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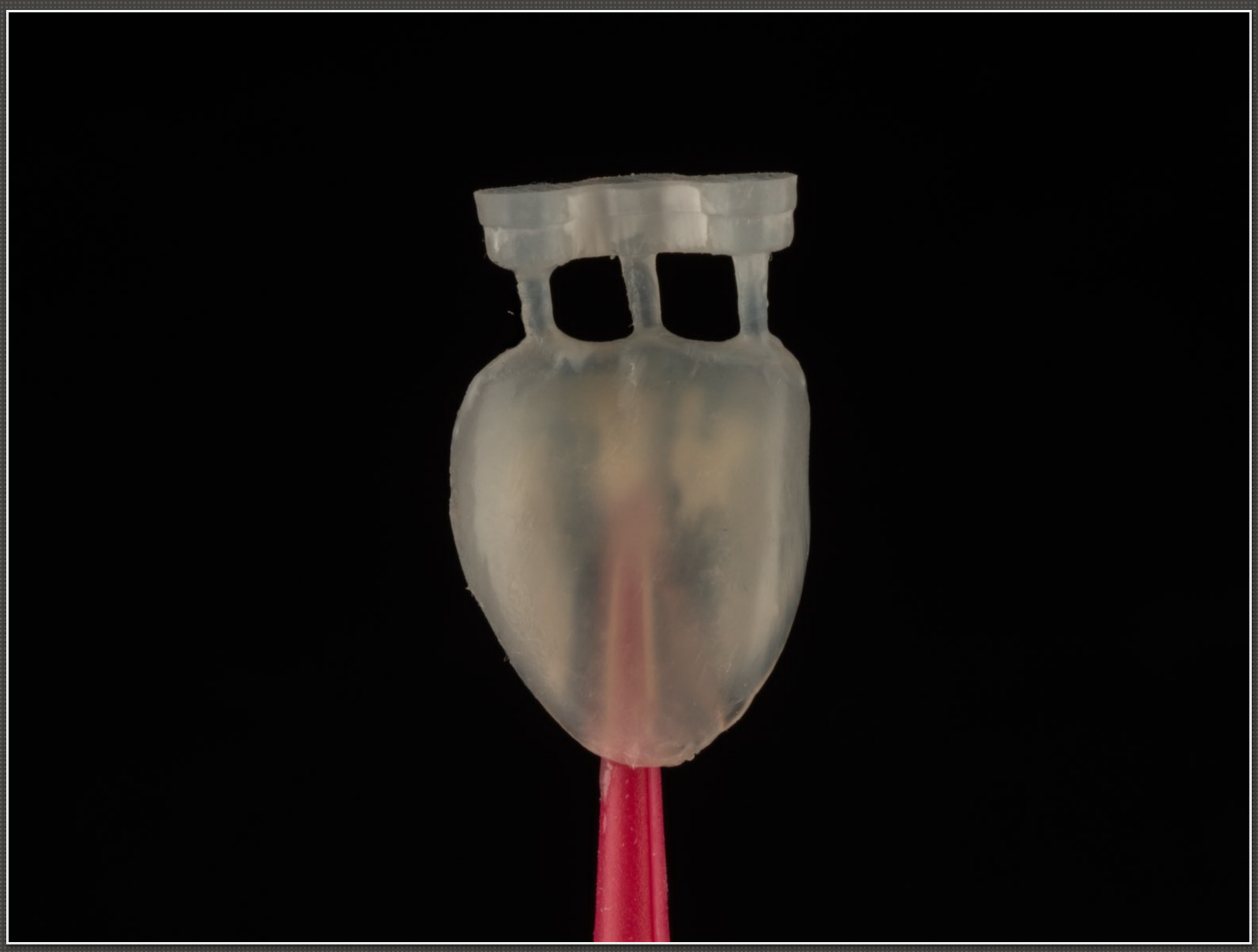
DR. WALLY RENNE
DR. MICHAEL DEFEE

3D Printing in Restorative Dentistry

3rd Edition



MODERN
OPTIMIZED
DENTISTRY

D

INTRODUCTION

Into the Future

This small ebook is designed to explore some applications of 3D printing in dentistry. Resin technology is advancing at an incredible rate leading to exciting new applications in 3D printing. This new technology opens up innovative avenues for patient care.

We need to unite behind technology and push the profession of dentistry into the future. 3D printing will save dentistry. The average dental school debt in the United States is over $500k. Inflation is soaring. Interest rates are flying to the moon, and insurance reimbursements are at an all time low. We feel the pressure, and so do our patients. So how will printing save dentistry? It's really simple. 3D printing brings affordable rapid manufacturing of virtually any dental prosthesis imaginable into your practice. How you implement it is completely up to you. You can partner with your laboratory for design, make an in house laboratory or use artificial intelligence for design. Regardless of the path you choose, the future is bright for dentistry and our patients who'll benefit from this technology.

My intention is to tell you in a very clear, organized way some of my secrets in 3D printing that have taken me years to master and develop. It is designed with clinical practice in mind and is not meant to be a research heavy document. I also have many tutorials on YouTube and on my web site www.TheMODInstitue.com.

Please understand this document is a work in progress and will be updated as needed.

Best,

Dr. Wally Renne

Front cover image by Dr. Wally Renne. Supporting images by Dr. Michael DeFee and Dr. Griffen Revell Names, places, products and events are the sole opinion of the author.

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This guide is dedicated to my friend
and mentor Dr. Bob Holmes.

Gone but not forgotten.

EPIGRAPH

In that moment, the patient is all that exists in the world.

The most important step to anything in life is the step you are on. Be in the moment and dedicate all your focus, all your energy and all your skill to the task at hand, the very step you are on. Do not dwell on what came before, or what needs to be done after, rather focus in the moment. If it is cutting a finish line on a tooth, nothing else should be on your mind except the bur as it presses on the tooth, the tactile feedback of the handpiece in your hand. You see the rotation of the bur, the diamond particles as they smooth the enamel.

Nothing is more important.

— DR. BOB HOLMES

TABLE OF CONTENTS

01 The Best of the Best 06

02 The Resin Revolution 16

03 Monolithic Dentures 28

04 Split File Dentures 56

05 Metal Free Partial 87

06 Introduction to Final Restorations 94

07 Direct Printed Mockups 104

08 3D Printed Veneers 112

09 Inlays, Inlays & Crownlays 119

10 Implant Definitive Crowns 129

11 Occlusal Guards 136

12 Implant Provisionals 145

13 Recommended Reading 162

CHAPTER 1

The Best of the Best

In this chapter, we will explore the best technology and resins of 2023. 2023 was an incredible year for 3D printing in dentistry. Companies are pushing new and exciting workflows to the market that are geared towards same day dentistry. At The MOD institute, we have extensively tested over 25 different 3D printers and a hundred different resins. We have recommendations on the best technology based on our unbiased experience. No money or sponsorship has been taken to ensure this book can be as unbiased as possible.

Best Overall Printer: SprintRay Pro 55s with Crown Kit and Arch Kit

Things We Love

- Fast 10 crowns in 10 minutes
- Easy to use
- Very low failure rate
- Top resins on the market
- Powerful cure unit
- Great support
- Powerful updates
- Heated vat and plate

Things We Hate

- The cloud slicer
- Not the most accurate printer
- Cure unit does not have nitrogen

Best Open Printer: Ackuretta SOL with Small, Medium and Large Plates

Things We Love

- Fast 2 crowns in 18 minute
- Easy to use
- Open system
- Hundreds of resin options
- Great support
- Powerful AI Nesting software
- New cure unit is much better
- Accurate

Things We Hate

- The wash unit is not great
- No vat or plate heater

Best Underdog Printer: Shining AccuFab D1s

Things We Love

- Models print in under 10 minutes
- Easy to use
- Open system
- Hundreds of resin options
- Powerful and easy slicer software
- Integrated design software
- Very accurate

Things We Hate

- The wash unit is not great
- The Cure unit is not great
- Slow for crowns and bridges

Best Lab Printer: Asiga MAX

Things We Love

- Insanely accurate
- Open system
- Hundreds of resin options
- Powerful slicer software
- Lucitone approved
- 385nm technology

Things We Hate

- Difficult to use slicer
- Slow print speed

Best Resin for All On X: ONX Tough 2.0

Things We Love

- Industry leading fracture toughness
- Multiple color choices
- Esthetic
- Radiopaque
- Long track record with ONX Tough 1.0

Things We Hate

- Only available on SprintRay

Best Resin for Crowns, Inlays and Onlays: Tie-Rodin Sculpture and Ceramic Crown

Things We Love

- Above 50% glass filler particles
- Multiple color choices
- Radiopaque

Things We Hate

- Relatively opaque looking
- Hard to polish

Best Resin for Veneers: Tie-Rodin Sculpture and ONX Tough

Things We Love

- Radiopaque
- Multiple color choices
- Can be printed 300 microns thin

Things We Hate

- Hard to polish

Best Resin for Dentures: Tie- High Impact Denture and Lucitone

Things We Love

- Multiple color choices
- High impact formulation
- Extremely strong

Things We Hate

- Premium Price point
- Special curing protocols
- Long cure time

Best Resin for Partial Dentures: Graphy Tera Harz Flexible Denture

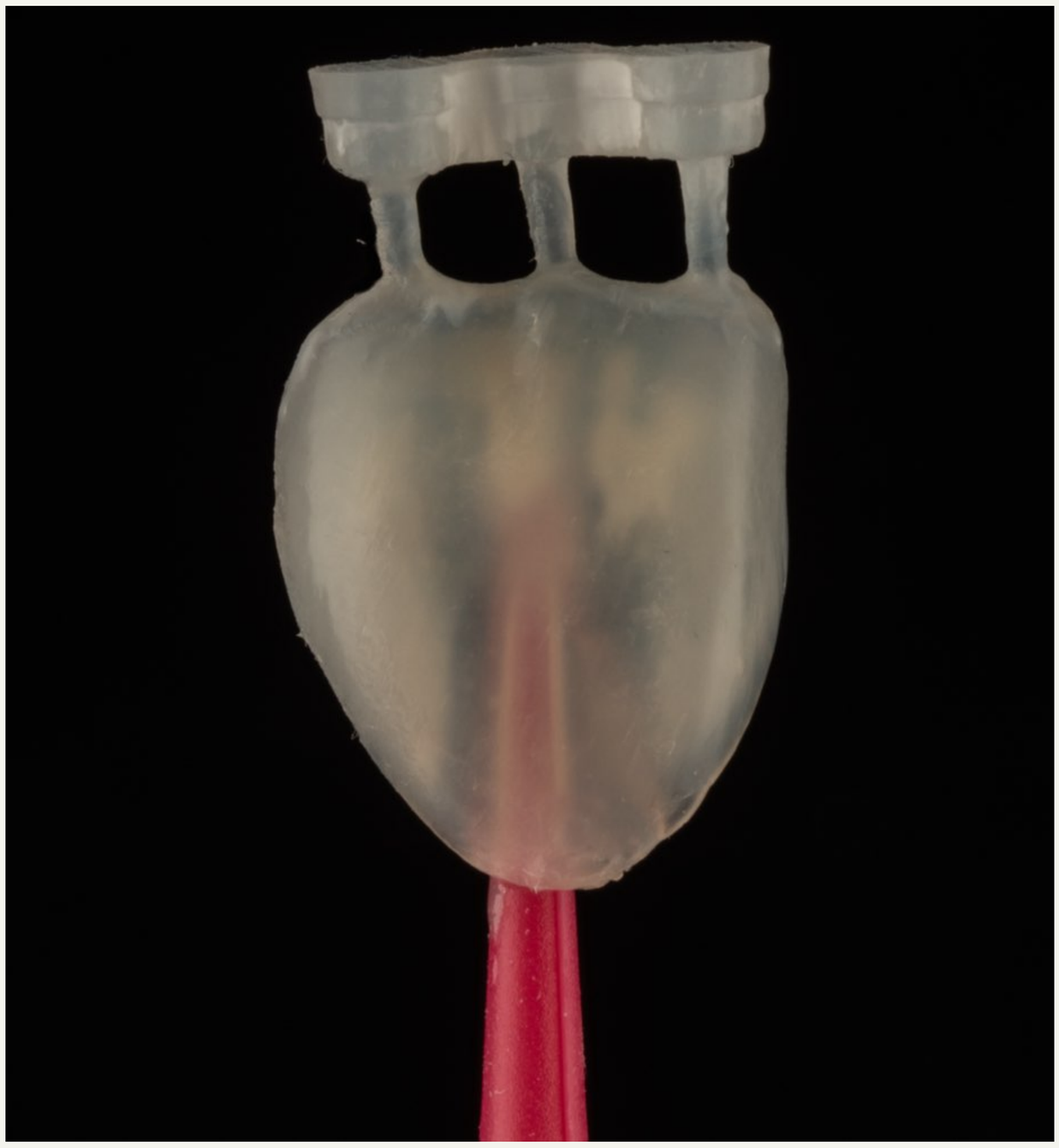
Things We Love

- First printed flexible base material
- High elongation at break
- Extremely tough
- Based on clear aligner material

Things We Hate

- Limited availability
- Only validated on a few printers

Sneak Peak 2024



2024 is going to be an incredible year for 3D printing. Two major innovations are going to come to market. First, we will see new high translucency resins that are also highly filled with ceramic from SprintRay. These will be an esthetic paradigm shift in 3D printing and this new esthetic resin is going to change how we think about 3D printed restorations.

Second, we are going to see some ultra high strength materials from PacDent, in the form of Titan and Sculpture 2.0, and from SprintRay, in the form of High Impact Ceramic Crown. These materials will take printed resins into the realm of porcelain in regards to fracture toughness and flexural strength. These two resin innovations in esthetics and strength will further blur the line between porcelain and resin while solidifying 3D printing as a definitive solution for indirect restorations.

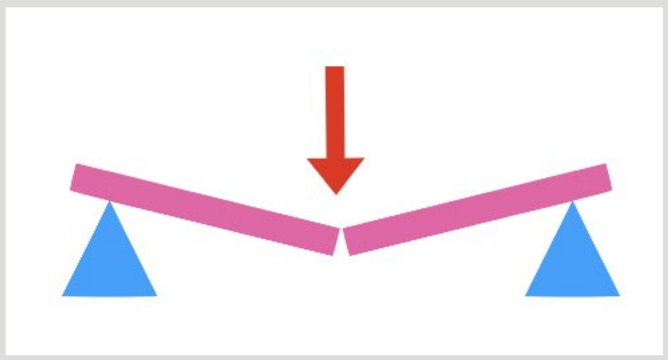
CHAPTER 2

The Resin Revolution

Before we begin to discuss specific resin materials we will briefly discuss testing metrics. Flexural strength is the holy grail of meaningless laboratory numbers that marketing teams have brainwashed into our heads as the value that means everything. The value that we should use to compare dental materials to each other to determine if a material is strong enough. What exactly is flexural strength and do we have data that correlates higher flexural strength to greater clinical success?

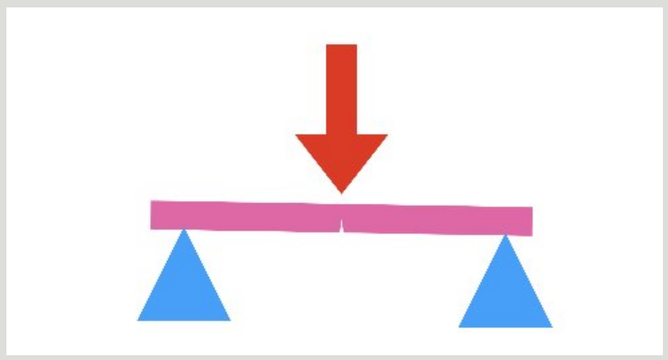
Marketing teams have built a story around flexural strength to play number games that do not matter.

In a recent Meta-analysis, Heintze, et al looked at laboratory values such as flexural strength and tried to determine if these laboratory values have any correlation to clinical success of single unit crowns.1 They found that the only real correlation between clinical and laboratory outcomes in regards to survivability was a material property called fracture toughness. Therefore, the number that we have been told is the number to focus on is actually quite meaningless. Fracture toughness is the real number that we should all be looking at as a predictor of clinical success.



Flexural Strength

Flexural strength is measured by applying a load to a material that is typically a bar shape as determine by ASTM or ISO standards. The bar is supported at each end, which combines the forces found in compression and tension. Typically, ISO 6872 standard is used in dentistry. Bar-shaped specimens are printed, milled or cut into dimensions 1mm x 4mm x ~12mm and then polished. Testing is conducted using a test fixture with a 10mm span and a crosshead speed of 1mm/min in a universal testing machine like an Instron.



Fracture Toughness

Fracture toughness (K1c) is related to the energy required to propagate a crack. In this test, a defined notch is cut into a bar of material. The bar is placed on a fixture that supports either end and the stylus is positioned above the notch in a 3-point bend configuration similar to that used for flexural strength. A high fracture toughness reflects a high ability of a material to prevent crack propagation. Fracture toughness is typically measured according to ISO 6872 where a notch is cut using the V-notch option in bar-shaped specimens but variations exist based on the material type and particle size. Testing is typically done with a crosshead speed of 0.5mm/min. K1c is calculated from the failure load, notch depth, and specimen dimensions. If we look at fracture toughness of some popular ceramic materials we can see an interesting trend that may have been able to predict recent material flops that over promised and under delivered.

Here we see fracture toughness all the way on the right. Dental materials typically range from 1-5 depending on the material. 3Y Zirconia is typically a 5, with certain 4Y and all 5 Y zirconias usually between 2 and 2.5. Dentin and enamel have a fracture toughness of around 2 and 2.5 K1c. A value of 2 and above for fracture toughness seems to indicate a material is going to be a forgivable material for intra-oral longevity.

Fracture Toughness[2]

IPS e.max CAD	2.04 K_{Ic} [MPa√m]
Generic Silicates	1.50-1.70 K_{Ic} [MPa√m]
Celtra Duo	1.51 K_{Ic} [MPa√m]
Tessera.	1.45 K_{Ic} [MPa√m]
Suprinity PC.	1.39 K_{Ic} [MPa√m]
Amber Mill	171 K_{Ic} [MPa√m]

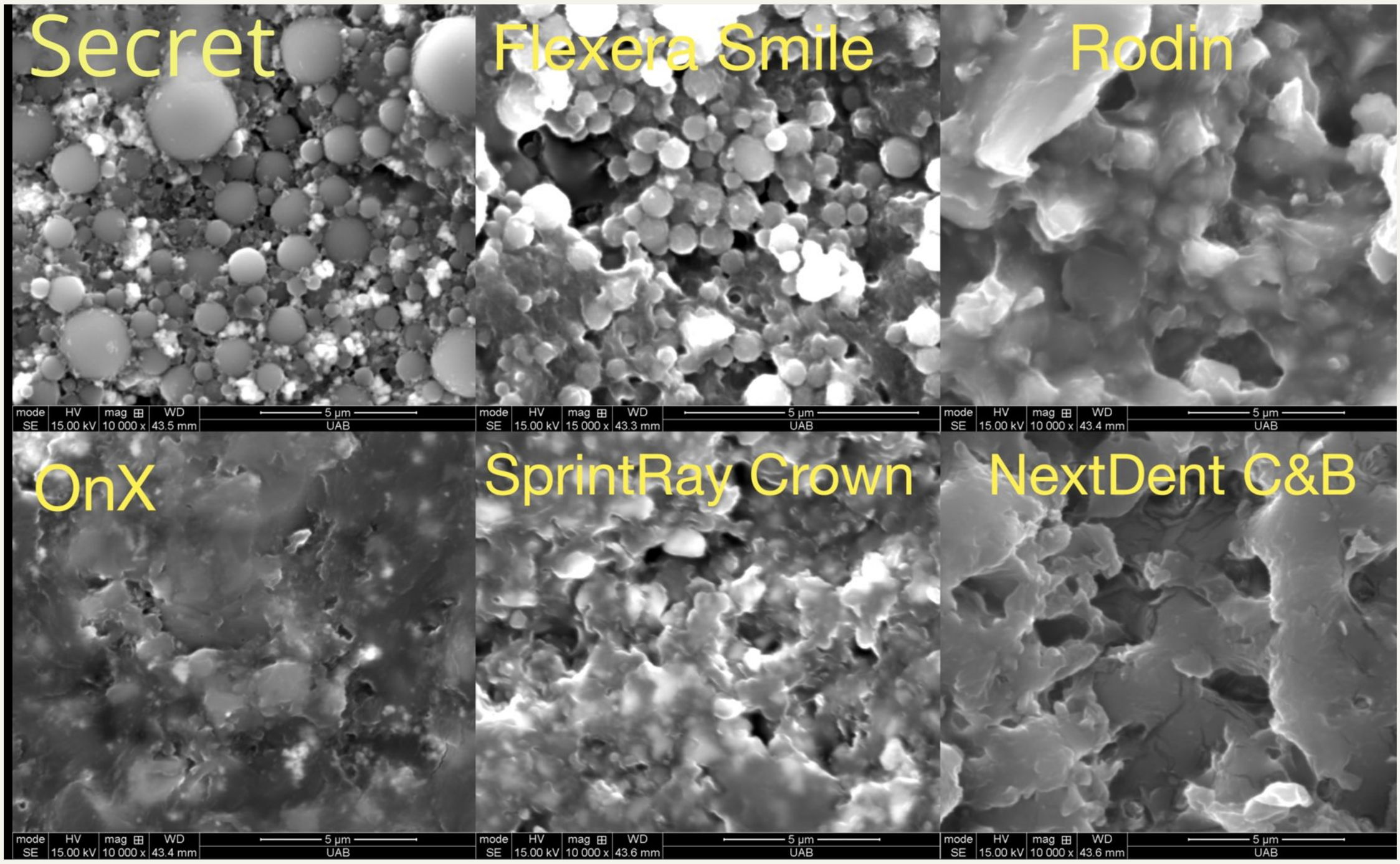
It’s not that materials with a lower fracture toughness can not prove to be an extremely viable long lasting dental material, it just means that those materials are probably more technique sensitive and, therefore, less forgiving to technique errors in bonding and material thickness. Those materials that fall below 2 and are between 1-2 are generally materials that rely heavily on resin bonding to reinforce them to the tooth structure. Printed materials as we will see can vary greatly regarding fracture toughness with new 3D print materials materials that breach the 2.0 K1c and even some coming in 2024 that claim 3.0 K1c.

Some manufacturers focus on having a high flexural modulus material (very stiff), touting the high flexural modulus as an important material breakthrough. This property is actually contrasting to materials like Flexcera, Graphy, Rodin Titan, and ONX Tough that have specifically been formulated to have a lower flexural modulus. What is flexural modulus and is this something that is good for a printed material? As previously postulated by Magne, et al,3 a lower flexural modulus correlates to increased deformation under load. This means a material with a low flexural modulus is more likely to absorb the stress than a material with a high flexural modulus. In addition, the combination of high strength with low modulus translates to greater resilience. Resiliency is the capability of the material to absorb energy when it is deformed elastically and then to recover its size and shape upon unloading. Type III Gold has the incredible ability to deform while remaining resilient under load. Flexural Modulus is represented by the area under the curve in the elastic region of the stress-strain curve; the units are of pressure (MPa). Materials with high flexural modulus tend to be stiff and brittle and are poor materials for absorbing impact and many ceramic materials are extremely brittle .

CHAPTER 2: THE RESIN RESOLUTION

One of the most exciting advancements to the field of dentistry has been the recent revitalized interest in photopolymers and subsequent rapid evolution of photopolymer chemistry driven by 3D Printing. Dentistry has a long history with composite resin materials and in the mid 20th century acrylic resins largely surpassed silicate cements as the esthetic material of choice for direct restorations. Buonocore discovered that etching using orthophosphoric-acid technique allowed acrylic to bond to enamel but other issues occurred. It really was not until Bis-GMA monomer was developed by Bowen in 1962 that the modern dental resin took off. This resin is the backbone of the modern day photopolymer. Over the years various mixtures have been successful containing Bis-GMA and other dimethacrylate monomers (TEGMA, UDMA, HDDMA), functionalized filler particles such as fluoroaluminosilicate glass, fumed silica, zirconia and other particles combined with photo initiators and radio pacifying agents such as elements including barium, bismuth or lanthanum oxides, strontium, zirconium, sulfates, carbonates or yterbium trifluoride. Filler particle size updates from microfill, to micro-hybrid, to nano filled to nano-hybrid have occurred over the years along with small tweaks to photo initiators that have allowed for more white resin materials.

Further, changes in monomer chemistry allowing for less polymerization shrinkage peaked in the early 2000's, and since then direct resin technology has essentially been stagnant. Manufacturers have more recently been focusing on things such as depth of cure and translucency, handling and chameleon like properties. However, one major disadvantage of direct resins have always had and continue to have is that the degree of methacrylate conversion is only around 60%.[4] This means that the cure of the material is never really near to complete; therefore, the full intrinsic mechanical properties of this incredible material are never realized with a direct resin and why they have a fracture toughness of around 1K1c. This is one reason why they suffer from accelerated wear, water uptake and staining.[5]

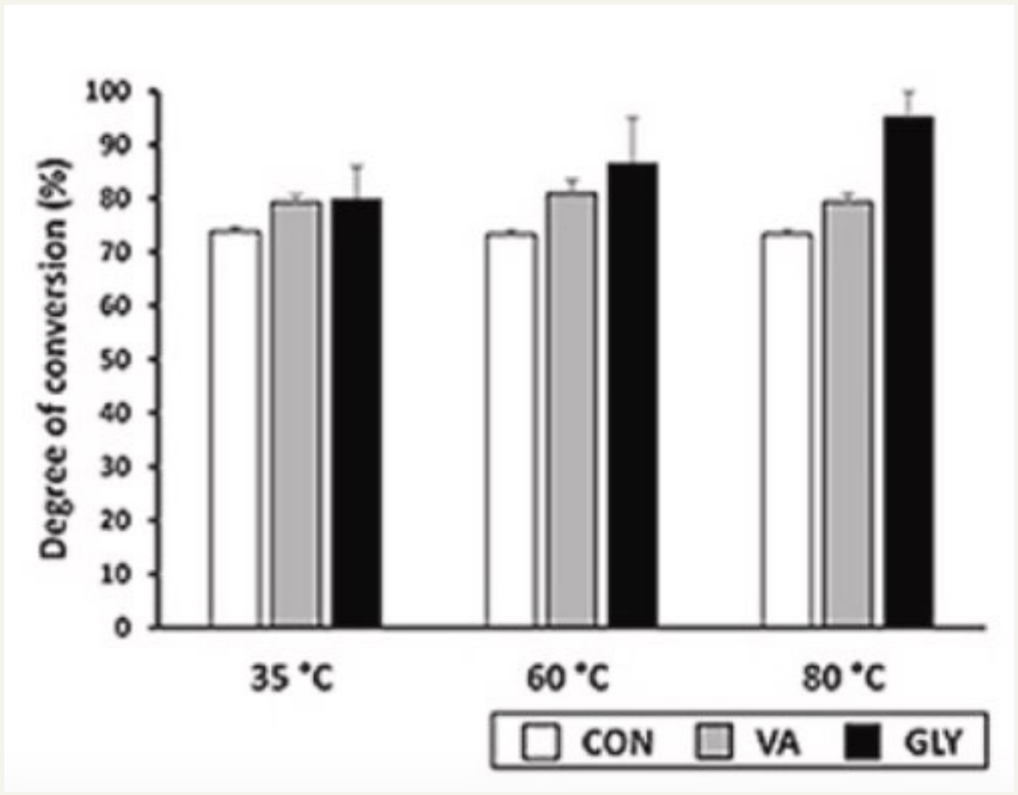


SEM of various print resin from Nate Lawson UAB

New photopolymers for 3D printing crowns, veneers, inlays, onlays, dentures, and all on x prosthetics are an evolutionary leap forward from the foundational chemistry of direct resin composite materials. This chemistry builds on the 60 years of innovation of direct resins, and does not represent a large deviation from the foundational chemistry of direct resins. Various filler particles with polydispersity and functionalization to the resin matrix have been used in order to increase mechanical properties and also to meet the new ADA code change that states that "if a 3D printed restoration has more then 50% inorganic filler content in may be coded as a ceramic." This is nothing new. CAD/CAM blocks that are resin have been able to be coded as a ceramic for the past decade. Materials like Cerasmart, Grandio, Camouflauge, and TetricCAD have been coded as ceramics and successfully utilized in millions of restorations. These milled nano ceramic resin materials have been very popular and successful as partial coverage restorations. CAD/CAM resin-based composite can be considered a reliable material for partial coverage restorations with clinical performance similar to glass ceramic restorations. Fathy, et al concluded that "CAD/CAM resin-based composites provide a potential alternative to ceramic indirect restorations."[5] These milled nano ceramic materials have phenomenal in vitro results showing equal fatigue testing compared to lithium disilicate.[6] However, clinically their success falls slightly short compared to lithium disilicate regarding full coverage crowns.[7] One reason CAD/CAM nano ceramic restorations have a slightly higher failure rate compared to ceramic is the higher debonding rate. Several theories exist as to why this happens including water uptake and expansion, flexure, and low bond strengths; however, bond strength seems to be the primary issue as clinical studies show these restorations have much better success if bonded using a multistep adhesive system compared to a self adhesive resin cement.[8]

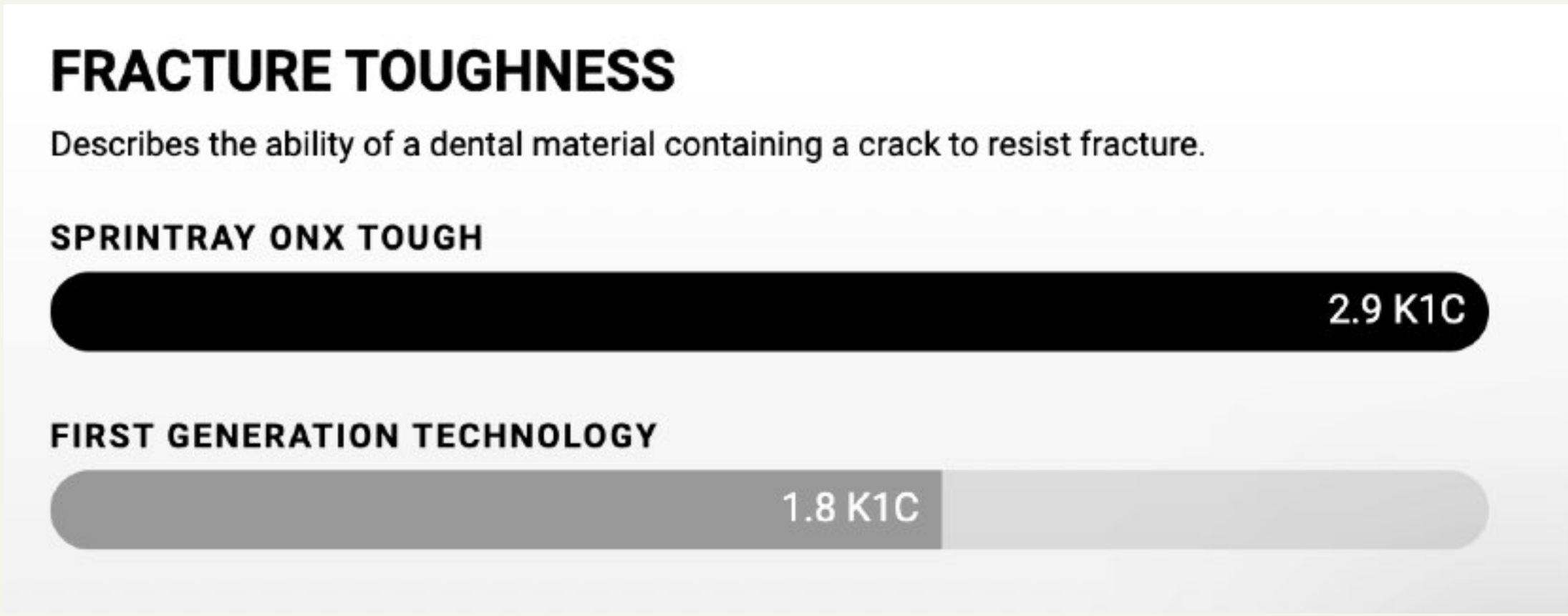
CHAPTER 2: THE RESIN RESOLUTION

If ceramic materials perform better than milled nanoceramic resin materials then why would we expect 3D printed nanoceramic resin to be any different? It has clearly been established that direct resins have incredible potential but suffer from polymerization shrinkage, shrinkage stress, micro leakage, accelerated wear, and poor degree of conversion. These shortcomings come primarily from in situ polymerization. 3D printing has built on the chemistry of direct resins but has eliminated some of the most critical shortcomings. By not polymerizing the bulk of the resin in the tooth, shrinkage and shrinkage stress are all but eliminated and confined to the resin cement layer which is nominal. Furthermore, the issue of the poor degree of methacrylate conversion is also essentially eliminated because in a 3D printer each layer is microscopically cured at 50 to 100 micrometers thick. Contrastingly, direct resins are cured in 2mm increments or more. Additionally, 3D printed resins are then post processed in high intensity cure units which increases the degree of conversion to over 90% especially if using nitrogen gas, glycerin and heat.[11]



Here we can see a figure from Lee, et al showing degree of conversion for 3D printed resins breaking 90% after properly post curing in glycerin. Glycerin or Nitrogen act to remove oxygen allowing complete curing of the resin by preventing oxygen inhibition of free radical photo polymerization. This is why it is always recommended to cure in Glycerin. This finding has been confirmed in separate study.[12]

Recently manufacturers have started to see the importance of fracture toughness and have begun reporting it in their material documentation. For example, ONX Tough has a reported fracture toughness of 2.9 K1c. This is a very high and very promising number for a 3D printed resin. However, it is important to mention that the best way to study fracture toughness is through an independent study that directly compares all the materials in the same study using the same methods, as slight variations in technique can lead to dramatically different numbers.



You can see that modern resins are resilient and very tough. These values may be more important than Flexural Strength values. Several independent studies compare 3D printed nano ceramic materials to classic ceramics like e.max. One study looked at fatigue testing after thermocycling.[13] The interesting design in this study is that the restorations were aged to mimic extreme conditions in the mouth, and what they found was quite remarkable. They looked at crowns 0.5mm , 1mm and 1.5mm thick. All the 3D printed crowns with 0.5 mm thickness survived fatigue testing. None of the crowns for group VITA Enamic (VE) and one crown for group e.max CAD (EC) with 0.5 mm thickness survived fatigue testing. Furthermore, at 1mm the 3D printed materials were shown to be stronger than the ceramics.

								95% confidence intervall	
	thick.	n	n*	mean	SD	Min	Max	lower	upper
3D	0.5	10	10	571.1	89.1	350.0	651.5	507.4	634.8
	1.0	10	10	1055.1	133.8	860.3	1306.2	959.3	1150.8
	1.5	10	10	1478.7	168.2	1190.1	1740.8	1358.4	1599.0
VE	0.5	10	0	-	-	-	-	-	-
	1.0	10	10	729.1	165.6	528.7	1009.6	610.6	847.6
	1.5	10	10	1016.8	176.4	701.7	1302.9	890.5	1143.0
EC	0.5	10	1	636.1	-	-	-	-	-
	1.0	10	10	838.0	108.4	715.1	1073.6	760.5	915.5
	1.5	10	10	1221.2	111.3	1104.2	1432.2	1141.6	1300.8

In this simplified chart from the Zimmerman paper where 3D is the 3D printed crown, VE is Vita Enamic, and EC is e.max you can see that 3D printed crowns where the only ones to reach measurable values in the testing. This fact is due to the resilience of polymer resin materials and their ability to absorb shock, something important we will see later on when we talk about implant restorations.

Similarly to Zimmerman's study, Corbani also found that printed restorations are remarkably strong even while very thin when comparing milled Brilliant Crios blocks and 3D printed crowns[14]

Group	Thickness	n	Mean [N]	SD	Min	Max	Lower bound	Upper bound
3D	0.5 mm	10	1345.0	101.15	1191.0	1548.0	1272.6	1417.4
3D	1.0 mm	10	1945.9	65.32	1824.0	2017.0	1899.2	1992.6
3D	1.5 mm	10	2383.5	188.58	2143.0	2703.0	2248.6	2518.4
M	0.5 mm	10	519.3	32.96	460.0	569.0	595.7	542.9
M	1.0 mm	10	932.1	41.29	866.0	986.0	902.6	961.6
M	1.5 mm	10	1284.7	77.62	1150.0	1368.0	1229.2	1340.2

3D= 3D Printed. M=Milled

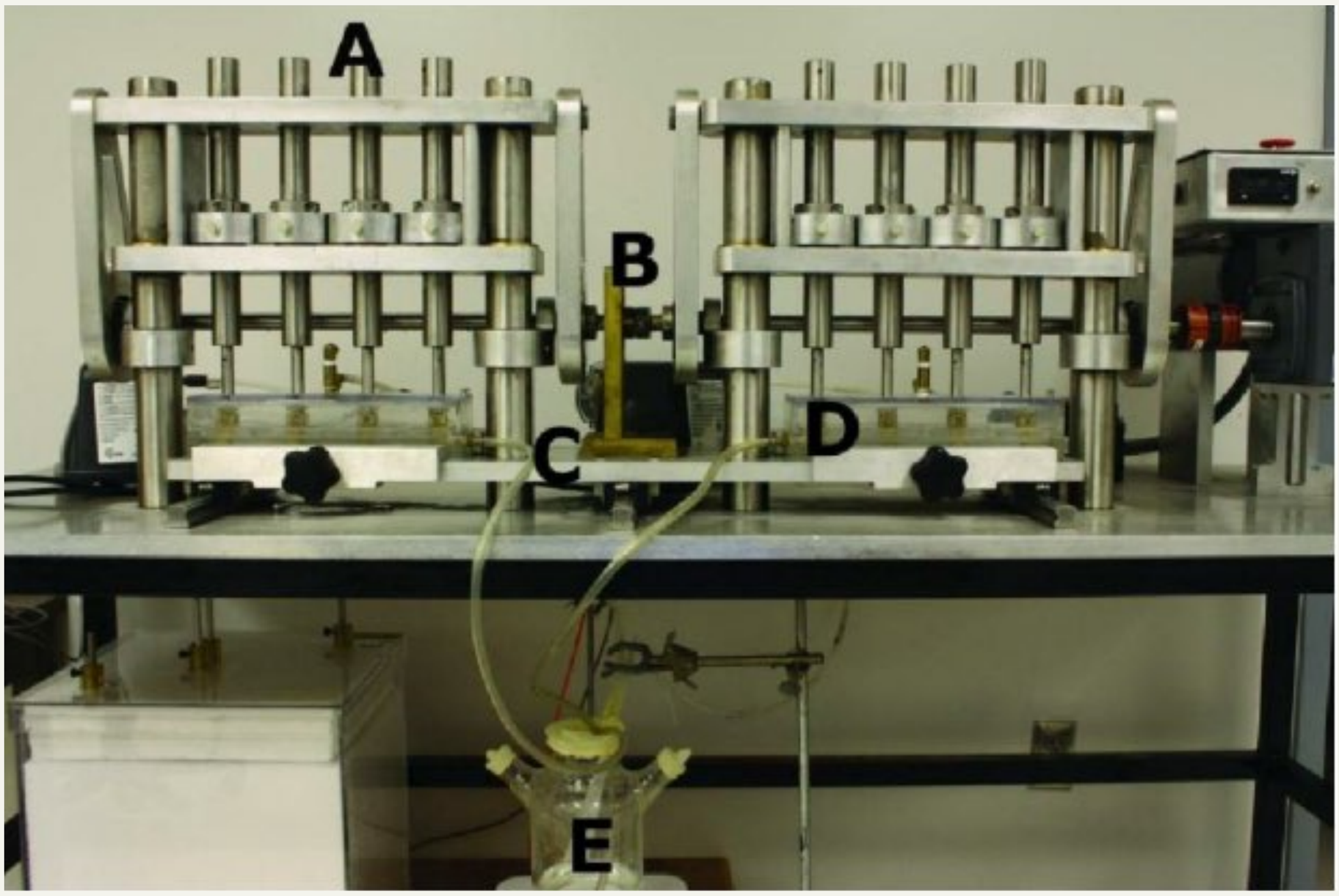
Here you can see the performance of 3D printed nanoceramic materials compared to milled nanoceramic materials for ultra thin restorations. 3D printing again performed exceptionally well and even better than some of the milled counterparts. Gomez looked at the fit and strength of printed restorations compared to milled materials and found that 3D printed restorations fit better while being just as strong compared to Cerasmart and other milled nanoceramics.[15]

	Mean ±SD (N)	95% CI (N)	Min (N)	Max (N)
SP	1413.91 ± 140.49	1313.41–1514.41	1193.45	1607.51
BC	1333.23 ± 144.73	1229.7–1436.77	1144.86	1526.31
VE	1359.25 ± 159.63	1245.05–1473.44	1150.8	1587.08
CS	1274.32 ± 135.8	1177.18–1371.47	1101.98	1493.96

3D printing (Saremco Print Crowntec, SP) or milling (Brilliant Crios, BC; Vita Enamic, VE; Cerasmart 270, CS) (n = 10).

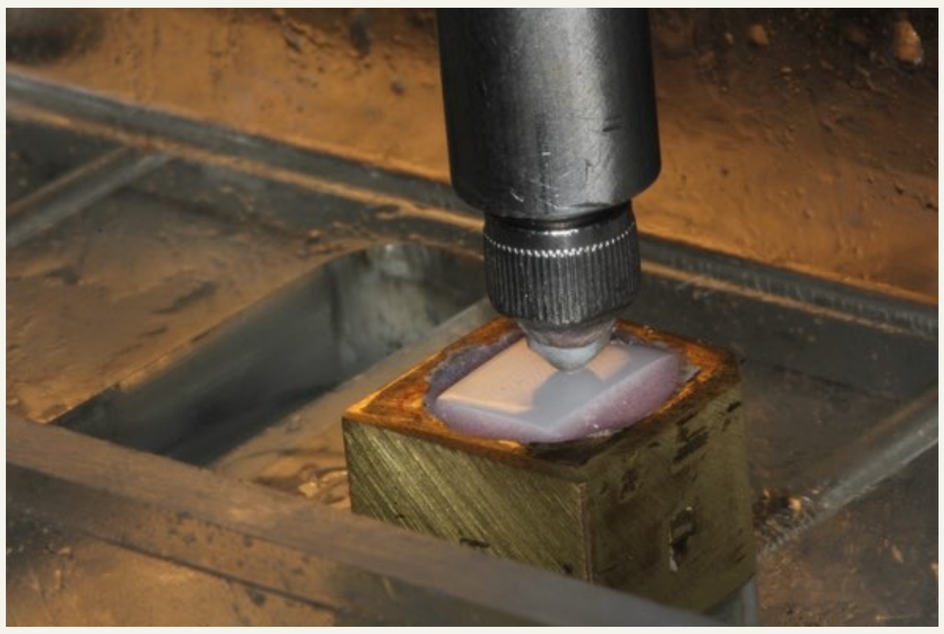
Volumetric Wear

The specimens are placed in a wear testing machine which applies a 20N load and slides a distance of 2mm to simulate bruxism. Steatite balls (diameter 2.5 mm) are used as opposing stylus. The test is run for 400,000 cycles at 1Hz. A circulating artificial saliva media is used as a liquid lubricant.



Customer wear machine

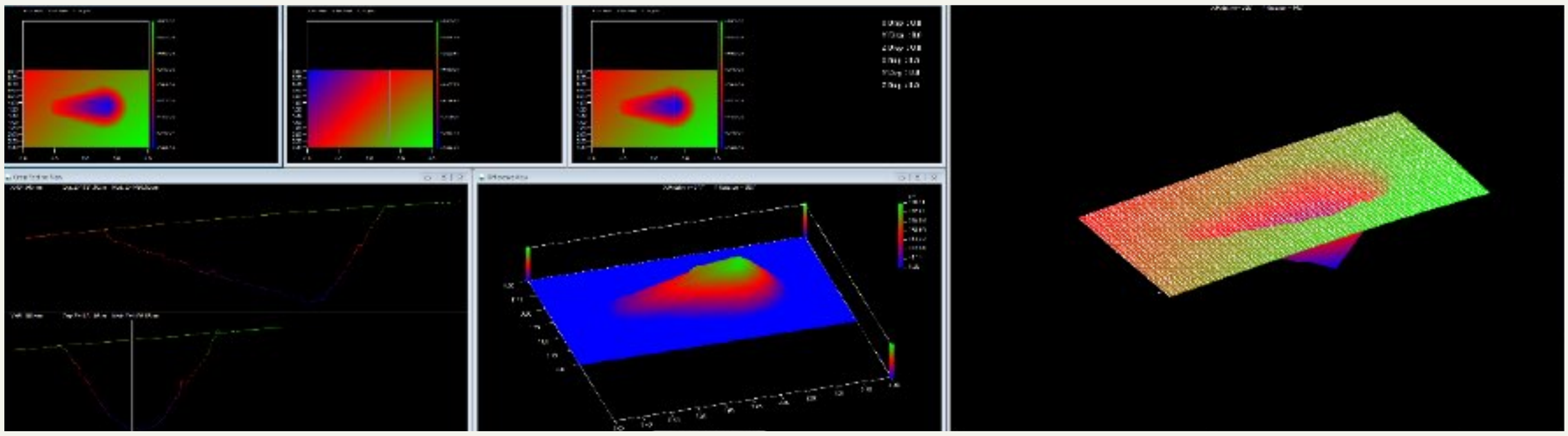
Typically, wear machines use stainless steel balls or a ceramic material called steatite on a robotic arm that pounds the specimen in a simulated chewing cycle under artificial saliva at forces commonly seen intraorally.



F SEATITE ball wearing against specimen

CHAPTER 2: THE RESIN RESOLUTION

Specimens are scanned before and after wear testing using a non-contact 3D surface measurement instrument (Keyence VHX) and superimposition software is used (ProForm software, Scantron Industrial Products) to determine the volumetric wear of the materials.



Material Wear In A 3D Heat Map

Using this method at an independent university, it was found that newer printed materials are extremely resistant to wear, with half the wear at 400,000 chew cycles compared to previous generation printed materials and better than direct resin.

Wear is one of the biggest issues facing printed materials and one that is critical for restoration success. Unfortunately, good independent data on material properties is hard to come by for 3D printed resins. Be cautious of drawing comparisons across different studies due to lack of complete standardization. For example, it is very hard to draw comparisons between different studies on flexural strength and fracture toughness because even small changes in the protocol such as temperature can lead to drastic difference in the results even within the guidelines of ASTM and ISO. Therefore, more studies need to be conducted with direct comparisons in the same study using identical laboratory and testing equipment. Data on printed materials is limited, and materials are advancing rapidly with independent data unable to keep pace with material releases. Therefore, it is with caution that you should adopt new materials.

A study demonstrated by UAB indicated that the direct resin Filtek had statistically much greater wear compared to 3D printed resins. This is a key differentiator between printed resin and direct resins. Better mechanical properties and wear resistance justify the upgrade from a direct resin to a printed resin restoration alone. Clinically some resins that tested to be very wear resistant in the laboratory seemed to perform poorly in the mouth such as Flexcera. This is most likely due to lower filler particle content and lack of functionalized fillers. More modern ceramic filled resins are expected to preform better compared to low filled print resins such as Flexcera, Bego and Trusana. Although wear resistance of modern highly filled 3D printed resins perform slightly better than direct resin, they still wear about double the rate of ceramic materials like e.max. This is the area that manufactures should focus on the most when developing new resin formulations for 3D printed crowns.

CHAPTER 2: THE RESIN RESOLUTION

Fortunately, several wear studies have been published in peer reviewed journals that we can draw conclusions from. While additional evidence is greatly needed for a more complete viewpoint on the wear of newer 3D printed resins, the initial findings are promising.

Here we can see a study that compared 3D printed resin to milled PMMA and conventional resin materials and they found 3D printed resins to be significantly more wear resistant even when compared to milled resins and conventional.[16]

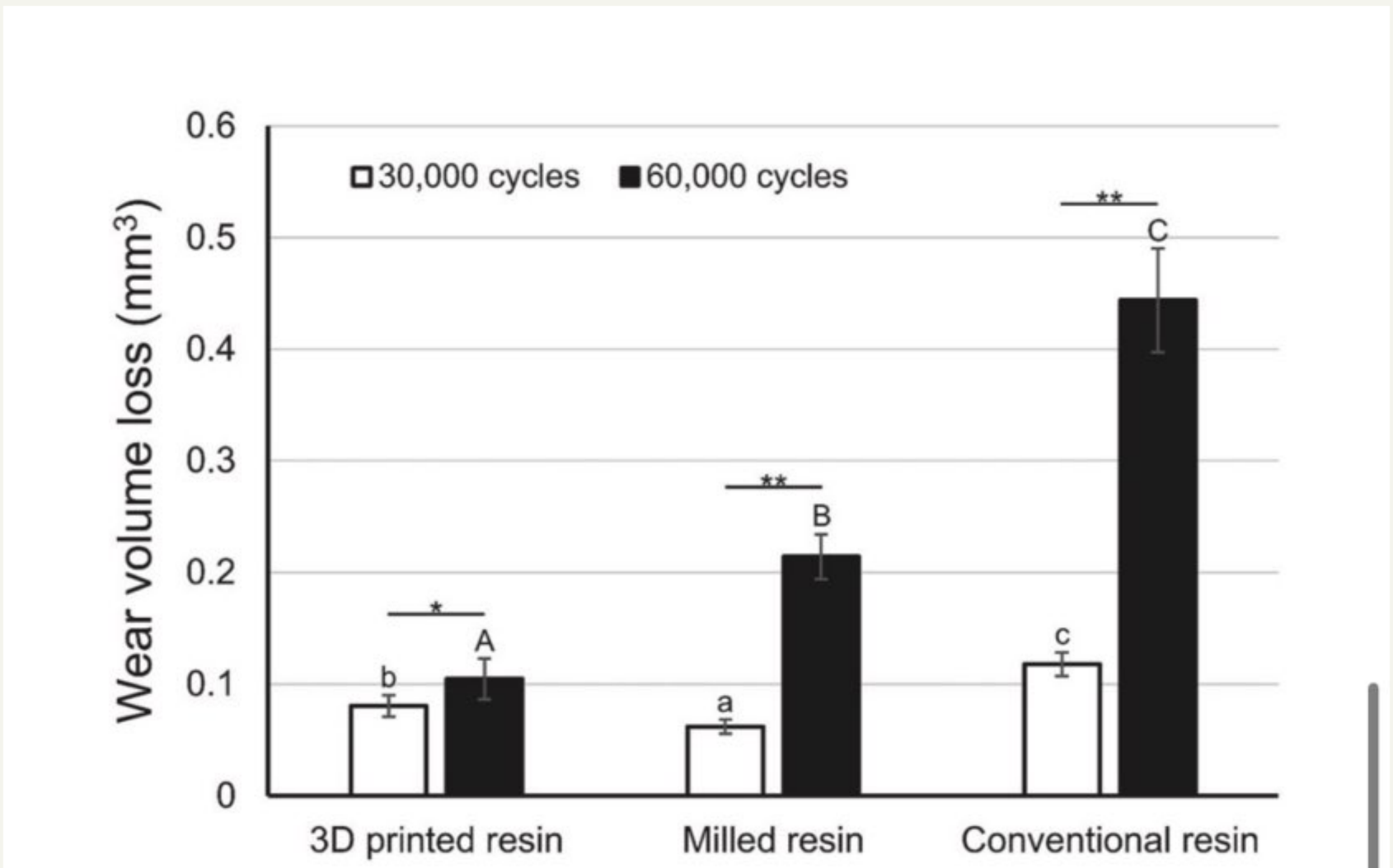


Fig. 2. Wear volume loss (mean ± standard deviation) after 30,000 and 60,000 cycles of simulated chewing. Same letters indicate no statistically significant differences. Lowercase letters for 30,000 cycles and uppercase letters for 60,000 cycles. * $P < .05$, ** $P < .001$.

