td>
<td>1202.00</td>
</tr>
</tbody>
</table>

Ulusoey et al 2007: At least as good fracture resistance with AH
Leakage
**In vitro** model for coronal leakage

*Upper chamber* with bacteria

*Sterilised, root filled root*

*Lower chamber, sterile medium*

*Bacteria penetrating the root filling multiply in the clear medium of the lower chamber, making it turbid.*

Barthel et al, 1999
Shipper et al. 2004
Streptococcus

Eldeniz et al. Similar resistance to leakage for AH and Resilon
AH Plus, RealSeal, Apexit; no smear

Days of incubation vs. Ratio resisting leakage for Enterococcus. The graph shows the performance of AH-ns, RS-ns, and AP-ns over different days of incubation.
Bacteria penetrating along sealer-guttapercha interface: AH Plus
AH Plus, RealSeal, Apexit; smear

Days of incubation
Ratio resisting leakage
AH-s
RS-s
AP-s

Enterococcus

Saleh et al. 2008
Antibacterial properties
Role of the root filling in eliminating microbes

- Root stubs preinfected with *Enterococcus faecalis*
- A gutta-percha point # 90 covered with sealer used to fill the canal
- 6 sealers and one group with calcium hydroxide

Specimen with root filling *in situ*
• Infected dentin slabs
• Root filled with GP and sealers
• Collection of dentin powder for culturing

Largo® Peeso Reamer size 5 (ISO size 150)

Saleh et al. 2003
Saleh et al. 2003

CT: control; KE: Ketac-Endo; RSP: RoekoSeal Automix + Primer; AP: Apexit; RS: RoekoSeal Automix; CH: Calcium Hydroxide; GS: Grossman’s sealer; AH: AH Plus
Prestegaard et al. 2014 in press

ER: EndoREZ; CaOH: Calcium Hydroxide; AH+: AH Plus; EpRe: Epiphany/Resilon. Short bars mean fewer bacteria.
Clinical-radiological testing
Critical factors in clinical testing

- **Randomization**: Each case stand an equal chance of being subject to either treatment
- **Confidence interval**: The range of probable value for an observation estimate
- Cohort study: Two or more groups; no randomization; typically different populations
- Case-control: typically retrospective: what separates cases that succeed from those that do not?
- Case series: self-explanatory

» Decreasing value
Preoperative Apical Periodontitis: Effect of Sealer

Waltimo et al., 2001

Range of s.e. of means: 0.03-0.17
Clinical research: RoekoSeal in comparison with Grossman’s sealer

Level 1 clinical evidence: randomized, unbiased  
Huumonen et al., 2003
GuttaFlow

![Graph showing PAI scores over time for different conditions.](image-url)
Sequence of decision

- **Clinical:**
  - Very difficult to prove superiority – only similar level of performance, or ‘feasibility’ (Sealapex, AH, Grossman, RoekoSeal, GuttaFlow, EndoREZ, Epiphany)

- **Biological:**
  - Avoiding harm
  - Supporting regeneration

- **Technological**
  - Avoiding mishaps
  - Speed and ease of application and control

- **Expert opinion**
  - without explicit critical appraisal, or based on physiology, bench research or "first principles" (logical deduction)
Conclusions

• Adhesive root fillings and silicones have stimulated research
• They have forced us to identify the important functions of root fillings
• Their clinical performance is similar to conventional root filling materials, or worse
• None have documented superior performance
DE «NYE» KERAMENE OG BIOKERAMENE
Types and terms and brands

- Cement
- Bioceramics
- Bioglass
- Biocompatible, biomimetic

Clinical usage
- Dental
  - Preformed
  - Setting
- Medical

- MTA, Portland cement, Biodentine
- Endosequence (iRoot, TotalFill)
  BC or SP
- Bioaggregate
- (Ceramir)

- Implants, cements, sealers
- (Bioceramic hip, knee, orbital implants)
MTA: the starting point for ceramics in endodontics

