Dr. Julian Webber
London, England
Management of Endodontic Failure

Dr. Webber opened with compliments to ROOTS and praised it as being one of Dentistry’s “most exciting recent innovations.

Management of endodontic failure is an important issue because the standards of endodontics around the world are poor, therefore we have many failures to deal with and retreatment is a big part of many practices. We need to know how to save some of these teeth lest they end up as fodder for the implantologists.

Firstly, we need a biological and anatomical understanding of endodontic success and failure. Rather than use the term apical periodontitis (AP), Dr. Webber prefers the term periodontitis of endodontic origin (PEO) because we all know PEO can occur anywhere around the surface of the root that is inside the supporting bone – not just apically. He quoted classic studies by Nakagashi (1965), Moller (1966, 1981) and Sundqvist (1976). Failures are undoubtedly bacterially related. We need to eradicate or eliminate the bacteria to a sufficient level that we will get healing. We must also eliminate the substrate that the bacteria thrive upon. However, the complexity of the RCS anatomy makes this a tall order.

Aim of Treatment

We need to eliminate infection in the canal system and at the same time add a coronal seal to enhance the apical seal at the end of the RCS (Sjogren 97 Saunders & Saunders, 94 Ray and Trope.) Although widely quoted, we shouldn’t let Ray and Trope’s study (that showed that quality of coronal restoration was sometimes MORE important than the quality of the endodontic treatment) be too influential. We need to do the best possible job in all aspects of treatment – eliminate bacteria, eliminate the substrate, fill in 3D and have a good coronal seal – in order to have optimal treatment success.

The quality of endodontic treatment around the world is generally poor. He showed a chart of studies of the Chart - Prevalence and Quality of Endodontic Treatment: Inadequate Treatment (where filling is not within 1-1.5 mm from radiographic apex). 10 studies from Eu and N. Am. were shown (1990-2002). Success rates varied from as high as 67% to a low of 50%. Webber makes an excellent point: While we on ROOTS continue to debate the merits of filling to the RT or patency – if we could just teach the general practitioners of the world to clean adequately to within 1 mm of the apex and then put in a quality endodontic filling with a good coronal restoration, we would see much better results for endodontics in general. While we endodontists continue to argue about prep size, taper, location of filling, puffs and patency, etc. – it will be a long time before we can persuade the whole world that endodontic treatment is predictable, retreatment is predictable and that implants are NOT the answer.

Chart - Prevalence and Quality of Endodontic Treatment: Inadequate Treatment (Preseence of AP (same studies from Eu and N. Am. (1990-2002)). We see that where the standard of RCT of poor – the associated level of PA disease is high. We need to elevate the standards so that these figures are not looked upon with glee by the implantologists and are used against us.

In 1986, the late Dr. Herbert Schilder quoted the term “Retreatodontics” and said that “the future of endodontics lies in the Retreatment of Endodontic Failures”. 75 % of the cases in Webber’s practice are retreatment. Even if our success rates are in the 90% range, we still have a significant percentage of retreatment that is required all over the world.

Do Retreatments work?

Webber quotes Bergenholtz et al Scand J. Dent Res 87 217-233 which states: Treatments with technical shortcomings could, following retreatment, be markedly improved as regards effectiveness and distance to apex. Following a 2 year observation period of 556 cases, retreatments carries out because of technical inadequacies alone were successful in 94% of cases. Abbott PV (Aust Dent J 1999) A retrospective analysis of the reasons for and the outcome of conservative endodontic retreatment and periradicular surgery. An in office study 575 teeth over 6 years. 555 (96.5%) were assessed as successful. All teeth were disassembled/removed all coronal obstructions/coronal caries and bacteria. When done in this way – (no compromises) 92% success was achieved after only 3-6 months.

Doornbusch et al IEJ 2002 Radiographic evaluation of cases referred for surgical Endodontics

278 radiographs of cases referred for surgical endo were assessed by an Oral surgeon, GP and endodontist. OS said 41% of cases were amenable to conventional endo retx, GP 67% and the endodontist 80%. It concluded that most teeth referred for surgical treatment to an OS could be retreated by orthograde nonsurgical TX rather than surgical RCT.

Indications for SRCT ReTx

Procedural errors in the apical third. Webber does only about a HALF DOZEN SURGICAL CASES PER YEAR!! He only does it in situations where there is no other possible avenue of treatment. He shows an example of previous tx with badly torn...
apex – he did SRCT on this max premolar but said that this was the only SRCT he did during about 6 months of cases last year.

NB: Nothing in life is quite as important as you think it is while you are thinking about it.

Retreatment Indications:

- Failure of initial therapy or inadequate retreatment
- Inadequate root filling radiographically or clinically checked in situ without evidence of failure in a tooth scheduled for placement of a new restoration. (It doesn’t matter if no symptoms or no pathology – it still needs a good endo under the new restoration)

Problems with Retreatment

- Frustration
- Unpredictable results
- Profitability

Retreatment Steps

- Coronal Disassembly
- Establish Access to the RCS
- Remove Canal Obstructions
- Establish Patency
- Shape, Clean and Fill

Costing Retreatment Fairly and Sensibly

Ruddle (1996) How to profit from Endo: Finding the fair fee for Endodontics Dent Econ 88(11)30

Retreatment is “a complex procedure that should cost the patient the same or less than the alternative to compensate the extra time required to achieve natural tooth retention.” If you charge the same fee for conventional tx that you do for retreatment you will:

1. Not make any money
2. Undervalue the worth of the procedure.

You must sell the value of the retreatment of the procedure to your patient. You need to educate the patient and say that saving the tooth in this manner will cost you “a little bit less” than having the tooth extracted and replaced with an implant. Webber feels that, when faced with this decision, most patients would opt for retreatment. (This assumes that the perio condition is good and that the tooth can be properly restored.)

Webber then shows a disassembly case. Crown cut off, core dissected. Post removal, silver cone removal from core material. Access reeamed, canals shaped and cleaned and then filled. Webber charges 50% more than conventional endo fee when retreating a case like this. Webber believes that in situation where the restorative dentist is not sure as to whether to proceed, the Endodontist should be the first consult. The Endodontist should be part of the decision making process.

Dealing with Retreatment Obstacles

- Crowns and Bridges
  - Webber has tried devices such as Morell, Richwil, Higa, Metalift System and WAMkey. But in MOST cases, he simply CUTS THE CROWN OFF.
- Posts
  - Hemostats and Microsurgical forceps (expensive!)
  - Ultrasorics
  - Dedicated Post removal devices
    - Thomas PRS (has Pizo type drills for going through fiber posts)
    - Gonon PRS
    - Ruddle PRS –

Webber prefers to try to ultrasonically vibrate the post and try to get it out that way. Always use copious water to prevent overheating of the post during vibration. If he can’t remove it ultrasonically in about 10-15 minutes, he moves on to a post removal system. It is rare that you can NOT remove a post with one of these PRS systems. You should always warn patients when post size or length /root size may risk fracture. In that case SRCT might be a better option. He then showed the Ruddle PRS video.

- Silver Cones
  - Microsurgical Forceps – ideal for when silver cone heads are sticking up in the chamber
  - Braided Hedstrom files
  - Ultrasonics - work around the periphery for the cone with an ultrasonic file

Some cases are best managed by to bypass the silver cones with very small hand files and then using them to remove the cone with an outward motion.

- Gutta Percha
  - Solvents
    - Webber is not a fan of solvents because of the sludge of softened GP it creates (Chloroform, Xylol, DMS IV). If you do use solvents, you must remove all of it with a paper point wicking technique before you start re-preparing it.
  - ProTaper Universal D1, D2, D3 @ 500-700 rpm
    - In may of 2006 this new ProTaper Universal system was introduced (except in the US)
      - D1 file: Removes Filling Material from the coronal third
        - 11mm handle - 16 mm cutting surface
        - 11mm handle - 18 mm cutting surface

NB: Adversity - That which does not kill me postpones the inevitable.
His strategy:
- In coronal third – attempt retrieval
- In middle third – retrieve or bypass
- In apical third – leave and observe

Do we need to remove all broken instruments?

Most literature shows that we cannot remove all the previously placed filling material. Crump and Natkin JADA 1970 89(3) 134. Relationship of broken root canal instruments to endodontic case diagnosis 53 cases of inadvertent breakage at apex compared to 53 controls. 2 year follow up as good as success from correctly filled canal.

Fox et al 1972 N NY State Dent Assoc 38 (3) 154 Filling Root Canals with Files Instruments twisted off at apex and locked tightly in the canal served to prevent apical percolation. Therefore in situations where the instrument is broken at the apex, there must be some consideration made for filling to the level of the broken instrument and then monitoring the case.

Minimal requirements:
- Microscope
- Assistant should also be able to see (via auxiliary scope or monitor)
- Webber likes the Satelec ultrasonic unit and uses various tips
- He uses the Carr technique for modifying a GG bur with a disc, then creating a staging platform before using an ultrasonic tip to rotate around the file in a counterclockwise manner to dislodge it. If you can’t see what you are doing – if you do not have the correct magnification- you should not be doing this.

The secret of removing the instruments broken in the coronal and middle thirds is understanding how much coronal tooth structure you have to remove in order to gain access to the instrument. If we must “over-prepare” the coronal portion to gain access, then maybe it is a better idea to leave the instrument in place rather than compromise the coronal dentin.

Cancellier devices and Krazy Glue can also be used. Sometimes it works, sometimes it doesn’t but you still must have several different strategies to allow you the option of selecting the best device for the situation. He showed Ruddle’s IRS System video. He said that while the video is impressive, it rarely works that easily. We all have a good laugh while watching how simply the system seems to retrieve the broken file – he comments that he wishes they all came out that easily.

- Bypassing Broken Instruments
  - Bypass with K file #8/10
  - Continue bypass sequence
  - (Dislodge with Ultrasonic K file #15 or 20
  - Copious irrigation
He showed a lower molar with a large portion of broken file in the middle and apical third. The angle of retrieval was such that too much coronal dentin would have to be removed to allow straight line access to the coronal part of the file. So he chooses a bypass strategy in this case. The canal was prepared well enough to incorporate the file into the prepared canal space. He shows another case that cannot be retrieved or bypassed. He remarks that breaking a file is not negligent, but NOT telling the patient is negligence.

**Saunders et al 2004 JOE 30(3) 177-179.** Effect of separated instrument on bacterial penetration of obturated root canals

The presence of 3mm of a fractured 40/.04 instrument did not speed up or slowdown penetration of bacteria compared to controls. Extruded sealer onto flutes equivalent of any other obturation technique. In the absence of residual infection coronal seal was the most important factor. In other words, in the absence of a periapical lesion, (i.e./a suspected vital case) we should consider leaving the instrument in place. If we can do a good job with the rest of the canal system AND we can get a good coronal seal as well. We need to reconsider the obsession with instrument removal at the expense of good tooth structure and risk of procedural or structural compromise.

- **Perforations**
  - MTA is the material of choice ( Tulsa or Angelus< faster set than Tulsa)
  - All the armamentarium associated with it is necessary – i.e./Dovgan carriers and Pluggers, Lee Block and instrument
  - Webber has had success with the MAP system (Produit Dentaire) now being sold by Dentsply as the MTA Gun.

- **Apical Closure and Perforation Repair**

Webber showed a case where the patient insisted that the anterior tooth be saved. Very large resorbed apex with LEO. An MTA plug was placed and the case re-restored. He then showed two perforation cases (furca and lateral). We must ensure that the perfor repair material is up against bone because it washes out of exposed to the oral environment.

Webber says that that retreatment is hard but that we need to take an optimistic view when approaching cases. (Tanaka’s Law – 1. Nothing is as hard as it looks 2. Everything is more rewarding than it seems. 3. Everything will go right and at the best possible moment)

**Single Visit Retreatments**

Webber usually does SINGLE VISIT RETREATMENT. The only indication for non-completion of retreatment in a single visit is when he is unable to get the canal dry. In that case he will fill the other canals and then treat the wet canal with CaOH. Note: He is the first of several “one steppers” who will present at the Summit. Fred Barnett, take note.

**Dr. Terry Pannkuk**

**Santa Barbara, CA**

**Opportunity and Ethics in Endodontic Practice**

Terry opens by thanking ROOTS for giving him (and all of us) the opportunity to make friends and professional relationships with dentists from all over the world.

On a recent trip to a Chinese restaurant, the message in one of his fortune cookies read “Don’t just learn the tricks of the trade. Learn the trade.” Terry felt that message was appropriate with respect to Endodontics. He told the story of his wife’s antique clock purchase – which he considered an extravagance. The clock had been made by an apprentice master clock maker in 1770 – the clock had been an apprentice piece – in essence the apprentice’s “Master’s Thesis”. It was the career defining accomplishment for this clock maker and although the clock was expensive, Terry realizes that it was material embodiment of this man’s heart and soul. It represents a commitment to excellence that we can all appreciate. “There is no material item that holds more value than the clock had been an apprentice piece – in essence the apprentice’s Master’s Thesis”. It was the career defining accomplishment for this clock maker and although the clock was expensive, Terry realizes that it was material embodiment of this man’s heart and soul. It represents a commitment to excellence that we can all appreciate. “There is no material item that holds more value than the material item that holds more value than the material item that holds more value than the ultimate effort of a human being aspiring to be great.” The man that inspired this level of excellence in Terry was his late mentor Dr. Herbert Schilder.

In his introduction, Terry asks us to ponder a few questions and the choices we make:

1. What is a Doctor?...a noble person
2. What is an Entrepreneur?...more of an opportunist
3. What is a Professional? And how does he fit in between 1. And 2.? To what extent does each of us make a choice to be one or the other or a combination? Where do we set our standards?
4. What is Health care? Should health care be tender with pure ethics of the Doctor or is it a business
5. What is a Business? To whom is it responsible? Ethics?
6. What is a Dental Practice? Where does your practice fit in between 4? And 5.
7. Are your patients just “customers”?

Pannkuk uses Stedman’s Medical Dictionary’s definition of a patient:

**One** who is suffering from any disease and is under treatment for it; **not to be confused with a case**. The term “case” seems more inanimate than “one” or a “person”.

The referral based practice has special challenges. He showed a case of a mandibular third molar with questionable restorative and functional value yet the referral instruction was to perform treatment and place a core. In the next case he showed what appeared to be a 6 unit cantilevered bridge - patient requested no implants! (Photoshopped) That made everyone laugh.

We need to make an ethical clinical judgment as to whether treatment is in the best interest of the patient. In some special cases we go “half way” with minimal patient investment and try our best in situations where the prognosis may not be optimal. Each patient’s needs must be assessed independently.

Terry then showed a case where two maxillary third molars had been prepared for crowns and were symptomatic. He performed a thorough examination of these and the opposing teeth and concluded that the patient was having trouble keeping them clean and
the crown root ratio was poor. The patient was symptomatic and wanted answers. Terry discussed options with the patient which included extractions of these two molars. Unfortunately, the referral had not communicated adequately and was not available for discussion at the time of examination. Terry ended up losing a potential referral because he suggested that extraction might be the best option under the circumstances.

Terry says that in situations like this we have CHOICES. We can choose:

1. **The Hippocratic Mode**
   - DO No Endo Treatment?
   - Confuse the Patient?
   - Upset the Referral - Your recommendation conflicts with that of the referring dentist
   If you choose to practice in this idealistic and inflexible manner – you will pretty much go broke!

2. **The Machiavellian Mode**
   - Do the Endo and cater to the referral instead of the patient.
   - The end justifies the means
   - Profits come first

Terry believes that these are the two ends of the spectrum and that each of us must decide how we must practice in between these two extremes. He then showed a mandibular molar failure in a tooth with anatomical issues.

Strategies and Selection of Options

1. Put the patient’s interest first
2. Evaluate other reasonable options considering:
   - a) Risks
   - b) Likelihood of Success
   - c) Cost

Photo-documentation is an important tool. Terry takes 10-12 photos during treatment. He will send the photos to his referral and also review them with his patients. This includes discussion of things like why his access was extended, extra canals located that may have been missed in the first treatment (DB2s or MB3s). The patients and referrals can literally see the difference and this reinforces the value of the treatment thereby supporting the fees that you charge.

He then showed a tooth with initially 8 canals! (MB1, 2, 3 P1, 2 and DB1, 2, 3.) When he completed the case some may have merged and the case may have had 5 or 6 canals. Showing images in that case shows the complexity of the case, the effort that needs to be made to treat it and reinforces the fee.

Terry then discussed *Freakonomics* – a popular book recently published by Levitt and Dubner (2005). In the book they state:

- Experts can use special information to your detriment
- Experts have information that isn’t available to a non-expert or if the information is available, it is poorly understood
- Non-experts are in awe of the expert

He then went on to use these dentally related examples:

**#1 - Endodontics**
- Dental suggest endodontic treatment
- Patient is experiencing reversible transient cold sensitivity due to an open margin in a crown the dentist just placed.
- The patient is unlikely to think that the dentist is using this situation to hide poor treatment and economically benefit from an additional procedure i.e./Endodontics. Because the patient is in awe of the dentist, he is able to abuse this power in this manner.

**#2 - Implantology**
- Implantologist suggests grafting into extraction socket for “socket preservation”
- The graft complicates healing and prevents ideal regeneration of been that would occur with a simple, natural blood clot.
- Patient is unlikely to think Implantologist is selling “socket preservation” in order to charge a higher fee for the extraction procedure.

Terry says we have gone from the extreme impractical idealism of the 50s’ to where we are now – entrepreneurship and opportunism. Each of us has to decide how much we are taking the patient’s interests to heart and how much we are willing to sacrifice to ensure that our overhead fees are satisfied.

We need to balance Compassion with Economic viability – relying upon Critical Thinking to achieve this balance. When he incorporates comprehensive reports, quality documentation and attention to detail into his practice, the stresses decrease and he is able to be paid a fee that is commensurate with the value of the treatment. It is about developing and discussing options blended with prognosis contingencies.

Terry has some pessimism that outcome studies tell us anything – other than how other people are doing. They don’t tell us anything about how we are doing in our practice. The best outcome study is your evidence based experience over the decades that you have practiced. But Terry believes (unlike some other Endodontists who are more skeptical) that is NOT impossible that we know what DOES and DOES NOT work in our practices and what our outcome trends appear to be. He also doesn’t need a comprehensive literature review of other people’s outcome studies to know what problems he may have in his practice. If you are an inexperienced clinician, this is more difficult.

If we want to elevate patient care we will perform Full Treatment Planning and our Full Effort. One example was a mandibular molar with an apparent furca perio/Endo lesion. In these cases, the outcome is likely to be a coin toss 50/50. Terry showed a case with

NB: Burnout - Attitudes are contagious. Mine might kill you.
several lateral canals that contributed to the furca bone loss and the prognosis was good. Some patients elect to take the gamble, others don’t. But we still must present this with the best information, communicate adequately and give the patient the choice.

**Medical History**
A thorough medical history should be performed because the implications can be significant. A recent example is the current potential problem with Bisphosphonates. Would the patient be better served by endodontic retreatment rather than risk extraction and implant placement?

A thorough examination should include palpation of the Muscles of Mastication and check for Lymphadenopathy.

**Complete Treatment Planning**

*The Sequenced Elements of Logic*

1. Chief Complaint – patients are in your office for a reason – WHY?
2. Dental History- If the referral doesn’t provide it – you must get it from the patient. i.e. / was there a history of recent crown prep or operative procedure in the area?
3. Medical History - Medications?
4. Head and Neck Exam
5. Intra Oral Exam – Other dental/oral issues competing with the chief complaint?
6. Radiographic Exam – we don’t want to unnecessarily take radiographs
7. Clinical Tests – all the standard endo related tests
8. Perio Probing- Is the tooth periodontally sound or does it require further perio TX?
10. Treatment Plan – funnels down to one single tooth and what you want to accomplish
11. Patient Discussion – What you want to do and what the patient wants may not be coincident.
12. Tx Team Discussion – All the dentists involved in the treatment need to be on the same page and they need to have the above train of information available to them.
13. Treatment Execution. Until you have done steps 1-12, you should not consider picking up a hand piece. In Terry’s opinion, steps 1-12 are often MORE work than the actual treatment itself. Unfortunately, few patients appreciate this and often don’t perceive the value of this level of pre-treatment preparation.

Other interesting aspects of Terry’s exams: He takes measurements of the inter-incisal opening. Anything over 45 mm represents normal. 40-45 may need oral sedative in lengthy procedures. Anything under 40 mm - higher level of difficulty due to poor access. Xanax meds no TX.

Terry then went through a case where he showed how he examined the patient thoroughly, made a differential diagnosis, prioritized the treatment sequence, coordinated treatment with other team members and discussed fees. As things started to settle down, a few areas were re-evaluated and 3 more teeth were added to the Tx plan. Progress was slow but the patient was receptive and was improving.

He then showed several examples of previously poorly managed cases and cases that he used alternative treatment modalities such as treatment of a Max molar DB root using a buccal access, and a mandibular premolar with three apical branches and restricted access.

Terry was the first endodontist who started placing implants in Santa Barbara. He recognized that 30-40 % of the cases that were being referred were untreatable due to lack of restorability, fractures, or hopeless perio. He was the clinician who had to make the decision of whether the tooth could be extracted or saved. Many times he was then asked by the patient if he could do the extraction for them and the subsequent implant. After a time Terry realized that he was the one who was spending a lot of time working up the cases for the Implantologist and that it was a “natural” for him to be doing this in his Endodontic practice.