Diana Pham found that 3D printed denture teeth were significantly more wear resistant compared to premium carded denture teeth when opposing zirconia.[17]

This finding is promising because it indicates 3D printed materials may be better at holding vertical dimension and centric relation positions compared to carded denture teeth. This also indicates that one arch in an all on x or full mouth reconstruction may be fabricated out of zirconia, and the other out of 3D printed nanoceramic which could decrease cost to patients.

One recently conducted study is worth mentioning that compared 3D printed resins to zirconia at 0.4mm thick.[18] This study is particularly well done because it looked at static and dynamic load of ultra thin cemented crowns.

polymers

MDPI

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Strength and Surface Characteristics of 3D-Printed Resin Crowns for the Primary Molars

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Tatjana Glaskova-Kuzmina, Academic Editor

They found that static and dynamic strengths did not differ between the 3D printed crowns and zirconia crowns in thermomechanical loading (p = 1, Wilcoxon rank-sum test). However after 120,000 chewing cycles wear facets were formed on printed crowns but not zirconia. Again 3D printed crowns have incredible strength, but wear more compared to ceramics.

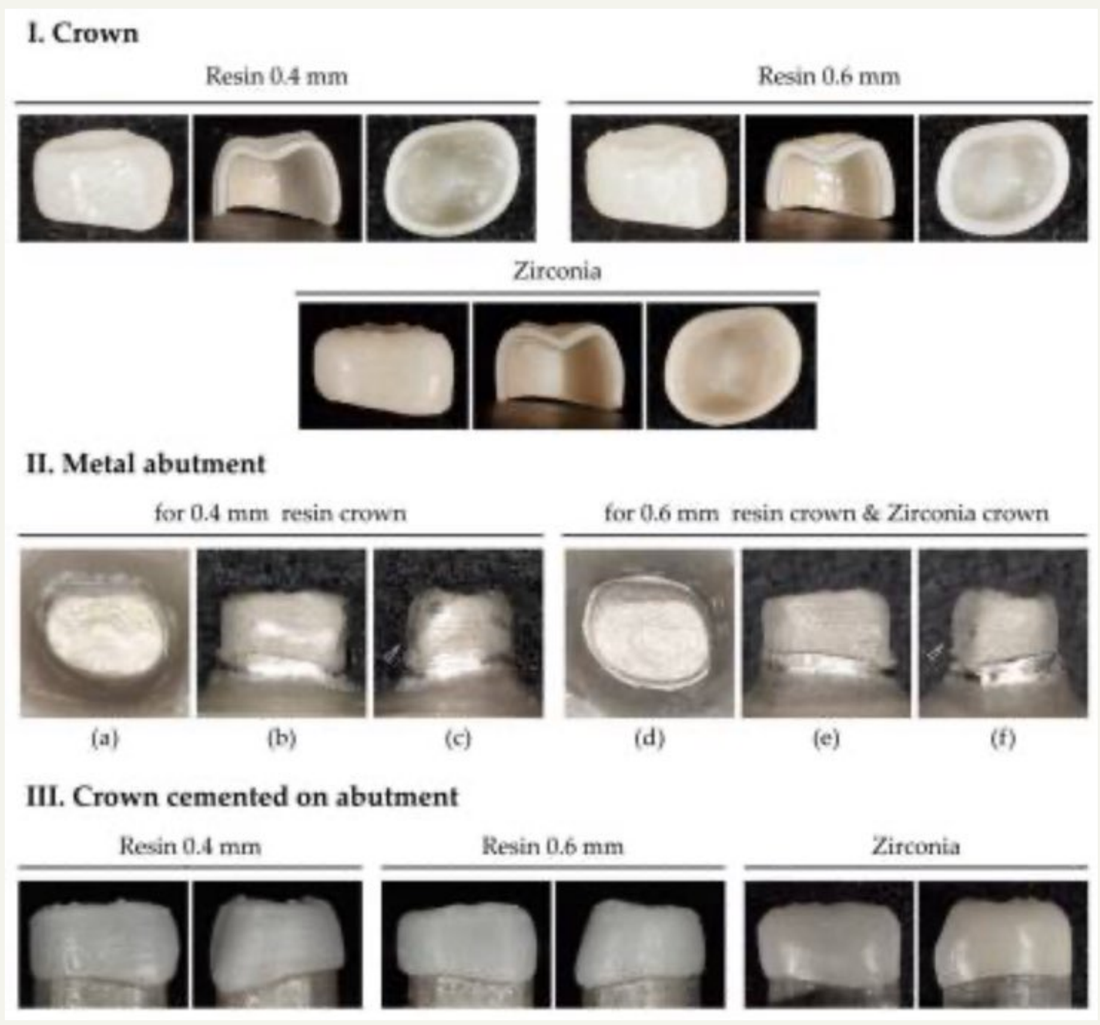

Table 2

The compression strength of crowns fabricated using different materials.

	Static Fracture Load (N)				
	n	**Mean**	**SD**	**Max**	**Min**
TC04	10	3079.20	955.57	4435.58	2152.3
TFD04	10	3533.92	644.19	4440.78	2958.1
Zr	10	3632.71	596.74	4435.97	2643.1
p			0.119		

Kruskal–Wallis test; N, Newton; n, number of samples; SD, standard deviation; Max, maximum; Min, minimum.

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CHAPTER 3

Monolithic Dentures

For years I thought we would never have a printed denture that I would put up against the best milled dentures.

I have said several times that a milled denture is the best denture possible. I have tried every printed denture material and have had major concerns about aesthetics, fit, color stability and durability. Early materials for printed dentures seemed to wear at an alarming rate, causing a collapse of vertical dimension. Then Lucitone came along as the first printed material that I was satisfied with as a permanent base material. It has great esthetics and durability and I still consider this denture material a great material, if not the best printed denture base.

ONX Tough is another resin that has promising characteristics for monolithic dentures and SprintRay converted that technology to High Impact Denture Base material. Other manufacturers have released new base materials that are also high impact and durable. Rodin Denture base material and SprintRay High Impact Denture have promising characteristics; however, many clinicians still prefer to print a monolithic denture out of a tooth material.

Monolithic dentures have several advantages in the short term:

- Faster print time
- Easier design
- Thought to be stronger
- Can be thinner (helps with immediate dentures)

However, there are also several disadvantages of monolithic dentures::

- Time consuming gingival characterization
- Expensive gingival characterization

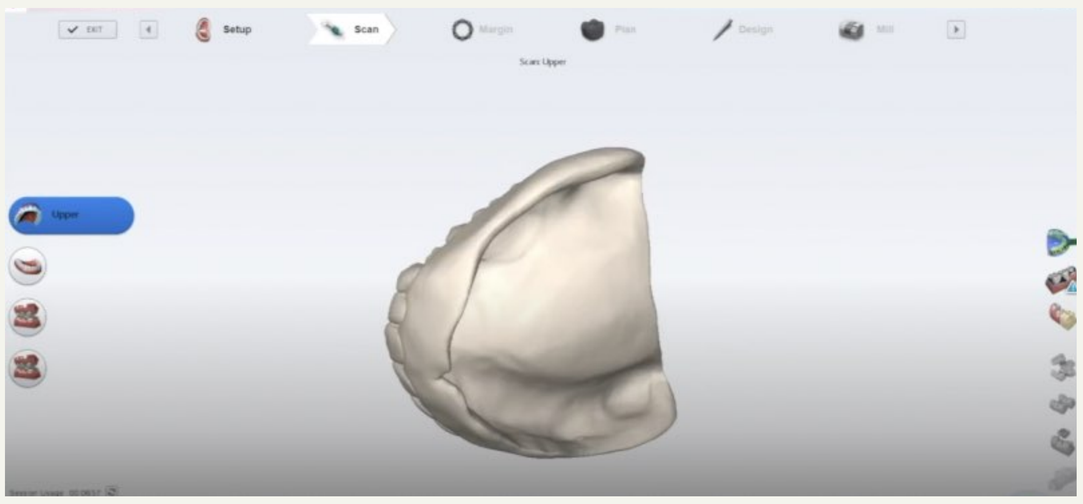
Monolithic Dentures, Tryin Dentures, or the Easy Copy Denture Technique

One of my favorite things to do in digital dentistry is the modern copy denture technique. It is so easy it feels like cheating. For this technique, the patient typically presents with an older denture that is a little loose, stained, possibly broken or missing a tooth. The first thing that I do is evaluate the denture esthetics and vertical dimension and make any changes to the denture that is needed. This may involve making such changes as opening the vertical dimension, changing incisal edge length, or relining with a soft functional reline material. I typically reline with a soft reline material or light body polyvinyl siloxane, and, in cases where the teeth are worn flat I will alter the anterior a little with composite. If the vertical is off, I open the vertical using a Lucia jig, deprogrammer or custom centric relation jig and keep that aside for later when scanning the bite.

Dentures Before Modifications

Step 1: Copy Relined Denture

The first step is to scan the denture after all the necessary modifications have been made. This typically is done in a laboratory scanner or with a hand held intra-oral scanner. In this case, the denture is out of the mouth and the clinician is scanning the denture as they rotate it in their hands. A good scan pattern is essential for accuracy using this technique. It typically takes 5 or more minutes to scan the entire denture including the outside and fitting surfaces.



An Example Of A Copy Denture After Modification, Scan Form An Ios

Monolithic Dentures, Tryin Dentures, or the Easy Copy Denture Technique

Denture scanning can be difficult, but utilizing these four tips will make it much easier:

I. Follow the MOD Institute scan pattern

II. Use a light body wash material

III. Titanium dioxide power

IV. Composite markers

I. Follow a scan pattern

6 overlapping passes with an intraoral scanner should be followed starting with the fitting surface of the denture in the hamular notch area and proceeding along the crest of the ridge to the opposite hamular notch, recapitulate slightly more lingual returning to the start point.

Step number 2, a serpentine motion starting at the incisive papilla and ending on the junction of the hard and soft palate. Step number 3 is the most difficult, you have to scan the flange of the denture capturing a small portion of the buccal surface while also capturing the fitting surface at the same time in order to allow the software to stitch the inside of the denture (intaglio) to the outside (cameo).

Step 4 is a serpentine motion to capture the entire buccal flange and facial surfaces of the teeth. Step 5 is capturing the occlusal and incisal surfaces while also favoring the facial surface to enable the software to stitch the facial surface to the occlusal. This pass recapitulates and on the way back capture the linguals. Last and least important is the smooth surface of the palate. Here we do a serpentine motion starting at the incisive papilla and working posteriorly. It may be necessary to add composite to the palate. If doing so use flowable composite in the pattern shown in image 6. Cure and then try to scan.

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WATCH A VIDEO ON DENTURE SCANNING TIPS

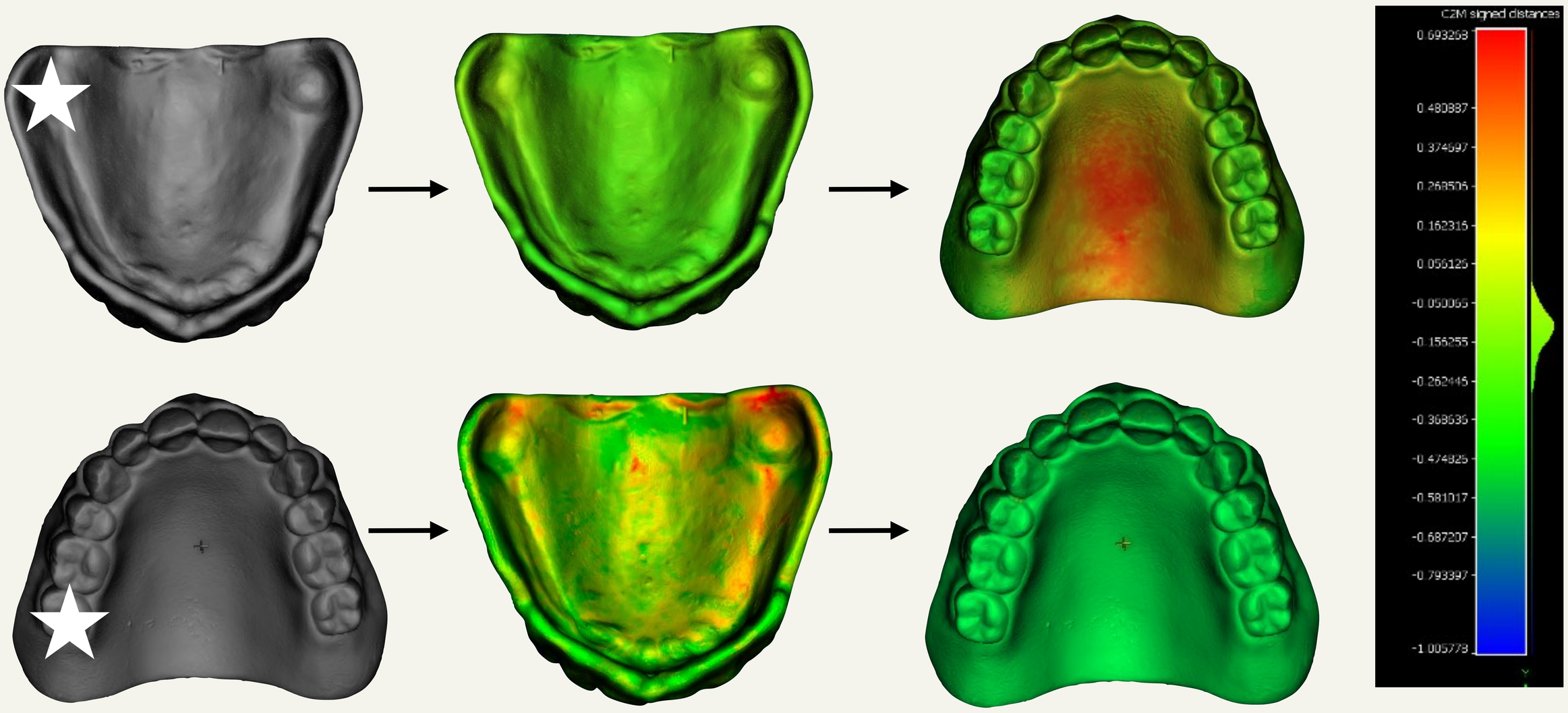
Monolithic Dentures, Tryin Dentures, or the Easy Copy Denture Technique

Denture scanning can be difficult, but utilizing these four tips will make it much easier:

I. Follow the MOD Institute scan pattern
II. Use a wash material
III. Titanium dioxide power
IV. Composite markers

I. Follow a scan pattern

SCAN ORIGIN



Starting on the fitting surface leads to a more accurate fitting surface compared to starting on the teeth. It is always preferred to start on the fitting surface if you desire a more accurate representation of the soft tissues. If you desire a more accurate representation of the occlusal surfaces it is recommended to start on the occlusal surfaces. The differences are roughly 75-150 microns depending on the scanner.

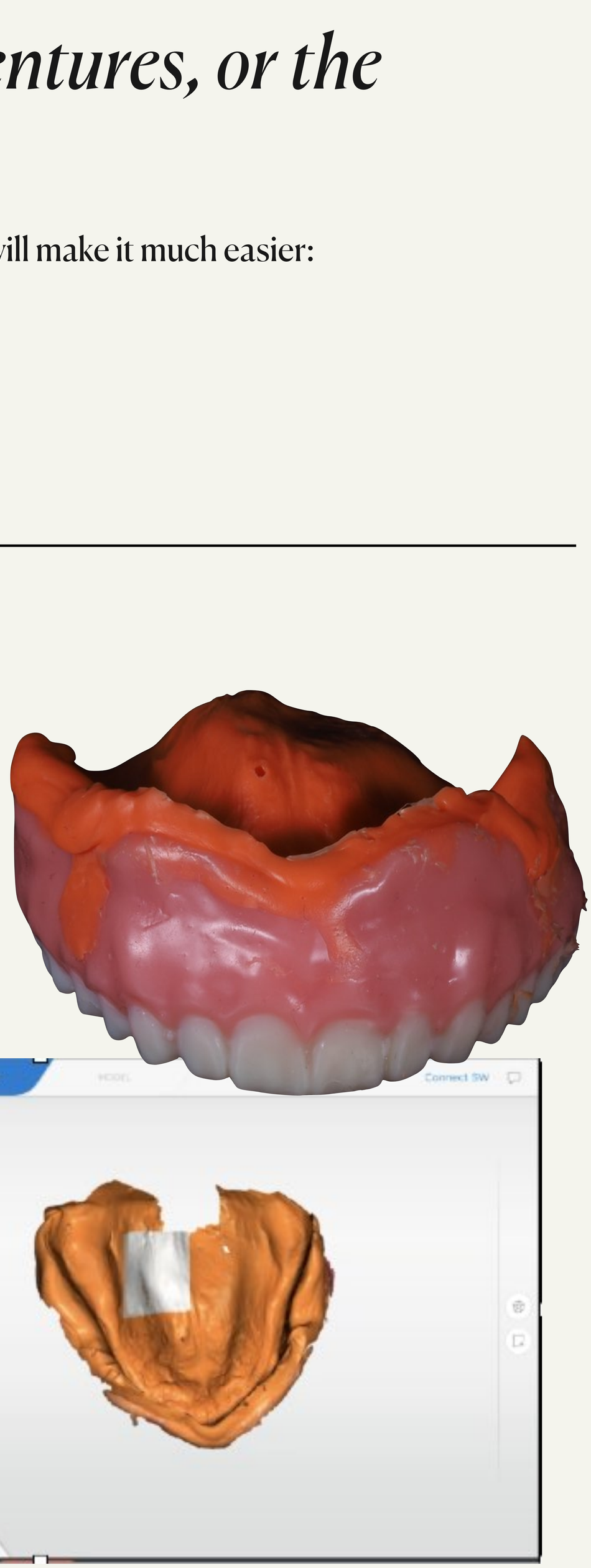
Monolithic Dentures, Tryin Dentures, or the Easy Copy Denture Technique

Denture scanning can be difficult, but utilizing these four tips will make it much easier:

I. Follow the MOD Institute scan pattern
II. Use a wash material
III. Titanium dioxide power
IV. Composite markers

II. Use a wash material

Using a soft reline material that is not transparent or light body wash using polyvinyl siloxane will dramatically help the scanning of the fitting surface and borders of the denture. It creates texture and irregularities that help the scanner stitch images together. Remember to use adhesive on the denture if using a reline or wash material to ensure no distortion when removing the denture.



Monolithic Dentures, Tryin Dentures, or the Easy Copy Denture Technique

Denture scanning can be difficult, but utilizing these four tips will make it much easier:

I. Follow the MOD Institute scan pattern
II. Use a wash material
III. Titanium dioxide power
IV. Composite markers

III. Titanium dioxide power

Purchase titanium dioxide powder, an atomizer spray bottle and 98% alcohol from a store like amazon, and mix one level teaspoon of powder to 5mL of alcohol. Spray a light coating on the denture. Please note that the entire denture does not need to one covered as the scanner will just need a light splattering of this material to help it track along the smooth shiny surfaces of a denture.

Monolithic Dentures, Tryin Dentures, or the Easy Copy Denture Technique

Denture scanning can be difficult, but utilizing these four tips will make it much easier:

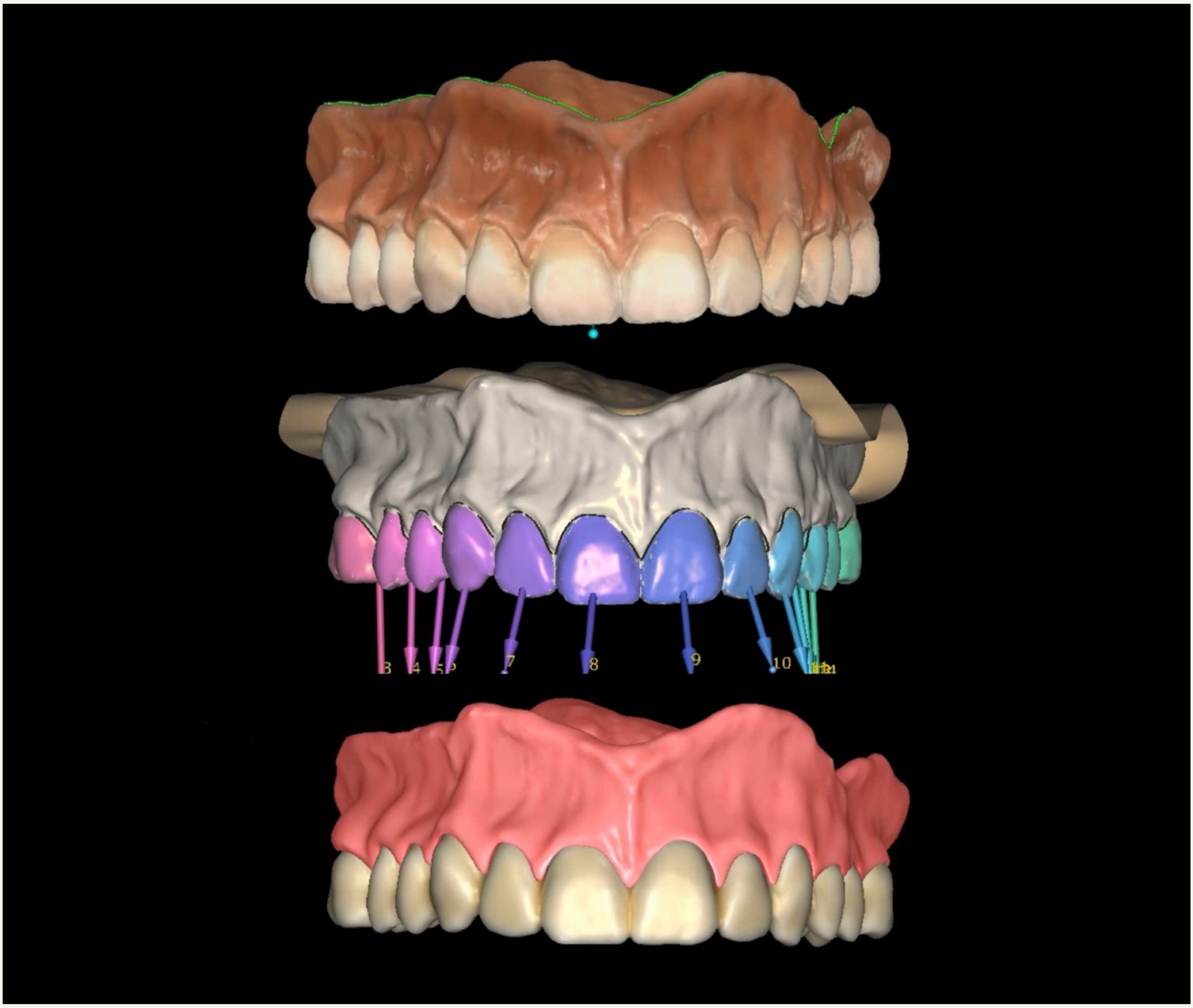
I. Follow the MOD Institute scan pattern
II. Use a wash material
III. Titanium dioxide power
IV. Composite markers

IV. Composite markers

I like to use flowable composite and cure it before it gets too flat. A lattice like serpentine pattern is best. The material peels right off when done scanning and does not damage the denture. This positive geometry helps the scanner stitch difficult images together. This is an old trick that can also be used in the mouth on keratinized tissue for long span edentulous arches as well.

Monolithic Dentures, Tryin Dentures, or the Easy Copy Denture Technique

A new copy denture workflow in exocad will allow you to go from a scan of a denture to a final design with split file gingiva and teeth in under 5 minutes! This new powerful workflow is an easy way to design a monolithic and split file denture extremely fast as the software creates both!



CHAPTER 3: MONOLITHIC DENTURES

Once the denture is scanned 360 degrees, the opposing arch is scanned in the mouth. If the opposing is also a denture then this is scanned out of the mouth using the same technique. In the case above, this denture was opposing a natural dentition. The natural lowers were scanned in the mouth. The next step is to capture the bite. The denture is placed in the mouth and the patient is instructed to close; the arch relationship is then captured in maximum intercuspation. If, however, you want to change the vertical dimension, the bite is made with an anterior jig which maintains the new vertical at the proper centric relation. Then the bite is scanned bilaterally into the scan software. This extra bite information allows for occlusal modifications if needed.

CHAPTER 3: MONOLITHIC DENTURES

From here several options exist. One can copy the denture exactly as scanned and print a monolithic replica, or one can place the denture into an advanced design software to separate out the teeth from the base and make tooth pockets for printing the base pink and the teeth white as shown previously in exocad version 3.2.

In this case, I am showing the monolithic copy technique and how to characterize the monolithic denture. This is my technique but many others exist with many different materials. Above we can see a monolithic copy denture, printed in bleach color and the characterized restoration to the right was made using TAUB Products LMD Elixirs and a specific protocol I will teach you along with a more lasting technique using anaxgum.

So what is the best way to turn a monolithic white print into a work of art? How do you protect those stains from brushing off over time? The answer is not so simple. If you spend the time to turn this print into something that is full of custom colors, the last thing you want is it to wear away. I have developed a long lasting technique. The teeth are treated differently than the tissue using different materials. Once you learn these techniques you can do anything with monolithic prints.

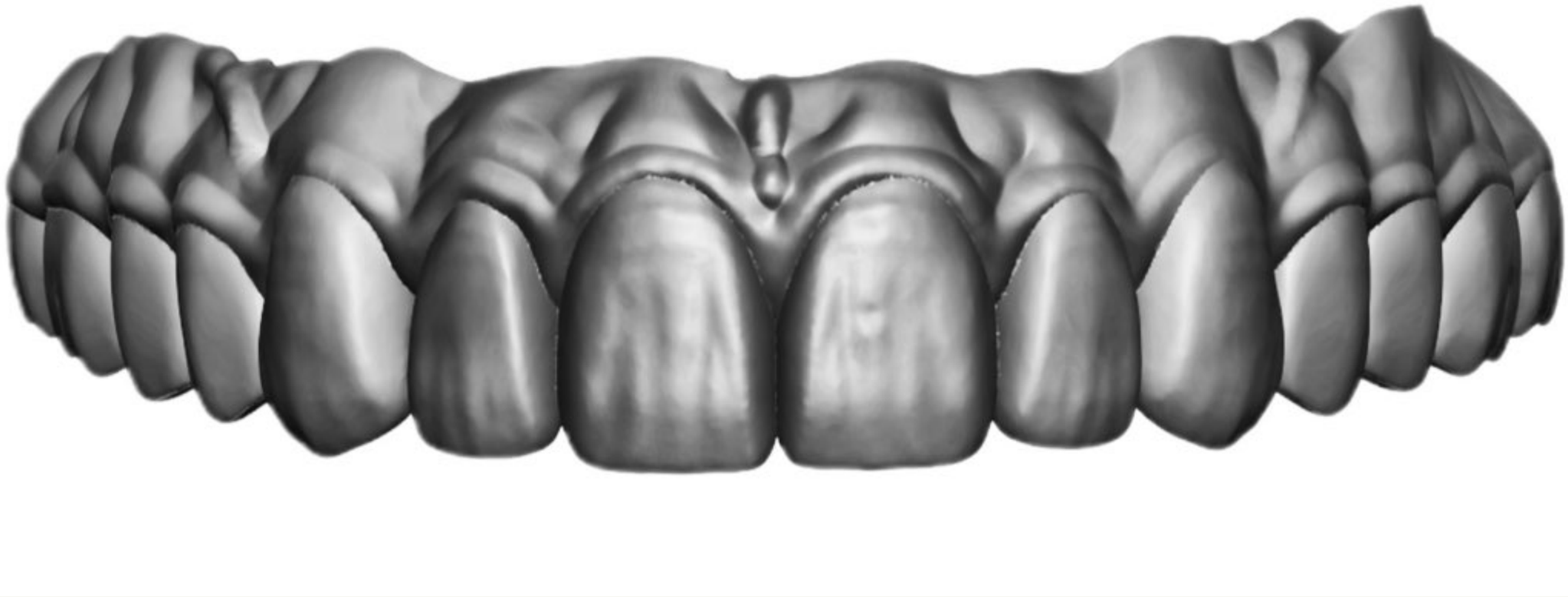
PRO TIP

Characterize before you cure the material but after appropriate washing steps

Get TAUB Products LMD Elixirs if you are in the USA. The rest of the world try to use Optiglaze colors or Vita and match them to what I am showing. I have also used Shofu lite art, Anaxdent or Triad-type composite. Here, I am going to demonstrate this technique using an All-On- X prosthetic but the technique for characterizing a denture is the same

Step 1: Clean your print

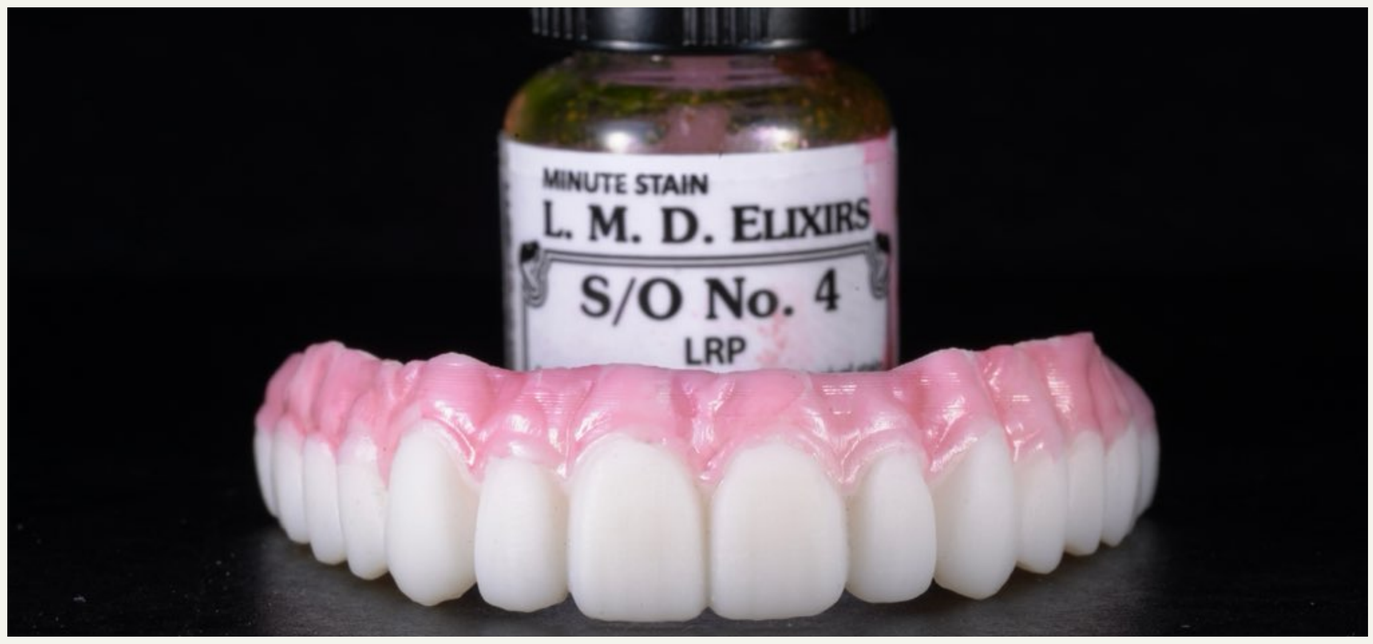
Make sure the print is clean and all supports are removed. Microabrasion is recommended followed by alcohol to clean. Here we did digital festooning of the STL file on an iPad app called Nomad Sculpt. This app is the best software I have found for adding really advanced gingival texture and shape.



Air abrasion with 30 micron aluminum oxide is recommended. Make sure to clean with 90% or greater alcohol after air abrasion to remove all particles. Use gloves to avoid getting oils from your hands on the prosthetic. Make sure your environment is clean and free of dust and lint. If you did not take the time to festoon digitally this is the time to do it using acrylic burs.

Step 2: First coat of Taub No. 4 bubble gum

The first coat that I do is a light bubble gum pink coat. This material is labeled No. 4. I always start with a light pink coat regardless of the final desired shade. Be careful not to get the material on the teeth although a little is probably inevitable. Do not waste time coating the teeth with a separating agent because it is very easy to remove with a diamond or air abrasion after the last coat.



Step 3: Accentuate the deep areas with dark pink.

Everything we do is to accentuate depth and color. Here we apply elixir No. 10 to the deep areas in between the root eminences to make these areas appear even deeper. Be careful not to overdo the dark. Taub elixirs dry really quickly and for that reason I dip the brushes into the jars rather than dispensing onto a tile or glass slab. I also dip the brushes into the brush thinner between colors to clean the brush.

Step 4: Accentuate the mucosa (unattached gingiva) with bright red Taub 13.

This layer is accentuating the more vascular and often more red area of the tissue. Once again, be careful here to not overdo it and give the illusion that the patient has erythema. Also, be careful to avoid getting this stain on any attached gingiva, otherwise, it will look like the patient has severe gingivitis.

Step 5: Tone down the color with No. 1

This step is optional and depends on how bright your patient's tissue is. In this case I painted an even coat of No. 1 on the entire surface of the prosthetic. This coat helps blend any irregularities in the other layers. Here you can see I was rushing and got some material stains on the teeth. This is not a problem as you will see in the next steps.

Step 6: White

To me this is actually the most difficult and yet the most critical step to making tissue look natural. The white is put on the attached gingiva in a very light splotchy way using a flared brush rather than a fine tip brush. This technique will take some practice to get it the way you want it. You want the white to not be runny when you put it on so avoid putting too much on the brush.

Notice the splotches of white, very subtle way of making tissue natural. Also apply the white to frenum.

Step 7: Protect the art

This step is arguably the most important part of the entire process. Coat the stains with the same liquid base resin you printed with. I like to use Light Pink because it is almost clear and does not impact the colors at all. This also fills in some anatomy which is why I like to festoon in great detail as some of it gets filled with this protective coating off resin.

Step 8: Cure

Now place in the appropriate curing unit. The point of this cure is to cure the pink coating of resin you placed over your stains, but it is not to get a final cure as that will happen after the teeth are finished.

Step 9: Get the pink off the teeth

This is actually very easy and fast. I use a flame shaped diamond as shown above and follow the CEJ. This is a good time, while you have the diamond out, to add any surface texture you want to the teeth. This might also be a good time to take a thin double sided diamond disc and accentuate facial embrasure and incisal embrasures.

You now have 4 options to get the teeth looking good.

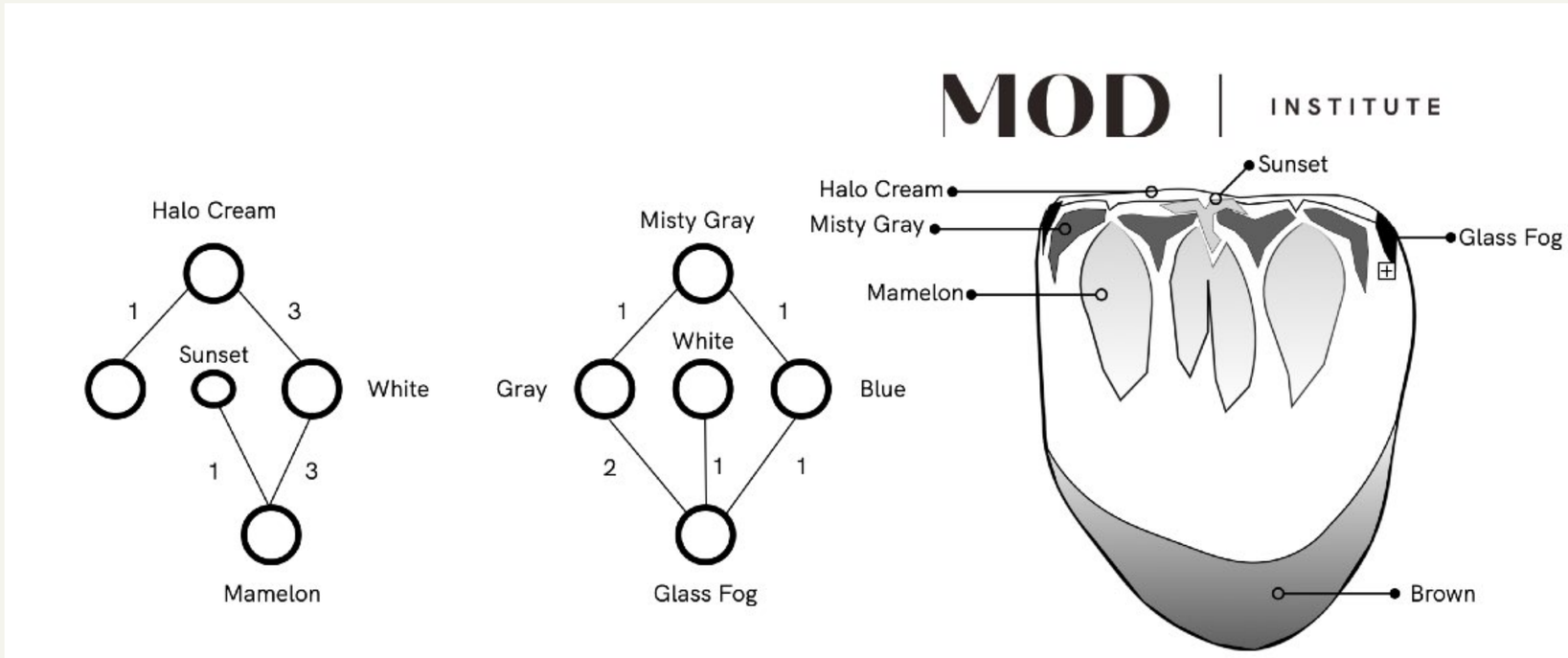
Remove the pink from teeth and add surface texture

Step 10: What do we do with the teeth?

1. If you want to have a surface finish that will last forever, the best thing to do at this point is to use a scotch bright type wheel, followed by pumice, followed by a soft cotton buff with a light touch of diamond polishing paste and just polish the teeth.
2. Alternatively, sand blast and clean with alcohol then paint a thin coat of liquid tooth colored resin and cure. I cure with a hand held light with a 385nm bulb, the Ivoclar Vivadent Powercure unit. This is the best for curing stains and resins to freeze them before using appropriate curing boxes.

3. Use resin stains like IPS Empress Direct resin stains and coat with the native print resin.
4. Use the scoop technique, which is a lingual cutback to apply colors from within and then this void gets filled with tooth resin. We will cover this later as this is the most advanced technique and deserves a special section.

For this restoration, I choose option 3 so I will attempt to highlight that below for you. Pros and cons exist for each option that we can discuss later.



WATCH A VIDEO ON CANDY COAT TUTORIAL

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Teeth Step 1: Brown

Paint a thin layer of tooth resin on all the teeth, Do NOT cure yet. IPS Empress Direct resin stain brown: Mix a tiny dot of brown with a drop of resin and mix until a uniform color is achieved that has no swirls. Apply to the new mixture cervical area and a little inter-proximal. It is important not to streak this. This is also a very quick way to turn a bleach into an A1 or darker, by applying a thin coat all over the teeth.

Teeth Step 2: Violet or Gray

A thin coat of violet or gray is applied to the incisal 1/3 of the tooth.
This will flow into the liquid tooth resin layer.

Teeth Step 3: Blue

Up until now I have used a brush, however, for blue you want to use an Endo file or spreader. I prefer a spreader.
Apply an ultra thin layer of blue as close to the incisal edge as you can get. This stain should be almost not visible.
Slight curve up the mesial and distal.

Teeth Step 4: White

Ivoclar has the perfect cream color, called white, use this color for the halo and mamelon effect if desired.

The final result

Teeth Step 5: Tack Cure

Cure with a hand held light on each tooth. Place an oxygen scavenger such as cover gel by anaxdent or drop in glycerin.

Teeth Step 6: Final Cure

Place in cure box. Make sure to appropriately cure the final prosthetic following full cure protocol that the manufacture recommends. After cure it can be additionally hand polished.

UNICORN

Bonus Content: Airbrushed Denture

I joke that we are now entering unicorn territory anytime a technique might be overwhelming to a new user so you will see these denoted with a Unicorn symbol.

I am going to show you how to airbrush your dentures. This saves time, and makes a more even coat and avoids brush marks. This is my favorite way to make a white denture pink. It is not without its own issues though. The things you will need:

i. IWATA air brush fine control
ii. Airbrush specific compressor
iii. All the hoses
iv. Time to practice

The Taub Elixirs are the perfect consistency for airbrushing a denture. Place about 5 mL of each color in the airbrush and just go to town.

The Beauty Of An Airbrushed Denture

PRO TIP

Practice using less expensive inks on paper first

Run some Taub brush thinner through the airbrush to clean it. Use the same exact color sequence I taught you above. Play around and have fun. This technique does take patience and practice.

UNICORN

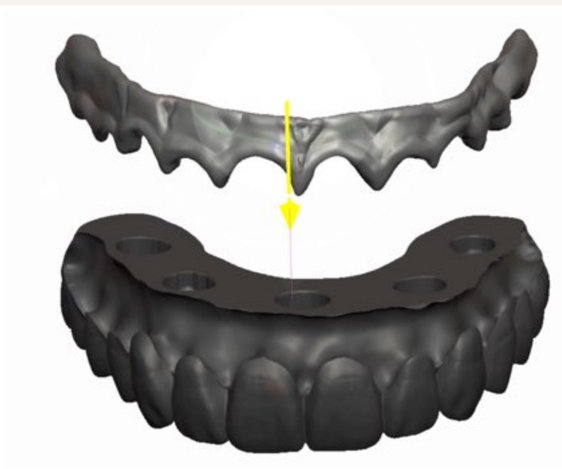
CHAPTER 3: MONOLITHIC DENTURES

Gingival Mask

This technique was first described openly by Dr. Ross. A technique that is rumored to be patented and not found as a default feature in even the most advanced design software.

Another unicorn technique where a monolithic denture or other prosthetic is digitally cut back where you can print a tissue part that is inserted into the main part. This technique can be accomplished in several advanced dental design softwares with the proper case set up. The tissue is bonded on the same way teeth are bonded to a denture base as described in the next chapter. This flat top all on X prosthetic is designed for a bone reduction conversion prosthetic.

DR. MATTHEW ROSS
DIGITAL DENTAL
SPECIALIST



EASY BUTTON

Anaxgum

Taub elixirs are great but they do lack durability for long term solutions. A better material exists that is more esthetic and more durable for long term applications. Anaxgum comes in many colors and consistencies. I will show the ones I use on my prosthetics.

The items you will need in addition to the adhesive:

i. Red
ii. Light Pink Gingiva
iii. Dark Pink Gingiva
iv. Light Pink Flow

Anaxgum on an all on x printed prosthetic. The material has the best esthetics out of any pink gingival material on the market allowing for easy life like gingival design. The teeth were characterized using the same method described with Taub.

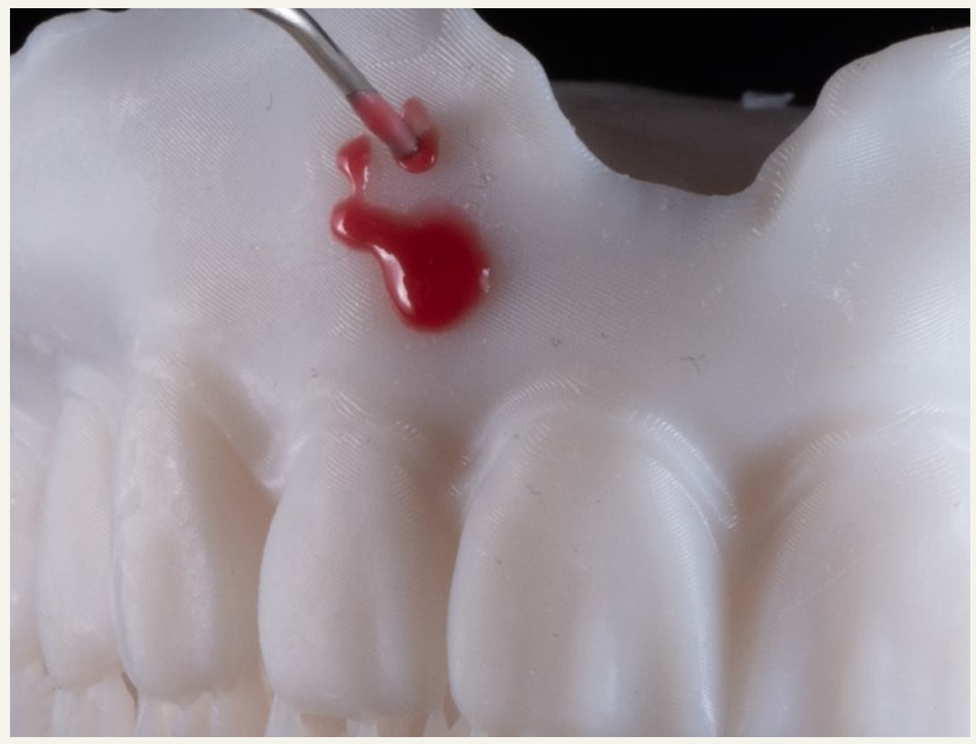
EASY BUTTON

Anaxgum

WATCH VIDEO ON MONOLITHIC DENTURE CHARACTERIZATION

1. Make sure print has been washed. Use Anaxdent bond LC on surface and cure

2. Use the red flowable material in the depressions



3. Titrate the amount for the desired effect. The amount below will lead to a dramatic effect

EASY BUTTON

Anaxgum

4. Use a clean brush to spread the material into all depressions

5. Start to spread the material up to the flange borders

6. You want to thin the material unit the red becomes almost a dark pink. Cure the material following IFU from Anaxgum. Next add Dark Pink Gum Paste to the anterior papilla as shown here.

Anaxgum

7. Use Light Pink Gingival paste and make a long narrow tube of material and lay it across the facial

8. With a gloved hand press the material onto the facial. Use an instrument to start to shape the gingiva.

9. You can add as much or as little texture as you want depending on the case and your style

EASY BUTTON

Anaxgum

10. Use gingiva flow light pink to add to the gingival cuff of each tooth and use a brush to create the proper anatomy, (To avoid resin sticking to brush wet the brush with Anaxdent Model LC)

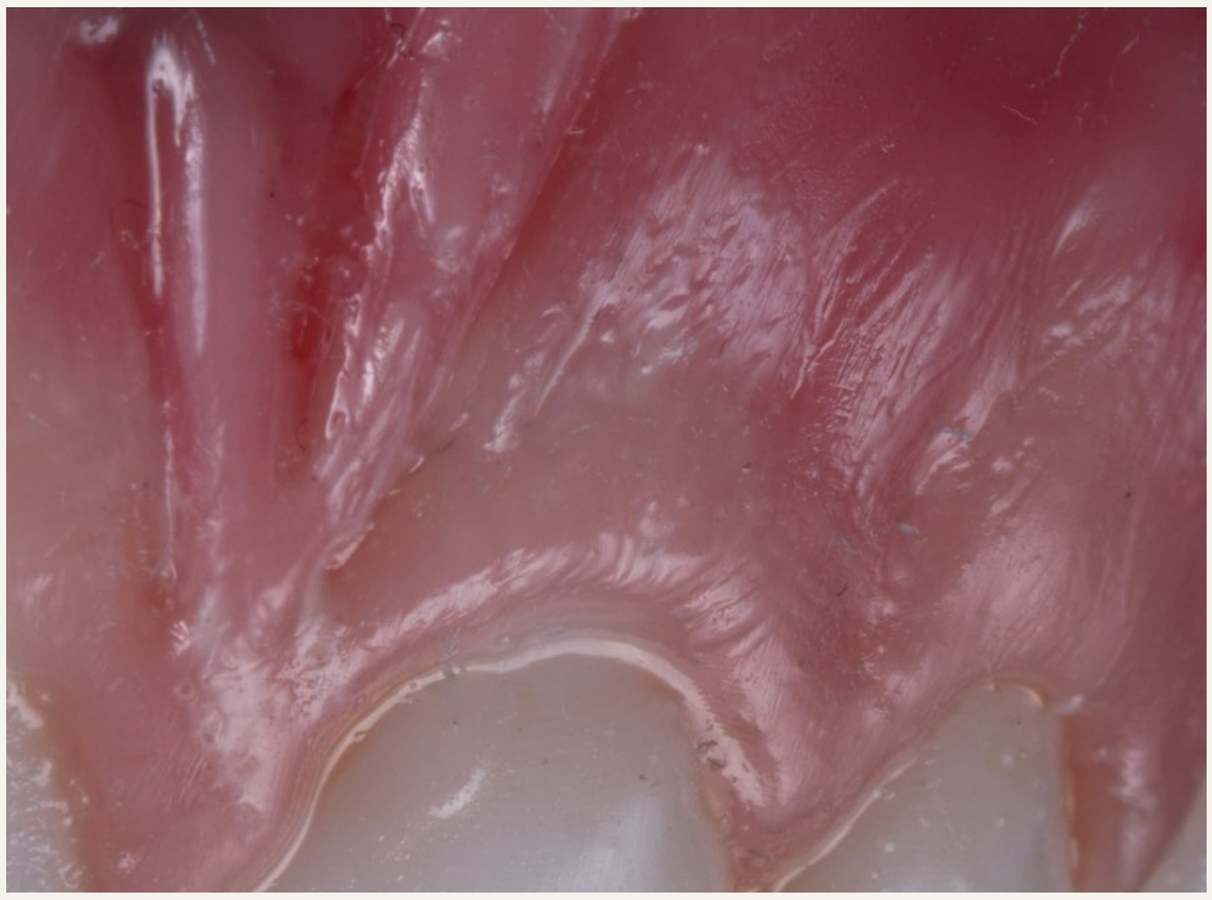
11. Use gingiva flow light pink around the borders of the denture as well to create anatomy of mucosa

9. You can add as much or as little texture as you want depending on the case and your style

EASY BUTTON

Anaxgum

Final Result



CHAPTER 4

Split File Dentures

Photo by Dr. Anthony Mennito

This beautiful denture is all printed, hand polished with no stains.

This technique is my favorite way to make a denture, as it requires less artistic ability compared to the monolithic technique and the entire denture can be hand polished for a lasting shine. Pumice followed by a soft cotton buff with some diamond paste and a light touch followed by a fine cotton buff with nothing on it will bring out a nice shine (only a properly cured denture will polish).

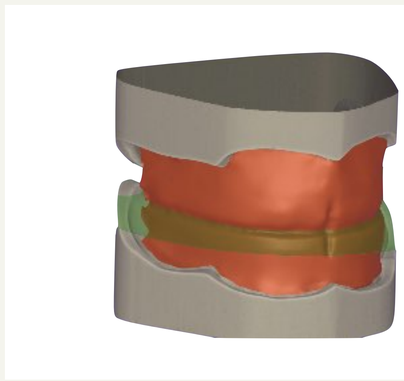
Here I am going to take you through the steps on how to bond the tissue to the teeth and then how to characterize the tissue if you desire. I will say I am starting to lean towards just hand polished as the way to go, but I will show you how to do both ways.

The Digital Impression… "Just because you can do something doesn't mean you should."

