Additive Manufacturing in Dentistry

A contemporary guide to clinical 3D printing.

Volume 1

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Dental
3D Printing

The Intersection of Art and Science

Thanks to recent advances in technology, design, and materials, the role of 3D printers in dentistry is rapidly expanding out from dental labs and into individual practices. As printing appears in more and more offices, we wanted to provide a comprehensive ebook that compiled many of our useful resources and knowledge into a single place. Whether you're brand-new to 3D printing or you've been at it for years, we hope that you'll find something new in these pages.

When SprintRay was founded, it was on the belief that 3D printing should be made more accessible. We identified three major barriers to mass adoption: cost, user-friendliness, and support. We build resources like this ebook in the hope that it will make printing feel less foreign and more familiar. The structure is simple: it begins with a survey of dental 3D printing and ends with a few notes on how to find support. In the middle, we hope you'll find that it's packed with useful information at the intersection of these two wonderful, inspiring communities.

We are ever grateful to the support we've received on our journey, and look forward to continuing to serve the unique needs of dentistry.

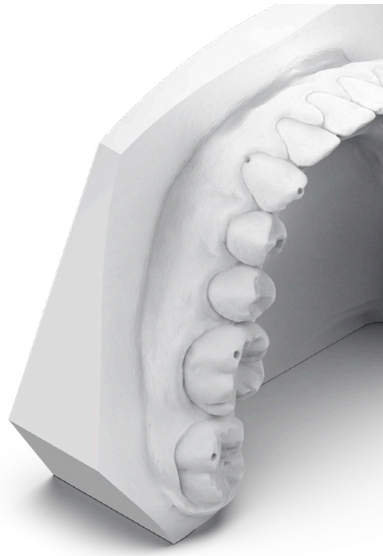
SprintRay

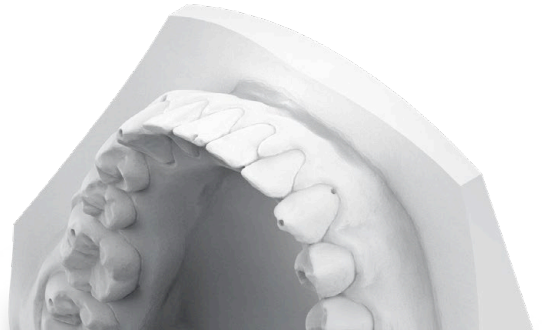
The Next 100 Years of Dentistry

The Wide World of Dental 3D Printing

You may not have thought about it, but 3D printing has been part of dentistry for a long time. Companies like Align Technology were some of the first to discover that this accurate, rapid technology was perfect for the unique demands of dental manufacturing. If you've ever delivered a set of Invisalign aligners to a patient, you've participated in the 3D printing revolution.

With the decrease in price, size, and maintenance offered by high-resolution desktop 3D printers, that technology can now be in your hands. 3D printing offers an incredible tool to speed up delivery times, increase efficiencies, and delight patients. But if you're new to the tech, where do you even start? In the following sections, we work through some of the fundamental questions of 3D printing in dentistry.





What is 3D Printing and Why is it Important to Dentistry?

In the last decade, widespread proliferation of dental 3D scanners, CAD/CAM treatment planning software, and dental mills have contributed to an improved patient experience in dentistry. Broadly conceived, contemporary technologies in digital dentistry consist of these two innovations as they exist in clinics and labs. But recent currents in the world of dentistry have argued that 3D printers can further improve this paradigm, closing the loop by offering affordable fabrication localized to the individual dental practice. Though mills can provide rapid in-office production for certain applications, printers are an order of magnitude less expensive, produce less waste and are useful across a wider range of treatments.

3D printing offers an affordable output step to the data capture and design component of contemporary digital dentistry that helps clinicians maximize their other digital investments.

3D printers can provide highly-customized manufacturing for single-unit or small-batch parts at a significantly reduced cost compared to traditional methods, with much less labor and greater reliability and repeatability. Because they are capable of printing disparate objects without the need for retooling, they are ideal for the type of production required in dentistry. Fabricating multiple copies of slightly different parts (such as models for clear aligners) or a single copy of a single part (such as a surgical guide) is a very expensive, labor-intensive process in the world of traditional dental manufacturing. Pouring-up models in stone creates a lot of waste and can be very time-consuming. But 3D printing has the potential to make this process much faster and less expensive, creating an affordable path for dentists to manufacture what they need right in their offices without the intensive labor previously required.

3D-printed dental appliances cut across a wide selection of therapies and disciplines, including orthodontic treatments such as models for making clear aligners, retainers, and indirect bonding trays. General dentistry can benefit from many of these same treatments with the addition of biocompatible full-arch surgical guides, splints and nightguards, digital dentures, cast retainers, removable die models, and temporary crowns. This list expands as the technology and materials capability expand. With such a wide variety of uses from a single tool, 3D printing can provide a huge benefit to dental clinics of all varieties. It's difficult to think of other tools within a dental office that are as broadly productive as 3D printers.

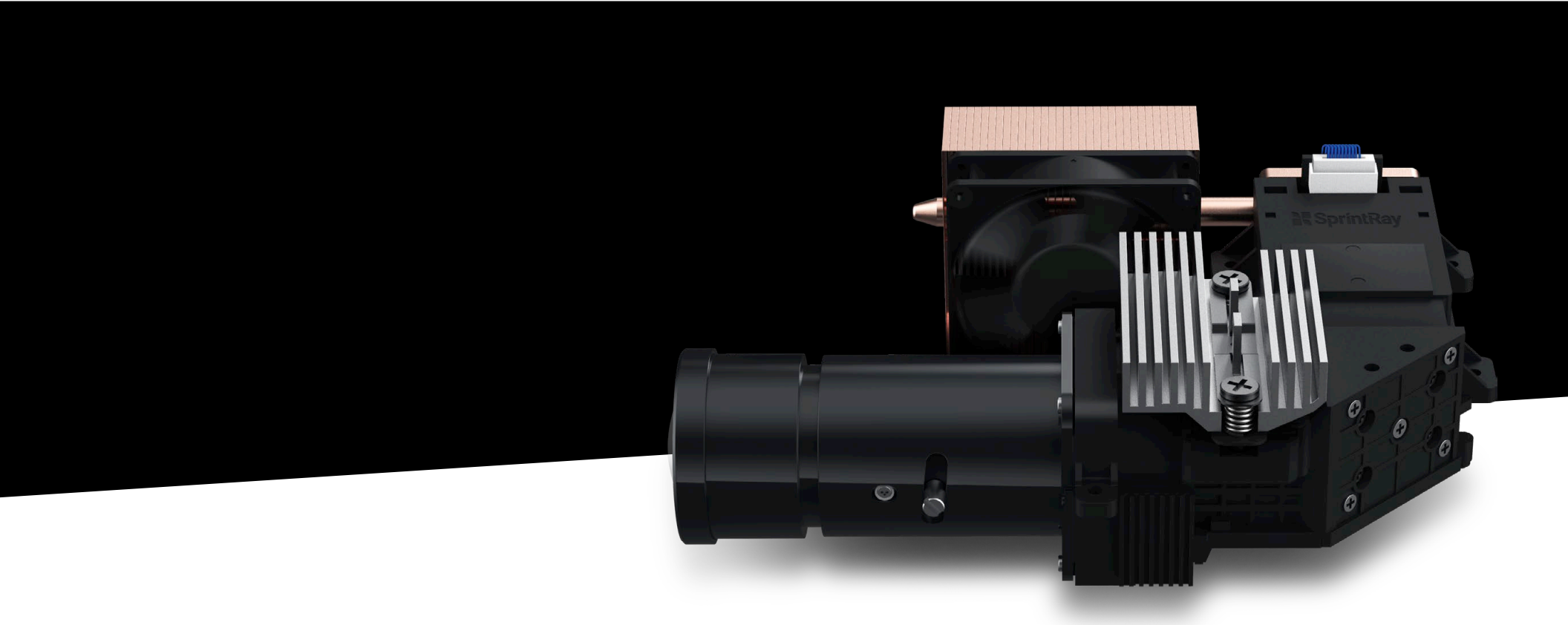
But additive manufacturing (another term for 3D printing) is a vast market. 3D printers can cost anywhere from $500 to $100,000. And individual products are marketed across a range of industries, which can sometimes make it difficult to find the information you need about dental-specific products. In the next decade, everything from consumer sneakers to professional-level race cars to jumbo jets will leverage 3D printing as part of their final production or development processes. With a technology that penetrates so many industries, it can be difficult to parse which features and technologies are needed in a dental clinic or lab.

A good dental 3D printer needs certain characteristics, chiefly the ability to 3D print functional dental appliances such as surgical guides, dentures, nightguards and more. This is one crucial difference between the way dental clinics will use 3D printers and the way they're used in many other industries. These final, FDA-compliant products are medical devices and are printed directly, with no significant intermediary steps before patient delivery. This means that printed items need to be ready for final delivery with minimal post-processing and maximum polish.

A dental 3D printer has a specific, well-defined use case: the printing of functional dental appliances such as surgical guides, dentures, nightguards and more.

Beyond the functional requirements, a good dental 3D printer should have a small footprint that can coexist with other equipment in limited space. It must be reliable for production, not just prototyping. This means achieving consistent, accurate results that are easily repeatable. It should also be affordable - both up front and over time - for a typical dental practice. Though this component of dental 3D printing doesn't get as much attention, it should also be user-friendly, with a good support system that helps clinicians take full advantage of all that 3D printing has to offer.

There are many desktop 3D printers on the market today that are capable of fabricating beautiful-looking parts. Many 3D printer manufacturers feature printed dental models on their websites to showcase their dental chops. A large number of these, especially those in the range of $4000 and less, claim to be valuable for dentists but lack the materials certifications to create FDA-compliant, final, printed dental appliances.



What Makes a 3D Printer ‘Dental’?

The adoption of dental 3D printers is driven by innovation in three major categories:

Biocompatible Materials

Materials innovation is at the heart of dental 3D printer adoption. While the production of dental models is crucial for many practices, the creation of dental appliances that can be placed intraorally, such as nightguards, surgical guides, and digital dentures, exponentially expand the functionality of the machine. These biocompatible materials help practices exercise control over the timing, cost, and quality of the appliances they deliver to patients.

Dental 3D printers reached an inflection point when biocompatible materials became widely available for desktop machines. These FDA-compliant resins make 3D-printed parts safe for intraoral use and offer great mechanical properties, fast production and low cost, propelling desktop 3D printers into dental practices all over the world.

Since the introduction of biocompatible materials for 3D printing in dentistry, there has been an emphasis on improving mechanical properties to provide printed intraoral parts that have great strength and high resistance to wear. Because materials innovations can come from anywhere, it's important to choose a 3D printer that offers support for third-party materials. We will cover materials in-depth later in this book.

Accuracy and Repeatability

Accuracy and repeatability are essential qualities for a 3D printer that will be used in dentistry. To provide the highest standard of care, extremely high accuracy is a non-negotiable feature. Recent advancements in materials and printing technology have supercharged the accuracy of 3D printers such as SprintRay Pro, propelling them beyond what was originally thought possible.

The central requirements of dental manufacturing are very high accuracy and repeatable results. Bringing the manufacturing of models and other appliances in-office only pays off if the technology can consistently provide the tight tolerances required for fitted parts. It isn't enough for a single print to provide good results; they need to be repeatable over time and across various environments. Though printers can be easily bucketed into categories based on the details of their underpinning technologies, these categories rarely tell the full story. We will cover accuracy in-depth later in this book.

Production Speed and Scalability

To keep pace with a busy office, a good dental 3D printer should offer rapid print speeds and high overall production throughput. These are a factor of build plate size and light delivery technology, and should not be overlooked. Though your practice may not need high throughput immediately, production needs tend to scale up quite rapidly once they start. A printer that seems adequate before you start may become a bottleneck when the versatility in applications becomes clear.

Same and next-day chairside production of dental appliances is a longtime dream of digital dentistry, and dental 3D printers have the capacity to make this dream a reality. But while certain aspects of 3D printing technology have begun to converge, there is still a big difference in production speed and scalability between individual printers. A large portion of these discrepancies is motivated by the technology that underpins each printer type, though some are not. We will talk more in-depth about the fundamental technologies that drive 3D printing later in this book.

While dental 3D printers are sometimes used to manufacture only one or two parts at a time, many cases require the rapid fabrication of a large number of parts. Clear aligner cases are the obvious standout, but batched nightguards, surgical guides, and denture bases all require large print volume as well. The emphasis of development in this region of the technology is focused on reducing both single-part as well as full-batch print speeds.

The Current Landscape of Dental 3D Printing

3D printing in dentistry can be bucketed into two major categories. On one hand are the industrial-grade, high-throughput machines that feature huge capacity and good accuracy. While these machines are often a good choice for dental labs that create hundreds of appliances per day, their high upfront cost, large size, and maintenance requirements mean that they're often an impractical solution for the needs of individual dental clinics. Though they are a great companion in a high-volume lab, industrial 3D printers are prohibitively expensive, physically large, require expensive maintenance, and may require a background in 3D printing technology to operate.

Desktop 3D printers, on the other hand, feature excellent quality at a significantly reduced price and are packaged in a much more manageable size: not much larger than your average laserjet paper printer. Desktop 3D printers are just as versatile as their larger counterparts but tend to feature smaller build platforms and lower overall throughput. For the general practitioner, oral surgeon, practicing prosthodontist or orthodontist, a desktop dental 3D printer with good throughput will supply more than enough capacity to satisfy high-volume offices.

Many companies are scrambling to add certified dental resin capabilities to their current 3D printer lineup. The simple fact of the matter is that 3D printing in dentistry is exploding. A cursory look at the most popular printers will give you the impression that any of their machines will dramatically improve your dental workflow. But many cannot print final dental appliances such as dentures, crowns, bridges, and indirect bonding trays. It's important to look beyond just the up-front acquisition cost, because if it can't produce a final printed dental appliance with certified biocompatible resin, its usefulness in dentistry will be limited.

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Post Processing
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Continue
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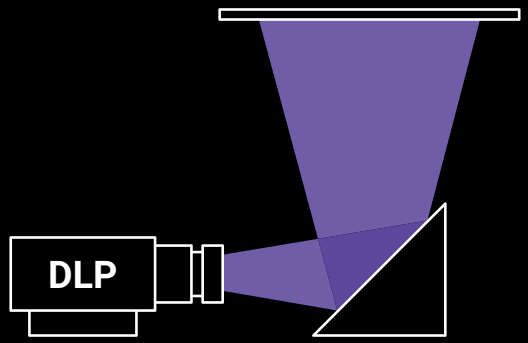
3D Printing Technology Types

Digital dentistry is largely served by a type of 3D printing that falls under the umbrella term stereolithography, often abbreviated as SLA. These printers use ultraviolet-spectrum light to cure photosensitive liquid resin. Broadly speaking, there are three ways to deliver that light in a desktop 3D printer, each with its own advantages and drawbacks.

