Michael D. Scherer, DMD, MS

Assistant Clinical Professor, Restorative Dentistry, School of Dentistry, Loma Linda University, Loma Linda, California; Private Practice, Sonora, California

Markus B. Blatz, DMD, PhD

Professor of Restorative Dentistry, Chair, Department of Preventive and Restorative Sciences; Assistant Dean for Digital Innovation and Professional Development, University of Pennsylvania School of Dental Medicine, Philadelphia, Pennsylvania

Ben Kellum, DDS

Program Director, AEGD Residency Program, Foundry Dental Center, Birmingham, Alabama

Q: How Does 3D Printing Compare Clinically With CAM Milling?

Dr. Scherer

In discussing the virtues of 3D printing (3DP) versus computer-assisted milling (CAM) among colleagues, I have learned that for many dentists and technicians *both* technologies are critically important. Interestingly, my journey with these two technologies started with 3DP and evolved to also include milling. This is because from a cost of entry standpoint, the choice seemed clear: the average desktop-level 3D printer typically costs between US$3,000–$5,000, while the average clinic milling unit ranges between US$20,000–$70,000. The simple financial fact of a much lower initial cost is what dictated my path.

After experimenting with printing, producing such items as surgical guides, models, and occlusal guards, I quickly realized that in-office production is quite incredible. Having to outsource these items to laboratories was terribly frustrating at times, because it would often take 10 to 14 days to receive them back from the lab, plus there were the not-so-modest production and shipping costs. An even bigger drawback, however, which also could result in adverse financial impact, was potentially having to reschedule surgical or prosthetic appointments because of a delay receiving the item, whether due to a production or shipping glitch. Having a 3D printer in the office allows me to check the next day's practice schedule and prepare any parts that might be needed.

After becoming comfortable with 3DP in our office, the need for milling became apparent. Crown-and-bridge cases, for example, were coming back from the laboratory looking great but not necessarily on a timely basis. If a patient was going away on vacation in a few days and wanted the work done before leaving, I was likely unable to accommodate the request. For years I resisted same-day ceramic crown workflows, because it didn't seem right for my practice. I wanted to make zirconia crown-and-bridges and be able to offer them to patients at affordable prices. Finally, I decided to make the investment and incorporated a five-axis dry laboratory milling unit into my dental office to be able to produce monolithic zirconia restorations. It took considerably more training to learn the milling machine compared to a 3D printer. However, once I became familiar with using it, I soon began to realize the power of milling in the office. Currently, our practice has a second mill, which is a wet and dry mill that allows milling of titanium abutments and lithium disilicates. Now, unlike before, if a patient has special requests or timely requirements, I am better prepared to deliver. This also helps serve as a practice builder.

Today, our practice, which includes an orthodontist, employs 12 3D printers and a milling machine. An in-house laboratory certified dental technician (CDT) and a trained dental assistant also utilize the equipment to produce amazing, functional objects. In our practice 3DP and milling efficiently co-exist. There is no need to choose between the two. Practitioners should determine what they want to make first then bring in the technology to match that need.

Dr. Blatz

I believe that 3D printing (3DP) is the future of restoration fabrication in dental laboratory technology. Printing a crown in various

dentin and enamel layers with different ceramics, translucencies, and colors to truly replicate a natural tooth, for example, remains a major goal. 3DP, also referred to as additive manufacturing or rapid prototyping, describes several related technologies in which objects are built layer by layer directly from a 3D computer-assisted design (CAD) model. Additive manufacturing techniques used in dentistry include selective laser sintering, stereolithography, photopolymer jetting (polyjet), inkjet-based systems, and fused deposition modeling.

The early hype and big push for 3DP in dentistry, however, have been slowed somewhat by the reality of current limitations. Presently, subtractive manufacturing, such as milling, is the predominant fabrication technology in the digital CAD/CAM workflow. Milling machines in a broad range of sizes and with varying degrees of complexity, ie, numbers of burs and milling axes, are widely available for dental laboratories and clinical practices. Laboratory-based systems typically mill from large blocks for extensive reconstructions or multiple restorations. Chairside mills are geared mainly toward single and short-span restorations, which make up over 80% of indirect restorations in the United States. Newer chairside systems can fabricate a full-contour zirconia crown within minutes. Plus, the cost of such chairside-fabricated restorations is lower than what is typically charged when sending them to a dental laboratory, although the quality is highly dependent on the skills of the clinician and the dental team. I still believe that highly esthetic restorations are best produced by a skilled dental technician.