Terry then went through a typical implant case. A maxillary premolar shows previous endo and a crown with what appears to be a lateral perio defect. It was referred for possible endo retreatment. The tooth is accessed and the presence of a vertical fracture on one side of the root is confirmed and documented with the SOM. He explains to the patient that the tooth requires extraction and offers an implant replacement. Extraction is done under rubber dam. The tooth is extracted under the scope (easy!) He takes the impression, makes the stent and uses radiographs for positioning (Endodontists are used to taking lots of radiographs!) The implant is placed. He uses no BioOss (Becker calls it Foo Foo dust!) in there. 4 months later he checks the torque and integration, places a healing cap and then sends it off to the referring dentist. The referral gets full documentation of the case with photos of the Guide pin and Stent construction. It was a beautiful result.
“You only find what you expect to see … so if you really care about your patients you should push the envelope and attempt to exceed your expectations. The details are important.” Terry says that it is possible to have a high level of idealism and still make a profit.

Terry reiterated (as he did in Salt Lake City’s Summit) how the book “Philosophy of Natural Science” by Carl Hempel 1966 had influenced his thinking. When trying to determine “the truth”, you have to inquire scientifically – but in Terry’s philosophy that means that you have to blend art AND science. He believes that his method of deductive reasoning regards these factors as complimentary rather than adversarial – as some pure scientists would have us believe. The science also does not always come out of book. There may be multiple explanations for a single phenomenon.

The next graphic summarized his view of “Reality”. It showed 4 intersecting circles, representing
1. The Truth
2. Empiricism
3. Thinking
4. The Literature

Terry believes:
1. The Truth is largely unknown
2. Empiricism – maybe makes up about half of the truth
3. Thinking – makes up another portion of the truth
4. The Literature – for the most part is 80% fraudulent (with a few exceptions ~ 20% validity). The hard part is discerning what is part of the literature is valid since everyone has a motive or agenda for publishing an article. Otherwise – why would they go to that much effort?

At one end of the spectrum - The Pure Clinician.
- may choose to ignore all the science.
- He views all the literature as crap. If he doesn’t see it, he doesn’t believe it.
- He is the type of guy that will get fooled by anecdotes.
- Scientists love to criticize these types because their view him as unscientific, has no respect for the literature and has a false sense of the world.

At the other of the spectrum - The Pure Academic/Scientist.
- They look at the literature as the Holy Grail and they have no clinical appreciation whatsoever.
- They don’t value the concept of intuitive trends of competent practicing clinicians.
- While they disregard anecdotes – they need to realize that mountains of anecdotes have a validity of their own – even if they haven’t been published.

There is value in literature, theory and empiricism. They all have to be appreciated.

Leadership means controlling the destiny of a comprehensive treatment plan. Influencing the positive behavior of your colleagues and patient:
- Be a resource versus being a judge

His final graphic showed a pyramid representing the “Apex of Enlightenment”
1. The base of the pyramid represents your education - you have to study the science.
2. Above this are the clinical skills that you develop during your practice career.
3. At the height of your profession you respect your conscience and your intuition - having 1 & 2 as support for your conclusions. You are the master clinician – the master clockmaker.

Dr. Liviu Steier
Mayen (Germany) and London (UK)
Novel Irrigants for Canal Disinfection

The goals of irrigation both in the coronal AND apical third of the canal system are:
1. Debris and smear layer removal
2. Disruption of adhesive biofilm
3. Disinfection
4. Opening of the dentinal tubuli

Should our disinfection/irrigation protocol be similar for all cases?

Dr. Steier believes that irrigation protocol can be divided into groups:
- Acute AP and
- Chronic AP

We need to address the irrigation protocol differently for different clinical situations.
Irrigation groups:
1. NaOCl
2. EDTA
3. Citric Acid
4. Chlorhexidine (CHX)
5. Factor “X” (Electro Chemical Activation - ECA of different solutions)

We must recognize the potential toxicity of NaOCl and the effects of ClO$_3^-$ and ClO$_2^-$ (the chlorates). In mammals these chemicals arise from oxidative damage to red blood cells -> hemolytic anemia and methaemoglobin formation. It is also cytotoxic for fibroblasts. Therefore we are searching for possible alternatives.

The new approach involves two areas of investigation:
1. Ozone
2. Electro Chemical Activation (ECA) (and not just ECA of H$_2$O)

Irrigants of Interest:
1. Ozonized water
2. Ozonized NaOCl
3. ECA water
4. ECA NaCl (saline)
5. Ozonized ECA water
6. Ozonized ECA NaCl(saline)

Dr. Steier says that after 18 months – the results are still being evaluated – but the irrigation groups have changed to these 5 areas of interest:
1. Water
2. NaOCl
3. NaCl (saline)
4. Ozone
5. Electro Chemical Activation - (ECA)

Ozone Generators are being produced but are not FDA approved. This is still years away. There is a big difference between Ozone generating units. With the one design now available (the cheaper version), ozone is liberated into the workspace and we know that ozone is toxic. The newer designed unit generates as much as 6 x the Ozone as another unit. Safety is assured by designing the unit to be functional only when a vacuum is achieved over the endodontic access by means of an airtight “cap”. This seals the access when the ozone generating device is applied. Without the tight seal and without a vacuum – the machine will not deliver the ozone. Caps (8, 6, 5 and 4 mm sizes) are made of silicon (and can therefore be customized by adding a silicone based material to them to make the airtight connection to the tooth.)

ECA is a product of the 70’s and was patented in the old Soviet Union by Dr. VM Bakhir. Since his papers and ECA patents were published in Cyrillic (Russian) they have been difficult to publicly review. This technology was first used for drilling. ECA fluids also have applications in endo preparation. All ECA devices are more or less electrolysis of water or saline.

What do we put into this machine?

- Water

Dr. Steier says that the quality of water that comes into our offices can vary from street to street, even in the same city. In older dental units, biofilm problems (as a result of long term exposure to these sources) can be a big problem. Higher quality (cleaner) water can be obtained by:
- Deionization
- Distillation

Water quality is also affected by temperature of action and PH. Reverse Osmosis technology is used in homes to improve water quality to that of the level of bottled water.

**OZONE in Endodontics**

The unit looks like a standard hand piece with a protruding needle and plastic cap that fits over the access. The needle goes in the canal and provides the ozone. Dr. Steier’s initial studies with this device were disappointing and did not correspond to the manufacturer’s claims. Since Ozone is applied as a gas, it can also be transported by a “carrier” media which may allow it to enter the deeper portions of the canal system and hard tissue. He then studied Ozonized water, Ozonized ECA water and Ozonized ECA NaCl (saline) as well as Ozonized NaOCl.

Dr. Steier showed that there have been many studies published on the use of Ozonization of solutions – with varying results.

The first studies used water:
Nagaoshi et al - Antimicrobial Effect of Ozonated Water on Bacteria Invading Dental Tubules

Ozonated water had nearly the same antimicrobial activity as 2.5% NaOCl during irrigation, especially when combined with sonication and showed a low level of toxicity against cultured cells. *

*Dr. Steier says that this study used a generator that only produced 1/8th the ozone of the HealOzone unit that he is currently testing. Therefore we must carefully scrutinize the results of these studies – i.e. / what solution did they use and what unit delivered the Ozone?

Cho et al - Disinfection of water containing natural organic matter (NOM) by ozone initiated radical reactions. **(NOM is the term used to describe the complex mixture of organic material such as humic acids, hydrophilic acids and hydrocarbons that are present in all drinking water.)** The type of NOM and the PH have considerable effects on the percentage of disinfection by hydroxyl radical, which ranged from 20 to 50%.

This is important because dissolved impurities in modern water supplies (ions such as calcium, sodium, chlorides etc.) can affect the properties of the ozone delivery. Ozonization of water by the cleavage of humic acid, PROMOTES bacterial recontamination. Therefore the TYPE and SOURCE of water used in the studies can actually promote recontamination if the “correct” type of water is not used.
One way to “clean” the water is by deionization. Deionization is a process that removes ions from the water via ion exchange. Positively charged ions (cations) and negatively charged ions (anions) are exchanged for hydrogen (H+) and hydroxyl (OH-) ions, respectively, due to greater affinity for other ions. Water quality is measured by measuring its electrical conductivity and electrical resistance. (It is the amount of ionized substances (or salts) dissolved in the water that determines the water’s ability to conduct electricity. Poorer quality water has a lower resistance and conducts electricity better – better quality water has less ionized substances and conducts water less easily.) Most dental units have very poor tasting water and the purity generally is actually not very high. Dental unit purity generally falls slightly above of below the “city supply” purity level – far from that of deionized or distilled water (depending on location and age of unit.) Dr. Steier has introduced technologies to clean the water in his dental units.

Reverse Osmosis units (for home use) use pressure and a membrane filter to remove impurities (ions) from water. We also must understand that Distilled water reacts with atmospheric CO2, which brings the PH of distilled water in an open air container down to a PH of about 5.8.

Liviu did a quick unscientific test using a TDS readout. (TDS (Total Dissolved Solids)= total amount of mobile charged ions, minerals, salts or metals dissolved in a given volume of water – measured in ppm parts per million). Distilled water had a value of 0 to 1. His dental unit value was 239 and water line was 191.

In absence of dissolved electrolytes, water will not conduct electricity, so no electrolysis occurs. This means that if we want to use this pure water - we will have problems. This is why manufacturers introduced saline for the electrolysis and to obtain the two (cation and anion) solutions.

Nagayoshi et al – Efficiency of ozone on survival and permeability of oral microorganisms
Ozonated water should be useful in reducing the infections caused by oral microorganisms in dental plaque. Again, in their study they used a Neo Ozone Water-5 unit that produced about 1/10th the ozone of a HealOzone unit.

Hems et al – An in vitro evaluation of the ability of ozone to kill a strain of E. faecalis
There were significant reductions of bacteria in the unwashed and washed broth cultures following 240 seconds of application. They concluded that Ozone had an antibacterial effect in planktonic E faecalis cells and those suspended in fluid, but little effect when embedded in biofilms. Its antibacterial efficacy was not comparable with that of NaOCl under test conditions used. But Dr. Steier again points out that the tests used devices and technology that produced low levels of ozone.

Electro Chemical Activation – (ECA)
- Definition: the process of passing a diluted saline solution through an FEM (Flow through Electrolytic Module) in order to generate (by electrochemical energy conversion) environmentally friendly, highly active solutions of anolyte and/or catolyte. Electrolysis of water is what is known as a “redox” reaction. That means that electrons are being moved from one molecule to another. At the anode, electrons are removed from the water and it is oxidized – as in 2H2O → O2+4H+4e-.
At the cathode, electrons are added to the water as it is reduced – 2H2O +4e- → 2H2 + 4 OH-.
So at the anode, we get oxygen gas and hydrogen ions, at the cathode we get hydrogen gas and hydroxide ions.

Dr. Steier points out that studies performed with ECA must be closely examined and scrutinized because the solutions that are used in the studies can be very different – depending on the effects of the device used for ECA AND the input solutions. Different FEMS can deliver different solutions. ECA involves 2 processes:
1. Chemical processes
2. Electrical process ( done without additives)

Chlorine gas can be formed, if the electrodes in the unit are made of carbon. (Dr. Steier asks Joe Dovgan about his Sterilox units and Joe says that he thinks they are made of Titanium.) It will only happen if NaCl is added to the water, CI ions in the water can oxidize to chlorine and combine with the OH ions to form Hypochlorite. Cl2 + 2OH- → Cl– + OCl– + H2O. The question is: What is the technology we are using? and what solutions are being created?

Source Solutions for ECA
- NaCl water solutions with no more than 5.0g/L concentration or fresh water of less than 1.0 g/L mineralization. What is best for ECA?

Electro treatment
- is accompanied by controlled mass transfer in the inter-electrode space with minimal heat generation and with obligatory creation of conditions for the closest contact of each microvolume of liquid under treatment with the dense and/or diffuse part of the double electric layer in the electrode surface where the electric field intensity reaches several million volts/cm.

Catolyte – is an anti-oxidizing, mild alkaline solution with a pH range of 10.5-12. The most common application for the catolyte is as a mild cleaning, detergent and degreasing agent. So by adding a sodium chloride solution to an ECA machine we get a "Metastable Solution" which has:
  - Changed pH of solution and high oxidation reduction potential
  - free radicals (High electron activity) in the catolyte
  - Extremely LOW electron activity in the anolyte.

(Dr. Steier reminded us that when we were discussing potential bonding of resin based endo filling materials we need to have a reductant for the final irrigation. If we don’t, the free oxygen radicals can inhibit polymerization of the material.) This “Metastable Solution” has excessive physical and chemical excitation. This gradually dissipates with time but - How long are the solutions stable? They can be kept for 7 days as long as they are kept in Brown bottles and stored in the refrigerator.

Anolyte- is a strong oxidizing solution with a pH range of 3.5-8.5. The most common application of anolyte is as a biocidal agent.

FEM types:
1. **Emerald Device** – mainly a technology to clean water of microorganisms, organic mixtures and heavy metal ions. Used in the purification of drinking water.
2. **Stel Device** – used for synthesizing electrochemically activated washing, disinfectant and sterilizing solutions. Mainly used in medical prevention and sanitary-epidemiological institutions.

These devices deliver an anolyte of two types: Acidic versions (pH<5) and Neutral versions (pH 6-8.)
The Catolyte produced is also of two types: an Neutral version (pH 7-0) and an Alkaline version (pH>9).

3. **Aquachlor** Device – (the most Endodontically important devices) are used in the electrochemical synthesis of gaseous oxidant mixture from NaCl aqueous solutions. The main components of the oxidant gaseous mixture are molecular chlorine, chlorine dioxide and oxygen – found at a ratio of 70:20:5:5% respectively. The ratio depends on the particular device and can vary widely. Dr. Steier felt this had great potential because he could increase the ozone production of the unit by ozonating the solution.

The most desired components from an anolyte are:
- Free chlorine (ClO-)
- H2O2 (Hydrogen Peroxide)
- O2
- Ozone

Dr. Steier initially did his investigations with the Sterilox unit. But he shortly found out that the technology used by Sterilox is actually an infringement of the intellectual property and patent originally taken out by Dr. Bakhir. The construction of the unit and resultant solutions are not in keeping with the original design parameters. The FEM anode plating is different resulting in less inadequate amounts of H2O2 that reduces the bacterial activities of one of the anolyte and leads to inefficient decontamination of water in Emerald.

Because the Sterilox element is made of titanium, Dr. Steier says that we really don’t know exactly what kind of solutions are coming out of this machine. He would prefer to see an Aquachlor technology based device rather than a Stel or Emerald based device. Because ECA activated solutions were first used in the drilling industry, he theorizes that (when ultrasonically activated) they may help us in our canal system preparation.

**Ozonization**

It is important to remember that we wish to avoid the formation of chlorates. The mechanism of chlorate formation is:

\[
\text{O}_3 (\text{ozone}) + \text{OCl}^\rightarrow 2\text{O}_2 +\text{Cl}^-
\]

\[
\text{O}_3 (\text{ozone}) + \text{OCl}^\rightarrow \text{O}_2 +\text{ClO}_2^-
\]

\[
\text{O}_3 (\text{ozone}) + \text{OCl}_2^\rightarrow \text{O}_2 +\text{ClO}_3^-
\]

When NaOCl (at pH10-12) interacts with organic tissue it produces 3 reactions:
1. Saponification - resulting in the creation of lipids
2. Amino Acid Neutralization Reaction
3. Chlorination Reaction

These 3 reactions are important in the disinfection of the RCS. Studies have shown that the Saponification reaction occurs ONLY if we have enough free radicals. In our normal bleach solution, these free radicals are not found in high amounts - so the solution is called “lazy” because of its low Saponification rate.

We want to use NaOCl solution at a pH of around 11 (where it is the most efficient) and where the maximum amount of hypochlorous acid is present. Dr. Steier suggests that we measure the pH of our NaOCl irrigation solutions to ensure maximum effect.

**J. T. Marais - Cleaning efficacy of a new root canal irrigation solution: a preliminary evaluation.**

The cleaning efficacy of electrochemically activated water in root canals was considered to be superior to NaOCl – producing cleaner surfaces and greater areas of smear layer removal. (But technology used in the study was unknown.)

Dr. Steier then cited several other studies that used various forms of ECA water:

- **Gulabivala et al** - Effectiveness of ECA water as an irrigant infected tooth model
- **Hata et al 1996** – Removal of Smear Layer in the Root Canal Using Oxidative Potential Water (OPW) They found that OPW used as an irrigant was as effective as 5% NaOCl or 17% EDTA for opening and keeping patent the dentinal tubules.
- **Hata et al 2001** - The Effectiveness of oxidative potential water as a root canal irrigant

This study concluded that OPW irrigation by syringe as effective as 5% NaOCl or 15% EDTA for removal of smear layer and debris. The description of the technology again was different than that of the inventor, Dr. VM Bakhir. SEM results showed the same results as in the JOE ‘96 study.

Dr. Steier’s studies (in Belfast) included the following:
1. Ozonated water
2. 0.5% NaOCl
3. 0.5% NaOCl & Ultrasonics
4. Ozonated Anolyte

**1. Ozonated Water (Ozone + water)**

In the apical areas this solution really didn’t do much. Smear layer and debris was present on the whole surface. In the area where the ozone delivering needle was placed, there was some minor improvement in cleanliness. The more coronal areas were not cleaned at all.

**2. 0.5% NaOCl**

In the coronal area – not clean. Middle canal – no effect. Same for Apical areas- not clean.

**3. 0.5% NaOCl & Ultrasonics**
Some improvement and tubule patency was noted. The best cleaned areas again corresponded to the location and depth of the ozone delivery tube.

4. Ozonated Anolyte
The coronal part showed improved cleanliness. The middle result showed less favorable results but the apical portions showed bigger surfaces of cleaned dentin.

Dr. Steier says that although the results were not optimal, he needed to repeat the studies with a higher concentration of NaOCl to see if the results were improved.

Further studies he later performed with Rimaldi and Beer - Antibacterial power of ozone activated NaOCl for root canal disinfection (at Universitat Witten/Herdecke) used the following solutions:

- a. 5.25% NaOCl
- b. 0.25% NaOCl
- c. 3 x 40° ozone activated 0.5% NaOCl
- d. 3 x ozone activated cleaned deionized water

They concluded that Ozone activated NaOCl 0.5% had a higher antibacterial effect than unactivated NaOCl 0.5%. The question is: What is the minimum concentration of NaOCl that we can use to get a good effect while at the same time limiting the toxic effects of the solutions of higher strength?

OVERALL CONCLUSIONS

1. Two different NaOCl solutions should be used for endodontic treatment: One for Disinfection and one for Smear Layer Removal.
2. For Disinfection – we still will use:
   a. NaOCl 5.5%
   b. Ethanol (to reduce surface tension)
   c. Elevate solutions to greater than 50 degrees C.
3. For Smear Layer Removal
   a. NaOCl 5.5% buffered to a pH of 11 (by using NaOH) AND making sure that the temperature is around 10 degrees C.
   b. Add H2O2 for at least 5 minutes - to avoid later chlorate formation – otherwise it could explode!
   c. Add Ozone for 240 seconds – then ultrasonically activated for 3 minutes.

How do we avoid chlorate formation?

1. The higher the pH the less chlorate (ClO3-) formation we will have.
2. H2O2 (Hydrogen Peroxide) by itself is a weak oxidant BUT it has a powerful synergistic effect when used with Ozone. ClO3- formation can be reduced by the addition of peroxide before Ozonization and allowing sufficient time for the peroxide to react with the free chlorine. Add H2O2 for at least 5 minutes.
3. Decrease the temperature of the Ozonization liquid to about 10 degrees C.
4. Buffer the solution pH to about 11 by adding NaOH.

Dr. Steier says that we now have a different set of irrigants to use. These include:

1. NaOCl
2. EDTA
3. Citric Acid
4. CHX
5. Ozone

The remaining question for the near future is: Which ECA technology will fit the needs of Endodontic therapy in the best manner? Dr. Steier sees the Aquachlor technology using Bakhir’s FEM design (jointventure with a US company) as the best prospect for the future.

Dr. Gianluca Gambarini
Rome, Italy
A Rational Approach to NiTi Rotary Instrumentation

Almost all clinicians have switched to Ni-Ti rotary endo. There are 3 main reasons for this:
1. It is a simple, easy and efficient technique that allows us to adequately prepare canals in less time than traditional SS files – and with fewer NiTi rotary instruments
2. Increased tapers allow predictable development of a tapering conical form. We have instruments of greater taper. Whereas initial Ni-Ti philosophy was to allow the file to “imprint” its shape to the canal – we now realize that as clinicians we have regained the knowledge that we can modify the canal shapes and not let the files simply dictate what shapes we obtain.
3. Superelastic Ni-Ti alloy allows easier negotiation and maintenance of the apical foramen in its original position.

After some initial reluctance to use Ni-Ti in retreatment cases, most clinicians have found them to be helpful, even in cases that have been zipped and ledged, etc.

Key points for Successful Ni-Ti Technique
1. Easy to Use
2. Efficiency
3. Safety

Ni-Ti Failure
Despite excellent Ni-Ti properties, separation is still a concern. Gambarini says that little progress has been made in the actual metallurgy. The problem is not with the metal itself but it is because we use them in a rotary fashion. Although we can bypass or remove broken files – we should emphasize ways to prevent separation – the prevention of breakage.

Factors to be considered to increase safety and efficiency:
1. Anatomy
2. Applied Forces
3. Design of the Ni-Ti Files

www.rxroots.com
Dr. Gambarini feels that the more you use Ni-Ti rotary files to the apex, the better your work will become because you learn to understand, anticipate and respect the canal anatomy. In some cases the challenges are finding more canals (upon access) than you expected, or dealing with apically merging canals. The cases may be complex but not impossible and can be well shaped.