- **MTA PATENT** (J Conserv Dent. 2008 Oct-Dec; 11(4): 141–143.)
- The MTA patent stated that ‘MTA consists of 50-75% (wt) calcium oxide and 15-25% silicon dioxide. These two components together comprise 70-95% of the cement. When these raw materials are blended, they produce **tricalcium silicate**, **dicalcium silicate**, **tricalcium aluminate**, and **tetracalcium aluminoferrite**. On addition of water, the cement hydrates, forming silicate hydrate gel.’ Also ‘MTA is Type 1 Portland cement (American Society for Testing Materials), with a fineness (Blaine number) in the range of 4500-4600 cm²/g. A radiopacifier (bismuth oxide) is added to the cement for dental radiological diagnosis.’
MTA

Retrograde fillings
Perforations
Dens invaginatus
Apexification
Apexogenesis
Sealing
Biocompatible
Antimicrobial
Pulp capping
Pulpotomy

Root filling??

Comparative studies
Arash Sanjabi, Oslo 2005
Silicate

• What is a silicate?

A silicate is a compound containing an anionic silicon compound. The great majority of silicates are oxides [SiO, but hexafluorosilicate ([SiF₆]²⁻) and other anions are also included. "Orthosilicate" is the anion SiO₄⁴⁻ or its compounds. Related to orthosilicate are families of anions (and their compounds) with the formula [SiO₂⁺n]²⁻.

(http://en.wikipedia.org/wiki/Silicate)
Silicate

Silica

$\text{SiO}_2$ many crystalline forms: quartz, cristoballite

Unit cell of $\alpha$-cristobalite; red spheres are oxygen atoms.
Calcium silicate

Silica

\[ \text{SiO}_2 \]

many crystalline forms

Di-calcium-silicate

\[ \text{Ca}_2\text{SiO}_4 \]
Calcium silicate

Silica
SiO₂
many crystalline forms

Di-calcium-silicate
Ca₂SiO₄

Tri-calcium-silicate
"3CaO·SiO₂":3Ca+3Si+9O
From MTA to ERRM

• MTA

• MTA *minus* aluminum:
  – Biodentine

• MTA *minus* aluminum, but *plus* CaP:
  – BioAggregate; ERRM, Endosequence, iRoot, TotalFill
iRoot = Endosequence (BC Sealer ≈ RRM)
BioAggregate Root Canal Repair Filling Material

Innovative BioCeramix Inc. (IBC) has successfully developed a new generation of a dental root canal filling material. BioAggregate® Root Canal Repair Filling Material (BioAggregate®) is a fine white hydraulic powder cement mixture for dental applications. It utilizes the advanced science of nanotechnology to produce ceramic particles that, upon reaction with water, produce biocompatible and aluminum-free ceramic biomaterial.

The BioAggregate® Powder promotes a complicated set of reactions upon mixing with BioA Liquid (deionized water), which leads to the formation of a nano-composite network of gel-like calcium silicate hydrate intimately mixed with hydroxyapatite bioceramic, and forms a hermetic seal when applied inside the root canal.

BioAggregate® has excellent handling characteristics after mixing with water, which aids in the repair process of the affected tooth. BioAggregate's® radiopacity properties, convenient setting and hardening time, easy workability and handling properties, make it an ideal root canal repair filling material. BioAggregate® is packaged to provide all the necessary materials for six complete root canal repair filling treatments.

FEATURES & BENEFITS:

Aluminum-Free and Biocompatible Composition
The effects of aluminum toxicity can cause serious health problems. Consequently, BioAggregate® is biocompatible and completely aluminum-free.
ENDOCEM MTA
New generation GRAY MTA
300mg/1package
P/L=300mg/0.12cc
Fast setting time
Excellent biocompatibility
Super sealing property
Long clinical data
Effective bleeding control · Fast neutralization · Least calcification

ENDOCEM Zr
New generation WHITE MTA
300mg/1package
P/L=300mg/0.14cc
Fast setting time
Tooth color formula
Adequate physical property
Optimized for partial pulpotomy
Effective bleeding control · Fast neutralization · Excellent biocompatibility and sealing property · Excellent radiopacity

ENDOSEAL
New generation ROOT CANAL FILLER
300mg/1package
P/L=300mg/0.14cc
Tooth color formula
Length control and Flowability
Unique physical property
Effective bleeding control · Fast neutralization · Hydraulic property · Biocompatibility and sealing property · Excellent radiopacity

“pozzolan”, a Ca-Si variant
**EndoSequence® BC Points™** are unlike traditional gutta percha and are subjected to a patented proprietary process of impregnating and coating each cone with bioceramic nanoparticles to allow for true chemical (cementation) bond between sealer and points.

