In Parts 1 through 4, the procedures were presented enabling the operator to atraumatically and predictably allow the retro-preparation (REP) to be sealed with any accepted retrofill (REF) material. The surgical crypt should be clean and dry so vision is clear and unobstructed. Remember, the ***steps must be followed completely in order to achieve as predictable a result as humanly possible****. If, for some crypt management is not complete, or REP is not clean and finished, it is required to "go back" a step or two to achieve the desired result. The importance of having total control at this point in the apical microsurgical procedure cannot be over-emphasized.*

Apical Microsurgery, Part 5: Retrofill Materials and Techniques

The operator is now at a stage in the microsurgical procedure where the tissues have been atraumatically retracted, the crypt is well managed, and the acid etched, rinsed and dried REP is ready to fill. Removing the smear layer barrier, exposing the organic component (collagen fibrils) of the resected cementum and dentin has been shown to enhance cementogenesis and is one of the keys to dentoalveolar healing. [1] There are several materials that are currently available as a retrofill: amalgam, IRM, Super EBA "SEBA" (Bosworth, USA), bonded composites Optibond (Sybron, USA), glass ionomers, such as Geristore (Den-Mat, USA), and more recently, Mineral Trioxide Aggregate "MTA" (Dentsply Intl). The number of publications in the literature about research on the above materials is extensive, so only a few of them will be mentioned due to space. The author doesn't want to recommend or condemn any retrofill material (except amalgam), but will generalize and relate his, and others experience with them and opinions about their applications.

Amalgam and IRM were used for many years as the only commonly available retrofill materials. However, in almost every "leakage" study published during the past few years, amalgam has proven to be the worst offender, exhibiting the most leakage. [2, 3] This fact, accompanied by the general controversy about mercury in amalgam, strongly suggests that there is no valid reason to continue its use as a retrofill material. The only real advantage to amalgam is the favorable radiopacity. **[Fig. 1- Amalgam is very radiopaque]**

Since the advent of the anatomically correct, ultrasonic retroprep, the most popular retrofill material has been Super EBA (SEBA). In the early part of the last decade, Drs. Carr, Rubinstein and Ruddle popularized SEBA in their many surgical lectures. A recent follow-up study demonstrated a success rate of 91.5% using SEBA. [4] The author used SEBA routinely in the early nineties with full confidence of its sealing capabilities

To some, the major drawback of SEBA is its technique sensitivity. The surgical assistant had to mix it until it was thick enough to roll into a thin tapered point with a dough-like consistency. For even a well-trained assistant, this was often the most stressful part of the microsurgical procedure. The "dough-like" tapered end of the thin SEBA "roll" was then segmented with an instrument (a small Hollenbeck Carver worked the best for the author) and the small cone shaped, end piece was then inserted into the retroprep and gently compacted coronally with the appropriate plugger. Two to five of these small segments were usually necessary to slightly overfill the retroprep. Another problem experienced by many, was that SEBA was unpredictable as to its setting time: sometimes setting too quickly, and at other times, taking much too long for

the tired surgeon. At any rate, after the retrofill was complete, an instrument, and/or bur, is used to smooth the resected surface, producing the final finish. A mild etchant is then used to remove the "smear layer" produced during the final finishing process. SEBA has a radiopacity comparable to that of gutta percha so it was necessary to educate the new referring doctor that a retrofill had indeed been performed. **[Fig.2- SEBA has a radiopacity similar to that of gutta percha]** However, in some recent studies, SEBA has been shown to have a better sealing ability that IRM, but not as well as MTA. [2, 3]

Bonding, using composite retrofill materials, is now completely possible due to having total control over the apical environment utilizing good crypt management procedures. Many different materials are available for use as a REF. Optibond and Geristore are popular because of their ease of use. They both have good flowability, dual-cure properties, and the ability to be bonded to dentine. Geristore is supported by research demonstrating biocompatibility to the surrounding tissues. [5] The usual etching, conditioning of the dentin, insertion of the selected material, and curing by chemical or light is accomplished in a routine manner when bonding into the retroprep. ***Note: Since the light source for the DOM is so intense, it is mandatory to obtain an orange filter to use while placing the composite to prevent a premature set.*** For most microscopes, an orange filter is available that easily and inexpensively replaces the "blood filter". After the composite is completely cured, the material is finished with a high speed finishing bur and the resected root end is etched with 35%, blue gel, etchant (Ultradent, USA) for about 12 seconds, to remove the "smear layer" and to demineralize the surface.