Here's why DLP is right for digital dentistry:

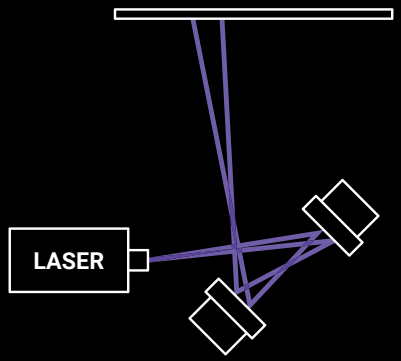
While the ability to produce dental appliances in-office is revolutionary to digital dentistry, the speed of an individual 3D printer can make a substantial difference. A practical way to measure the outcome of this speed is to measure its output via the 30-minute test, which shows both the on-demand printing speed as well as the overall throughput of the printer. Because of its bespoke DLP projector, SprintRay Pro can produce a full platform of up to 8 dental arches in around 25 minutes, an order of magnitude faster than previously-dominant laser-SLA technology.



Projector-based Stereolithography

The technology used in DLP 3D printers is the distant descendant of what you might find at work in your local movie theater. Projecting in a wide arc that reaches the entire build area at once, DLP printers are low maintenance, accurate, and fast, making them a great fit for digital dentistry.

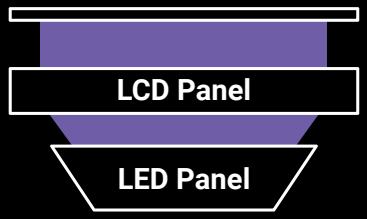
- Long operating life
- Highly accurate
- Fast print speeds



Laser-based Stereolithography

Like a consumer laser pointer, the light source in laser-SLA printers is a tiny pin dot of light. This pin dot reflects off of a rotating mirror and into the resin vat, drawing each layer as it goes. Because it must trace each part, laser printers are much slower for large jobs.

- Smooth surface finish
- Slow print speeds
- Complicated system



LCD-based Stereolithography

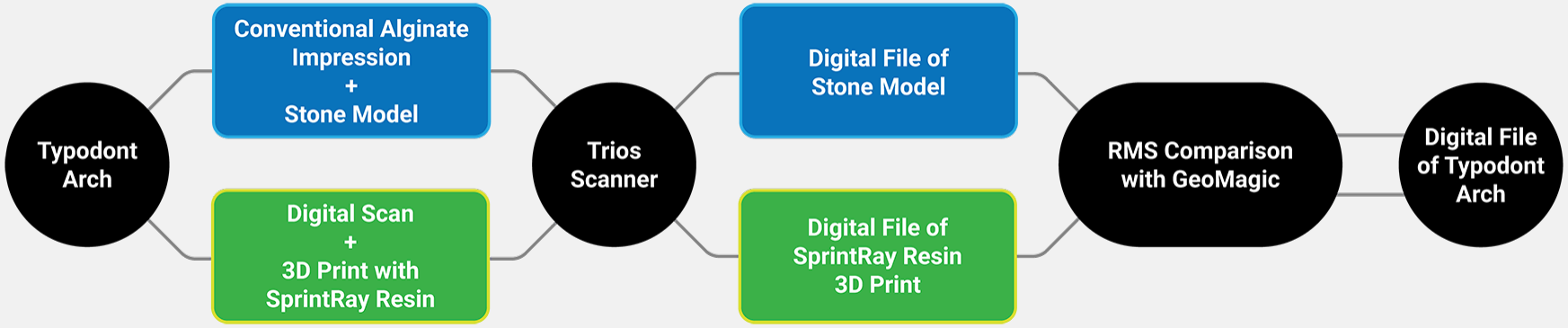
Using parts similar to those found in a smartphone, LCD printers use a small LCD screen to deliver light to the resin vat. These printers are very similar in principle to DLP, but they leverage consumer parts that are inexpensive to produce. However, the LCD screens in these printers are often consumable, requiring frequent replacement.

- Smooth surface finish
- Fast print speeds
- Costly, frequent repairs

Are 3D Printers Accurate Enough for Dentistry?

One of the hesitations holding back the adoption of dental 3D printing is the question of accuracy. Anxiety around materials, speed, and price are often underpinned by the lingering suspicion that, when all is said and done, the output of a desktop 3D printer might not stand up to the accuracy demands of real-life clinical use. If the aligners created from printed models don't fit, after all, then the whole enterprise of in-office 3D printing can fall short of the mark. Fortunately, clinicians have found that, given the right hardware and materials, this is not the case.

In the intervening years since 3D printing landed in dental offices, much has been made of the accuracy issue. Intrepid clinicians and labs, undaunted by skepticism, marched forward in their private practices, demonstrating that the technology could be useful in a clinical environment, changing the perception from tinkerer's toy to production workhorse. As dental 3D printers have become a more mainstream option for in-office manufacturing, dental universities have begun releasing their findings about accuracy, and the results speak pretty clearly: some of these machines are incredibly accurate when used as part of a fully-digital workflow, often exceeding the clinical requirements of dentistry.



A recent study performed by a major university of dental medicine measured the accuracy of SprintRay Pro and compared it to the accuracy of a model poured up in stone from an alginate impression.

Taking Stock of the Accuracy Landscape

Finding reliable studies of dental 3D printer accuracy isn't always easy. Verifiable, repeatable studies take time, resources, and expertise to complete. But finding trusted sources that verify the accuracy of a 3D printer is important. Dentistry demands extremely tight tolerances, so any new piece of technology introduced into the practice needs to be able to deliver highly-accurate results.

When 3D printer manufacturers publish claims about final print accuracy, they are often the results of internal testing. While internal tests can be a helpful metric, it's important to keep in mind that the results are not impartial, not verified by an independent third party, and therefore not necessarily repeatable. Even if the results are genuine, the test may be designed specifically to play to the strengths of a given product. When seeking accuracy numbers, it's best to find data published by reputable universities or dental journals. Just as with any dental product, 3D printer manufacturer claims should always be supplemented to corroborating evidence from dental schools and other credible sites.

Understanding Dental 3D Printer Accuracy

Methodologies for determining the accuracy of 3D printers vary, but the foundational principles tend to remain similar:

1. Establish a physical model to use as a baseline
2. Digitize the baseline model using a digital scanner
3. Use 3D printer to fabricate a replica of the baseline model from the digital scan
4. Digitize the newly-fabricated replica using a digital scanner
5. Utilize CAD software to measure the difference in dimensional accuracy of the second scan (3D printed model) against the first scan (original model)
6. Repeat with additional test groups until a statistically significant sample size is reached

Depending on the software and particular methods used, this process can measure hundreds of thousands of individual points of data on each scanned model. The numbers are added and an average is reached. This average, a difference usually expressed in microns, is a representation of the printer's

Traditional Alginate **VS** **3D Printed Model**

dimensional accuracy. Using this method, a printer with a higher average deviation from the original data set (in this case, the scan of the first physical model) scores a lower overall dimensional accuracy.

Accuracy vs. XY Resolution

XY resolution and accuracy are sometimes used interchangeably in the world of 3D printing, but they are crucially different. Understanding that difference, and what it means for the final output of 3D printed dental appliances, is essential to choosing the right printer for your office.

Defining XY resolution

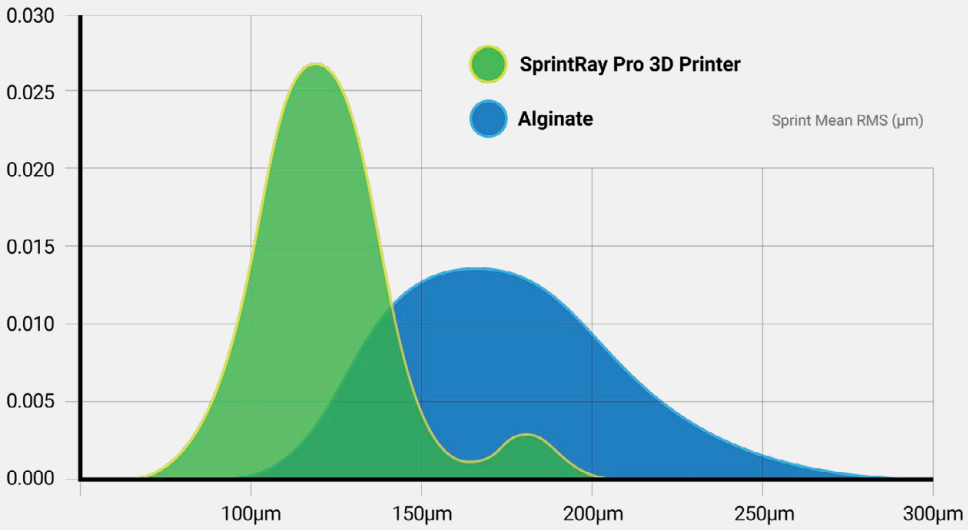
XY resolution refers to the smallest single point of light that a 3D printer can deliver. This number is worthy of attention for a few reasons. First, XY resolution tells us something about how smooth the final surface texture of printed parts can be. A smaller number in the XY resolution category means that the printer can, theoretically, create finer detail. But XY resolution represents only the finest detail that can be rendered by a printer under theoretical conditions.

A lower XY resolution value means that a projection of light onto paper in perfect conditions could show finer detail, but mechanical and optical imprecision will often largely invalidate these claims. This is especially true among budget printers, which frequently use off-the-shelf parts and resins that are white-labeled, rather than bespoke materials and purposive construction. Though it would be convenient for many manufacturers, XY resolution is not a shortcut to accuracy.

Defining Accuracy

Accuracy is the measurement of a 3D printer's real-world ability to create parts that are true to the exact dimensions of the digital blueprint. Parts that have a smooth surface finish aren't useful if they don't accurately represent a patient's dentition, particularly in the case of fitted parts. Imagine a surgical guide printed three times, where each time the guide holes had a slightly different angle. Even very small variations in accuracy can have adverse effects on clinical outcomes.

Though accuracy is more difficult to measure than XY resolution, it is an excellent way to express a 3D printer's output quality. Build quality and



The study data shows that SprintRay Pro demonstrated both higher accuracy values and more consistent results. This means that printed models will be more accurate, resulting in better fitting parts for better clinical outcomes. This is fantastic news for clinicians, who can have complete confidence in the accuracy of their SprintRay 3D printers.

components, such as chassis construction, Z-axis motor quality, tank materials, build plate surface, resin calibration, and many more factors can and do affect dimensional accuracy. As discussed in the previous section, the light delivery method, typically a choice made between DLP, Laser-SLA, and LCD, also plays a substantial role in accuracy. The best way to determine a printer's clinical accuracy is by recording measurements through impartial, third-party testing.

University Study: Dental 3D Printer Accuracy

A recent study performed by a major university of dental medicine measured the accuracy of SprintRay Pro and compared it to the accuracy of a model poured up in stone from an alginate impression. The findings concluded that SprintRay Pro, using SprintRay Die & Model Tan resin, created models that were more accurate than their conventional counterparts.

For clinicians and dental professionals concerned about accuracy, SprintRay Pro presents a highly-flexible manufacturing package that is more accurate than stone. Alginate impressions and models have long been considered clinically acceptable for their applications. . But SprintRay Pro improves the accuracy of model creation when compared to traditional methods while offering increased speed and flexibility. Though performance and efficiency are often in opposition to each other, highly accurate 3D printing is one place in which they operate in harmony.


SprintRay
3D Printing Material
DIE AND MODEL
TAN
REF
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1 Liter
SprintRay
3D Printing Material
CASTABLE 2
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SRI-0205004
1 Liter
SprintRay
Biocompatible 3D Printing Material
TRY-IN
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SRI-0205003
1 Liter
SprintRay
Biocompatible 3D Printing Material
SURGICAL GUIDE 2
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3D Printing Material

Dental 3D Printing Materials

3D printing has come to dentistry in a big way. In the last five years, the technology has matured from high-end mass manufacturing enterprises to an accessible way for dental professionals to bring chairside production into their clinics. There are a handful of desktop 3D printers available today that can satisfy the basic accuracy and speed requirements of most clinics, and the spec sheets for printers seem to be telling a story of converging capabilities.

While the hardware of a printer is important, the story of that printer's materials ecosystem is often what separates the truly great, essential printers from the merely useful. While advancements in printer hardware necessarily drove the cost of the technology down, breakthroughs in the materials space will be the driving factor in the next 5 years of dental 3D printing innovation.

What Makes a 3D Printing Resin 'Dental'?

When we call 3D printing material 'dental', we're often referring to one of two types of resin: dental modeling or biocompatible. Compared to other 3D printing customers, dental professionals have unique needs that are not served by the industry at large. Because dental offices produce parts used in medical procedures, acceptable materials must meet a higher and broader performance threshold.

Generally speaking, when we refer to a dental 3D printing material, we're talking about a resin that is FDA-compliant and can be placed intraorally. However, even standard model resins can be considered 'dental' if they are markedly set apart by their accuracy, speed, and mechanical properties. Dental models manufactured for the creation of clear aligners, for example, must exhibit high levels of accuracy and must hold their shape and maintain mechanical integrity under high temperatures and pressure in order to create accurate trays. There are two types of dental 3D printing materials, then: biocompatible and model.

Biocompatible Dental Resins

In the last five years, no innovation has changed dental 3D printing as much as the biocompatible 3D printing material. The introduction of these resins was a boon to the industry: whereas before only models could be created, now doctors can now directly print final appliances for intraoral delivery, from digital dentures to nightguards to surgical guides. This has wildly expanded the use-case for 3D printing in dentistry.

Biocompatible resins must pass cytotoxicity and other tests similar to other FDA-compliant dental materials, and likewise tend to have excellent mechanical properties and resistance to wear. Innovation in this category often comes from outside of printer manufacturers. Materials companies such as DENTCA and KeyStone are major contributors, each releasing industry-leading resins in their categories that continue to push dental 3D printing forward.

With biocompatible materials playing such an important role in dental 3D printing, it's important to purchase a printer that can leverage these 3rd-party materials. Rather than being locked into a single materials ecosystem, many manufacturers allow for the use of outside resins. However, a fully-open system can lead to difficulty. Having to program each resin manually, figuring out the cure times and then loading those times into your printer's software, can lead to low speeds and inconsistent results.

For these reasons, SprintRay offers an open-certified resin system, which allows end users to rapidly take advantage of the best new materials innovations without the long development cycles. This strikes the right balance between maximizing the versatility and capability of the printer, while maintaining the reliability practices need to continue to deliver outstanding care for their patients. Our 3rd party resin network helps ensure our customers always get the best of both worlds. We work directly with companies such as DENTCA and KeyStone to test and validate their

materials for our printer. Our engineering teams work closely together to ensure maximum accuracy and FDA-compliant biocompatibility. Our resin portfolio is always expanding as we bring on new resin partners each year.

Dental Model Resins

You may think that all model resins are the same and that in this category the needs of dentists are similar to those of hobbyists, animators, and engineers. While the overlap is certainly greater, dentistry does have certain requirements that are not met by modeling resins on sale today. A dental model resin needs to be able to print very rapidly, must be extremely accurate, and should hold its shape against forces such as pressure and heat.

