SEALERS – Rob Goldberg – From ROOTS 5/16/2006

General Review:
Cohen and Burns 6th edition pp 230-2:
Sealer acts as :1)binding agent, 2) filler and 3) lubricant
All sealers are ***highly toxic*** when freshly prepared, but dissipates upon setting

Rickert's sealer: POWDER: ZO (41.2 parts), precipitated silver (30parts), white resin (16parts), and thymol iodide(12.8parts) LIQUID: oil of clove(78parts), Canada Balsam (22parts). Silver may cause discolor of crown, otherwise good sealer b/c it is germicidal, good lubricant and adhesive qualities and sets in about half an hour.

Tubuliseal: 2 mixable tubes: ZO (57.4%), bismuth trioxide (7.5%), oleoresins (21.25%), thymol iodide(3.75%), oils (7.5%), modifier(2.6%). Sets rapidly in presence of moisture.

Wach's Sealer: Powder: ZO (10g), calcium phosphate (2g), bismuth subnitrate(makes it set faster)(3.5g), bismuth subiodide(0.3g) and heavy magnesium oxide (.5g) Liquid: Canada balsam (20ml) and oil of clove (6ml). Germicidal, not good lubricant, but low tissue irritation. Do "string out" test to confirm adequate mix. (should string out 1 inch off of slab)

Chloropercha or Eucapercha: dissolve gp in chloroform or eucalyptol. Careful of shrinkage after set due to evaporation of solvent. Though good for filling curves or ledges

Grossman's sealer: Powder: ZO(42parts), staybelite resin (27parts), bismuth subcarbonate (15parts), barium sulfate (15parts), and sodium borate (1part), liquid: eugenol. Again use string out test or drop test (mass of cement will not fall off of spatula for 10-12 seconds when held edgewise) to confirm mix. Sets on slab in 6-8 hours. Moisture in canal makes cement set in about half an hour. Slow setting time due to presence of sodium borate anhydrate. Good sealing ability and minimal shrinkage. Can be absorbed, which is an advantage if pushed beyond apex (Augsburger JOE '90)

Diaket: resin reinforced chelate of ZO and diketone. Highly resistant to absorption. 1st reported in 1952. Used to cement "endoserous implants" (???? Quoted from book)

AH-26: 1st reported in 1957, it is an epoxy resin cement. Made of silver powder (10%), bismuth trioxide (60%), titanium dioxide (5%), and hexamethylene tetramine (25%). Liquid is bisphenol diglycidyl ether (100%). Good adhesive, antibacterial activity and low toxicity, though reports made of parasthesia caused by extruded AH-26. Like Rickert's, it also has silver, so will discolor tooth, make sure none in crown.

Polycarboxylate cements: ZO and polyacrylic acid. Will bond to enamel and dentin. Set too fast. Unsatisfactory for endo purposes.

Nogenol: may expand on setting, increasing its sealability. Found less irritating than Rickerts and Tubuliseal.

Calcium hydroxide based sealers: it has the ability to preserve the pulp stump, unlike zoe based sealers. Sealapex showed good sealing and biocompatibility.

Ingle and Bakland's textbook:
Grossman listed 11 requirements: 1)tacky to provide good adhesion, 2) provide hermetic seal, 3) radiopaque,4) mix easily, 5) no shrinkage upon setting,6) no staining, 7)bacteriostatic,8) set slowly,9) insoluble in tissue fluids,10) non-irritating,11) soluble in a common solvent for retreatments, (Ingle adds 2 to the list , 1) not provoke an immune response, 2) neither mutagenic or carcinogenic)

ZOE sealer: forms zinc eugenate which decomposes in presence of H2O, giving continuous loss over time, making it weak and unstable material and precludes its use in bulk such as retrofillings.

Wach's cement: Canada Balsam makes it tacky, disadvantage is its odor

N2, RC2B(American type of N2), Spad and Endomethasone: all contain formaldehyde in one form or another, making these sealers highly tissue toxic, because of release of formalin into tissue(manufacturer's state that this formalin release is antibacterial), but this dissolution breaks the seal and leads to their destructive behavior.