If designing a denture from scratch, and not copying a denture, the easiest way to do it if you are new to digital dentistry is still with a custom tray and make physical impressions with proper borders. I start with a digital impression to make a 3D printed custom tray. The tray is then used to make physical impressions with border molding. It is not that a digital impression of edentulous arches can not be easily obtained with modern scanners, it is that the movable tissues will be difficult to capture with an scanner for inexperienced clinicians and the denture borders will be poorly captured as the patient can not undergo muscle movements during scanning to determine the best borders. Some clinicians look at the color of the tissue in the PLY file of the IOS scan to determine the borders, and with experience this is certainly possible. However, some clinicians love the mucostatic fit from a complete digital scan. This technique will be explained later in this chapter.

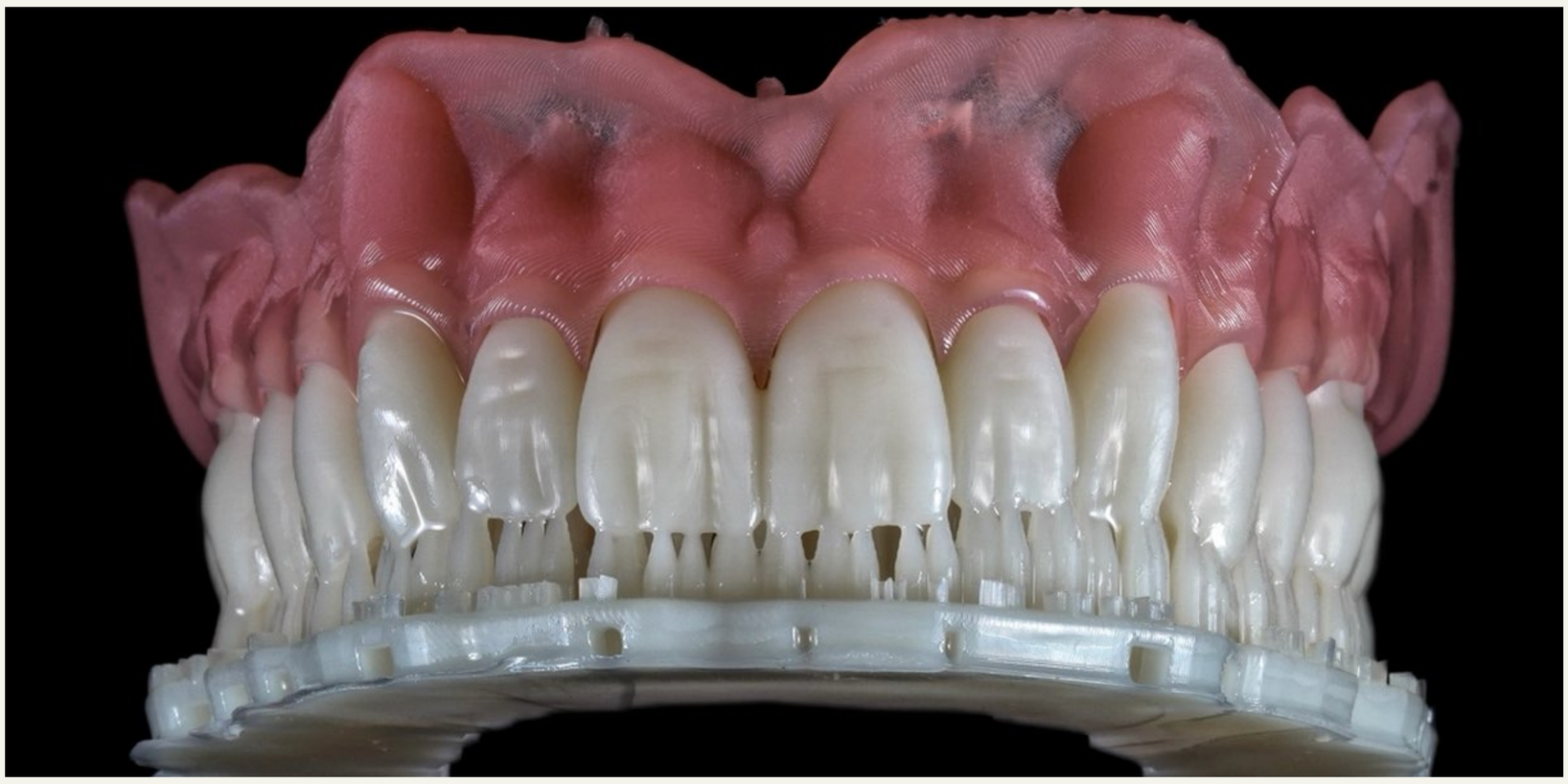
If you are new to digital dentistry use 3D printed custom trays or trial dentures made from a digital impression and a border molded

This type of scanning is best accomplished with a laboratory scanner; however, it is possible with an intra-oral scanner. Using this information, it is easy to design a digital denture with split file design. I typically like a 200 micrometer pocket gap or spacer between the teeth and the base.



I recommend exporting the file and importing it into the iPad and using the NOMAD sculpt app to festoon, and re-export for printing. This allows for incredible control using the Apple pencil.

I know what you are thinking! That looks way too intense almost like that denture lifts heavy weights! Remember my staining though, I add colors and then a thick coat of pink resin on top to protect everything. The top coat fills a lot of the anatomy in. Let't take a look at the bottom image and see the anatomy starting to become less intense after top coating.



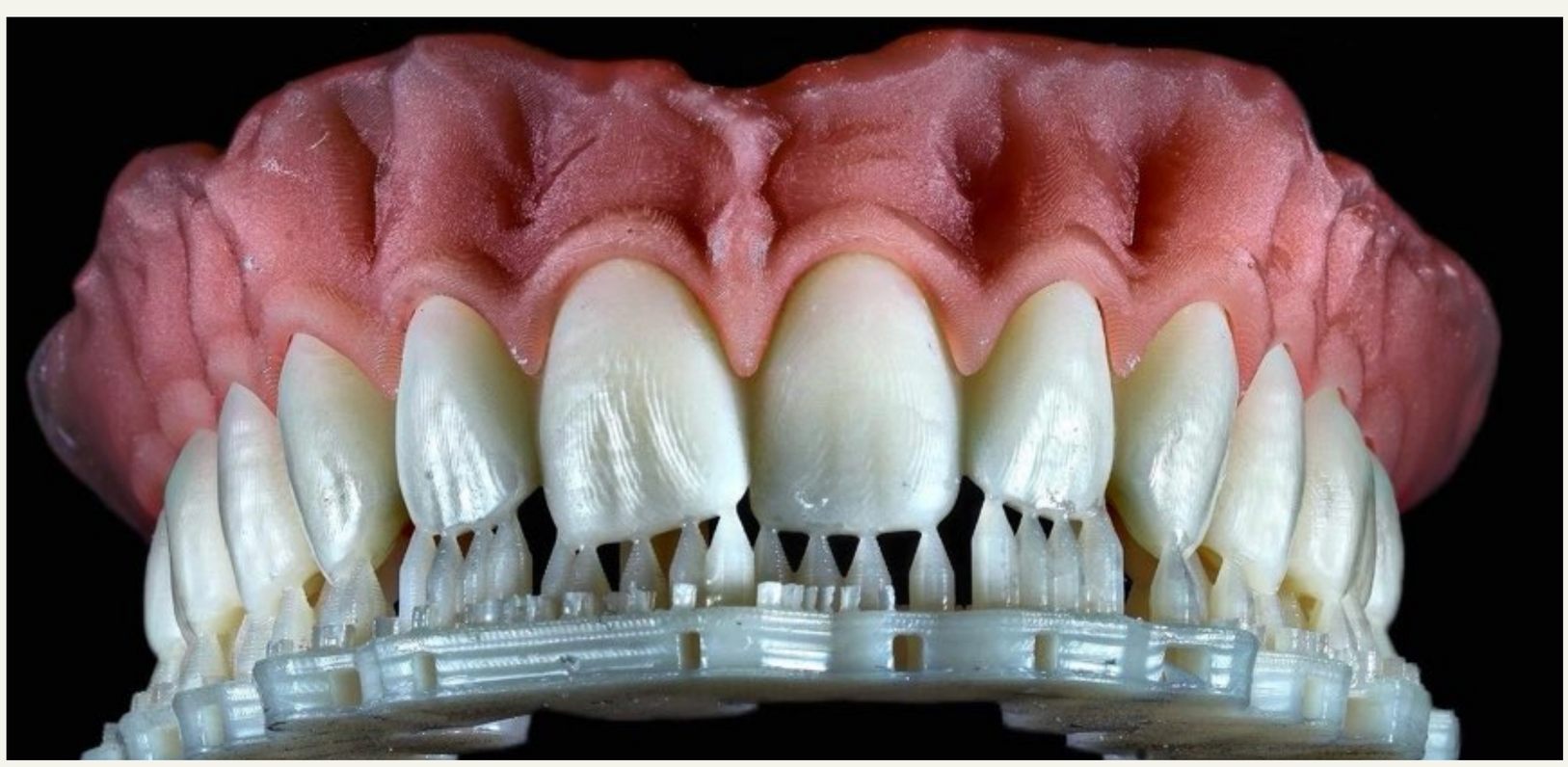
The tissue in this photo is finished. I added my traditional colors and my top coat of liquid print resin. The combination of these tones down the anatomy greatly. If this denture was hand polished only I would not design such aggressive anatomy but since a coat of denture base is applied, and since this fills in a lot of the anatomy I over do the festooning.

Now on to the teeth.

I pumiced and polished the teeth with no glaze, this toned down the anatomy and gives the surface a more natural look. Let me break down the steps on a different denture to show you how to characterize the pink. Remember this is all optional, straight out of the printer and just hand polished is still a smoking hot denture!

Let me show a more intense example before we dive into the details.

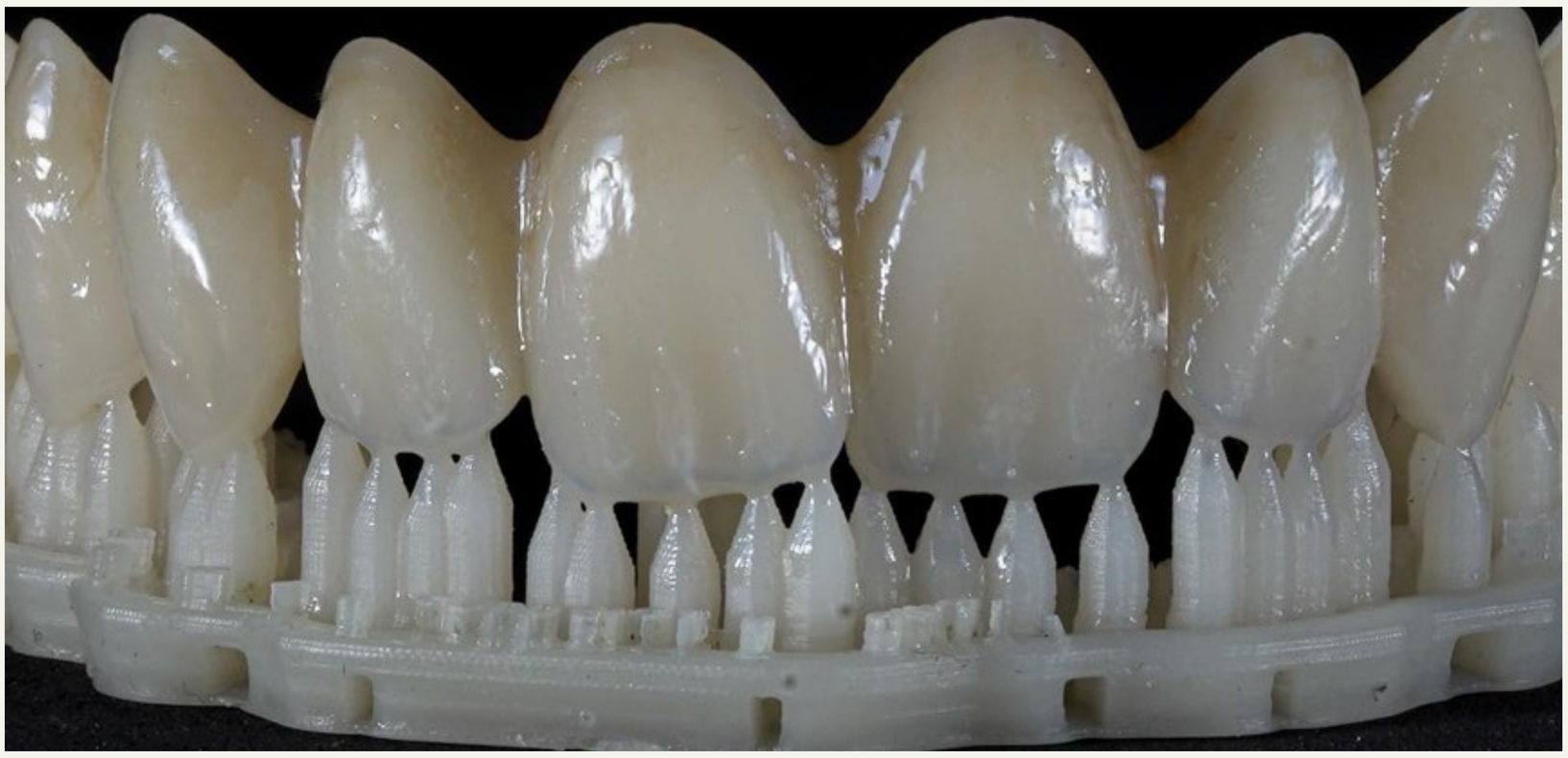
This is the denture immediately after cleaning with no post print processing. The supports were removed from the base but left on the teeth. The teeth have not been bonded yet to the base (Notice the intense characterization). This look is totally personal style, and I know some would think this is overkill.



CHAPTER 4: SPLIT FILE DENTURE

Here you can see the tissue has been finished, characterized and coated with a top coat of liquid denture base print resin.

The teeth have been characterized using the IPS Empress direct technique already discussed using the candy coating technique. It is essential to cure this layer twice. First, with a handheld light that has a 385nm bulb and then again in glycerin in your printer’s curing unit



CHAPTER 4: SPLIT FILE DENTURE

The final denture, and yes in case you are wondering, the front teeth are misaligned on purpose. This individual wanted a natural setup the way his teeth looked before he lost them, so that no one would know he had a denture.

Okay, Let's get into the steps of pink characterization...

For demonstration purposes, the next case the teeth have supports left on them, and they have not been bonded to the base yet. I am using them as a platform to take the photos.

Here we can se the way I positioned this denture on the platform. We can discuss nesting a little later but all slicers should enable you to just selectively place the supports on the border of the denture like this to make finishing easier.

Step 1: White around the attached gingiva and root eminence

Step 2: Dark Taub No. 10 Apply a thin coat of dark red in the deeper areas. Be careful not to apply too much.

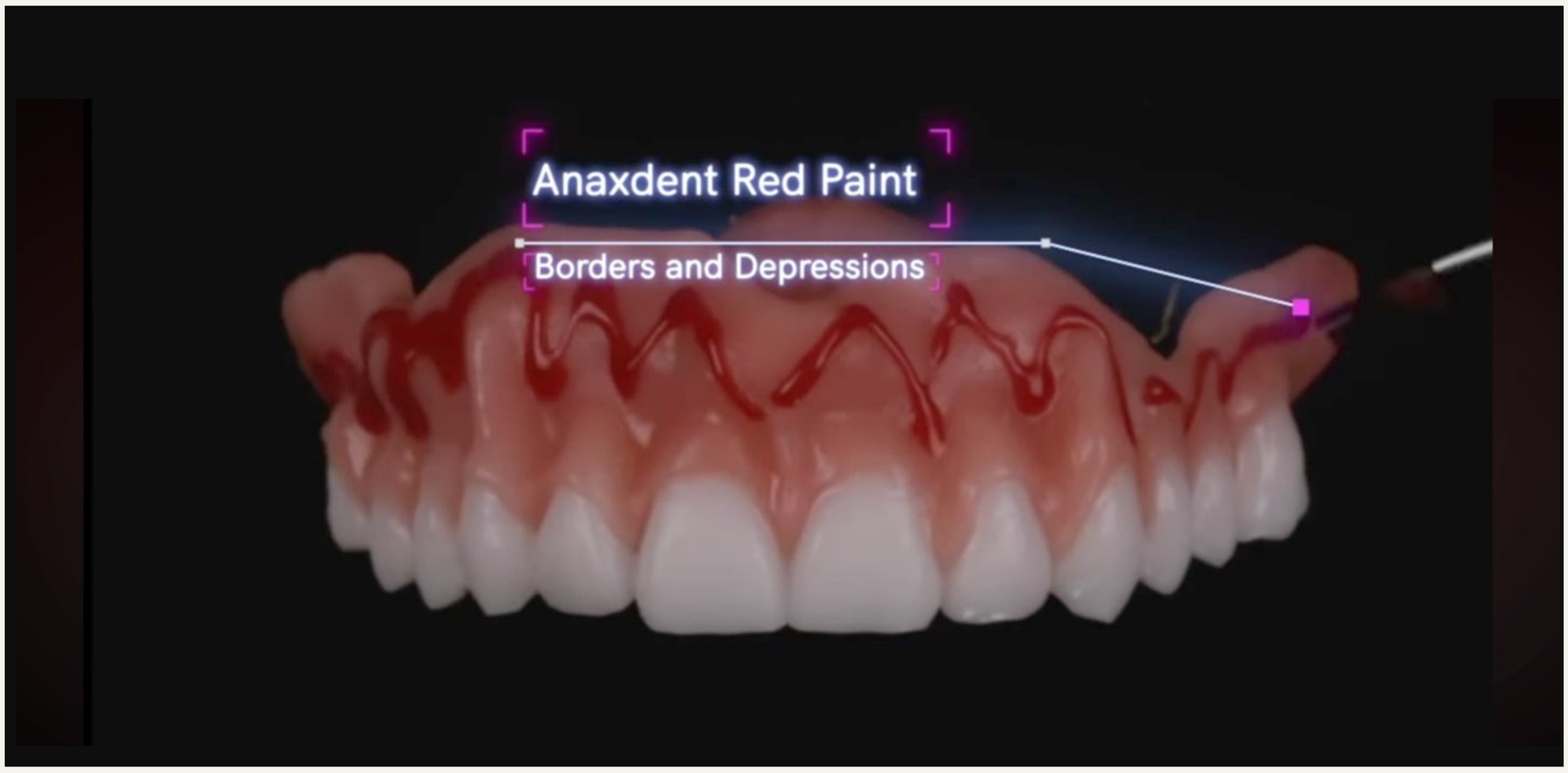
Step 3: Bright red Taub No. 13 for the unattached mucosa area.

Step 4: Coat the denture with Liquid Base material.

Anaxgum

WATCH A VIDEO TUTORIAL

Step 1: Red paint on borders for the unattached mucosa area.



Step 2: Spread the red paint thin

Step 3: Light Pink Flow around the attached gingiva of each tooth .

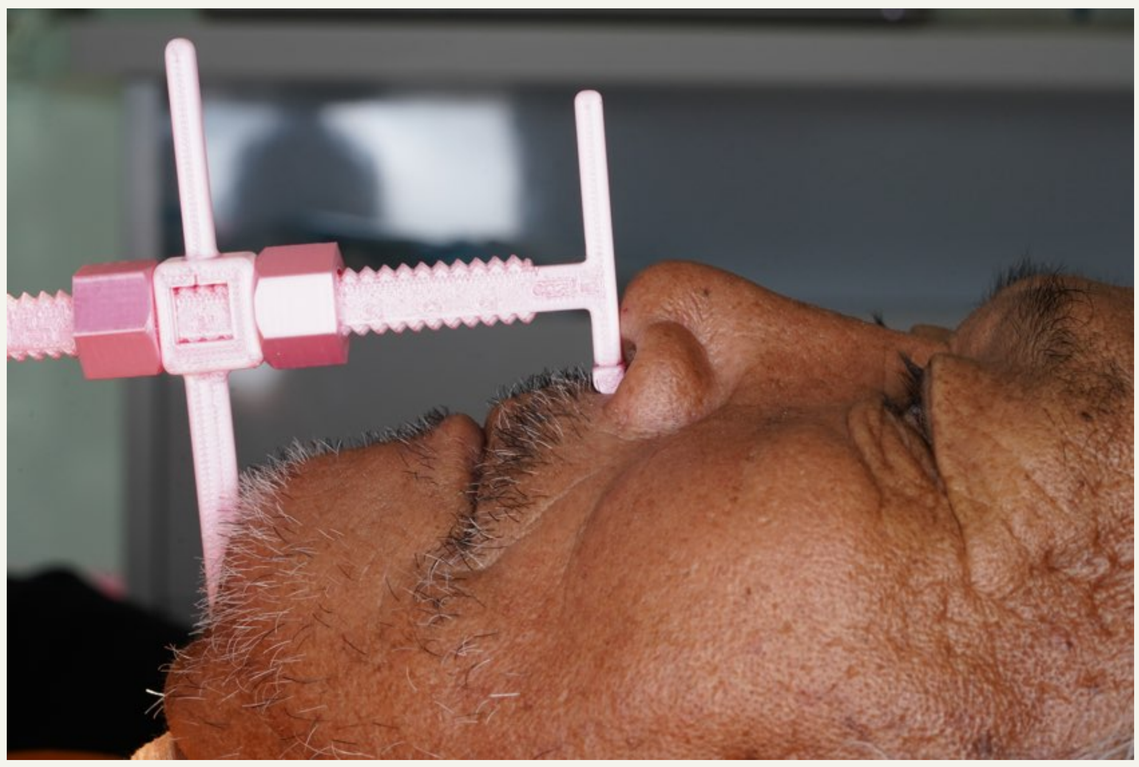
Step 4: Spread the light pink up the root eminence

Case 1

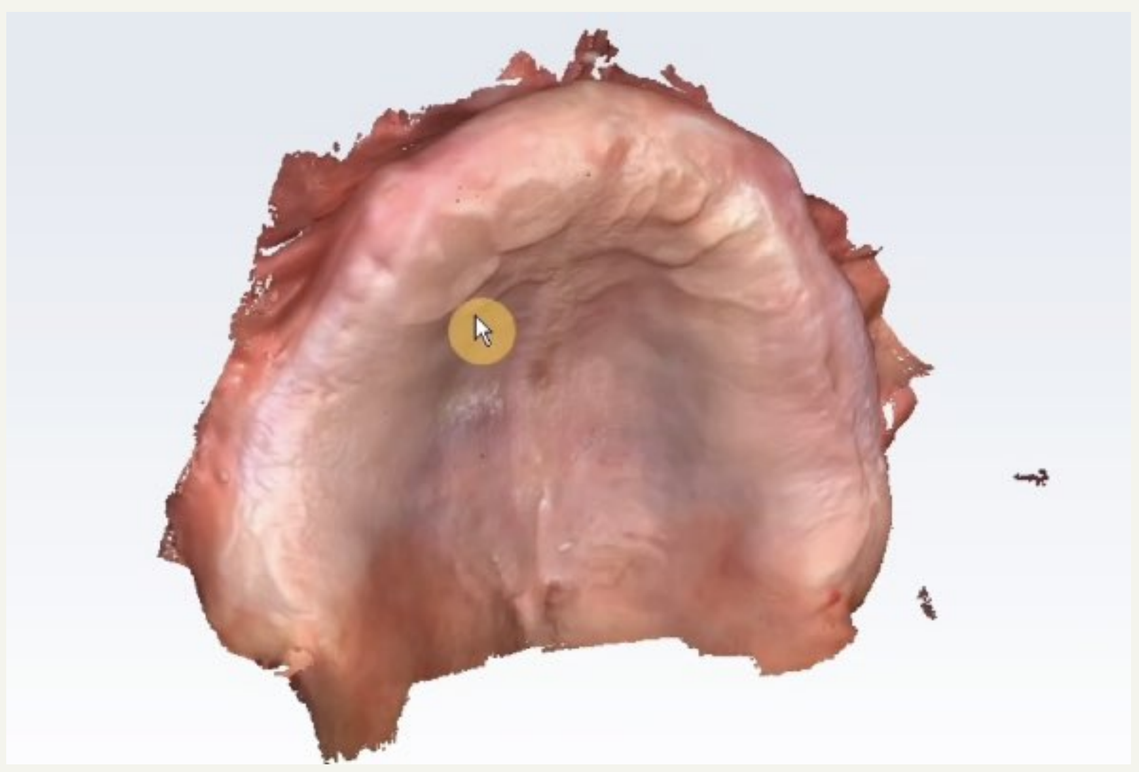
DOWNLOAD FREE
3D PRINTABLE
VDO GAUGE

Here I have a patient who presented needing a complete maxillary and mandibular denture. He presented completely edentulous and discarded his old dentures because he said they were terrible.

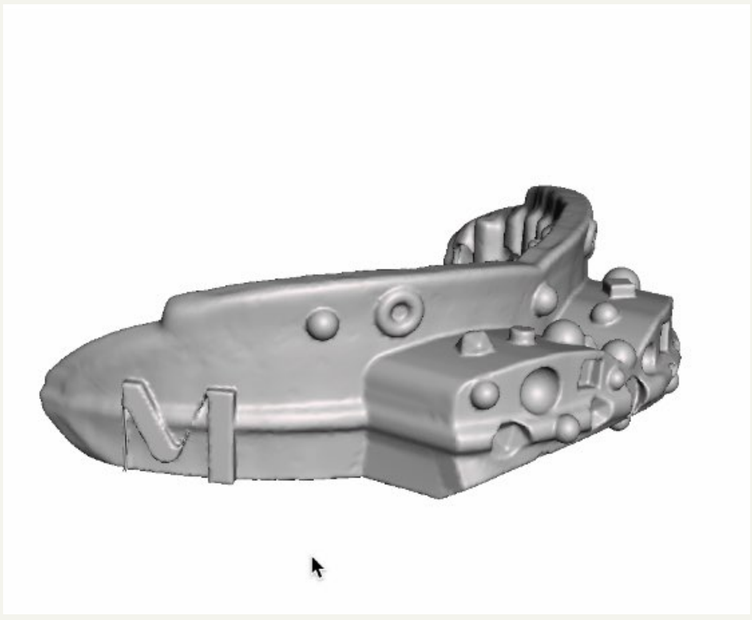
1. Find the new Vertical dimension. Start with the MOD VDO gauge available to download for free on the MOD Institute website.
2. Scan the edentulous arches using an intraoral scanner of choice.

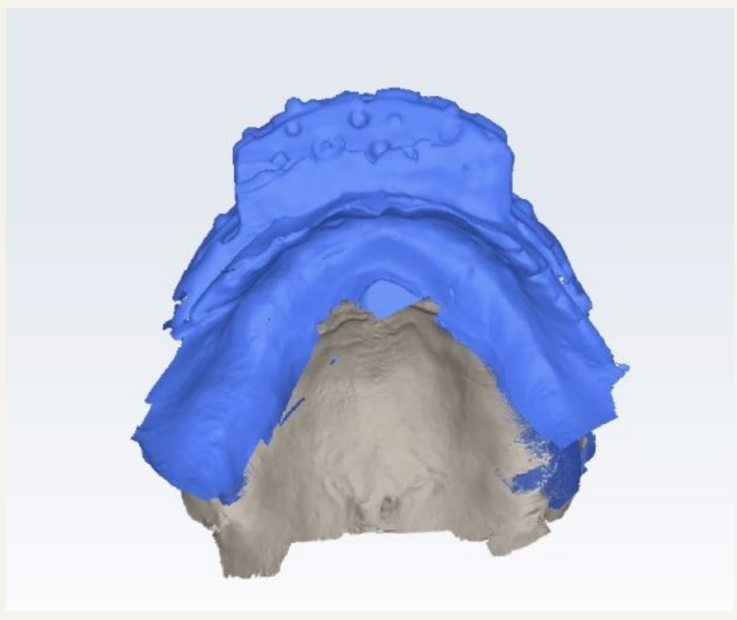


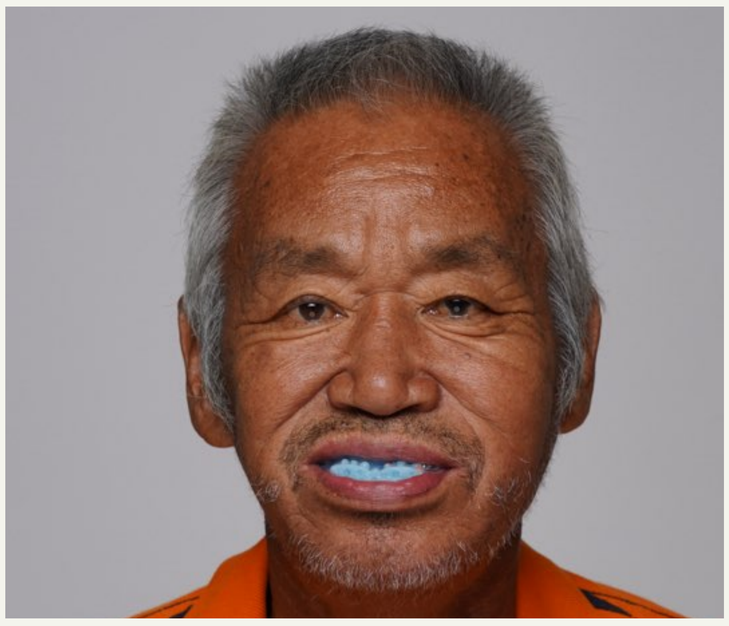
Make sure to scan the borders and critical anatomy such as the hamular notch and retromolar pads. It is recommended to use specific retractors for edentulous arches to help with scanning and retraction.



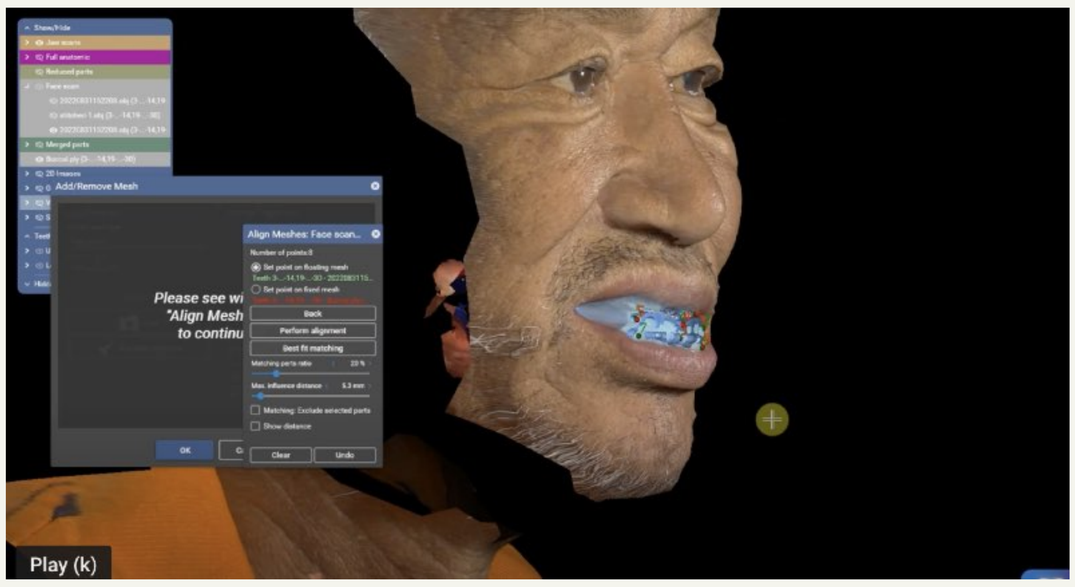
Case 1



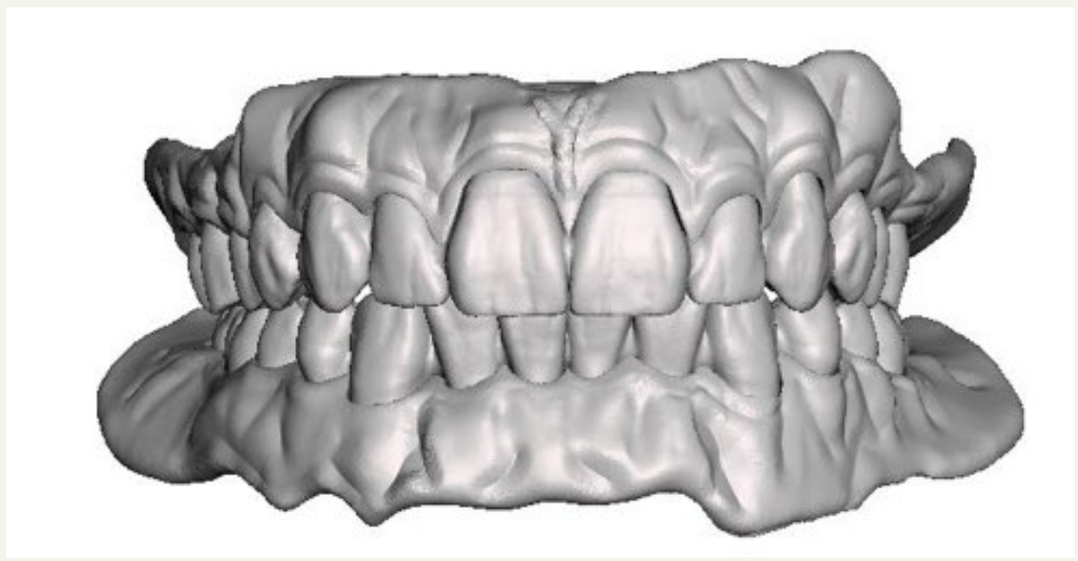




You need a way to capture the bite and merge the digital impressions at this new vertical in Centric Relation. This traditionally has been difficult using digital workflows. The MOD Centric (available for download on the MOD Institute website) tray is designed to be used as a holder for a putty mush bite. The putty is packed into the tray and then a bite is made. This entire tray system and putty is scanned with an IOS and used to pin the maxillary and mandibular arches to the centric tray bite. Some IOS software will do this automatically, but, if not, it is possible to do in lab software.



Any lab software will allow the laboratory to pin the upper and lower individual intraoral scans to the centric tray. Furthermore, a 3D face scan can be also pinned to the centric tray providing the design team with the ability to see the arches in the face for the smile design. If a 3D face scan is not obtainable 2D photos can work as well.



Case 1

Typically, a trial denture is printed monolithic and used as a combination of a record base and custom tray. These trial dentures are often made the same day the patient comes in for the consultation, especially if you have an in house dental laboratory with a design team. We then use the trial denture to verify the occlusion and the esthetics. The dentures are washed using heavy body for the borders and light body everywhere else. New photographs and face scans are made using the trial dentures. From this information, final dentures are then designed and fabricated typically using the split file workflow.

Here we can see the monolithic trial dentures, stained and tried in with the wash impression. New photos are made and face scans and these dentures are scanned 360 degrees using an IOS scanner. This becomes the final impression for the final printed denture.

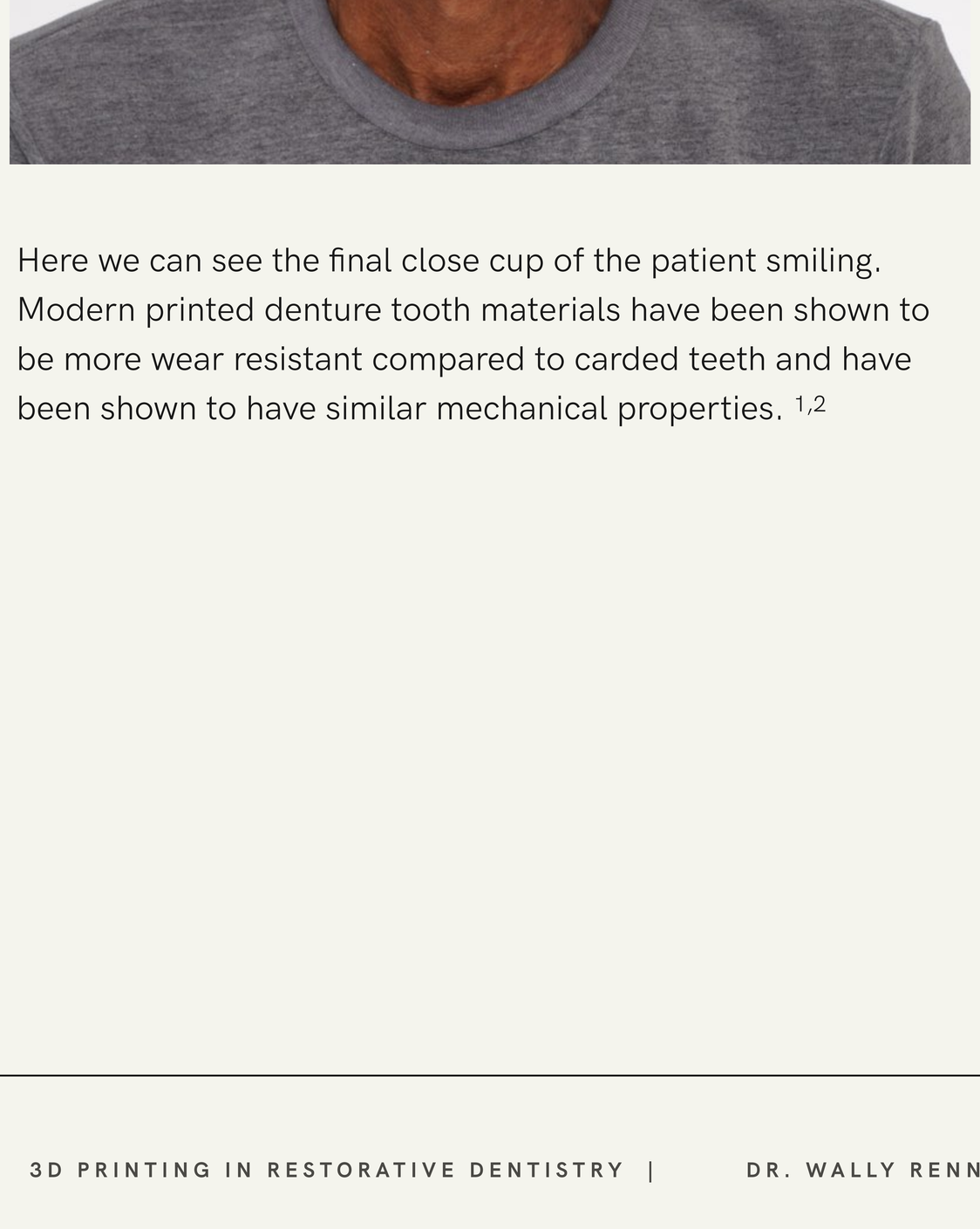
Here a split file denture is made using the information from the trial dentures. These will be the final dentures with accurate borders from the border molded trial denture. Often no changes need to be made to the tooth setup from the trial denture and that setup can be copied over to this design saving significant time.

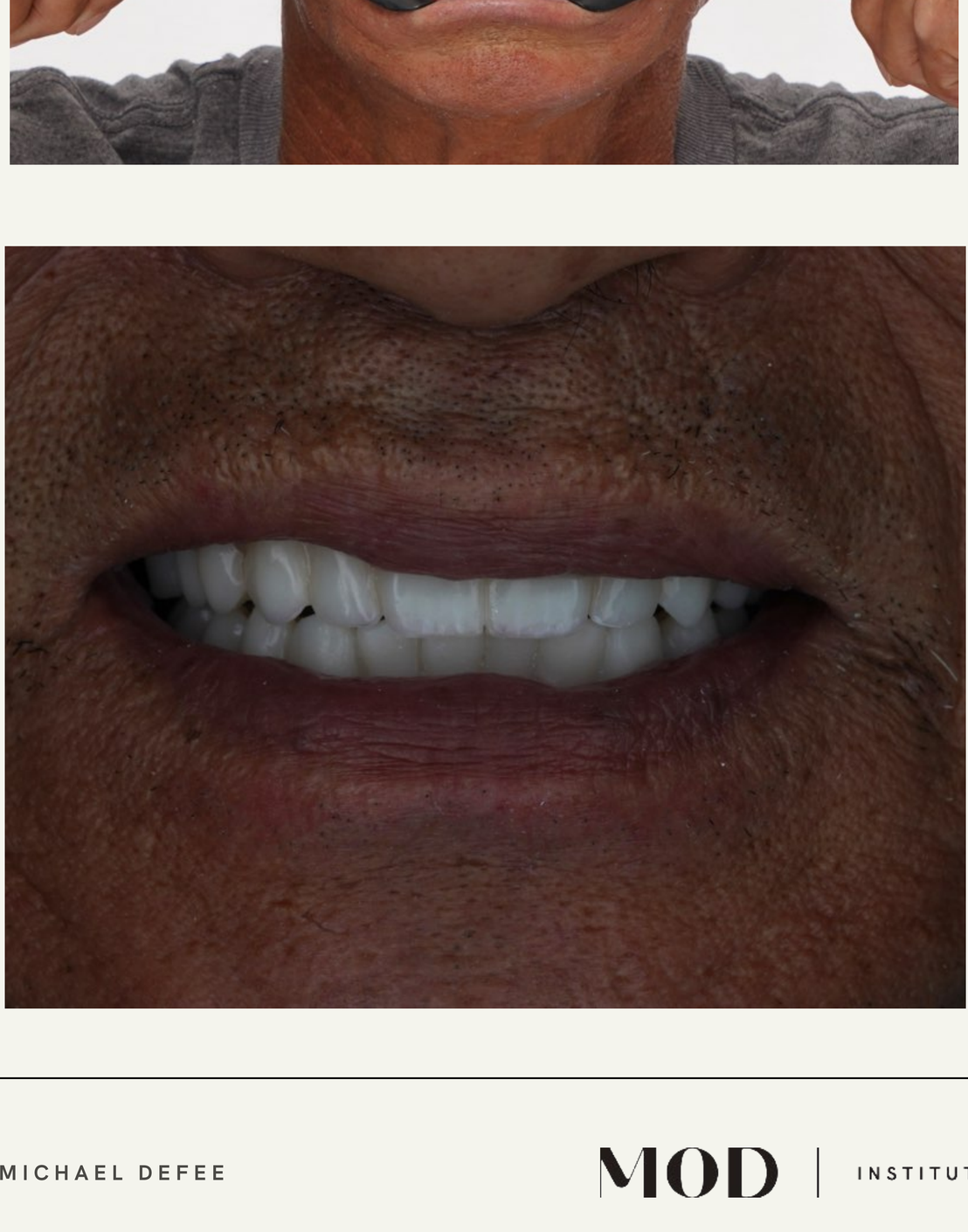
CHAPTER 4: SPLIT FILE DENTURE

Anaxgum is used to add depth of color and texture to the split file denture. Although the tissue is pink, customization using Anaxgum helps create a more realistic appearance. Here we use their light pink and red flow gingival materials to create texture and a 3D color effect.

CHAPTER 4: SPLIT FILE DENTURE

The maxillary and mandibular dentures were fabricated in two visits. The first visit was preliminary records and the 3D printed monolithic trial dentures and final records. The second visit was delivery of the final split file denture. Using this workflow dramatically reduces patient appointments. Although the initial appointment was long (3hrs), it included a printed trail denture that visit, the accuracy of the jaw relations using the 3D printed Centric Tray combined with 3D face scans provides all the necessary information to create perfect dentures. For this workflow, the trial denture is currently necessary prior to fabrication of the final prosthesis. Often no adjustments are needed to the occlusion or esthetic tooth setup; however, border molding and the light body wash create a better fitting final prosthesis compared to trying to just use the original IOS.





Here we can see the final close cup of the patient smiling. Modern printed denture tooth materials have been shown to be more wear resistant compared to carded teeth and have been shown to have similar mechanical properties. [1,2]

CHAPTER 4: SPLIT FILE DENTURE

Here we can see how I often position the teeth on the printer build platform. If I am in a rush I will print flat, but if not I will print at a 45 degree angle like shown.

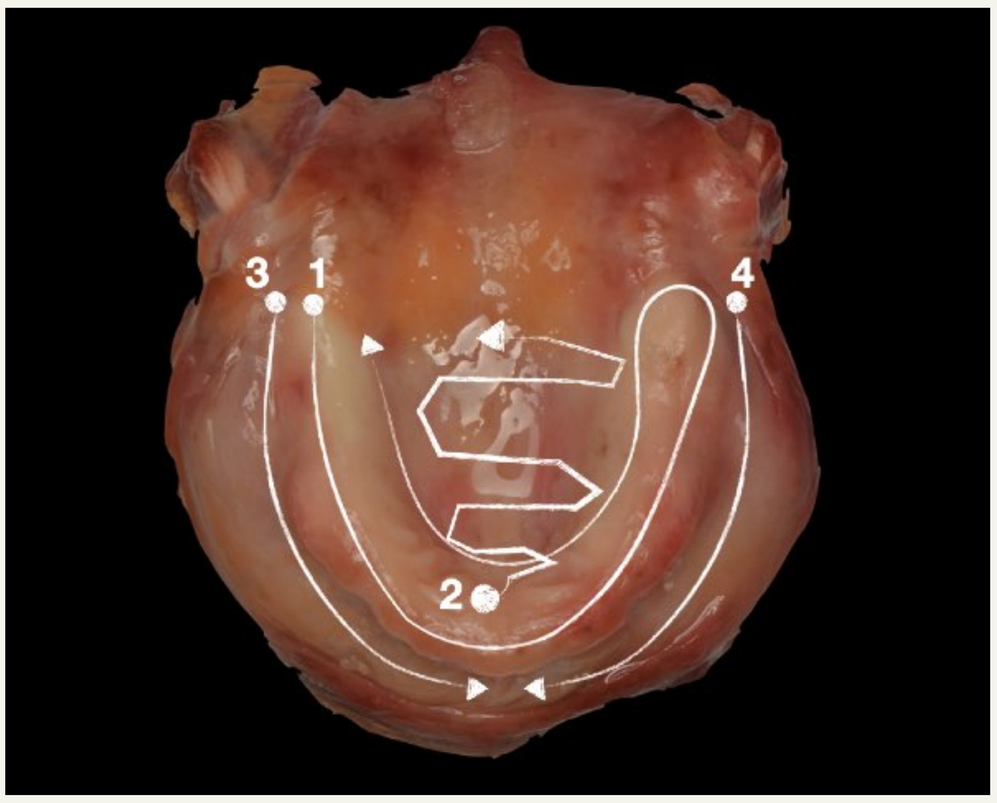
From here the supports are removed from the teeth and the teeth are bonded into the base. The best way to bond the base to the teeth is as follows:

1. Place a nice thick coat of liquid base into the tooth wells.
2. Press the teeth into the tooth wells and hold tight.
3. While holding the two together use a brush to clean excess resin.
4. Cure with the Ivoclar Vivadent Powercure or any 385nm light to tack cure 10 seconds each tooth.
5. Place in Ottoflash OR other approved curing unit and follow manufacturer's IFU
6. Pumice and polish
7. Cure again for 1000-1800 flashes or appropriate time in the manufacturer recommended cure unit.

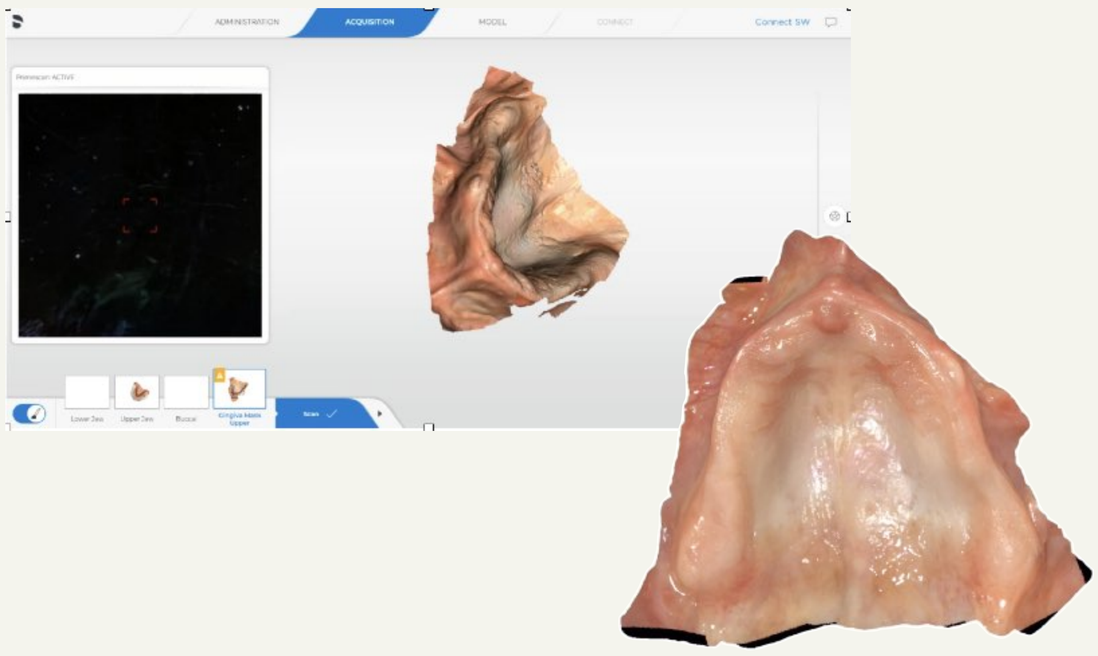
DOWNLOAD FREE COMPREHENSIVE NESTING GUIDE TO REVIEW HOW TO SET THIS UP ON ANY PRINTER

Case 2

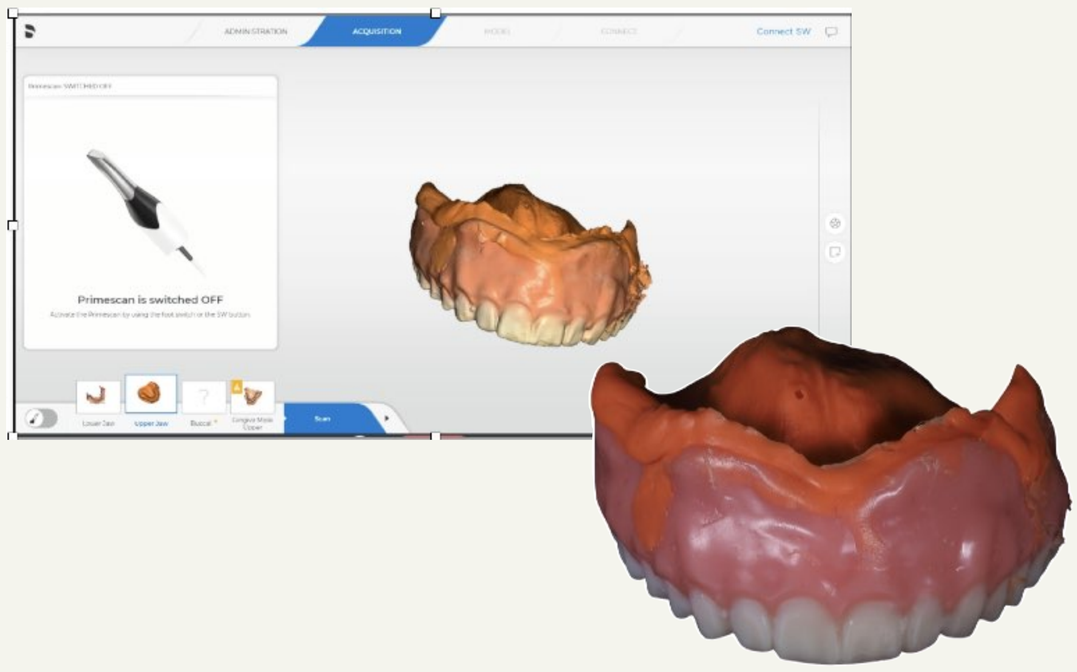
In this case I compared the fit of scanning a reline copy denture to the fit of scanning the tissues in the mouth using the above scan pattern. To my surprise the 3D printed denture made with the intraoral scan was more comfortable and fit better compared to the denture fabricated using the existing denture as a custom tray with reline wash impression. In both cases the bite is scanned with the existing denture in the mouth.