Many materials brands market and sell their own model resins with the claim that they are, essentially, the same material as the name-brand option but offered at a lower cost. Testing shows the reality of the situation is much different. SprintRay Die & Model resins are developed alongside and formulated specifically for our 3D printers. This means that they are extremely accurate, fast, and reliable. In a recent test, we also found that models printed with our materials have better flexural strength and modulus, meaning they're less likely to deform or break.

It's important to remember that many of the use-cases of dental model resins require extremely tight tolerances. Checking crown margins on a model is only useful if it is an extremely accurate recreation of a patient's real dentition. Similarly, models for clear aligner production are not useful if they deform and create trays that don't fit properly.

Bet on the Future of Printing Materials

SprintRay provides a certified open resin platform because we believe in the power of 3D printing. Closed systems only certify and support their 3D printing materials. Here's what having an open certified system means to us:

- ✓ **Certified:** SprintRay's product engineers collaborate with resin partners. We do the hard work of certifying and supporting these materials so that you can maximize your production reliability.
- ✓ **Open:** While many competitors only offer a few resins for dental, SprintRay opens up our machines to the kinds of advancements in materials that truly revolutionize dentistry.
- ✓ **Platform:** Materials for dental 3D printing require testing, distribution, and support. SprintRay is fully committed to dental, so we offer a suite that fulfills all three of these.

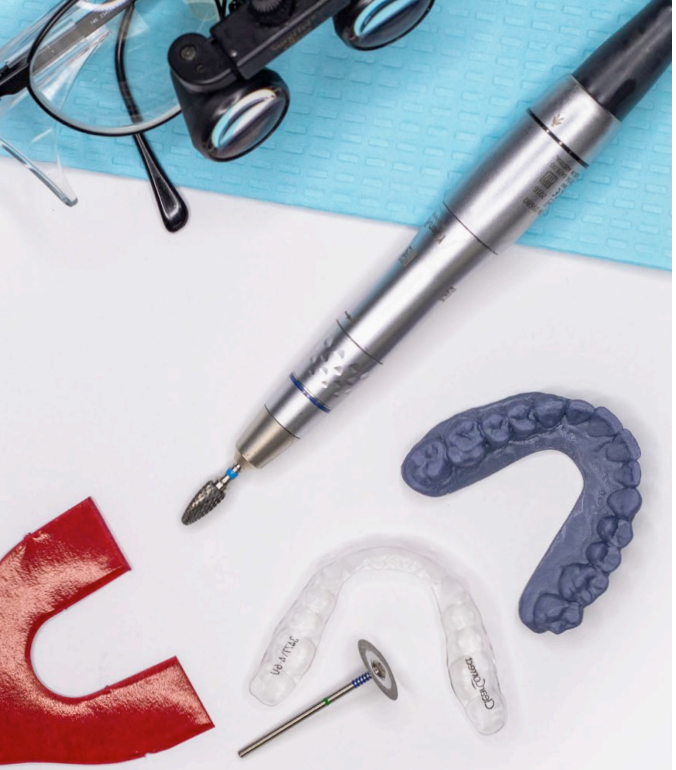
As the world of 3D printing continues to revolutionize dentistry, new materials will continue to push the envelope of what's possible. Because of our open certified resin platform, SprintRay is the ecosystem of choice for dentists and labs across the nation who want to secure the future of their investment in 3D printing.

SprintRay Practice Insights

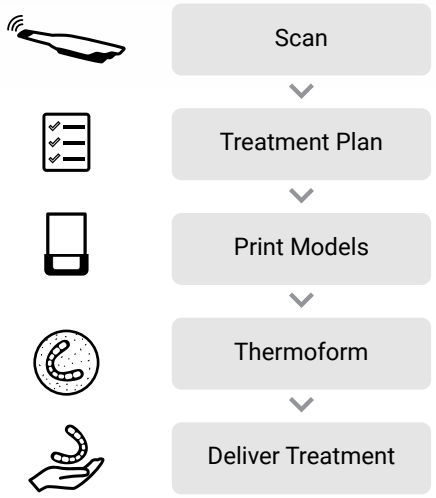
Real Doctors, Real Stories

At SprintRay, our mission is to help bring 3D printing into the offices of dental professionals around the world. We believe that our products help dental clinics operate more efficiently, ultimately improving the experience of both patient and doctor. Adding any new technology into your workflow can be intimidating - upfront expenses, learning curves, and uncertainty about efficacy are all important factors to consider.

We go to great lengths to validate, test, and prove our products in the field. Practice Insights is a series of interviews with dental professionals who have made the leap into 3D printing. In the following chapters, you'll hear the stories of real doctors who use our products as part of their everyday workflow. They open up about the benefits of dental 3D printing and share their tips on how to avoid common hiccups along the way.



Aligner Fabrication Workflow



Dr. Baron Grutter:
Pioneer of In-Office Clear Aligners

When it comes to manufacturing clear aligners in-office, Dr. Baron Grutter is one of the process pioneers. His videos offer a step-by-step workflow that's simple to follow, taking viewers all the way from case planning through 3D printing and post-processing. His popular in-person courses often focus on digital orthodontics and 3D printing, but his expertise and coursework extend into many specialties and disciplines.

Dr. Grutter owns Happy Rock Dental in Kansas City, Mo., where he has focused his efforts around digital dentistry. As for what prompted him to begin using 3D printing to manufacture aligners in-office, his decision was motivated by the economics of production. "Dealing with the larger labs have made aligners unnecessarily cost-prohibitive for many patients in my practice. Plus, I don't like being beholden to anyone else's schedule," he says.

For those unfamiliar, the workflow for creating clear aligners in-house begins with an intraoral scan of a patient's dentition. That file is imported into a software or sent to a digital lab, where the therapy is planned. Each stage of the treatment has an associated model, and those models are fabricated rapidly using a 3D printer. The models are then placed in a positive pressure or suck-down machine, where the aligners are formed over the models and then trimmed for delivery.

"By doing it in-house, my overhead is significantly reduced," Dr. Grutter says. This makes the price more attractive and improves case acceptance." And improved case acceptance is huge for a treatment that's known for its high earning potential. Speaking of practice growth, creating clear aligners in-house also can improve the patient experience. Dr. Grutter finds the in-house method to be more predictable compared to outsourced production, since he prepares the cases himself.

But do the costs of purchasing all the equipment and materials outweigh the benefits? At only around $2 per full-arch model in materials and with the relatively low price point of desktop 3D printers, the return comes quickly, and not just

for high-volume clinics. “Compared to using the larger labs, it takes about 3-4 cases [to break-even on the investment],” Dr. Grutter says.

The applications of 3D printing extend far beyond just the production of clear aligners. Though they present a well-defined path to return-on-investment, 3D printers can be used to manufacture all kinds of parts for treatments. “We routinely print surgical guides, occlusal guards, temporary dentures, implant hybrids, etc,” Dr. Grutter says, “It has many, many uses in our office.”

Advances in materials continue to improve the scope of care that 3D printing enables, with new and improved formulas being released all the time. For companies that verify and allow the use of 3rd party resins, this means that the investment continues to evolve with time.

As for choosing exactly which 3D printer to invest in? “I use the MoonRay almost exclusively,” Dr. Grutter says, “I’m waiting for the Pro to remake my processing videos.”

Dr. Grutter’s Top 5 Tips to Increase Clear Aligner Case Acceptance

5 Have before and after photos of similar patients.

4 Get 7-9 photos on ALL new patients, place them on a large screen, and discuss openly and without judgment with the patient.

3 Virtual smile design software can help the patient see the potential in VERY short time.

2 Have financial options to make aligners affordable via monthly payments.

1 Design and fabricate your aligner cases in-house, GREATLY reducing your overhead and making it more affordable for your patients!

★ BONUS: When you do #1, you’ll find smaller cases that would typically not be worth outsourcing now becoming an option. And the more cases you do, the more word of mouth will generate even more cases. Not only that, but your team will begin identifying more opportunities to help your patients.

About Dr. Baron Grutter

Dr. Baron Grutter attended Graceland University for his undergraduate degree and received his dental degree from the University of Missouri - Kansas City. He has focused his practice around digital dentistry, particularly in the areas of Orthodontics, Implantology, and Cosmetics.

Outside of clinical practice, he serves as the project manager of Blue Sky Bio Orthodontics. He spends much of his non-clinical hours refining digital workflows to optimize treatment outcomes and efficiency. You can find many of his free educational videos on his website (www.BaronGrutterDDS.com) or by following him on YouTube (YouTube.com/BGrutterDDS), Facebook (Facebook.com/BaronGrutterDDS), or Instagram (@BaronGrutterDDS).

He also teaches courses on Digital Dentistry, Digital Orthodontics, Guided Surgery, and 3D Printing in Dentistry. He has a true passion for working with and helping his colleagues to master all that digital technologies have to offer the dental field.

Winner

Dr. August de Olivera:

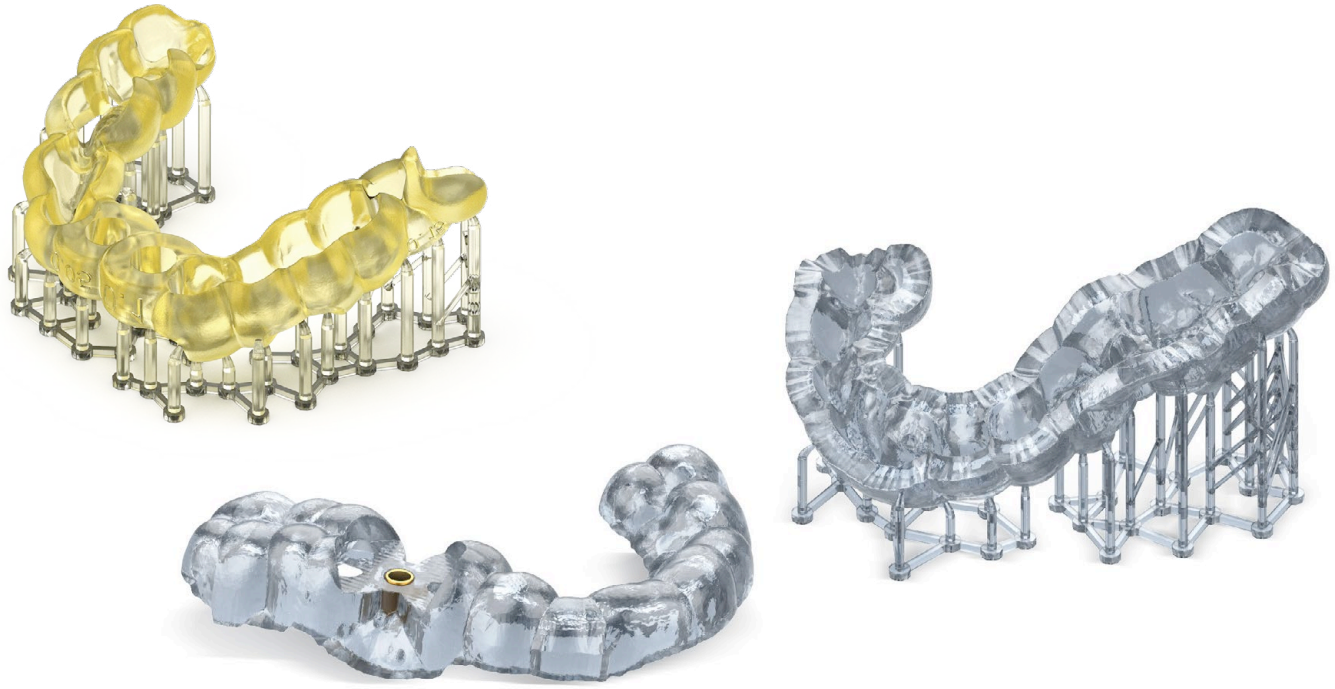
The 3D Printer Tipping Point

How Dr. August de Olivera's investments in 3D printing have helped him elevate the patient experience and increase case acceptance.

Dr. August de Olivera is a household name in digital dentistry. A lecturer on chairside CAD/CAM since 2005 and on guided surgery since 2009, Dr. de Olivera is no stranger to integrating new technologies for clinical use. As an early adopter of 3D printing, he has championed the idea of using the technology in dentistry since the early desktop FDM days at the turn of the decade. As for the moment when 3D printing stepped into his regular workflow? "The tipping point was surgical guides," says Dr. de Olivera, "I was probably spending about two to three grand a month on surgical guides, and there were a lot of guys making their own guides for under 30 dollars apice."

This kind of savings made bringing a 3D printer in-house a no-brainer for Dr. de Olivera. "Usually when we buy dental equipment we're worried about the cost. The cost [of a 3D printer] is pretty negligible," he says, "I got in on some of the early 3D printing systems out there and quickly found SprintRay Pro.. And that has by far been our workhorse since then."

Dr. de Olivera uses his SprintRay 3D printers primarily for the production of surgical guides and models for making clear aligners. As these treatment types make up a big part of his daily workflow, he's noticed a big difference in delivering these treatment types. "We've reduced the price of our aligner cases by around 20 or 30 percent, which allows us to be competitive," he says, "Nowadays we have at-home aligner companies and we can compete with those companies because we've dropped our price."



Beyond the Financial ROI

Of course 3D printing isn't just about lowering costs - case acceptance is a crucial component of bringing this technology into the office. Less expensive treatments give patients a reason to say yes. "I probably did, four years ago, maybe two or three aligner cases per year and now we're doing at least that per month," Dr. de Olivera says, "So patients are definitely saying 'yes' more to aligner treatment. And one of the cool things about it is that people always lose or break aligners. So we have the ability to just 3D print another model and make them another aligner that they can get the next day."

"Our turnaround time for most aligners is about a week and it used to be a couple of weeks. My turnaround time for surgical guides was a week and now it's a day - I can do same-day guided surgery," Dr. de Olivera says. This flexibility is one of the key components of in-office 3D printing. Offering dental professionals the maximum number of options in any given situation empowers them to provide a high standard of care to their patients. But one barrier that can come with flexibility is increased workflow complexity.

For those who want to learn how to control the entire process from treatment planning to design to printing, there are dental CAD software suites. For those who'd rather eschew the learning curve that comes with appliance design, there are many options for 3rd party digital design available today. "There's a number of design houses like Full Contour. There are

$350

Per Surgical Guide

Inefficient

$30

Per Surgical Guide

In-office Surgical Guides

VS

Lab Surgical Guides

I got in on some of the early 3D printing systems out there and quickly found SprintRay Pro and that has by far been our workhorse since then.

Dr. August de Olivera DDS

designers in China that can design a crown for $2.50 and $3.50 better than what I can design in my CEREC. So if I don't need it as a same-day restoration, I can pay two or three dollars and have it done the following day."