Calcium hydroxide sealers: CRCS(calciobiotic root canal sealer), Sealapex, Life, Apexit(Australian), Imbiseal, Vitapex(Japanese). CRCS does not dissolve well in tissue fluids so limited release of CaOH. Sealapex expands upon setting and may dissolve too much (absorbed 1.6% water weight gain in study), possibly allowing for loss of seal.

Plastics and Resins: Diaket and AH-26 and Lee-Endofill.
AH-26 will set under water(not sensitve to moisture), but will not set in presence of H2O2, and is also sold as Thermaseal.
Endofill is a silicone rubberlike material, virtually non-toxic and very radiopaque.

Glass ionomer sealers: Ketac-Endo
Greatest concern is that there is no solvent for GI, so retreatment tough, but recommend use chloroform and hand instruments followed by ultrasonics to effectively remove GI.

Experimental sealers:
Dentin bonding agents possibly used in conjunction with single cone technique to reduce shrinkage. Disadvantage is difficult to remove smear layer completely especially in apical third (as shown by Rawlinson), so seal would be questionable. Also these materials are not radiopaque and are technique sensitive (many do not set in presence of moisture). Finally they set very hard, making retreatment difficult.
Calcium phosphate cements: injectable and set up hard in 5 minutes.

Sealer efficacy: all sealers leak to some extent, some more than others. Hovland and Dumsha (IEJ ’85) found there is probably a critical level of leakage that is unacceptable for healing, leading to endo failure.
Methods of testing sealers for tissue tolerance(4 tests):

1) Cytotoxic evaluation: measure leukocyte migration in Boyden chamber, eval effects on HeLa cells or fibroblasts in culture, radioactive labeled tissue culture cells, or a fibroblast monolayer on a Millipore filter disk.
2) Subcutaneous implants: needle injection under skin of animals or insert product alone or in Teflon cups or tubes. Results are similar to cytotoxic studies
3) Osseous Implants: material directly implanted into bone
4) In vivo tissue tolerance tests in humans: the best test method, but often dangerous, expensive and unethical. Have to do many in vivo tests on lab animals first.

N2/Sargenti controversy:
N2 is used as a “codeword” for formaldehyde containing endo cements
RC-2B and N2(from Switzerland) recommended by American Endodontic Society
FDA barred its use around 1980
Pitt Ford found that N2 and Endomethasone caused ankylosis and root resorption.
A study out of Indiana U. on monkeys showed apical periodontitis in7 out of 9 apices, and that the “treated pulps with RC-2B were in no better shape than untreated inflamed controls” In fact they were worse than necrotic cases left open to salivary bacteria.
Sargenti recommends trephination at the periapex upon overfilling due to the chemical trauma of the paraformaldehyde periradicularly. The “Fistulator” bur used to trephine the apex to relieve the pressure and pain following N2 treatment.

Sealers

<u>Rationale</u>

1) gutta percha does not adhere to dentin
2) aids in the filling of canal irregularities (fins, cul-de-sacs)
3) Skinner and Himel (JOE’87)
    - 70 extracted max anteriors were divided into four groups and filled using the Obtura system with/without vertical compaction and with/without Procosol sealer; placed in fluorosceine dye for 24h and X-sectioned at 1,3,5 and 7mm
    - group with sealer leaked significantly less; no different w/ or w/o compaction

Requirements and characteristics of a good sealer (Grossman ’82)

- tacky when mixed to provide adhesion to canal wall
- should create a hermetic seal
- radiopaque
- particles of powder should be fine so that they mix easily with liquid
- should not shrink on setting
- should not stain tooth
- bacteriostatic (or at least not encourage bacterial growth)
- slow setting

- insoluble in tissue fluid
- tissue tolerant (non-irritating to PA tissue)
- soluble in a common solvent