Many studies showed no leakage with bonding techniques and many operators use it as their technique of choice. However, there is some controversy as to whether the resected surface of the root should also be coated with thin layer of the bonding material. A "cap" of material (usually Optibond) was placed with the intention of sealing the exposed tubules on the resected surface. The operators covering the resected surface believed it was necessary to ensure a good seal and the predictability would be better. On the other hand, there were also operators that did not believe the exposed tubules were a factor concerning the predictability of the healing process. They reasoned that nothing would heal as well, or was more biocompatible, than the exposed dentin of the apically resected surface. The author did not cover the exposed apical surface and is convinced the jury is still out on this issue!

More recently, another material has become very popular and is widely used by many. Mineral Trioxide Aggregate (MTA) has attracted many converts. There is so much research that has been done, and so many publications presented, that just one reference would be futile. The evidence extolling the virtues of MTA, regarding its sealing capabilities and its biocompatibility with the surrounding tissues, is overwhelming. The author has talked to many respected endodontists, and most are now using MTA as their routine retrofill material. MTA is chemically similar to "Portland Cement" and handles very similar to it.

The main advantage of MTA is its ease of use. The secret to using MTA is to keep it dry enough so it doesn't flow too readily (like wet sand), but yet moist enough to permit manipulation and maintain a workable consistency. The desired "thickness" is easily accomplished by using a dry cotton pellet, or dried with a dedicated, air-only, Stropko Irrigator (Vista Dental, Racine, Wisconsin). If the MTA is too dry, and needs moisture added, it can be easily accomplished

with a cotton pellet moistened with sterile water . MTA can be easily placed with a Dovgan Carrier (Quality Aspirators, Duncanville, Texas), extruded in a pellets of various sizes (depending on the size of the carrier used), and then condensed with an appropriate plugger. **[Fig. 2a- Set of 3 Dovgan MTA carriers]** For a denser and stronger consistency the assistant can touch the non-working end of the plugger, or explorer, with an ultrasonic tip during the condensation process. The flow is increased and a much denser fill is achieved. As a result, this procedure also increases the radiodensity of the MTA's appearance in the post-op radiograph, but is was still similar to gutta percha. **[Fig.3- The MTA has a radiopacity about the same as gutta percha]**

MTA has approximately an hour of working time, which is more than adequate for apical microsurgery and takes much "time pressure" out of the surgical procedure. Finishing the MTA is simply a matter of carving away the excess material to the level of the resected root end. The moisture necessary for the final set is derived from the blood, which fills the crypt after surgery. The MTA is very hydrophilic and depends on moisture for the final set, so it is imperative that there is enough bleeding re-established after crypt management to ensure the crypt is filled. **[Fig. 3a- Blood supply re-established to cover MTA]** This can be considered the final step in "crypt management", especially when MTA is used as the retrofill material. If the size of the lesion indicates the use of Guided Bone Regeneration, good blood supply is indicated anyway, so allow the blood to cover the MTA before placing the GBR material of choice. In a large lesion, it is sometimes difficult, even after curettage, to restore bleeding into the crypt (perhaps the crypt management was a little too effective) and it may be necessary to use a small round bur to make several small holes in the bone to re-establish blood flow.

Based on current studies, the operator can choose any one of the above mentioned REF materials and be comfortable that, if the proper protocol is followed, the apical seal will be predictable and healing uneventful.

Apical Microsurgery, Part 6: Sutures and Suturing Techniques

All steps have been meticulously followed, the retrofill has been placed, the crypt has refilled nicely, the final radiograph has been approved and it is time to suture the flap into position. Sadly, most operators now push the microscope aside and suture without it. To do this robs the operator of an opportunity to demonstrate to themselves, and their patients, the amazing capabilities of the SOM. The doctor must make a commitment to master the suturing technique using the SOM. It will never be accomplished with the SOM pushed aside at this critical step in the apical microsurgical procedure. The following will be based largely on the author's own experiences over the eleven years of doing, and teaching, apical microsurgery.

Dr. John Harrison has published some of the most clearly written and comprehensive work on wound healing associated with periapical surgery. There are five publications that are a "must read" for the endodontic surgeon. These publications can be found in the Journal of Endodontics: 1991, Volume 17, pp. 401-408, 425-435, 544-552; 1992, Volume 18, pp. 76-81; and 1993, Volume 19, pp. 339-347. After reading these articles, the microsurgical protocol developed by Dr. Gary Carr becomes clearer and is more easily understood.