Choosing the Right Hardware

As an early adopter to 3D printing technology, Dr. de Olivera is widely considered an expert on the subject. He uses his printer every day, and has made it a hallmark of his practice, educating his patients and printing toys and other trinkets for his patients and their children. So what does he look for in a printer? "For me there's three big things. One is the size of the build plate. So if you're going to get into printing aligners or do a lot of surgical guides and you only have a little dinky build plate, you're only going to be able to print one or two things at a time.

"[Second,] I would look at the cost of the printer itself. I always tell a lot of doctors: you know you probably don't want to spend more than twelve thousand dollars on a 3D printer. And there's a lot of companies that have twenty-five-thousand dollar printers, and for what we can do with seven thousand dollars really encompasses 99% of what we do with 3D printing in the office.

"And then finally, it should have FDA resins that are reasonably priced... S one thing that's great about the SprintRay Pro is you can utilize SprintRay resins but you can also take advantage of NextDent and 3rd party resins as well. So you have a wider range of choices." Dr. de Olivera says.

After using SprintRay's MoonRay S printer as his main production workhorse, Dr. de Olivera

has recently upgraded to SprintRay Pro, which features a reasonable price, massive build plate, and compatibility with biocompatible resins from SprintRay, NextDent, KeyStone, and DENTCA.

“Look, if you’re doing any clear aligner therapy, if you’re doing any surgical guides, you’ll pay for this [SprintRay Pro] in three months and then after that it’s all gravy. So I’d say, definitely, right now get into 3D printing.”

About Dr. August de Oliveira

Dr August de Oliveira graduated from dental school in 1997 from the University of Washington and completed his General Practice Residency in Los Angeles in 1998.

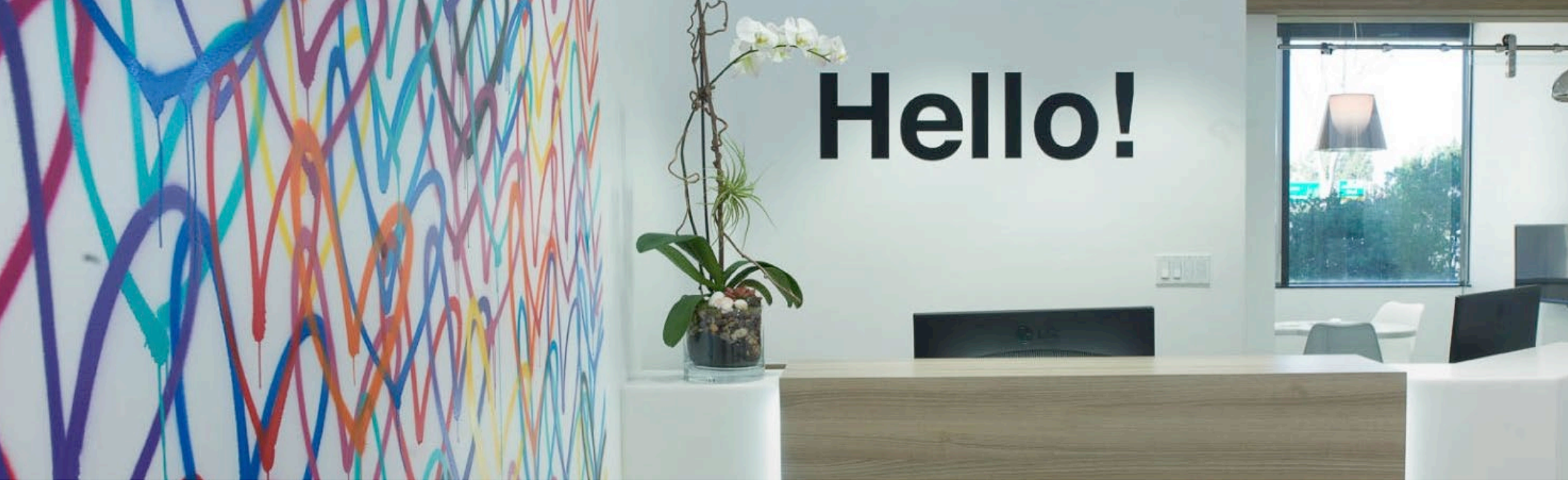
Dr de Oliveira has been lecturing on 3D technology since 2004, when he started as a CEREC Basic trainer. Since 2008 he has been involved with Implant Direct’s R and D department developing Guided Surgery Software and Hardware and testing their CAD Milled Bars and Substructure Department. Dr de Oliveira has written two books on Implantology: Implants Made Easy and Guided Implantology Made Easy. He has been involved with beta testing Sirona’s Sidexis Program, as well as developing the Opti and CEREC Milled Surgical Guides.

Dr de Oliveira lectures nationwide for Sirona on the Galileos Cone Beam system and Sirona Guided Implant Surgery. He also teaches for Implant Direct at their Las Vegas Educational Facility and with the Engel Institute in Charlotte. Dr de Oliveira lives and practices in Los Angeles CA.

Dr. Lawrence Fung:

High-Speed Digital Wax-Ups

Silicon Beach Dental is located just a few miles from Santa Monica, California, a hub for technological innovation in southern California. The boutique practice is owned by Dr. Lawrence Fung, who specializes in digital aesthetic dentistry, emphasizing the role of technology in his workflow. “The things we’re able to do with technology allows for a much more efficient practice, which leads to a much more pleasant visit for our patients,” he says. Dr. Fung opened Silicon Beach Dental with digital technologies in mind: each operatory has a dedicated, floating screen that features streaming services for his customers to watch during their appointments. Intraoral scanning, digital smile design, and advanced photography all figure prominently in his daily workflows.



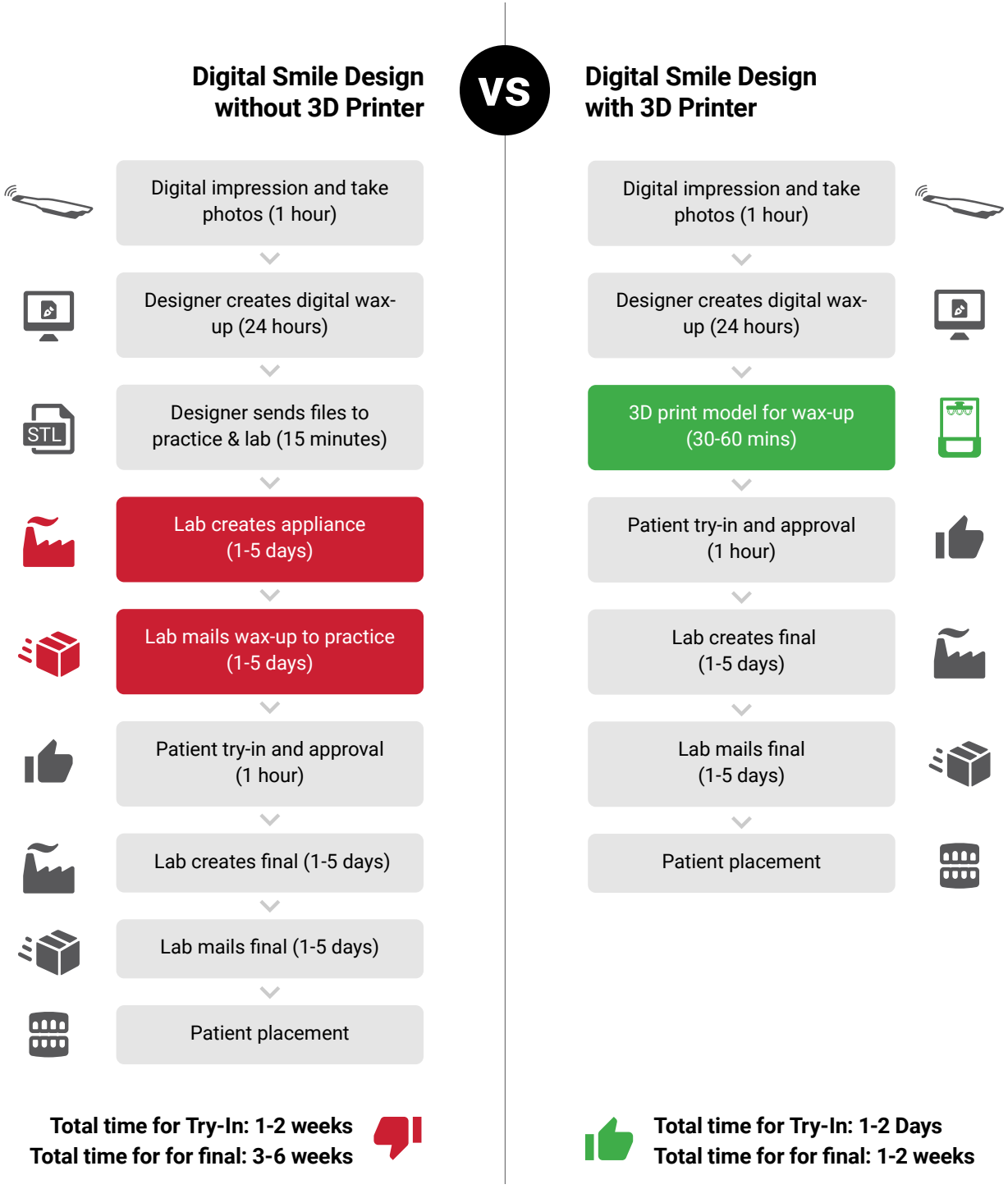
But there was one piece of digital technology that Dr. Fung hesitated to incorporate: in-office 3D printing. “For me, it just didn’t make sense, because we’re so busy. Traditionally, the assistant would take the impression, send it out, and I don’t have to worry about a thing,” he says, “But with digital, it’s a little bit different.”

Dr. Fung’s existing digital technologies and relationships, such as his intraoral scanner and digital design partner, already allowed him to increase delivery speed for esthetic wax-ups compared to traditional workflows. “Once it’s scanned and we’ve taken the photos, then we send it digitally to my designer, but what’s nice is that with digital impressions it only takes a few minutes. Once the designer has the file, it will take a day, at most, to get the design back,” Dr. Fung says. Once he has the 3D design, he can bring his patient back in for a consultation or simply send them the digital files for review at home. This drastically reduces the need to make changes to the physical model, as digital adjustments can be made in a matter of hours and at a low cost.

Once the design is complete and the patient is satisfied with the digital results, the next step was to create a wax-up to allow the patient to see the results intra-orally. But despite all of his investments in digital technology, Dr. Fung still had to wait for a lab to fabricate and ship his physical model, reducing the effectiveness of these investments. Crucially, this time bottleneck occurred right at the point of gaining case acceptance, which could lead patients to reconsider for any number of reasons.

For Dr. Fung, then, recapturing the try-in step with digital technology seemed like a low-hanging fruit to increase case acceptance, reduce lead times, and increase patient satisfaction by providing rapid, customized service. To solve this problem, he looked to 3D printing despite certain apprehensions about the technology’s real-world efficacy in his practice. “I was afraid it was just going to be a really expensive paperweight. That none of us would use it. And luckily,” Dr. Fung says, “I was wrong.” After a quick remote training session with a SprintRay print technician, Dr. Fung’s SprintRay 3D printer became an asset to his daily workflow, helping him capitalize on his existing investments in digital technologies.

With 3D printing, the lead time between presenting the digital wax-up and providing an intraoral try-in is drastically reduced, “They get to see it on the screen and now, instead of sending it off to the lab and waiting, I just print it. It less than an hour to print, so they’re back within a day or two after their initial consult,” Dr. Fung says, “Case acceptance is almost a hundred percent.



It's a pretty big game changer, at least for my practice. And now with 3D printing, if something needs adjustment or something didn't work out the first time, I can just revise and reprint it right away in a fraction of the time it takes to send it back to a traditional lab."

In contrast to his initial reservations about 3D printing, Dr. Fung discovered that getting up and running with his SprintRay printer was easier than expected. Rather than having to spend his own time using the printer, he has delegated all of the printing and processing to his staff, whose reactions have been very positive. "Once it goes to print, I don't touch it at all. It's so easy; the staff just clicks 'print' and then when it's done they post-process with alcohol, throw it in the Pro Cure, press 'start.' It's very simple.

Sure I'm trusting of my staff, but it's also a testament to how easy SprintRay has made the printing process," he says, "My staff actually like using it because it changes up their day. It's fun."

Another common concern with 3D printing is the mess and maintenance - a concern which Dr. Fung shared when he initially considered bringing the tech in-house. Compared to pouring stone and working with traditional dental model and impression materials, Dr. Fung says his staff love how low-maintenance the SprintRay printer is. "It's almost nothing," he says, "For us, the only recurring tasks are cleaning the platform and changing the resin. It's as easy as changing a cold sterile - it's pretty much no maintenance."

Now that Dr. Fung has acclimated to using his 3D printer for wax-ups, he has plans to expand to other applications, such as night guards. The

proliferation of these useful appliances has been limited by the high cost of lab fabrication and long lead times, creating a barrier for many patients. Until recently, 3D printing splints wasn't practical due to materials constraints. But thanks to new 3D printing resins from SprintRay, in-office printed night guards are becoming feasible. "I have barely touched the tip of the iceberg," Dr. Fung says, "We're starting to use SprintRay's new nightguard material, and the results are quite promising."

The things we're able to do with technology allows for much more efficient practice, which leads to a much more pleasant visit for our patients.

Dr. Fung DDS

About Dr. Lawrence Fung

Dr. Lawrence Fung graduated from the University of Southern California with a BS in Dental Hygiene in 2007 and his DDS at the Ostrow School of Dentistry in 2011. Dr. Fung has a very diverse academic background replete with service, research, and leadership. He served as class president for both his undergraduate and his graduate classes. He subsequently earned the Century Club and the Robert E. Cruse Memorial Awards for exemplary character, ideals, and leadership.

Dr. Paul Zhivago:

The Power of 3D-Printed Provisionals

Thanks to 3D printing, Dr. Zhivago's practice provides increased customization, efficiency, and peace of mind.

Dr. Paul Zhivago understands the value his patients place on time and convenience. So when he founded DOWNTOWNDENTAL in Westfield, NJ, he prioritized creating aesthetic and implant workflows that offered increased customization and efficiency.