Additional requirements (Ingle)

- should not provoke an immune response
- should be neither mutagenic nor carcinogenic

Cytotoxicity

Friend and Browne (British Dent J '68)

- 32 rabbits used had polyethylene tubes filled with one of 11 diff materials and placed into subcutaneous tissues and left for 2d,4d,7d,2wk,4wk,3 mo,6mo and 12mo.
- Tested fresh unset mixes of: amalgam, AH26,Diaket Normal,Diaket A, Putridomers 22 (ZOE with iodoform), N2 (zoe with formalin), Kalzinol (resin bonded zoe), zn-phosphate, Ledermix, Kri-I (resorbable iodoform paste)
- Most had stronger init reaction that subsided over time. Tissue rxn to N2 was strong at first that dissipated to mild after 2 weeks, Ledermix showed complete resolution after 7d, AH26 and amalgam had no inflamm response at 3 mo and Diaket normal had moderate inflamm response at 12mo.
- Showed hollow polyethylene tubes don't cause a severe rxn (agrees with Torneck '66, disagrees with Rickert and Dixon '31)

Briseno and Willershausen (JOE'90, 91, 92)

- tested different sealer types on gingival fibroblasts
- Pulp canal sealer showed initial moderate inflammation; almost no toxic effect after 13 days; all other ZOE sealers produced severe cytotoxicity
- AH26 showed severe toxicity; contrasts Safavi et al (JOE'89) who showed cell recovery after 24h
- Sealapex demonstrated relatively low cytotoxicity after 3 days

Spangberg and Langeland (OS'73)

- Studied toxicity of various filling materials on HeLa cells (Henrietta Lacks, 31 yo black female from Baltimore with cervical cancer in 1950); assessed initial mix and 24-h set, used Cr- labeling procedure.
- GP relatively inert
- Chloropercha least toxic material after evaporation of chloroform (probably takes much longer in vivo – removed through tissue)
- AH26 initially toxic, but decreases upon setting
- ZOE sealers were toxic throughout the experiment
- N2 was increasingly very toxic

Biocompatability:

Intraosseous testing:

Berit Olsson, Anthony Sliwkowski, and Kaare Langeland(JOE '81):

Eval use of Teflon cups containing endo materials in guinea pig mandibles (intraosseous technique), tested Kloroperka NO, Kerr Sealer, and AH-26 over 30, 90 and 180 days. Kloroperka and Kerr had longer lasting acute inflammation, chronic inflammation noted around AH-26 implants. This new testing method showed the reaction of material in direct contact with bone.

HeLa cells and fibroblasts:
James Kettering and M Torabinejad (IEJ '84)(ZOE was LEAST TOXIC)
5 sealers tested: Tubuliseal, 2)Diaket, 3) AH26,4) Grossman's,5) Wach's
Tested both set and unset forms of the sealers after dilution b/t 1:25 and 1:600 on fibroblasts and HeLa cells to see when the sealer became non-toxic to the cells. Tubuliseal(ZOE based) found least toxic and AH26(resin) and Diaket(resin) found the most toxic, interchanging among a couple of the tests. Study agrees with Spangberg's study in '69. Though great variability among previous studies and rankings of toxicity of sealer, concluded that these in vitro tests may not correspond directly with those of testing in vivo.

Tissue toxicity:
Morse et al (JOE '81): Tested RC sealer liquids: eugenol, chloroform, eucalyptol injected subcu in ct of rats backs. Eugenol found more inflammatory than others after 6hr

Neurotoxicity:
Pal Brodin (EDT '88): Lit review on parasthesias (great table) and nerve study showed neurotoxic effects of sealers. ZOE based sealers had reversible parasthesias from eugenol, but those with formaldehyde showed irreversible neural effects. CaOH based sealer also showed neurotoxic effects probably due to high pH and excess Ca ions, and chloroform (kloroperka) found toxic. Interesting note: at conc above 2.4mM eugenol irreversibly inhibited nerve conduction, and with formaldehyde and formocresol it was concentrations above 8.9mM and 6.7mM. Due to high solubility of formaldehyde in water, this concentration is easily reached, and can cause damage. All toxic concentrations are achievable with current sealers, depends on what and how much contacts the nerve directly.