Gianluca says that (being Italian) he especially appreciates appearances and achieving “the fashionable look” in his cases (not only radiographically, but clinically). He believes that the best cosmetic results are NOT easily achieved by extracting the tooth and replacing it with an implant—and that a properly endodontically treated and restored tooth offers a better aesthetic solution. He also emphasized that these results are much easier to maintain than an implant—with respect to soft tissue management and hygiene.

Ni-Ti Separation

Instrument breakage is caused by two factors:
1. Excessive torsion and flexion stress
2. Cyclic fatigue (overuse)

Although it seems simple to understand, when an instrument breaks it is actually a combination of these two factors and in clinical practice you can’t easily tell which has occurred. Frankly, once an instrument breaks—why it has broken is basically irrelevant. You now have to deal with the problem.

3. Iatrogenic errors—this is the true reason of why instruments break. It happens because we make a mistake—we are unable to understand or did not anticipate anatomic complexities. As a result of our asking the instrument to do “too much” we overstress them and they break. We should then learn how to reduce the amount of stress on the instrument while we are working.

He agrees with O. Peters (ESE 2005) who said that when we use Ni-Ti instruments we must have an “increased attention to details”.

Dr. Gambarini feels that in the majority of cases, Ni-Ti separation is easy to prevent because in over 50% of the cases that he has been asked to retreat—the file broke in the merging area of a canal. This means a greater awareness of merging canals (MB 1 & 2 in maxillary molars, mesial canals of mandibular molars, maxillary premolars and mandibular anteriors are all examples). This depends on us diagnosing these merges and anticipating them before we start. We manage this anatomy by preparing one canal to the working length and the other canal to the point of merging. Therefore, the only problem we have is to try to determine which of the merging canals is the straightest—to allow us for the easiest method of preparation that stresses the files the least. Or, if you are not sure—instrument and fill one canal before proceeding to the next.

Can we use Ni-Ti rotaries to the apex?

Dr. Gambarini tries to use instruments to the apex in all cases—with some exceptions. It can be done routinely but only with:
1. Good knowledge of the anatomy
2. Knowing the physical limitations of the selected Ni-Ti files.

Which files are more resistant?

This is a “loaded” question. By this we mean that it depends on the anatomy of the case. We know that in a straight canal the ability of a file to resist fatigue varies directly with the square of the diameter. BUT in curved canals it is the opposite: smaller sizes and less tapered files are more resistant to cyclic fatigue.

Another general rule in all canals is that bigger files tend to be more resistant to torque failure while thinner files are more resistant to cyclic fatigue.

A lot of studies have investigated the mechanical properties of files with respect to the anatomy of a case. Some of these general rules are:

1. The fatigue of a file varies:
   a. directly with the degree of the curvature of the canal,
   b. directly with the length of the canal AFTER the curvature
   c. inversely with the radius of the curve and
   d. inversely with the canal diameter (narrow calcified canals)

If we have to pick the LEAST important factor with respect to Ni-Ti files—it is the degree of curvature. The RADIUS of curvature is MUCH more important as a factor because when we have a small radius only the tip will be able to enter the small radius. At that point the “safety range” (i.e. the number of rotations that the instrument can make without breaking) is very low and the tip breaks very easily. This can happen in as little as a fraction of a second.

Two other often forgotten factors are:

b. The length of the canal AFTER the curvature—this can cause separation of large portions of files as the file tries to negotiate a “high curve.”

d. The canal diameter—in some cases larger canals may allow us to negotiate fine apical anatomy with Ni-Ti that could not normally be negotiated if the canal walls were also contacted in the more cervical portions at the same time. (e.g. cases in young patients with very curved canals but large diameters can often be easier than they initially appear.)

Dr. Gambarini approaches a case this way; he examines the preoperative radiograph and tries to anticipate the canal anatomy. He then classifies the difficulty of the case into one of 3 categories depending on whether he can negotiate a hand file to the WL (regardless of degree of curvature).

1. File size to apex – 20 -> EASY—minimal stress to the Ni-Ti file working to WL easily achieved
2. File size to apex – 10/15 -> AVERAGE—more care required when using Ni-Ti to WL near end of shaping procedures

Pressure: It can turn a lump of coal into a flawless diamond, or an average person into a perfect basketcase.
3. File size to apex – 6/8 or not to WL > DIFFICULT - may not be able to get Ni-Ti to WL even after attempting final shaping because this is stress demanding situation for the files.

With larger diameter canals we can use larger diameter files more safely to the apex. When we have more difficult narrow or curved canals – we need to avoid using bigger tapers to the WL. In abrupt or severe curvatures it may be advisable not to place Ni-Ti rotary files to the apex regardless of how little taper these instruments may have.

Reducing stress on instruments:

Since we cannot alter the tooth anatomy, we must find ways of preparing canals that will minimize the stress on the files:
1. Use more Ni-Ti instruments – we may need to hybridize our sequence
2. Use hand instruments in complex cases – Gambarini prefers to do as much work as possible with Ni-Tis but he acknowledges that some cases he needs to use hand files.
3. Straighten root canal curvature (access) We need to eliminate enamel and dentin interferences – more direct access to the apex. – create a more linear access
4. Use a Glide path – Gambarini is not "for or against" creation of a glide path.

Gambarini’s views on Glide Path

A Glide path is a way to overcome NiTi instruments limitations because of the most difficulty work (apical enlargement) is done with SS hand filing. A glide path is required when dimensions and taper of instruments demands high mechanical work; Or when canals are very difficult to negotiate. Part of the most difficult work (apical enlargement) is done with SS files. The drawback is all the problems that were associated with SS files in the past (lodging, zipping, transportation) are still present. If we are skilled clinicians we may be able to overcome this but this is often not easy to do especially in complex canals. When we have canals that are difficult to negotiate (especially when using Ni-Ti files with a NON cutting tip) - we need to use hand files with more aggressive tips in order to find and maintain patency. He prefers to establish the glide path as "a way to make root canals similar in initial minimum diameters", so that canal preparation becomes more predictable. (with less mechanical stress on instruments). He prefers to have a “starting point” where he can confidently use Ni-Tis, so in that respect he is in favor of establishing a glide path to allow his to use a more consistent instrument sequence with more predictable management of stresses on the instruments.

Gambarini showed two teeth (mandibular third molar with moderate curvature and a mandibular premolar with a sharper curvature) and asked “which is more difficult?” He raised an excellent point when he said that the ability to get our Ni-Ti files into the canal orifice greatly influences this. Although the premolar curve may have been more difficult – the fact that you have to “finesse” your files into the posterior areas of the mouth greatly influences how “straight” their initial insertion is into the orifice. If, in doing this you introduce an “extra curve” at the orifice, you are greatly increasing the “length of file after curvature” and risk of fracture in the third molar. Files that have to be “finesed” into the orifice in this way due to restrictions of the cornoid process or limited opening have a greatly increase risk of breakage. Gambarini calls this the “Peter Pan NeverCurve” – because it technically does not exist in the morphology of the tooth but DOES exist in clinical situ. It is an interesting and important concept – a “virtual curve” not present in a radiograph.

File Design - Selecting the Right File

1. Decide whether you want a cutting or non-cutting tip. If you instrument to the apex Gianluca recommends a non cutting tip. A non cutting tip helps minimize ledges, zips and apical transportation.
2. Find a balance between strength and flexibility. No manufacturer makes the perfect instrument. This balance is difficult to achieve. If you want greater flexibility then select a smaller instrument. It’s not a question of brand – it’s a question of dimensions. Differences in cross sectional area and flute design can achieve differences of 10-30% in flexibility. Reducing taper from .06 to .04 to .02 can increase flexibility from 50-100%. In certain cases where increased flexibility is required – a .02 taper might be better – which also has greater resistance to fatigue. In that case he may use .02/25, .02/30 and .02/35 in a step back fashion – which yields a .05 taper - this may be sufficient for very challenging, very curved cases. In some cases you may choose to use .02 tapers “after the curvature” and larger tapers before the curve – in order to limit risk of breakage.

Torque-diameter ratio

Gambarini then discussed McSpadden’s findings regarding limiting engagement of files, taper lock and the fact that when the file is totally engaged, torsional resistance at D16 is much higher that at D3. We must always try to limit the amount of engagement of the file in the canal. If both segments of the file lock up, the torque required to turn the thicker part of the file at D16 is much greater than that required to break the file at D3. The file breaks at a point 3-4 mm from the tip – but the reason for the breakage is coronal and it lies in engaging the entire length of the file.

Cutting Ability

Gambarini says that there are many factors that influence cutting ability:

- Cutting vs. rake angle
- Positive vs. negative angles
- Lands vs. small cutting edges
- 2 or 3 (or more) cutting angles
- Symmetrical vs. asymmetrical designs

He believes that it is difficult to understand cutting ability because of these many variables. To make things simpler, he prefers to categorize files into two groups:

- Efficient (files that require low or medium torque to cut)
- Non-Efficient (files that require high torque to cut – most often with radial lands)

Other factors influence the cutting ability – such as tip design. A file with a “cutting tip” seems to cut much more easily than a file with a “non-cutting” tip. An study with older style Quantec files (same exact file- only the tip designs were different) showed that the version with the cutting tip was 10 x more efficient.

Lateral Cutting

Gambarini says that lateral cutting ability is something that needs to be further investigated. He cited McSpadden’s Monterey Summit presentation and the studies of the side cutting ability of files as measured when cutting into plastic material. Depending in the actual preparation technique (i.e. whether you use a more “lateral” or brush stroke when inserting files into canal) – this can greatly influence the stresses on the instruments and your preparation results.

Instrument Sequence

An operative sequence is needed to overcome files’ limitations: if instruments were perfect we would not use a sequence-only ONE file. Although manufacturers provide a clinical sequence for file use, not all canals can be prepared using a sequence. We need to think carefully about the canal preparation and add customization according to our experience and skill levels. A sequence should:
Gambarini suggests an alternative – using different 2 different actions of file movements with the instrument:

1. Progression to the WL should be done with minimal increments of 1 mm
2. Once you have reached the WL without forcing the instrument – you can do circumferential flaring with a lateral brushing action.

Most techniques emphasize moving the file down the canal to make an “imprint” of the canal- shaping the hole to the size of the instrument. Gambarini suggests that we should use more lateral movements (taking advantage of the side cutting ability of the files – as shown in McSpadden’s work) to “make room” in the canal space and be less focused on downward apical movement of the file. The instrument is not only negotiating the canal to the apex (like a reamer) – it is also working when it is being retrieved from the apex (like a Hedstrom file). (Editors note: reaming upon withdrawal while at the same time using lateral forces is in essence the EOM as advocated by Schilder – albeit now with an engine driven tapered file). The instrument can be used in this way to increase flare, and get more taper.

The most important thing to remember is to prevent the tip from locking. (Remember: If we want to cut laterally with the thicker part of the file – it requires much more torque. If we catch the tip when this much torque is applied we risk breaking the tip. So the tip must always be “floating and free” in the canal. He suggests that the instrument be withdrawn approx 2mm so that there is no possibility of the tip catching. At that point you can do either circumferential filing, anticurvature flaring AND you can stay a LOT longer in the canal space (20-40 secs) without risking high levels of mechanical stress to the instrument. Even if you DO break a file (because of too much deflection of the file) it is usually very high up (were the flutes start). Because the file fragment is in the coronal part of the canal, it can usually be easily retrieved because the fractured portion is not locked into the canal space and is very loose. As coronal flare is increased, you can use the same instrument more deeply or progress to the next instrument in a much safer manner.

Two other advantages of the technique:

1. By using each instrument with lateral action and coronal flaring you are likely to use less numbers of files during a shaping sequence
2. By creating coronal taper you allow the subsequent instrument to be placed with less restoring force (in a curved canal) with results in a better centered canal
3. Less restoring forces means less potential for apical transportation.

Summary:

1. We need to use Efficient instruments that cut and prepare the canals efficiently
2. We need to take advantage of eth safety features of file designs and know how to use them
3. We need to have a rationale for canal preparation that takes into account the canal anatomy
4. We need to take advantage of the different operative movements that are available to us with these rotary files. We can use a reaming motion in the deepest portions of the canal as well as a using Hedstrom style lateral motion in the coronal aspect - to give us good flare, better access and reduce the stress of the file when it is placed more deeply to the apex.
5. We need to use Rational operative sequences – based on logical canal preparation.

Gambarini’s Hybrid Technique - Crown Down with the Same Instrument

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Summary:

1. We need to use Efficient instruments that cut and prepare the canals efficiently
2. We need to take advantage of eth safety features of file designs and know how to use them
3. We need to have a rationale for canal preparation that takes into account the canal anatomy
4. We need to take advantage of the different operative movements that are available to us with these rotary files. We can use a reaming motion in the deepest portions of the canal as well as a using Hedstrom style lateral motion in the coronal aspect - to give us good flare, better access and reduce the stress of the file when it is placed more deeply to the apex.
5. We need to use Rational operative sequences – based on logical canal preparation.

Gambarini’s Treatment Sequence – a Multi-Step Approach to Ni-Ti Rotary Preparation

STEP 1 – APPROACH TO Ni-Ti - Access, followed by evaluation of complexities and patency (Hand SS files). NiTi glide path (size 20) in the majority of cases

STEP 2 – CANAL SHAPING – using a maximum of 3 or 4 NiTi files with crown down technique.

STEP 3 – REFINEMENT AND CLEANING – Increased coronal shaping and/or increased apical diameters, ultrasonic debridement. The goal of STEP 3 is to achieve better cleaning and obturation objectives. Dr. Gambarini is less concerned about irrigation in Steps 1 & 2 – but wants maximum irrigation in Step 3.

Final Apical Diameters

Gambarini says that this topic is controversial. Some advocate small apical preparations, other say this doesn’t correspond to the apical sizes that occur naturally. O. Peters ESE 2005 says “as large as necessary”. We know that apical anatomy is complex. Gambarini’s philosophy is this:

1. Instruments should ideally touch all canal walls to increase debridement and disinfection
2. Larger size files with larger tapers can thin the apical areas too much
3. .02 tapers are needed. They can be used in a step-back technique to ensure more taper if needed.

Apical Gauging

After completion of STEP 2 – he determines the size of the apex with an .02 taper manual file. He then finishes the apex with a .02 taper rotary Ni-Ti file that is 2 sizes larger than the size gauged. (e.g. if apex is 25 – try to finish with 35. The only way we can do this is with .02 taper Ni-Ti Rotaries.) If the canal is less complex, we can use larger tapers .04 or .06 – depending on the canal.
Dr. Gambarini’s students are currently doing research in the areas of:

- Ultrasonics (quantitative studies of the type of vibratory motion, solutions, time of exposure in relation to cleaning efficiency)
- Studies with artificially infected teeth (strept. mutans) and the effects of (a) NiTi + Irrigation (Phase 2) s. (b) NiTi and Step 3 (Increasing diameters, increasing irrigation procedures). Preliminary results show dramatic reduction when comparing (b) to (a), though no tooth has ever been completely disinfected.

Single Visit Endodontics

Dr. Gambarini is another clinician who advocates SINGLE VISIT ENDOdontics – even in infected cases. He is frank in saying that much of the motivation is financial – but also because he is concerned about inter-appointment reinfection. “Over the years we find no big difference between post operative pain and overall success rates when doing treatment in a single vs. multiple appointment with CaOH or other medicaments.”

To close, Dr. Gambarini showed several how his preparations have evolved over the years and how his apical sizes are bigger. He feels that by increasing the apical sizes (while still using Ni-Ti rotary) he believes he has gotten better results.

Dr. Paul Lambrechts
Leuven BIOMAT Research Cluster
Belgium

Photoactivated Disinfection (PAD) - Paintball Endodontics

Dr. Lambrechts acknowledges that the level of endodontic treatment in his home country of Belgium is poor. But, he says, that it is simply a matter of dedication to good treatment principles. In a study of the Belgian (Flanders) population, 40% of teeth that had endodontic treatment had radiographic evidence of AP. Lambrechts suspects that part of the reason for this is the lack of common use of rubber dam in Belgian endodontic treatment. More sophisticated disinfection techniques are useless if the most rudimentary methods of keeping the tooth isolated are observed.

Dr. Lambrechts’ background is in cariology/restorative field with an interest in Endodontics. The best endodontic treatment is actually the prevention of endodontic involvement and this all begins with caries control.

The concept of minimally invasive procedures

“Restorative Dentistry is evolving from extension for prevention to adhesion for retention.” From various sources (cracks, caries, and leaking restorations) bacteria end up in the dentinal tubules, produce lactic acids and proteolytic enzymes, digest the peritubular dentin and eventually can end up in the pulp. Treatment of dentinal caries involves, assessing the level of decay and removing the infected dentin in a minimally invasive manner. Dr. Lambrechts wishes to have similar minimally invasive preparation of the tooth during endodontic treatment. He says this is consistent with what is also happening in the medical field. Caries needs to be treated with a “smart” approach – a combination of mechanical, physical and chemical methods in order to reach those sheltered microorganism. We use micro drills with micropreparation so as not to unnecessarily destroy tooth and diamond tipped ultrasonics in proximal areas. He also likes air abrasion technology to treat fissures and stained grooves. He believes lasers have some potential but still have some problems because they result in enamel and dentin fractures.

Dr. Lambrechts showed an example of a molar with deep stained occlusal fissures. Removal of only denatured dentine (dentin where all structure has been lost) is necessary. After this stage, the area could be treated with a PAD technique with remineralizing materials applied prior to restoring the tooth with materials which seal the cavity such as glass ionomer cements.

Depending on how you prepared the dentin, (drill, air abrasion, ultrasonics, laser) you will have different substrates and smear layers. This is where the bacteria are hiding and they can survive and multiply in the dentinal tubules under this layer. So how we deal with the smear layer that is produced by each of these preparation techniques will determine our access to bacteria.

How does PAD work?

Certain photoactive agents are taken up by bacteria preferentially, the agent becoming attached to the cell wall. It locks on to all bacteria - not on healthy human tissue. PAD techniques use low power lasers to elicit a photochemical reaction in a photosensitizer which in turn exerts a lethal effect on particular cells, such as bacteria. PAD = Lethal laser photosensitization. Low power (diode) laser energy in itself is not particularly lethal to bacteria but is useful for photochemical activation of oxygen releasing dyes. Singlet Oxygen, a protoplasmic poison, released from dyes causes membrane and DNA damage to microorganisms.

Dyes

Toluidine Chloride (Toluidine Blue) (TBO)
- Pharmacological Grade
- Aqueous Solution
- Sodium Phosphate Buffer
- Peak absorption 633 nm
- the most powerful
Methylene Blue
- Peak absorption 670 nm

Aluminum disulphonated phthalocyanine
- Peak absorption 675 nm

PAD can be obtained with ten kinds of blue, purple and green dyes, mainly of the phenylmethane family. Blue seems to work the best.

Diode Laser Generators
Visible Red Semiconductor diode lasers available commercially:
1. Savage diode laser Aseptim™ PAD - Denfotex Light Systems Ltd. (Scotland) & SciCan (Germany)
   - 635 nm, 50-100mW with TBO + customized emitters
2. Ceralase PDT diode laser (CeramOptic Germany)
   - 662nm, 0.5W with chlorine dyes
3. Biolitec diode laser (Germany)
   - 665 nm with chlorine dyes

Factors that Affect PAD
- Type of Dye
- Dye Concentration
  - Typically 12-100 microgram/ml
- Radiation Dose
  - Typically 40/Sq cm
  - Power (100mw)
  - Time 120-150 sec.
  - Power and energy density
- Species of Microorganism

PAD Applications
- PAD can be applied effectively for killing Gram Positive bacteria, Gram negative bacteria, fungi and viruses.
- PAD can kill bacteria in complex biofilms such as subgingival plaque, which are typically resistant to the action of microbial agents.
- PAD can be made more species specific by tagging the dye with monoclonal antibodies.

Disinfection
- Root Canals ( E. Faecalis)
- Perio Pockets ( P. gingivalis, F. nucleatum, E. corordens)
- Sites of peri-implantitis
- Deep carious lesions ( S. Mutans, S. sobrinus, Lactobacillus species)
- PAD can be used effectively in carious lesions and root canals since visible light transmits well across dentine.

Research by Gavin Pearson et al (London) did a study of S. mutans in planktonic environment. When exposed to PAD for 30 s contact time with the dye, 60 sec. exposure at 60 mW with laser - It showed 99% kill. Further studies ion carious dentin in vivo showed a similar almost complete reduction of bacteria.

Safety of PAD
- PAD does not give rise to deleterious thermal effects for adjacent tissues
- PAD treatment does not cause sensitization and killing of adjacent human cells such as fibroblasts and keratinocytes.
- Neither the dye nor the reactive oxygen species produced from it are toxic to the patient
- Bacteria are not able to produce resistant strains to the photoactive agent
- TBO is used in high concentration for screening purposes for malignancies of the oral mucosa and oropharynx. It does not exert toxic effects at the low concentrations used in the PAD technique.

Tests
An ESEM is an SEM allows us to examine the microorganisms and dentin biofilms in the microscope when you have the right conditions of humidity, temperature and environment for proper observation. He showed an example picture of a Biofilm symbiotic relationship between E. faecalis and F. nucleatum that appeared “out of focus”. In fact the image was representational of a biofilm because it accurately showed how bacteria are embedded in their own juices - extracellular membranes and proteins. A half an hour later you could take another image and see how the bacteria have doubled. The reason that these images don't have the “classic” sharp look of SEM bacteria is that they are not “fixed” and dried.