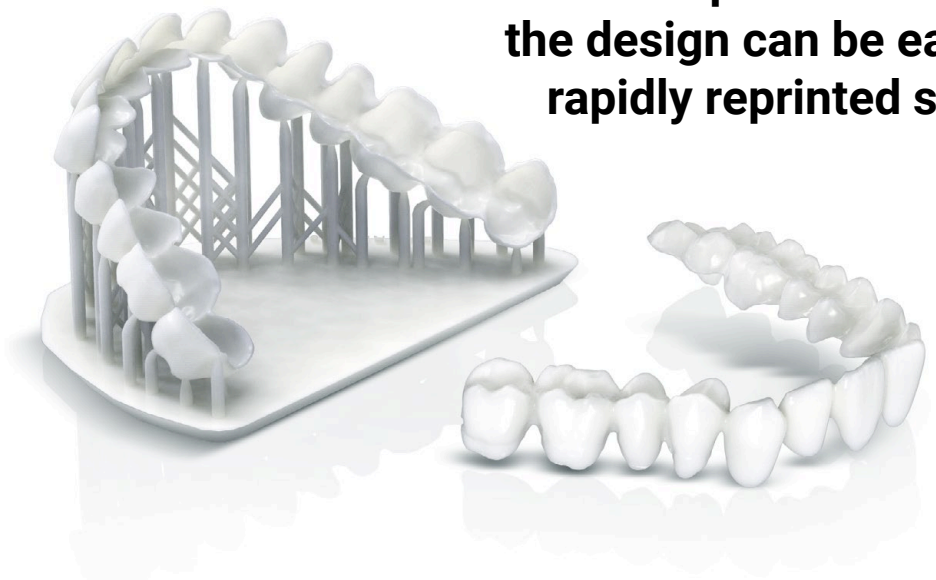
In a traditional dental workflow, personalization and speed are often at odds with each other, so Dr. Zhivago turned to 3D printing to achieve his clinical goals. "Now, I can't even imagine trying to practice without a 3D printer," he says.

One of the biggest uses of 3D printing for DOWNTOWNDENTAL is creating temporaries for aesthetic restorations. "The patient comes in for an aesthetic evaluation that includes clinical pictures, an intraoral scan, and a full-face scan to capture their features," Dr. Zhivago says. After their digital information has been captured, a digital mockup is designed using information provided by the patient.

"Because I have a 3D printer in my office, I can offer my patients a next-day appointment to evaluate the results of our smile design," Dr. Zhivago says. At this follow-up appointment, the patient gets to see not only the digitally-designed smile, but also a 3D printed cast. This printed cast is used to transfer the design into the patient's mouth to further evaluate if the new smile is to their liking.

Thanks to the speed of 3D printing and CAD software, changes can be made without having to wait for offsite manufacturing. "If the patient isn't totally satisfied, the design can be easily modified and rapidly reprinted same- or next-day," Dr. Zhivago says.

Once the design is approved, the provisionals can be directly 3D printed - even multiple sets. "3D printing allows me to keep multiple spare temporaries ready to go in case anything happens," Dr. Zhivago says. "When it does, I don't



If the patient isn't totally satisfied, the design can be easily modified and rapidly reprinted same- or next-day.

Dr. Zhivago DDS

3D Printed Provisional
$8 Material Cost
1 Hour to Print

have to spend time on repairs; I just replace them."

The ability to print multiple temporaries for a negligible cost is key for Dr. Zhivago's patients, many of whom travel frequently or visit his office from overseas. "Providing my patients multiple spare provisionals is huge. In the case of breakage or loss, the spares can be inserted or replaced by any practitioner in an emergency situation without any need for modification," Dr. Zhivago says. His patients know that wherever they are in the world, Dr. Zhivago has them covered.

This level of convenience and customization didn't exist before 3D printing. Since printing a set of provisionals only costs a few dollars in materials and can be done in less than an hour, Dr. Zhivago can provide a unique level of service. It doesn't hurt his bottom line, either. "By being able to do this all in-house, my production cost is dramatically decreased," Dr. Zhivago says. Now, rather than waiting weeks and spending hundreds on lab bills for fabrication, both patient and doctor get a better value.

Dr. Zhivago uses his 3D printer for more than just aesthetic restorations. "We use the printer for many applications," he says. "Implant surgical guides, splints, and even removable traditional prostheses." And, as he becomes more experienced with 3D printing, the number of uses continues to expand.

Of course, not all 3D printers are capable of keeping up with Dr. Zhivago's demanding production schedule and wide breadth of treatment options. "I'm glad that I chose the MoonRay 3D printer due to its openness and large variety of printing materials," he said. "Now I'm also the proud owner of a SprintRay Pro, which makes my printing workflows even faster and more efficient."

About Dr. Paul Zhivago

Dr. Paul Zhivago received his Doctor of Dental Surgery from New York University College of Dentistry where he also completed his education as a prosthodontist. He then trained at Columbia University's College of Dental Medicine as a surgical and implant fellow.

He is a board-certified prosthodontist specialized in esthetic, restorative, and implant dentistry. He lectures nationally and internationally on the topic of digital dentistry and is the founder of DOWNTOWNDENTAL in Westfield, NJ.

Why You Want a 3D Printer in Your Office

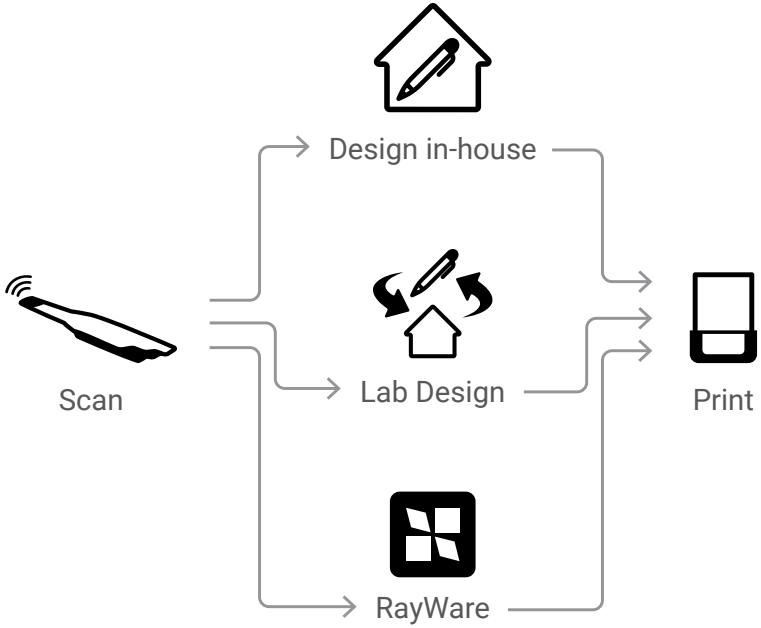
3D printing is an exciting new technology for dentistry that promises better treatment customization and increased margins for clinics. From the outside looking in, it can be difficult to separate bullish hype from the daily reality of in-office use.

Though future innovations will continue to add value to this technology, investing in a SprintRay 3D printer for your office today can have immediate benefits, including a rapid return on investment, improved patient experience, and complete workflow control.

Rapid Return

Just like any other office tool, a 3D printer needs to offer a rapid break-even and a continuous return on investment. With downward pressure on treatment fees and lower insurance reimbursements, this component is more important than ever. While the use of each 3D printer varies from practice to practice, SprintRay 3D printers offer many routes for rapid return and increased profits.

Clinicians who offer aligner therapy can use a SprintRay Pro to rapidly produce models for aligners, reducing or eliminating lab fees for a massive



Dr. Grutter uses 3D printing to manufacture clear aligners in-office, making the price more attractive to patients and increasing case acceptance.

Dr. Olivera uses 3D printing to fabricate digital dentures at a fraction of the cost and time of traditional fabrication.

OrthoSelect uses SprintRay 3D printers to manufacture indirect bonding trays, allowing doctors to place a full arch of brackets in 5 minutes.

Dr. Kelliny prints his own surgical guides for endodontic surgery, reducing procedure time from over an hour to a consistent 10 minutes.

profit increase. Orthodontists can 3D print indirect bonding trays, reducing bracket placement time by up to 90% while saving on lab fees. Surgeons can offer guided implant surgery for only a few dollars in materials, increasing speed and surgical confidence while improving the patient experience.

Improved Patient Experience

An exceptional patient experience is the best way to grow your practice. Adding a 3D printer to your office allows you to cut treatment times, provide personalized care, and increase case acceptance by setting your own fees for production. Respond quickly to patient needs; if something is lost or broken, replace it in an hour from its digital file rather than starting from scratch.

Complete Workflow Control

Owning a 3D printer can mean having total control over the entire treatment process. It can also mean streamlining efficiency with a less hands-on approach. Regardless of which design method you choose, 3D printing appliances only costs a few dollars in materials and can be completed in under an hour, rather than days or weeks.

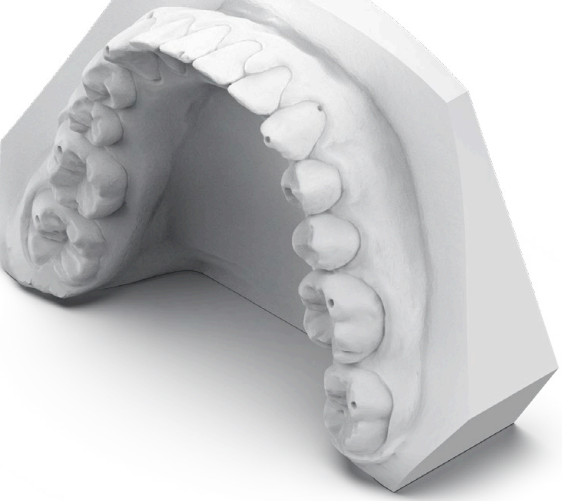
Doctors who want to be in full control of digital dentistry can design their own appliances using one of our software partners and then print the digital files in-house.

To produce appliances without being involved in the design, clinics can benefit from their existing lab relationship. Simply submit your scanned data, then receive a printable file.

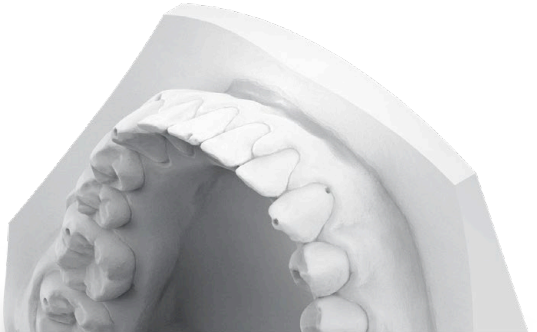
If you just need a study model, directly import your intraoral scan data into SprintRay's RayWare software and make the model printable with a single click, a feature completely unique to SprintRay.

The Practice Revolution

With the SprintRay Pro, 3D printing is truly ready for primetime. SprintRay 3D printers offer rapid return on investment, an improved patient experience, and full workflow control. With so many innovations that can be leveraged today, 3D printing can revolutionize almost any dental practice.

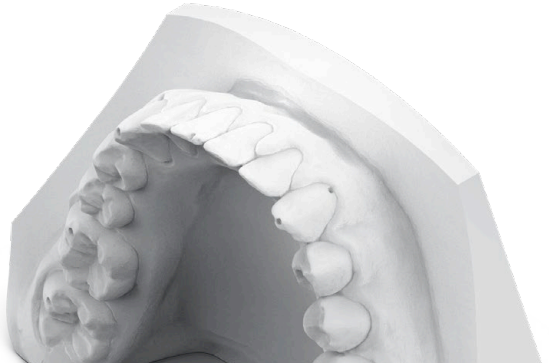





Clinical Considerations for Purchasing a 3D Printer

When it comes time to purchase a 3D printer, it's easy to be intimidated by the sheer number of options and the insider vocabulary. The industry can certainly be a bit opaque at times, so we've broken down some of the main things you should consider before you buy.



Production Workhorse

7
Full Arch Dental Models
25 Minutes

SprintRay printers offer excellent speed and throughput thanks to DLP technology and innovative design. To offer a sense of what kind of speed you can expect from SprintRay Pro and other competitive printers, we put together a set of test prints to demonstrate the real-world difference that these speed and throughput differences can make.

To ensure fairness, we used data freely available from our competition and recreated each print on each machine as closely as possible in order to represent real-world dental printing scenarios.

Unparalleled Speed of DLP

Printers like SprintRay Pro and the MoonRay S offer incredible production capacity due to their advanced DLP technology, vastly increasing flexibility for myriad treatments. This flexibility translates to a better experience for your patients, allowing them to receive treatment same- or next-day.

Thanks to DLP technology, SprintRay 3D printers are both incredibly fast and outstandingly accurate. They have the speed for rapid single-part prints and the capacity for huge production batches. With robust 3rd party materials support, they are some of the most flexible printers on the market.

Case 1: Dental Models

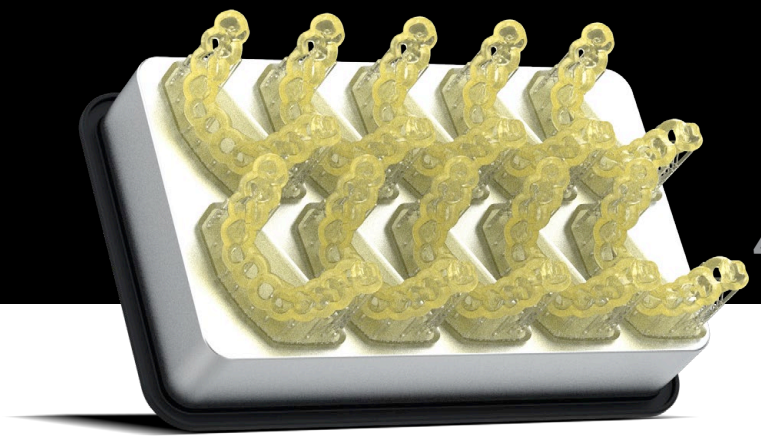
Whether you're fabricating models for the production of clear aligners or creating wax-ups, diagnostic models or anything else, speed is paramount. For this test, we printed as many full-arch models as possible, oriented flat against the build platform, to simulate clear aligner production.

SprintRay Pro and Die and Model resins are specifically designed to work together, creating models with outstanding accuracy at a breakneck pace. So what does the speed differential look like when we level the playing field and fill the platforms of SprintRay Pro, MoonRay S, and a laser-SLA competitor?

Because SprintRay 3D printers utilize DLP, they can print a full platform of models without sacrificing speed. Thanks to advances in materials and tank technology, SprintRay Pro is faster still than MoonRay S, completing 8 flat full-arch models in just over 30 minutes. When you combine the speed of SprintRay Pro with the volume of its build platform, you begin to see the multiplying gains of DLP technology.

While SprintRay Pro has around 10x more throughput than its SLA competitor when producing models, many doctors use their in-office 3D printers to produce biocompatible dental appliances such as surgical guides or nightguards, and such appliances are usually printed in lower volumes than models for clear aligners, so we decided to test two more dental applications to see if the speed difference was still relevant.

8
Nightguards
45 Minutes



10
Full-Arch
Surgical Guides
40 Minutes

Case 2: Nightguards

Nearly every patient can benefit from wearing a nightguard; they can reduce wear and gingival recession plus protect restorative treatments. Without 3D printing, the fabrication process can be long and the final results can be very costly. Thanks to digital impression scanners and SprintRay Pro, you can manufacture up to a dozen nightguards per hour for only a few dollars per guard in materials cost.

For this test, we once again oriented the models flat against the build plate. However, because nightguards don't feature a flat base like dental models, we used automatically-generated supports at medium strength and density for all three print jobs generated within the relevant print prep software.

For the first test, we prepared nightguard designs for four patients to gauge speed for this application. For the second simulation, we filled the platforms with as many nightguards as possible in flat orientation to test the max throughput.