Technique One: Scan the tissues in the mouth



Technique Two: Scan the existing denture



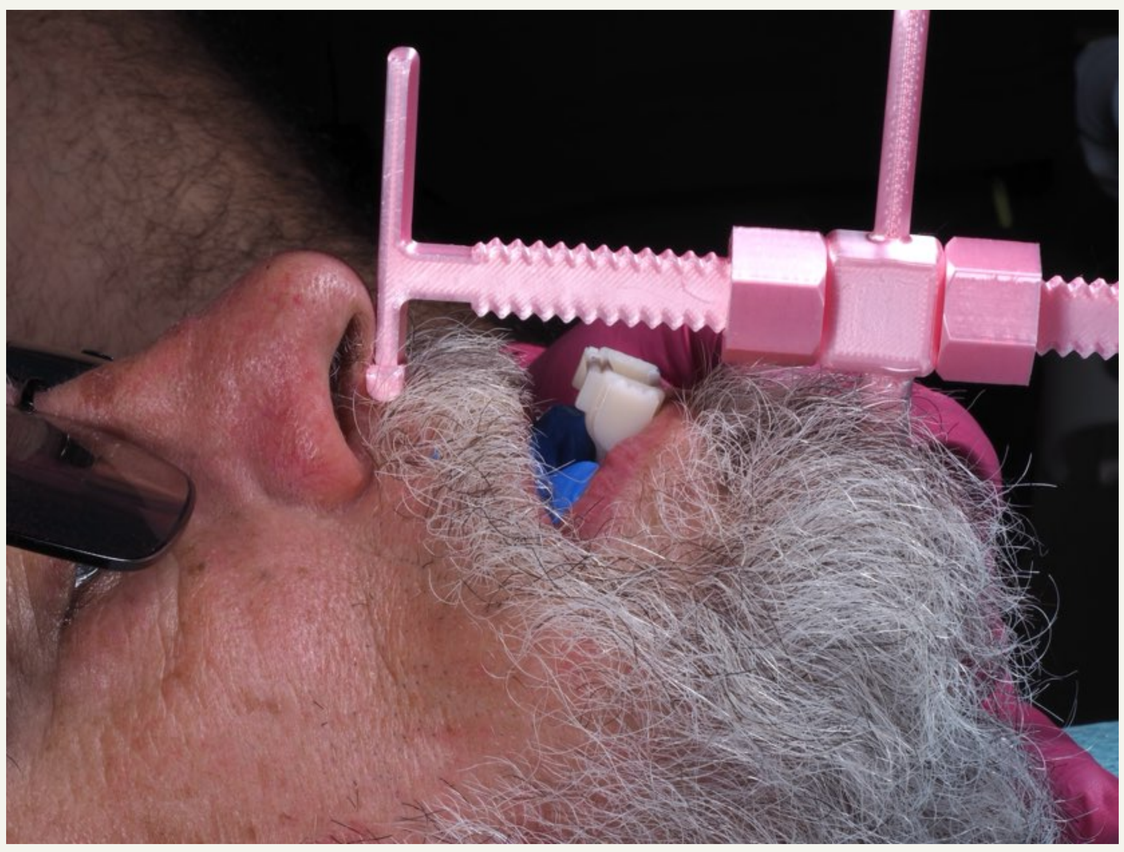
Case 2—All Digital

In this case, I found the denture I made with the intraoral scan to be better in almost every aspect. This set me along a path of trying to scan all my denture patients rather than using physical impressions. Below we see the denture at 2 years in function. Many people question the longevity of printed dentures, I have not found issues with dentures as far as 3 years out with most modern printed materials. Lucitone and High Impact Denture Base by SprintRay have been the best clinically, with Flexcera Base being much worse than expected.

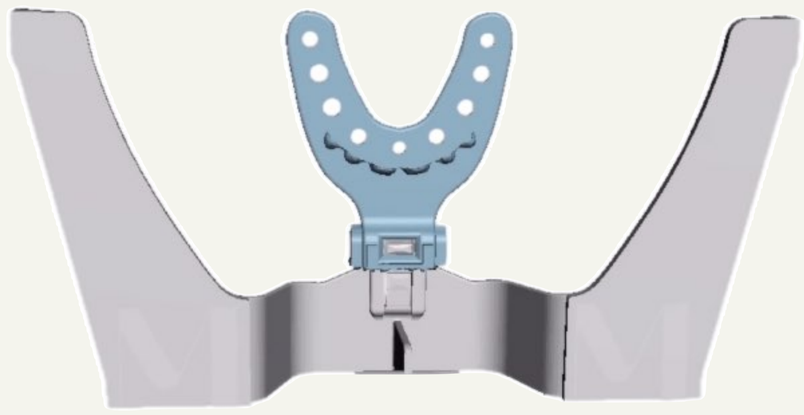
The MOD Denture Record System

When a patient comes with no existing denture, or you want to start from the complete beginning we created an effective record system for edentulous arches. This is a more advanced evolution of the system we developed and demonstrated in case 1. It is a 3D printed centric tray attached to a fox plane device.

Step 1: Find the correct VDO. I recommend using the MOD VDO Gauge that you can freely download and 3D print



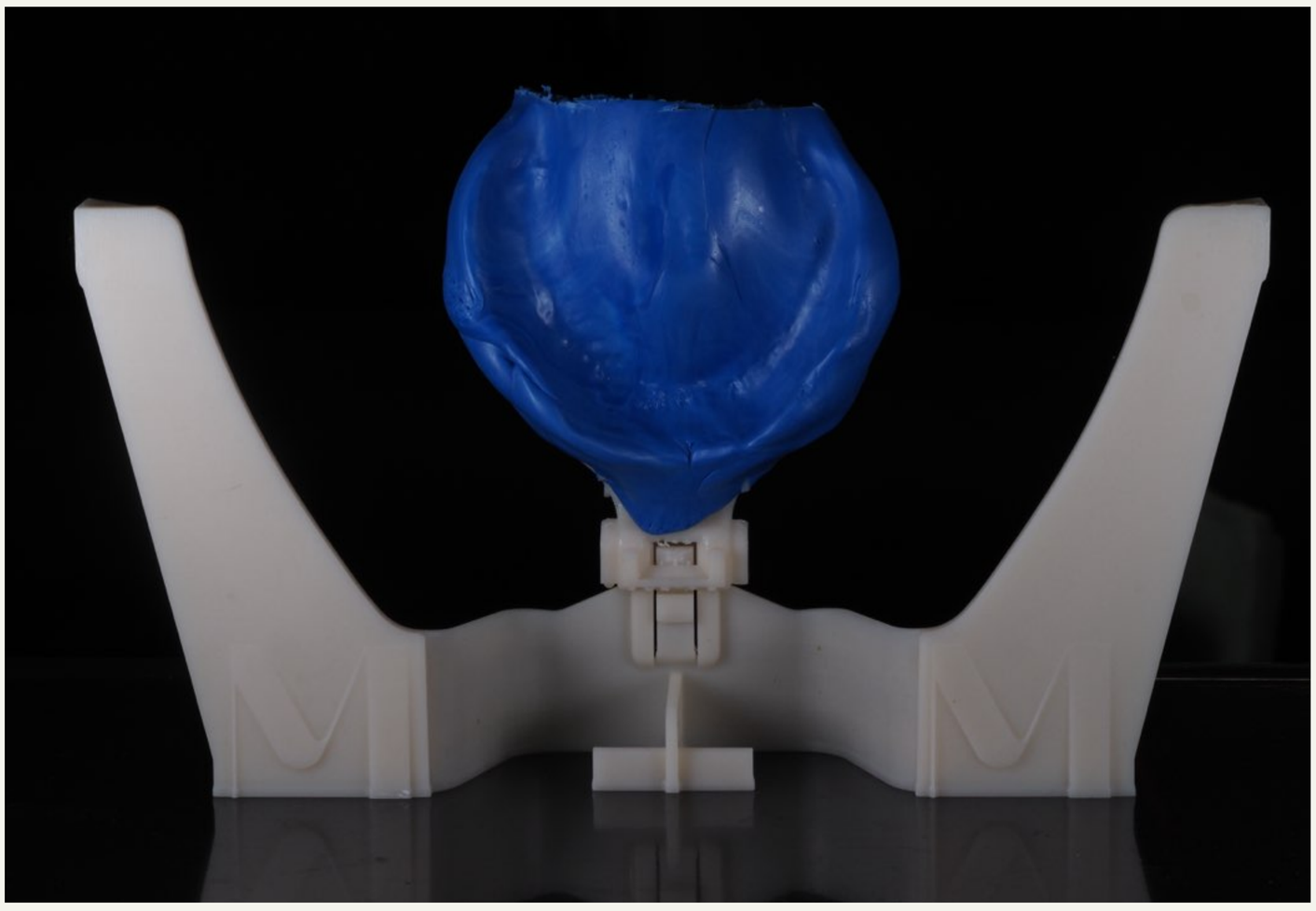
Step 2: Scan code to download and 3D print the MOD denture record system and follow along the free tutorial on how to use it.



The MOD Denture Record System

When a patient comes with no existing denture, or you want to start from the complete beginning we created an effective record system for edentulous arches. This is a more advanced evolution of the system we developed and demonstrated in case 1. It is a 3D printed centric tray attached to a fox plane device.

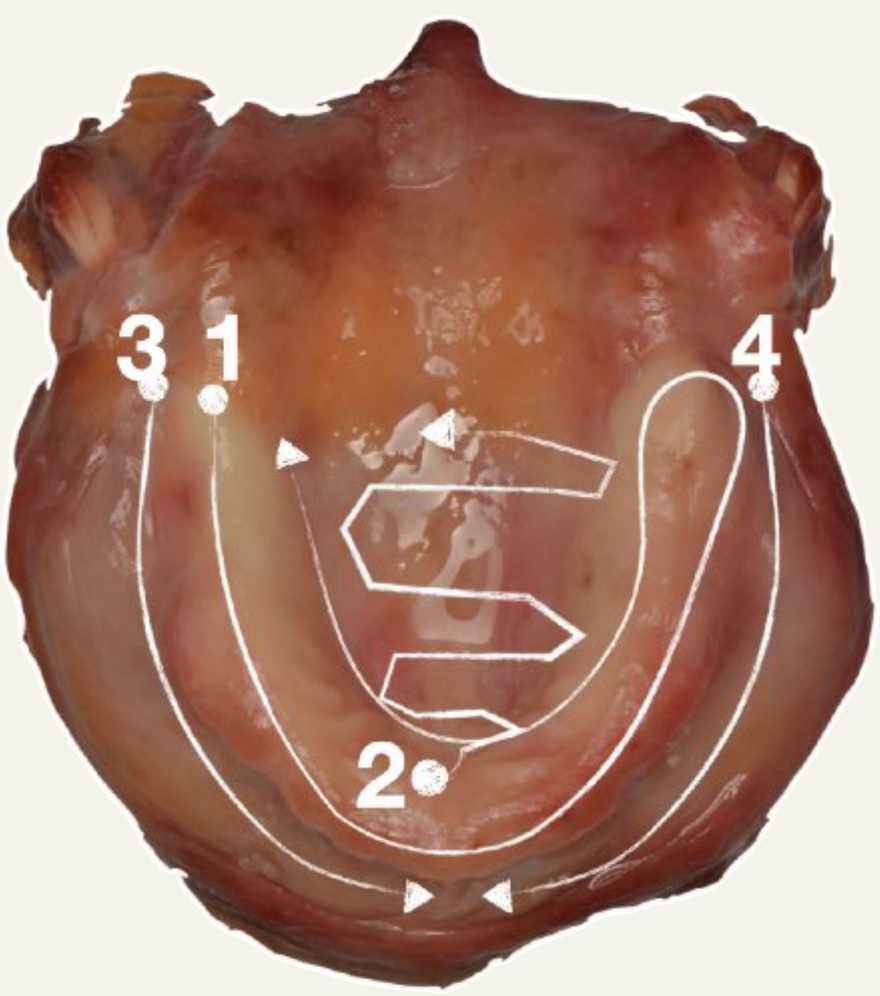
Step 3: Make putty indices of the maxilla arch and then the mandibular arch at the correct vertical suing the MOD record system



Step 4: Make a smile and retracted photo with the tray in place. Make sure the patient's head posture and the camera position remain the same between photographs

The MOD Denture Record System

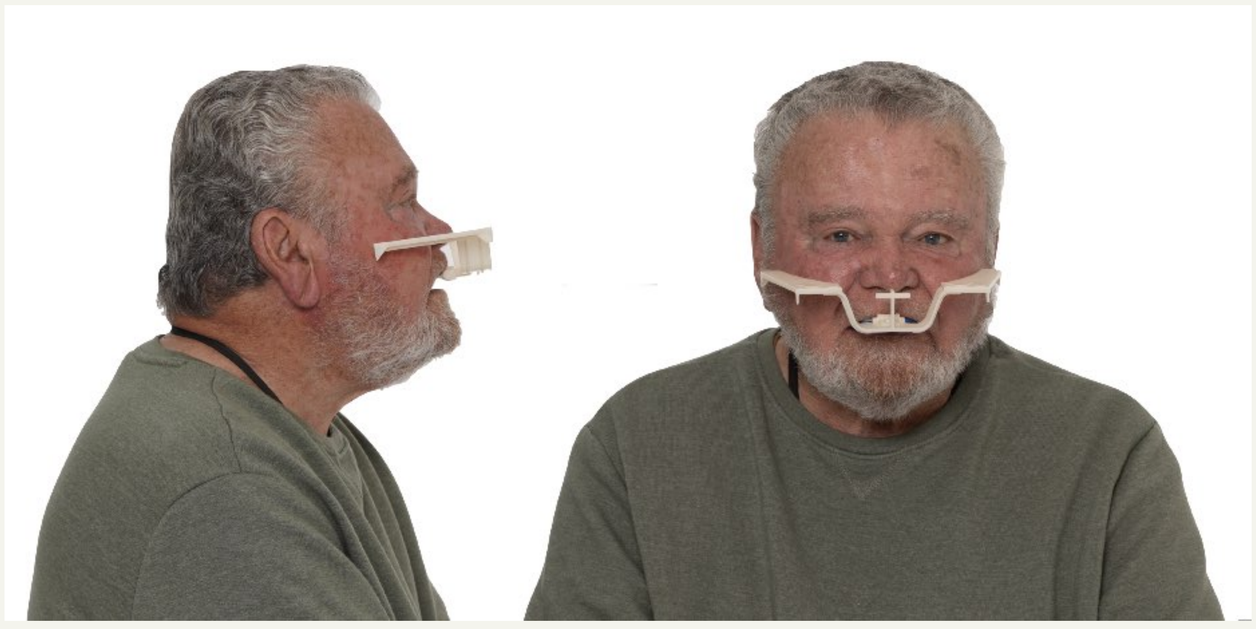
Step 5: Make high quality impressions or intraoral scans of the edentulous arches using the pattern above. It is worth investing in a set of high quality edentulous retractors such as the Lo Russo Retractors or the MOD Retractors



DOWNLOAD FREE 3D PRINTABLE
MAXILLARY ARCH RETRACTOR
FOR EDENTULOUS SCANNING

Case 3—Single arch using The MOD Denture Record System

This was a same day denture. Patient presented to my practice in the morning. A 30 minute records appointment was completed which consisted of face scan, photographs digital impressions and the MOD Denture Record system. The patient returned after lunch for the delivery of the final dentures.

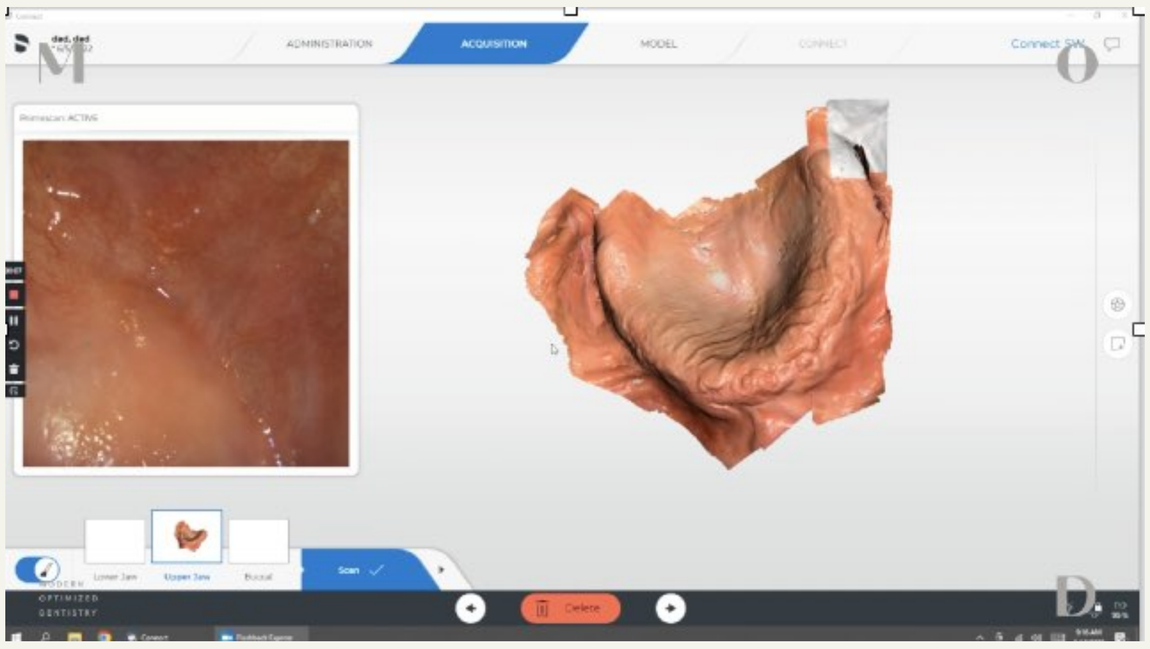


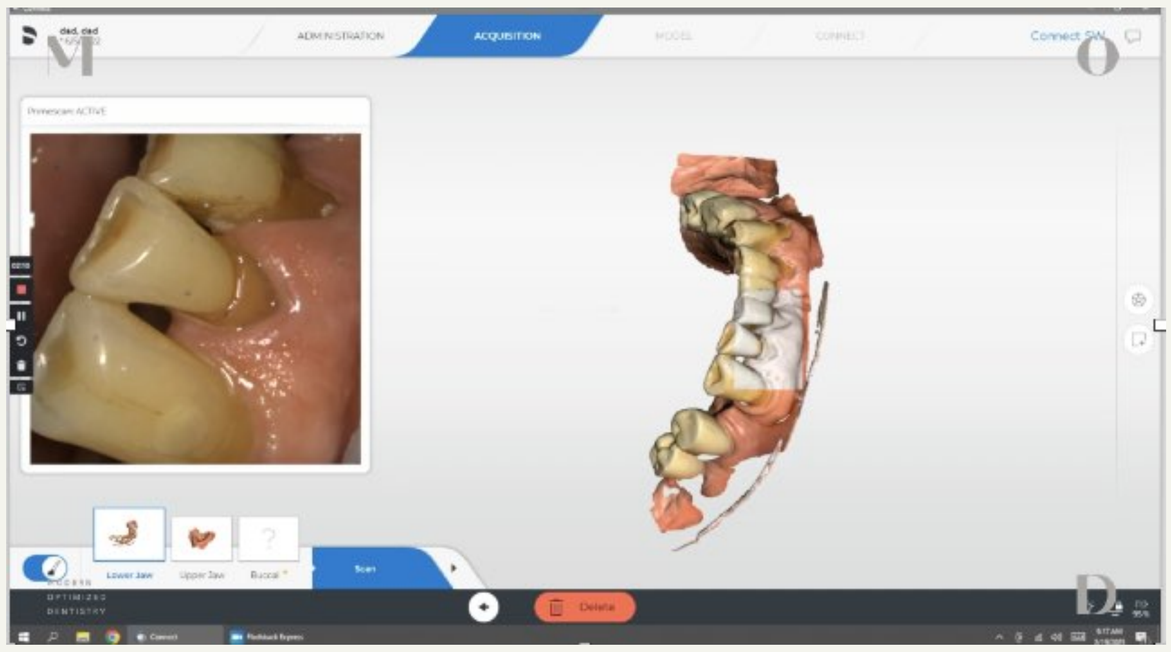
The proper vertical is marked using the MOD VDO gauge as previously shown. The MOD denture record system is used to make a putty index of the maxilla. Then the tray is removed from the fox plane and a bite record is made closing down to the determined vertical in Centric Relation. In this case, the patient has natural dentition on his lower arch so bite registration was used to capture the location.

Note in this instance the putty was relined with a light body wash. This can be used as a backup master impression in case the intraoral scan is not acceptable.

Case 3—Single arch using The MOD Denture Record System

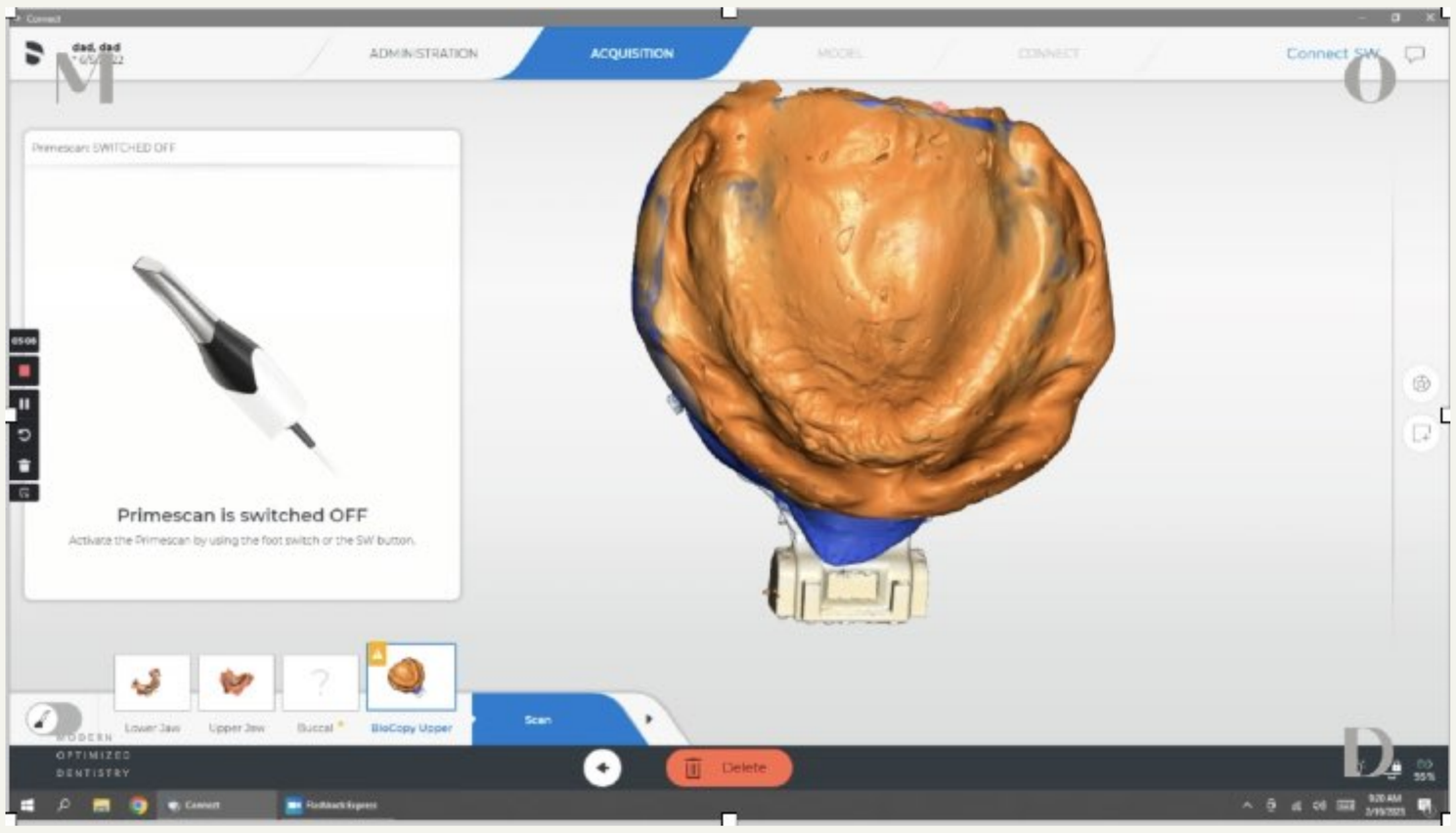
Next, high quality intraoral scans are made of the edentulous arch and opposing dentition.





The MOD Denture Record System is then scanned completely. This will be used to pin the bite. Note for Primescan you must call the scan something else such as a Pre-op scan. An arbitrary bite scan can be made. It will be discarded and models will be pinned to the scan of the MOD Record System using laboratory software.

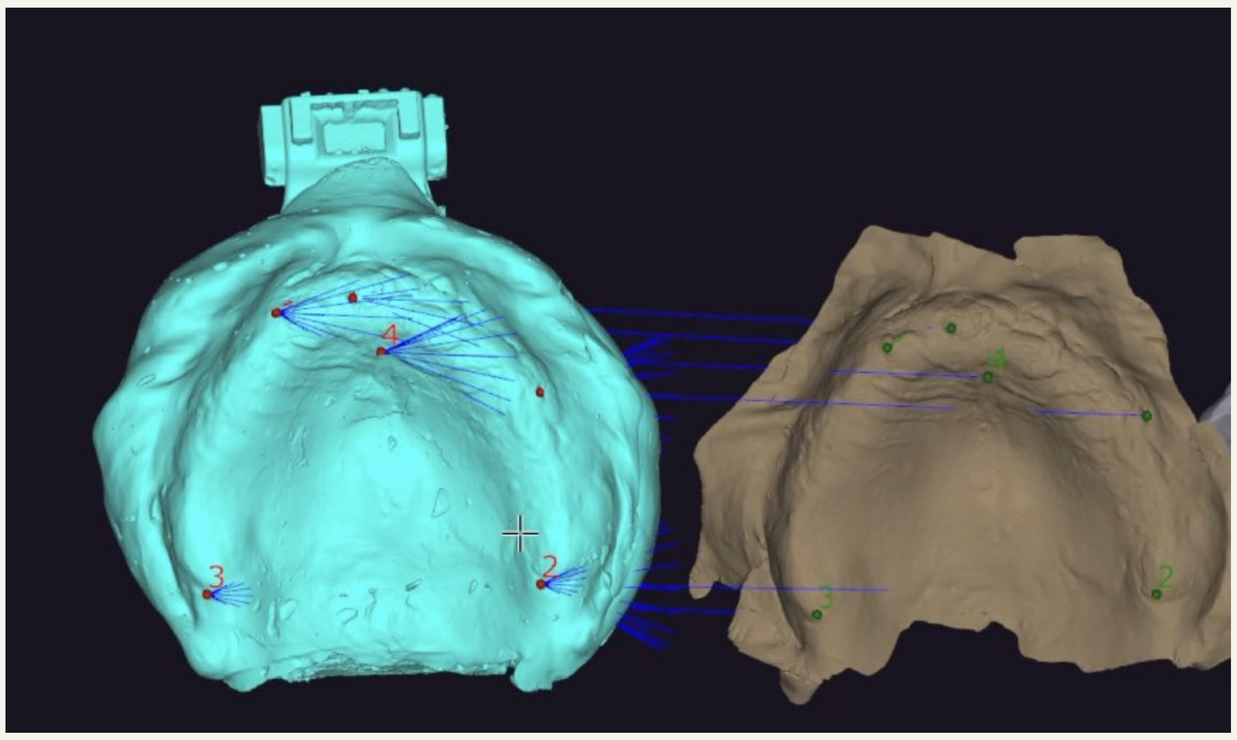
A high quality scan of the entire tray is used later on to pin the photos and also to pin the bite during design.

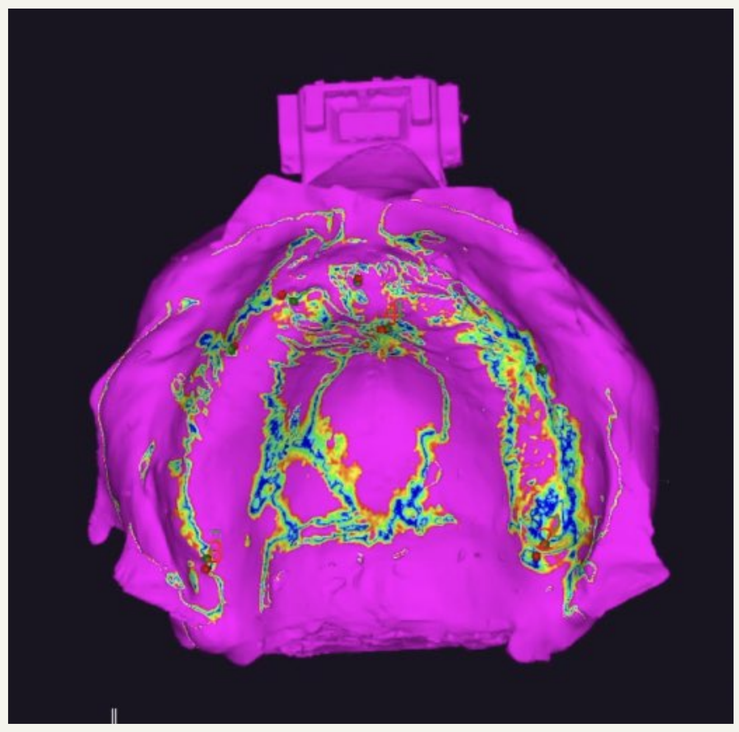


Case 3—Single arch using The MOD Denture Record System

Both a retracted and smile photo are made with the tray in place. It is important the head does not move and the camera is stationary during photographs. It is mandatory to have a tripod. The retracted photo is always made first. We also recommend a face scan but this is optional.

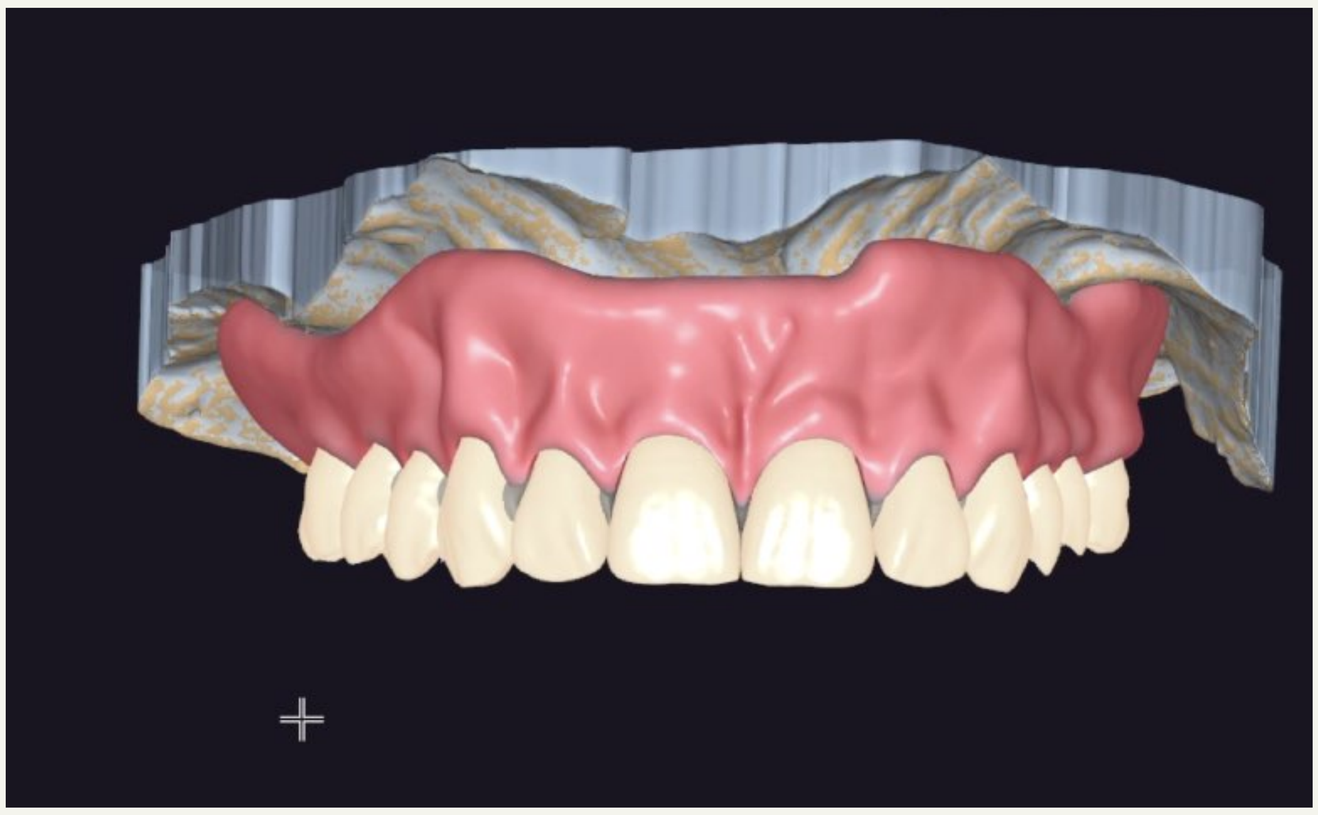
In exocad, the intraoral maxillary scan and the intraoral mandibular scan are pinned to the scan of the tray. The tray is the jaw relation record as it is what determines the bite and VDO. That is why when making the record it is best to do the putty of the maxillary first. Then capture the mandible after the maxillary so you can take your time and get the centric bite correct at the proper vertical. Doing both jaws at the same time clinically is too difficult.





Case 4—Dual arch using The MOD Denture Record System

In exocad, the scan of the tray is pinned to the photos and therefore the scan of the jaws is now pinned to the photo. This means you have everything you need to design the denture and can skip the wax trying and esthetic checks.



We find minimal to no bite adjustments are needed. Also, the dentures are very comfortable because they are made from the intraoral scan. We have done over a thousand same day and next day dentures using this technique. With a few cases for practice this executable efficiently for any practice.

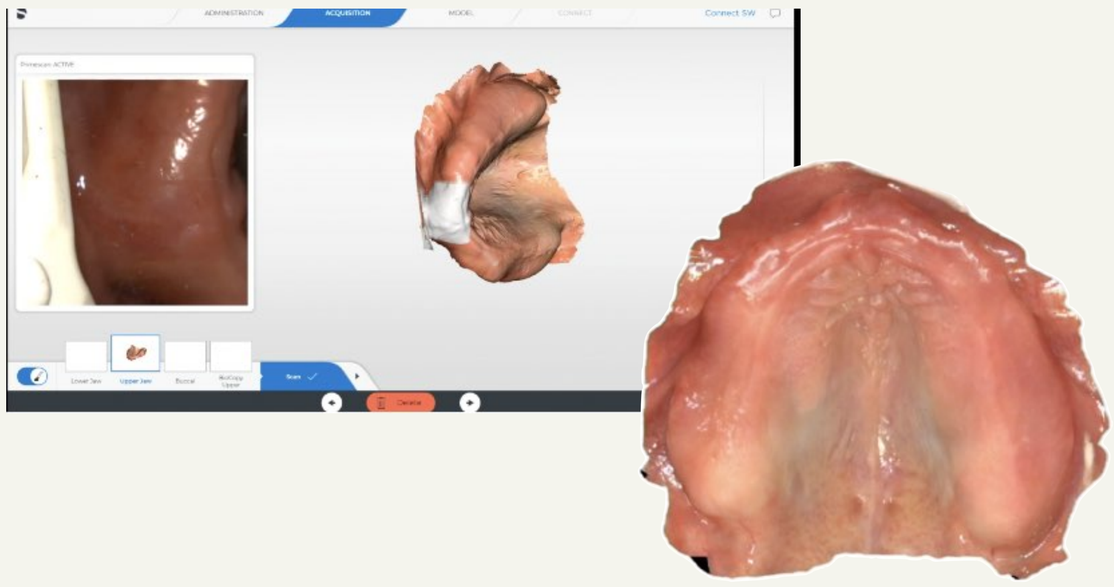
Case 4—Dual arch using The MOD Denture Record System

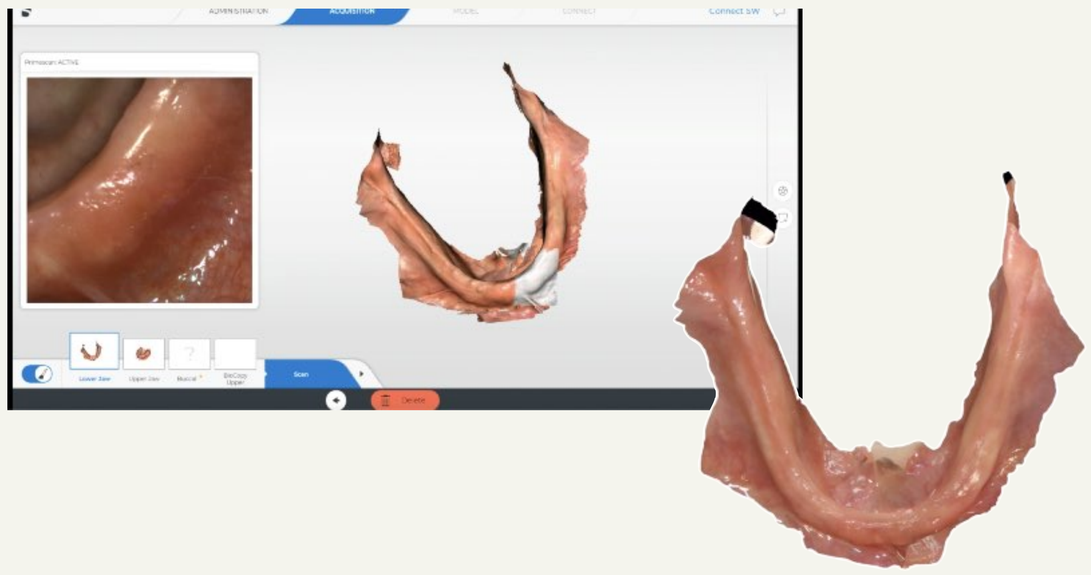
WATCH VIDEO FOR THIS CASE

This patient presented completely edentulous and had been without teeth or a denture for over 3 years. She had given up on ever having teeth again. We did next day dentures using the MOD Denture Record System.

This patient presented completely edentulous and had been without teeth or a denture for over 3 years. She had given up on ever having teeth again. We did next day dentures using the MOD Denture Record System.

Step 1: Make high quality scans of the maxilla and mandible. Make sure to capture borders and hamular notch on the upper and retromolar pads and retromylohyoid fossa on lower.

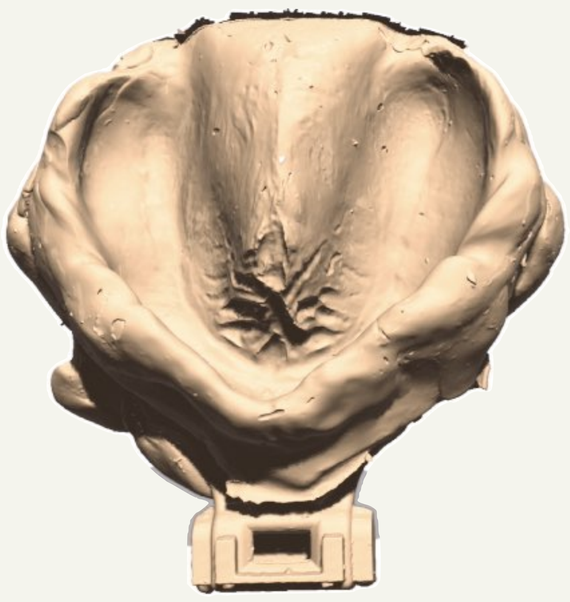




Case 4—Dual arch using The MOD Denture Record System

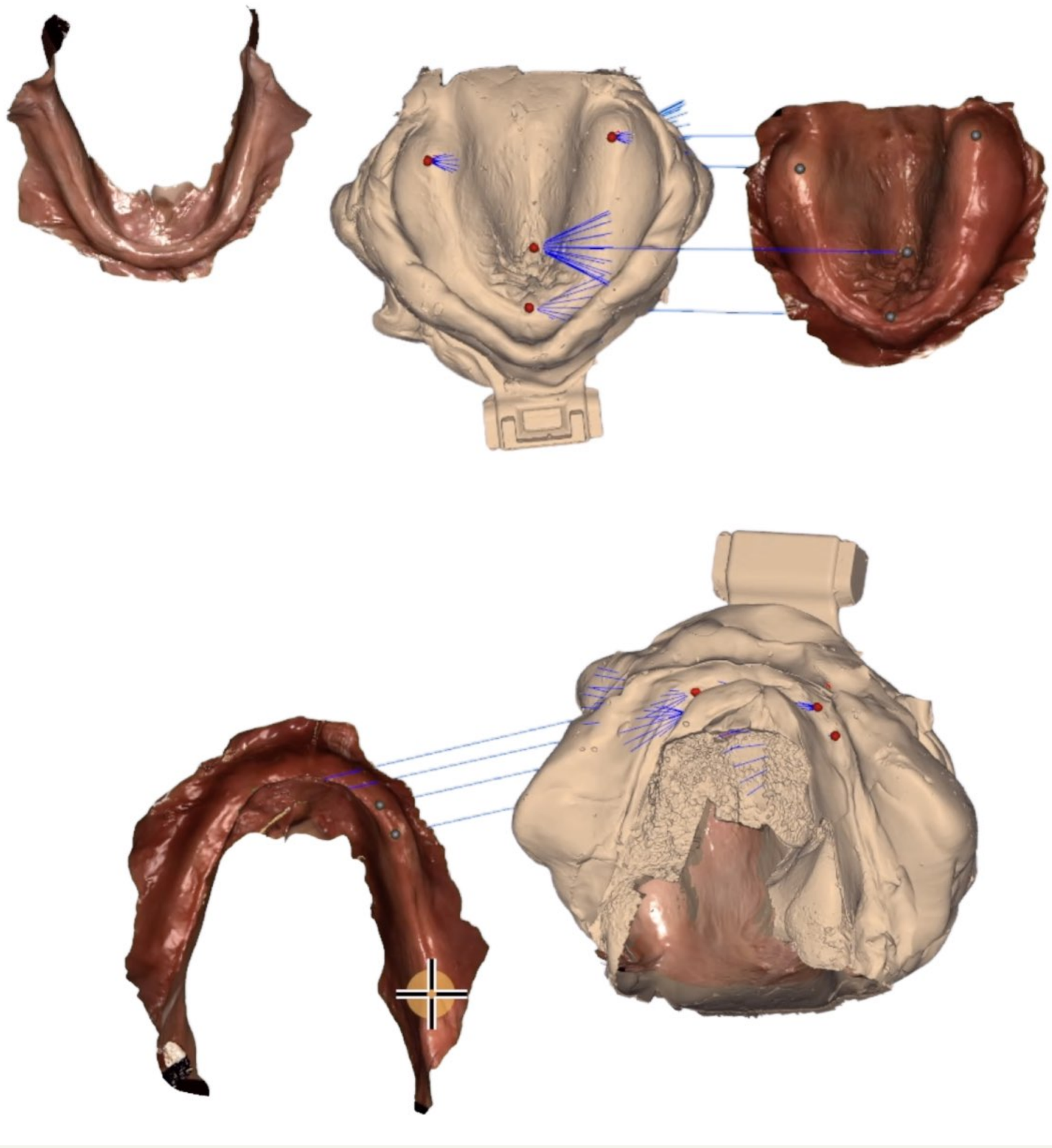
Make the Maxillary index using the MOD Denture Record System. After allowing the maxillary to set completely, then remove the tray from the fox plane and capture the lower arch index by having the patient close into the lower putty at the proper VDO. Using bimanual manipulation, chin point or tongue to top and back of the tray. It is important to then make photos with the tray in place which will be used to pin the tray scans and edentulous arch scans to the face scan or photos.

Make high quality scans of the tray system. This will be used in the next step to align the edentulous arch scans to the tray scan for bite articulation in laboratory software.



Case 4—Dual arch using The MOD Denture Record System

Using exocad here, we are aligning the upper arch scans followed by the lower arch scans to the tray scan. The software will also use best fit alignment for a closer merge.



Case 4—Dual arch using The MOD Denture Record System

From here the tray is now aligned to the photos and 3D face scans and this now provides the opportunity to set the teeth in the face using smile design software.

We are also able to use Jaw Motion tracking from systems like the Modjaw as this will allow for bilateral balanced occlusal setup.

Case 4—Dual arch using The MOD Denture Record System

The split file dentures are finished and ready for delivery. Candy coating technique with empress direct and anax gum stains were used to improve the aesthetics.

What a difference a denture can make for someone! Here the patient said “you gave me my life back.”

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CHAPTER 5

Metal Free Partial

30 million Americans wear a complete denture, and even more wear partial dentures.

Therefore, it is very common to have to make a partial denture for a patient. I almost always make split file partial dentures with the pink material composing the clasps and tissue fitting surfaces and tooth material making up the teeth, and bonding the two together. The only time I make a monolithic partial is during an emergency when I need to print a partial really fast or for immediate partial dentures..

I often have these prosthetics for implant cases when I am concerned about immediate loading and want a backup plan. Partial dentures are one of the easiest things to design and can really add value to your practice. I recommend having two 3D printers so you can print the teeth in one printer while at the same time print the pink base material in the other printer. This efficiency allows you to do same day partials.

Let’s take a closer look at case 1...

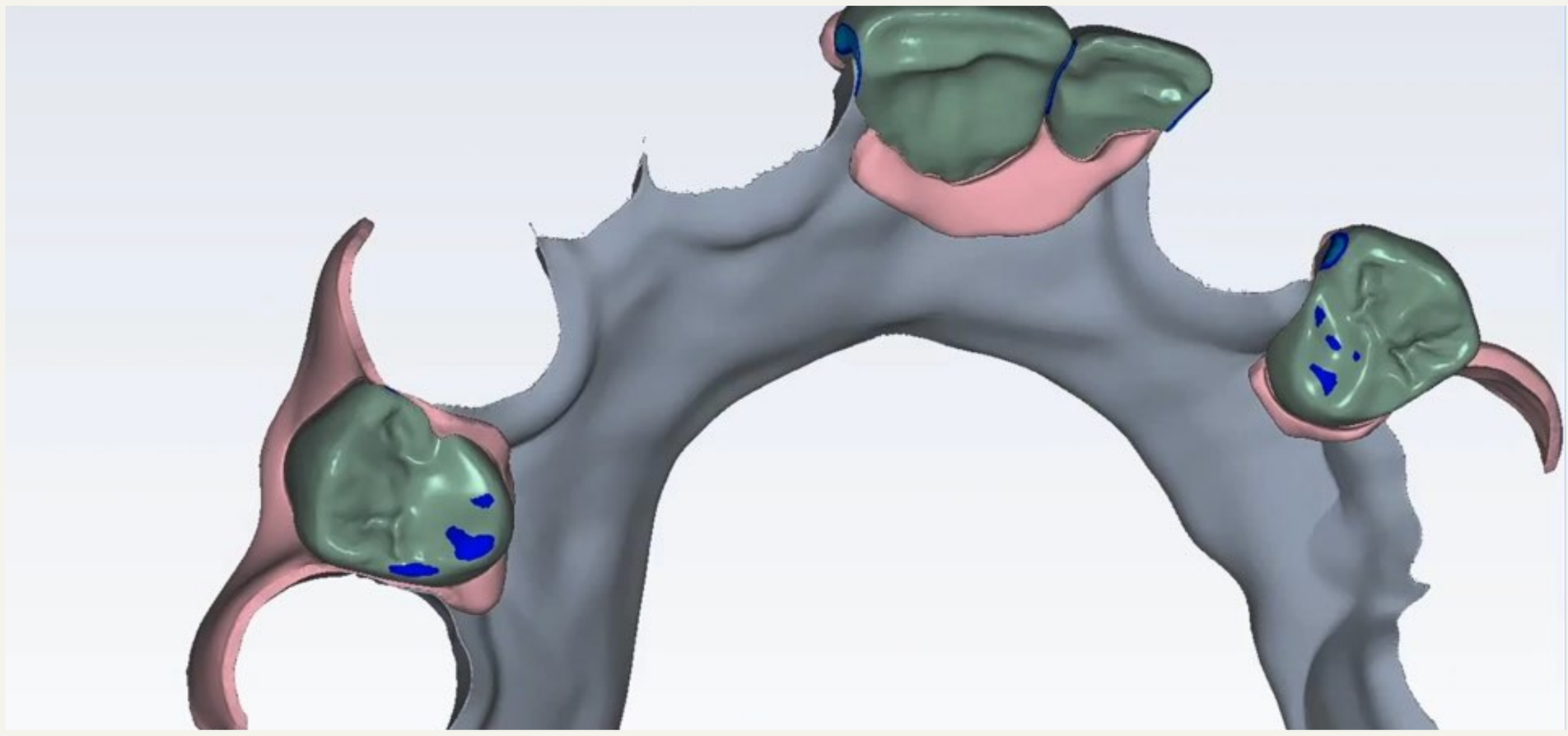
This patient presented with missing teeth #5, 9 , 10 , 12 and a severely compromised #8 due to carries and fracture. Utilizing technology, we were able to provide definitive prosthetics same day.

The first step I did was to prep and a design a crown on tooth number #8.

CHAPTER 5: METAL FREE PARTIAL

I exported the arches and the crown design and merged everything in my digital design software. This allowed me to design the partial denture while the crown was milling and before it was delivered.

The ability to be fabricating both the partial and the crown at the same time is a major time saver when executing these cases for same day delivery



Using several printers, I dedicate one printer to each material, which in this case, means more efficient chair time as I can print pink material on one printer, and at the same time print the teeth. For this print, we utilized a flat orientation to focus on the speed.

CHAPTER 5: METAL FREE PARTIAL

The teeth are printed and bonded to the Base using liquid base resin as outlined below. I leave the supports on the teeth and use them as a handle.

After bonding the teeth to the case, the next step is to customize these teeth to match her natural dentition.
To accomplish the customization, I used IPS Empress Direct Resin stains and original print resign as a top coat. Make sure to cure this layer following protocols and in nitrogen or glycerin after an initial tack cure.

CHAPTER 5: METAL FREE PARTIAL

The ultimate test now is how will this look in the mouth? Let's take a look and see if we have a perfect match. They always look better in the mouth than on the bench.

We are ok here but if you have not noticed the lateral incisor #10 has the neck of the tooth tipped mesially, the worst possible angle to tip a lateral. This fact was a design error that should have been caught early on. The patient however was in tears she was so happy. The power of digital dentistry is life changing for our patients. To think this was all accomplished in a single 2 hr appointment to include the crown and final partial denture is amazing!

PRO TIP

Design tips: Keep clasps a minimum of 2 mm thick and 5 mm tall inciso-gingivally.

Before curing: bond teeth using the technique described below using liquid base resin in the wells and pressing the teeth into the wells. Spot curing using a hand held light with a 385 nm bulb like the Ivoclar Powercure light.

