In 1985, Dr. Gary Carr introduced microscopes and ultrasonic handpieces to the specialty of endodontics in an effort to improve the quality and outcomes of surgical retrograde procedures. Before this, we used micro-head handpiece attachments that were still too big to use effectively, and their gears were prone to seizing up in the middle of the retro-prep procedure. The best visualization tools we had were headlamps and loupes — making it nearly impossible to retro-fill canals in a definitive manner. With perfect light and multiple levels of magnification, endodontic surgery became a much more predictable procedure as we became better at finding roots and their canals from an apical approach. Perhaps as important, ultrasonic cutting tips allowed us — for the first time — to literally prepare up the root canal, dramatically increasing the quality of the preparation and the integrity of the following retro-seal. Thank you, Gary.

But a funny thing happened on the way to surgical heaven. As more endodontists trained up and incorporated these tools into their practices, they found out that light, magnification and ultrasonics could also aid us in non-surgical retreatment of failing RCT cases. Suddenly we could find calcified canals that were invisible before, we could remove separated instruments, we could remove cemented posts, and surgery became the procedure that was done only after non-surgical retreatment had been done and had failed.

As much as non-surgical retreatment improved our retreatment successes — placing a perfect retro-seal over a leaking, infected canal is an invitation to failure — there was an unintended consequence of this new endodontic treatment planning concept. Graduate students were trained to first do non-surgical retreatment on every failing RCT case before doing any surgical retreatment; however, the reality of two-year, post-graduate endodontic programs meant that the residents typically graduated before they could see their conventional retreatment cases fail, and were thus cheated of the opportunity to practice their surgical skills before getting out into practice.

Furthermore, while some dental schools such as UCLA and UOP (Westwood in Los Angeles and Pacific Heights in San Francisco, respectively) are situated in nice neighborhoods, most are not, making it less likely that a patient undergoing non-surgical retreatment would have the means to return to the post-grad clinic if that treatment did not work out. At that point, the offending tooth would usually be extracted, again, cheating the resident of the chance to save the tooth.
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For some of us in the specialty, that’s just fine. Me? I fear for our specialty’s future.

Clinicians typically treatment plan procedures they know and avoid those procedures they do not know how to do. That’s why implant surgeons replace teeth with implants when it would be more ideal to save some of those teeth, it’s why endodontists became known for treating and retreatting hopeless teeth, and it’s why so many cases are retreated with complex and laborious non-surgical procedures, cutting off well-done crowns, posts, and cores — despite the fact that the added cost of restoration afterward makes it cheaper to remove the tooth and drop a titanium bolt in.

So how do we train our endo residents to be better surgeons? The best solution I’ve heard is what Dr. Tom Levy has done at USC — all RCT failures are retreated non-surgically, then they are cut — and several positive things have come from this. Most important, endodontists who come out of USC now are much more confident when the flaps are back and the bleeding begins.

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The other payback for this teaching strategy — non-surgical retreatment, followed immediately by the surgical placement of apical retroseals — was that retreatments done in USC’s program became much more successful. That’s not surprising in light of the study by Andreason, Rud and Jensen in 1972 — a computer-driven, multi-variate analysis of the factors involved in success and failure of root canal therapy.\(^2\)\(^3\) They found that when well-done RC treatment failed, apical surgery usually resolved the case. Why? Because most of the anatomic complexities in root canals are found in the apical third, so removal of the root apex removes the etiologic factor.

It was with these issues in mind that I resolved to find better ways to teach endodontic surgical skills, not only to residents but also to those endodontists already in specialty practice. Of all the challenges I see when residents begin their surgical experience, it’s the sheer terror of the unknown that most inhibits them, specifically, where are the dangerous places underneath the soft tissue flap? In considering the best way to address this challenge, I was reminded of how pilots and astronauts are trained to do the most dangerous things in a safe, predictable manner — with flight simulators. So why can’t we do this in endo training?

We can train on cadavers, as Dr. Carr did when developing his ultrasonic surgical technique, but that is a whole can of worms, so to speak. Cadaver heads are gross, expensive and they are hard to come by. But until recently, cadavers were our best option, short of training on living humans; however, 3-D printing technology has come into its own over the past couple of years and now offers an alternative. In a previous article published in this journal, I described how 3-D printing can be used to create anatomically authentic tooth replicas, complete with all the accessory canals, fins, isthmi and canal curvatures.
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This same technology can also be used to create replicas for teaching surgical concepts and procedures; however, printing a complete jaw section requires more preparation as well as a more sophisticated printer, because several different replica materials are needed to model hard and soft tissues. Before that can happen, each of the different anatomic structures to be represented must be “segmented” from the full CT volume. In other words, a computer-savvy anatomist must discriminate between the different structures. In the illustrations shown, first the canals, roots and crowns of the teeth were segmented together (Fig. 1), followed by the PDL (Fig. 2), the bony structures (Fig. 3) and, finally, the soft gingival tissues (Fig. 4).

Seen in Figure 5 is the first 3-D printed prototype from this segmented CT dataset. The surgical replica has the soft tissues modeled with a clear, rubber-like material (colored with a red felt-tip marker), that incises nicely with a standard 15C blade (Fig. 6), after which it is easily reflected with a periodontal elevator (Fig. 7).

Like the TrueTooth Replicas, the model material is a bit softer than dentin, so handpiece burs are run at half speed to better replicate the tactile feedback from cutting bone tissues. Cutting through the replicated bone reveals the MB root end of the MB (Fig. 8), and further osseous access reveals the MB1 and MB2 canals in the simulated cut root surface (Figs. 9, 10), after which an ultrasonic retro-prep tip is used to prepare the canal ends for filling (Fig. 11). Suturing the soft-tissue material (Figs. 12, 13), again, simulates very accurately the experience of closing surgical flaps in patients.

While this prototype has been printed with clear soft tissue and white bone and tooth structure, following replicas will be printed with red-colored soft tissue, PDL and intra-trabecular medullary tissue polymers, the teeth will be colored light yellow, and the bone and enamel will be printed in white model medium.

Editorial note: A complete list of references is available from the publisher.

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**about the author**

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