[https://www.dentalaegis.com/products/brasseler/endosequence-bc-points](https://www.dentalaegis.com/products/brasseler/endosequence-bc-points)

---

**BioAggregate**

Bioceramic Composition  
a. Chemically bonded ceramic (bioceramic) raw materials. It's not a mineral (ceramic in nature) aggregate.  
b. Aluminum-Free Composition  
The effects of aluminum poisoning can range from subtle symptoms to serious diseases. BioAggregate is completely aluminum free and will not pose any toxic threat to the human body.  
   - No toxic heavy metals. (No tricalcium aluminate - C3A - in MTA.)  
c. No unnecessary heavy elements (ex. iron)  

**BioAggregate** is pure bioMaterial without any unnecessary contaminants, thus is considered safer for use as medical devices. (No tetracalcium aluminoferrite - C4AF in MTA)

Root canal repair cement

The introduction into the market of MTA (Mineral Trioxide Aggregate) in the 90s has been a veritable revolution that allows successful repair of iatrogenic accidents while reducing the associated pathological complications. Currently, clinically approved MTA products are available within the dental marketplace. However, MTA traditionally has a long setting time and an often grainy consistency which makes placement more difficult.

MICRO-MEGA® now offers the “State-of-the-Art” MM-MTA™, an endodontic repair cement that has excellent physiochemical characteristics delivered in innovative packaging. MM-MTA™ incorporates a faster set time with a pasty consistency for easy handling and placement.
Innovative characteristics

Thanks to its unique characteristics, MM-MTA™ offers indisputable advantages compared to other existing materials:

An adapted packaging:
- Consisting of capsules containing MM-MTA™ powder and liquid, automatic mixing is achieved quickly with a vibrating mixer. In addition, the resulting MM-MTA™ blend is extremely homogenous with transformation properties which are always optimal and reproducible.
- Each capsule contains the exact dosage of MM-MTA™ to avoid waste.

A homogenous consistency:
- MM-MTA™ packaging insures a consistently high-quality product mix for simple handling and easy placement within the root canal.

A reduced setting time (20 minutes):
- The addition of calcium carbonate (CaCO3) considerably reduces the setting time and also allows filling in the same session.
Likheter og forskjeller

• MTA har aluminium blant ingrediensene
• ”Alle” prøver å unngå det, også Biodentine
Likheter og forskjeller

- MTA og Biodentine er "IKKE" biokeramer, fordi
Likheter og forskjeller

• MTA og Biodentine er ”IKKE” biokeramer, fordi
• de IKKE har et kalsiumfosfat (Ca-P) med i formelen/produksjonen
Likheter og forskjeller

• MTA og Biodentine er "IKKE" biokeramer, fordi de IKKE har et kalsiumfosfat (Ca-P) med i formelen/produksjonen, men har

• **tricalcium silicate**, dicalcium silicate, (tricalcium aluminate og tetracalcium aluminoferrite i det opprinnelige patentet for MTA)
Likheter og forskjeller

• MTA og Biodentine er "IKKE" biokeramer, fordi de IKKE har et kalsiumfosfat (Ca-P) med i formelen/produksjonen, men
• **tricalcium silicate**, dicalcium silicate, (tricalcium aluminate, and tetracalcium aluminoferrite) som
• reagerer med vann til et hydratisert skikt (C-S-H) mellom kornene, som stivner etter hvert
Likheter og forskjeller

• **MTA og Biodentine** er ”**IKKE**” biokeramer, fordi de **IKKE** har et kalsiumfosfat (Ca-P) med i formelen/produksjonen, men dét **HAR** biokeramer, slik som **Endosequence** og **BioAggregate**

• [Ca-P-forbindelser: f.eks. hydroxyapatite (HA), tricalcium phosphate (TCP), biphase calcium phosphate (BCP)]
Bioceramics

- **Ceramic**: an inorganic, nonmetallic solid prepared by the action of *heat and subsequent cooling* (“sintring”).