Enterococcus faecalis - Lambrechts calls them the “Osama Bin Laden of Endodontics” because they manage to be sheltered in the “Tora Bora Mountains” of the dentinal tubules where they are not easily approached. But is it a true pathogen or just a nuisance? The challenge is to penetrate these clumps of colonies and biofilms with our irrigants and PAD.

He cited Nair et al - Microbial status of apical root canal system of human mandibular first molars with primary apical periodontitis after “one-visit” treatment 2000, 99 No. 2 231-251 (2005)

He showed Photomicrographs of sequential transverse sections at varying distances in corono-apical direction from the apical portion of a necrotic non-instrumented and non-obturated distal root.
- (MC) Main canal contains microorganisms.
- (AC) Accessory canals are clogged with bacteria.
- Both bacteria (filamentous and coccus forms) and yeast were clearly visible

Biofilm Life Cycle in 3 steps
4. Attachment
5. Growth of Colonies
6. Swarming phenomenon and detachment in clumps or “seeding dispersal”.

A biofilm is a 3D “community”of bacteria attached to a surface. It has the following characteristics:
- Fluid interactions
Mistakes
It could be that the purpose of your life is only to serve as a warning to others.

We think of Biofilms as static – they are not. These biofilm structures are viscoelastic. Hydrodynamic forces/turbulent flow of liquids can lead to shear induced adherence failure but only after a time. They are fairly resistant and how much flow and penetration of irrigants do we need to get until they are finally dislodged? In order to dislodge a biofilm, we need active long term agitation. The SonicCare toothbrush uses a similar principle - acoustic streaming and agitation to attempt to remove plaque biofilm. If we want to disturb any biofilm, we must do it actively and not passively. He then showed the RinseEndo device (Durr) which has a compressed air driven dynamic root canal irrigation system for vigorous controlled flushing. It uses alternating “flushing-suctioning” action to actively flush the RCS. However the needle insertion must be well controlled because it is an “active” rather than passive irrigation system.

Cleaning and Disinfection - NaOCl

NaOCl is a fairly corrosive liquid and can not be applied for a long time when using Lambrechts type of FEM equipment. When 1 minute of NaOCl 2.5% was applied to a 2 day old biofilm of S. anginosus – good reduction. Similar tests done with 6 day incubated biofilm of S. anginosus showed similar results. Not only does NaOCl kill bacteria – it dissolves organic material and membranes – Diffusion time and contact time are important.

Studies of bacteria in biofilms subjected to PAD showed:

- S Anginosus reduction with PAD – 94%
- E. Faecalis - reduction with PAD – 88.4%
- F. Nucleatum- reduction with PAD 98.5%

However, Lambrechts makes a good point when he says that if the original number of bacteria in the canal was 10 million (for example) – a 99% reduction will still leave 100,000 bacteria in the tubules. If you DON’T entomb these remaining bacteria with a good endodontic seal – you still may get failure due to regrowth of these remaining bacteria.

Different bacteria also show different levels of susceptibility to PAD. That is because the complex structure of the biofilm means that different bacteria may be protected by being located in deeper layers of the biofilm of have resisting properties because of their location and interaction with other organisms.

What does this means for Endo Treatment?

During Endo treatment we need to:
- Neutralize microorganisms
- Seal the tooth (and preserve healthy tissues!)
- Preserve the periapical tissues

Lambrechts wants to do this successfully while at the same time working in a minimally invasive and effective manner. We all know that the ideal situation is complete cleaning and sealing of the canal system. The problem is the anatomy - the root canal “system”. It has very complex anatomy. It is frustrating to see cleared teeth with their complex structures. The ideal situation is complete cleaning and sealing of the canal system. The problem is the anatomy - the root canal “system”. It has very complex anatomy. It is frustrating to see cleared teeth with their complex structures.

Lambrechts says that it is impossible to prepare all canal surfaces – files do not contact all surfaces. He gave pre-scanned mandibular mesial root samples to Machtou and Ruddle and asked them to prepare these mesial root canal systems. The preps were nicely centered and shaped but there were still lateral areas that were not encompassed by the preparations – as well as the interconnection of the isthmus. Preparing the canals with this technique can actually push debris into the isthmus and lateral areas. This makes rinsing these isthmus and lateral areas almost impossible. The bacteria can then multiply in these areas- every half hour.

Paul then showed a horizontally sectioned mesial root that had two canals – one each prepared with K3 and ProTapers. The canals were nicely centered and shaped but there were still lateral areas that were not encompassed by the preparations – as well as the interconnection of the isthmus. Preparing the canals with this technique can actually push debris into the isthmus and lateral areas. This makes rinsing these isthmus and lateral areas almost impossible. The bacteria can then multiply in these areas- every half hour.

That is a major problem.

How do we deal with these organisms that have sheltered themselves in the dentin tubules and have culture reversal potential?

He then cites Nair’s study where showed a mandibular molar with primary AP, instrumentation, filling and then surgery of the root 8 months after treatment. A photomicrograph of the transverse section of the resected root apex showed incomplete obturation of both canals connected by debris filled wide isthmus that was just as wide as the prepared canals. TEMs of the bacterial masses in these isthmuses showed islands of “fibro-dentinal structures” - this is the pulp and dentin debris that was pushed into the isthmus during preparation of the MB and ML canals. The bacteria are protected by this debris layer. TEM of a necrotic accessory canal in the area showed numerous filamentous and cocci bacteria embedded in an extracellular matrix.
How can we deal with this problem and the Use of PAD?

TREATMENT PROTOCOL
1. Electronic and radiographic length determination
2. Inspection of the canal system (looking for isthmuses and anastomoses). He uses hand Micro Debriders to try to clean these areas. BUT the more we try to clean these areas this way- the more we realize how difficult these areas are to clean. We need more.
3. SO... we use ultrasounds instead. Lambrechts says that the Super-elastic Ni-Ti Smooth File (EMS) ESL Endo Soft Instrument # DT-069 is an ABSOLUTE MUST HAVE - is you want to use sonic (1,500-500 Hz) or ultrasonic (25,000-40,000 Hz) activation of irrigants in canals. This instrument is an “inactive” instrument because it is totally smooth and without flutes, therefore it does not alter your prep. It creates cavitation effects, micro-acoustic streaming as well as primary and secondary streaming. Use of NaOCl on pulp tissue (without some form of agitation assistance) is a slow process – requiring 30 minutes (depending on concentration and temperature).
4. Lambrechts showed a video of the effects of the DT-069 and produced what looked like “Biofilm smoke” in the NaOCl of the access. He referred to this as the “Biofilm Flatus” - which brought quite a laugh from the audience. Use of the instrument in this manner disrupts the debris in the anastomoses and lateral areas and allows them to be aspirated in after being placed in suspension. Rinsing should continue until no more debris is visible in suspension.
5. Cliff Ruddle has a similar instrument that is being developed (a biofilm disruptor) called the EndoActivator (Patent Pending).
6. It is a battery driven small handpiece that activates a nylon fiber and 3 speeds. It is used with a pumping – in and out motion. It can also be used to enhance the penetration of the TBO solution when PAD is used.

DO WE NEED CaOH inter-appointment after PAD treatment?
Lambrechts believes that it is not necessary and that the canals can be filled immediately after completion of the PAD and drying phase of treatment. Therefore, he believes in single appointment treatment with the exception of cases of obvious acute periapical symptoms.

Is it difficult to remove the CaOH?
Lambrechts uses the Rinse Endo by Durr and says it is relatively easy to remove the CaOH with the dynamic rinsing and flushing action of NaOCl and the device. He also uses CHX as a rinse as well – it may be “overkill” but he prefers this method.
9. Fill as usual with a good obturation technique.

Lambrechts and Thermafil
Paul acknowledges the negative comments about Thermafil – the technique he uses. However, he points out that this technique has taken quite a bit of criticism because it was used with poor shaping procedures. When used with a well shaped canal, many clinicians say it works well. His cross section and microCT scans of his fills showed very nice results. He uses TopSeal sealer (and epoxy resin based sealer like AH Plus) inserted only at the orifice and just below. He does not fill the entire canal with sealer because Thermafil (being a “top-down” filling technique) would extrude too much of this sealer during placement. He cuts the carriers off with a “Preppy” bur.
Paul did intensive analysis of the mandibular molar mesial root fill with a “Preppy” bur. Lambrechts showed a video of the effects of the DT-069 and produced what looked like “Biofilm smoke” in the NaOCL of the access. He referred to this as the “Biofilm Flatus” - which brought quite a laugh from the audience. Use of the instrument in this manner disrupts the debris in the anastomoses and lateral areas and allows them to be aspirated in after being placed in suspension. Rinsing should continue until no more debris is visible in suspension.

Bacteria can escape from the apex of the tooth but we have our host defense system to help us. Our immune system has the ability to summon macrophages, neutrophils, and PMNs to deal with those bacteria that may be exposed to it.

Can we truly expect our filling materials to enter the dentinal tubules to entomb the bacteria?

Gutta Percha Alternatives are the Answer
Superior flow and seal
- throughout the root canal system
- Good adaptation
- Long term stability
→ Interlocking <> Adhesion

EndoRez (Ultradent) a UDMA Resin Filler uses a two phase automixing tip with Injectable Resin Filler Navitip.
- Hydrophilic
- Methacrylate based (UDMA)
- Superior flow
- Simplified application
- Infiltration capacity? Can it actually get right into the tubules?

Lambrechts study of EndoRez – if you cannot kill the bacteria – entomb them.
Done in vitro. He used a plastic carrier as a GP cone substitute to drive the sealer into the dentin and filled prepared anterior maxillary canals with EndoRez. The tooth was dissolved in Hydrochloric acid 30% for 36 hrs to remove the inorganic component. NaOCl 2.5% for 10 min was used to remove the organic component. What remains is the canal obturation with the filling material in place and dentinal resin tags – if they are present. Photomicrographs showed thousands of spaghetti-like resin tags that had flopped
Dr. Leif Tronstad  
Hovik, Norway  
Biofilms in Endodontics

Editor’s note: The presenter of this lecture specifically requested that he not be videotaped. The following notes were taken by hand. If anyone has any corrections, please let me know.

We were indeed privileged to have one of the Endodontic giants address the Summit- Prof. Leif Tronstad. Although Prof. Tronstad is primarily associated with research and academics, he prefaced his lecture by saying that he does respect the practicing clinician. Tronstad practiced clinical Endodontics for 8 years, until one year ago when he stopped seeing patients. Why? Because by his own admission he was “not good enough anymore”. (Editors note: This was a startlingly frank admission from a man of great endodontic stature but I believe it was meant to show the audience (mostly composed of practicing dentists) that he recognizes the need for and the importance of good clinical technique. One of his “claims to fame” is that he spent 11 years at Penn working with ROOTS’ own Dr. Fred Barnett.)

Prof. Tronstad said he first heard the term “Biofilm” used at a Perio conference around 25 years ago. But biofilms do not resemble plaque, physically. Biofilm research is now one of the hottest topics.

Biofilms
- Most bacteria live in Biofilms
- Bacteria colonize surfaces of everything
- Biofilms have an impact everywhere: Cooling towers, oil recovery, food processing, paper manufacture, medical implants, our drinking water, etc.

How are Biofilms formed?
1. Biofilms start with a “pioneer bacteria” that sits on a surface
2. More bacteria arrive and multiply/divide and make an “extracellular matrix” which is basically a polysaccharide. Interestingly, if the bacteria come upon “hard times” and cannot secure a food source, they can use this external matrix as a food source instead. In other words, they adapt well to their environment and are adept at self-preservation.
3. When bacteria come into close enough contact - “they begin to talk to each other”. By this we mean that they exchange information about how to best deal each other and their environment. They are “smart”.
4. At a later stage, “new” bacteria (not the original pioneer bacteria) arrive. The pioneer bacteria are very selective about which bacteria they will allow to colonize the area. Oral studies show that 20 or 30 species can occur together.
5. They make “channels” in the Biofilm for waste materials and nutrient transport
6. We can have both aerobes and anaerobes next to each other – it depends on the needs of the colony.
7. When the colonies mature -> bacteria can be released into the blood stream, either as:
   - A steady Stream of bacteria
   - Bacteria pushed out in different amounts at different times
   - A piece of the biofilm loosens and breaks off

Summary- Biofilms
- Composed of Micro-colonies of bacteria
- Multiple species (as a rule)
- Extracellular matrix composes 70% of the Biofilm
- Have channels

Biofilms other functions
- protect the bacteria from competing bacteria
- protect the bacteria from outside influences
- Resistance to antibiotics increases 1000-1500 times when they are in a Biofilm. This explains why Ab do NOT have an affect in some cases – need SRCT

Examples of Cooperation in Biofilms
1. “Quorum Sensing” are Biofilms talking together
2. Metabolic cooperation
3. Cross Feeding - e.g. P. Gingivalis need Vitamin K to exist – therefore they can only colonize areas where this Vitamin K can be obtained from other bacteria in the colony
4. Removal of harmful products

over (they were no longer supported by the surrounding dentin). These tags were an astounding 1000-1500 microns long!! They were completely polymerized and continuous. The resin tags perfectly correlated with the size and shape of the tubules - even down to the inter tubule branching. If there were any bacteria in these tubules, they would certainly have been entombed in the material. The drawback with resin based systems is the shrinkage. They shrink approximately 6%. The can results in severing of the material in the tubules from the core material and gap formation along the periphery. If this gap is re-infected – the case can fail. Therefore more work is needed to reduce the polymerization shrinkage so that this gap is minimized or eliminated.
5. Genetic Exchange – e.g. after use of a drug or Ab – the few remaining resistant cells can give off genes to the other bacteria conferring resistance to them as well.

6. Detachment of bacteria – allows the bacteria to colonize new sites. Example: 60 deaths due to Legionnaire’s disease traced to cooling tower contamination in Norway.

**Oral Biofilms**

- Normally present in healthy oral cavity – on tooth surfaces and in pockets, enamel grooves, cavities.
- Approx. 169 different bacteria recently found in caries by Forsyth Inst.
- ~ 800 species of microflora are present in the normal mouth.
- 50% are uncultivable or have not yet been cultured.
- Oral biofilms are made up of about 20-30 species: doesn’t matter what part of the mouth you sample.
- Associations of bacteria in the mouth are NOT random.

Sokransky (at Forsyth) examined the plaque of 13K people found that there are 6 complexes involved in Perio disease. Actinomyces are generally the pioneer bacteria. They build “scaffolds”. Other bacteria are attracted to the area and a biofilm develops. The most important bacteria are:

- P. Gingivalis, B. Forthyus, T. Denticola -> all highly anaerobic. If they are present as a complex, disease develops. Not all bacteria are equally pathogenic (there aren’t that many that are) and cause active disease.

**ENODONTIC INFECTIONS**

Pathways of infection

1. The exposure of coronal dentinal tubules by whatever means.
2. Direct pulp exposures. Bugs enter coronally and disease moves coronally-> apically with the creation of a biofilm.
3. Exposure of the Root canal system (e.g., lateral canals)

Vital Teeth

If the tooth is vital, bacteria do not generally penetrate the dentinal tubules. This occurs because tissue fluid in the tubules has the same properties as vital tissue fluids – antibacterial effects. The exception is in retrograde pulps where pocketing to the apex causes pulp irritation.

Non Vital Teeth

In the non-vital tooth dentin are present in the tubules. If sufficient numbers can colonize a poorly obturated canal they can form a biofilm on the canal wall and can cause the case to fail.

E. Faecalis

Prof Tronstad stated that this microorganism is an “unimportant bug” and that it is over-rated. Researchers use it because it grows easily. Tronstad refers to this as the “Dental School Bug”. Usually found in very low numbers. If we perform modern endodontic treatment, these bacteria should not be a problem.

4. Enamel and enamel/dentin Cracks – seen now because more of us use scopes.
5. Cervical Lesions
6. Restorative procedures (leakage)

The same bacteria in the Root Canal System are present in the pocket samples studied.

B. Forsythus is the most important because it is important for perio disease, when you observe it with the right tools. Endo infections are caused by the same bacteria that cause perio infections:

- B. Forsythus found in 90% of cases studied
- P. Gingivalis found in 80% of cases studied
- T. Denticola found 40% of cases studied
- Actinomyces found in 90% of cases studied

The “Classic” view - if the root canal systems is infected, the resultant periapical granuloma occurs from the effects of bacterial byproducts – but the lesion itself is NOT infected. Tronstad says this is not correct. Root resorption is present in all infected teeth with AP.

**Extra radicular infection**

These cases do not fit into the gospel of the Classic view. Tronstad then showed a very puzzling case where a single appointment one step treatment was performed on a lower molar. The patient developed a lesion where there was none originally. Then, by only giving the patient Penicillin meds, the lesion healed. This simply does not fall under the current model that we understand. In a second case he showed how a cultured periapical lesion of Staph. Aureus did not heal. A SRCT was needed. The bacteria had established a foothold and antibiotics were not sufficient to treat it.

**Super Infection**

Infections of Non-oral bacteria e.g. Pseudomonas auriginosa can be very nasty to deal with. He showed an endodontically treated case that had not healed over an 8 year perio and that had multiple unsuccessful surgical procedures. After the lesion was cultured and Pseudomonas was found the patient was finally given Cipro and improved without any further procedures being performed.

Extra-radicular infection

- Bacteria cultured from lesions
- DNA-DNA hybridization
Found bacteria in the RCS were the same kind found in Perio lesions and some non-oral bacteria
- In refractory cases, or cases where conventional treatment is not successful, bacteria found:
  - B. Forsythus found in 70% of cases studied
  - P. Gingivalis found in 75% of cases studied
  - T. Denticola found in 60% of cases studied
  - Actinomycetes found in 7% of cases studied

More recent research done in Berlin with a Fluorescence Technique has shown a high prevalence of spirochetes.

Other studies have shown that biofilms form on the surface of root tips and also can form on the surfaces of excess filling materials.

**Sulfur Granules**
The phenomenon of “sulphur granules” (named because of the yellow granular appearance) is actually a form of biofilm. These are most often found inside the apical lesions of refractory cases where actinomyces are involved. Because of the way these lesions are physically organized, NSRCT is not effective, antibiotics are not effective and even a combination of Abs and NSRCT are not effective. These must be surgically treated by apicectomy, surgical curettage and systemic antibiotics. Tronstad insists that antibiotics are necessary in these special cases. We should not be stubborn; antibiotics should be given in addition to treatment with SRCT. This should include Penicillin and Metronidazole.

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**Dr. Rick Schwartz**
San Antonio, Texas
**Adhesive Dentistry and Endodontics**
(Presented by Dr. Ron Fransman)

**Editor’s note:** Dr. Schwartz was unable to travel to the ROOTS Summit but was kind enough to send his PowerPoint Presentation. Special thanks to Dr. Fransman who courageously presented this lecture on his behalf. Dr. Fransman prefaced the lecture by saying that he was an Endodontist and that many in the audience probably know more about adhesive dentistry than he did. He also requested that any questions be directed to Dr. Lambrechts, whose studies were featured in Dr. Schwartz’s presentation.)

**How do adhesives work?**

**Enamel:**
Acid etching creates a porous surface with high surface free energy. A low viscosity resin is drawn into the etched surface by capillary actions and is polymerized in situ.

**Dentin:**
Acid etching demineralizes the dentin surface and exposes the superficial collagen matrix. A hydrophilic primer, containing resinous material in a volatile liquid is applied to the surface and penetrates the collagen matrix. The volatile liquid evaporates away. An adhesive resin is applied which co-polymerizes with the resin in the collagen matrix. Once polymerized, it is locked in place. The layer between the restorative material and the dentin consists of collagen fibers surrounded by resin and is referred to as the Hybrid Layer or the Interdiffusion Zone.

- This paper laid the groundwork for adhesive dentistry. Presented the current theory of dentin bonding. Unlike in enamel, the mechanical retention is achieved by using the collagen matrix.

- It is important that we remove the smear layer to allow us to present a clean surface that will accept our bonding material. A properly prepared surface looks like “seaweed underwater”. It is moist and ready to accept the bonding agent. Of this surface is dried too much, the seaweed “collapses” and lies flat against the surface dramatically reducing the bond strength. Therefore we need to keep the dentin wet. The optimum length of these fibers for bonding is 4 micrometers. If we overdry the layer, the collagen collapses - the resin cannot adequately bond to the collagen. When the resin shrinks during polymerization a gap develops between the resin and the dentin surface. Patients then can develop post of sensitivity when chewing as a result of the pumping effect of the fluid in the dentinal tubules.

- There are different kinds of adhesive systems:
  - **1, 2 in 1 Systems** - these have strong or mild self etch adhesives with a low ph. Both types report good bond strengths and no post op sensitivity.
  - **2, 2 Step Systems**

**Dentin and Enamel Bonding Systems**
- Corrects to popular belief, dentinal tubules are not major contributors to retention.
- The collagen matrix in the intertubular dentin is more important to retention than the tubules.

Dentin tubules account for only ~15% of retention

Dentin and Enamel Bonding Systems
- Etch and Rinse
  - 4th Generation: Etch, rinse, primer, air dry, adhesive, polymerize. 3 steps (Scotchbond Multipurpose, Optibond, Allbond 2)
  - 5th Generation: Etch, rinse, combined primer and adhesive, polymerize. 2 steps (Not recommended)

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Self Etching

6th Generation: Acidic primer. Air dry, adhesive, polymerize, 2 steps (Clearfil SE Bond, Nanobond)
7th Generation: Acidic primer and adhesive combined, polymerize 1 step (Not recommended now but may be important in the future)

In general, 3 step adhesives work the best and are the most durable.

