Recent advances in 3D-printed dental replicas for procedural training and board exams

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Medical and dental procedural training has always had the severe limitation of being done on living patients in a one-on-one preceptorship basis unless cadavers are used. But cadavers are severely regulated and short in supply, thus quite expensive, as well as being biohazardous and creepy. A common alternative, of training dentists to do implant surgery in pig jaws, allows only the most fundamental procedures to be practiced — none of which present doctors with the case-by-case, on-the-fly treatment planning decisions that must be honed to empower predictable success when tissues have been incised and soft-tissue flaps have been reflected.

In this light, 3D-printed dental replicas offer an amazing paradigm shift in dental procedural training. Impossible otherwise, 3D printing authentically reproduces human anatomy in much the same way body parts are created — through additive means — rather than by reductive CAD/CAM milling of material blocks or by injecting material into the limited geometry of molds. Stereo-lithography offers the ability to re-create internal morphology just as human bodies do, layer by layer. Multi-ink printers even allow both hard and soft tissues to be replicated in a single training jaw.

It has been truly fortunate that we can train dentists to do endodontic procedures in human extracted teeth that are no longer attached to their original owners; however we are still faced with the random endodontic anatomy that presents as collected in extracted tooth jars. With extracted teeth, educators cannot choose the exact anatomic challenge presented to their students to satisfy a given training objective, nor do they typically know what is inside all of the student’s practice teeth during a hands-on course. When we control the anatomy that is practiced in, educators can better control the students’ experience and further shorten their learning curve.1,2

Beyond that, when students fail to achieve their procedural objective in an extracted tooth, there are no do-overs, thus it is a truism that it typically takes hundreds of endodontic procedural experiences in extracted teeth and patients’ root canal systems before predictable competence can be achieved. Airline pilots, astronauts, musicians, police and soldiers are all taught with simulation exercises that allow iterative improvements in skill sets, something that has previously been impossible in dental and medical procedural training.

When we consider traditional methods of training health care professionals to do dangerous procedures safely in human beings, it becomes obvious that medical and dental education is different than almost every other endeavor to create human competence in complex processes. Thus 3D-printed replication has and will continue to change everything about conventional and surgical training. This article describes recent advances beyond the printing of individual teeth for endo-

Fig. 1. 3D-printed dental board exam replica embedded in rubber sleeve, allowing complete standardization between candidates and examiners for the first time, while it eliminates the need by the student to find acceptable extracted teeth and for examiners to check and approve candidate’s choices. This sleeve fits in commonly used typodont cavities. (Photos/Provided by Dr. L. Stephen Buchanan)

Fig. 2. Radiograph of exam replica after a candidate’s finished endodontic procedure.

Fig. 3. Molar exam replica in typodont cavity with apex locator leads attached.

Figs. 4a, b. Practice replica with reusable rubber sleeve. This sleeve allows multiple inexpensive practice sessions without the need to buy new typodont modules, yet it delivers the same ideal apex locator function as the more expensive exam replicas.

Fig. 4a

Fig. 4b
dentistry, both in educational as well as board exam arenas.

About two years ago, the president of a prominent board of dental examiners asked if we could model and print replicas that would authentically replace extracted teeth in their exams. Because 3D-printing allows fabrication of literally any organic or inorganic form that can be modeled on a graphics computer, it was obviously possible although many’s the slip between cup and lip. In these cases I follow the advice of Richard Diebenkorn for any creative project. I begin by doing research to understand the context, the art, that has preceded my efforts. What I found was that existing endodontic models were not anatomically authentic — their canals were like soda straws in their oversimplified form, they were much softer than tooth structure when cut with high-speed handpiece burs, and, despite claims to the contrary, they did not work with apex locators. Over a period of two years our design and development process resulted in board exam testing replicas (Figs. 1-3) that had:

1. Coronal hardness very similar to natural teeth when cut by high-speed handpieces.
2. The exact anatomy found in human teeth.
3. Apex locator function that was as accurate as natural teeth.
4. Embedment in a rubber sleeve (with serial numbers) that fit readily available typodonts.
5. Authentic radiopacity.

That development process also inspired an inexpensive version of these exam replicas that allowed our TrueTooth training replicas to be used in a better simulation than with individual replicas. While the exam replicas are expensive with milled composite/ceramic crowns, non-reusable sleeves and unique identification, the TrueTooth practice replicas now have reusable split sleeves that hold them in a typodont and perform perfectly with apex locators, allowing dental students to practice on replicas that cost less than $15 each (Figs. 4a,b).

The other recent advance was what I call TrueJaw 2.0 — full-jaw replicas designed to train endodontic residents to do periradicular surgery, including incision, ostectomy, apicoectomy, retrograde preparations and fills, bone grafting and suturing. Each upper and lower jaw has five teeth with various periapical lesions, some perforating the cortical plate and some with root ends that need to be located through intact bony structures (Figs. 5a-12).

Procedural dental education and testing will never be the same.

References

About the Author
L. Stephen Buchanan, DDS, FADC, FICO, is a diplomate of the American Board of Endodontics, a fellow of the American and International Colleges of Dentists and serves as part-time faculty to the UCLA and USC graduate endodontic programs. He holds patents on the Endobender Plier (SybronEndo), System-B and Continuous Wave obturation tools and methods (SybronEndo), GT and GTX file systems (DENTSPLY Tulsa Dental Specialties), LA Axxess Burs (SybronEndo), and Buc ultrasonic tips (Spartan/Oxura). Buchanan lives in Santa Barbara, Calif., where he enjoys a practice limited to conventional and microsurgical endodontics and dental implant surgery. He is the founder of Dental Education Laboratories, a hands-on training facility in Santa Barbara that he has directed for 28 years.