While numerous printing systems are currently available for dental laboratories and practices, the key advantage of milling systems is their versatility. Just about any material that can be formed into a milling block can be milled, from composites and acrylic resins to metal alloys, waxes, and many different types of ceramics, such as hybrid and feldspathic ceramics, lithium silicates, and zirconia. Milling blocks are now commonly available with multiple layers of shades and translucency levels for improved esthetics.

Because these blocks are fabricated in an industrial manner under optimized conditions, the materials are much more homogenous than when fabricated conventionally or through 3DP. A number of research studies have confirmed better mechanical properties of milled versus conventionally produced or 3DP restorations.[1,2] Greater homogeneity not only improves strength but also leads to better optical and even biologic properties. For example, in internal research data not yet published by the author, significantly lower bacterial adhesion to milled versus conventionally fabricated acrylic provisional restorations was seen, even when the restorations were polished in the exact same manner.

Fewer impurities and porosities provide greater homogeneity not just within the material but also on its surface. And here lies one of the disadvantages of current 3DP technologies available for dental laboratories and practices. Material options for such in-house systems are mostly limited to resins, which, depending on the type of printing process used, are less strong, less homogeneous, and more porous. In addition, even with industrial-grade

printers the accuracy is still inferior to milled objects,[3,4] and even with industry-based 3DP systems the time to print and finish a ceramic restoration, such as zirconia, takes several days! Despite these current limitations, 3DP certainly has its place in the digital workflow, namely for fabrication of occlusal splints, surgical guides, denture bases, provisional restorations, study models, and more. Accuracy and material properties of current 3DP resins are still limited; for example, they are not accurate enough to adjust the marginal fit of indirect restorations on 3DP models. Dimensional stability, too, is problematic as the more porous resin materials tend to deform when exposed to temperature and humidity changes.[5]

3DP is widely used in other manufacturing industries with unparalleled success, and the future of dentistry undoubtedly lies in 3DP for all types of materials and restorations. This is due largely to the ability to reproduce countless objects in the exact same shape and manner, which reduces cost tremendously. One reason why dental technology has lagged behind and been all but ignored by large 3DP manufacturing companies is because every restoration created is unique, thereby negating some of the key advantages of 3DP, specifically reproducibility and cost savings. However, dental technology is catching up and great improvements can already be seen in 3D printers and materials. To achieve real development and progress, however, current capabilities to overcome existing limitations must be improved. The goal of printing a tooth-like crown in various ceramic layers remains unchanged, and dentistry is getting closer to its realization.

Dr. Kellum

A few years ago when initially exploring digital dentistry for our nonprofit facility, where we primarily treat patients in drug recovery, the uninsured, and the homeless, we thought incorporating advanced digital technology into a community clinic, although exciting, would be cost prohibitive. On the contrary, this proved not to be the case. As we integrated digital scanning, design, 3D printing (3DP), and milling into the clinic workflow and took a deeper look into our digital dentistry processes, we noticed a drastic reduction in overhead. Partnering with companies that shared our values, we created a digital workflow that produced more accurate results while decreasing the time and money needed to generate exceptional outcomes for our patients.

One of the most significant ways the digital workflow has led to more precise, higher-quality, and cost-effective work is in the complementary use and functionality of 3DP and milling. We utilize 3DP to fabricate study models, implant surgical guides, splints, denture wax rims/try-ins, immediate dentures, and full-arch fixed try-in restorations. We are particularly pleased with how our denture workflow has been impacted. We are able to print esthetic denture try-ins that reduce appointments and cost when compared to a more traditional approach.

The workhorse of our new digital lab is a robust five-axis dental mill that is capable of handling just about any case we give it. This has led to a seismic shift in our workflow and the quality and expenses of our work. With this mill we are able to cost-effectively fabricate final dentures, titanium bars, monolithic zirconia full-arch bridges, custom abutments, traditional and implant zirconia crowns, splints, and lithium-disilicate crowns.

We find 3DP and milling to be complementary to one another such that it is hard to imagine working with one technology and not the other. 3DP has given us the ability to create things quickly on a large scale at relatively low cost. It also allows us to print complex structures without concerns about bur access or challenges with nesting that we might encounter with a mill. Milling, conversely, allows us to predictably create remarkably strong, esthetic final products at low cost. The synergy of these two technologies helps patients be able to afford more treatment than they ordinarily could, without sacrificing quality of the results or efficiency of the process.

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While digital workflow technologies have enabled us to keep our lab costs down—plus, we are grateful to the many individuals and manufacturers who donate their time, equipment, and supplies to further the mission of the clinic—the need to have talented lab technicians is still paramount in our process. These individuals are able to turn the manufactured product into a work of art. With these new technologies, we are better equipped to offer our patients, many of whom have overcome the devastation of addiction, a confident smile that may help them as they transition into a new and better phase of life.

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