Because of its large build platform and high-definition DLP projector, SprintRay Pro can produce nearly a dozen nightguards per hour when oriented horizontally with the build platform. Even if you're printing only one or two guards at a time, you can easily provide same- or next-day guards with a mere 30-minute print time.

Case 3: Full-Arch Surgical Guides

Guided surgery improves the experience for both doctor and patient. Before in-office 3D printing, a mill was required to manufacture surgical guides in-office, and even then only quadrant guides were possible. 3D printing makes it easy, cost-effective, and fast to fabricate full-arch guides in-house for very little cost - without the waste and undue stress of making them on your mill.

Since implant placement is less common in some offices, we set up this job with 2 guides to simulate a common printing configuration. Similar to the nightguard test, we oriented the models flat on the platform and populated automatically-generated supports in the print prep software.

When printing two guards, it took SprintRay Pro less than half the time of the SLA competitor. MoonRay S performed well in this test, too, completing two guides in just over a half-hour.

And when larger capacity is required, SprintRay Pro's throughput is multiplied, fitting 8 horizontal arches simultaneously and printing them in a half-hour, offering a total throughput of over a dozen full-arch surgical guides per hour.

Upfront Price and Cost of Ownership

In the world of dental 3D printing, price can vary wildly from product to product. Some printers purely for the creation of models can be had for as little as a few thousand dollars, while certain top-end models sell for a few hundred thousand. The printers that meet the needs of dentists tend to fall between the ranges of $5k - $20k. Printers that fall below this threshold tend to be built for hobbyists or prototyping, and lack the dependability required in a clinical environment. Above this ceiling are printers meant for labs, with much higher maintenance cost, larger form factors, and steep learning curves.

Dental 3D Printing: Where High-tech Touches Tried-and-true

One of the things that makes dental 3D printing unique is that it exists at the intersection of two very different industries. On the one hand is dentistry, which is itself a composite consisting of one part art, one part science. Dentistry relies on a specific set of tried-and-true methodologies and tools that serve as a benchmark for performance. Digital technologies are, in some cases replacing these tools , helping to push this profession into the high-tech world of tomorrow. Highly-specialized products built specifically for dentistry such as intraoral scanners and cone-beam CT scanning are changing the landscape of the profession.

3D printing with resin is rapidly becoming a go-to method for manufacturing highly-customized, low-volume plastic parts. While the technology is still maturing, industries from aerospace and automotive manufacturing to biomedical production are adopting the technology with seven-figure budgets. On the opposite side of the 3D printing industry are the hobbyists; there are many 3D printers available to the general public for less than $1000 that are used for printing a vast array of home-use items from figurines to cable organizers.

So where does 3D printing touch dentistry? At the clinical level, doctors who are interested in creating dental models, implant surgical guides, nightguards, digital dentures, and many other functional appliances in-house can now do so without the intervention of traditional lab processes. To review, the requirements for a dental 3D printer are extremely high accuracy, availability of FDA-compliant biocompatible materials, and reliability/user-friendliness. So how much should that cost? To understand how to find the sweet spot between price and quality, it helps to understand a bit of 3D printing history.

Breaking Down the Cost/Quality Paradigm

One of the breakthroughs that make in-office 3D printing possible is the advent of the desktop SLA 3D printer. SLA, or stereolithography, is the fundamental technology that allows for the selective curing of liquid resin into plastic parts. Around the turn of the last decade, engineers began solving one of SLA's chief problems: these printers required a massive amount of space.

The solution they found was to turn the curing system on its head, allowing for a light source to be mounted below a resin tank with a light-permeable floor. This innovation allowed manufacturers to create 3D printers no larger than a typical household microwave. But there was one more major hurdle before 3D printing was ready for dentistry: the light delivery method of laser-SLA was slow, cumbersome, and not accurate enough for clinical use.

Until MoonRay shipped in 2016, there was no affordable desktop SLA 3D printer that leveraged Digital Light Projector technology. DLP printers

	Estimated Total Cost w/ 3DP	Estimated Cost Traditional	Savings per Case	Cases to Break Even
 **Guided Surgery**	$50	$350	$300	23
 **25-Tray Aligner Case**	$350	$2,000	$1,650	4
 **Night Guard**	$25	$350	$325	20
 **Digital Denture**	$250	$1,500	$1,250	5

were much faster than their laser-SLA predecessors. Using a projector to deliver light not only sped up the process when printing multiple parts simultaneously but also drastically reduced the number of moving parts. A DLP projector simply turns on and off as needed. There are no galvanometers, no servos, no stepping motors.

With the arrival of desktop DLP 3D printers, the technology had arrived in dentistry, and the cost/quality paradigm that had ruled the industry shifted dramatically. Suddenly, affordable printers could render previously unbelievable details with a repeatable accuracy that was within 100 microns. Intrepid dentists, who had long been looking for an alternative to traditional lab manufacturing methods for certain therapies, took notice.

The Leap Into Dentistry

With the introduction of the affordable, accurate 3D printer, materials companies rushed to create 3D printing resins that were FDA-compliant and could be placed intraorally. When they succeeded, dentists could suddenly spend less than $5,000 for an in-office manufacturing system that could make surgical guides, clear aligner models, try-in dentures, and more. The MoonRay S, with its rapid build times and low operating costs, rose to prominence in dentistry.

But despite the success of these first-generation dental 3D printers, there was more work to be done. While printers like MoonRay could produce many types of biocompatible dental appliances, Throughput and ease-of-use remained significant opportunities for improvement within dentistry.

SprintRay Pro was released in 2019 to address these potential improvements and also to anticipate the future needs of dental clinics and labs, while maintaining the same incredible value position as its predecessor and has gone on to receive great acclaim for its achievements in these areas. Lauded as the first 3D printer truly built for dentistry and dentistry alone, its wide resin compatibility, proven accuracy, and user-friendliness have made it the first choice of clinics, labs, and dental education centers alike.

The Pricing Landscape Today

Dr. August de Oliveira, dental 3D printing expert, advises that dental clinics should spend around or less than $10,000 on a 3D printer. Generally speaking, printers that cost more than $10,000 will have diminishing marginal returns for clinical use. This rough price point includes many competitive dental players: printers from SprintRay, NextDent, Asiga, Formlabs, and more.

So what about the printers far below this price point? There are many 3D printers available today that advertise high accuracy for less than $1,000. Printers in this price range tend to be made for hobbyists and prototypers who do not need printing for their daily operations. Tradeoffs in reliability and accuracy are acceptable for the target users at these prices, as are the higher maintenance burdens and costs. But their performance is not aligned with the needs of dental offices that require consistent and reliable production. They will often include software that is not user-friendly, and their claims about accuracy are not generally validated..

Based on our experience, the right price for a 3D printer to be used in a dental practice is between $5,000 - $10,000. Printers in this range provide ample support, resin options, and accuracy verification, but are still inexpensive enough to provide break-even on investment after only a few months of operation. Purchasing printers that are above this ceiling tends to provide marginal gains, if any, for an individual dental clinic. On the other hand, buying a cheap printer can often result in more headaches than productivity, negating much of the positive impact of 3D printing in the first place.

SprintRay Pro

Formlabs 3B

NextDent 5100

Asiga MAX

Phrozen Shuffle XL

Speed	2 inches per hour	0.15 - 1 inch per hour	2 inches per hour	2 inches per hour	1 inch per hour
Build area	31 in sq.	35.2 in. sq.	13.7 in. sq.	12 in. sq.	34.87 in. sq
User-friendly software	★★★★★	★★★★	★★★	★★	★
Supported Materials from 3rd party brands	DENTCA, KeyStone, NextDent	None	None	Open platform	Open platform
Annual cost for live support	Free Phone Free Email Support	$250/year	Free Phone Support	Not available	Not available
Onboard computer	7” Touchscreen	Basic Touchscreen	Basic Touchscreen	Basic Touchscreen	Basic Touchscreen
Consumable parts	Resin tank	Resin tank	Resin tank	Resin tank	Resin tank, LCD light source
MSRP	$6,750	$4,999	$9,999	$10,999	$1,000


SprintRay
DIE AND MODEL
TAN
SR-0202006
1 Liter
Print
Ready to Print
Upload Print Job from Desktop or Insert a USB drive to start.
Fantastic Dragon
P95-KH4N124
SprintRay

Is Now the Right Time to Buy?

This is a question that we hear from many dentists. While some believe that the technology is still maturing, and that waiting is the prudent move, many doctors have demonstrated that 3D printing presents a clear, rapid path to improved workflow control and massive ROI today. So where is dental 3D printing in its development, and what factors will drive innovation in this category going forward?

The Core Technology

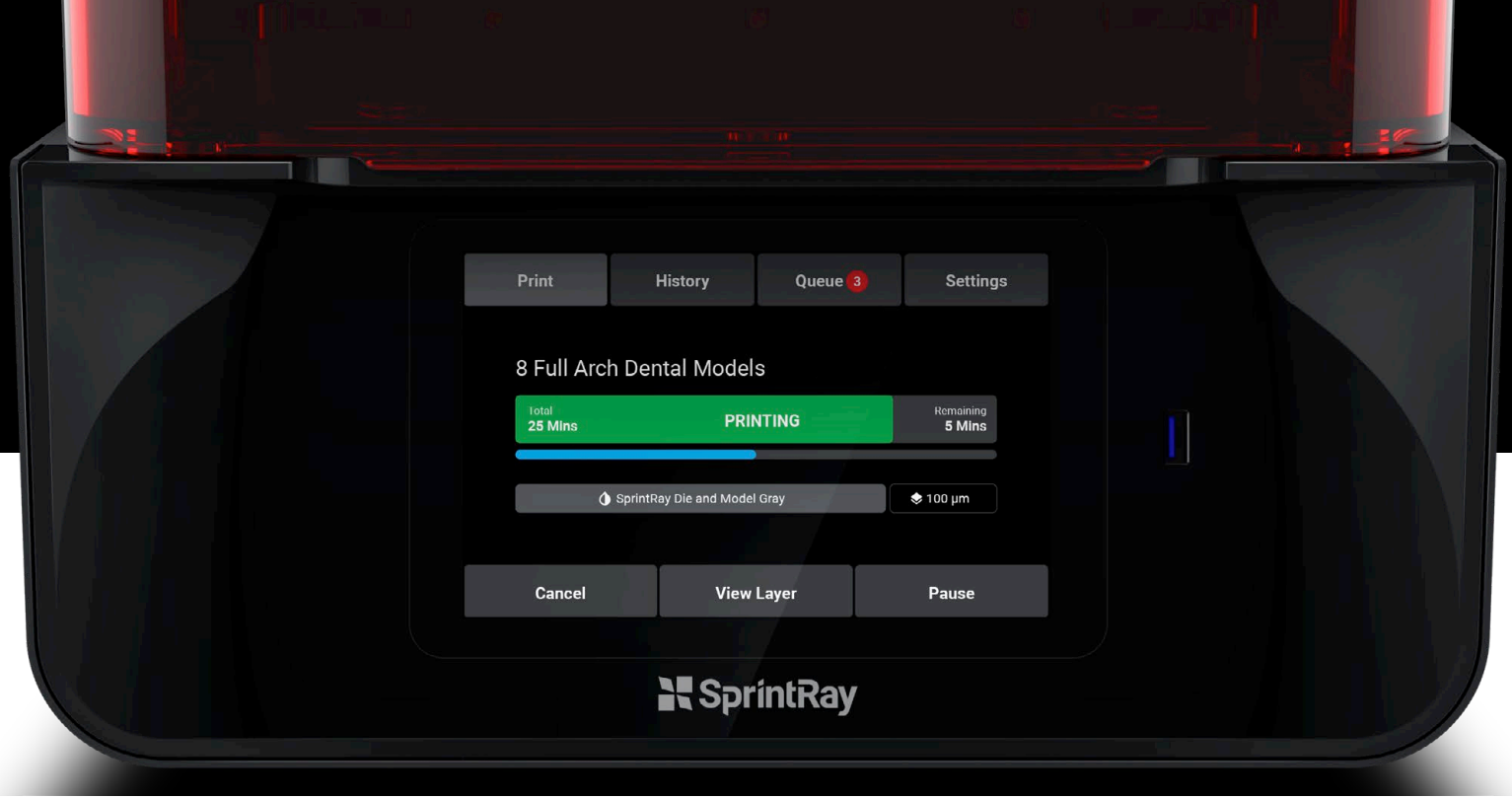
As covered in previous sections of this book, 3D printing in dentistry is driven largely by the broad technology category of stereolithography, or SLA. These three technologies have enjoyed relative stability in the last three years, and are currently experiencing substantial refinements to usability, reliability, and accuracy.

The variety of printers producing good results in dentistry all rely on one of these technologies. The technology and engineering that underpins 3D printing in dentistry, then, is in a stable place and it is unlikely that any major innovation will drastically change its ability to perform in a clinical environment.

3D Printing Materials

Industry professionals believe that materials will be one of the biggest areas of growth in the next several years for dental 3D printing. Indicators of this are breakthroughs such as KeyStone's new nightguard material, KeySplint Soft. This revolutionary resin provides an outstanding balance of rigidity, dimensional accuracy, and flexure to ensure a comfortable fit. DENTCA denture resins are another example, with teeth and base resins that are far superior to their predecessors.

These resin breakthroughs have, so far, been happening largely outside the realm of 3D printer manufacturers. This means that to keep pace with these innovations, 3D printers that use a locked resin system must wait for their



manufacturer to ape these new resins before they can leverage the benefits. Systems that allow for 3rd party resins, like SprintRay Pro, can rapidly test, validate, and distribute curing profiles, allowing end-users to immediately benefit from new materials.

Buying a 3D printer with a locked-down resin ecosystem, then, means that you're taking a gamble that your manufacturer can keep up with materials science. Printers that can accept 3rd party resins, however, can continue to keep pace with innovation without needing to replace costly hardware.