Tay et al - Have dentin adhesives become too hydrophilic J Can Dent Assoc 2003 Dec;69 (11) 726-31
Inoue et al - Micromechanical bond strength of eleven contemporary adhesives to dentin J Adhes Dent 2001 Fall; 3(3):237-45

Other studies that have shown this:
Fabianelli et al - Adhes Dent 2003 Fall 5(3) 21-23
DeMuinck et al - J Dent Res 2003 Feb 82(2) 136-40
Armstrong et al - J Adhes Dent 2003 Spring 5(1) 47-56
Chersoni et al - Dent Res. 2005 Mar;84(3) 223-7

• The “simplified” adhesive systems have problems with permeability of moisture from the dentin through the adhesive layer. (i.e. if the etch/primer combination takes some time to infiltrate. The fluid from the dentinal tubules can affect this during the wait time. This can result in a small layer of moisture under the hybrid layer)

• Not a problem with the 3 step adhesives. (i.e. if you use a 3 step method you can etch, dry and then let the primer diffuse into the hybrid layer)

All Dentin Bonding Agents (DBA) leak to some extent. This has been shown by many studies:
Boulliau et al - J Dent Adhes Dent. 2000 Autumn 2(3)210-8
Ceballos et al - Dent mater 2001 Jul 12(4) 340-6
Fabianelli et al - J Adhes Dent 2003 Fall 5(3) 217-23

All Dentin Bonding Agents (DBA) lose bond strength with time. This also has been shown by many studies:
Hashimoto et al - Biomaterials 2003 Sep 24(11) 1795-803
Hashimoto et al - J Dental Res 2000 June; 79(6)1385-91
Sano et al - J Dent. Res 1999 Apr 78(4) 906-11
Takahashi et al - J Adhes Dent 2002 Summer 4(2) 151-9

And more
• Over time Metalloproteins attack the adhesion layer between the resin primer and the collagen fibers. (Chlorhexidine as a final rinse has been shown to reduce the effect of these metalloproteins.)

- First evidence of the breakdown of the dentin/resin bond is at 3 months!
Okuda et al - Oper Dent 2002 May-Jun;27(3)289-96
Okuda et al - Oper Dent 2001 Sep-Oct;26(5)482-90
Microleakage increases as the bond strength increases over time

Which dentin bonding system should I use?
Schwartz recommends the original Optibond or Optibond Dual Cure
• 3 step etch and rinse (4th generation)
• High bond strength
• Stable bond over time
• 7 year clinical results
• Allow wet or dry bonding because it contains water
• Compatible with self or dual cure composites

Dentin adhesive systems that contain water can be used for wet or dry bonding.

What composite should I use?
• The one that goes with your dentin bonding system OR
• The one that looks the best (if you are into aesthetics!) OR
• BuildIt (Pentron) and Tetric Ceram (Ivoclar) and Herculite (Kerr) – if you still don’t know. These have good track records.

Goals of Endodontic Treatment
4. Eliminate microorganisms from the RCS
5. “Entomb” remaining organisms in the RCS
6. Prevent coronal leakage
He cites Nair et al - OOO 2005 Feb 99(2) 231-52 to show that it is impossible to completely eliminate microorganisms from the RCS with current methods.
Quite a battle has developed between the "Pro Resilon" and the "Anti-Resilon" groups. Critical apical sections whose contents are more likely to cause failures? Proponents focusing more on midroot and coronal cross sections that show good adaptation of the material – rather than the more seal. If apical seal is so important to endodontic success – and one of our goals to entomb bacteria and biofilms, why are Resilon? Many other articles came to similar conclusions.

Limitations of Dentin Bonding in the RCS

1. Effective application of the primer deep in the canal space
2. Effective removal of the volatile carrier from the canal
3. Deterioration of the bond with time and function
4. Bonding with dual cure resins
   - Dual cure resins and self etching adhesives are not very compatible.
   - Slow polymerization produces less stress on the bond to dentin
   - Adhesive layer acts as a permeable membrane, allowing moisture to interfere with the resin/resin bond
   - Residual acid from the self etching acidic primer interferes with the high pH amines which initiate polymerization of the composites.
5. Unprepared canal walls
6. Residual CaOH
7. Bonding to Resilon cones
8. Retreatment issues with resin sealers

What has been published about Resilon? Epiphany?

Franklin Tay has published studies that show less favorable results. Resilon has been company sponsored and performed, and published by Trope et al. - JADA 2004 May 135(5) 646-52; JOE 2004 May 30(5) 342-7; JOE 2005 Feb 31(2) 91-96.

Resilon system does NOT strengthen roots as had been claimed. Resins shrink 2-6% on polymerization. Polymerization shrinkage often exceeds the bond strength of dentin adhesives. Dilacerated or branching canal anatomy can make application of primer difficult or impossible. Dilated or branching canal anatomy can make application of primer difficult or impossible.
Dr. Fransman speculates that like many new resin systems, it is probably still in development and needs more work. It certainly is no worse than gutta percha but it may not be that much better.

Application of a DBA to resin coating increased bond strength but still less than 2 Mpa.

**MTAD and Resin Sealers**

- Tay et al. JOE 2006 May 32(5): 473-7
  a. When used for 5 minutes, MTAD produces a demineralized zone of 10-12 microns.
  b. This is too deep for resin to effectively penetrate.

The way to neutralize this is to rinse with NaOCl but this in turn reduces the residual effects of the MTAD – so there still is work to be done with this combination.

**Future in-vitro studies look for:**
- Discount the value of company sponsored research
- Or, at least, wait for independent testing to confirm the results
- Were the samples aged?
- Was the bond stressed before testing?
- Discount the value of SEMs

**Conclusions**

- Resins behave in a predictable manner and Resilon/Epiphany/RealSeal is no exception
- We have a long history of success with a resin sealer (AH 26) as well as Gutta Percha
- There is no reason to believe we won’t have success with Resilon
- As Martin Trope says, it is probably no worse than gutta percha
- The primary benefit may be in reducing coronal leakage
- Any strengthening of the tooth is going to be minimal and temporary
- The idea that it will repair teeth with cracks is wrong
- Success will depend on locating all canals and effectively disinfecting them
- Resilon system should be OK but it is not a big step forward
- It is hard to get too excited about EndoRez

**The Future?**

- Ongoing independent testing with Resilon/Epiphany won’t be as favorable as company supported testing
- Some improvements in methods to apply the primer?
- Some improvements in the products?
- Addition of antimicrobials? (ZOE based products do have this)
- Non-shrinking resins?
  - Materials with chemistry that form ring shaped bonds – less likely to shrink. Handling properties of these materials need improvement.
- Resins that expand slightly?

**The role of the restorative dentist in the success and failure of Endodontics**

**What is the success rate for Endodontics?**

It depends on your point of view.

- De Moor et al. - IEJ 2000 Mar 33 (2) 113-20 (Belgian population study)

The above studies had success rates (indicated by periradicular pathosis) of <60%

On the OTHER hand - when Endodontists themselves do the studies:

- Abbott PV - Aust Dent J 2004 Mar 49(1) 33-9 (a retrospective study of conservative retreatment in his practice)
- Salahrabi and Rotstein JOE 2004 Dec 30(12) 846-50 (an epidemiological study based on insurance records of teeth having endo treatment)

The above studies had success rates of >95% (as classified by “functional teeth”)

**How many teeth with crowns eventually need endodontic treatment?**

3-22% depending on the study

- Pulp tests should be part of the patient evaluation. All teeth that are being crowned should have pulp tests.

Karlsson S. - A clinical evaluation of fixed bridges 10 years following insertion | Oral Rehab 1986 13:423-32

- About 1% of teeth with crowns develop necrotic pulps each year
- Teeth with crowns should be tested periodically
- This is sometimes difficult to do because of the insulating effect of the porcelain or the restoration. EPTs can also be used with specially fitted small probes to use under crown margins.

**Frequency of Endo - Amalgam vs. Composite**

(Washington State Delta database - Dr. Max Anderson)

<table>
<thead>
<tr>
<th>Surfaces</th>
<th>Amalgam</th>
<th>Composite</th>
</tr>
</thead>
<tbody>
<tr>
<td>One</td>
<td>2.37</td>
<td>0.10</td>
</tr>
<tr>
<td>Two</td>
<td>2.41</td>
<td>0.14</td>
</tr>
</tbody>
</table>
Three 3.40 0.36
Four 4.78 0.63

This data seems to support the theory that composites are associated with less endo. However, it also may be that clinicians recognize that very large restorations are best restored with alloy and that some of the three and four surface composites are much smaller than their alloy counterparts.

Before Endodontics is contemplated, the restorative dentist should:
- Have an overall treatment plan for the patient.
- Evaluate the tooth for restorability. This may involve removal of existing restorations/caries.
- Evaluate the need for periodontal treatment.
- Determine the patient’s desires.

(Fransman said: “If only this was true, we’d be in Endodontic heaven. It would save us so much time and frustration. But it will probably never happen. Most restorative dentists leave that up to us.”)

**The Goals of Endodontic Treatment**
- Reduction or elimination of bacteria from the root canal system
- Prevent recontamination

**How Do We Accomplish This?**
- Restore the Tooth Immediately
- Orifice Barriers
- Caries detector
- The problem with post spaces

**Avoid Contamination of the RCS**
- Bacterial contaminants from leaky restorations or caries quickly penetrate through the full length of the root canal system. Teeth should be restored ASAP with restorations that are well sealed
  - Saunders and Saunders - Endod Dent Traum 1984;10:105-08
  - Swanson et al - JOE 1987 13: 56-9
  - Maquera et al - JOE 1991 17: 324-31
- Teeth with poor coronal restorations had low success rates
  - Ray and Trape IEJ 1995 28:12-18
  - Tronstad et al Endod Dent Traum 2000 16 :218-221

To avoid recontamination of the canal – restore the canal immediately. And restore the tooth properly-> No spaces left in the orifice or post spaces. Appropriately sized posts, only used where indicated.

**I is there a benefit to placing a post with an existing crown?**
- Fokkinga et al- Ex vivo fracture resistance of direct resin composite complete crowns with and without posts on maxillary premolars IEJ 2005 Apr;38(4):230-7 – The addition of a post to an existing crown does NOT improve fracture resistance.

**Orifice Barriers**
If teeth cannot be restored immediately, use orifice barriers. It is important to ensure that the pulpal floor and chamber are clean and that all sealer remnants (especially ZOE based sealers) are removed entirely. They can affect the bond.

**Technique:**
- Countersink the orifices
- Clean the chamber
- Etch and rinse
- 4th generation primer
- Adhesive or Clear resin
- Or use 6th Generation system if non-eugenol sealer was used
- Or use a flowable composite
- Or use a resin modified Glass Ionomer material

Schwartz did an in house study of 100 composite build ups under crowns.
- 5 years or more ( according to patient)
- Endo Access
- Caries Detector
- 37/100 had decay
- 22 others were stained but hard

**Avoid Contamination of the RCS: The Problem with Post Spaces**
- Fox et al IEJ 1997 30 361-8
- Demarchi and Sato JOE 2002 28:328-9

These studies concluded that Temporary posts don’t seal.

**Glass Ionomer**
Glass Ionomer is an effective barrier to use at the end of a post space.

**Endodontic Issues in Adhesive Dentistry**
1. Eugenol - Most temporary cements and endodontic sealers leave oily debris on the tooth surface that needs to be removed.
   - Woody and Davis Oper Dent 1003 Sep-Oct 17(5) 175-80
2. Clean surfaces with an “etch and rinse” adhesive system produces normal bond strengths. You can use microetchers or use alcohol to get rid of the sealer.
   - Wolanek et al JOE 2003; 27 :354-7
3. NaOCl rinse reduces the bond strength of DBAs
   - Erdemir et al. JOE 2004 Feb 30(2):113-6
   - Morris et al. JOE 2001 Dec; 27(12):753-7
   - Ozuruk et al. JOE 2004 May; 30(5):362-5
   NaOCl reduces bond strengths to as low as 8.5 Mpa. (Normally around 25-20 Mpa)

4. NaOCl rinse increases microleakage

5. NaOCl reduces the bond to dentin because it is an oxidizing agent that leaves behind an oxygen rich surface.
   - Morris et al. JOE 2001 Dec; 27(12):753-7

6. This oxygen rich surface can be reversed with a reducing agent such as ascorbic acid (Vitamin C) or sodium ascorbate. Use 10 % solution (powder), dilute it a bit, leave it in the access for 3 minutes and it scavenges the oxygen.
   - Morris et al. JOE 2001 Dec; 27(12):753-7

7. Hydrogen Peroxide reduces bond strength due to Oxygen release
   - Erdemir et al. JOE 2004 Feb 30(2) 113-6

8. Chlorhexidine – NO effect on bond strength
   - Erdemir et al. JOE 2004 Feb 30(2) 113-6
   - Perdigao et al Am J Dent 1994 Apr ; 7(2) :81-4

9. Chlorhexidine – NO effect on leakage with AH26, Roths or Sealapex sealer
   - Ferguson et al. JOE 2003 Feb 29(2):91-4

10. Caries detector – NO effect on bond strength

Restoring Access Openings

1. Bulk Fill as much as possible ( e.g./ glass ionomer)
2. Do it efficiently – we don’t want this to take too long
3. Need a material on the surface that will withstand occlusion
4. Need satisfactory esthetics some of the time

How do we avoid most of the problems related to polymerization shrinkage, C factor and resin incompatibilities?

1. Bulk fill most of the access cavity with GI or dual cure composite
2. Light cure composite at the external surface, placed in two increments
3. Etch and bond to dentin, enamel and porcelain

Dr. Fransman then showed an extraordinarily beautiful restoration of a molar PBM crown access with perfect color and anatomy – his case - truly a work of art!

For further information about restoration of endodontically treated teeth, Schwartz refers us to his article: Post placement and restoration of endodontically treated teeth: a literature review. JOE 2004 May; 30(5):289-301

Are Endodontically treated teeth different than “vital” teeth?
Some studies say yes, others say no.

- Mulvey and Abbott Aust Dent J. 1996 Apr; 41(2):134-9 as well as Hachmeister et al Oper Dent 2002 May-Jun; 27(3):254-8 showed that restoration of the access opening of a crown restored the original crown retention values.

Do Endodontically Treated teeth fracture more often?
Some studies say yes

- Finnis et al Int J Prosthodont 2002 Nov-Dec; 15(6):559-63 (surveyed cusp fractures in 46,000 patients)

The Endodontist’s perspective is that Cuspal coverage is the most important restorative factor in the survival of endodontically treated teeth. Endodontically treated teeth with cuspal coverage had six times greater rate of survival.

- Aquino et al. - J Prosthet Dent 2002 Mar; 87(3):256-63
- The 3 year survival rate of teeth without cuspal coverage was 36%
- Nagasiri and Chitmongkolsuk - J Prosthet Dent 2005 Feb;93(2):164-70

The research also shows the following when it comes to restring the tooth after endo:
1. Coronal tooth structure should be preserved
2. Radicular tooth structure should be preserved – if possible the canal should not be enlarged after the Endo treatment.

3. The length of the post should be at least equal to the length of the crown coronal to the bone

4. At least 4 mm of gutta percha should be left apically

5. None of the posts tested (metal, fiber and ceramic posts) made the teeth more resistant to fracture than the controls. There was no difference in failure modes.

6. Posts are associated with higher occurrences of fractures and failure in general

7. Therefore, only use a post when absolutely necessary to retain a core.

**Important Post Principles**

- Retention and resistance form
- Failure mode
- Preservation of tooth structure
- The Ferrule Effect
- Retrievability

**Prognosis for teeth with Posts**

  - 316 metal posts tested, 10 years or more -> 82% success
- Torsboe and Thorsen 1993:0:49-51
  - 788 teeth with metal posts, 5 years or more , 2.1% failure per year
  - Metal posts- mean survival of 17.4 years
  - Cast gold posts, 10 years or more , 9 failures out of 138 teeth
  - Teeth with post and crowns vs. crowns only. 25 years, No difference in survival rates, 83% of pulps remained vital

Fransman then showed several research papers that suggested the failure rate for fiber posts was generally found to be around between 1.7 to 7.7%

Schwartz named off all the post materials but suggested that Titanium alloys, ceramic and zirconium alloys should be avoided because or fractures.

**Which are better metal or fiber posts?**

Schwartz listed 4 or 5 papers supporting each kind- and then another 5 papers that said it made NO difference. So there is no consensus in the research as to which is better.

Fiber posts have been shown to be better in failure “mode”- i.e. / how they break and where they break - they generally are easier to deal with and cause less problems. During cyclic loading metal and fiber posts undergo similar process of cement failure. Metal posts have the highest failure load, ceramic the lowest. Fiber post had the most favorable fracture patterns upon failure. Fewer root fractures occur with fiber posts and composite BUT they have more caries associated with them.

**Questions about Fiber Posts**

1. Is radicular dentin different?
   - There are fewer tubules than in coronal dentin
   - It forms a thinner hybrid layer than coronal dentin

2. Is it a problem to bond to radicular dentin?
   - Research showed both higher and lower bond strengths and no difference -> No consensus

3. Do bonded posts strengthen teeth?
   - Research shows both higher and lower bond strengths and no difference -> No consensus

4. Is it beneficial if the post has the same Modulus of Elasticity as dentin?

5. What is the affect of thermocycling and cyclic loading?

**Other findings:**

- Glass Ionomer materials lack adequate strength to be buildup materials.
  - **If you use amalgam, bond it** - it needs 2 layers of DBA. Cure only the first layer. Use dual cure or chemical cure material.
- Pretreatment of fiber posts with Hydrogen peroxide or sodium ethoxide and silane improves the bond to dentin.
- Some research says Air abrasion improves the retention of fiber posts – others say it denatures the fiber post because of the possible introduction of foreign materials that can cause micro cracks.

**FINAL CONCLUSIONS**

- Avoid bacterial contamination of the root canal system – ALWAYS USE RUBBER DAM!! That includes POST PLACEMENT and core construction!
- Provide cuspal coverage for posterior teeth
- Preserve radicular and coronal tooth structure
- Use posts with adequate strength in thin diameters
- Provide adequate post length for retention
- Maximize resistance form including adequate ferrule
- Use posts that are retrievable
- Avoid titanium, zirconium and ceramic posts
- Use metal when minimal tooth structure remains
- The literature is cautiously favorable toward fiber posts, but the jury is still out.
Dr. Pierre Machtou  
Paris France  
Irrigation: Controversies and Facts

Dr. Machtou first acknowledged the previous presenters and their discussions of irrigation. He offered his clinical insights as to the possibilities for irrigation today.

Controversies in Irrigation – Machtou points out that we really don’t agree about much of the protocol:
1. Types of Solutions?
2. Concentrations?
3. Combinations?
4. Ultra-Sound Activation?
5. Heating?

NaOCl
- has antibacterial and Solvent Effects
- but has a level of cytotoxicity as well
- we don’t know what the best concentration

Evidence Based Dentistry (EBD)
Machtou believes that EBD is the intersection of three circles of influence:
1. Patient (preferences) 2. Dentist (expertise) and 3. Literature (evidence)
EBD is: “The integration of the best research evidence with clinical expertise and patient values” Sackett et al 2000. Machtou says that the clinical experience of the operator is very important (the main factor).

Dr. Machtou does not like the term “Apical Periodontitis” (AP). When we use the term “periodontitis”, it can be confused with periodontology. And when we use the term “Apical” we limit the location of the radiolucency to the area around the apical portion of the root. There is also no mention of the origin of the lesion when using the term AP. He prefers Schilder’s term Lesions of Endodontic Origin (LEO) or more precisely Periradicular Inflammation of Endodontic Origin (PIED).

The goal of treatment is to remove this infection and eradicate the bacteria (Sjogren et al 1997). We then neutralize the root canal system with a good 3D filling to isolate the Peridontium from the oral environment. It is critical (as we have see in other presentations) to place a tightly sealing coronal restoration as soon as possible after completion of Endo treatment.

- Byström & Sundqvist 1981 (studied impact of each stage of cleaning and shaping on outcomes. They used hand instrumentation and saline.)
- Dalton et al 1998 repeated Byström & Sundqvist’s 1981 study but this time using hand instrumentation and saline. They got the same results – saying that there was no difference between hand instrumentation and rotary instrumentation.

Dr. Machtou thinks that this conclusion is misleading because the focus of the research was on instrumentation, without considering the effects of their irrigation protocol on the results.

We know that the main action of irrigation is to flush out debris. This important action and compliments the act of instrumentation. Baker et al J OE 1975
- Siquera et al J OE 1999 said that it was “the combined effects of instrumentation AND irrigation that cause a significant decrease in bacterial cell numbers in the root canal.”
Endodontic research then moved to the concept of “Chemomechanical Preparation” where the researchers used NaOCl instead of saline.
- Byström & Sundqvist 1983 used 0.5% NaOCl (Hand Inst.) – much better efficiency than saline
- Byström & Sundqvist 1985 used 0.5% NaOCl or 5% NaOCl +EDTA (Hand Inst.) - surprisingly, they did not find any difference between the different concentrations. It was difficult to understand why a weaker solution would give the same results as the stronger solution. They theorized that the action of the EDTA on the smear layer permitted the weaker solution to be just as efficient.
- Shuping et al 2000 used 1.25% NaOCl (Rotary Inst.) - got the same result as Byström & Sundqvist 1983
- Siquera et al J OE 1999 used 1%, 2.5%, 5.25% NaOCl (Hand Inst.)