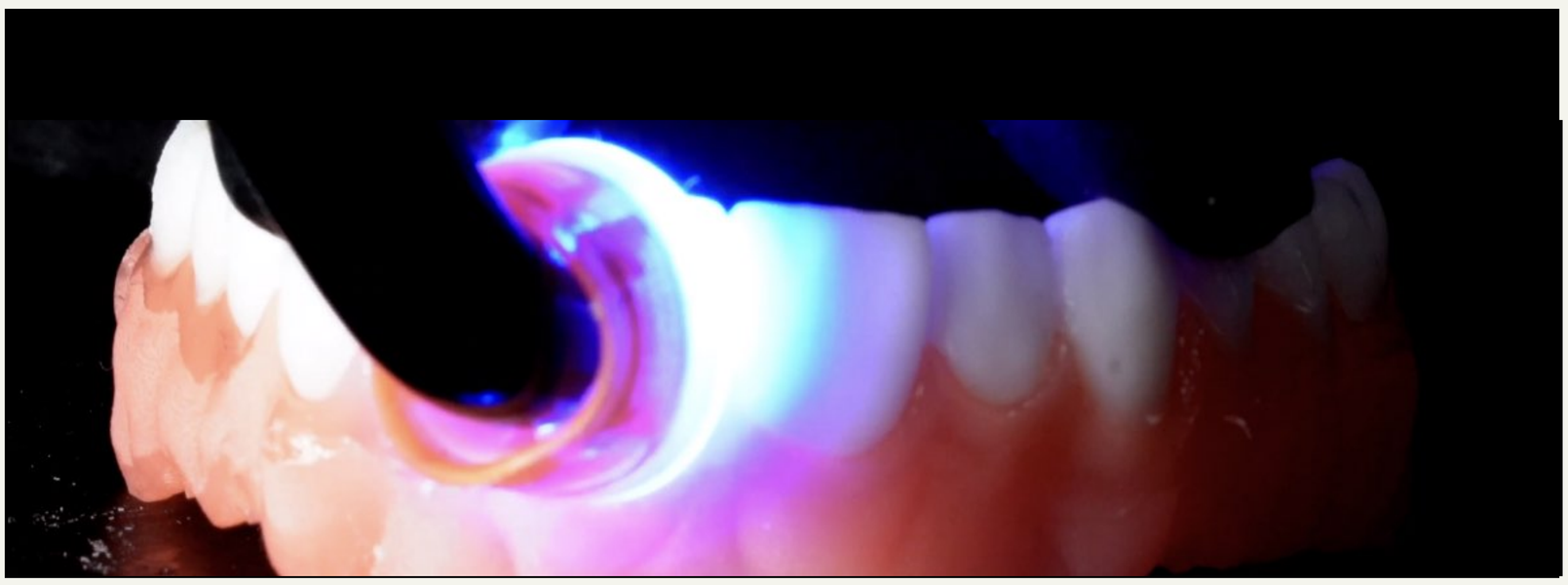
WATCH VIDEO OF BONDING DENTURE TEETH

Let's take a closer look at a Bonding...

Bonding Step 1: Fill the tooth pockets with liquid base material

Bonding Step 2: Press & Cure

Press the teeth into the wells, use a brush to wipe excess liquid Base off the teeth and cure using a composite resin curing light with a 385nm bulb like Ivoclar PowerCure.



Bonding Step 3: Curing

Then place the prosthetic in a manufacturer recommended curing unit for the specified time as outlined in the approved instructions for use.

Bonding Step 4: Characterize or Polish

You can use either pumice and diamond paste for final polish.

This is a polished denture made by Absolute Dental Lab entirely printed and polished. If you are bonding milled teeth (PMMA) to a printed base make sure you micro abrade the PMMA teeth really well before bonding with liquid base material. However, you should always consult with IFU as some systems require special bonding agents.

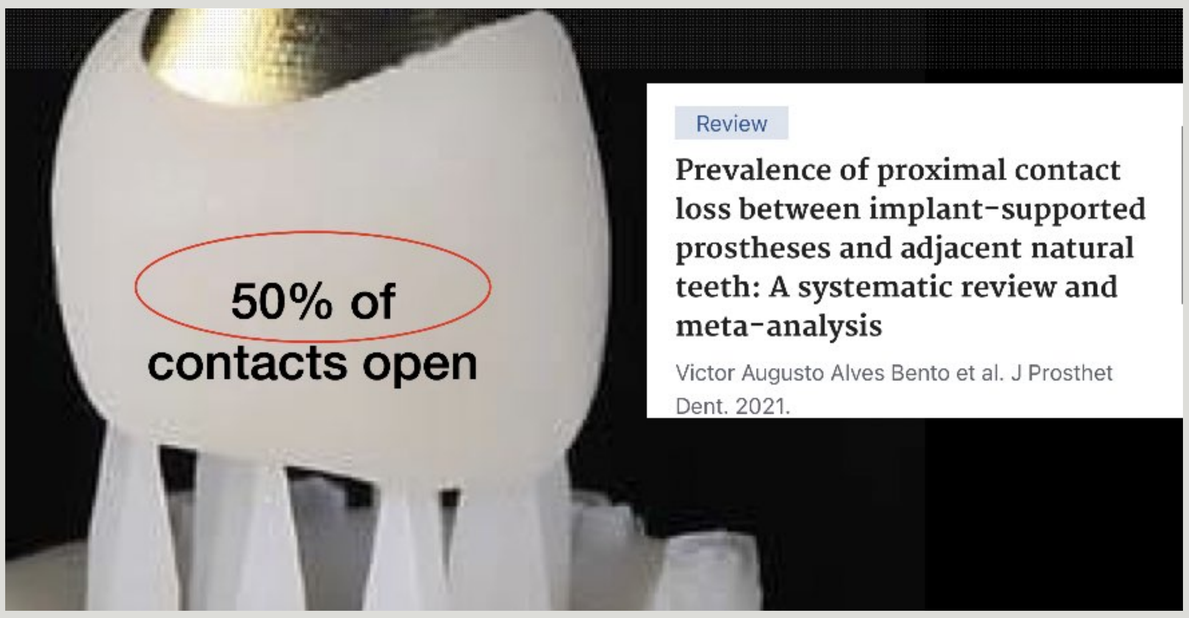
CHAPTER 6

Introduction to Final Restorations

Starting in January 2023 “3D printed restorations that have more than 50% ceramic filler can be coded as a ceramic.”

3D printed nanoceramic crown on an implant custom abutment by TruAbutment. Scoop Technique used for Characterization

Now I love a good e.max restoration, and that is the most common material used in my practice; however, over the past 4 years I began to sprinkle in printed restorations for my restorative workflows. I started using them as a lower cost option for my patients. Nowadays, 3D printed restorations have become my standard for a few restoration types: inlays, onlays, no prep veneers and implant crowns. In some instances, 3D printed restorations can offer unique advantages over porcelain or zirconia. For example, with implant prosthetics, the number one reason I like to print resin implant crowns is the ease of repairability. In a recent systematic review, it was concluded that 50% of proximal contacts open in a mixed dentition implant case over time! With a printed restoration, you can easily add to the contact by simply unscrewing it, sandblasting the contact and adding resin.



Building a Forgiving Implant Restoration

A natural tooth has a roughly 100 micrometer wide periodontal ligament (PDL) composed of collagen fibers that act as a shock absorber during chewing and normal function. An implant does not have a PDL, and, therefore, placing a rock solid unforgiving material like zirconia on an implant means all the forces are being transmitted from the restoration down to the implant which can lead to screw loosening, fracture, or more rarely early crestal bone loss and potentially implant failure. The selection of a favorable combination of crown and abutment material for implant supported restorations is recommended to mediate the stress distribution pattern to the peri-implant bone. The unique combination of a less rigid crown with a rigid underlying abutments might enhance force absorption capacity and preserve the restorations force absorption behavior over time.[1-12]

Pascal Magne previously suggested this fact as an important consideration when restoring implants. 8 Here he said,"The present work confirmed that the inclusion of composite resin restoration allowed dental implants to demonstrate a significantly increased damping behavior."

I feel this workflow leads to a more forgiving implant restoration. Many types of implant restorations are successful, but the incorporation of 3D printed screwmentable restorations into my practice has been an incredibly cost effective way to provide a repairable high quality restoration.

I typically use the TruAbutment workflow if a custom abutment is needed. For all workflows, a digital impression is made in the following steps:

Soft tissue scan with healing abutment off.

Scanbody scan. Use a TruAbutment scan body for the specific implant you have placed, if using the TruAbutment workflow.

Scan the opposing and also the bite.

1. Make a digital impression using a TruAbutment scan body for the specific implant that was placed. Please note that a complete digital impression includes the above steps.

With this scan data, TruAbutment will make a custom abutment and send you the crown file to print. You can ask for either a screw-retained or cement-retained crown. If cement-retained, the design will not have a hole in it and the clinical workflow is to try the abutment in the mouth, take a check radiograph to confirm seating of the abutment, then try the crown in. If crown fits, torque the abutment then bond the crown. I try to avoid this because I do not like cleaning excess cement in the mouth.

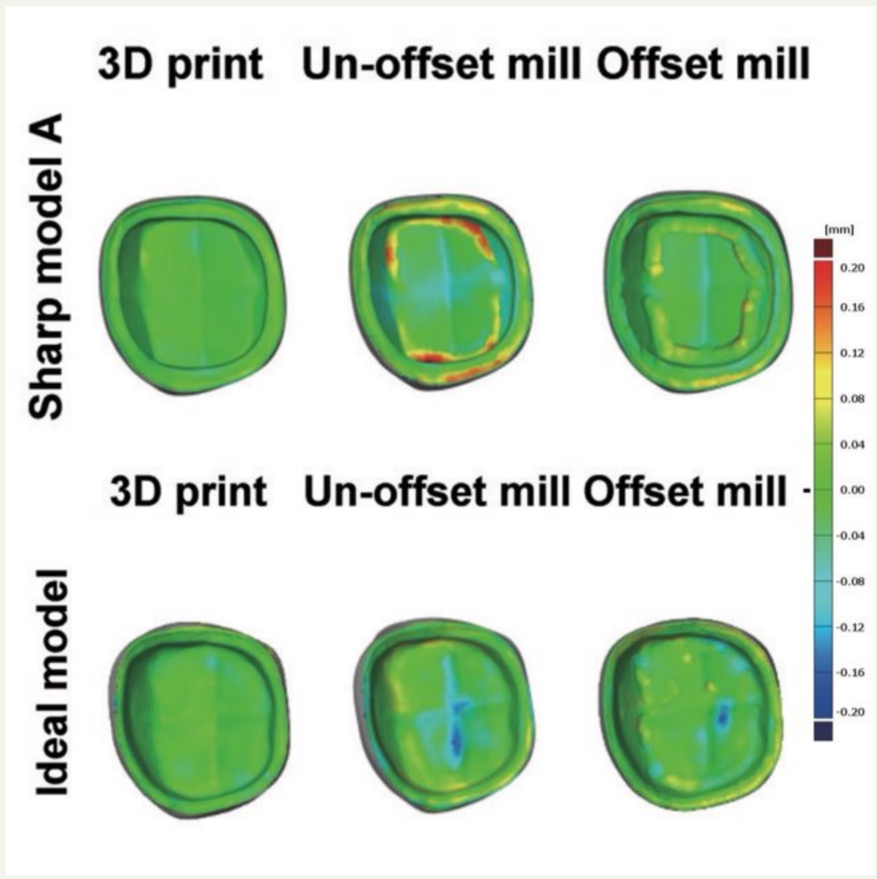
Printed Nanoceramic crown on a gold anodized abutment from TruAbtument.

CHAPTER 6: INTRODUCTION TO FINAL RESTORATIONS

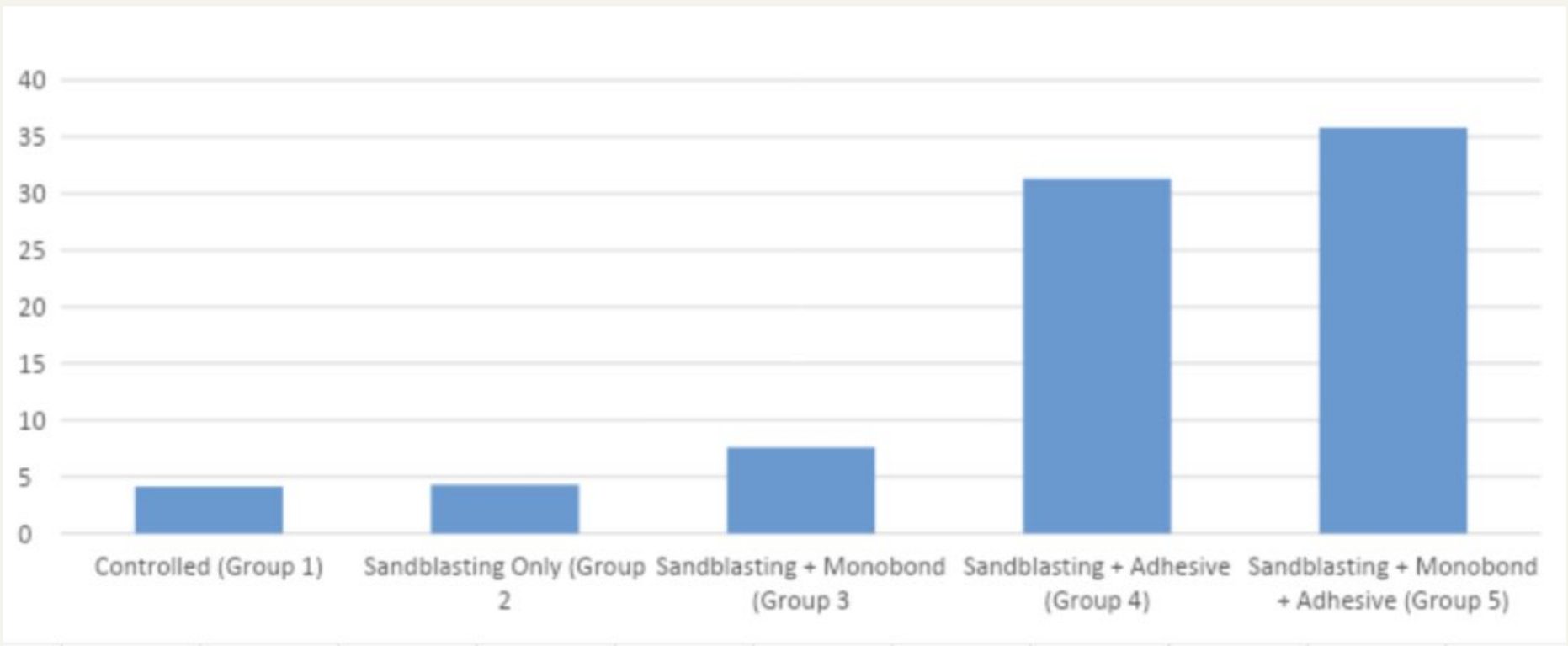
Many people are concerned about 3D printed material strength and also bond retention often thinking back to Lava Ultimate and the debonding of that nanoceramic material. Several differences exist between milled nanoceramic materials, direct resins, and 3D printed nanocaeramic materials. To begin with, direct resins suffer from poor mechanical properties and high wear rates. However they have amazing bond strength to enamel and dentin. One reason for the poor mechanical properties of direct resin is the lack of complete polymerization. Under the very best circumstances, in a laboratory out of the mouth, the degree of methacrylate conversion for a direct resin is only around 60%. This makes them have incredibly poor mechanical properties like wear but extremely good bond strengths because the free methacrylate can polymerize with the next layer or the adhesive layer.[13, 14]

Contrastingly, milled nano ceramics have a complete cure leaving no free methacrylate to polymerize with resin cement. This is because they are processed in high heat ovens using argon or nitrogen gas. These materials are very inert in the milled state which causes them the be difficult to bond to, which can lead to debonding of printed nanoceramics.

However printed materials are in the middle of these two categories regarding reactivity. The degree of cure off the printer is around 60%, however, after proper post processing in the appropriate curing unit the degree of cure will be 85-95% depending on the resin. Even with just 5% of the material not cured, this leaves millions of free methacrylate esters to copolymerize with the resin cement used during delivery of these restorations. Furthermore, with 3D printed the restorations have great retention due to better fit and great reactivity with resin cements. This means that restoration strength is increased due to the fantastic bonding ability of printed resins. [15-17]



Graphic showing a heat map of errors with milled compared to perfect relocation of the design with 3D printed.



The best way to bond any printed nanoceramic is through micro abrasion, followed by Silane primer then application of adhesive.

3D printed Crown fabricated on the Ackuretta SOL using Rodin Sculpture resin

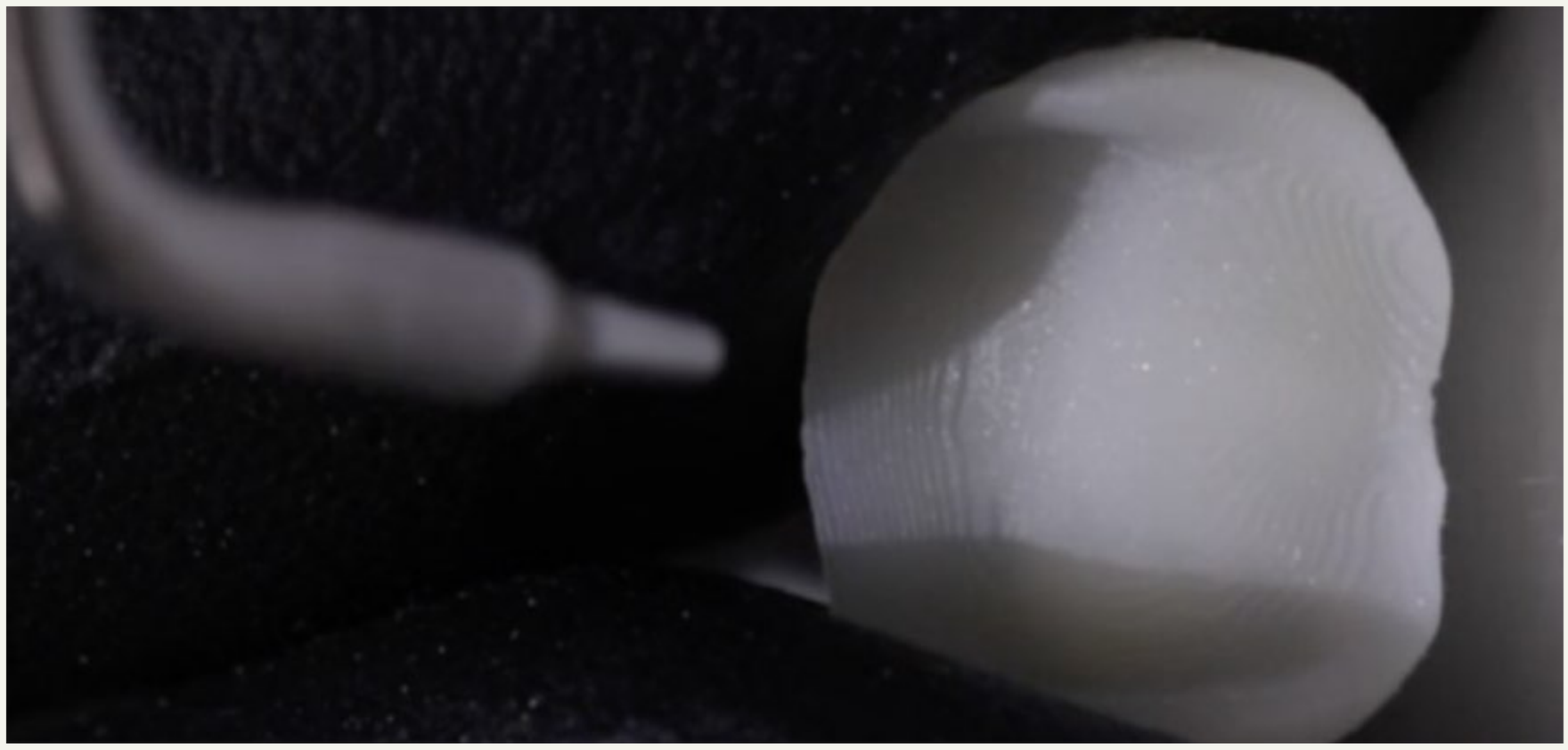
In addition to better fit, 3D printed restorations also follow the digital design more closely, Giannetti, et al showed that printed restorations have better anatomy and a more accurate representation of the occlusal surfaces compared to milled restorations. [18]

Bonding printed resin to natural tooth

WATCH VIDEO ON BONDING

Step 1

Microabrade the restoration using 30-50 micrometer aluminum oxide particles at 2 bar pressure. This adds roughness to the surface for a micromechanical bond.

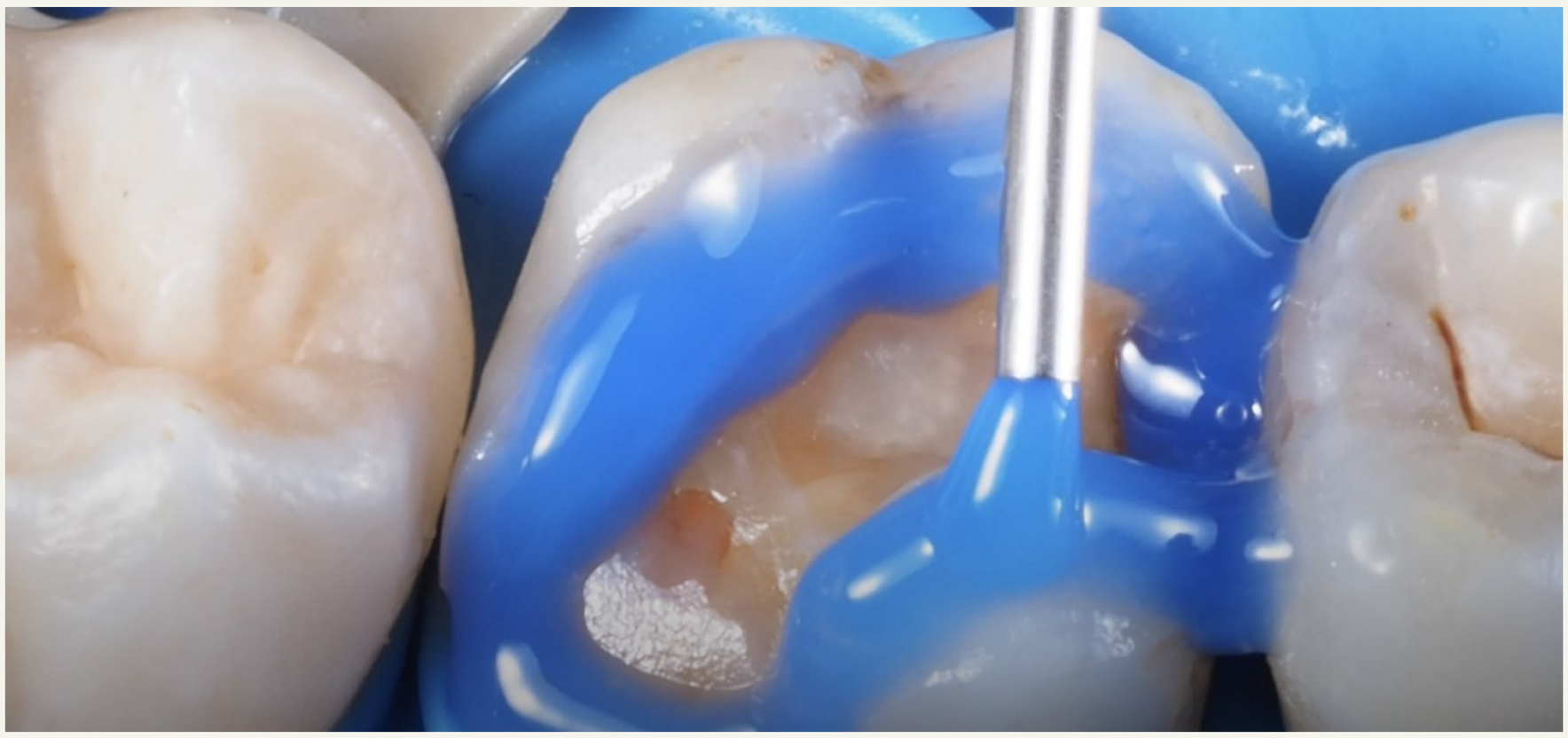


Step 2

Add an MDP-containing adhesive to the restoration and blow thin (do not cure). Place restoration in a dark area to avoid premature photo polymerization. I typically use Ivoclar Vivadent Adhese Universal as the MDP-containing adhesive to coat the printed restoration with. (Optional step is to apply silane before the adhesive)

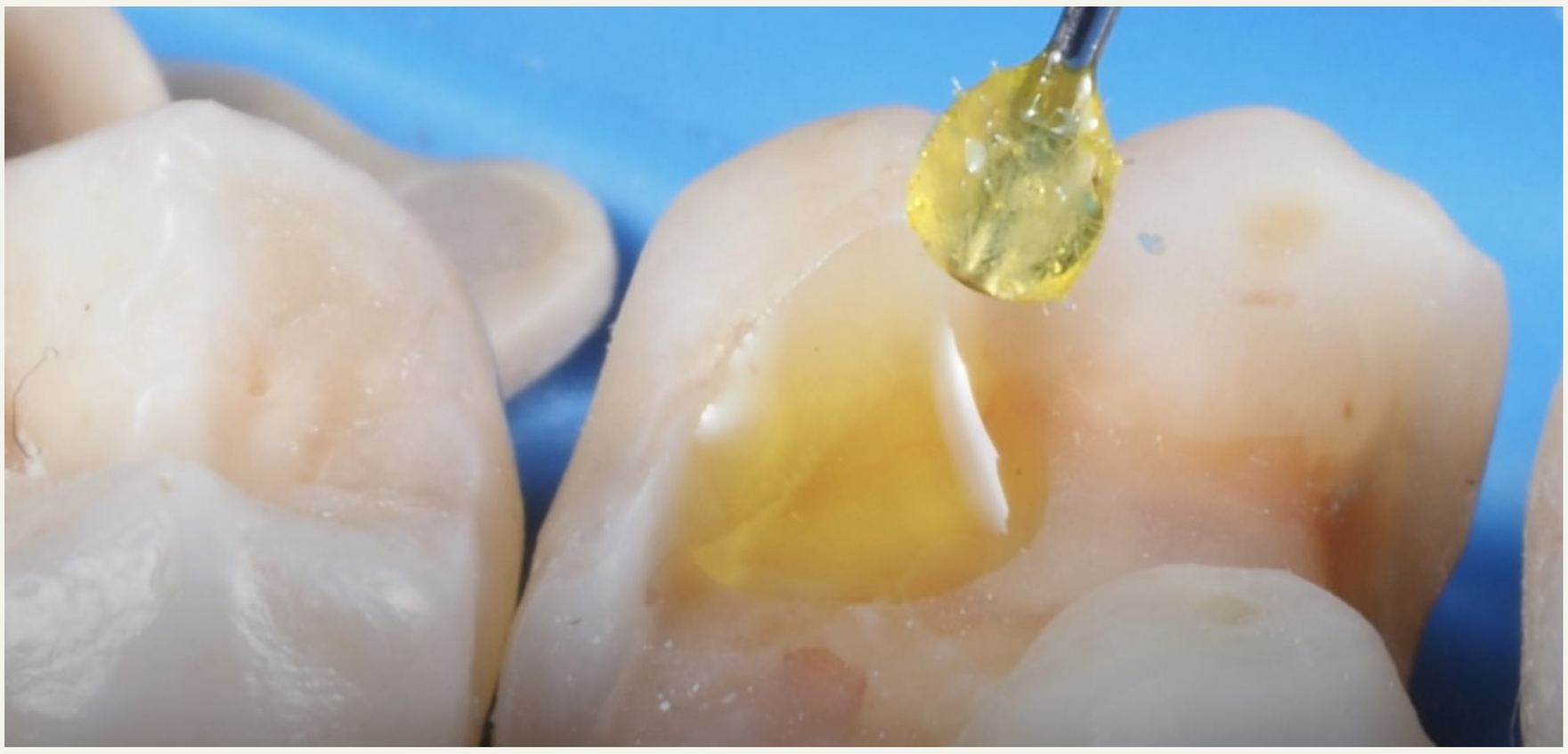
Step 3

Prepare the tooth with a selective etch technique.



Step 4

Place the adhesive system on the tooth (Ivoclar Vivadent Adhese Universal), air thin, and cure.

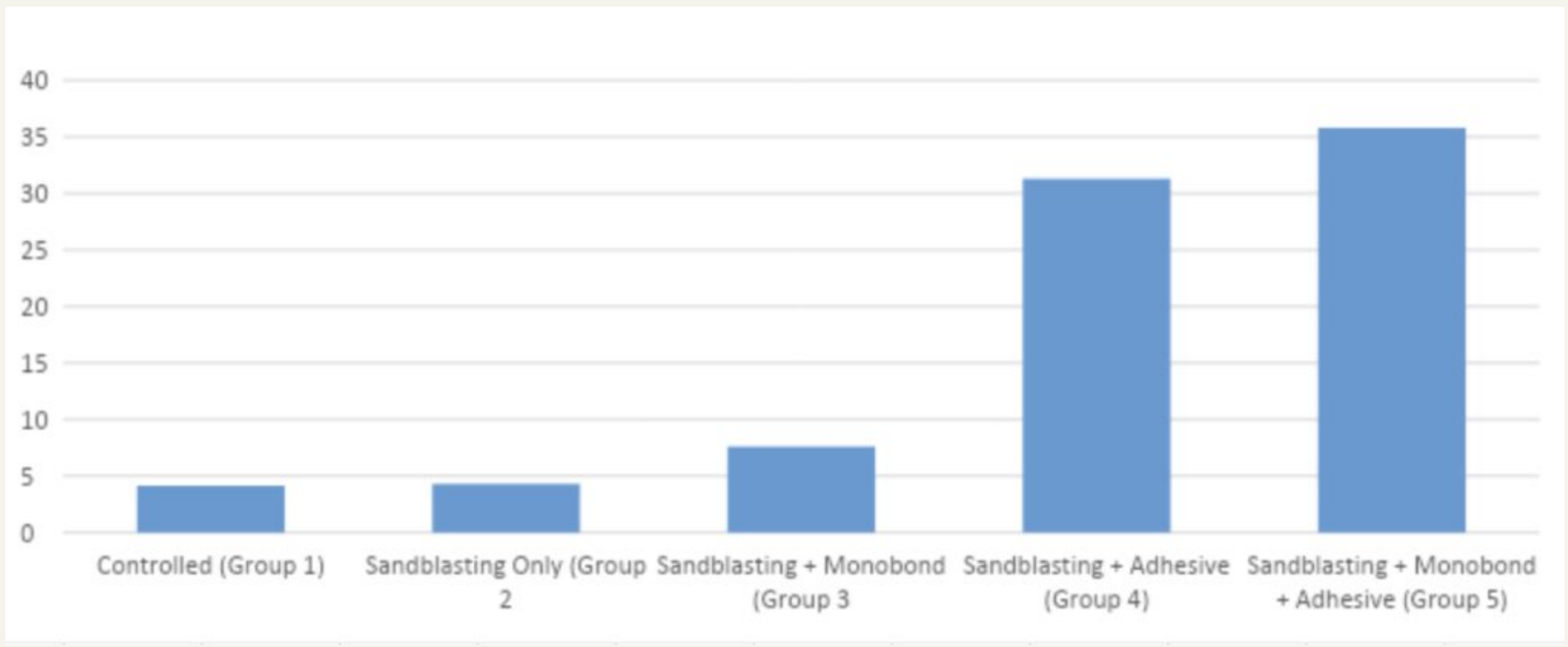


Step 5

Load the cement and seat the restoration and follow with meticulous cleanup. The choices for bonding are heated composite, light cure cement, or dual cure cement. I personally use dual cure in the posterior (Variolink Esthetic DC) and light cure only in the anterior (Variolink Esthetic LC).

Supporting Data

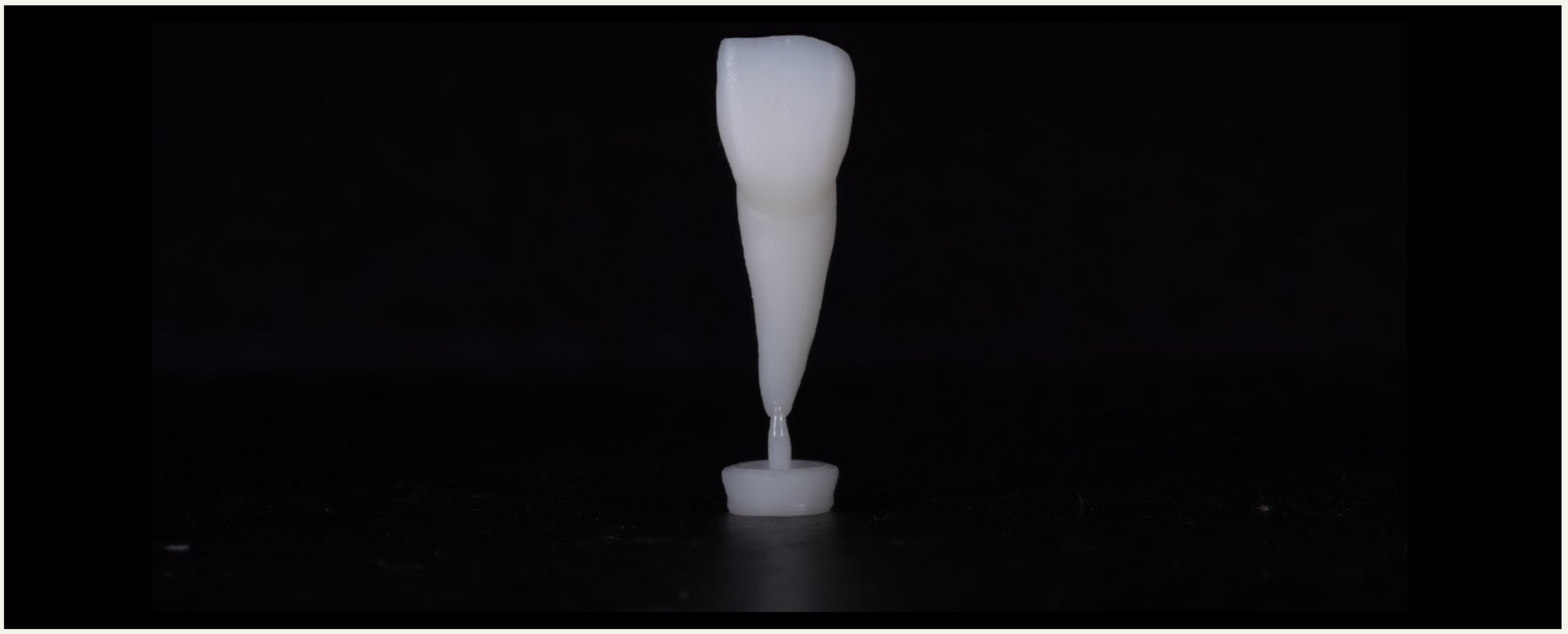
A recent independent University looked at bond strength of resin cement to printed crown material and this is what they found:



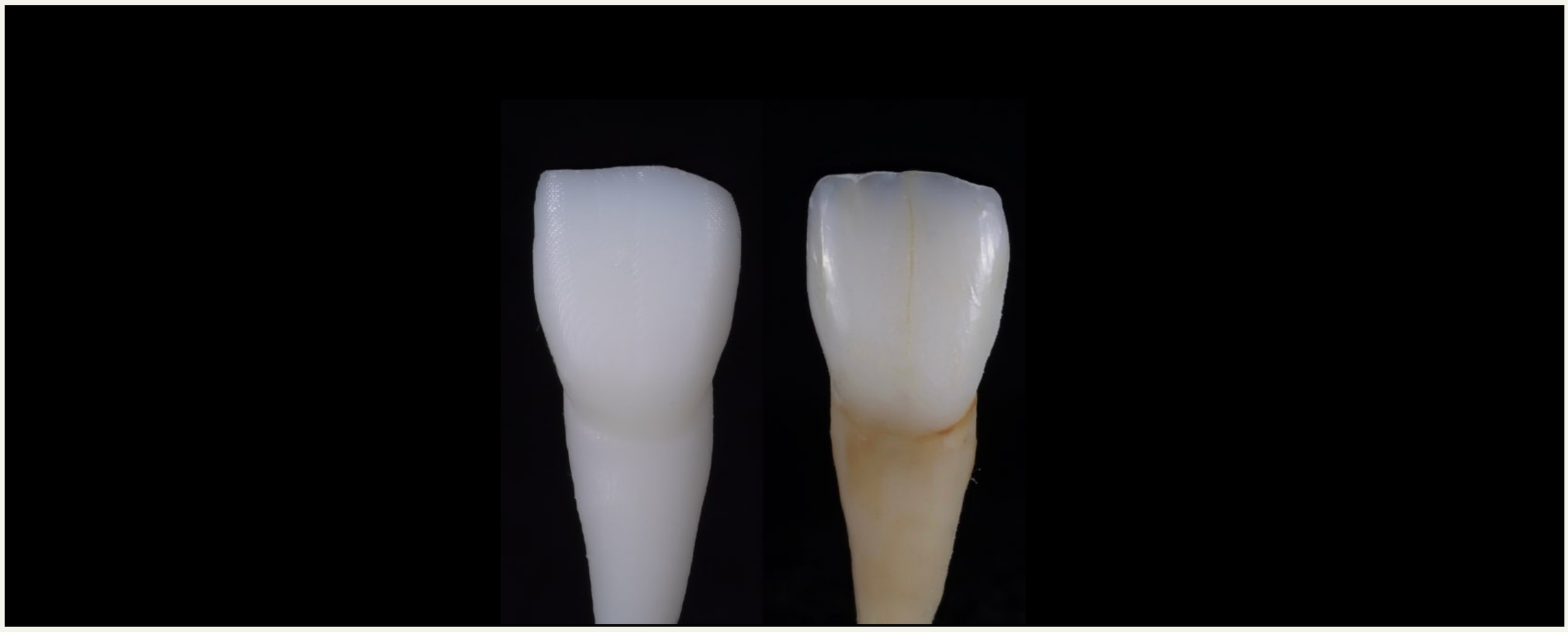
Sandblast plus adhesive had over 30MPa of shear bond strength while adding a MDP containing silane before adhesive placement leads to over 35 Mpa of shear bond strength. This protocol is also true for all other modern nanoceramic printed resin materials.

CHAPTER 6: INTRODUCTION TO FINAL RESTORATIONS

This tooth is printed in bleach color resin. Let's see what a little internal color can do to this. This is a fun exercise you can do to get better at characterization. For this case, I used a combination of internal and external characterization utilizing IPS Empress Direct Resin stains and print resin on top to protect everything. The restoration was sandblasted to ensure the resin stain photopolymer bonded to the print and also to ensure the surface was clean. As you can see, the material is naturally beautiful and with a little color can be indistinguishable from nature. I am excited about the aesthetics of new printed materials. That leads me to my next favorite application, Veneers. Resin veneers can be printed as thin as 150 microns thick.



This means no prep veneers and minimum prep veneers are possible. I like this workflow due to the more favorable economics of printing the veneer opens up many new opportunities for patients to get veneers. Some printers are extremely fast allowing for 10 units in under 15 minutes.



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CHAPTER 7

Direct Printed Mockups

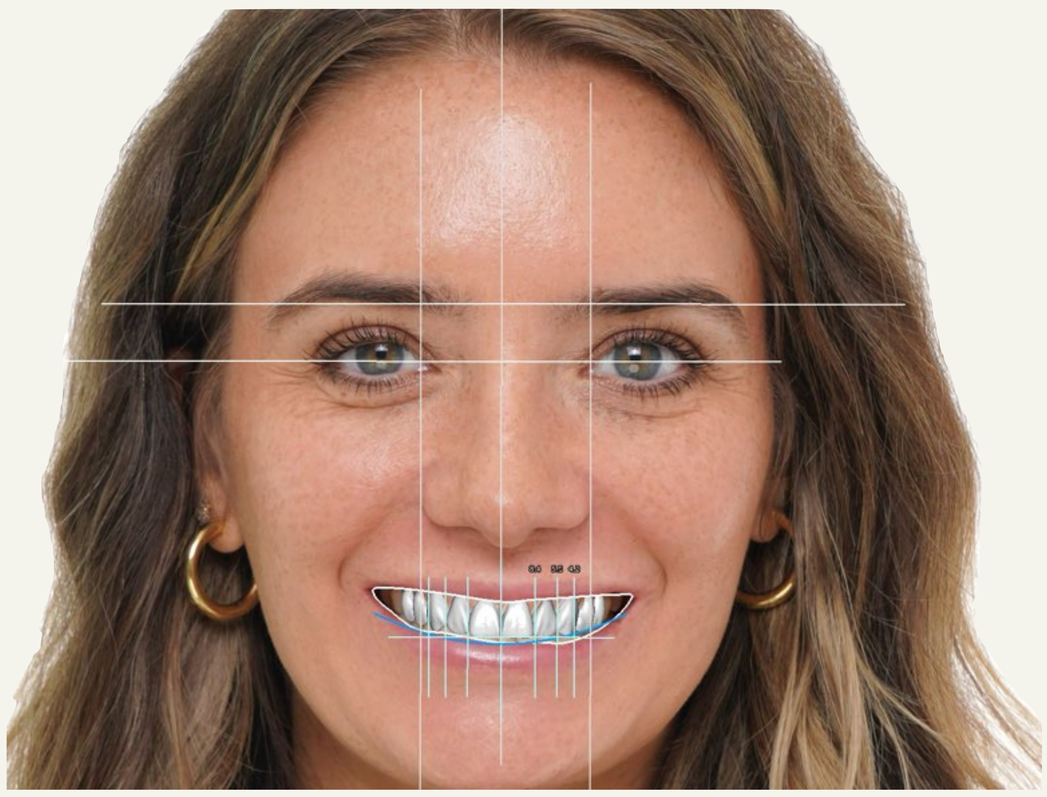
CHAPTER 7: DIRECT PRINTED MOCKUPS

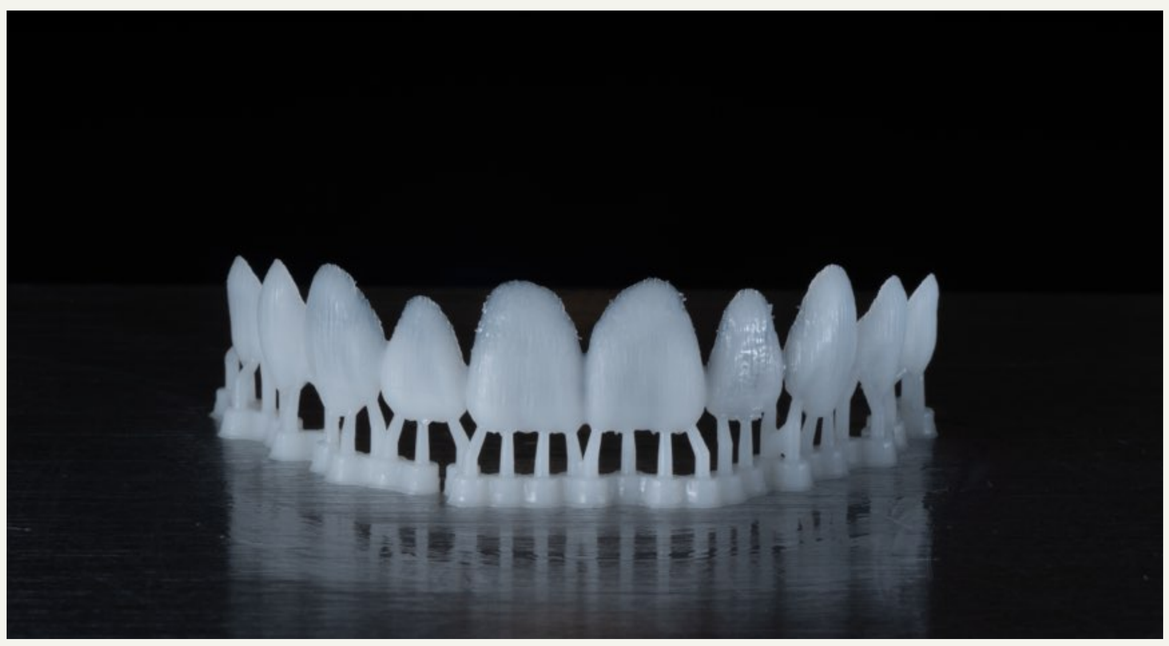
Nothing has been a bigger practice builder for me than learning how to design and print my own mockups in a short smile consultation appointment. It is probably the easiest thing to learn how to do and once mastered you can have a smile design completed in under 10 minutes if using exocad. This can then be printed rapidly and tried in, with most modern printers having a speed print option. SprintRay, for example, can print a mockup using ONX Tough in under 15 minutes.

My cosmetic case acceptance dramatically increased when execution of a same day mock-up became routine in my practice. Patients love the ability to not have to come back multiple times for a trial smile.

CHAPTER 7: DIRECT PRINTED MOCKUPS

This patient had a canted midline after 4 years in orthodontics and wanted to see what could be achieved with no prep veneers. The mockup is the first step in every case and will provide a wealth of information to both you and the patient.

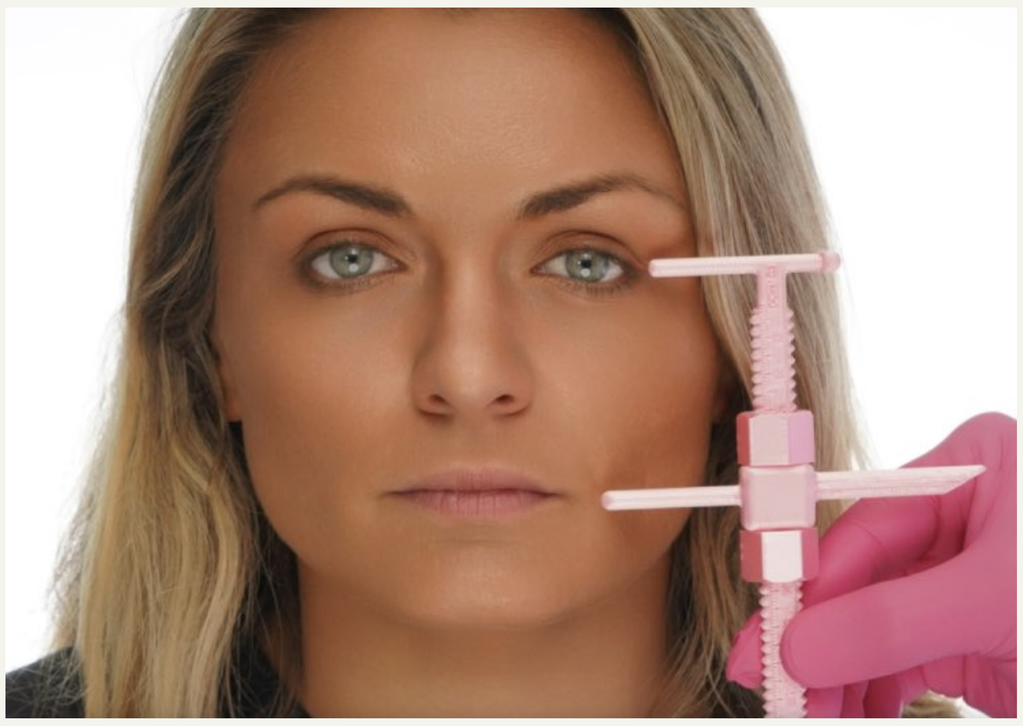


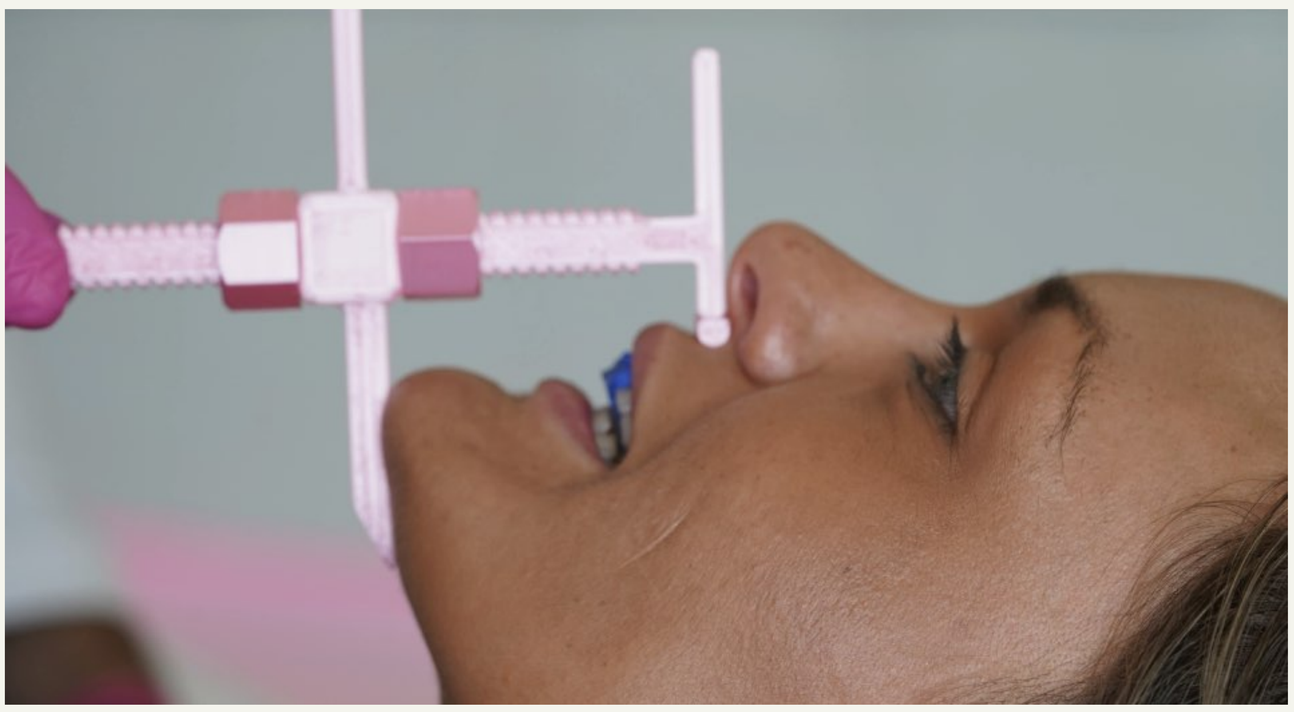


CHAPTER 7: DIRECT PRINTED MOCKUPS

In the past I would do a digital waxup, 3D print the model, and make a putty wash of the model to inject bis-acryl into. Now I make my trial smiles and provisional prosthetics by printing the actual mockup or provisional itself. This patient presented with a worn dentition and collapsed vertical. Her central incisors were only 7 mm long with multiple areas of wear into the dentin.