Sunzel (scand J of plastic and reconst hand surgery)'90: showed ZOE is antibacterial and cytoprotective to tissue cells.

Bernath M, Szabo J (IEJ '03) :

- 2 monkeys, 64 teeth, but eliminated almost half due to complications
- instrumented the 1st pres long and overfilled, perfed furca of 2nd pres and filled with GP at length for the other using one of four sealers (Apexit, Endomethasone, AH 26, or Grossman's Sealer)
- found that apexit and grossman's sealer caused mild reaction (no rxn when kept in canal) when out of canal , but Endomethasone caused a foreign body rxn and AH26 and endomethasone both caused more sever inflamm rxn. than the other two.

- Also noted study by Pascon in ’91 who found AH26 particles in baboons with inflammation around them 3 years after filling done
- Concluded to prevent inflammation, maintain fill within canal.

Physical Properties:
Dimensional changes:
B Harvey Wiener and Herbert Schilder(OOO ’71): 8 sealers eval for volumetric changes over time. (AH26, procosol, roth’s(4 types), Kerr, Tubuliseal) All sealers shrank, mostly in “shrinkage lakes”(localized areas), except AH26, which showed craze lines in glass, owing to possible initial expansion of ah26, but shrank in later stages. Sealers that set more rapidly shrink more, than those with a slower set. Setting time decreases as humidity and temp increase.Stressed use as little sealer as possible due to shrinkage and maximum solid core as possible.

Louis Grossman (JOE ’76): AH26, Kerr, Mynol, N2 ,Procosol, Roth’s, RC2B, Tubuliseal, and ZOE checked for part size, flow, setting time, adhesion and leakage. No correlation b/t part size and setting time. Humidity and Temp play a role to increase set and thinness of film (the thinner the film the faster the set). Flow: AH26 and Mynol flowed a lot, Diaket, N2 and ZOE flowed none. Adhesion components given by resin or rosin part of cement. ZOE had no adhesion , where AH26 and Diaket were the strongest. Leakage: Diaket had the least and Mynol had the most.

Film thickness and it’s effects:
Dag Orstavik (JOE ’82): 28 sealers and cements evaluated. Found that some sealers (particulary ZOE and those of similar consistency) could restrict the seating of the gutta percha point, depending on the thickness(not consistency here) of the cement. AH26 restricted seating by over 2mm, Kloroperka had virtually no effect(due to chloroform dissolving GP allowing it to seat). NO correlation b/t powder size and film thickness.

Kozam G and Mantel GM JDR ’78: showed toxicity of eugenol on mucous membranes, showed eugenol is neurotoxic

Non Eugenol and Calcium Hydroxide Sealers:
Sealapex:
Hovland and Dumsha (IEJ ’85): 30 day apical leakage study: compare Sealapex, Procosol, and Tubuliseal. No difference among the sealers. A lot of leakage when filled w/o sealer. Most leakage occurred b/t root canal walls and sealer. Hovland and Dumsha (IEJ ’85)

- Leakage test with silver stain technique on 105 single rooted teeth and eval over a 30 day period, compared Sealapex (new sealer at time), w procosol and tubuliseal.
- No diff b/t Sealapex, tubuliseal and procosol used in cold lateral condensation

- Lots more leakage of control (gp without sealer) showing that gp w/o sealer leaks significantly more.
- THIS IS THE PAPER WHERE THEY STATE THAT ALTHOUGH "SEALERS LEAK TO SOME EXTENT(branstetter and von Fraunhofer JOE'82, Osins et al '83) THERE IS PROBABLY A CRITICAL LEVEL OF LEAKAGE THAT IS UNACCEPTABLE FOR HEALING, AND THEREFORE RESULTS IN ENDODONTIC FAILURE."