From these studies we can conclude that the by using either hand or rotary instrumentation – we can get the same results when the same solutions are used.

- Dalton et al J OE 1998 – Bacterial Reduction with NiTi Rotary Instrumentation
  - 48 patients, Mandib. Premolar and MB of molars
  - Used saline, manual step back vs. Profile .04 – 3 bacterial samples
  - Concluded- No significant difference in intracanal bacterial reduction was detected between hand and rotary instrumentation (negative samples 28%). Substantial reduction was achieved with progressive filing regardless of the file type. The larger we make the canals the greater the reduction of the bacteria.
- Shuping et al J OE 2000 – Bacterial Reduction with NiTi Rotary Instrumentation and Various Medications
  - 42 patients, Mandib. Premolar and MB of molars
  - Used 1.25% NaOCl, Profile .04, and Ca(OH)2/5 bacterial samples
  - Concluded- NaOCl irrigation with rotary instrumentation is an important step in the reduction of intracanal bacteria (negative samples 61.9%) significant difference in intracanal bacterial reduction was detected between hand and rotary instrumentation (negative samples 28%). Substantial reduction was achieved with progressive filing regardless of the file type.

The increase in size of the NiTi rotary files and one week use of Ca(OH)2 intra canal medication significantly reduce bacteria from infected canals (negative samples 92.5%).
- Card et al J OE 2002 – The effectiveness of Increased Apical Enlargement in Reducing Intracanal Bacteria
  - 40 patients, Cuspids, Mandib. Premolar and MB of mandib. Molars
  - Profile .04 to 60 on single rooted teeth and 45 on molars
  - Light Speed to size 80 in single rooted teeth and 60 on molars
  - Used 1% NaOCl
Bacteria can be found in 2 forms:

- Clinically relevant
- Biofilms

Machtou believes that instead of thinking in terms of apical enlargement, it should be better to think of the canals themselves. The more we enlarge the canal system – the more we seem to be able to reduce bacterial levels. He then discussed these results in detail:

- The trend toward increase the size of the apical preparation was shown in Baugh & Wallace JOE 2005. The role of apical instrumentation in root canal treatment: a review of the literature.

Machtou said that larger apical preparations evolved because of the concern about bacteria in the dentinal tubules and not just in the canals themselves. The more we enlarge the canal system – the more we seem to be able to reduce bacterial levels. He then discussed these results in detail:

- The association between the size of the apical preparation and bacterial levels is evident in many studies. For example, in Molven et al Endod Traumatol 1991, it was shown that larger apical preparations were associated with lower bacterial counts.

Machtou says that Apical Patency is a controversial issue but that in infected teeth it is a critical factor. Routine patency checks and the use of patency files were first advocated by Schilder in his classic Dent. Clin of N. Am articles. Because each time we clean the canal system, we expect to remove these bacteria mechanically and by irrigation. But they are often difficult to remove, especially in the isthmus areas.

Many studies (e.g. Peters et al IEJ 2001) have shown that large amounts of canal remain uninstrumented. In this study it was 35%. This results in a lot of biofilm remaining. BUT when shaping procedures are carefully carried out (he showed 3D reconstructions of canals shaped by himself and Ruddle) very little canal surface was left untouched – less than 10% (with the exception of an isthmus area in the apical third). It is possible to do this with a crown down approach. If we use a "pre-enlargement" technique we can address these areas.

**Bacteria can be found in 2 forms:**

- **Planktonic state:** a freed suspension, easily removed during cleaning and shaping procedures
- **Biofilms:** mostly found on the canal walls – we expect to remove these bacteria mechanically and by irrigation. But they are difficult to remove, especially in the isthmus areas.

Many studies (e.g. Peters et al IEJ 2001) have shown that large amounts of canal remain uninstrumented. In this study it was 35%. This results in a lot of biofilm remaining. BUT when shaping procedures are carefully carried out (he showed 3D reconstructions of canals shaped by himself and Ruddle) very little canal surface was left untouched – less than 10% (with the exception of an isthmus area in the apical third). It is possible to do this with a crown down approach. If we use a "pre-enlargement" technique we can address these areas.

**Patency**

Machtou says that Apical Patency is a controversial issue but that in infected teeth it is a critical factor. Routine patency checks and the use of patency files were first advocated by Schilder in his classic Dent. Clin of N. Am articles. Because each time we use a patency file between an active or working file we:

- Confirm the end of the canal is not blocked
- Stir debris into solution
- Move fresh irrigant into the apical 2mm
This does not mean that we will place all files to the point of patency. Use of patency files in this way does not transport large amounts of bacteria into the apical area because the file sizes are very small and the files are only placed a very small distance past the foramen when checking patency. We shape “behind” (coronal to) this file. This means that the subsequent files are placed to a level coronal to this file and NOT at the level of the patency check.

Machtou points out that the main entity responsible for the periapical tissue repair is the PDL, therefore it does not matter whether or not the pulp stump is removed by the patency files. [Sequeira JF - Endodontic Topics 2005] Machtou insists that use of the patency file is very important for the elimination of procedural errors.

Machtou said that there are two main factors that affect the successful outcome of treatment and that these had been confirmed by the results of the Toronto Study (Faranzeh et al J OE 2004 – part 2 of the study) and Marquis et al J OE 2006 - part 3 of the study). They are:

1. The presence of apical periodontitis prior to treatment
2. Treatment Technique (The Schilder technique was significantly more efficient regarding the outcome). Machtou says that this shows that treatment technique and operator proficiency have a great influence on the results and are important factors.

Chugal et al OOO 2003 - Endodontic infection: some biologic and treatment factors affecting outcome. In infected teeth, each mm lost in working length decreases the rate of success by 49%. Therefore Machtou asks “Why do we choose to work short?”

John West (Boston U Thesis) asked Oral Surgeons to send him extracted, previously Endo treated teeth. After discarding perioc involved and other non endo related failures he cleared the 95 sample teeth. In 100 % of the cases, he found at least one POE had not been cleaned and filled. Most of the cases had one thing in common -> blockage of the apical portion of the canal by dentin mud – not allowing for cleaning and filling of the complex apical anatomy.

Irrigation has two main objectives:

1. Mechanical Effects
   - Flush or loosen debris
   - Lubricate the dentinal Walls
2. Chemical Effects
   - Have antibacterial effectiveness
   - Dissolve organic matter
   - Prefer to have limited or No cytotoxicity (to patient tissues)

Machtou says that while literally hundreds of papers have been written about the chemical effects of irrigation solutions, very few have focused on the most important aspects of penetration and exchange of these solutions – the DYNAMICS of irrigation. Because even the most powerful solution will be useless if it cannot penetrate the apical portions of the canal where it can dissolve the tissues and it also needs to be exchanged frequently for best effect.

NaOCL as a Tissue Solvent

Noenni et al JOE 2004 - Soft Tissue Dissolution capacity of currently used and potential Endodontic Irrigants. They used 1%/wt/vol NaOCl, 10% Chlorhexidine (CHX), 3% and 30% Hydrogen Peroxide (H2O2) , 10% peracetic acid, 5% dichloroisocyanurate (a.k.a. hypochlorous acid) (NaDCC) and 10% citric acid. Results: None of the test solutions except for NaOCl had any substantial tissue dissolution capacity. It was concluded that this might be important when considering the use of irrigants other than NaOCl.

Machtou showed a video recreation of Grossman’s 1943 pulp dissolution experiment. (Broached pulps dissolving in a glass of NaOCl.)

Why is NaOCl such a good tissue solvent, as seen in this experiment?

Two reasons:
1. We have a lot of available chloride in the solution that is in the glass
2. We have perfect contact of the solutions with the pulp. They are literally swimming in the NaOCl.

Therefore, in order to try to get similar results in treatment, the NaOCL solution needs to have as much contact with the pulp tissue as possible AND the solutions need to be exchanged frequently to keep the levels of available chloride at maximum.

NaOCL Solvent Action - 4 main factors:
1. Large amounts necessary (The, 1979)
2. Contact with the Tissue (Trepagnier, 1977)
3. Mechanically agitated (Moorer, 1982)
4. Exchanged ( Baumgartner & Cuenin, 1992)

The Most Important Factor - Irrigation Dynamics

- Canal Size and Irritant Penetration
Machtou said that although the initial research was done in the 70 and 80s (Ram 1977, Moser & Heuer 1982, Abou-Rass 1982 and Chow 1983) he was pleased to see newer research in this area: Sedgley et al 2005 and van der Sluts et al 2006. They concluded that if we want to get good irrigation we should use thin needles or enlarge the RCS in order to facilitate the penetration of the needle or both. Machtou says that this is NOT the best way to irrigate the RCS.

Machtou says that the recent excellent paper by Zehnder’s (J OE 2006) is a paper about irrigants but not about IRRIGATION. He disagrees with the recommendation that the apical sizes be enlarged to a minimum size 35 (for adequate penetration and exchange of NaOCl). He believes he can do this without such enlargement.
Sequeira et al 1997 used 5 different preparation techniques with different apical sizes. They concluded that “None of the five instrumentation techniques (Step back to #25, Step Back + NiTi files to #25, US Technique #30, Roane to #40, Canal Master to #32.5) totally debrided the entire RCS, especially when variations in the internal anatomy were present.” Machtou says that this study shows no matter what apical size you select – the apex is not perfectly cleaned.

In another Sequeira et al study in 2002, 4 different methods and solutions (NaOCl, Citric Acid, and CHX) to instrument canals (1. ARM – Alternating Rotary Method i.e./watch winding and GT Rotary Files) and a control. They were used to test the bacterial reduction of preparation techniques. They concluded that “There was no significant difference between the experimental groups. All of them were significantly more effective than the control group. They recognized the importance of using antimicrobial irrigants, regardless of the solutions or instrumentation techniques used.

Machtou concludes that using different apical sizes and different irrigants makes no difference in the final results.

Instruments shape, Irrigants Clean (Baumgartner & Mader 1987)

Instruments create space inside the RCS in order to allow penetration of the irrigants. Machtou is NOT concerned about smear layer removal. Why? – Because he says that this occurs where the instruments have already worked. So, if we have “already been there”, it should be easy to remove the smear layer at this location.

Machtou then showed a crude experiment in a standard “plastic block simulated canal”. (Pierre said that if you wish to use plastic blocks in experiments it is important to plug the apical foramen with wax in order to simulate the PDL – leaving the apex open prevents air bubble formation at the apex and this is NOT similar to the PDL. i.e./ bubbles DO form in vitro and we have to simulate this as well). He used red dye to illustrate that even with the first scouting file: it was possible to get the dried irrigation solution to the apex. When we deliver irrigating solution into a canal with the irrigating tip alone- the solution does not move more than 1 mm beyond the length of the tip. The more we shape the canal system, the further the solution can be placed into the canal. Irrigation is therefore only efficient at the END of the cleaning and shaping procedure. That is the only time that we can completely exchange the solution at the apex.

It is also important to use an “up and down” motion with the needle. Thin needles are NOT used to get the needle tip further down the canal!! They are used because we need “reflux space” between the needle and the canal wall. The needle is always free in the canal. It is possible to exchange solutions in this way - even in lateral canals.

Yana, Y. Thesis - Boston University 1989. – In vivo comparison of NaOCl in RCS during cleaning and shaping procedures using BU technique and sonic instrumentation. The objective was assessment of irrigant penetration and exchange. 60 canals from vital teeth. 4 groups of 15 canals from anterior and posterior teeth. 23 gauge needles, Hypaque (a radio-opaque solution with similar properties to that of NaOCl and NaOCl). Each time he irrigated, Yana took a film – 21 possible radiographs per canal. Both techniques were compared with NaOCl and Hypaque irrigating media. After WL was achieved, the canal was irrigated and he found that the irrigant only traveled one mm or so further than the tip. (As in Machtou’s plastic block experiment). Yana referred to this as “Passive Irrigation”. Using a pre-bent #15 K file he was able to move Hypaque to the WL. Using the files with the irrigation in this manner gives us “Dynamic” or “Active” irrigation.

(Although it appears that the placement of the instrument into the canal space moves the solution down the canal, Machtou says this is not entirely true. It is not the placement of the file (which merely displaces the irrigant in the canal) it is the movement of the file in and out of the canal that carries the solution apically. Machtou points out that it is only possible to create these conditions IF we have a 4 walled access cavity with a sufficient reservoir of irrigant in the chamber. If we do not reconstruct the lost tooth material prior to treatment – we lose the advantage of having this reservoir of fresh solution and that makes Active irrigation impossible to achieve.)

Yana continued to shape the canals using the standard BU cleaning and shaping technique and was able to get a #25 to WL. Without further work on the apical “deep shape” he still was not able to get passive irrigation to move the Hypaque to the apex. After working on the deep shape and apical finishing, finally he could achieve this. Furthermore, once this occurred, the proper shape allowed him to completely exchange the Hypaque irrigant with NaOCl – yielding a canal with no radio-opaque material in it after NaOCl rinse. Tapered preparations are integral to this process because they create a better hydraulic circuit.

Klinghofer, A. Thesis - Boston University 1990 duplicated and confirmed Yana’s research but this time on necrotic teeth. She showed that it was possible to involve the lateral canals in properly shaped necrotic teeth. She was able to demonstrate that if no mistakes are made during canal irrigation (i.e./ clog the needle) then if we inject solution without pressure, there is no risk in immature teeth or wide open apices of extruding the irrigant beyond the tip of the root.

Sequeira et al 2000 - concluded that there was no significant difference between 1%, 2.5% and 5.25% NaOCl solutions tested with respect to reduction of bacterial population after instrumentation. A regular exchange and the use of large amounts of irrigant is possible to exchange solutions in this way – even in lateral canals.

Cunningham et al 1999 studied the antibacterial capability of NaOCl at different temperatures. They found that 2.6% NaOCl at 37 degrees C had the same collagen dissolving ability as 5.25% at 20 degrees C.

But for heated solutions, because the antibacterial elements in NaOCl (the available OCI- (the anion hypochlorite) and HOCI (hypochlorous acid). In weaker solutions are more quickly dissipated by evaporation - we have to change them more frequently than more concentrated solutions at lower temperatures. The solutions we get at the store (bleach) are mostly hypochlorite and contain little hypochlorous acid.

Heating Solutions?

Temperature optimizes all chemical resections. Should we heat NaOCl? Machtou says “Yes”. He uses a “Coffee Warmer” technique in which a glass beaker is filled with NaOCl and set on a coffee warming device. The irrigants are aspirated into the irrigation syringes from this warmed source.

Berutti et al 1996 did a study of the debridement capability of NaOCl at different temperatures. They found that 2.6% NaOCl at 37 degrees C had the same collagen dissolving ability as 5.25% at 20 degrees C.

For heated solutions, because the antibacterial elements in NaOCl (the available OCI- (the anion hypochlorite) and HOCI (hypochlorous acid). In weaker solutions are more quickly dissipated by evaporation - we have to change them more frequently than more concentrated solutions at lower temperatures. The solutions we get at the store (bleach) are mostly hypochlorite and contain little hypochlorous acid.
Circuits and complete canal irrigation to length can be obtained.

Volumes of solution needed. By increasing the volumes during the final flushing sequence, there is an increase in the hydraulic RCS is possible. Further studies are being done to assess the 

Machtou uses the UltraDent Navi-Tips (Yellow 29 gauge). He recommends the use of smaller syringes (Monoject 3 cc) with these tips. 

Irrigation – 

Irrigation we use combine and this can be dangerous. If you use the smaller Monject syringe, the solution will be safely ejected from the syringe into the canal and this can be dangerous. If you use the smaller Monject syringe, the solution will be safely ejected from the syringe into the canal. 

F3. At that point the third could not be rinsed with Passive Irrigation. He then 

instruments as before and to length (up to a size F1) only 

by agitating the solution with a master gutta percha cone 

replenished irrigation to the apex. In his clinical technique 

patency files) in this manner predictably moved and 

40 extracted Mandibular molars. 4 groups Size 20, 25, 30 and 35 with .06 taper. 2 ml of 5.25 % NaOCl & 27 gauge needle. Final flush images were sufficient to demonstrate that no Hypaque was left in the RCS. Measurements of the extent of Passive and active irrigation were made using digital subtraction. (Adobe Photoshop and Image J) The instrumentation sequence included final shaping with F1 to the apex, F2 .5 mm short and F3 1 mm short to get deep shape. 

Machtou says that the larger apical size was required to achieve the desired results. 

because they were using a .06 rather than a .10 taper, as he recommends. 

Brennec, F. (MS Thesis Paris 2004 to be published- done with Machtou) studied the "Dynamics of irrigation during the cleaning and shaping of curved root canals with the ProTaper system. " 30 MB curved and S curved canals of extracted mandibular and maxillary 

.10 taper, as he recommends. 

Machtou says that the larger apical size was required to achieve the desired results because they were using a .06 rather than a .10 taper, as he recommends. 

Machtou adds that unshaped canals cannot be disinfected. 

Similarly, Albretch et al | JOE 2004 stated: "When a taper of .10 can be produced at the apical extent of the canal when a suitable coronal taper is achieved to allow satisfactory irrigation of the RCS with antimicrobial agents."

Yared et al | JOE 1994 - duplicated Ostravik's initial study on apical enlargement. They found: "No statistically significant difference was noted between the size 25 and 40 file groups after instrumentation and after 1 week of CaOH dressing." 

Khadiem et al | JOE 2996 performed a study of minimum instrumentation size for penetration of irrigants in the apical third of the RCS. 40 extracted mandibular molars. 4 groups Size 20, 25, 30 and 35 with .06 taper. 2 ml of 5.25 % NaOCl & 27 gauge needle. Final flush 17% EDTA for 5 min/canal and 5.25 % NaOCl for 5 min. SEM evaluation. They concluded: Based on the results, it appears that the minimum instrumentation size needed for the penetration of irrigants to the apical third of the RCS is a #30 file. 

Machtou says that the larger apical size was required to achieve the desired results because they were using a .06 rather than a .10 taper, as he recommends. 

Machtou then showed a profile image of the canal and superimposed colored images of the levels of penetration of the irrigants when used with Active Irrigation. The scouting files managed to get irrigation to the apex but subsequent use of ProTapers showed increasing ability to get irrigants to the apex as the canals were shaped and instruments re-introduced: S1 (coronal 2/3-> much better), S5 (better), S1 to length (perfect) , S2 to length (perfect), F1 to length (perfect). He concluded that use of files (and patency files) in this manner predictably moved and replenished irrigation to the apex. In his clinical technique Machtou supplements movement of the solution to the apex by agitating the solution with a master gutta percha cone placed to the apex. This not only results in better cleaning of the main canal but the pumping action allows entrance of the solution into lateral canals as well. 

The same procedure was repeated in the experiment, this time using Passive Irrigation. Even with insertion of all the instruments as before and to length (up to a size F1) only 

approximately 70% of the canal was irrigated and the apical third could not be rinsed with Passive Irrigation. He then increased the size of the apical preparations with size F2 and F3. At that point Passive Irrigation levels were greatly improved (to 95% of the length of the RCS). Although we want to use as much Active Irrigation as possible for best results, it is the deep shaping that allows the solution to reach the apex, even when Passive Irrigation is used. Therefore, we can conclude that during irrigation we use combine Active Irrigation and Passive Irrigation - and that when proper deep shape is achieved (with .10 taper), full access to the apical portions of the RCS is possible. Further studies are being done to assess the volumes of solution needed. By increasing the volumes during the final flushing sequence, there is an increase in the hydraulic circuits and complete canal irrigation to length can be obtained. 

Conclusions of this Study 

- For active irrigation penetration is complete from S2 use 
- Passive irrigation penetration increases after each instrument utilization 
- Passive irrigation penetration improves with apical taper increase but involves partly the last 2 mms 
- Patency files improve penetration & exchange of irrigant 
- Mechanical agitation improves the penetration & exchange of irrigant in the last few apical mms. 
- Volume of irrigant during the final flush enhances the penetration of passive irrigation 
- Anatomical factors (length and curvature) are not limiting factors for the penetration & exchange of irrigation.

The importance of a tapered canal preparation is confirmed. 

Machtou uses the UltraDent Navi-Tips (Yellow 29 gauge). He recommends the use of smaller syringes (Monoject 3 cc) with these tips. If you use larger syringes and press hard on the plunger, significant pressure can be developed as the solution moves through the tip and this can be dangerous. If you use the smaller Monoject syringe, the solution will be safely ejected from the syringe into the canal.
Zhang and Torabinejad (JOE 2003) evaluated the cytotoxicity of MTAD. MTAD (Biopure) had previously shown good cleaning results. The SEMs showed good cleaning results. Irrigant activation and used a SEM. They studied the effects of agitation of the master cone with irrigation as he had developed a model to assess the cleaning efficiency of the apical few mm of curved canals using 3 different modalities of irrigation.

One of Machtou’s students, G. Charon (2006), did some recent work at the School of Chemistry in Paris. They have been using Sybron’s Smear Clear or Septodont’s version of EDTA. Alternating the solutions is a good idea since it actually decreases the effectiveness of NaOCl. Machtou prefers to use Sybron’s Smear Clear or Septodont’s version of EDTA.

We now recognize 3 objectives that are required to obtain the best irrigation:
1. Intracanal Delivery
2. Intracanal Aspiration
3. Activation (Agitation)

Fukumoto et al. (IEJ 2006) produced an in vitro device that introduced a separate canal and suction into the canal space. They delivered the solution in the coronal area and aspirated it out using the apically positioned tube. This created a very efficient hydraulic circuit. They found there was no need to place the irrigating tip close to the apex. (In fact, when they reversed the configuration (aspiration in coronal aspect, delivery at apex) they got a lot of extrusion.)