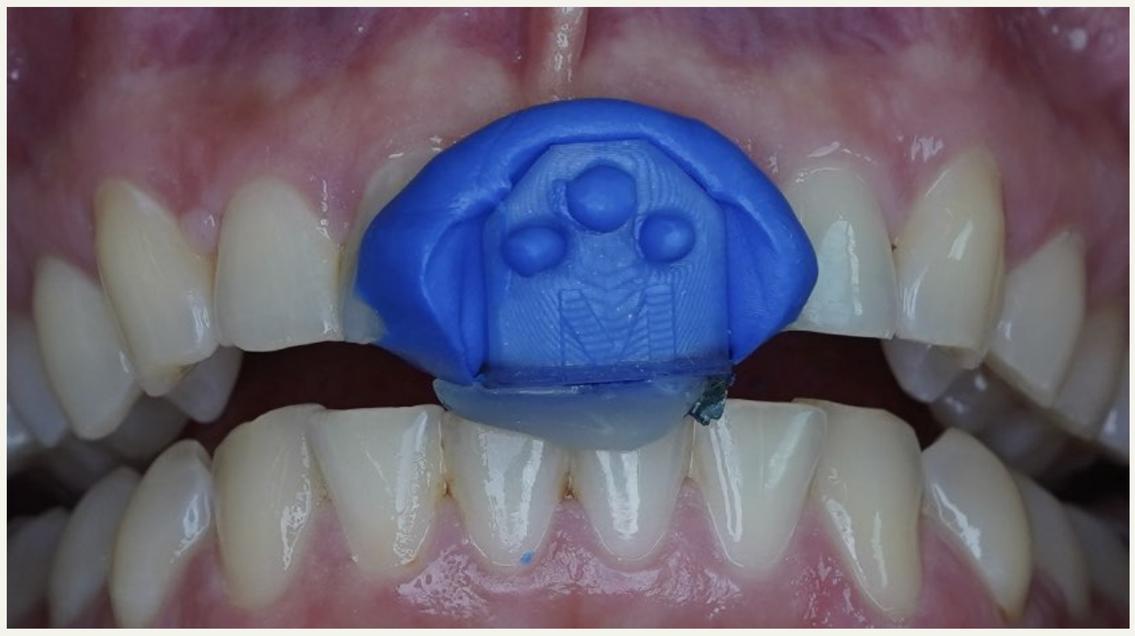
We used the MOD VDO gauge, which is free to download and print from our website, to provide a starting point for determining the desired vertical dimension. This measurement is then fine tuned considering freeway space, phonetics and esthetics.

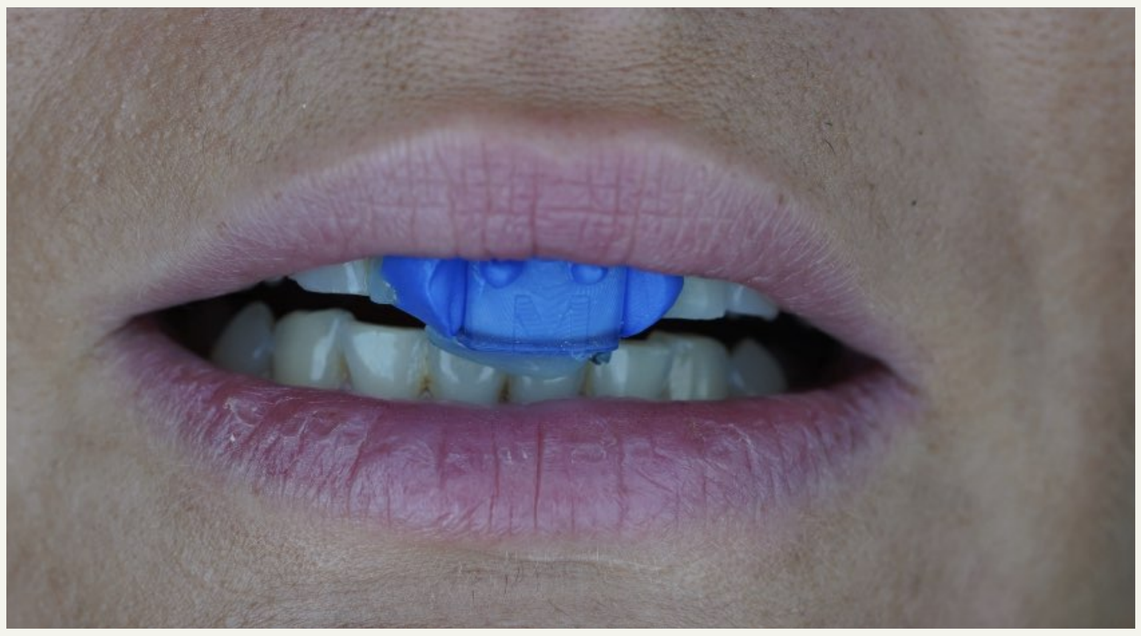


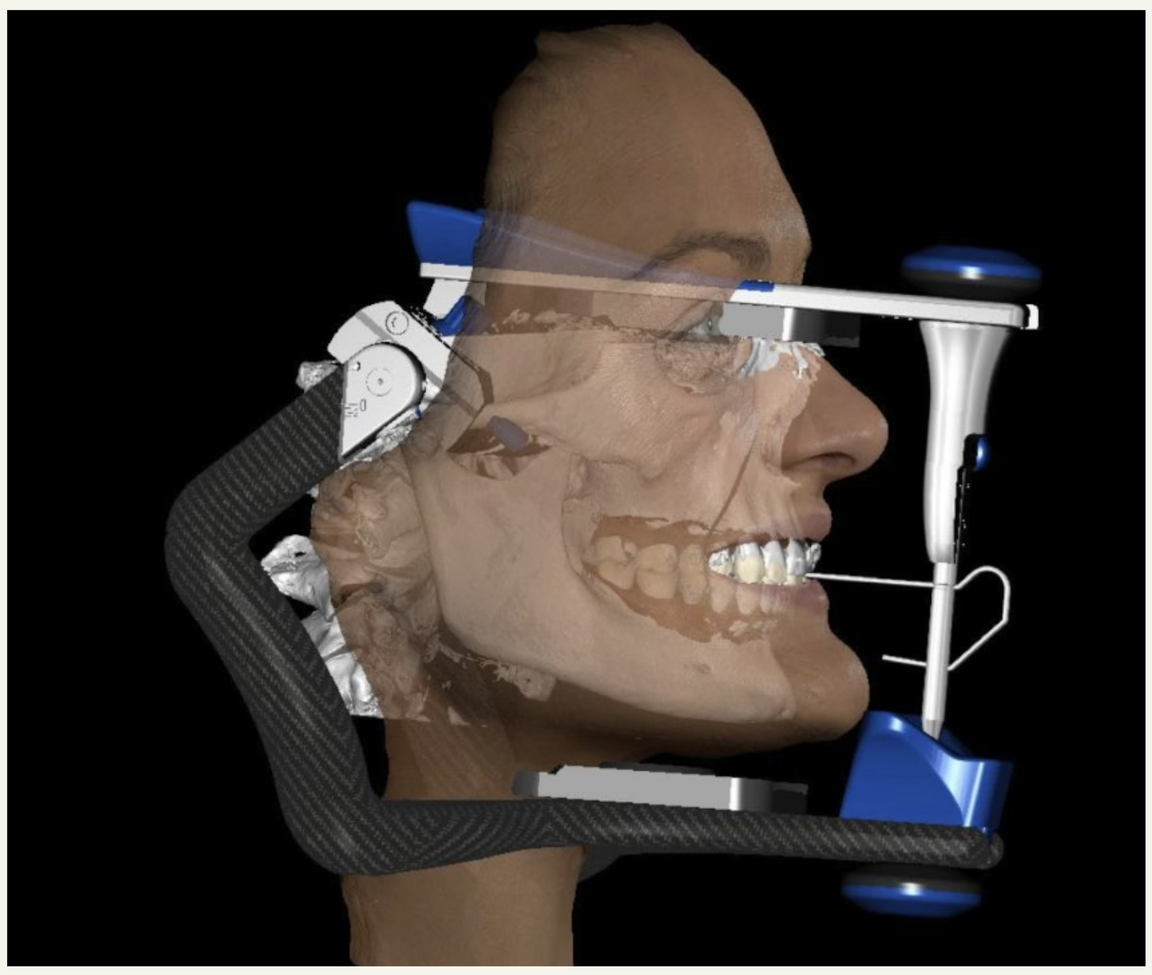


CHAPTER 7: DIRECT PRINTED MOCKUPS

A centric relation record is made at the new vertical using the MOD jig (also available free to download on The MOD Institute website). This jig is left in place when scanning the digital bite record and also for the CBCT capture.



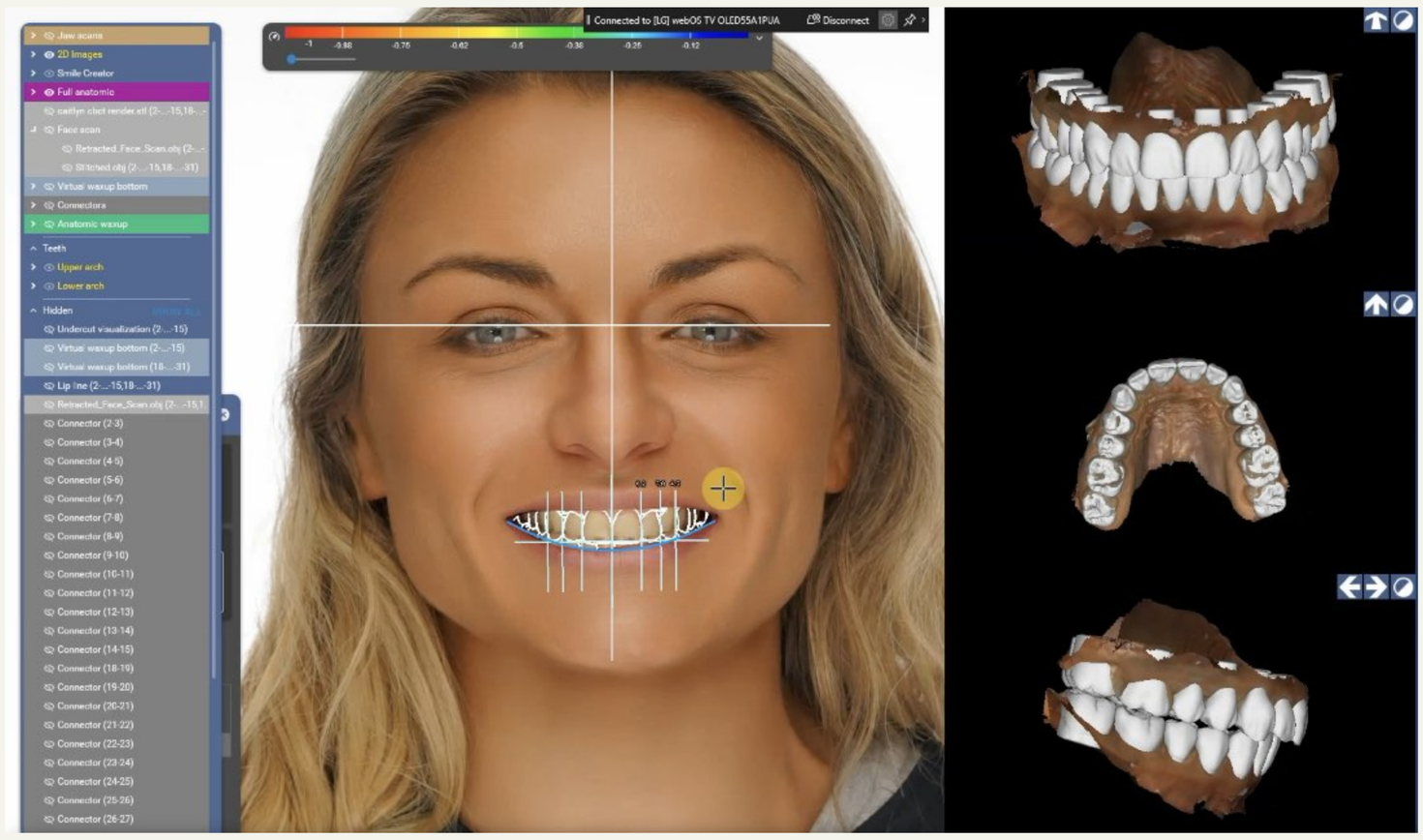




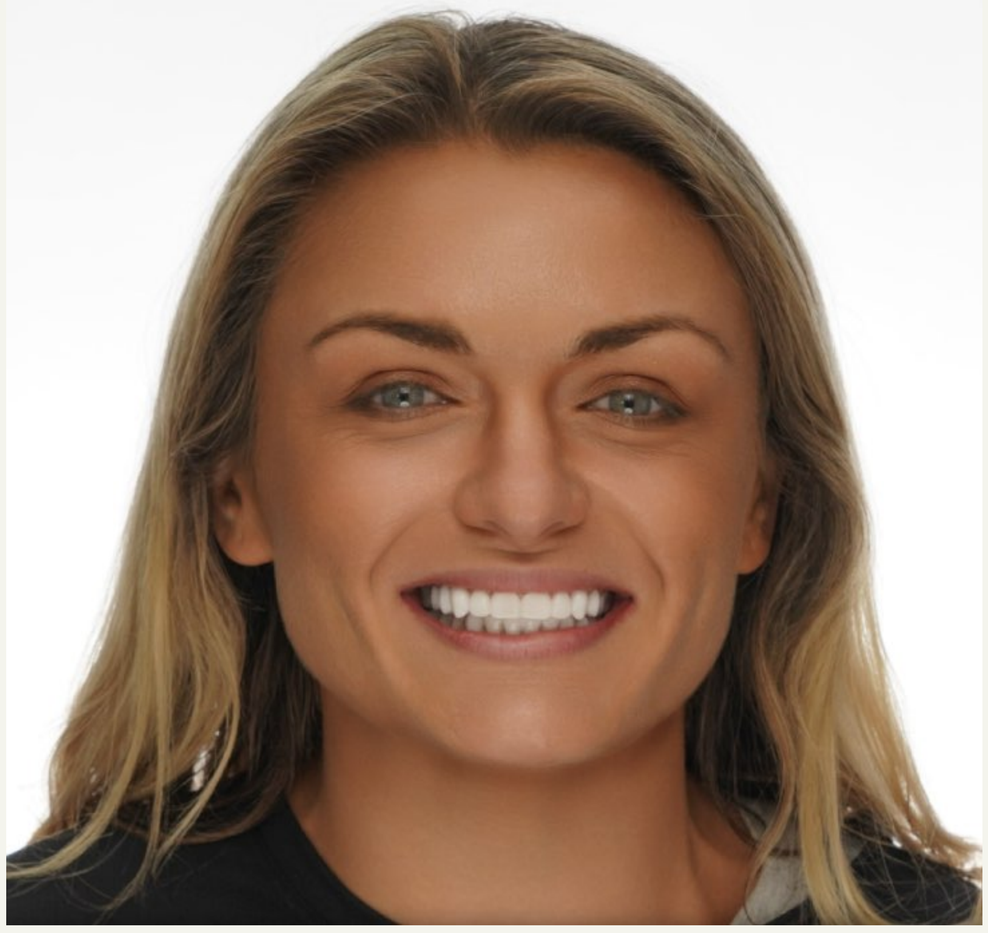
Using the CR bite while capturing the CBCT and the intra-oral scan, we are able to export this information to the virtual articulator for proper mounting. We can also measure condylar inclination on the CBCT and enter that into the virtual articulator.

CHAPTER 7: DIRECT PRINTED MOCKUPS

Leveraging exocad, the case was digitally waxed at the new vertical in centric relation utilizing the smile design module. We are able to do all this the same day as the initial consultation and then 3D print additive shells to bond onto the teeth. Adding in house design that is both efficient and high quality has been the single best investment in my team. The patient leaves same day as the consult with the bonded additive printed shells and can try the new bite and esthetics for a few weeks before committing to the final restorations. The entire appointment including records, design, printing and delivery is 3 hours.



Here we can see the 3D printed shells that printed in 15 minutes. Although hard to see in this image, the printed shells do cover the linguals and occlusal. The patient was able to leave the office to trial out her new smile with these bonded mock-ups.



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BY DR. WALLY RENNE, DR. AUGUST DE OLIVEIRA & DR. MIKE DEFEE

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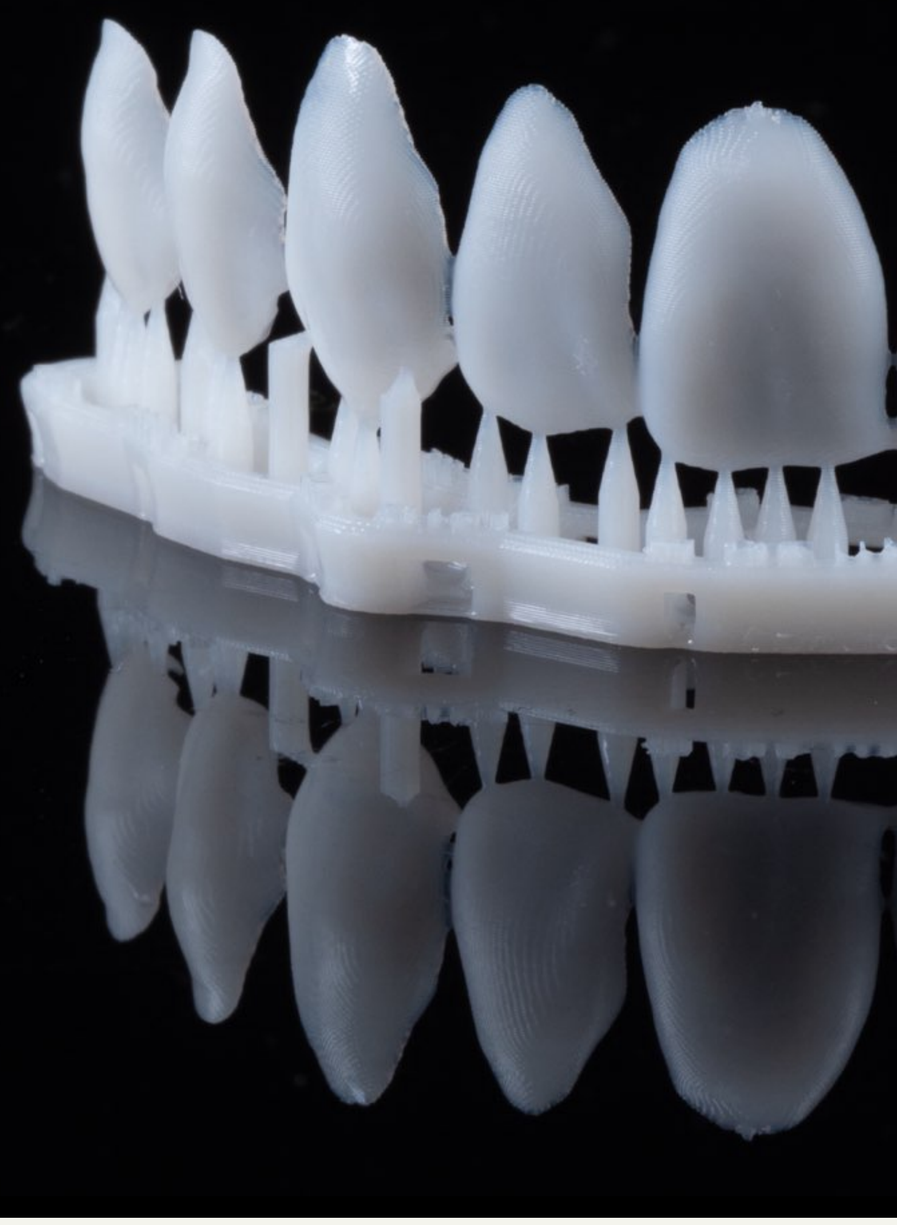

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CHAPTER 8

3D Printed Veneers

Veneers this thin are something milling simply cannot accomplish. I offer these restorations at a price point between a direct resin and a ceramic veneer. For most practices, that price point will be $500-700 a unit. Ceramic veneers are still offered, but the option of 3D printed now gives me a more affordable option to present to my patients. In order to make these high quality restorations, it is important to discuss proper polishing and bonding protocols.

One of the most critical aspects of a veneer is color stability and bonding of which we don’t currently have long term data to compare printed veneers to ceramics. However, we can be certain that 3D printed veneers are better than most direct resins and on par with the very best milled resins. My favorite way to polish 3D printed veneers is to use Komet Acrylic Polishers intended for dentures.

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WATCH A VIDEO ON BONDING 3D PRINTED VENEERS

CHAPTER 8: 3D PRINTED VENEERS

One extremely easy way to create a lasting high shine pre polishing is to paint a thin coat of liquid print resin on the veneer and cure it with a handheld light followed by a second cure in the manufacturers curing unit under glycerin or nitrogen. You can also do this following the candy coating technique. Here we have 10 units of Rodin Sculpture veneers printed 200 microns thick on the Ackuretta SOL printer. These veneers are no prep, meaning they are reversible and ultra conservative. 3D printed materials are the best material for this indication as they can be printed extremely thin without becoming brittle.

CHAPTER 8: 3D PRINTED VENEERS

Here we can see the results a few months later with 3D printed no prep veneers. Proper finishing and polishing is essential for clinical success; however, a lot of people do not know how to properly finish the 3D prints for durability. The soft tissue health around the no prep veneers is remarkable and the lack of plaque accumulation can be attributed to a properly post processed veneer.

One Year Later

WATCH A VIDEO ON HOW TO POLISH VENEERS

At 1 year we can see a pretty amazing result. These look better compared to direct resin, but not quite as good as well done porcelain veneers.

I invite you to take a course with me in 2024 and learn about 3D printed veneers and trial smiles.

This is a level 2 course in our 3D printing track — my favorite course to teach.

DR. WALLY RENNE

LEVEL 2

3D Printed Smile Design & Veneers

Rapidly convert aesthetic designs to reality by harnessing 3D printing technology.

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Case 2

This is another no prep veneers case that is also 200 microns thick. These veneers were delivered on a fellow dentist who was seeking conservative cosmetic treatment. These veneers were candy coated, polished to a high shine, and delivered using the bonding protocols discussed in this book for a long lasting result. The design, printing, polishing and delivery is something we focus on in our 3D printed veneer course at The MOD Institute.

Not a perfect result but no enamel was destroyed in the making of this smile. I was able to design these veneers myself using exocad and 3D print these in office just 200 microns thick out of a highly filled ceramic print resin. The 8 veneers took 10 minutes or so to design and 12 minutes to print. Considering washing, curing, and polishing the total time to manufacture these veneers was less than 1 hour.

Case 2

This photo was taken immediately after delivery. We have developed efficient delivery techniques at MOD that made the entire delivery under 20 minutes for these 8 units. The efficiency of 3D printed veneers is incredible.

Case 2

WATCH A VIDEO ON THIS CASE STUDY

CHAPTER 9

Inlays, Onlays & Crowns

Onlays and Crownlays

This printed restoration was first hand polished and then characterized using Empress Direct Resin stains. Nobody knows how long these resin stains will last, and debates exist on the benefit of stains compared to just hand polishing as some resin glazes collect plaque and discolor over time. Therefore, a good hand polish may be the best long term result for most restorations. One way to protect the stains is to cover with native print resin rather than with a clear glaze as the native resin provides more durable exterior surface than an applied glaze.

WATCH A VIDEO ON TOOTH PREP DESIGN

Case Example: Crownlay

This is my tooth, a 10-year-old SonicFill resin, which is about 6mm deep and in close proximity to the pulp. As you can see, the marginal integrity is failing and the restoration is in need of replacement. For this case, we decided to go with an ultra thin printed restoration.

The treating clinician removed the failing SonicFill to find no decay under the restoration, the dark color is old amalgam stain. A resin buildup was bonded in the tooth using a selective etch technique. A printed inlay would have been an acceptable option here as well .

After the buildup, a Crownlay prep was completed with just 0.5 mm of reduction. The treating clinician wanted to do more, but I would not let him. I designed the crown in Exocad and exported the STL to the printer.

The restoration printed in 15 minutes and we tried it in after the appropriate cleaning and curing procedures were followed including a 5 minute wash in 99% alcohol, and 3000 flashes in the ottoflash on both sides of the restoration.

The restoration was bonded using the bonding protocol described for veneers. Here we see the final bonded restoration with a beautiful marginal fit. Even though, I am a clincher and grinder, as you can see on my premolar, I am not concerned about the 0.5 mm thick bonded 3D printed crown on my tooth.

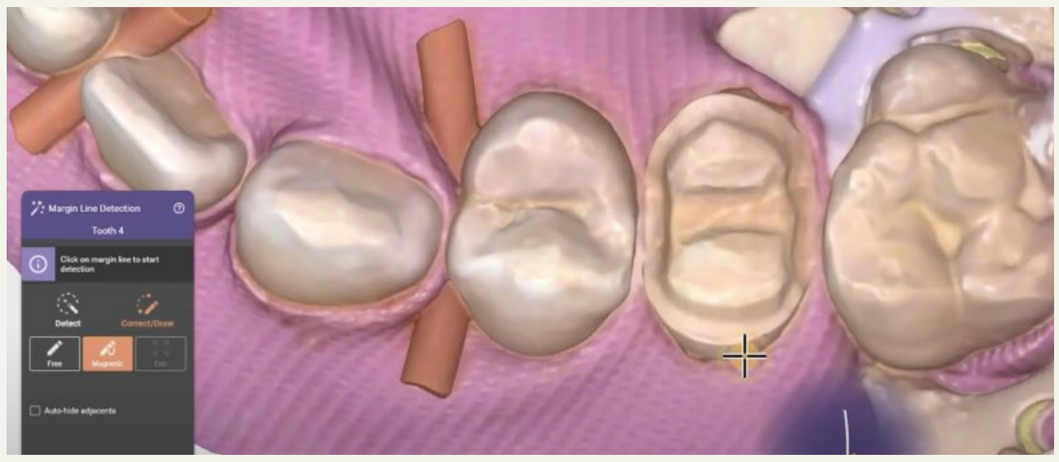
Please keep in mind the recommended minimum material thickness is 1.5 mm, but I am willing to go thinner on my tooth because I would rather my crown break than my tooth fail or break. I also tend to prep conservatively for my patients with this same philosophy.

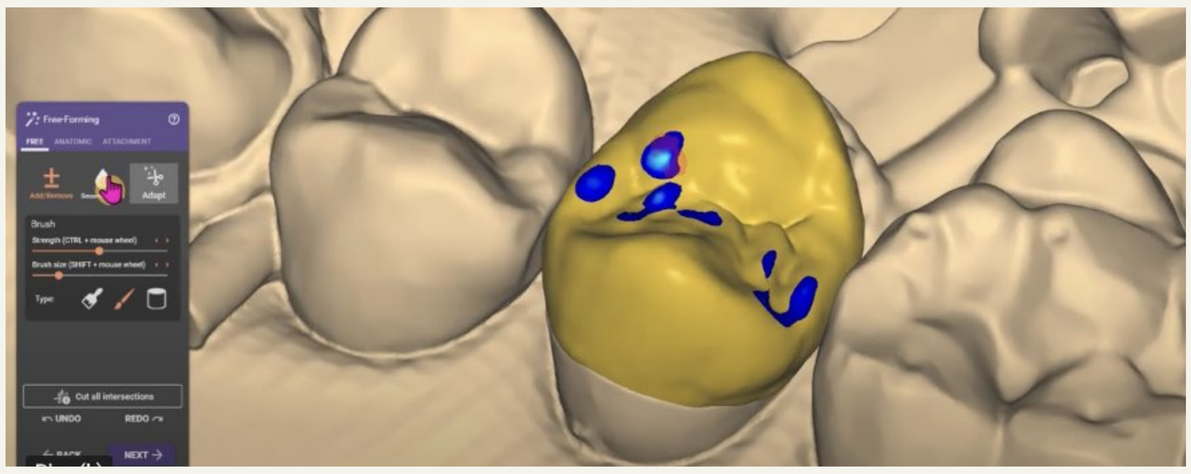
Case Example: Cracked Tooth

This patient had an unrestored tooth with a split down the middle mesial to distal. Pain was intense upon release of pressure so I decided to prep a conservative overlay.

WATCH A VIDEO ON THIS CASE STUDY

Here my assistant is scanning my preps into the system and getting them ready for design in exocad. She will then design and print the crown and prepare it for bonding.

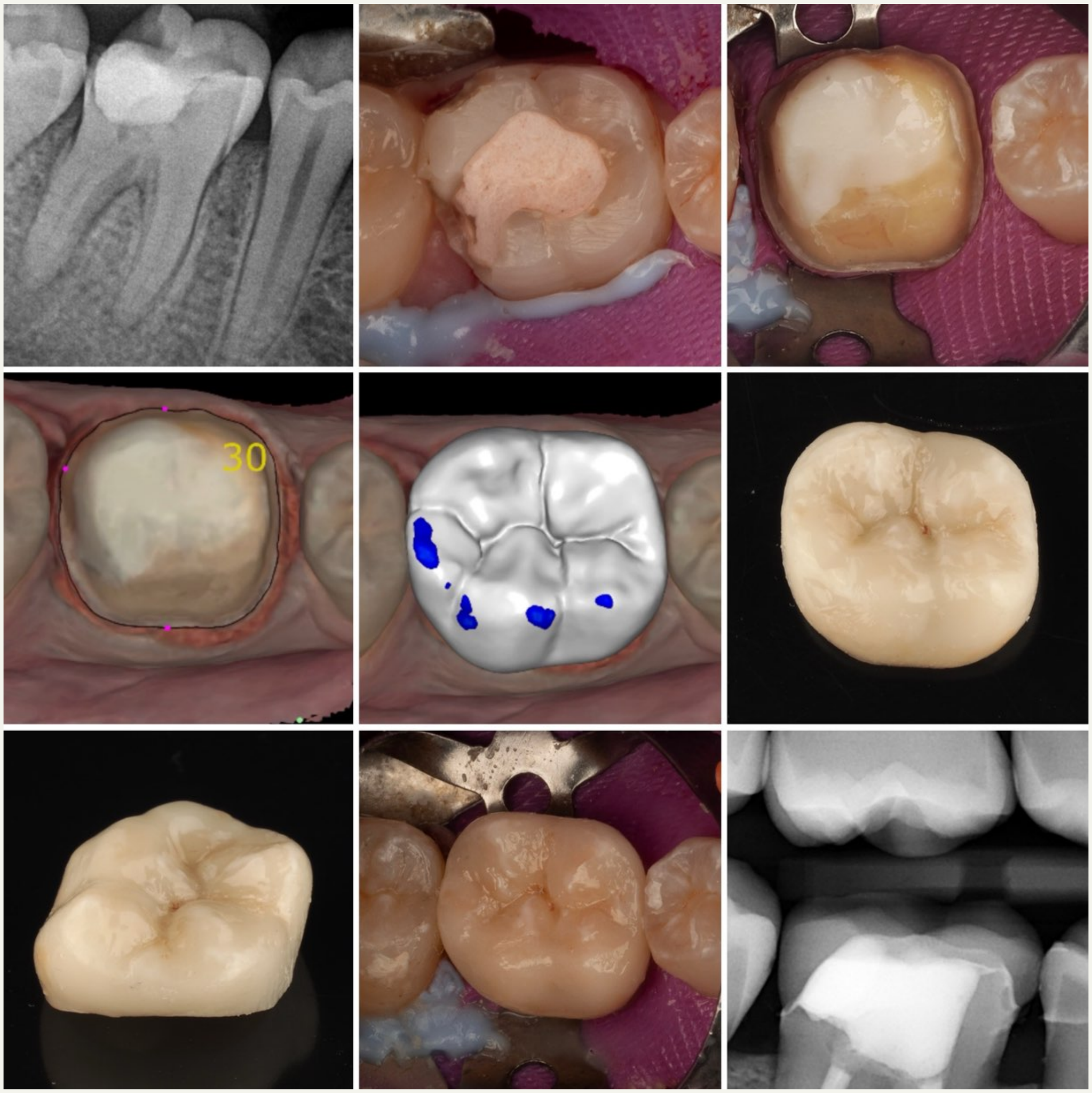




Case Example: Crown

WATCH A VIDEO ON THIS CASE STUDY

This patient is 17 years old and has endodontic treatment on tooth 30. The perfect restorative option for this patient is a 3D printed crown. Almost the entire process can be delegated to well trained team members such as scanning, design, printing and characterization. This crown took under 5 minutes to design, 12 minutes to print, 1 minute to wash, and 10 minutes to characterize and cure.

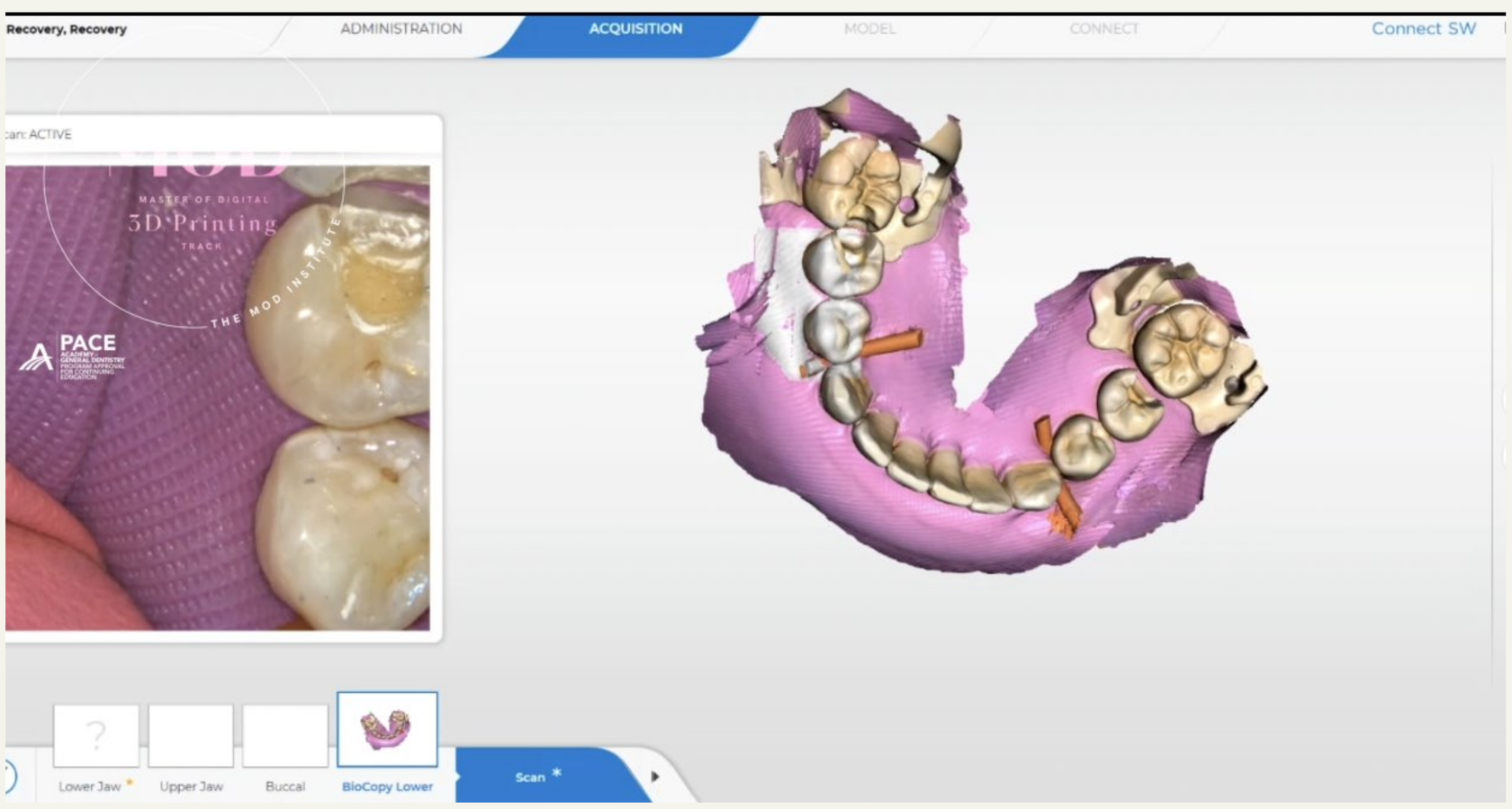


Case Example: Inlays

WATCH A VIDEO ON THIS CASE STUDY

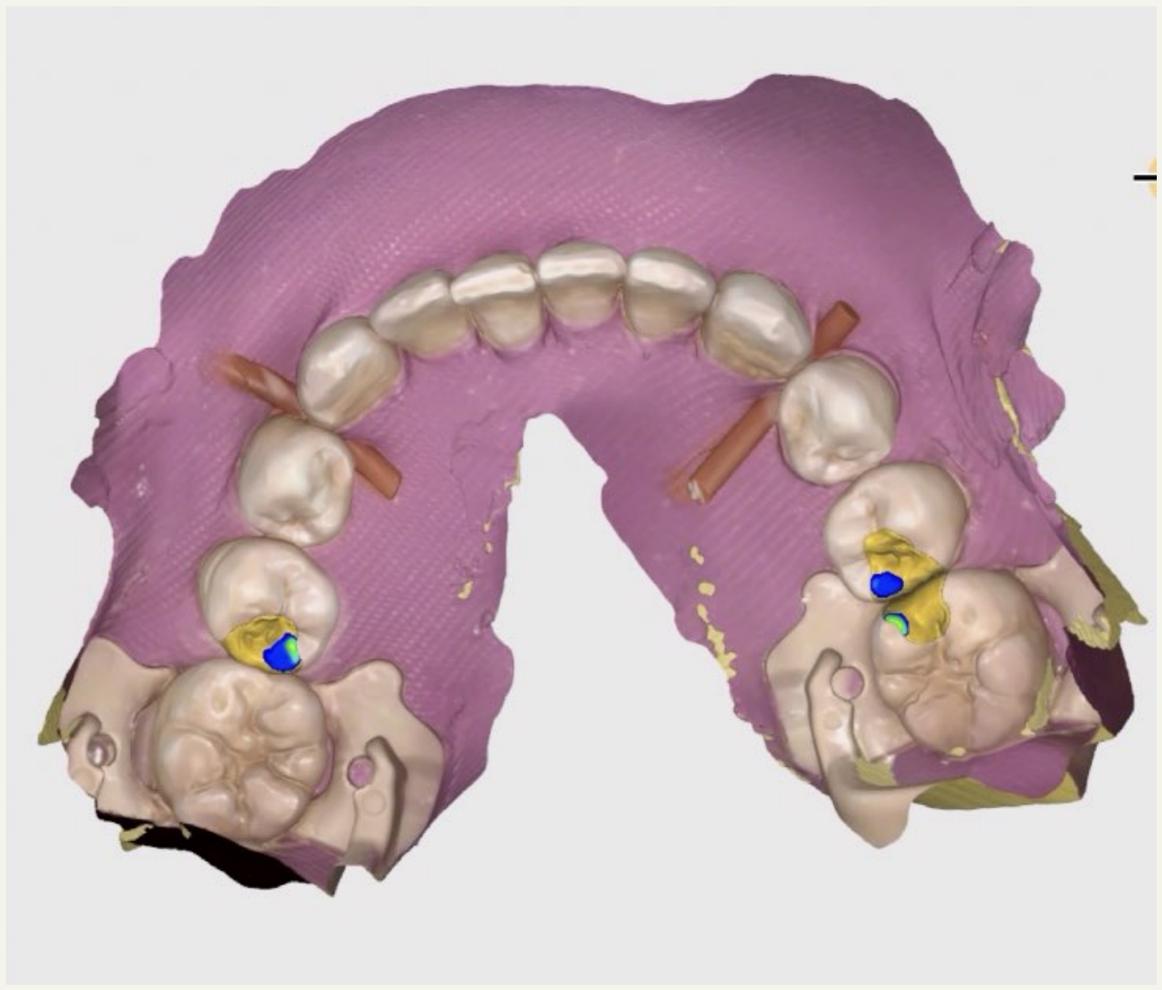
One of my least favorite things to do is Class II fillings. I find 3D printed inlays to be both much more enjoyable and efficient because most of this workflow can be delegated to talented team members such as the scanning, design, printing and finishing.

Here my assistant is scanning my preps into the system and getting them ready for design in exocad.



Case Example: Inlays

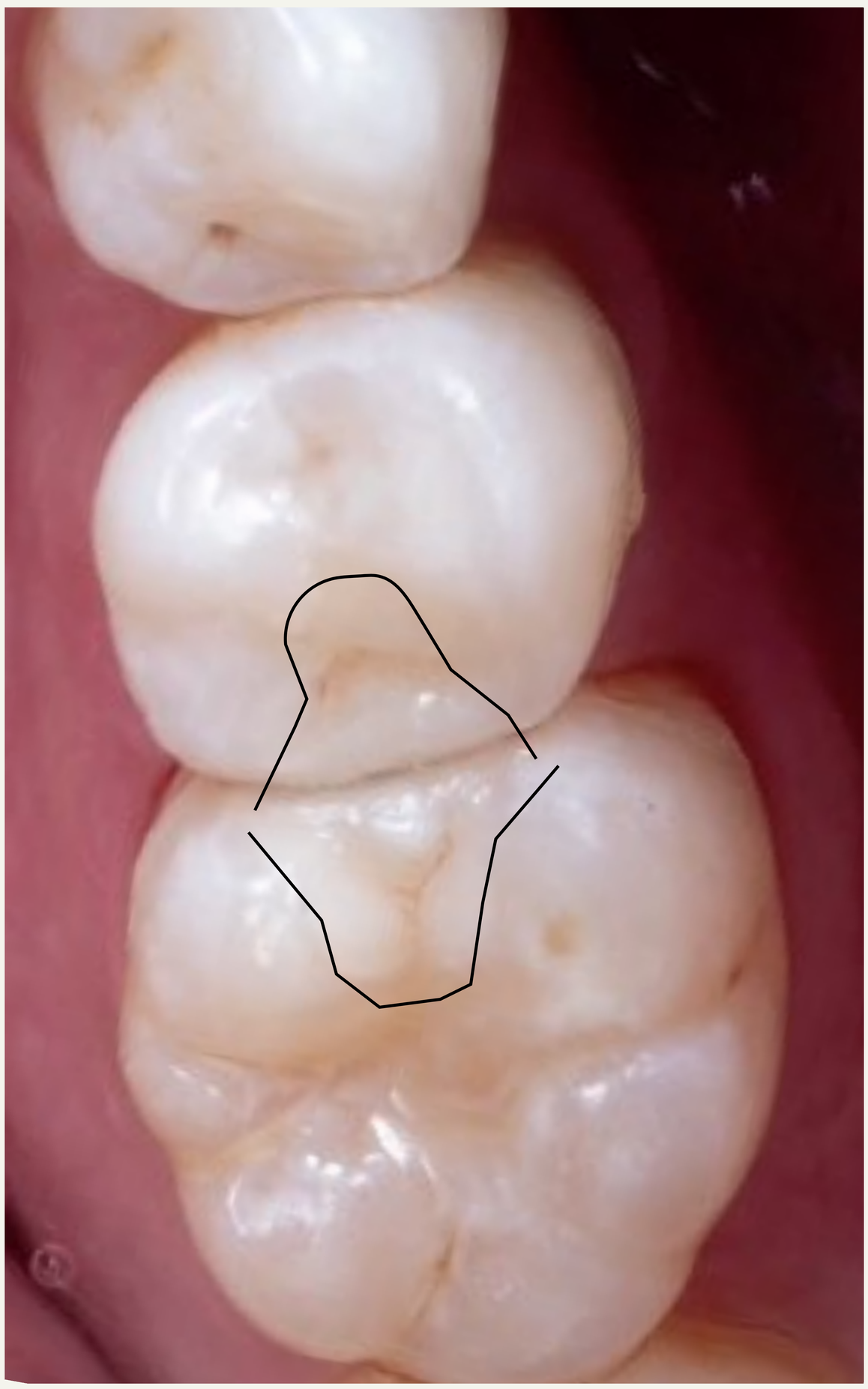
After she scans, she designed the restorations using exocad with the entire design being under 10 minutes.



She then printed and processed the restorations getting them ready for bonding. These restorations were printed on SprintRay using the Crown Kit in about 10 minutes. Including the delivery of the restorations, my total chair time is under 30 minutes for appointments similar to this. Additionally, I feel more confident about the results and the proximal contacts and contours are always better compared to my direct resin restorations.

Case Example: Inlays

Notice how the restorations blend in perfectly with the natural tooth. 3D printed resin esthetics are improving and translucency is increasing to allow for better chameleon like effects during delivery.



Case Example: Inlays

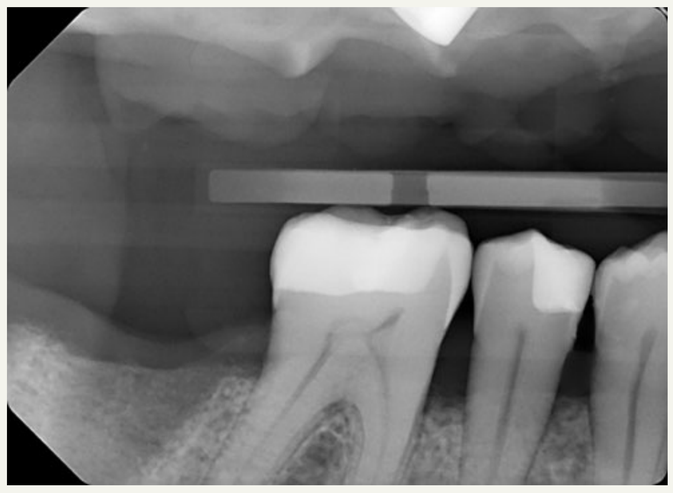
3D printed inlay and onlay restorations have several distinct advantages over direct resin. As discussed earlier, the wear resistance of printed resin is better compared to direct resin. This fact along with the increased mechanical properties, minimum polymerization shrinkage stress and the ability to have contours perfectly crafted make 3D printed partial coverage restorations more ideal when compared to direct resin.

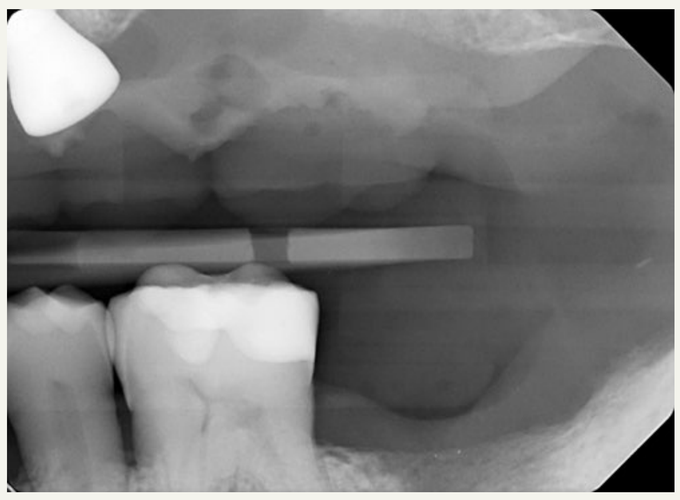
Here we can see the preoperative condition with failing direct restorations. Certainly indirect ceramic could be used here but one advantage of printing over milled ceramic is better adaptation to complicated preparation outlines and efficiency. All 3 restorations can be manufactured in under 15 minutes.

Here we can see the intra-oral scan of the preparation. In this case, we also designed buccal pit indirect restorations mostly to test the ability of the printer to fit such a small preparation.

The tiny buccal pit restorations printed perfectly even at 100 micron layer height. Here we used Pacdent Rodin Sculpture on the Ackuretta SOL.

Final restorations were bonded in place using the method described earlier in the bonding section. Here we can see the nice color match and the ideal radiopacity and fit on the radiograph. In this case, even the buccal pit was printed to test the limitations of the 3D printer.

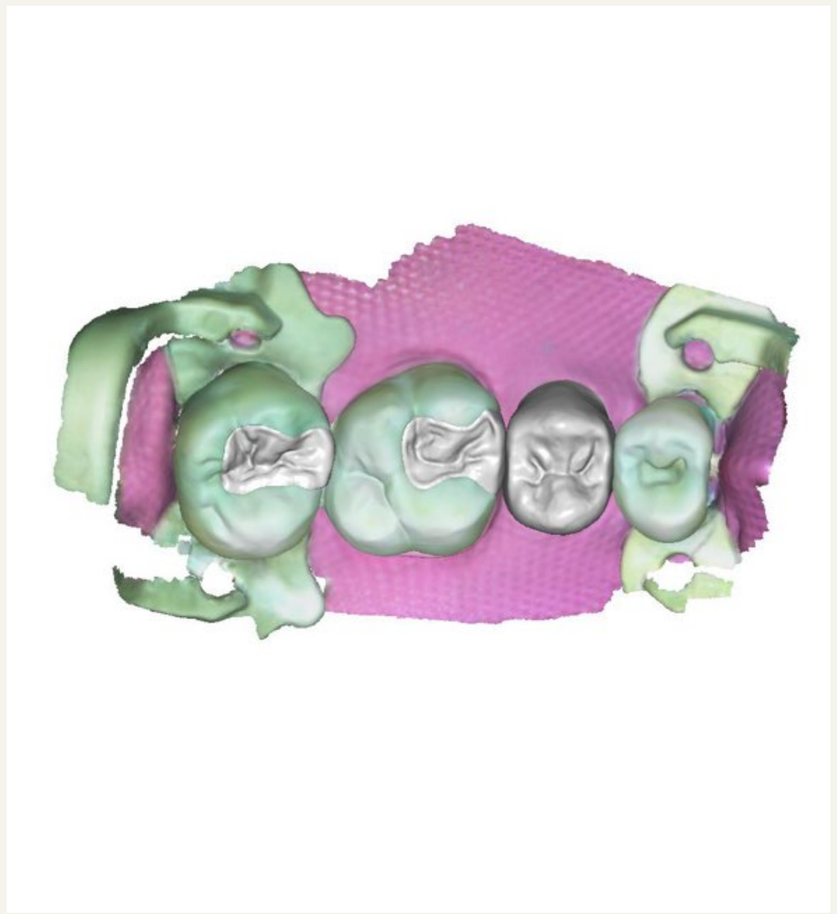




Case Example: Quadrant

3D printing really begins to make financial sense when you start to think about restoring quadrants same day. This is because a 3D printer takes the same amount of time to make a quadrant of restorations as it does to make one.

Here we can see the preoperative condition with failing direct restorations. It was decided to do full coverage on the premolar due to the extreme destruction after removing the direct resin.