AH-26 and AH PLUS and Ketac Endo(GI):
Barthel et al(abstract 274, JDR '96): Ketac endo vs Roths 801 vs AH26 comparing bacterial penetration from coronal aspect. AH26(32% leaked) was best, Ketac Endo(53%) was worst. Stressed importance of high quality coronal restoration after endo.

****SOARES, GOLDBERG ETC JOE '90: 120 canals in 6 dogs instrumented and filled with Lateral Cond. Using CRCS, Sealapex or ZOE cements. At thirty and 180 days kill dogs and do histo on demin paraffin embedded slices (20 canals per group). RESULTS: All three sealers were essentially the same fills that stopped at WL showed chronic inflammation immediately against fill and apical area showed ingrowth of connective tissue with new hard tissue deposition along apical canal walls. Both CRCS and Sealapex showed black particles in macrophages at some distance from filling material. Overfills all showed chronic inflamm against overfill

Rohde et al (JOE '96): Ketac Endo vs. Roths vs. AH26: dye leakage study. Roths was best, Ketac endo showed more leakage than AH26 and Roth's, though no difference b/t Ketac Endo and single cone technique and Ketac Endo used in lateral condensation technique. And the single cone technique gave better results (though not significant) than lateral condensation with Ketac Endo. Leakage poss. due to Ketac Endo not setting properly.

Zmener et al (IEJ '97): AH-26 vs AH PLUS, leakage study with meth blue for 2,4,10 days. AH Plus is faster setting and more radioopaque than AH26. AH26 showed less leakage than AHplus. AH plus with faster set may have more shrinkage stresses, leading to increased leakage, than AH-26 with slower set. (see Weiner and Schilder OOO '71)

Huumonen S, Lenander-Lumikari, Sigurdsson A, Orstavik D (IEJ '03):
- Did multicenter study comparing healing at 3 and 12 months of apical perio using silicone based sealer (Roeko seal) vs ZOE based sealer (Grossman's)
- Treated 199 teeth by lots of endodontists and found that there were no sig differences b/t the 2 groups. The healing was noted at 3 months in both groups and improved at 12months. Overall success was 76% (that's low)
- This study also showed that overfilling did not make a difference in success rates.
- Used PAI to determine success (which was invented by Orstavik in '86 and is based on Brynolf's comparative histo and radiographic studies from '67

- According to a study by Kerouso and Orstavik in ’97, healing can be seen on a radiogrpah as early as 1 week after endo treatment.

N2

In support of :

Snyder DE, Seltzer S, Moodnik R (OOO ’66):

- Thorough debridement and obturation was more impt than filling material used for healing, this was a study on dogs
- N2 treated teeth had less apical inflamm than silver cone treated teeth
- N2 less irritating at apex than ZOE when forced out
- Pulp stumps contacting N2 became totally necrotic in every case

Sargenti A (5^{th} int conf on endo. 1973):

- States importance of having formaldehyde, b/c without it the cases fail, argues that all sealers are toxic, and in small amounts is acceptable
- N2 method endorses 1 sitting RCT.
- N2 is a ZOE based cement mixed with formaldehyde
- Formaldehyde immobilizes a section of remnant vital pulp forming a “scurf” which insulates the small apical remnants from the N2 material, called the sclerotic zone
- Formaldehyde is a gas slowly developed from trioxymethylene
- N2 is semi-resorbable, if extruded beyond apex (cites Snyder et al)
- Concludes stating that over 48,000 teeth treated by 411 dentists show “brilliant rates of success” radiographically.