**Activation of Solutions**

Methods:
1. Mechanical – agitating the master cone in the canal space for 1 minute using EDTA – then followed with NaOCl rinse. Machtou showed that this worked in plastic blocks. Even when the apical foramen was sealed with resin and an apical air bubble was intentionally introduced at the start, the solution could be easily distributed to the apex and lateral canals by GP cone agitation and pumping with a master cone.
2. Hydrodynamic – RinseEndo by Durr. This device is a mechanical automatic delivery/aspirator system. Machtou points out that deeper placement of the tip actually creates LESS efficiency in the apical and lateral areas and that it is best left in the straight portions of the canal. The needle has a 7 mm groove to allow flowback of the irrigating solution.
3. Sonics - Machtou and Ruddle have developed the EndoActivator - a wireless sonic handpiece device that uses a nylon tip to activate the solution. Studies are currently being done in 7 universities to assess the efficiency of the device.
4. Ultrasound
   - Gutats et al. (JOE 2005) attached a 20 gauge needle to a Min-Endo Ultrasonic unit, used at full power. They showed impressive isthmus and apical cleaning. However Machtou said that the study had a lot of flaws:
     - Used “unrestorable teeth”
     - Used GG burs 1-5 on MB canal of mandibular molars
     - Used GG series (30 tip) in a decreasing manner
     - Used GG accessory 35/12 50/12 and 70.12 instruments! (Machtou said he was skeptical of the shapes of these canals!)
   - Full power ultrasonics
Machtou also has some serious questions as to whether ultrasonics are as effective as we think they are. When we see debris in solution, is this the result of the tip contacting the canal or loosening biofilm debris? Or do the results occur because of the heating action of the ultrasonics on the solution? Van der Sluts et al. (IEJ 2005) placed an ultrasonically activated smooth wire or K file 1 mm from the apex removed debris from an artificially created groove in the canal walls of resin blocks. Machtou said that he is not in favor of using any ultrasonically activated metal instrument that close to the apex. He feels metal contact can create more smear layer.

**Laser**

Chelating Agents

Huismann et al (IEJ 2003) and Zehnder (JOE 2005) are good reviews of chelating agents. Gräwehr et al (IEJ 2003) studied the interaction of EDTA and NaOCl in aqueous solutions. They concluded: “EDTA retained its calcium complexing ability when mixed with NaOCl but EDTA caused NaOCl to lose its tissue dissolving capacity and virtually no chlorine was detected in the combinations. Copious amounts of NaOCl should be used to wash out the remnants of EDTA.” Machtou says that alternating the solutions is not a good idea since it actually decreases the effectiveness of the NaOCl. Machtou prefers to use Sybron’s Smear Clear or Septodont’s version of EDTA.

One of Machtou’s students, G. Charon (2006), did some recent work at the School of Chemistry in Paris. They have developed a model to assess the cleaning efficiency of the apical few mm of curved canals using 3 different modalities of irrigant activation and used a SEM. They studied the effects of agitation of the master cone with irrigation as he had previously shown. The SEMs showed good cleaning results.

**MTAD (Biopure)**

Zhang and Torabinejad (JOE 2003) evaluated the cytotoxicity of MTAD.
- Removes the smear layer
- Residual antimicrobial action
- Used as a final rinse after 1.3% NaOCl
- No solvent action on organic tissue

In this paper they decreased the NaOCl to 1.3% and said that MTAD was less cytotoxic than 5.25% NaOCl but more cytotoxic than 2.25% NaOCl. The rationale behind the use of MTAD was to limit the erosion of the peritubular dentin that was caused by using EDTA solutions. When comparing the SEM results obtained with NaOCl 5.25% + EDTA and NaOCl 5.25% + MTAD (used for 2 minutes), we find no difference. However the written instructions that come with MTAD say that is should be used as a 5 minute rinse (a long time!).
Tay et al JOE 2006 examined the ultrastructure of smear layer covered intra-tubular dentin after irrigation with MTAD. They concluded that MTAD is comparatively more aggressive in demineralizing intact intraradicular dentin, exposing demineralizing collagen matrices that were 1.5 to 2 times as thick as those produced by EDTA.

Tay et al JOE 2006 showed that use of MTAD had the potential for iatrogenic staining of the root.

Ruff et al JOE 2006 showed MTAD had no antifungal properties.

Dunavant et al JOE 2006 tested 1% and 6% NaOCL, 2% CHX, REDTA and MTAD. They concluded that both 1% and 6% NaOCL were more efficient in eliminating E. faecalis biofilms than the other solutions tested.

Cleeg et al JOE 2006 tested 1%, 3% and 6% NaOCL, 2% CHX, and 1% NaOCL/MTAD. They concluded that 6% NaOCL was the only solution capable of rendering the bacteria nonviable and physically removing biofilms.

**Chlorhexidine (CHX)**
- No cytotoxicity.
  - Not cytotoxic at .02% topical skin application. But IS cytotoxic at the 2% level we use in canals.
- Residual antimicrobial action
- No Solvent Action
- Less effective on Gram (-) bacteria.
  - This is important to recognize because many often studies with CX have used E Faecalis - which is Gram (+). This means that it is not generally that effective in primary AP cases.
- Produces a brownish precipitate when mixed with NaOCL

CHX 2% is basically used a FINAL FLUSH after NaOCl and as a INTRACANAL MEDICATION.

Machtou asks “Why do we continue to search for something else when we already have the most efficient, economical, easy to use product available to us – NaOCl? It is still the best.”

**HealOzone**

Machtou said that he was amused that Ozone was now being discussed and used by some groups of clinicians in 2006, considering that the French did research on it back in the 1960s. He said that although they used poor cleaning and shaping techniques back then, they found that application of Ozone did nothing. (Deltour et al Rev. Odontosomatol. 1970 (French)) Machtou said that Ozone has been completely discarded.

**Machtou’s Irrigation Protocol**

We need to avoid a complicated irrigation protocol; we need to keep it simple with a minimum number of instruments and a lot of solution.

**Irrigant Stage**

Glyde or File Eze (Canal Lubricant) – for scouting narrow canals

Initial Negotiation

NaOCl 1-2.5% (Heated) 2ml/canal approx until the canal liquid is clear of debris
Aspirate remnants of NaOCl

Crown Down Shaping

Liquid EDTA 2 ml or enough to fill the canal – activated with the master cone for 1 minute (timed)
Final Flush

NaOCl 1-2.5% - to remove EDTA – no activation
Final Flush

**Dr. Arie Jan van Winkelhoff**

Amsterdam, Netherlands

**Antibiotics and Endodontics**

**Back to the Roots**

Dr. van Winkelhoff’s background is in Medical Microbiology and Immunology. He did his PhD on black pigmented bacteria in periodontitis and root canal infections. He is currently chairman of the Dept. of Oral Biology and head of the Laboratory for Clinical Oral Biology at ACTA. The tests for the presence and levels of periopathogens in patient samples, performs susceptibility tests, analyzes Endodontic samples and provides therapy advice relating to the use of antibiotics.

**The Three Steps in Dentistry at Dr. van Winkelhoff’s Lab**

1. Diagnosis -> 2. Infection Control -> 3. Regeneration and Repair

1. Diagnosis –
   - a. Medical anamnesis
   - b. Clinical Parameters
   - c. X ray Images
   - d. Microbiology
   - e. Genetics

This is a very important phase. The better your diagnosis, the better you can choose which infection control measures you need to take.

2. Infection Control – the quality of the infection control phase is dependent on the quality of the diagnosis
   - a. Mechanical Tx
   - b. Antiseptics
   - c. Antibiotics
d. Surgery
   - e. Control microtest

3. Regeneration and Repair
   - a. Bone regeneration
   - b. Implants
   - c. Mucogingival Surgery
d. Orthodontics
Dr. van Winkelhoff’s lab does Antibiotic susceptibility tests using a disc/agar diffusion method. It is also one of the few that still does anaerobic cultures. Molecular diagnostics have become the main tool for diagnostics in his lab. Robots and mechanical methods are used to isolate the bacterial DNA. A real time PCR (Polymerized Chain Reaction) machine multiplies these small pieces of DNA to allow closer examination. The read out shows the different pathogens and the differing amounts in which they occur. This has changed the way we look at endodontic microbiology because the technique is more sensitive and specific than past methods. It can also detect dead bacteria.

Dr. van Winkelhoff is most famous in the Endodontic world for providing us with our own specific bacteria - Porphyromonas (Bacteroides) Endodontalis.

- Van Winkelhoff et al Infect Immun 1985 Sep 49(3) 494-7 Bacteroides Endodontalis. And other black pigmented Bacteroides species in endodontic abscesses.
- Van Winkelhoff et al  Serological characterization of black-pigmented Bacteroides Endodontalis Infect Immun 1986 Mar 51(3) 972-4
- Van Winkelhoff et al J Clin Microbiol 1985 Jul 22 (1) 75-8 Further characterization of Bacteroides Endodontalis. an asaccharolytic black-pigmented Bacteroides species from the Oral Cavity
- Van Winkelhoff et al JOE 1992 Sep 18(9) 431-4 Porphyromonas (Bacteroides) Endodontalis: its role in endodontal infections

More recently his studies have focused more on periodontally related pathology. He says that while the endodontic infections that we are treating are in relatively close in physical proximity to periodontal pockets, they are quite different.

Dr. van Winkelhoff says that medically, periodontitis and AP infections are unique in that they are generally:
- Multi-species infections
- Chronic
- Treatment is based on mechanical biofilm removal with additional chemical decontamination
- Surgery

Other characteristics shared by both Periodontitis marginalis (Perio Disease) and Periodontitis Apicais (AP)
- Biofilm Infection
- Mixed non-specific infection
- Large contribution of strict anaerobes
- Gram positive and Gram negative bacteria
- Spirochetes

Dr. van Winkelhoff says the complex microflora of the infection has consequences. As a microbiologist he regards the problem as one that occurs due to lack of integrity or seal of the body - conditions in the outside "hostile" world have allowed ingress into the inner "friendly" world of the body. This is basically a very complicated matter – almost non treatable. The invasion of this microorganism into the body results in the inflammatory process - production of Cytokines/chemokines, PGE2 and Osteoclast activation. It is our job to control this process and reverse the results of the infection. 

We also must deal with biofilms, which Dr. van Winkelhoff says are one of the most difficult challenges. In most cases, it is very difficult to treat. For example, in medicine when pacemaker wires or prosthetics become infected with biofilms, they are simply removed and replaced. In Endodontics (unlike in Periodontics) we are also interested not merely in changing the nature or composition of the biofilm, we need to deal with the concept of removing it entirely or neutralizing its effects - without having the ability to remove the tooth. To complicate matters, the antimicrobial agents we use must also be able to penetrate the biofilm, which is a difficult task. If we are not successful, remnants of the biofilm can cause residual infection. So Dr. van Winkelhoff has respect for the clinical skill needed to deal with all these factors.

Treatment of (Oral) Biofilm Infections involves:
- Mechanical reduction of total bacterial load +
- Chemical Decontamination +
- Host defense system (phagocytosis and antibodies) = REDUCTION BELOW MINIMAL INFECTIOUS DOSE

During our cleaning and shaping procedures we shift the biofilm composition from predominantly Gm (-) species (Bacteroides, Porphyromonas, Fusobacterium, Eikenella, Tannerella) to predominantly Gm (+) species (Actinomycoses, Streptococcus, Peptostreptococcus, Enterococcus). This is the same process that occurs in the treatment of perio disease. Unfortunately, Endodontics must also deal with the contents of the dentinal tubules and lateral canals, as well. This makes our job much more difficult.

How much of the Biofilm is removed during deep Perio scaling? Even with the best technique, Dr. Van Winkelhoff says that in 8 mm pockets, scaling and root planning will reach a maximum of 50% of the root surface. Nevertheless, we expect improvement because the host defense system is effective.

Dr. van Winkelhoff then did a quick survey (show of hands) of the endo success rate of eth Summit participants. The responses varied from 90%+ (a few) to ~ 70% (many more). Dr. Van Winkelhoff said that still is a good % considering the difficulty of the job we face and the refractory cases that sometimes occur.

Factors that may cause incomplete healing/incomplete infection control:
- Professional
  - Wrong Diagnosis
Is there a place for Antibiotics in Endodontics?

1. Is there a clinical need for antibiotics?
   - We use antibiotic therapy for infections that do not respond to the standard, mechanical treatment (refractory infection).
   - We use antibiotic therapy when it is likely that progression of disease will occur without additional antibiotic treatment.
   - We use antibiotic therapy when complications occur: spread to other body site: abscess formation, soft tissue infection.

Clinical Findings | Treatment Approach
---|---
Uncomplicated endodontic lesion | No compromised host resistance
Debridement or Root Canal | Antibiotics NOT indicated
Soft Tissue Swelling of endodontic origin | Well localized swelling
Endodontic lesions confined to bone | No soft tissue swelling
Endodontic lesions/ Soft Tissue Swelling | Spread of infection. Fever, cellulitis, trismus, lymphadenopathy

Systemic Immobilisation
Trismus
Progressive infection
Mediatinitis

Indications for Adjunctive Antimicrobial Therapy

<table>
<thead>
<tr>
<th>Drug</th>
<th>Instructions</th>
<th>Dosage</th>
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<tbody>
<tr>
<td>Penicillin VK</td>
<td>Drug of ChoiceCheck for Allergies</td>
<td>500 mg q 4-6 h for 5-7 days</td>
</tr>
<tr>
<td>Amoxicillin</td>
<td>Alternative for Pen, compromised patients</td>
<td>500 mg every 8 hrs for 5-7 days</td>
</tr>
<tr>
<td>Metronidazole</td>
<td>Can be added to Penicillin</td>
<td>500 mg every 8 hrs for 5-7 days</td>
</tr>
<tr>
<td>Clindamycin</td>
<td>Alternative for Amox or Pen allergy</td>
<td>500 mg every 8 hrs for 5-7 days</td>
</tr>
<tr>
<td>Clarithromycin</td>
<td>In case of Pen allergy</td>
<td>500 mg every 12 hrs for 5-7 days</td>
</tr>
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| Co- Amoxiclav (Dr. Van Winkelhoff's suggestion) | In case of recurrent infection | 625 mg every 8 hrs for 5-7 days |

There are two family members in the Beta-lactam antibiotics family (1.) Penicillins and (2.) Cephalosporins. They are related but are not identical. Both interfere with cell synthesis and are bactericidal. Penicillin has a Small Spectrum:

- Streptococci
- Staphylococci
- Pneumococci
- Some Gram negatives

By changing a side chain we have Amoxicillin a Broad Spectrum drug:

- Gram positive pathogens
- Gram negative pathogens
- Enterics

The major reason that some bacteria are resistant to Penicillin is their ability to produce an enzyme- beta lactamase – that inactivates the Penicillins. (Prevotella sp., Fusobacterium sp. Staphylococci sp. Veillonella sp. Enterics are examples.) The addition of Clavulanic acid counteracts this. Clavulanic acid has 10 x the affinity for the beta lactamase enzyme. Clavulanic acid scavenges the beta lactamase and protects the Penicillin against degradation. Amoxicillin + Clavulanic Acid = Protected amoxicillin (Augmentin)

2. Which are the target bacteria?
   - The microbiology of infected root canals can vary considerably between cases; from mainly strict anaerobic to predominantly facultative organisms. You can not tell initially and from the "outside". Target bacteria are unknown.

   - Gram Positive
   - Gram Negative
   - Enterics

   Facultative StaphylococciEnterococciActinomycesStreptococciLactobacilli

Enteric Rods±seudomonas
Anaerobic PeptostreptococciEuobacteriaActinomycesPropionibacterium
Bacteroides PrevotellaPorphyromonas Fusobacterium TannerellaTreponema

Organisms in bold can produce Beta Lactamase

3. Does the antibiotic reach a concentration high enough to kill the target bacteria?
   - Dr. van Winkelhoff says there is no information in the literature about relative concentration of antibiotics in the RCS when they are prescribed. He suggests further research be done when "normal doses" are used.

   When is an antibiotic clinically effective?
   - When the local concentration is high enough to kill the pathogens
   - When the contact time is sufficient to kill all pathogens. (if it is too short - it can cause refractory infection)
   - When the pathogen is sufficiently susceptible to the drug.

Dr. van Winkelhoff says that unfortunately, in the case of the endodontic environment, these parameters are largely unknown.

The half life time (in hours) is the time required for the concentration of the drug to decrease to 50% of the initial concentration. We need to know this because if we wish to assure that the levels are above that of the Minimal Inhibitory Concentration (MIC) then we will need to ensure that the drug is taken with the proper frequency and amount. Levels below the MIC can not only encourage regrowth, they can sensitize the bacteria and create resistance rather than kill them!

4. What antibiotic would be the most appropriate? To Kill or Not to Kill
One of the most important decisions we make is whether to use a bactericidal or bacteriostatic drug?

**Bacteriostatic drugs** stop multiplication of the pathogen and the host immune system clears the pathogens through phagocytosis. Such drugs are Tetracyclines and Clindamycin. **Bactericidal drugs** kill bacteria. Examples are the beta lactams, Metronidazole and Ciprofloxacin.

Dr. van Winkelhoff says it is best to use a bactericidal antibiotic in endodontic infections.

5. What is the most effective regime?
   - Concentrations of systemically administered antibiotics relevant to the treatment of refractory endodontic infections are largely unknown.
   - Optimal regimens of specific drugs have not been established.

**Empirical Choice of Antibiotics in Endodontics**

- Broad spectrum
- Protected against beta-lactamases
- Bactericidal
- Low Toxicity
- High concentration at infected site

Since we don't know those exact concentrations in Dentistry, Dr. Van Winkelhoff found an example of research in the mandible, performed in Veterinary medicine.

- Zetner et al Vet. Ther. 2003- Concentrations of Clindamycin in the mandibular bone of companion animals. They found cats had twice the concentration when the same concentration (11mg/kg) was administered. (Humans generally are administered 25 mg/kg). The research concluded that Clindamycin was a good choice when infection was present in the bone. Dr. Van Winkelhoff says this is the kind of research that is needed in Endodontics so we can choose the optimal drug.

In medicine we use small spectrum and broad spectrum antibiotics. We can also use a combination of drugs. Sometimes the microflora we have to deal with are unknown or are very complex. In a disease such meningitis (where we are dealing with a single bacterium) we may be able to give a single small spectrum antibiotic. If we have a microorganism community of two organisms - a wide spectrum drug may be indicated. In the biofilm situation where we have a complex mixture of bacteria, we may be asking too much by administering just one drug and expecting it to be effective.

**The advantages of drug combinations**

- Broaden the Spectrum of antimicrobial activity
  - Van Winkelhoff et al 1989, 1992 showed that combinations can be effective in A. actinomycetemcomitans associated periodontitis. We cannot this pathology with single a drug regime
- Exploit Synergy (1+1=3,4)
  - For example - MIC drug A = 10 microgram/ml, MIC drug B = 6 microgram/ml for kill
  - When combined - MIC drug A = 2 microgram/ml, MIC drug B = 1 microgram/ml for kill

Most of the time, synergy is directed against a specific bacteria rather than many bacterial species. Dr. van Winkelhoff thinks that the key to dealing with bacteria in biofilms is using combinations. This is because the penetration of most antibiotics is poor in biofilms and success may better be achieved in using the right combination of drugs, used in synergy. In other situations we can use two separate drugs that act on two specific bacteria (i.e. / one drug against facultative bacteria in the infection and another against anaerobes)

- Lower dosages of individual drugs
- Decrease odds for resistance development

6. What are the side and adverse effects of the endodontal antibiotic treatment?

**The Triangle in Drug Therapy (Bugs <-> Patients <-> Drugs)**

Antibiotics are only effective in doing one thing - killing bacteria. They are NOT effective combating pain. Bacteria are also “smart”. They multiply every 45 or 60 minutes and we know that they produce substances that can counteract the effects of the drugs. They also adapt very well to its environment because of their short “generational” time. The triangle also “smart”. They multiply every 45 or 60 minutes and we know that they produce substances that can counteract the

**When Antibiotics should NOT be Used**

- Sutherland - Evid Based Dent 2005 – Are systemic antibiotics effective in providing pain relief in people who have irreversible pulpsitis? **Antibiotics do not reduce toothache caused by irreversible pulpsitis.**
- Keenan et al JOE 2006 A Cochrane systematic review finds **no evidence to support the use of antibiotics for pain relief in irreversible pulpsitis.**

The consequences of misuse overuse and poor compliance of antibiotics is that today people all over the world (including children) are dying from infections that display a wide resistance to normal antibiotics. In places such as Germany, France, Spain and the US because of such wide use, resistance of streptococcal strains is as high as 65%. Certain medications are no longer effective against resistant bacteria. We have seen the rise in multiple resistant strains of tuberculosis, a disease that was considered almost eradicated a decade or so ago. There is nothing wrong with the use of antibiotics. The problems start with misuse, overuse and poor compliance – the result is bacterial resistance.

- Cars et al – Lancet 2001 studied the Variation in antibiotic use in the European Union. It analyzed outpatient antibiotic sales in 1997 in the EU. They measured the DDD (Daily Defined Dose) per 1000 inhabitants. It varied from 37 (France - highest) to 9 (Holland - lowest).
What is Resistance?
Normal susceptibility: normal dose will clear clinical signs of infection
Decreased susceptibility: higher dose is required to control infection
Resistance: normal or increased dose does not result in clearance of the infection.