- **Bioceramics**: the combination of calcium silicate and calcium phosphate applicable for biomedical or dental use.

- **Bioceramics** and bioglasses are biocompatible.

Biodentine

• Septodont

• Active Biosilicate Technology™

• “Biodentine™ was developed by Septodont’s Research Group as a new class of dental material which could conciliate high mechanical properties with excellent biocompatibility, as well as a bioactive behavior.”
Biodentine

1.1 - Setting reaction

The calcium silicate has the ability to interact with water leading to the setting and hardening of the cement. This is a hydration of the tricalcium silicate $(3\text{CaO} \cdot \text{SiO}_2 = \text{C}_3\text{S})$ which produces a hydrated calcium silicate gel (CSH gel) and calcium hydroxide $(\text{Ca} (\text{OH})_2)$.

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

This dissolution process occurs at the surface of each grain of calcium silicate. The hydrated calcium silicate gel and the excess of calcium hydroxide tend to precipitate at the surface of the particles and in the pores of the powder, due to saturation of the medium. This precipitation process is reinforced in systems with low water content.
The unreacted tricalcium silicate grains are surrounded by layers of calcium silicate hydrated gel, which are relatively impermeable to water, thereby slowing down the effects of further reactions. The C-S-H gel formation is due to the permanent hydration of the tricalcium silicate, which gradually fills in the spaces between the tricalcium silicate grains. The hardening process results from the formation of crystals that are deposited in a supersaturated solution.
1.2 - Formulation of Biodentine™

In order to reach a formulation with a short setting time (12 minutes) and high mechanical properties in the range of natural dentine, calcium silicates could not be used alone.

Usually calcium silicate cements have setting times in the range of several hours, which is too long in most of the protocols in clinical practice.

Increasing the setting time was achieved by a combination of different effects. First, particle size greatly influences the setting time, since the higher the specific surface, the shorter the setting. Also, adding calcium chloride to the liquid component accelerates the system. Finally, the decrease of the liquid content in the system decreases the setting time to harden within 9 to 12 minutes.

<table>
<thead>
<tr>
<th>Powder</th>
<th>Liquid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tri-calcium Silicate (C3S)</td>
<td>Calcium chloride</td>
</tr>
<tr>
<td>Di-calcium Silicate (C2S)</td>
<td>Hydrosoluble polymer</td>
</tr>
</tbody>
</table>
Biodentine

Reaching high mechanical strength is also quite difficult for these systems. The first cause of low mechanical properties of Portland cements are the aluminate components, which make the product fragile. Septodont controls the purity of the calcium silicate through the Active Biosilicate Technology™ which consists in eliminating aluminates and other impurities.

The second axis of formulation was to adjust the particle size distribution in order to reach an optimal powder density. The additional charge system selected was calcium carbonate, for both its biocompatibility and calcium content.

The paradox of calcium silicate systems is also that water, which is essential for the hardening of the product, can also affect the strength of the material. On the hand, excess water in the system will create some remaining porosity, significantly degrading the macroscopic mechanical resistance, but on the other hand decreasing the water content leads to reducing the possibility of a homogenous mix. The addition of hydrosoluble polymer systems described as “water reducing agents” or super plasticizers, helps in maintaining the balance between low water content and consistency of the mixture.