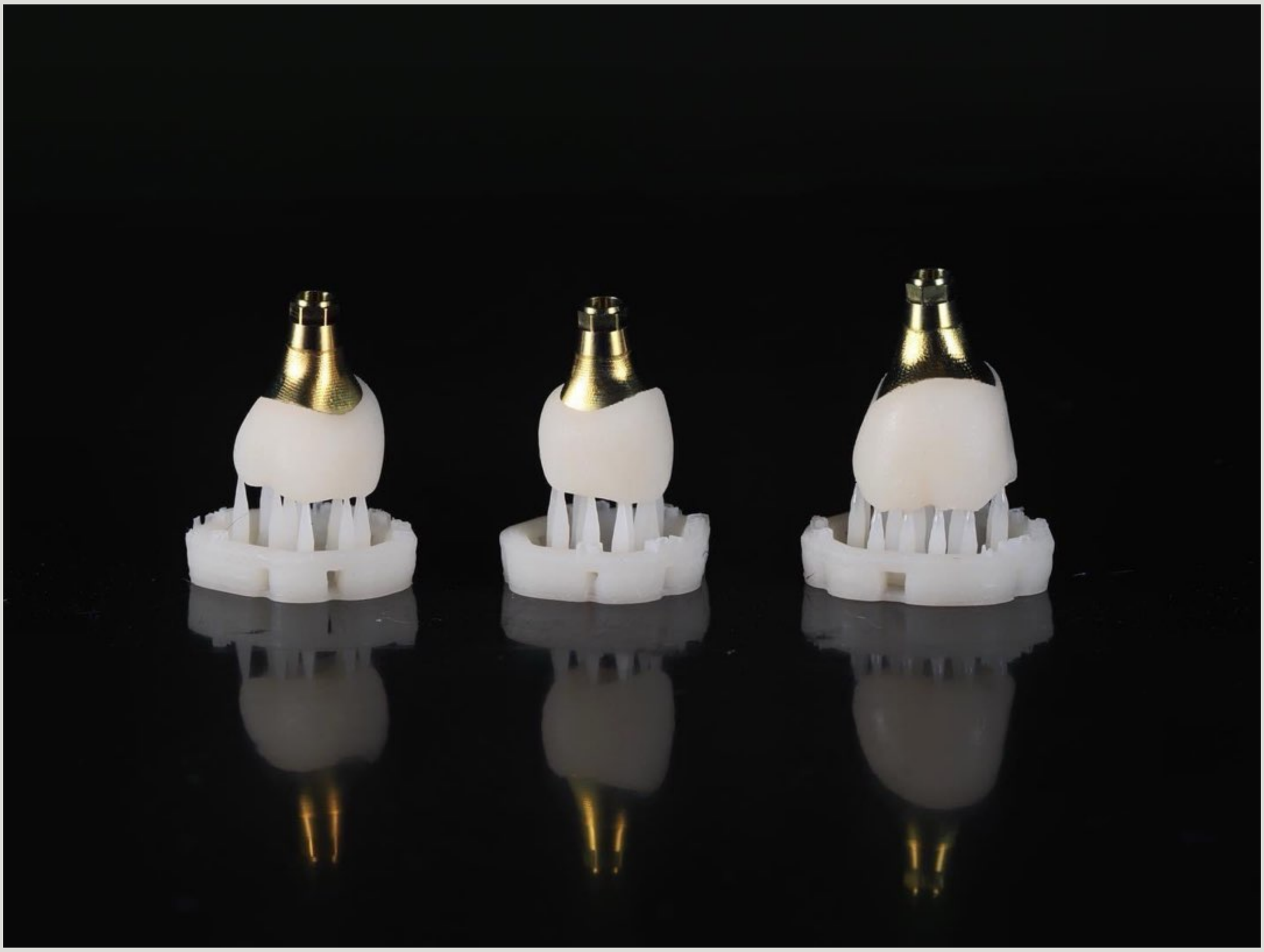
The real time to design this quadrant was under 5 minutes. Modern design software is remarkably fast and easy to use. One of the best investments any office can make is learning how to do quality and efficient digital design in house.

All 3 restorations were printed in under 18 minutes and with modern printers continuing to get faster, soon printers will print a crown under 1 minute.

The restorations were polished using techniques described earlier to ensure an ideal surface finish, and here we can see the result immediately after delivery of the 3D printed restorations.

CHAPTER 10

Implant Definitive Crowns



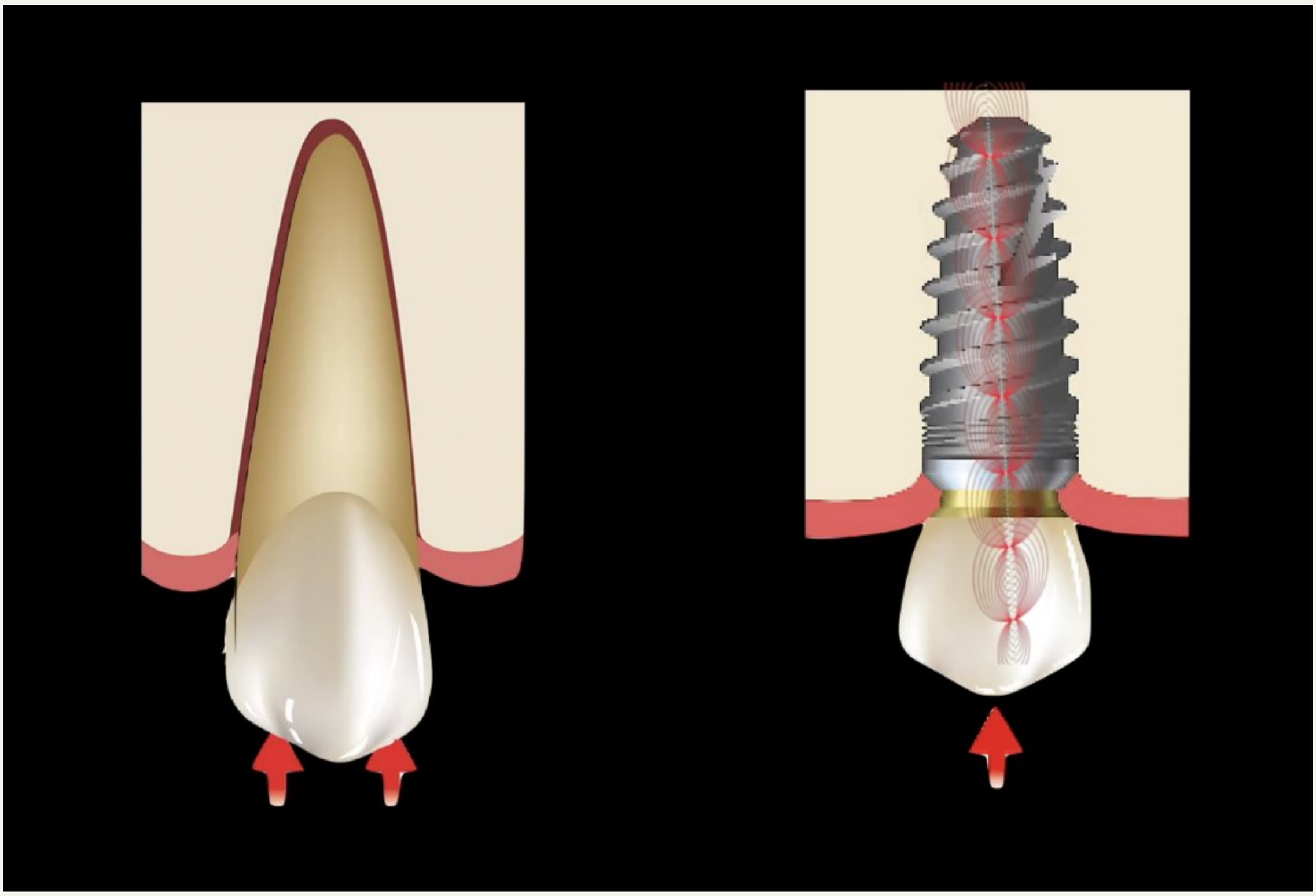
3D printed restorations make the perfect final restoration on an implant custom abutment or tibase due to both their ability to act as a shock absorber in the mouth and ease of contact repair.

CHAPTER 10: IMPLANT DEFINITIVE CROWNS

There are 3 main reasons why I primarily 3D print my implant restorations: fit, repairability and shock absorption. Studies show better fit with similar fracture resistance and retention for 3D printed restorations compared to milled restorations when bonded on implant abutments. 1,2

In a recent systematic review it was found that approximately 50% of proximal contacts became open when an implant crown was adjacent to a natural tooth.[3] With a polymer nanoceramic material, simply unscrew, sandblast the contact, flow some liquid print resin and cure per IFU in the cure box. This is one reason why I always do screw retained.

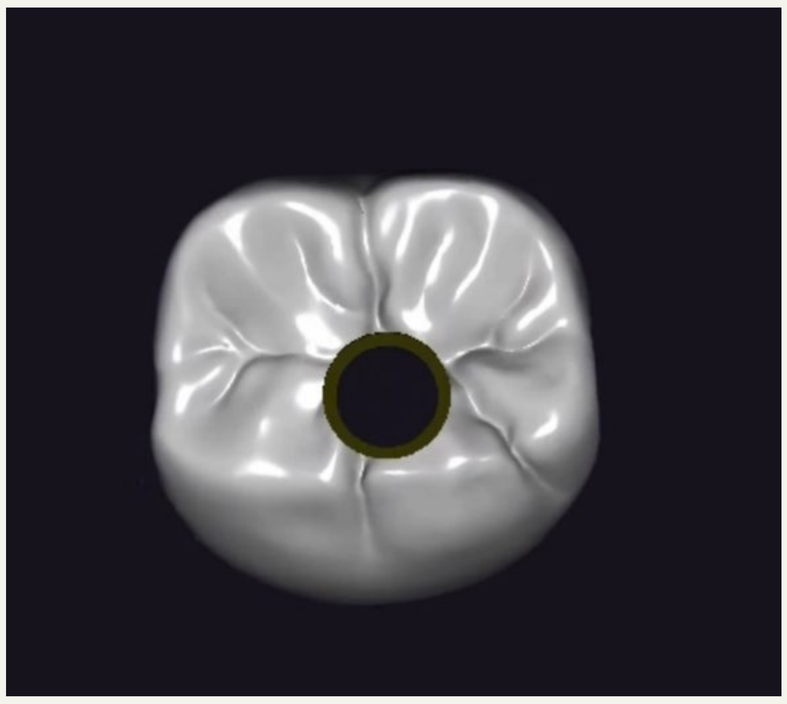
Polymer nano ceramic materials are able to absorb forces and transmit less force to the implant screw and perimplant bone.4-10

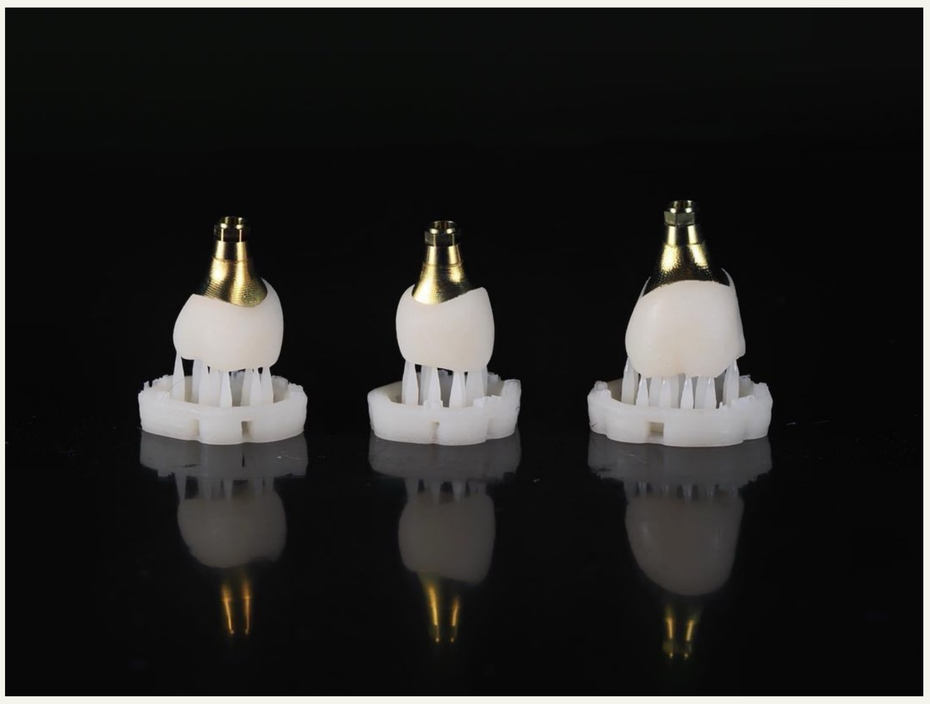


Natural teeth have a PDL that acts like a shock allowing the tooth to take impact. Implants lack a PDL space which can result in forces being transmitted to the bone or to implant components like the abutment screw. Polymer nano ceramics can help mitigate this impact and lessen forces.

Case 1: Screw Retained on Custom Abutment

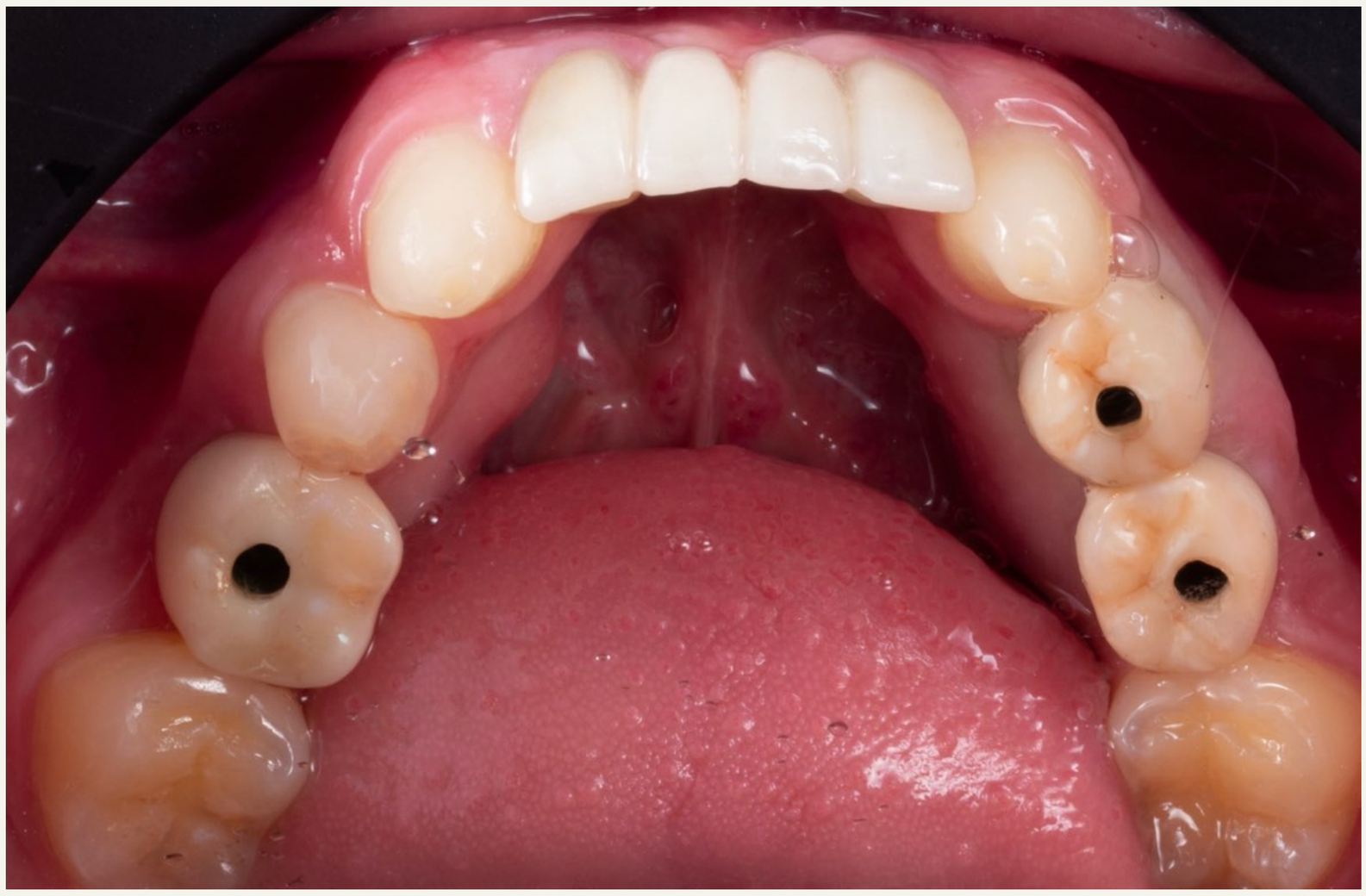
Here we can see this patient is ready for restorations. Due to ideal implant location, thanks to guided surgery, we can do screw retained restorations. For this case, I sent digital impressions to TruAbutment for fabrication of custom titanium abutments for each site. They also sent me the crown designs to print in my office. The printed restorations were bonded onto the titanium abutments before the patient delivery appointment.

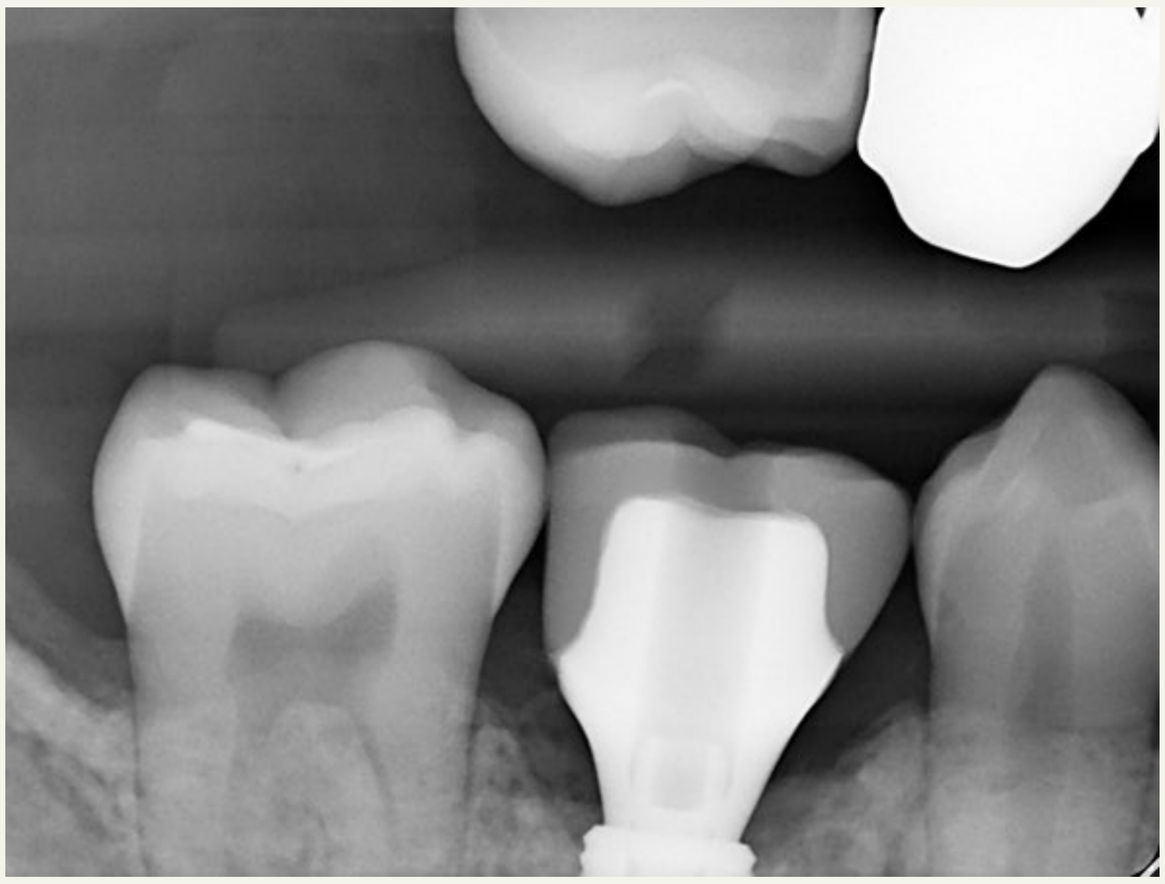


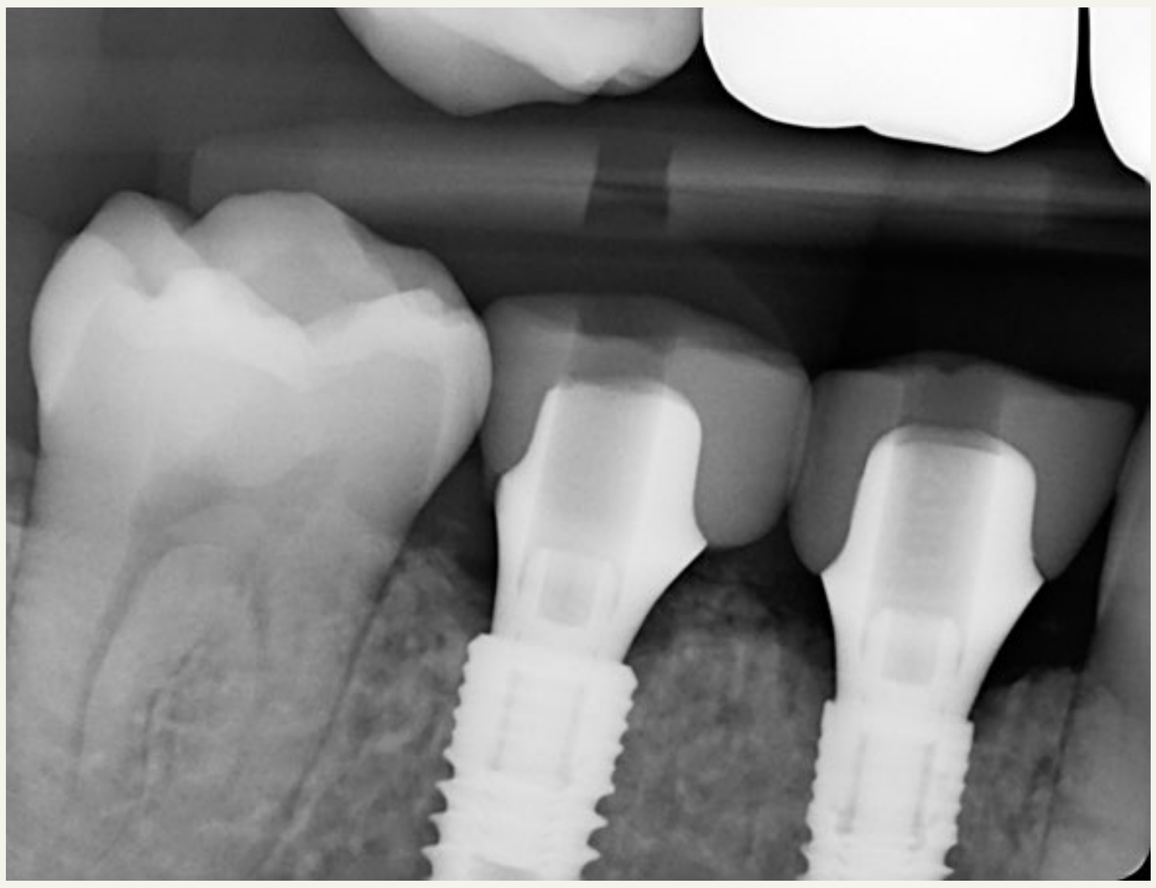


Case 1: Screw Retained on Custom Abutment

Here we can see the restorations in place. The esthetics, function, and radiographic appearance are ideal. Additionally, I like the ability of the crowns to be easily repaired if a contact opens along with the ability of the material to help absorb occlusal forces without damaging the implant or bone. In addition to the custom abutment restoration, 3D printed tibase restorations are a great restoration of choice.

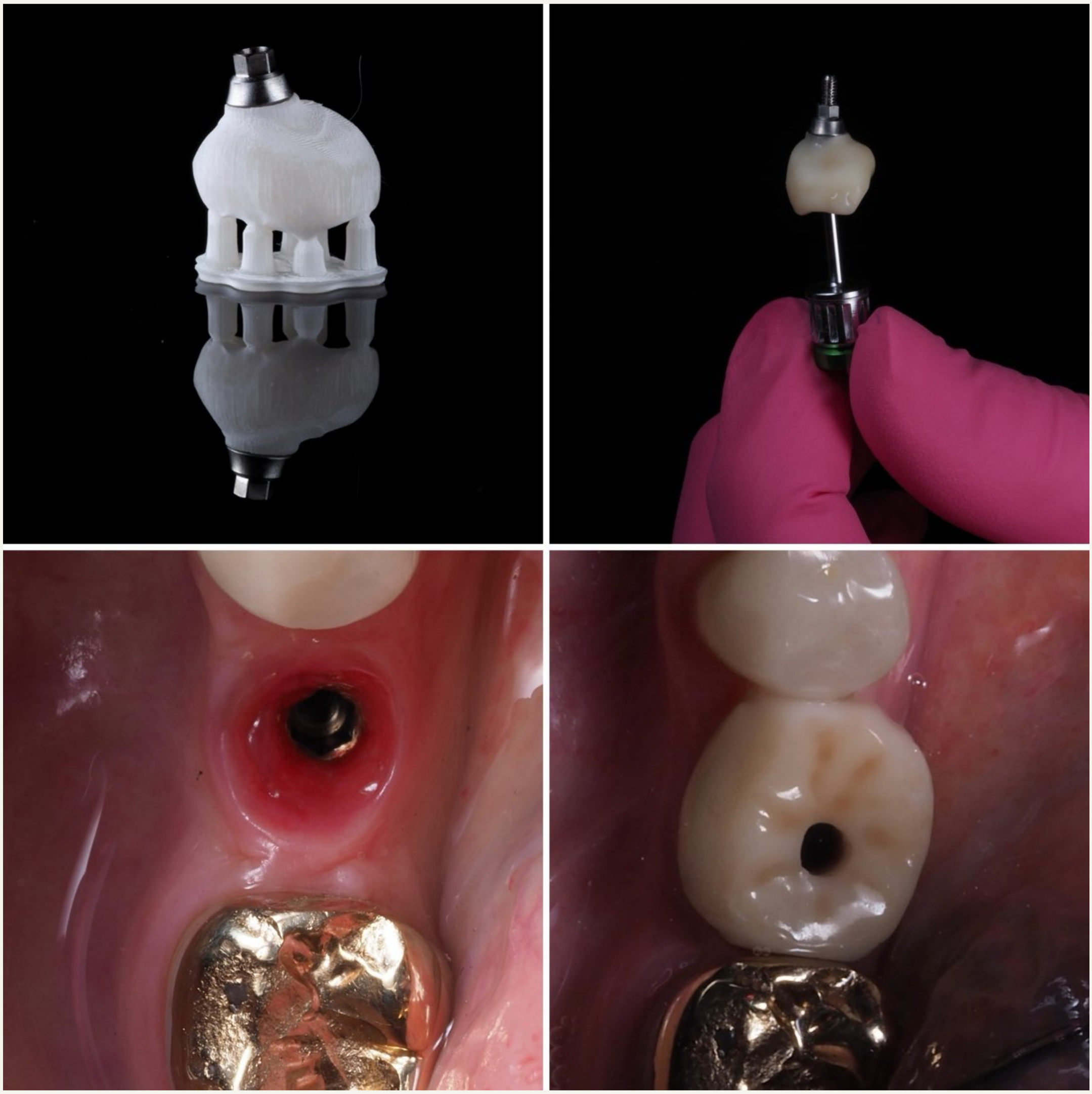






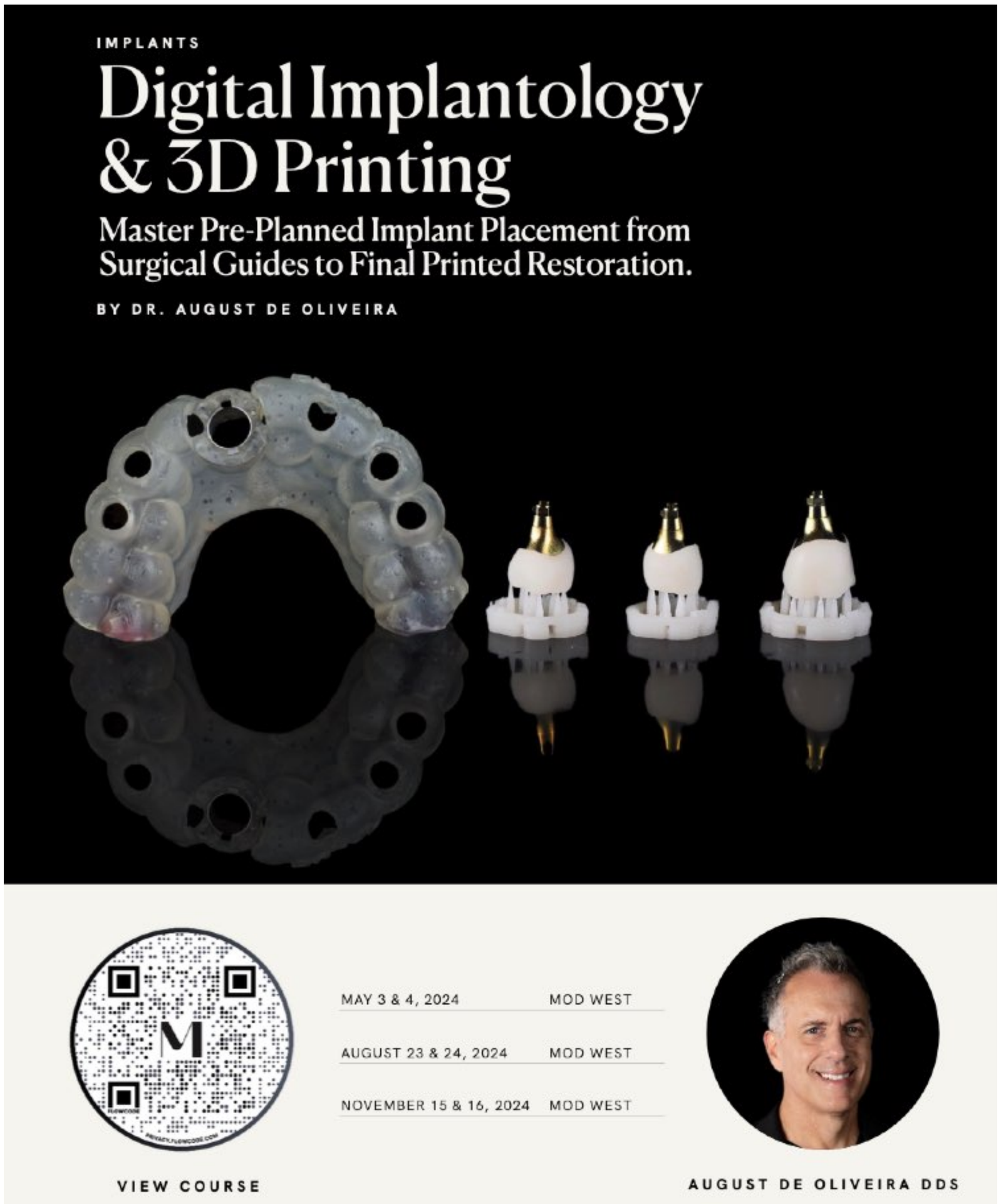
Case 2: Screw Retained on Tibase

Here we can see a bonded screw retrained crown made using a TruAbutment tibase and designed in exocad. The Printer used was a SprintRay Pro 55S with OnX resin.



I want to invite you to MOD West to take a course in implantology and 3D printing with Dr. August De Oliveira where we cover these workflows in detail.

DR. MIKE DEFEE



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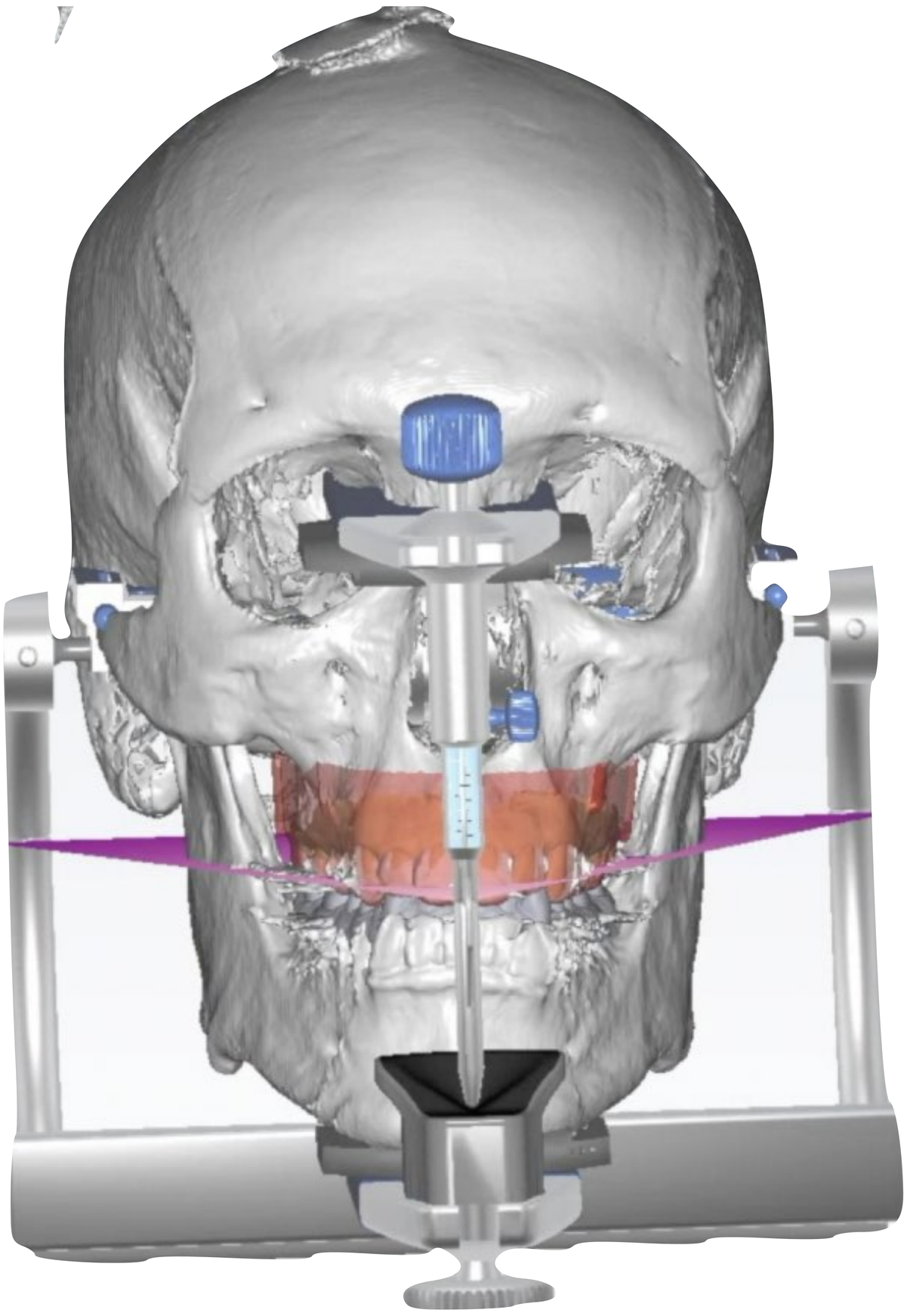
CHAPTER 11

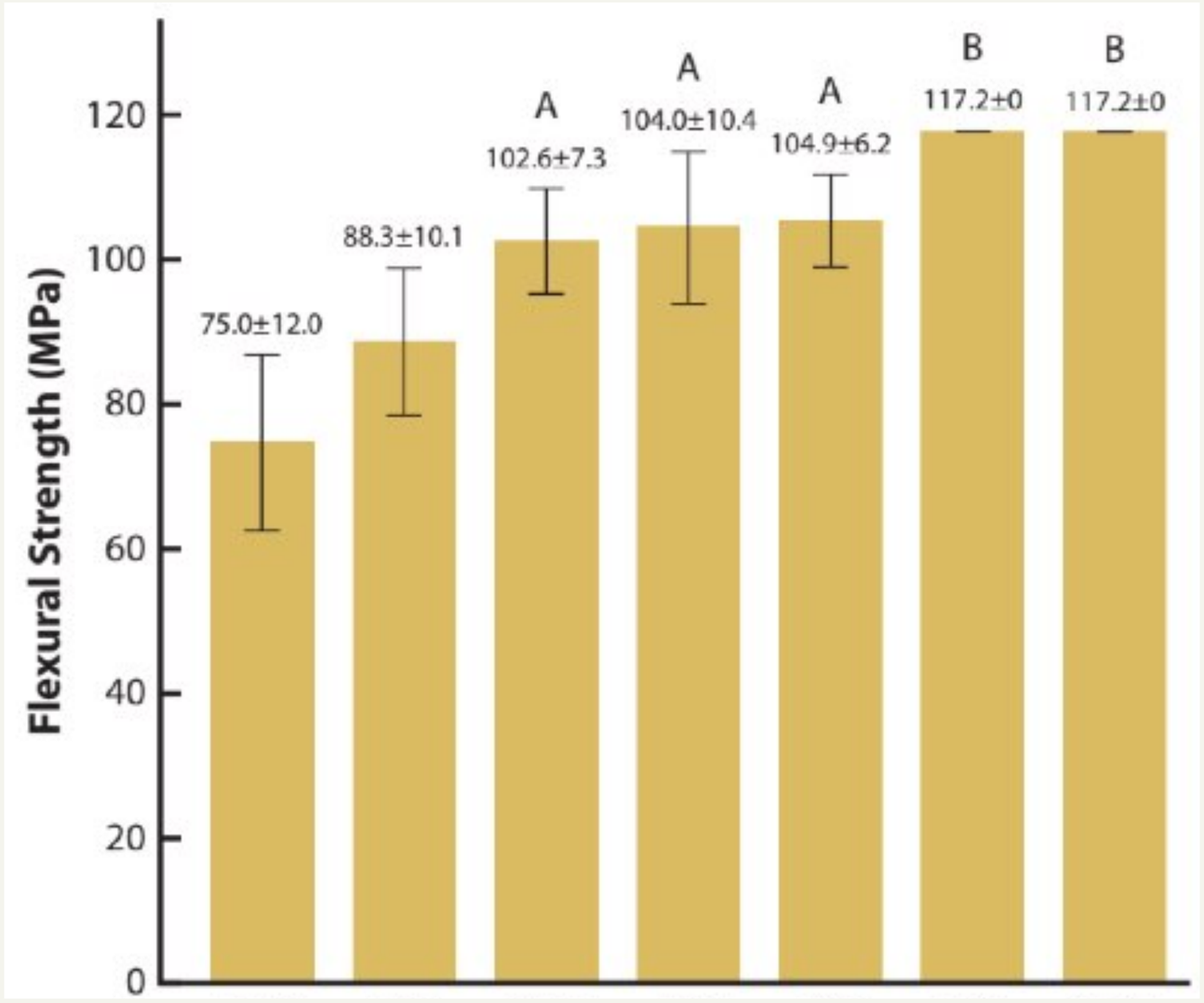
Occlusal Guards



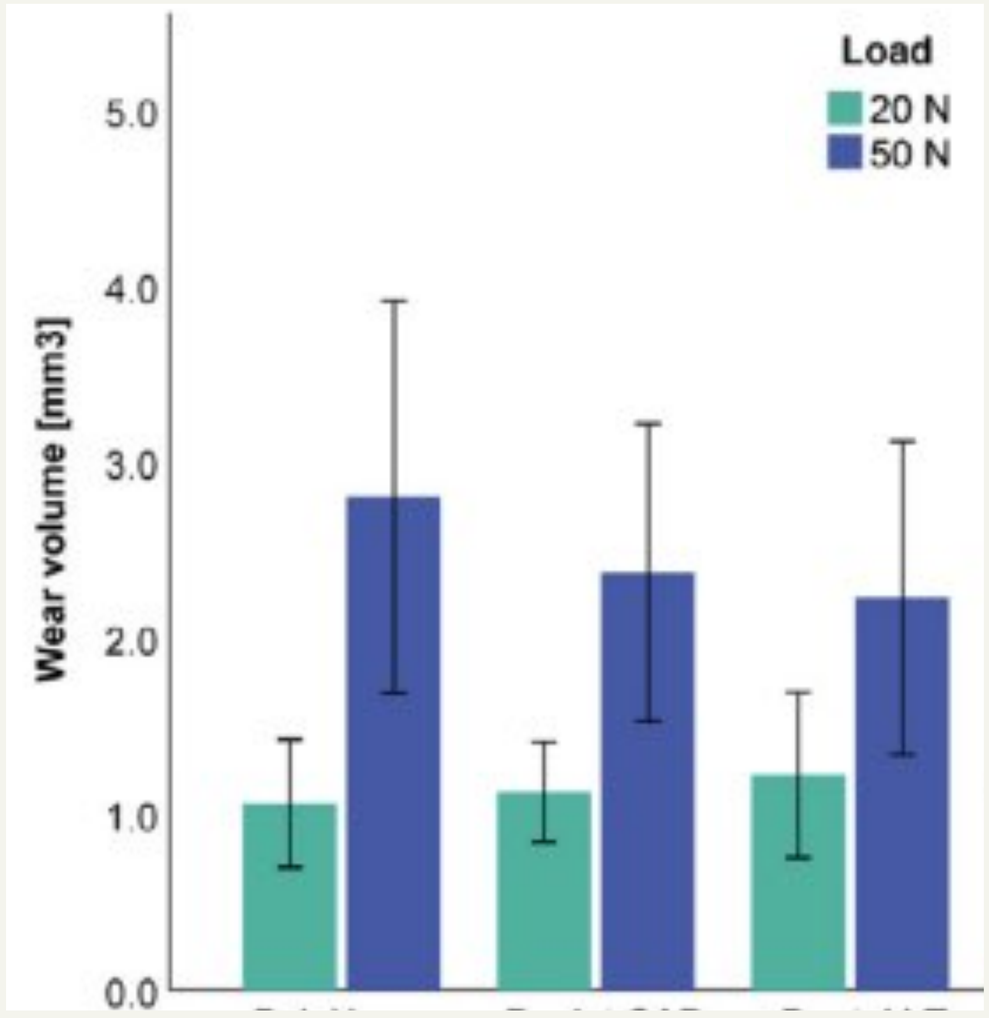
I love printed occlusal guards. The digital guard design is in my opinion a more efficient, and more accurate way to dial in perfect occlusion.

Are the materials there Yet?

Naturally, one of the questions that arises when considering 3D printed occlusal guards is the strength of the materials especially when compared to a milled guard? A recent study found that 3D printed guards had the highest flexural strength of all the occlusal guard materials tested as you can see in the below figure with 3D printed being the two bars to the far right.[1]



The other important facet that dictates the long term success of occlusal guards is the wear resistance. One of the reasons we all prescribe occlusal guards is to help manage the deleterious effects of parafunction, and so we need to be certain that the 3D printed materials will stand up to the stresses of parafunction. A couple recent studies examined this exact question and found no statistical difference in wear for 3D printed occlusal guards when compared to other manufacturing methods.[2,3]



Build Angle Effect

One of the poorly understood factors affecting both the fit and mechanical properties of 3D printed occlusal guards is the effect of the build angle. What we mean by build angle is the angle that the print is oriented at in relation to the build plate itself. The build angle consequently determines how the layers of the print are built and cured in the printer. In the below image, we demonstrate three popular build angles for occlusal guards (Left to Right): 0 degrees, 45 degrees, 90 degrees.

While there needs to be more studies to fully elucidate the build angle effect, a recent systematic review underlies a few important factors when considering 3D printed occlusal guards as they note that a 45 degree build angle for printed guards provided surface hardness that exceeded conventional heat polymerizable materials. Additionally, they noted that, "Resins for 3D printing had satisfactory mechanical performance for interocclusal devices."[4]

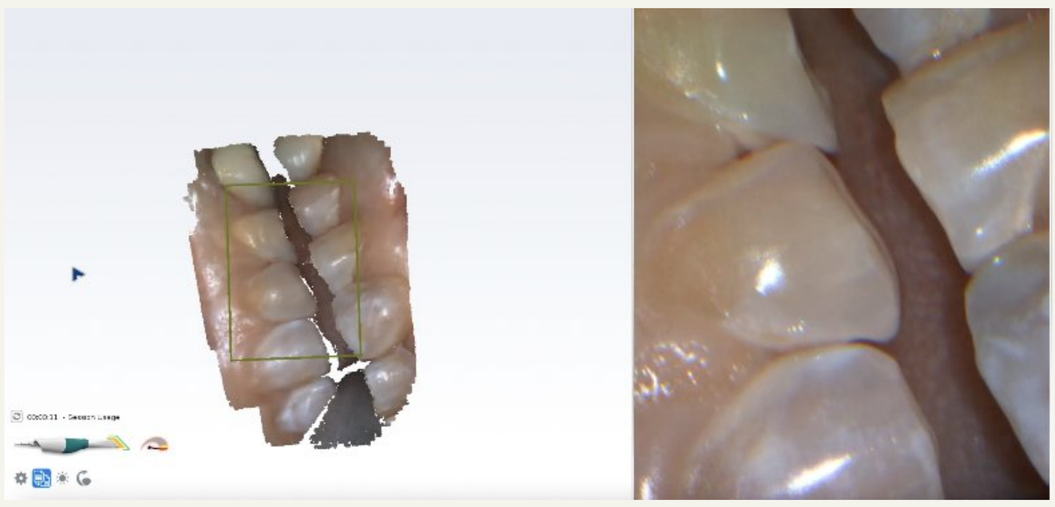
Another consideration when printing occlusal guards is that the 0 degree build angle will result in the fastest prints because of the smaller Z-height, which is especially important if you like to fabricate same day guards for large cases like we do.

Our preferred build angles for occlusal guards are either 0 or 45 degrees based on this data and our clinical experience

Case 1

We fabricate all our occlusal guards from intra-oral scans. with a bite scan in CR at an open vertical dimension using a custom jig. A critical piece to understand about the fit and occlusal accuracy of digitally designed occlusal guards is that the bite records should be taken at the desired vertical to minimize inaccuracies in the digital design from the need to digitally open the occlusion.

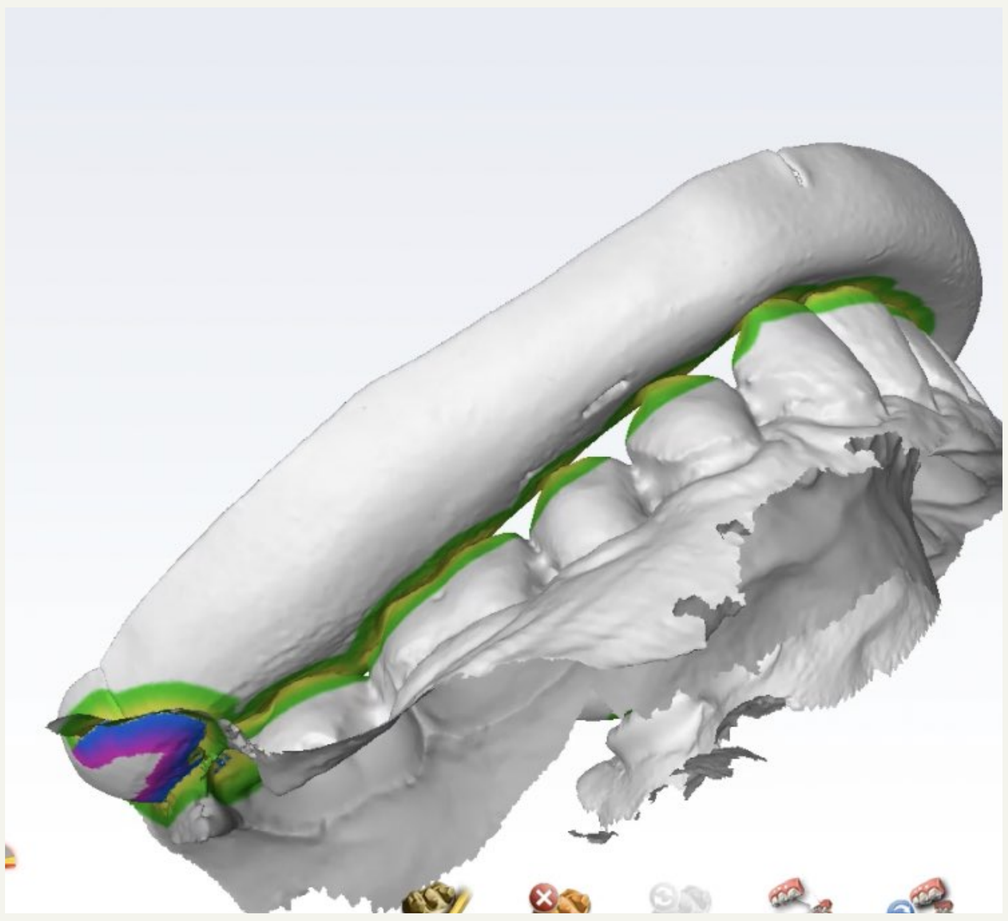
Here we have a soft ball of heated custom tray material that is placed on #8 and #9, the patient is manipulated into CR using chin point or bimanual manipulation, and then the material is cured. The jaw is then hinged into the polymerized material to verify CR. The jig is placed when scanning the bilateral bites. From here the files are exported into a digital design software and a guard can be custom fabricated. Alternatively, a design service can be utilized that will design the guard for you and send you the file to print. Nightguard Flex by SprintRay, Smile Guard by Desktop Health or Keystone Soft are not actually "soft"materials." They are hard plastics with high impact toughness that have the ability to be softened in hot water and slightly formed. We do this sometimes at delivery if the guard is too tight to help improve the fit. Typically, for a full arch permissive splint all the teeth touch in centric relation at the desired vertical dimension. Then during dynamic movements you have anterior guidance and posterior disclusion. This is the most basic guard design



Here we can see the digital bite is made open, and the jaws are stable at this centric position due to the custom jig holding the teeth in place in CR. From here a printed full arch permissive splint is easily designed and fabricated.

Case 2: The Copy Guard

Some patients have existing guards that they love and have worn for years but they are starting to crack and stain. One technique is to scan the guard and then print an exact duplicate. This is achievable with most intra-oral scanners and some patience. Use titanium dioxide spray to opaque the guard for scanning, similar to how we described for denture scanning. This patient presented with a bag full of new guards made at other offices. He had one 5 year old guard he loved and wore every single night. He complained the other guards did not feel right and asked if we would make him a new one. Rather than start over and attempt to make a new appliance for him, we simply scanned his old one and refabricated it. After scanning the guard, we also scanned the lower arch, and then scanned the bite with the guard in the mouth. By doing this you have the ability to edit the guard virtually if needed because I have the virtual bite information.

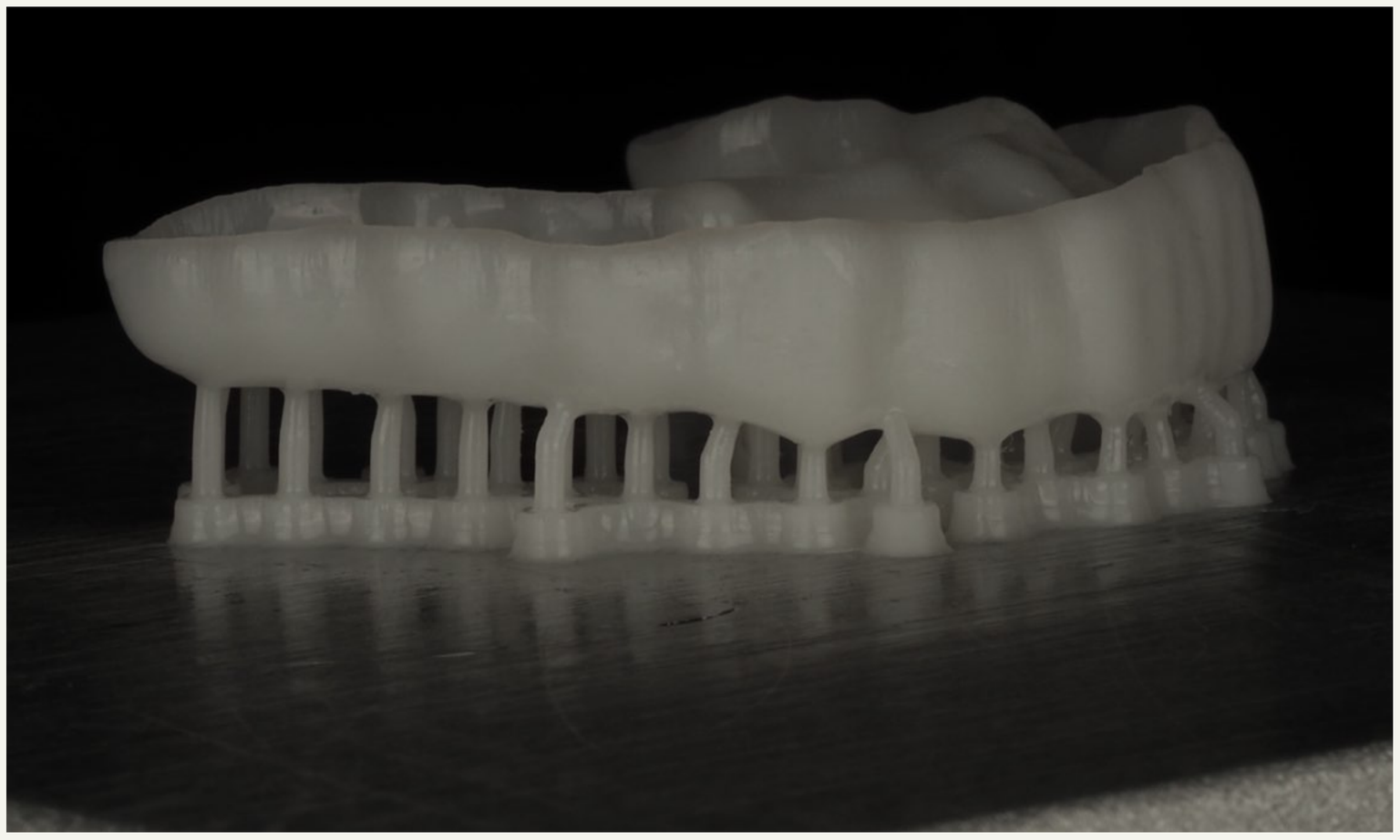


Using this information, we printed a new guard that was an exact copy of his old guard with the same fit and same wear facets. The supports were removed, the guard was cleaned in alcohol, cured, and then polished. He was so happy we were able to do this for him.