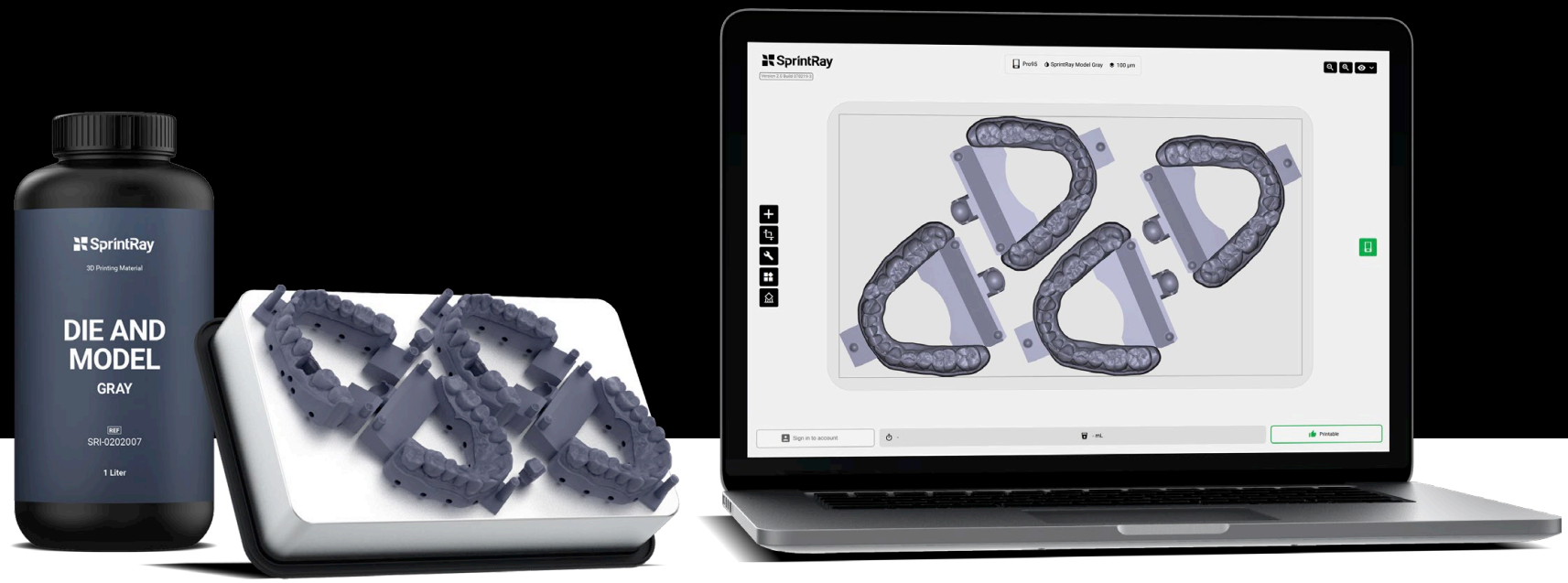
Software and Usability

One major area of innovation in the coming years of dental 3D printing is the specialization and maturation of the full software experience. Software has the potential to make or break a 3D printing experience. It can also unlock new features and improve existing hardware with firmware updates and new features.

Many printers on the market today come with rudimentary onboard computers that are basic in their functionality, and so this can be a concern for prospective buyers. In dentistry, clinicians and auxiliary staff must navigate through these for successful integration. But SprintRay Pro features a large touchscreen computer with a powerful 6-core processor and an intuitive user-interface.

Already, months after SprintRay Pro launched, new improvements have been enabled through software in the form of tank heating, which increases the reliability and reduces the strain of printing with viscous resins. Because of its forward-thinking design, SprintRay Pro will continue to receive enhancements to improve the 3D printing experience.

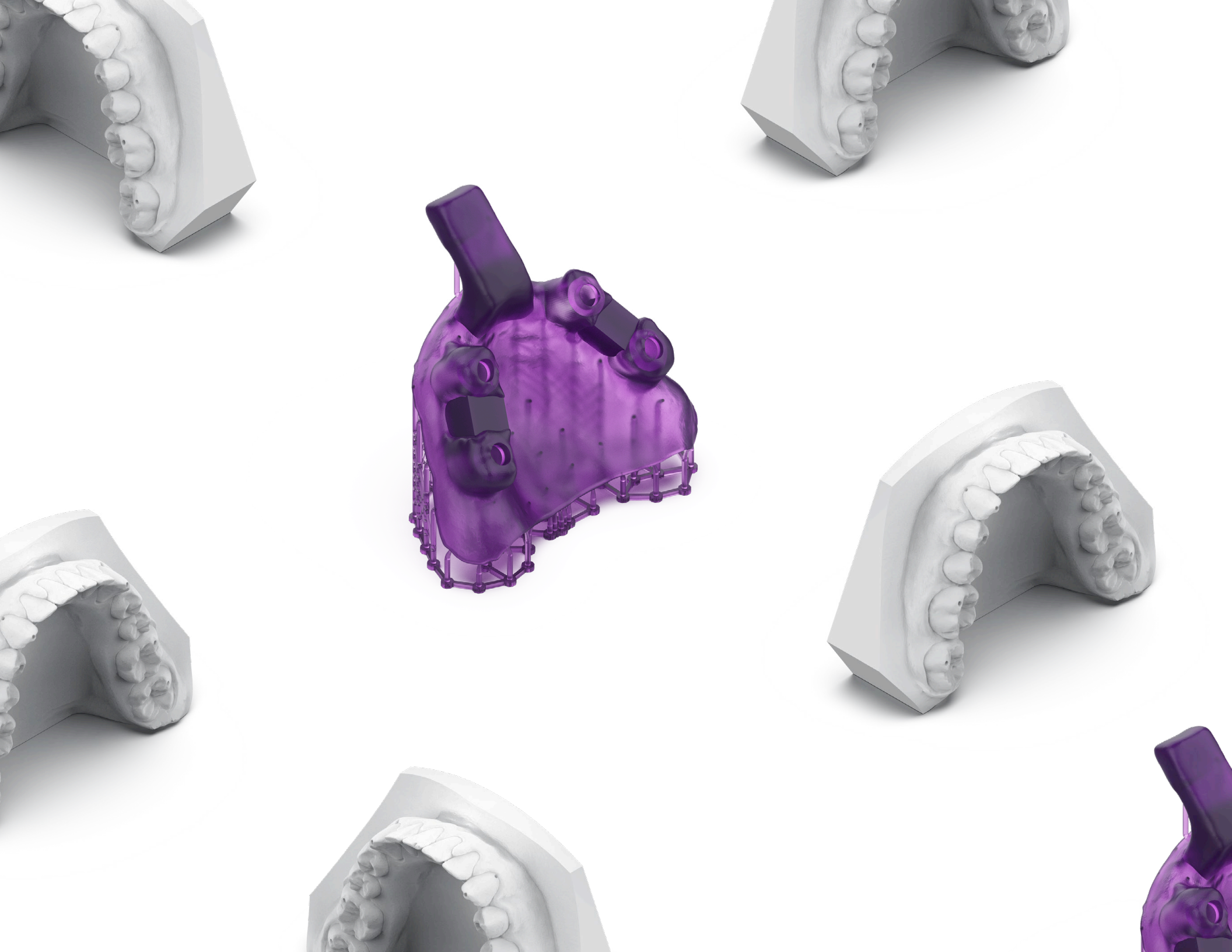
Beyond the printer itself, the nesting software that accompanies a printer is also critical. Fortunately, this piece is not typically not locked into any one piece of hardware. This means that software will continue to become easier

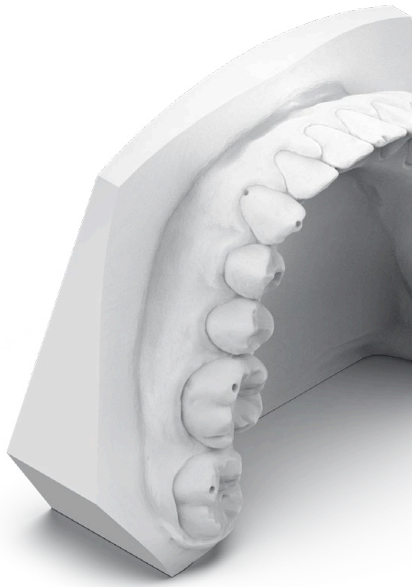


to use and expand in functionality. RayWare, the software for SprintRay Pro, already includes advanced dental CAD features that allow users to close and base raw intraoral scans in a single click. New features are being added all the time to improve this aspect of the 3D printing experience.

The Time is Now - If You Choose Wisely

When it comes to being ready for the future, not all 3D printing products are created equally. But if you're worried that now isn't the right time to invest, think again. 3D printing will continue to make amazing advances in performance and reliability - but even today, these machines can dramatically improve the speed, quality, customizability, and costs of the procedures you are doing today. If you carefully consider your choice and select a printer that allows for 3rd party resins and has a robust software and hardware ecosystem, then there's never been a better time. SprintRay Pro allows you to get in ahead of the curve without the growing pains that come with being an early adopter and will continue to be cutting-edge for years to come.

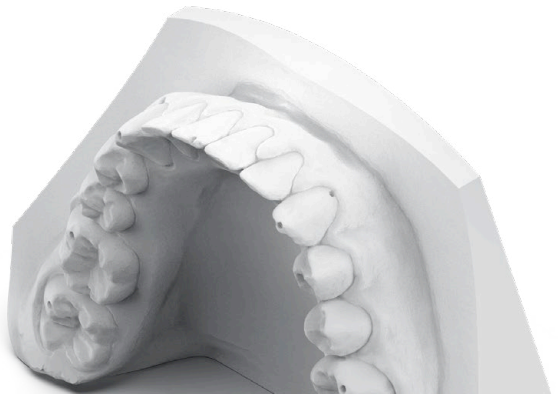




Handbooks and Guides

Sometimes, what you need is a little bit of context. These guides are designed to give you everything you need to be successful at printing by giving you the background and understanding you need in order to make good decisions. Ultimately, everything we build is to make your printing life easier.

Remember: 3D printing isn't just about learning one skill and then moving on. It's a continuous path of improvement and there's always more to learn. If at any point during the process you'd like some help, call us up. Printing what we do, and we're here to help you get the most out of it.



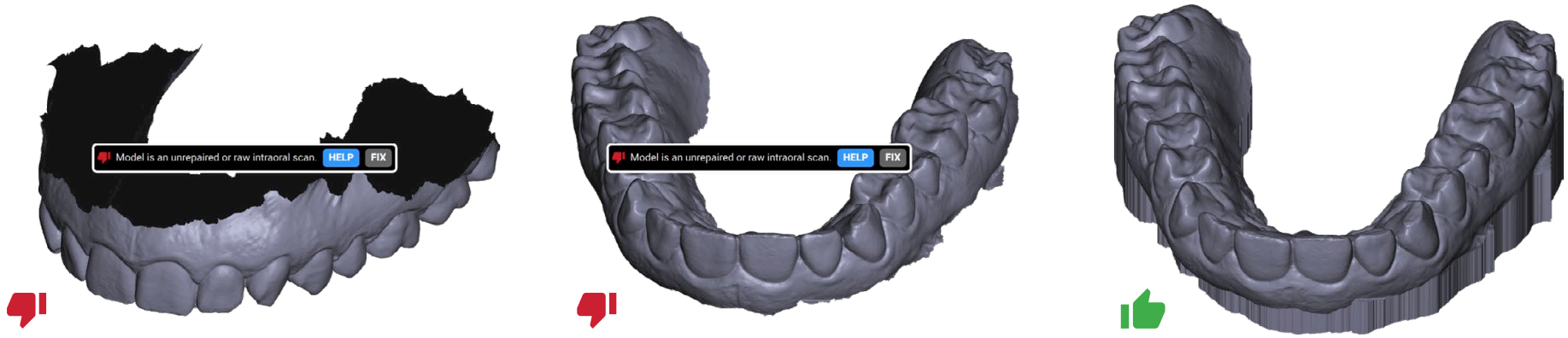
Dental 3D Printing Success Handbook

It's a fantastic feeling when you open the lid of your SprintRay Pro to see a full platform of perfectly-formed parts. But finding that your models are malformed or have fallen into the resin tank can be confusing and frustrating. Recent advances in 3D printing technology have made it easier than ever to achieve success with this powerful tool. But while SprintRay goes to great lengths to ensure you reach your production goals, there are a few external factors that can affect the final success of any print job.

SprintRay's mission is to help dental clinics and labs grow to meet their production goals. To help you on your way, we put our heads together to help you identify and help avoid 3D printing problems. Whether this is your first 3D printing experience or you're a veteran of the first affordable desktop FDM models, we hope that this guide helps you unlock the incredible potential of in-office dental 3D printing.

Follow Best Practices for Preparation and Design

The preparation and design phase encompasses three major activities: capturing patient data, using that data to design an appliance, and importing that file into RayWare for print nesting. Mistakes made during this first phase can have wide-reaching effects. Inconsistencies in scan data, CAD design problems, and improper print setup can all lead to problems if not corrected.



RayWare uses machine learning to check your models for holes and non-manifold surfaces. If you receive a warning from RayWare, double-check your model before printing to verify that there are no issues.

Ensure Consistent Scanned Data

Intraoral scanners are a fantastic piece of technology, enabling dental professionals to digitally capture patient data without the problems associated with traditional impressions. But even small imperfections or gaps in scan data can have adverse consequences on the quality of your final print, as the scanned data is the blueprint for every part of the process going forward, including 3D printing.

When scanning, ensure that all data is complete and there are no visible holes. Pay close attention to the rendering of the patient's dentition to ensure that the digital scan matches up with reality. Once the scan is complete, take a detailed look at the 3D file. Rescan any areas that appear to be missing data to maximize success downstream in the process.

Ace the Model Design

If you're using dental CAD software such as 3Shape or Exocad, ensure that your models are fully closed and watertight before exporting them to your printer. RayWare uses machine learning to check your models for holes and non-manifold surfaces. If you receive a warning from RayWare, double-check your model before printing to verify that there are no issues. Additionally, ensure that you are designing your appliances correctly for your printer – different printers can have different requirements for settings such as offset, retention, and tolerance. Proceed with these desired settings in mind.

If you outsource the design of your appliance to a lab or other 3rd party, make sure to communicate to them which printer you'll be using for fabrication. Despite their expertise, labs and design services may occasionally provide you with models that have printability issues. If you receive errors in RayWare or notice any black holes on the surface of your model, ask them to double-check their work. For help verifying if your 3D model has printability problems, reach out to SprintRay Support.

Nail the Nesting Phase

There are two major, related considerations when orienting your models for printing: support structures and orientation. If you are printing models that have a large, perfectly flat base, such as models for clear aligners or waxups, then printing the models flat against the platform is the most rapid way to proceed. This method will provide the highest print speeds and require the least post-processing, as there are no support structures to contend with. However, printing flat against the platform is only possible when your model has a perfectly flat base and is free of major overhangs.

For models that do not have a flush base, such as surgical guides, nightguards, and denture bases, support structures will be required. Because

most desktop 3D printers fabricate upside-down, support structures are necessary to achieve good adhesion with the build surface. RayWare can automatically generate supports with the click of a single button. When printing with supports, we recommend that you orient your models between 30- and 60-degrees from the platform.

Care for and Store Resin Properly

Resin and SprintRay Pro function together as a team. If there's a problem with your printing materials, your printer may not be able to produce consistent, desirable results. Resin care isn't difficult, but certain rules and processes can help you avoid common mistakes that can lead to print failure. Resin management can be broken down into two core handling phases: resin when it is in the bottle and when it is in the printer's resin tank.

Resin in the Bottle

With the cap secured tightly and when stored at room temperature, resin can be kept in the bottle until its expiration date. The expiration date for SprintRay resin is listed on the back of the bottle. If using a resin that has been on the shelf for a while, make sure to check this date, as the photoinitiators lose efficacy after their expiration date, increasing the likelihood of failure.

SprintRay resins are packaged in bottles designed to limit contamination.