Radiopacity is obtained by adding zirconium oxide to the final product.
Bioglass

• In 1969 L. L. Hench and others discovered that various kinds of glasses and ceramics could bond to living bone. Hench was inspired with the idea on his way to a conference on materials. He was seated next to a colonel who had just returned from the Vietnam War. The colonel shared that after an injury the bodies of soldiers would often reject the implant. Hench was intrigued and began to investigate materials that would be biocompatible. The final product was a new material which he called Bioglass. This work inspired a new field called bioceramics. With the discovery of bioglass interest in bioceramics grew rapidly.
Bioglass

- **Bioglass** is a commercially available family of bioactive glasses, composed of SiO$_2$, Na$_2$O, CaO and P$_2$O$_5$ in specific proportions. L. L. Hench 1969 (not Ca-Si)
- **Glass** means it is not crystalline
- **Bio**: a thin layer of apatite forms on the glass-tissue interface
- High pH in surrounding tissue: **antibacterial effect**
Conclusions

• Ceramic root fillings have stimulated more research
• They have played on the impressive properties of MTA
• Their clinical performance has hardly been tested
• None have documented superior performance
Thank you!
Investigation of the physical properties of tricalcium silicate cement-based root-end filling materials, L. Grech, B. Mallia, J. Camilleri
Dental Materials Volume 29, Issue 2, February 2013, Pages e20–e28
<table>
<thead>
<tr>
<th>Level</th>
<th>Therapy/Prevention, Aetiology</th>
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<tr>
<td>1a</td>
<td>Systematic Review (with homogeneity) of Randomized Clinical Trials</td>
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<tr>
<td>1b</td>
<td>Individual Randomized Clinical Trials (with narrow Confidence Interval)</td>
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<tr>
<td>2a</td>
<td>Systematic Review (with homogeneity) of cohort studies</td>
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<tr>
<td>2b</td>
<td>Individual cohort study (including low quality RCT; e.g., &lt;80% follow-up)</td>
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<tr>
<td>3a</td>
<td>Systematic Review (with homogeneity) of case-control studies</td>
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<tr>
<td>3b</td>
<td>Individual Case-Control Study (few cases, matching controls)</td>
</tr>
<tr>
<td>4</td>
<td>Case-series (and poor quality cohort and case-control studies)</td>
</tr>
<tr>
<td>5</td>
<td>Expert opinion without explicit critical appraisal, or based on physiology, bench research or &quot;first principles&quot; (logical deduction)</td>
</tr>
</tbody>
</table>

6 THROUGHOUT HISTORY – ALL FLAWED

26 – MOSTLY FLAWED

HUNDREDS

Number of observations: effect on measures of spread

Clinical, comparative studies on performance of root canal filling materials.
Cumulative PAI Scores

TIME: 0 to 4 years

Ørstavik et al., 1986
...a total of 295 root canals were treated with laterally condensed gutta-percha cones in conjunction with a methacrylate-based endodontic sealer (EndoRez). ... The results were assessed clinically and radiographically 14-24 months postoperatively and a comparison to baseline radiographs was made. 145 patient records were available for a follow-up examination. Success of root canal treatment was based on absence of clinical symptoms, a normal or slightly widened periodontal ligament and reduction of periapical radiolucencies with an absence of pain in patients that had pre-existing lesions associated with pain. RESULTS: The overall success rate was 91.3%.
Clinical Outcome of Teeth Treated Endodontically with a Nonstandardized Protocol and Root Filled with Resilon

Deborah A. Conner DDS, MS, Daniel J. Caplan DDS, PhD†, Fabricio B. Teixeira DDS, MS, PhD‡ and Martin Trope DMD§

<table>
<thead>
<tr>
<th>Pre-operative PAI Score</th>
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<th>3</th>
<th>4</th>
<th>5</th>
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<tbody>
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<td>8</td>
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<td>3</td>
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<td>3</td>
</tr>
</tbody>
</table>

Each cell represents # clinical cases (N=82)

**Post-Operative PAI Score**

**N:**
- 39 Not worse, still healthy
- 8 Worse, but still healthy
- 15 Better and healthy
- 5 Worse and now unhealthy
- 7 Not better and still unhealthy
- 7 Better, but still unhealthy
Clinical Outcome of Teeth Treated Endodontically with a Nonstandardized Protocol and Root Filled with Resilon

Conner et al 2007

Case-series (and poor quality cohort and case-control studies)