Against the Use of N2:

Erausquin J, Devoto FCH (OOO’70): Study on 253 albino rats using different sealers with: Formaldehyde, Formalin, trioxymethylene, and prednisolone vs. ZOE and Grossman’s Sealer. Results show:

- ZOE or Grossman rarely caused ankylosis, and was limited to periapical area
- Formaldehyde containing cements caused severe and frequent partial ankylosis of PDL, and sometimes total ankylosis was seen.
- Pure Formalin and 50% Formalin caused extended or total ankylosis
- Trioxymethylene produced extended alveoloar bone necrosis and acute inflamm.
- Trioxymethylene with pred. cause either ankylosis or inflamm reaction affecting necrotic pdl with huge sequestra and an encapsulating fibrous reaction.

Nygaard-Ostby B. (5^{th} int conf on Endo 1973):

- Rips apart the research done by Zerosi et al, which forms the basis of N2 method, showing too few teeth used and chronic inflam still present in a section after 8mo
- States that the “sclerotic zone” is actually a “necrotic zone” b/c formo fixes tissue

- Sargenti method uses partial pulpectomy (propounded 1st by Clyde Davis in 1922), with a devitalizing medicament, but this medicine should not be used, b/c you want to maintain the apical vitality not fix it.
- States that reduction of a pa rarefied lesion is not and cannot be considered a criterion of success, nor can absence of pain. This can be achieved by just leaving a tooth open and doing nothing.
- Histo evidence must be provided to show success!
- Lead is present also in N2, which has been shown in studies to be taken in by internal organs of animals after placing N2

Larz Spangberg (OOO 1974):
N2 and Riebler's paste implanted in Guinea pig mandibles. Eval after 3d, 1wk,2wk,12wk. Showed extensive tissue necrosis replaced by granulation tissue without signs of bone regeneration. The fixation by intra vitam or "sclerotic zone" is actually necrosis. Both contain formaldehyde, Riebler's more than N2, which explains why Riebler's had a stronger necrotizing reaction.

Robert Block et al (JOE 1978): showed that dog pulp became antigenically altered when combined with 6.5% paraformaldehyde solution within the root canal, by injecting the fixed tissue intramuscularly, resulting in a cell mediated immune response, not seen in vital or necrotic pulp tissue injected intramuscularly in the dog.

Spangberg and Langeland '69 (IEJ??): did study with HeLa cells on sealers!!!!!

P Brodin et al (JDR 1982):
Inhibitory effects of root filling material on rat phrenic nerves done:
- Endomethasone and N2 irreversibly inhibited conductance
- Procosol caused complete but reversible inhibition of nerve conductance
- Kloroperka caused total inhibition which was sometimes reversible
- AH26 and Diaket showed partial inhibition which was partially reversible

Kleier et al (EDT 1988):
Paraformaldehyde containing pastes are capable of causing parasthesia or dysethesia:
- Case report of 47 yo white female with lip numbness after tx of 2nd premolar
- Even in small amounts, the sealer can cause irreversible damage to the nerve

ZUT (ZEOMIC or zeolyte containing glass ionomer sealer)
Shimon Friedman has been the major researcher in this field.
Zeolites are microporous, crystalline solids with well defined structures contatiningn aluminum, silicon, an oxygen in their regular framework. Void spaces within the framework allow for cations to be placed within them (ie silver,, which is in zeomic) and allows them to be antimicrobial b/c the frame does not decompose over time and the silver can be selectively exchanged for other species, which makes it antimicrobial and this is called "molecular sieving". The silver can leach to surrounding environments, exerting the antimicrobial effect.

Thom et al (and friedman): OOO (jan 2003): showed that the zut (mixed with ketac endo gic) was less cytotoxic and less hemolysis occurred than AH26 with and Ah26 without silver. The study was done with disks and cylinders of the sealers mixed and set and added to hela cell lin(in a Millipore filtration test)e for the cytotoxicity test and hemolysis test done with rabbit's blood. All 3 gics (ketac endo, ketac cem and zut) tested similar to both hemolysis and toxicity (all non toxic after 1 hr, whereas the ah26 were toxic at 3 hrs)

HAUMAN AND LOVE IN IEJ MARCH'03 gave great general review of sealers and gutta percha. Pts I and II