When the surgical site is ready for closure, the flap should be gently massaged to close approximation with the attached tissue. But, keep in mind, the flap has probably lost dimension, or "shrunk" slightly, due to the mere act of retraction over a period of time and has had a slight decrease in blood flow to it. Fortunately, this is usually not a problem. If the initial incision was planned with this final step in mind, the tissues should re-approximate with minimal manipulation without any problem. Now is when the operator will appreciate nice "scalloping" and a sharp scalpel when making the incision in the beginning of the surgery. **[Fig. 4 - Incision design allows accurate flap re-approximation]** Remember the old saying, "Hindsight is always 20/20". The smooth edge of a small #2 mouth mirror can be used to hold the tissue in position while the second surgical assistant (on the same side of the chair as the doctor) hands the doctor the needle holder with the suture in it so the incision can be closed.

All suturing is accomplished using 6-0 black monofilament nylon (Supramid, S. Jackson). Some microsurgeons are using 8-0 and, even 10-0 sutures; but the 6-0 is stronger, doesn't tear through the tissue as readily, and the results are no different than with the more difficult to use, thinner sutures. Keep in mind, the sutures will be removed in 24 hours so it is really a mute point as to whether the suture is 6-0, 8-0, or 10-0. The results achieved with 6-0 suture seem to be well suited to apical microsurgery. The black silk suture, traditionally used in surgery, is a detriment to the rapid healing we are trying to achieve. Not only does bacterial plaque more readily accumulate on it than monofilament, but also, the braiding acts as a wick for the migration of bacteria into the wound. This can result in an increased inflammatory response and compromised healing.

The type of needle used depends on the type of flap to be sutured. For the **Oshenbein-Leubke Flap**, a taper point needle (TPN), 3/8 circle (Supramid, S. Jackson, code MEA-60B) is used. The TPN is far superior to the reverse cutting type needle (RCN) because there isn't the tendency to cut, or tear, the flap edges. Also, the TPN tend to go more willingly to an exit point in the attached tissue where the operator wants the needle point to exit, not where the needle wants to exit. In other words, it is easier to guide a TPN to the desired point of exit in the attached tissue than it is a RCN. They just seem to co-operate more when suturing this type flap! One of the nicest things about using this flap design is the ability to easily see the healing taking place:

[Fig. 5- Immediate post-op sutures]
[Fig. 6- 24 hours post-op, before sutures are removed]
[Fig. 7- Immediately after suture removal, 24 hours post-op]
[Fig. 8- Two weeks post-op, *note scar from 10yr old previous apical surgery*]
[Fig. 9- Six months post-op, nothing can be seen but old scar]

For the **Sulcular Flap**, **a** reverse cutting needle (RCN), 3/8 circle (Supramid, S. Jackson, code MPR-60B) is used. This needle was chosen because the larger size facilitates passing it through the contacts when doing a sling suture. The sling, or mattress type, suture is routinely used to save time on closure, rather than doing individual buccal to lingual sutures. On many occasions, the TPN (see above paragraph) is also used to suture the attached gingival area of the flap at the coronal aspect of the releasing incision.

A technique for suturing using the SOM: Using a small Castro-Viejo type needle holder, the beaks of the holder should be grasping the needle approximately 3/4ths of the distance from the pointed end. It is important to keep the beaks of the holder away from either end of the needle, as this is the area of its greatest weakness. **[Fig. 10- Grasp the needle 3/4ths from the pointed end]** This gives the operator the most control over the direction and stability of the needle. While grasping the needle holder in the doctor's normal working hand (right if you are right-handed), the needle is passed through both sides of the incision. Then, with the needle holder, place the needle between the thumb and index finger of the other hand. While the doctor is doing this, the second assistant is taking hold of the end of the suture so it won't inadvertently be pulled through the tissues. The doctor now makes the 3, or 4 "twirls" to begin making the first knot. While the doctor is making these "twirls", the second surgical assistant is placing the end of the suture into the doctor's visual field of the microscope, so the end of the suture can be easily grasped. **[Fig. 11- The assistant hands the free end to the doctor]** The "twirls" around the beaks of the needle holder allow enough friction so there is always a little tension *between* the doctor's other hand (holding the needle) and the beaks of the needle holder. Care must always be taken that the tension is only *between* the other hand and the holder, and not exerted on the tissue. The purpose of maintaining this tension is to give the doctor a positive tactile sense when taking up the "loops" of excess suture material in the other hand. As the suture is taken through the tissue, the needle holder is raised to the other hand. To take up the excess suture, it is gathered in the other hand as the holder "descends" to create the tension and get ready to pull more suture through the tissue. It is an alternating rhythm of movement that is difficult to describe in writing, but is actually very easy for the beginning microsurgeon to learn.