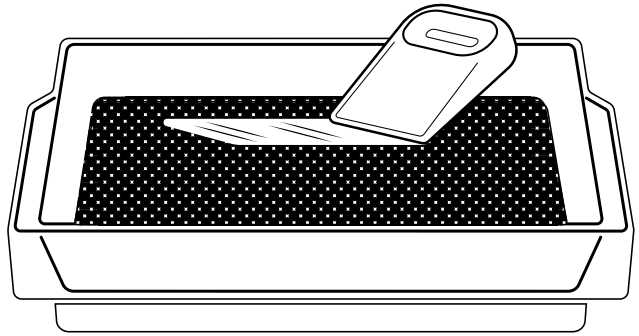
Before pouring resin from the bottle into SprintRay Pro's resin tank, always shake the bottle for a few moments. Note that particularly viscous resins must be shaken longer to ensure proper mixing. Resin that sits for an extended period is subject to phase separation, which can cause print problems. If pouring a new type of resin into your resin tank, ensure the tank was thoroughly cleaned with isopropyl alcohol and a soft cloth.

When pouring resin back into the bottle from the resin tank, we recommend that you filter it through a fine-mesh strainer. Chunks of partially-cured resin that may have formed in your tank can contaminate the resin in your bottle, leading to print issues down the road. This is an especially important practice when replacing resin into the bottle after a print failure, as there is an increased likelihood of cured particles in the resin tank.

Resin in the Tank

Resin exposure most commonly happens when resin sits in your printer's tank. Because the lid is frequently lifted during the printing process, resin is exposed to light, heat, and air each time the print bed area is accessed. Resins compatible with SprintRay printers use photoinitiators with peak absorption at 405nm, which is present in most forms of artificial lighting and certainly in direct sunlight.

Even when the print bed is not being accessed, resin should not be left uncovered in SprintRay Pro's resin tank for more than three days. If left in the tank for more than three days, resin should be strained through a filter before use to remove cured bits. If you'd like to store resin in the tank for longer than 3 days, simply use the provided black tank cover to minimize the risk of contamination.



When significant time elapses between print jobs, make sure to use the resin wiper to thoroughly mix the resin in the tank. The resin should have a consistent, homogeneous appearance. Just as resin must be shaken in the bottle, so too must it be mixed in the tank after it has been left to sit.

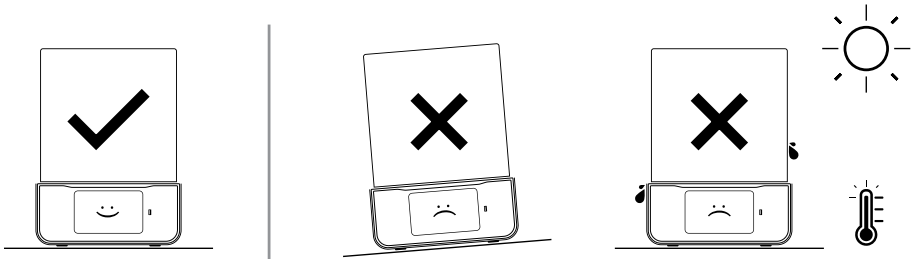
Optimize Your Printing Workspace

Contamination of your printing environment can lead to problems with your final, finished appliances. While potential environmental contaminants are myriad, the rule of thumb is twofold: choose the appropriate environment in which to operate your printer, and keep the environment clean and organized.

Choose the Right Environment

Ensure that your printer is placed away from windows or other sources of bright natural light. If exposed to direct sunlight for even a very short time per day, the chances of resin contamination are greatly increased.

Additionally, high levels of humidity and extreme temperatures can negatively affect your prints. Make sure your printer is in a dry, temperature-controlled room so that proper curing and adhesion can take place. Persistent airflow, such as from a duct or door that is frequently opened, can also cause problems. Place your printer out of the way and keep its environment at a steady temperature, even overnight, between 20-30 degrees Celsius (68-86 Fahrenheit).



Level Surface | Uneven Surface | Warm Environment

Dust and air particles can easily get trapped in liquid resin, so make sure the room you keep your printer in is kept as clean as possible. Small smudges and dust that land on the projector mirror or the glass below the tank can obscure the light's optical path, decreasing the likelihood of print success.

Keep it Clean and Organized

Because SprintRay printers rely on specifically-metered light, even something as minor as a smudge on the bottom of the resin tank can interrupt the optical path. Just as small amounts of cured composite or adhesive on a curing light can interfere with intraoral curing, contamination anywhere along the optical path of the printer can affect print quality and accuracy. Regularly inspect your tank and the glass below for fingerprints, smudges, or bits of partially-cured resin.

The cleanliness of your post-processing environment is paramount for accurate final parts that have the proper fit and finish. One often overlooked but frequently troublesome sore spot is the wash process. Make sure to use a two-stage IPA system: first rinse your printed parts in a vat of IPA, then let them soak for 10-15 minutes in an agitated concentration of IPA 91% or higher. When the IPA in your wash station begins to appear cloudy, replace it with fresh IPA immediately. If you fail to frequently change out your wash station IPA, your parts can come out tacky and sticky.

A general rule that can drastically reduce misprints is to keep everything as clean and organized as possible. Routinely inspect your printer for anything out of the ordinary, and wipe up any resin spills immediately to prevent them from curing to your Pro. Create specific areas used for performing particular sets of tasks: print prep, washing, post-curing, etc. These help limit contamination, reduce mess, and eliminate mistakes.

If you do need to clean your printer, use IPA with a soft cloth and gently wipe out your tank or the glass beneath. IPA helps break down partially-cured resin that has hardened to the printer's surface, so it may take a few moments for the cleaning agent to take effect.

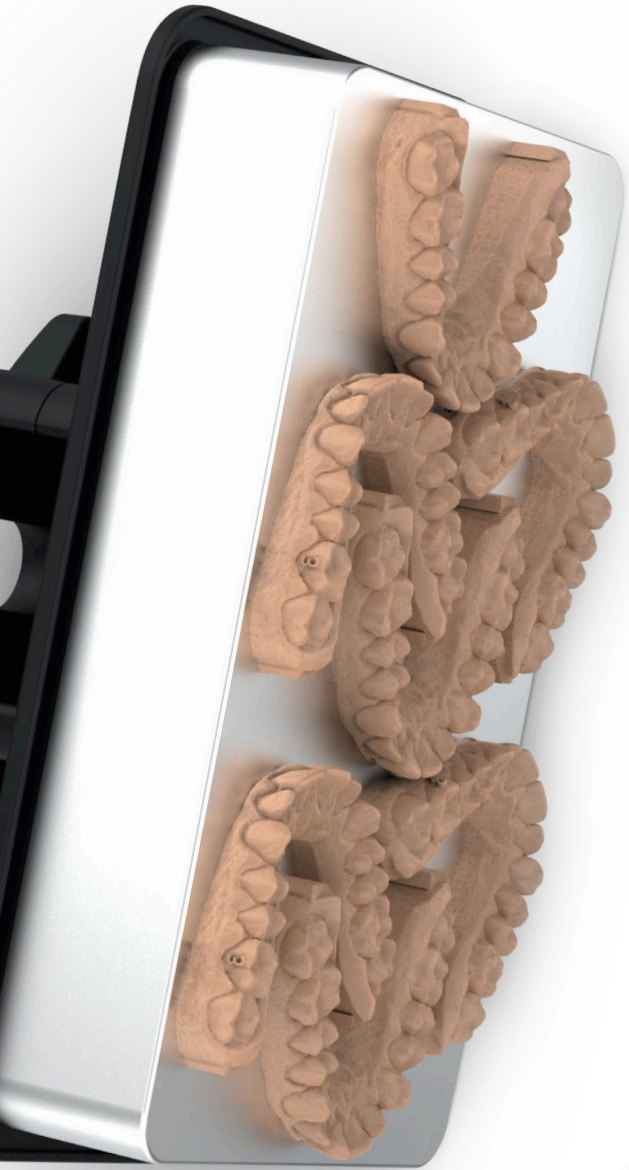
Your Printing Lifeline

At SprintRay, we pride ourselves on our product support. While the suggestions above are great guidelines to make sure your prints succeed, we're on standby to help make sure that things go smoothly. If you want to read on and learn more about the ins and outs of 3D printing, we recommend you start with our knowledge center, where you'll find tricks of the trade and general instructions on dental printing and post-processing.

3D printing is the fastest, easiest way to create many dental appliances. It can provide huge ROI, revitalize your workflow, and delight your patients. But sometimes you're going to want help. Thanks to recent advances in 3D printing technology and usability, 3D printing is easier and more productive than ever. If you're ever confused about something, need troubleshooting help, or just have a general printing question, we'd love to hear from you.


Print
History
External
Settings
Ready to Print
Upload Print Job from Desktop or Insert a USB drive to start.
Fantastic Dragon
P95-KHBN124
SprintRay


SprintRay



Dental 3D Printing Workflow Tips

Keep a clean workspace

- ✓ Create a system for printing that makes good use of your space
- ✓ Build good habits - once you start a process, stick with it
- ✓ Limit access to the print space to only those using the printer

Maintain your printer

- ✓ Filter resin and clean your tank with IPA after misprints
- ✓ Clean the tank thoroughly when switching between resins
- ✓ Stir resin in the tank before each print to ensure thorough mixing

Post-process efficiently

- ✓ Minimize the number of steps and space required for post-processing
- ✓ Use two-stage IPA wash: rinse parts in one vessel, then wash for ten minutes in a separate vessel
- ✓ Use Pro Cure to rapidly post-cure, maximizing the mechanical properties of your parts

Check prints in RayWare

- ✓ Closely examine prints to ensure sufficient build surface contact
- ✓ When printing with supports, orient parts at a 30- to 60-degree angle from the built plate
- ✓ Double-check resin type, layer height, and printer before hitting ‘print’

Fine-tune your printer

- ✓ Calibrate your printer for each resin type that you use
- ✓ To ensure good part fitment, perform ‘Tolerance’ fine tuning until your printer scores a ‘3’
- ✓ Perform ‘Dimensional Accuracy’ fine tuning to calibrate for your post-curing setup

How to Find Help and Resources

Depending on where you purchased your 3D printer, a variety of different options for support will be available. Typically, 3D printer manufacturers are responsible for supporting their products. Dental dealers may sometimes assist, but because this technology is new to dentistry we recommend working with the printer manufacturer first. If you've purchased a SprintRay 3D printer, getting support is as simple as dialing 1-800-914-8004 or emailing support@sprintray.com. Additionally, a vast library of 3D printing tutorials and how-tos can be found at support.sprintray.com. Live phone and email support are free for SprintRay products.

If you purchased your 3D printer from a different manufacturer, getting live support might not be so easy. Many 3D printing companies charge annual fees for even basic support in addition to hardware service plans. To get help with a problem, start by contacting your manufacturer to see if they offer phone or email support. Many manufacturers will have online forums or social media groups where members offer helpful advice to one another when problems arise.

If you're interested in learning more about 3D printing, our Regional Additive Manufacturing Specialists have decades of dental experience. To schedule an appointment, visit our Digital Dentistry Consultation page. We'd love to chat.

SprintRay Support

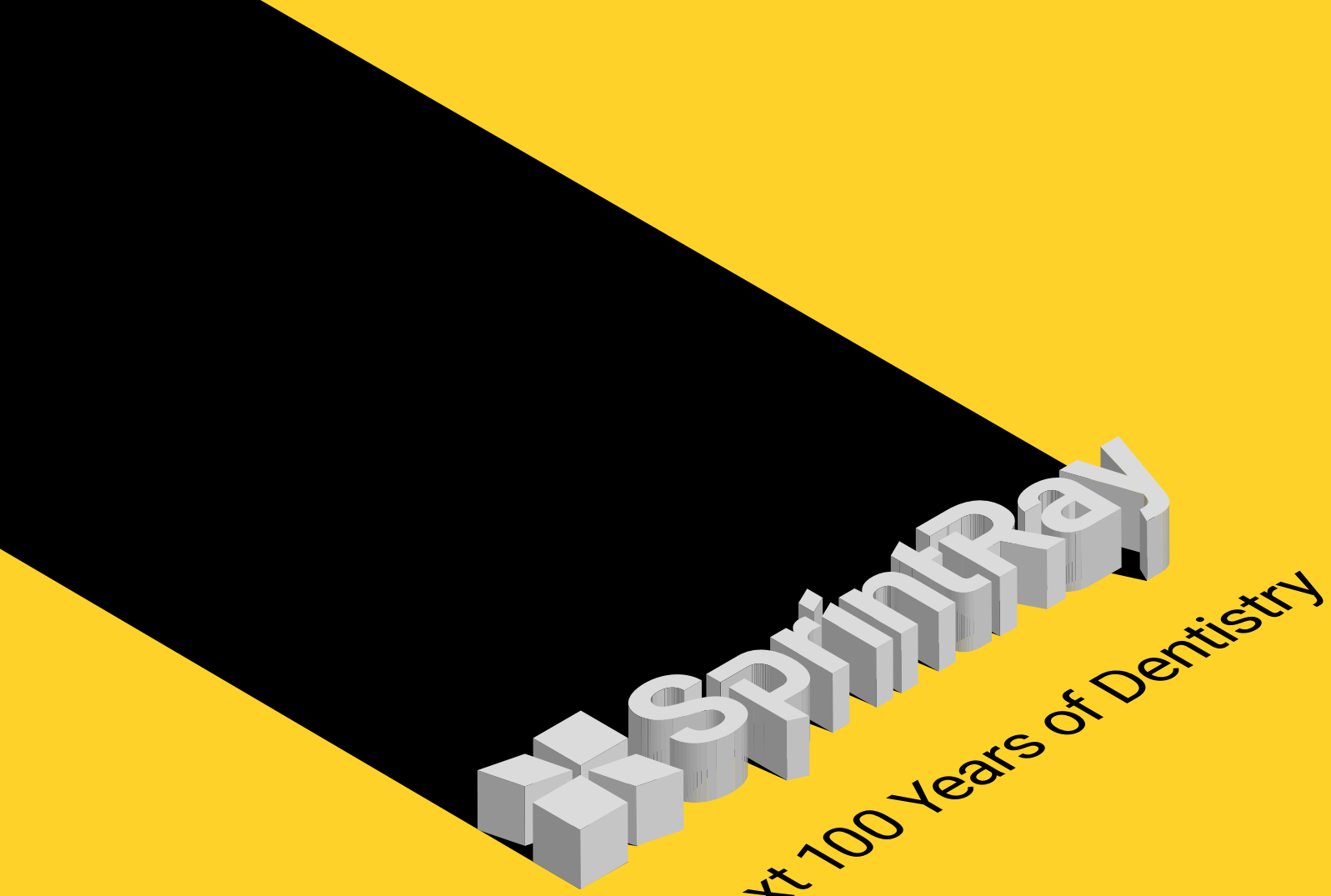
Call 1-800-914-9004

Email support@sprintray.com

Monday through Friday

From 7 AM to 5 PM

Pacific Time



The Next 100 Years of Dentistry