- Van Winkelhoff et al. J. Clin Periodontol 2000 - Antimicrobial resistance in the subgingival microflora in patients with adult periodontitis (A comparison between the Netherlands and Spain). They studied the question: if the overuse or greater use of antibiotics causes resistance, is this also true in the oral cavity? They compared the resistance of plaque samples of patients living in Spain and in Holland. The bacteria were plated onto culture media and exposed to 7 different antibiotics. The results showed penicillin resistance in Spanish patients was twice that of Dutch patients. Tetracycline resistance was 10 x higher; Metronidazole was twice as high, Clindamycin three times higher. The only exception was Erythromycin, where Dutch patients showed 25% resistance vs. Spanish patients 17%. What this means is that in different countries it is likely that different regimens will be necessary.
- They also studied frequency of usage as reported by patients:

<table>
<thead>
<tr>
<th>Last AB use</th>
<th>Spain</th>
<th>Netherlands</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-12 mos.</td>
<td>54.8%</td>
<td>25.8%</td>
</tr>
<tr>
<td>13-48 mos.</td>
<td>25.8%</td>
<td>25.8%</td>
</tr>
<tr>
<td>&gt;60 months</td>
<td>4.4%</td>
<td>19.4%</td>
</tr>
<tr>
<td>never</td>
<td>10%</td>
<td>10%</td>
</tr>
</tbody>
</table>

Other countries showed even higher resistance where patients in Yemen that showed anaerobic periodontal bacteria (P. gingivalis) showed 40% resistance to Metronidazole. Dr. van Winkelhoff said he has never seen levels that high because anaerobes are generally not resistant to Metronidazole. He said that this is a serious omen and that it appears that Metronidazole is used as an “appetizer” in Yemen.

- Van Winkelhoff et al continued their research, this time comparing the antimicrobial susceptibility profiles of 5 periodontal pathogens isolated from adult patients with periodontitis in Spain and the Netherlands. Instead of whole plaque samples, they isolated the strains and determined the MICs for them. 24 Madrid patients, 56 Amsterdam patients, 25 years old with PPD ≥ or = to 5mm, radiographic evidence of bone loss and no evidence of recent topical or systemic antibiotics. They sampled 4 pockets and isolated A. Actinomyctecomitans, P. gingivalis, P. intermedia, F. Nucleatum, and P. micros. The results showed P. intermedia, F. Nucleatum basically were resistant to Amoxicillin in Spain while being quite susceptible to the same drug in Holland. P. intermedia required 4 x the dosage of Tetracycline. Some of the more significant results:

<table>
<thead>
<tr>
<th>MIC90 Values - concentration required to kill 90% of bacteria</th>
<th>PenSp NL</th>
<th>AmoxSp NL</th>
<th>TTCSp NL</th>
<th>CiproSp NL</th>
<th>MetroSp NL</th>
<th>AzithSp NL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aa</td>
<td>32</td>
<td>0.4</td>
<td>2</td>
<td>.008</td>
<td>3</td>
<td>.87</td>
</tr>
<tr>
<td>Pj</td>
<td>24</td>
<td>5</td>
<td>256</td>
<td>2</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Fn</td>
<td>1</td>
<td>.015</td>
<td>256</td>
<td>.023</td>
<td>256</td>
<td>.016</td>
</tr>
</tbody>
</table>

A value of 256 represents resistance to antibiotics. Note how NL values are frequently a fraction of the MIC90 values required to be effective in Spain. For example, in Spain it is impossible to treat Aa with Cipro. Fn cannot currently be easily in Spain with either Amox or Metro.

Final Conclusions
- Most endodontic infections can be successfully treated by mechanical treatment.
- Antibiotics should NOT be used to combat pain.
- There is insufficient data on the usefulness of systemic antibiotic therapy in Endodontics.
- Research on the pharmacokinetics on antibiotics in the root canal system is needed.
- Clinical microbiology might improve diagnosis of recalcitrant endodontic infections and might support adjunctive antibiotic treatment in individual cases.
Dr. Paul Wesselink  
Amsterdam, Netherlands

Can and Should We Treat that Periapical Lesion?

Dr. Wesselink thanked ROOTS for the invitation and had some very nice things to say about the cases posted and the concept of our version of online education. He also said that he realized that on of the last papers that he published had caused quite a lot of feedback from ROOTS members. He then proceeded to don an orange suit jacket – saying it was his Dutch version of the “bullet proof vest” (Orange is Holland’s football colors and it was World Cup time!)

Dr. Wesselink opened by showing “Mr. Thompson’s Case”. Info:
- 51 yr. old male recently moved, presents himself in your office with a radiolucency.
- Patient has been regularly seen and treated for 25 years by his previous dentist.
- This dentist has extensively restored his dentition 20 years ago; at that time a lot of fixed prosthetics was made.
- “It has cost me a fortune” but otherwise I would – he thinks- have lost all my teeth.
- Request: he has no specific complaints; he wants to keep his teeth still for a long period of time and expects that you will do everything to make that happen.
- Medical history - nothing special.
- He is a University teacher.

Photos of the mouth were shown. Perio notations are probings were shown. No caries, large restorations. Bridges lower left and right, crown in 1-7 and 2-5. Some porcelain surfaces broken. Radiology showed post/crown placed with unfilled root in #25. Dr. Wesselink makes a diagnosis of apical periodontitis in 2-5 with an unfilled canal and asks: “In this mouth- are you going to treat?”

Treatment options include:
- Extraction
- Disassembly retreatment (Crown and Post removal and conventional retreatment)
- SRCT and retrofill
- Watchful Waiting (Monitoring)

Possible Solutions
Reasons to do nothing:
- The tooth has been like this for 20 years!
- The crown and post are in good condition.

Reasons to do something:
- You do not leave radiolucencies untreated
- They may flare up and cause pain
- They are damaging for the host system (e.g./atherosclerosis and endocarditis – C reactive proteins)

Considerations to be made before treatment:
- Prognosis of treatment – Good, fair poor?
- Consequences of untreated disease – What happens if we leave things as is?
- Position of the tooth – Does the patient truly benefit from retaining this tooth?
- Risk of complications of therapy- What could go wrong of we try to treat/retreat?
- Access to the root canal- How easy is it to gain proper access and visibility?
- Quality of the original treatment- Can we improve on the original treatment?
- Economic costs- Is the cost/benefit ratio reasonable for the risk?
- Personal values – Is this the right treatment for THIS patient?

Wesselink then presented two quotes:
“Since prevention and elimination of disease is the benchmark of health professions and since apical periodontitis is the disease unique to Endodontics, it is logical to define clinical Endodontics as the prevention and/or elimination of apical periodontitis.” Trope M Endodontic Topics 2003;5:1-11

Clinical Endodontics is defined as the prevention and/or elimination of apical periodontitis. Orstavik & Pitt Ford ed. Essential Endodontology 1990

On the other hand, Wesselink says that if you go the World Health Organization definition of health it is: “Health is a state of complete physical, mental and social well being and not merely the absence of disease or infirmity.”

Wesselink then showed another case-an 8 year old endo treated and crowned mandibular 1st molar with slightly short fills and what appeared to be small radiolucencies at the apices. He polled the audience as to how many would retreat? He then “Photoshopped” the image to remove the root fillings and create a radiographic image without an Endo treatment – very similar to Mr. Thompson’s # 2-5. He asked again, would you now treat this?

A third case was shown a 34 year old endo treated and crowned mandibular 1st molar. The tooth had an acute apical abscess in 1972. Films taken in 1989 and 2004 show no change in the M root LEO. He then asked if we would treat this. Before we could answer he said “No, because it is my tooth”. He said he would never let anyone touch it even though he understands that there are those in audience who think this is mistake.

Desirable Outcomes
1. Asymptomatic
Symptoms and Function
Salehrabi & Rotstein JOE 2004 showed 97% of 1.4 million teeth were functional in the oral cavity 8 years following non-surgical root canal treatment.

The AAE definitions have also changed recently.
“Healed” is defined as “Functional, asymptomatic teeth with no or minimal radiographic periradicular pathosis.”
“Healing” is defined as “Teeth with periradicular pathosis which are asymptomatic and functional or teeth with or without radiographic periradicular pathosis, which are asymptomatic but whose intended function is not altered”.

Dr. Wesselink was discouraged by this definition. He asked: Why are we doing this? Is it for legal reasons? Or is it because of implants?

So if an asymptomatic inflammation remaining after endodontic treatment is considered as acceptable then what is the logic of treating asymptomatic lesions associated with teeth that have not received endodontic treatment? Is Endodontics merely fighting symptomatology?
Dr. Wesselink makes an interesting point about implants. He says that initial observations claim 96-97% success rate. Can you imagine something so simple that the success rate is 97% and if that is the case – do we need an “Implantology Specialist” to do this? Wesselink says we should not shift our criteria for success because of the implant threat. Where we really need specialists is in Adhesive Dentistry – an “Adhesive-odontist” because the 5-10 year success rate for the average bonded restoration is abysmal. Let's eliminate infection.

2. Infection eliminated
Can we eliminate canal system infection?
Ca(OH)₂ 1 month (Bystrom et al 1985)
Root filled (RF)
teeth with lesions sampling (-) 100%
(Molander et al 1998)
RF teeth without lesions sampling (+) 45% ->bacteria present in RC treated with NO lesions!
(Molander et al 1998)
RF teeth with lesions histology (+) 88%
(Nair et al 2005)

The fact is that current procedures are not effective enough reduce root infection to the 0% level.

3. Bone defects repaired
Orstavik et al Eur J Oral Sci 2004 – Success rate 90%
Negative predictive value of radiolucency: 60%
90% x 60% = 54%

Radiographic assessment (scores 1-5): no radiolucency to bad radiolucency
(Brynholf 1967, Orstavik et al 1987)

Histological inflammatory status from no inflammation to severe inflammation (r:0-1.0)
Scale for Average RIDIT
0………………1………………2………………3………………4………………5
1 1 1 1 1
2 4 4 4 4
3 6 6 6 6
4 8 8 8 8
5 10 10 10 10

This above scale shows the association of PAI scores with average ridits. A group of roots with a PAI score of 1 would have an average ridit of 0.036; PAI score of 2 would give r=0.240 and so on. This is based on Brynholf’s study of cadavers. Let’s relate this to a study by Orstavik.

Orstavik et al Endod Dent Traum 1987
Diminished Recall Rate PAI – 1
0 Year 100%
1 Year 87%
2 Year 61%
3 Year 56%
4 Year 36%

Wesselink says this is an example of misleading results. Why does PAI 1 level (success) go up with time as the recall rate decreases? It is likely that many of the teeth that would have recalled were extracted. The ones that CAN be recalled (ones that are still in the mouth) are recalled and hence the increase is apparent success rate. Any recall rates below 70% in a study render it meaningless from an epidemiological standpoint.

If we combine PAI 1&2 (Orstavik et al IEJ 1996)
Diminished Recall Rate PAI=1+2
0 Year 100%
1 Year 88%
2 Year 63%
3 Year 59%
4 Year 37%

It goes up even further! Is this realistic?
All these studies used the same PAI index:
Orstavik et al Endod Dent Traumatol 1987
Orstavik et al IEJ 1991
Orstavik et al IEJ 1993
Trope et al JOE 1999
Waltimo et al OOOOE 2001
Huominen et al IEJ 2003
Friedman et al JOE 2003
Orstavik et al Eur J Oral Sci 2004

You can easily create a hole in the bone (mandible) and still have little radiographic evidence of pathology. So when we see results in Orstavik et al Endod Dent Traumatol 1987 that show 4-yr longitudinal studies using PAI with only a 36% recall rate and success rates of >90%, we must ask- how valid is this data?

We have to also remember that the PAI index is based on the study of Ingrid Brynolf - Odont Rev 1967 that was a radiographic study of human upper incisors. Mandibular teeth display different radiographic characteristics depending on the thickness and type of bone. So Dr. Wesselink says the use of such an index is questionable.

Wesselink showed an example of a maxillary anterior 3 unit bridge in which the left central had been prosthetically replaced. A radiolucency was present in the area of the apex of the previously extracted tooth (could have been incisive foramen) but he drew our attention to the right central that had a silver cone fragment in the apex. Radiographically there appeared to be no lesion. However, cross sectional CT scans showed a distinct area that was not visible in standard PA radiography. So how reliable are the studies that use radiography indices in this manner? So when Orstavik et al – Endod Dent Traumatol 1987 gives us the following data:

Success rate (AH26) at year 4
PAI=1 62%
PAI=2 33%
PAI=1+2 95% ← Is this realistic. Can we call this healing?

The European Society of Endodontology (ESE) 1994 has a slightly different definition of healing:
“Following successful root canal treatment clinical symptoms originating from an endodontically induced apical periodontitis should neither persist nor develop and the contours of the periodontal ligament space around the root should radiographically be normal.”
Wesselink was involved in creating this but wonders if this too will change.

Orstavik Eur J Oral Sci 2004 showed PAI 1(Success) = 26%, PAI 2(Success or failure?) = 53% PAI 3 (failure) = 21%. Wesselink asks: What is the true success rate according to our definition? Is it 26 % or 26+53%=80%?

Comparison of success rates for AP cases in two longitudinal university studies
Sjogren et al JOE 1990
N = 204 Recall Rate 46% 0.5 % NaOCl , Lat Condens, no sealer, root filling 0-2 mm to apex 60%
Criteria for success included teeth with perio contours widened around excess of material - 86% SUCCESS
So using ‘bone effects repaired’ as a measure of our success has some serious problems.

4. Safe for General Health

The fact is that when we tell patient that if they don’t treat a lesion there is risk of flare up and further disease, we really don’t have any way of telling them (in a supportable quantitative way) what the risk may be. (Erikson – Essential Endodontology 1998) says that “the incidence of exacerbations per year is less than 5%.” The truth is we have idea.

Potential systemic effects of endodontic post treatment disease

Two areas have been investigated with regards to Dentistry and systemic effects:

1. Coronal Heart Disease
2. Adverse Pregnancy Outcomes

It all has to do with CRP (C-Reactive Proteins), an inflammation marker in the blood. It is quite a hot topic, especially in Perio.

- Riediker al New Eng J Med 1997 found that patients with a CRP <0.5 mg/L – none of that group had a heart attack. CRP 1-3 mg/L: a risk factor for coronary heart disease.
- Fredriksson et al J Periodontol 1999 showed that patients with Periodontitis had CRP= 2mg/L. Patients without Periodontitis had CRP=0 mg/L
- Loos et al J Periodontol 2000 showed Periodontitis results in higher CRP and Interleukin-6 – potentially increasing the risk of Coronary Heart Disease.
- Bultke et al JOE 2005 – Chronic AP is not associated with elevated CRP levels in dogs

How important is AP in this? We have to examine the role of all sources of inflammation. If the Total Index is over a certain level, does it contribute to systemic disease?

Total burden of dental infection (Total Dental Index) is a combination of:

- Carious Lesions
- Periodontitis
- Apical Periodontitis

(Oral infection includes diseases of mucous membranes)

- Mattila et al J Dent Res 2000 found that the risk of Coronary Heart Disease (CHD) increases in individuals with high Total Dental Index. 5 other studies by Matilla et al showed similar results.
- Other studies DeStefano et al BMJ 1993, Joshipura et al J Dent Res 1996, Frisk et al Acta Odontnt Scand 2003 and Hung et al J Public Health 2004 all showed that tooth loss was significantly associated with CHD.

We can conclude from these studies that:

- 3. Total Dental Index was significantly associated with CHD
- 4. Tooth loss was significantly associated with CHD
- 5. Periodontitis results in higher CRP, potentially increasing the risk of CHD.

Questions remain:

Does the risk of CHD increase in individuals with AP?

- Caplan et al IADR Abstract 2004 - Links between AP and CHD
  During a maximum follow up of 32 yrs with 708 males, LEDO among those <40y old were statically associated with CHD after controlling for baseline values of education, income, total cholesterol, triglycerides, diabetes, hypertension and smoking. This article has not been published yet.
- Frisk et al Acta Odontnt Scand 2003 – Endodontic variables and CHD
  Age, tooth loss and individuals with 2 root filled teeth were significantly associated with CHD.

  BUT, the logistic regression analysis did not support an association between PA radiolucency and CHD.

  Failing to show the link between AP and CHD does NOT prove its absence.

  Absence of radiolucency DOES NOT EQUAL Absence of AP.

  The category of “AP absent” contains many cases with radiographically non detectable AP.

  Debelian et al 1994 and Murray et al 2000 – Root canal infection as a systemic health hazard has been debated over the years, however controlled clinical studies are rare and most authors judge the risk for the medically uncompromised individual as low.

Does the persistence of AP harm the general health of the patient?

WE STILL DON’T KNOW FOR SURE.

So, we now refocus on the patient first shown by Wesselink – the one with the maxillary premolar post/crown with no endo and a LEO. What do we do?

Compromised Outcomes:

We still don’t know for sure. Wesselink says that we sometimes impose our will on the patient whereas it should be the patient that makes the ultimate decision. We as clinicians make assumptions when we lack the hard evidence – such as the question “Do we leave radiolucencies untreated?” Wesselink says in his case he chooses not to treat his tooth. The other male patient example may choose to disassemble and retreat. Each situation and person is different.

References:

- Wesselink et al – Endodent Traumatol 1987 with Cheung and Chan IER 2003 we find that Cheung and Chan had much higher rate of failure because unlike Orstavik they DID make an effort to include those teeth that had been lost or extracted.
Wesselink says that his explanations to patients and now different than they were in the past. In the past patients with radiolucencies received this explanation: "I will explain to you about LEOs. I am going to clean the tooth for you because as I have explained the cause of the lesion is bacteria in the canal system. I will clean and rinse it all out very carefully and then I will fill it and after everything is gone it will heal. This is NOT true. Now I say "We can at least eliminate most of the microorganisms, reduce them and the level of the inflammation to level that is tolerable. That's all I can say. In some healthier patients that's all I need to do. In other patients that are less healthy, I may have to do more—SRCT for example, because they have a lesser ability to tolerate inflammatory stimulus. We shouldn’t be disappointed because we still do a good job but we must realize that no two cases are the same. ”

Wesselink asks: If we have such high success rates (96%) why change? Why do research? We still have to move forward. We are finally mature enough as a profession to say that we need to do better, with all kinds of different methods. Wesselink believes that the Implantologists are still far away from that and that we should be so concerned about them.

Questions from ROOTs members:

1. Terry Pannkuk questioned the idea of leaving teeth with LEOs or with active perio disease untreated. He said that there are clinicians that have the ability to treat these complex cases and that disease should not be left untreated.

Dr. Wesselink said that he did not advocate leaving active disease but that he again referenced the premolar case with post/crown no endo and a LEO that was asymptomatic. The patient did not really want this treated because it was asymptomatic. Wesselink said that he would recommend treatment but that he could not be sure whether the lesion would ever flare up, whether it would contribute to (C reactive proteins) Coronary Heart disease etc. He simply did not know, and that was the truth. The patients are the architects of their own care. We can say “If it was my tooth, I would do this”.

2. Pannkuk asked “Do patients have the expertise to make these judgments?”

Dr. Wesselink said that we can make recommendations based upon the individual case. Many times patients are sent for treatment by their dentist and do not want treatment or are functioning perfectly without treatment. If patients ask for unreasonable expectations Wesselink will refer them to someone else (e.g. Palatal root surgery of 2nd Max molar). You have a life and a right and the patient has a life and a right. Too often we say we know what is best for the patient when that simply is not the case. It is easy to do redo things, with an intellectual justification. One clinical level, it may not be desirable from a clinical management or patient preference standpoint

3. Pannkuk states that he feels there is a middle ground between “Supervised Neglect” and “Overtreatment” that involves working with the patient and educating them while using his expertise.

Wesselink responded with “That may be the case, but the fact remains that we really know so little. We assume that these lesions may cause disease but we really don’t know. How small does a lesion have to be before we consider retreatment or resection? I basically feel that we are not there yet. We need to improve in Endodontics. That was the purpose of my paper. Don’t lean back, dream and think that by spinning some white stuff in the canal it will work.” We need to improve our disinfection by many different methods, improving instrumentation, irrigation, how much to open the canals etc.” Wesselink said that he changed one of the recent course titles from “Excellence in Endodontics” to “Endodontics – Sense and Simplicity” because he feels we need to uncomplicated treatment. He acknowledges that many in the room perform at very high levels, but he also realizes that the rest of the world does not function at this level and what we need is good teaching at the undergraduate levels – not just by Endodontists. Everyone can do good Endodontics if they take the time and trouble to do it properly – endodontic treatment is not that technically difficult. The majority of endo is done by GPs – we need to get to them early – before they graduate.

4. Question: Are early extraction edentulous patients less likely to have coronary heart disease? Have studies been done? Wesselink says there is insufficient data. Also, it may depend on how long the teeth were in the mouth in a poor state before the patient became edentulous. How does “older” pathology contribute to problems later in life?

5. Question: Do you treat teeth with AP in one or two visits?

Wesselink says he performs treatment in a single visit. Whether you believe in CaOH or not – you need to take your time. ROOTs discusses this all the time. He says that “CaOH may put you to sleep”. He believes that the important part of endo is the cleaning and irrigation portion. He acknowledges that those such as Trope and Barnett use this as an adjunct but he wants to go in the OTHER direction – better cleaning and shaping procedures in the ramifications and isthmuses and LESS reliance on CaOH. CaOH doesn’t get into these areas, our culture methods don’t get to these areas and no one has ever shown that canals are cleaner as the result of CaOH use. I don’t want “magic drugs” in Endodontics; I want improved quality of clinical treatment and before more drugs.