Then, using the same basic rhythm of movements, the second two knots, of 2 "twirls" each are tied to secure the knot. The doctor now allows the second surgical assistant to take the needle holder and be handed the micro-scissors so the suture can be cut very close to the knot. After the second assistant takes the scissors and the suture, the doctor is handed a micro-forceps so the knot can be moved as far away from the incision line as possible, preventing plaque build-up over the incision. **[Fig. 12- The suture knot is "pushed" away from the incision]** *Note:* when moving the knot with the micro-forceps, it is important that the knot be ***"pushed"*** to place, not ***"pulled"*** to place. This ensures the knot's original integrity is maintained.

One of the most common mistakes made when suturing is to make the suture too tight. It is better to make the suture a little too loose than to make it too tight. When it is too tight, it causes ischemia and thus compromises rapid healing. When making a sling suture in a sulcular flap, it is easy to be too aggressive when tying the knot, causing the other end to get too tight. So the doctor should always recheck the tightness of the entire suture before completing the securing knots.

The ***releasing incision*** is usually an integral part of every flap and is considered differently from the rest of the incision. Normally, the releasing incision is not sutured, but if it is, the suture should be looser than the other sutures. It has been shown that *epithelial creep*, or *streaming*, occurs rapidly, or at a rate of about 1mm per side per 24 hours. In other words, a wound whose edges were separated 2mm would be expected to come together within a 24 hour period. In hundreds of surgeries over the past 12 years, there were only a few cases the releasing incision wasn't completely closed. Of those few that didn't close within 24 hours, they all closed within

48 hours. **To repeat:** if the operator prefers to suture the releasing incision, is must be sutured loosely. **[Fig. 13- The vertical releasing incision should be sutured loosely]** Another consideration is to be sure to suture "like tissues to like tissues". Never suture attached gingival tissue to unattached gingival tissue. If one side of the suture "tears out", it will be the attached gingival side.

When using the DOM to suture, the incision can be closed accurately with extremely good approximation. It is because of well-planned and nicely scalloped incisions; atraumatic flap elevation procedures; and the very close repositioning of the flap with thin, hair-like sutures (6-O) that we can plan on routinely removing sutures in 24 hours. **[See Figs. 6 & 7]** The sutures have completed their task after 24hrs, and in fact, have now become foreign bodies that can cause irritation, excessive inflammation, be a source of infection, and ultimately result in a retardation of the healing process. [6] For those that doubt the ***24hr Suture Removal Theory***, an easy exercise is as follows: 1) At the next surgery, be sure to place at least five sutures. 2) After 24hrs, have the patient in and remove the **worse looking suture**, the one you think isn't healing as well as the others. 3) Then, the next day, remove the **next worse looking suture**. 4) The next day, do the same, and so on. At the end of the fifth day, the **worse looking suture** will be the **one remaining!** If that doesn't convince you, nothing will.

Post operatively, the usual result is little, or no, pain or swelling. The postoperative instructions are ice packs 15 minutes on and then 15 minutes off for the first 6-8 hours only, gentle rinsing with Peridex for the next 48hours, and have sutures removed the next day. Experience has demonstrated that prescribing Ibuprofen 600mg every 6hours, along with 1-2 tabs of Tylenol OTC (taken between the doses of Ibuprofen), has a very effective anti-inflammatory effect. It is the exception, rather than the rule, that a patient requires a stronger medication for post operative pain. Antibiotics are not usually prescribed. If everything is within normal limits, the patient is instructed to begin gentle cleaning of the area on the third day post-op, using a wash cloth over their index finger, and to begin gentle brushing on day five. The patient is scheduled for a follow-up visit two weeks after surgery. At the two-week visit, normally the incision is barely visible, and on most occasions, can hardly be detected. **[See Fig. 8]** *A word of caution:* Not all patients respond to treatment as well as others. Don't be in a hurry to treat a problem that may not exist. On a few occasions, patients may be slower than normal in response to treatment, sometimes taking several weeks to heal as well as that of other patients in just days. If there is any doubt, place the patient on antibiotics and an anti-inflammatory for a week as a precaution, but what is really desired is more time for delayed healing to occur.

The apical microsurgical technique described in the previous six parts has become the new standard of care in endodontic treatment and raises endodontic apical surgery to a new and exciting level. For the first time, apical surgery can be performed with predictable results. But, these results can only be achieved if the proper protocol is followed meticulously. The steps must be followed without compromise. Much more could be written, but hopefully enough of an overview has been given to stimulate just one more endodontist to begin using the surgical operating microscope (SOM), the finest tool our profession has ever been given. Apical microsurgery can be an enjoyable part of the daily regimen, for both the doctor and the newly involved dental team!

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