More sophisticated guards can be fabricated including dual arch guards and sleep appliances using this material. It is outside the scope of this eBook to venture into these more sophisticated appliances, but know that with 3D printing you are only limited by your imagination.

Case 3

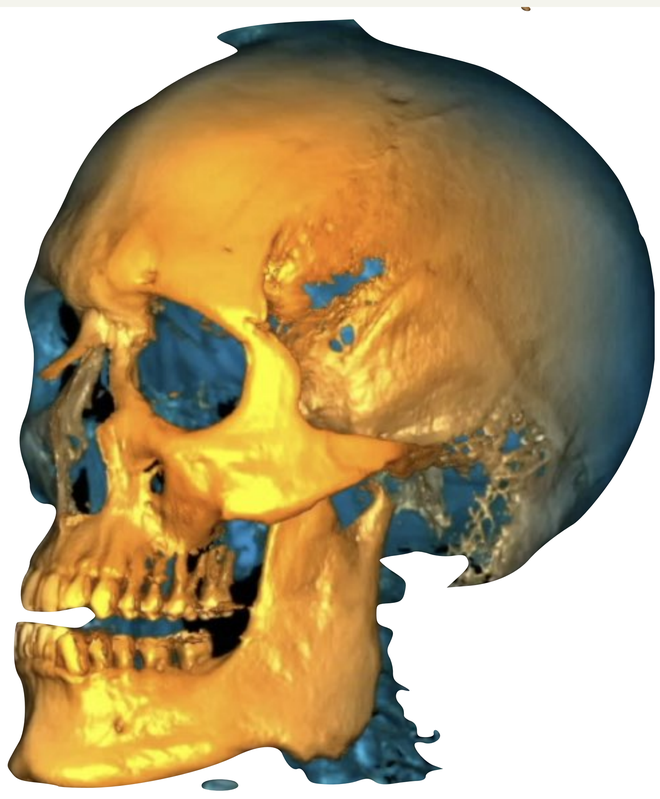
This patient had a complete rehabilitation and we needed to fabricate her an occlusal guard to help prevent her from damaging the restorative work with her parafuctional activity. She was a self described "crazy grinder" who had never had a guard made that she didn't break within a couple weeks. In fact, she noted that her last dentist had made her more than 5 guards and she broke them all until he gave up. Another challenging part of this case was the patient's small lips which prevented from opening the vertical much to allow for a thick guard. We decided to fabricate this patient's occlusal guard out of a material with better toughness properties (OnX Tough) to provide a guard that would withstand stress at a relatively small thickness.

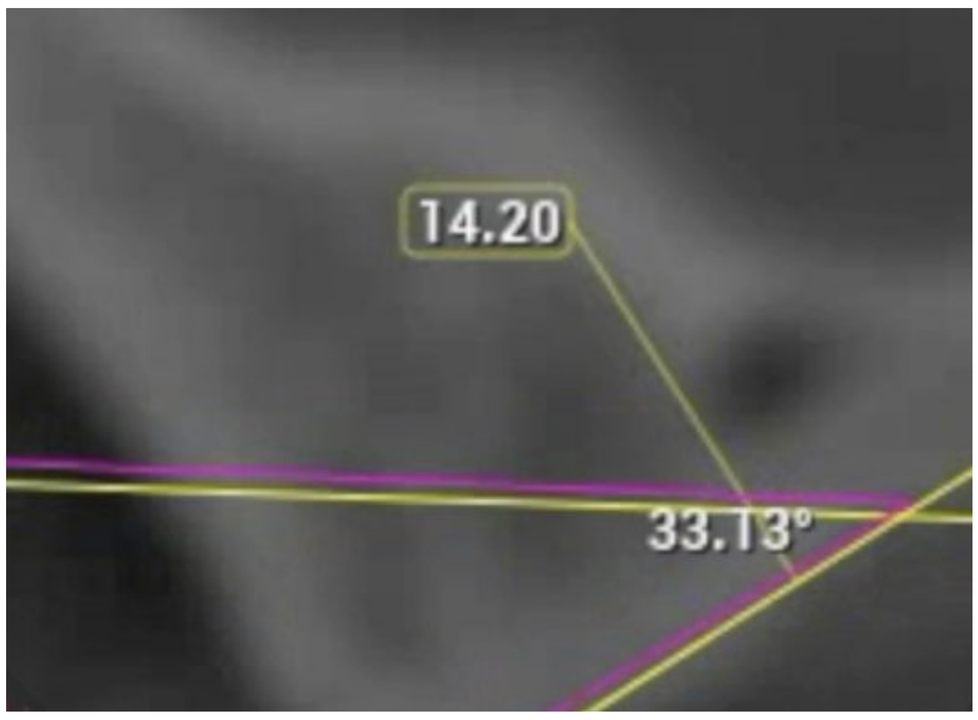


With some minor adjustments to how we approached the design the design in exocad, we were able to achieve a perfect fit and custom canine guidance at delivery with no adjustments all with a design time of under 5 minutes

CBCT Mounting Technique

Using a CBCT to make a virtual face bow in CR and mount this on the virtual articulator for digital design is a common technique I do. For this technique, an IOS is made with the same custom CR jig described above, and then a CBCT is made with the CR jig in place. The models are then all exported and the CBCT is used to virtually mount the models in the articulator. Additionally, condylar inclination is measured from the CBCT and entered into the articulator settings. Here a full skull Ultra Low Dose CBCT was made on the Planmeca Viso G7 and intra-oral scans were aligned to the CBCT. Condylar inclination was measured using a line drawn from porion to orbitale, then a line drawn from the crest of the glenoid fossa to the articular eminence. The angle of where these lines bisect is the condylar inclination. From here, this information is exported into the design software. The virtual models are then mounted using Bergstrom's point which is 10 mm anterior to Porion and 7 mm inferior to Frankfort Horizontal. This point is used to align the skull on the virtual articulators.





In this case, exocad is used as described above and the models are mounted on the virtual articulator. Also, custom condylar inclination is entered as measured on the CBCT. In this way the dynamic articulation is nearly identical to reality and the need for recorded jaw motion is dramatically diminished. One step beyond this would be to use 4D jaw motion tracking such as ModJaw or Planmeca 4D jaw motion tracking and then import the XML data into the software for custom patient movements.

Join us in our Occlusion track to learn how to make 3D printed occlusal guards an efficient, profitable part of you office workflow along with how to incorporate splint therapy in to a comprehensive treatment philosophy

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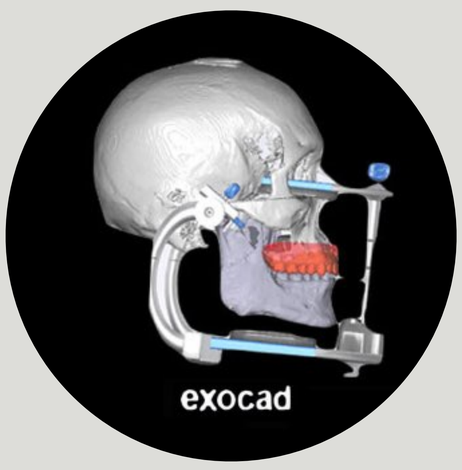

LEVEL 3

Digital Full Mouth Reconstruction

Confidently complete complex restorative cases with modern occlusal concepts.

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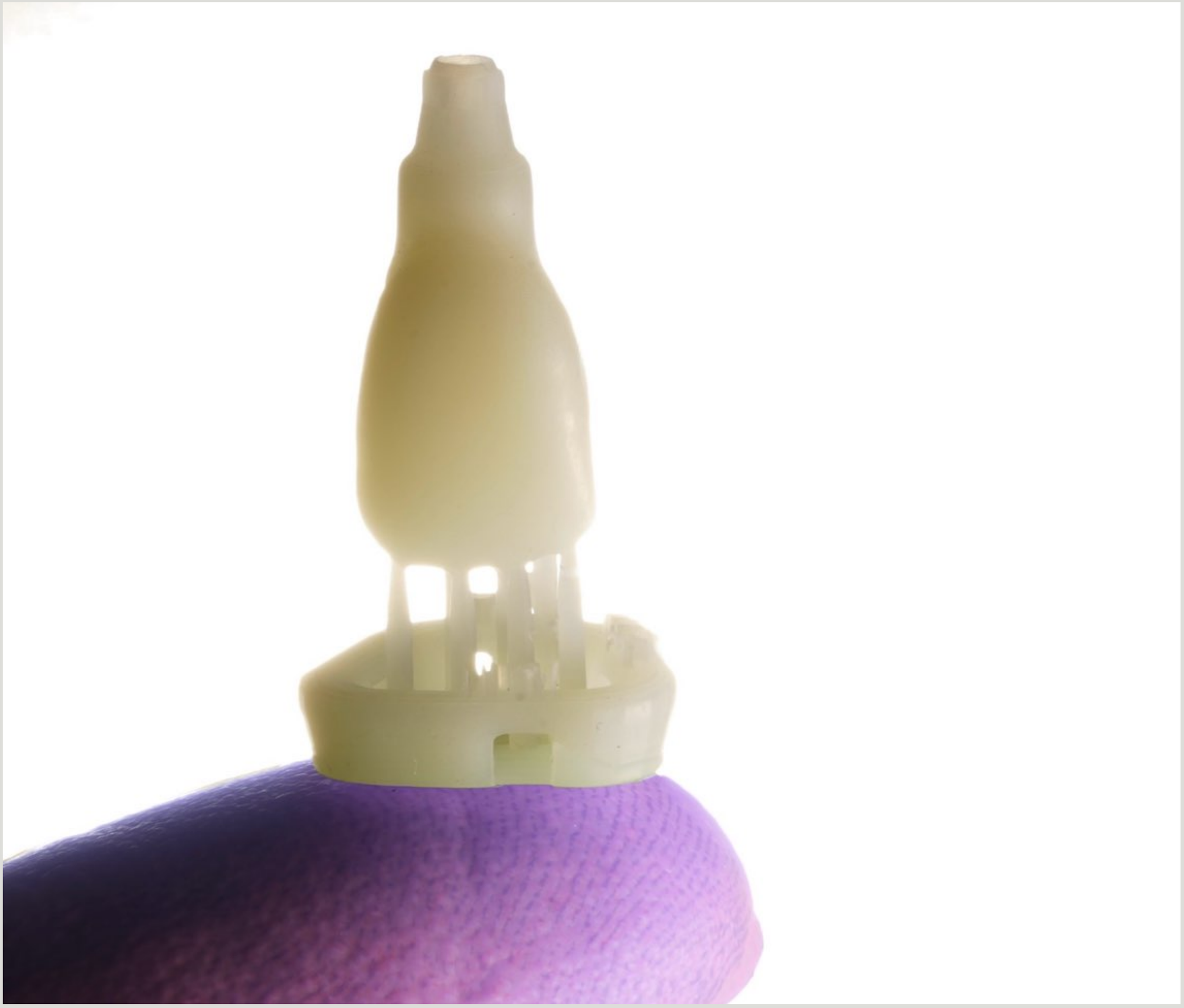
CHAPTER 12

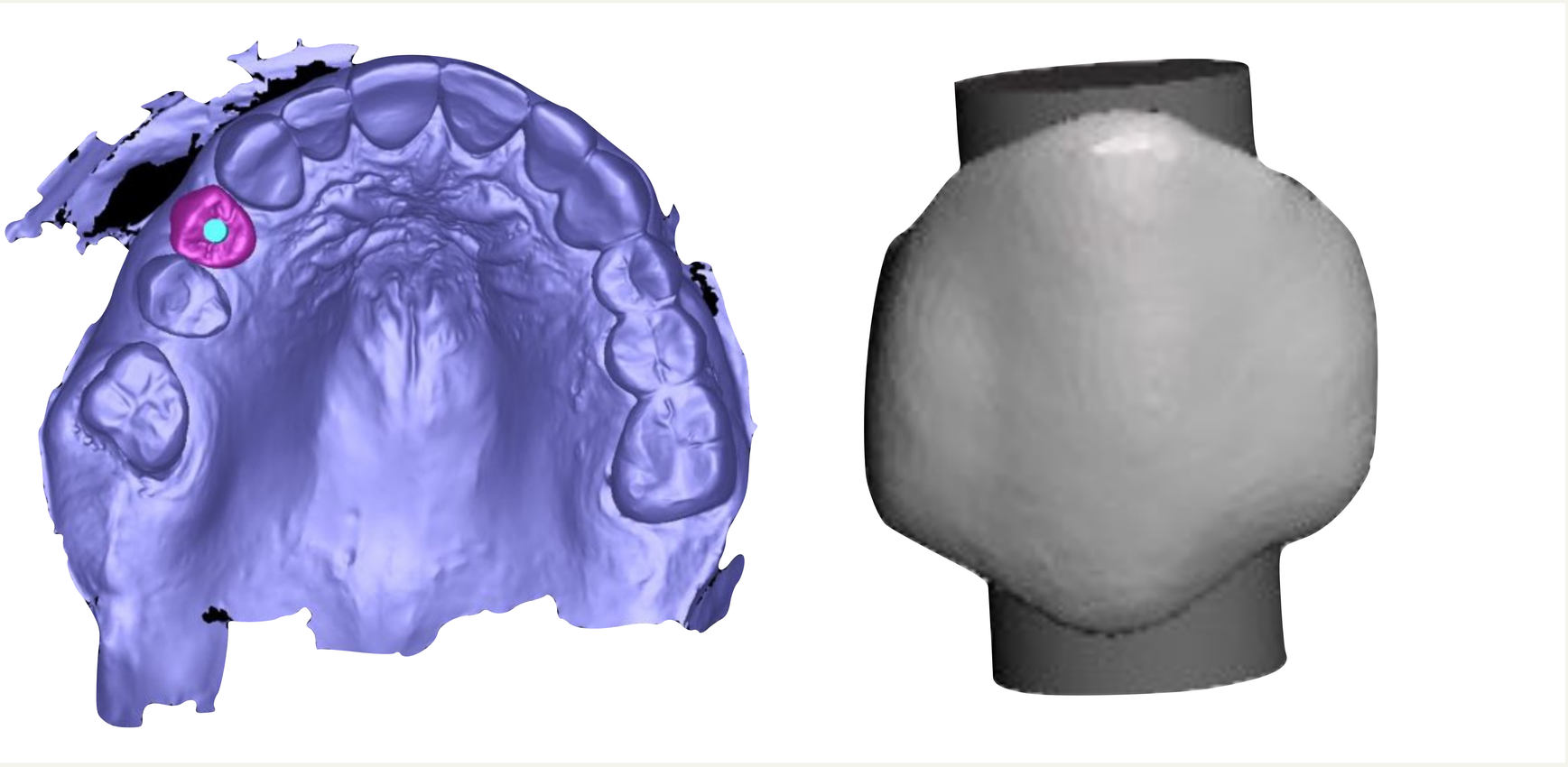
Implant Provisionals



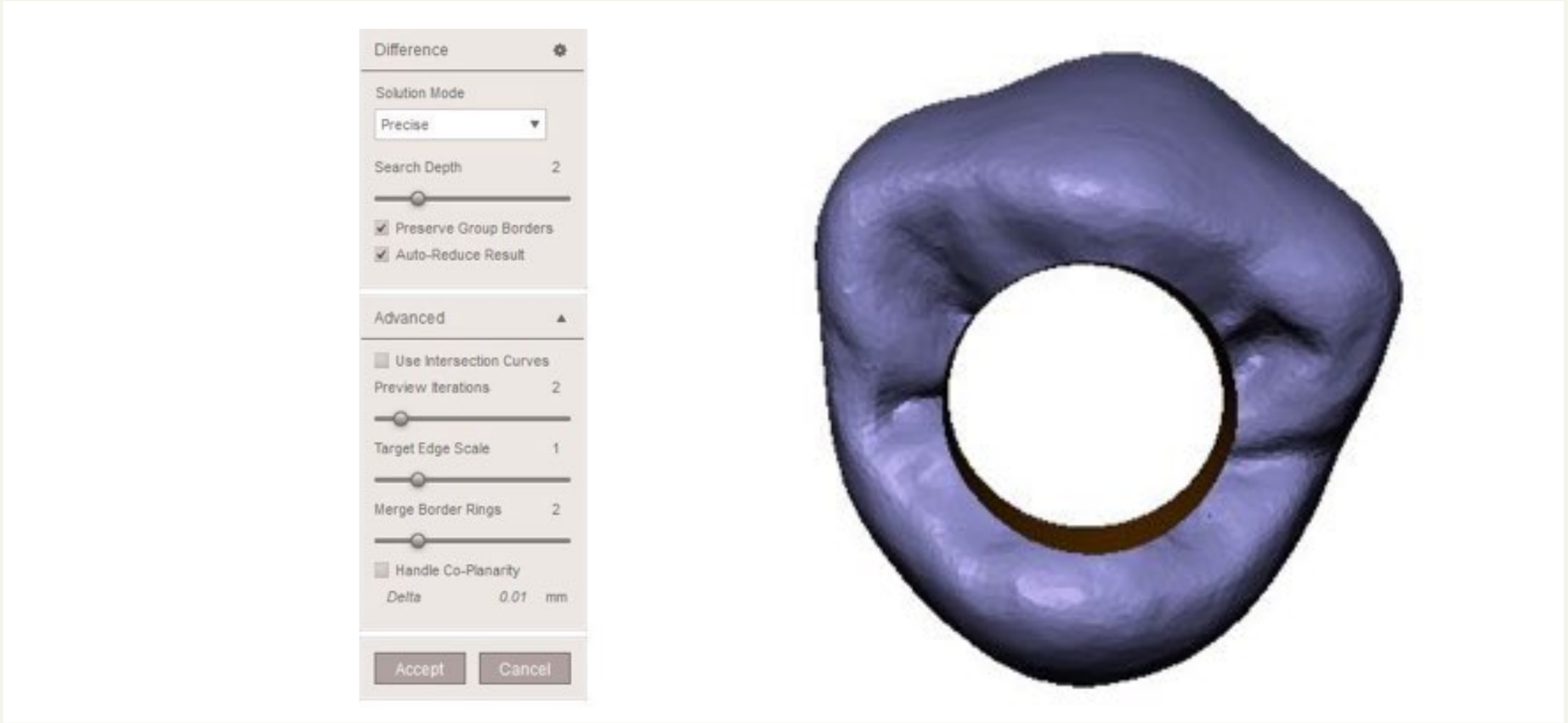
Printing has dramatically simplified the provisionalization process for implant restorations. You can get as simple or as complex as you want. In this chapter we will cover both the simple and the complex.

Case 1: Simple technique—a digital crown with a hole in it

Most implant planning softwares allow you to export the crown design that was used to plan the surgical guide, and to also export an implant extension tube. This object can then be placed in Meshmixer and utilizing a subtract tool (boolean difference) a hole can be cut in the crown exactly where the temp cylinder would emerge.



To do this in Meshmixer, first highlight the crown and then the cylinder and click Boolean difference. In order to get the most ideal cut you have to make the tube a solid first. The restoration is designed slightly out of occlusion, the implant is virtually planned and then the objects are exported to cut the hole where the implant tube is extending. In Meshmixer, the Boolean operation is achieved and the files can be exported to print.

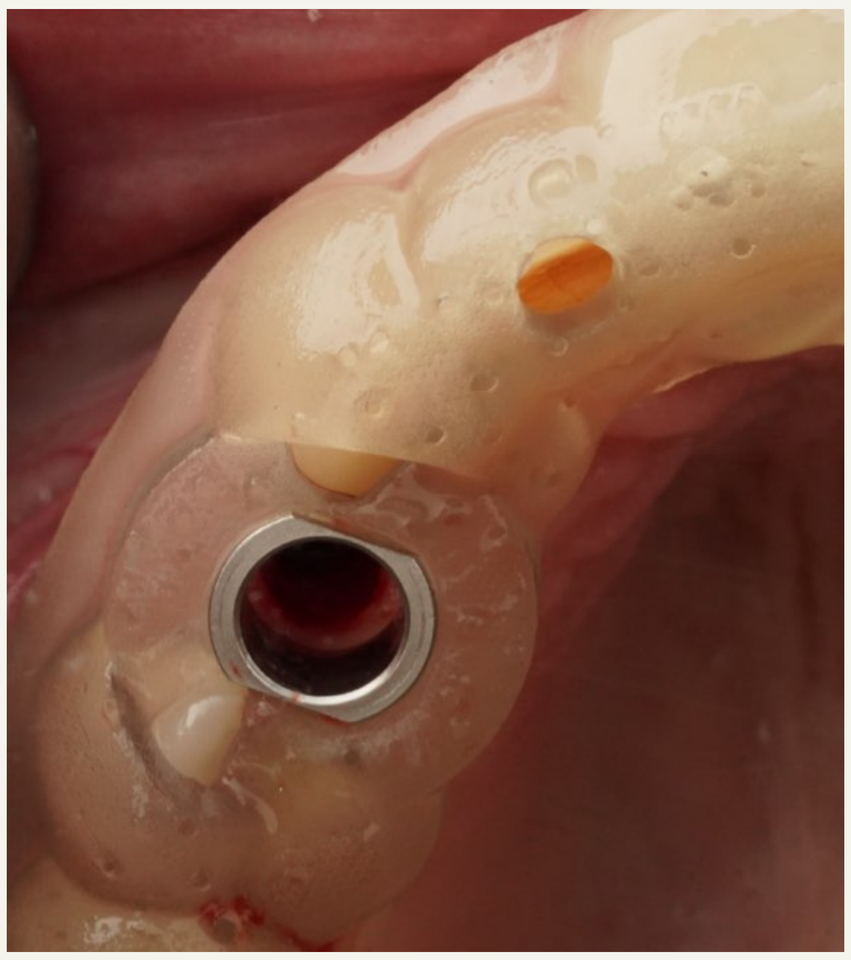


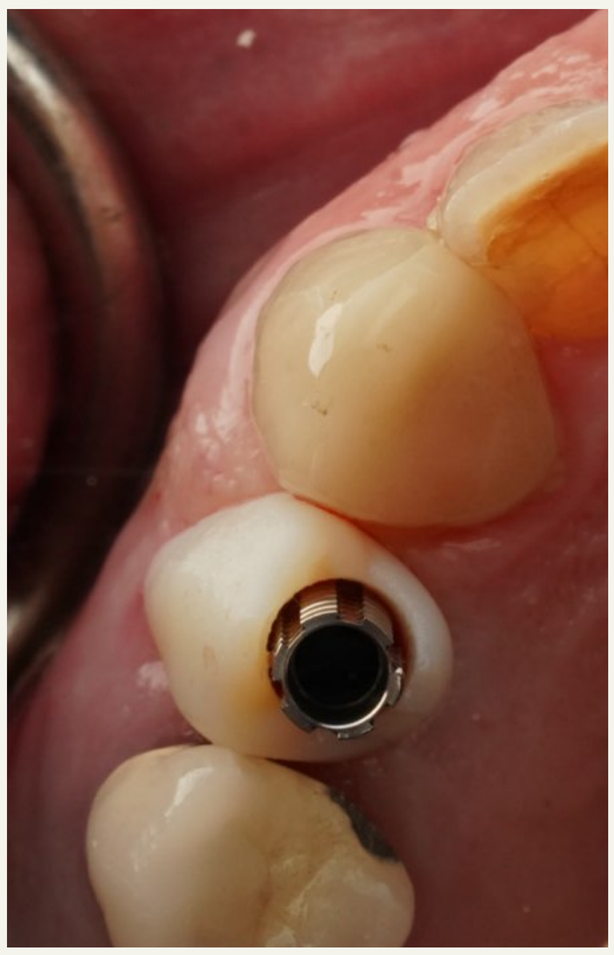
CHAPTER 12: IMPLANT PROVISIONALS

The day of surgery you have a guide, a printed temp and a temp cylinder.

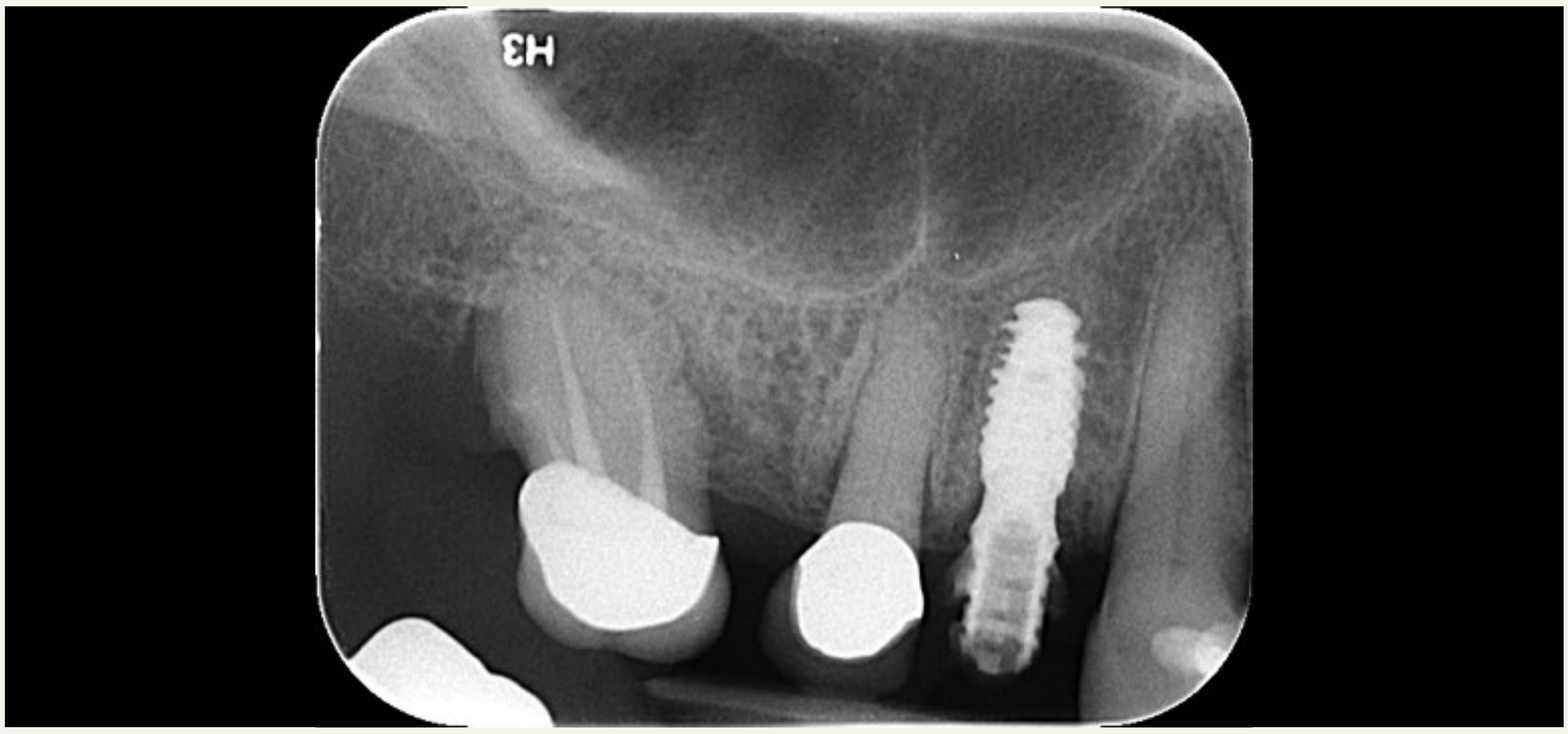
The surgical guide is placed and the implant is placed to depth at the proper location. If torque is achieved, the case can be immediately loaded and the provisional made from the previously printed plan can be placed. I only ever attempt this type of restoration premolar forward. The temp cylinder is placed and the printed restoration is then picked up around the temp cylinder using a flowable resin composite cement such as Ivoclar Vivadent Variolink Esthetic DC.

Once the resin is locked on to the temp cylinder you can then unscrew the entire provisional, add to, and polish the subcritical contours of the restoration. Then, you remove the extended titanium from the occlusal and polish the surface.





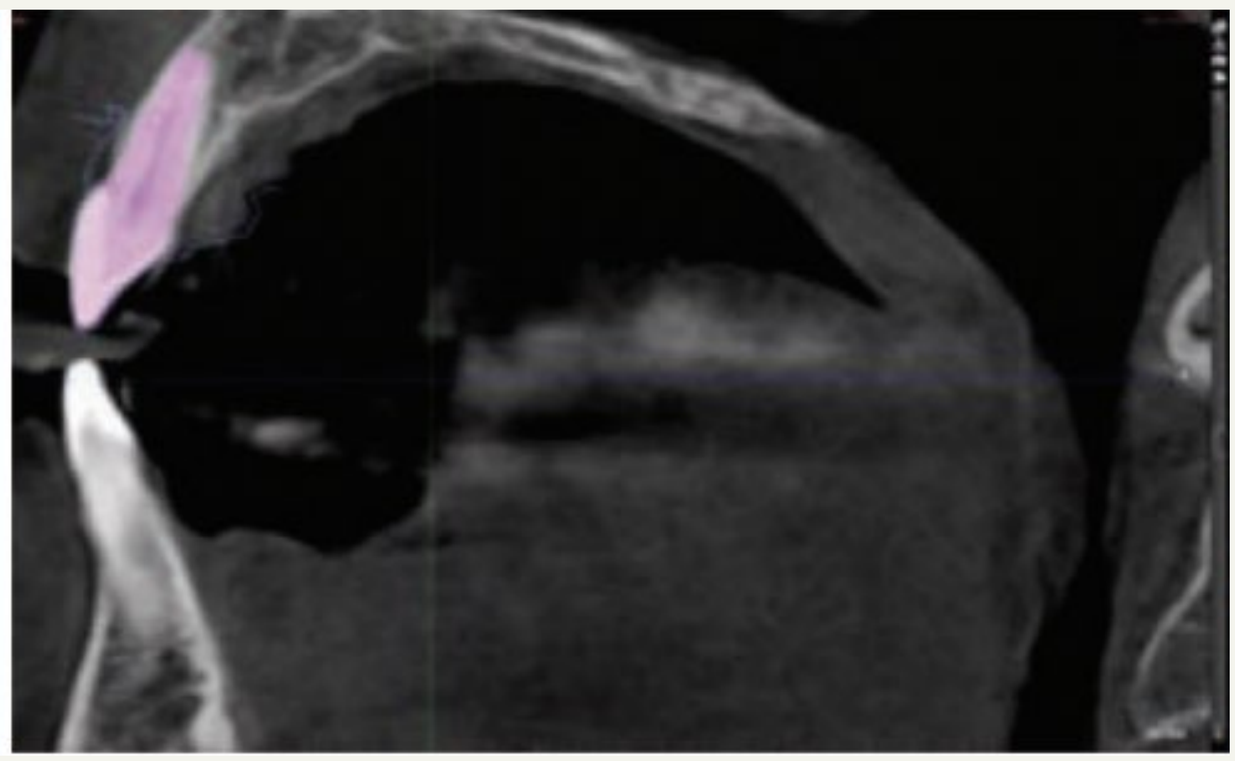
Once the provisional is polished and sculpted you can then screw the restoration into the fixture, verify no contact in occlusion and then make a check radiograph to ensure everything is seated correctly.



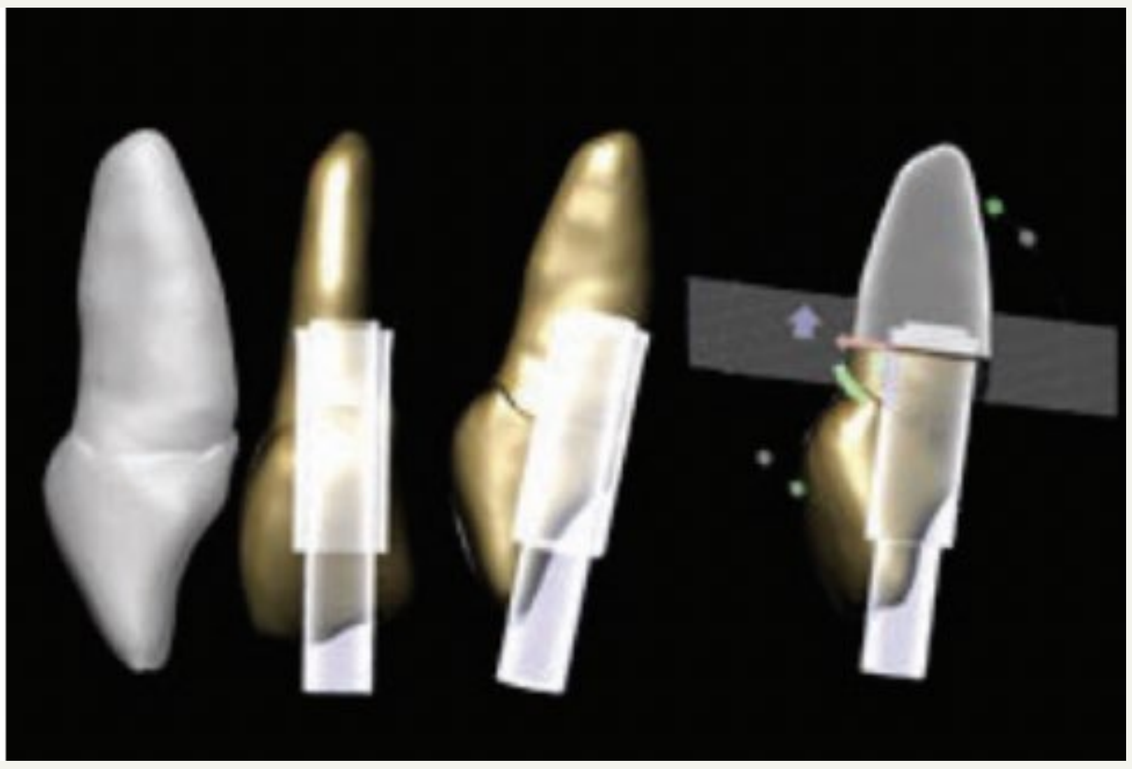
Teflon tape is then placed in the access hole, followed by any composite material you have.

This technique was the way I provisionalized implants 5 years ago. Now, I tend to go direct to fixture using timed guides. I prefer this method, even though it requires meticulous attention to detail. I like the printed connection which acts as the weak link in an immediate load prosthetic where if the forces are too great it will break at the connection functioning much like a fuse in an electrical system designed to protect the system. In this instance, the connection will break letting the patient and the clinician know the forces are too great, possibly alerting that a problem exists before implant failure occurs due to heavy forces. Once the resin is locked on to the temp cylinder you can then unscrew the entire provisional, add to, and polish the subcritical contours of the restoration. Then, you remove the extended titanium from the occlusal and polish the surface.

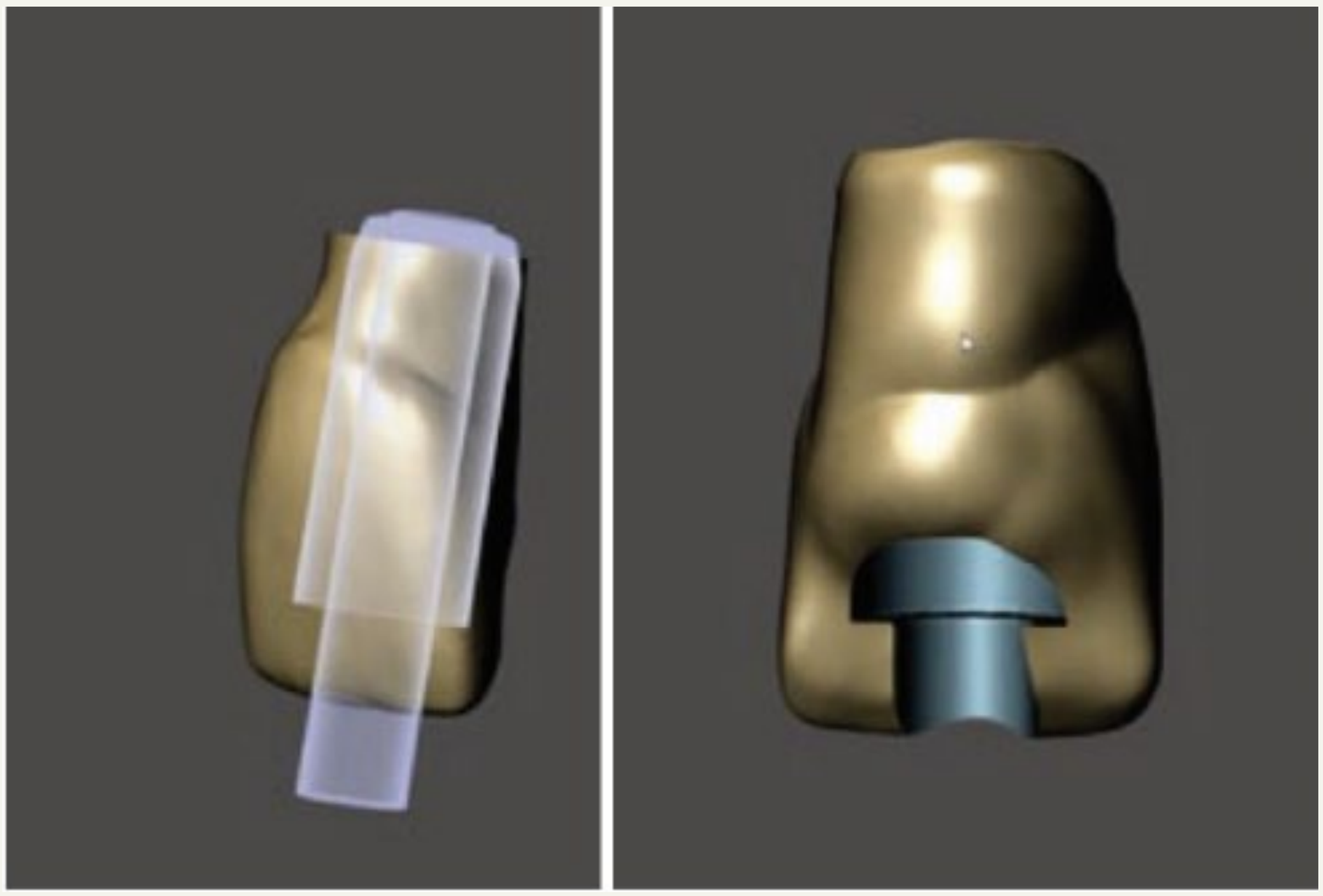
Case 2: Using a virtual extraction and mirror image of an adjacent tooth to capture subcritical contours for the printed prosthetic.



Here a patient presented with missing tooth #8. Using the same technique described above with one minor change, the contralateral root was segmented out of the CBCT, merged with the new digital design of tooth #8 and used to fabricate the subcritical contour of the provisional.



Then a digital impression is made, tooth #8 is waxed, and this file is merged with the CBCT. A virtual implant is placed and a guide fabricated. An abutment is created in the software that corresponds to the temp abutment or Tibase dimensions. Also, the root of tooth #9 is segmented. The root, the design of #8, the implant location and extension are all exported into Meshmixer, where the root is mirror imaged and merged with the crown design. The root is cut at the level of the abutment margin.



The restoration can be printed and attached to a Tibase before the surgery. On the day of surgery you have a printed guide, a pre-made provisional with a natural contour that is a perfect mirror image of the natural tooth.

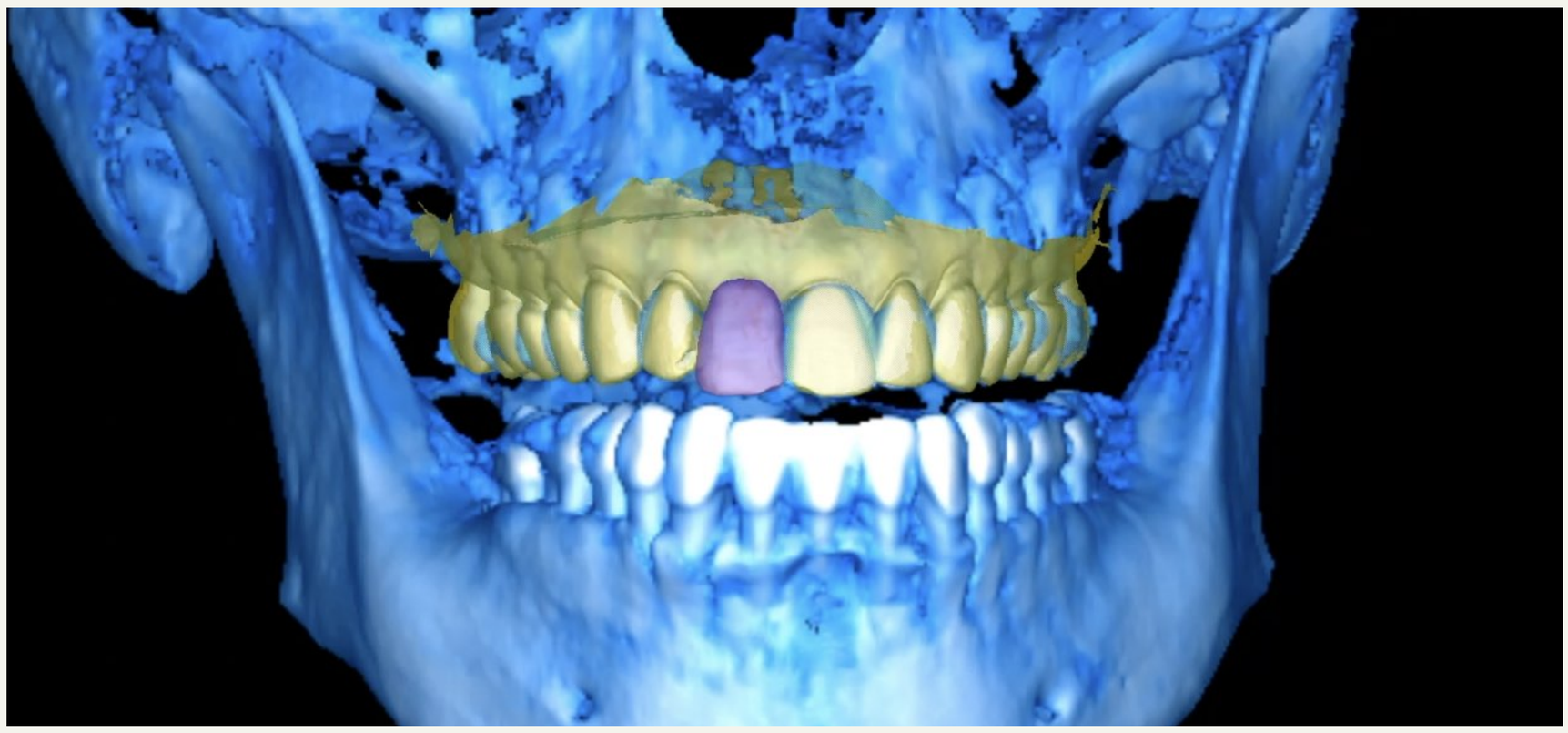
The implant is placed, and the temp cylinder is placed. Then the restoration is picked up on the temp cylinder, except this time it bottoms out at the temp cylinder margin at the correct vertical height due to the added step of recreating the temp cylinder virtually in the implant software.

Case 3: Timed guide and premade temp direct to implant, TiBase, or custom abutment.

This patient is also another tooth #8 case. She lost tooth #8 in an accident. She fell, avulsed the tooth, fractured the facial cortical plate and arrived to my office with tooth in hand. I did guided bone regeneration and now the patient is ready for an implant. She has an event coming up and does not want to go with the removable appliance that was made in the anterior. For this case, I used Planmeca Romexis to plan using the option to attach a scan body to the implant plan and then export that into a design software for restoration fabrication.

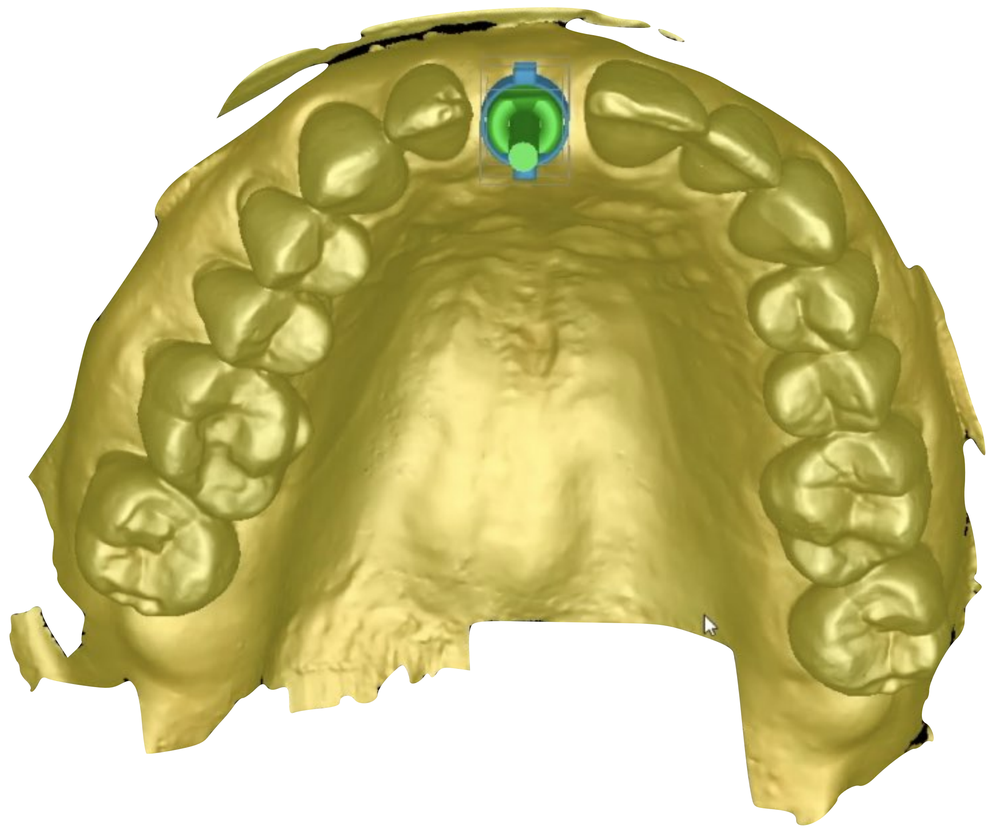
Step 1

A high quality intra-oral scan is made and tooth number 8 is digitally waxed and merged with the CBCT.



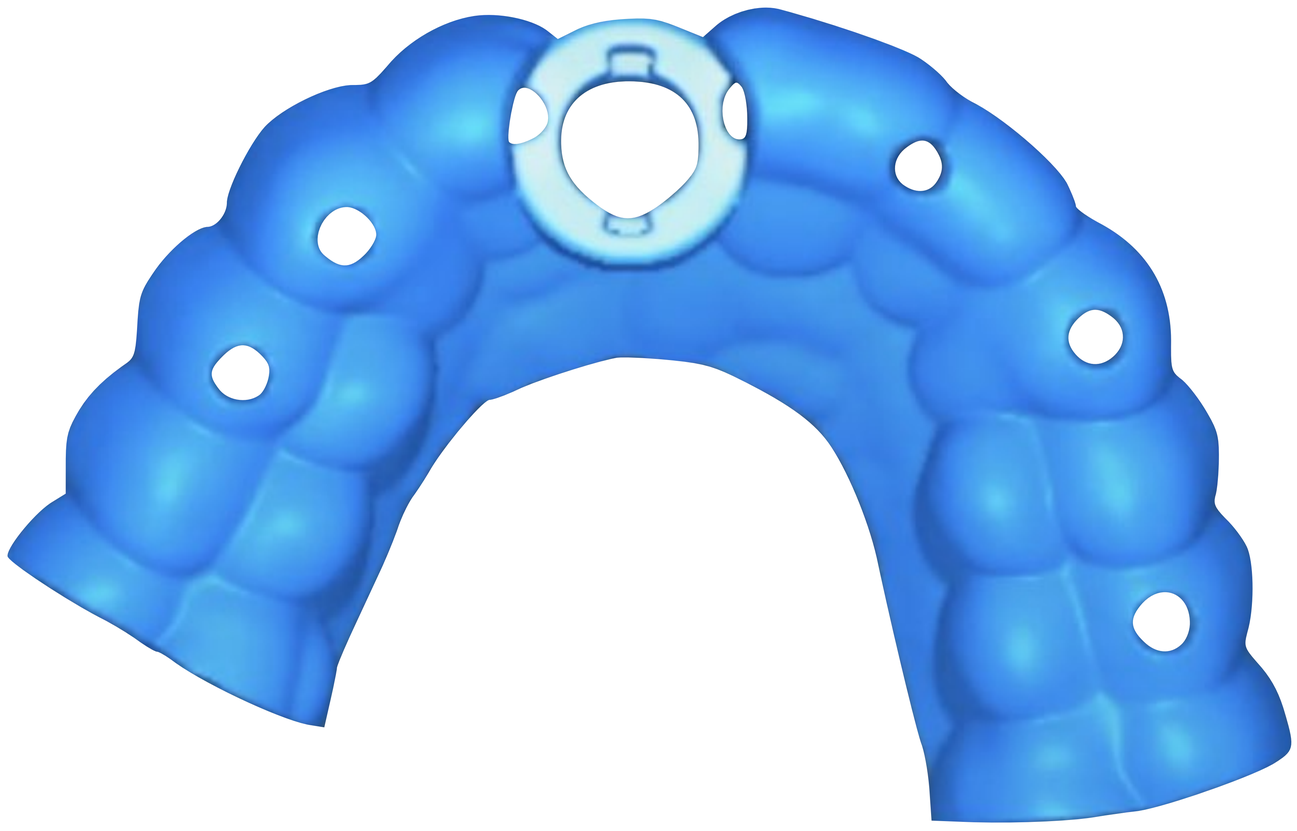
Step 2

A virtual scan body is attached to the case using the feature in the Romexis implant planning software.



Step 3

A timed surgical guide is designed and fabricated.

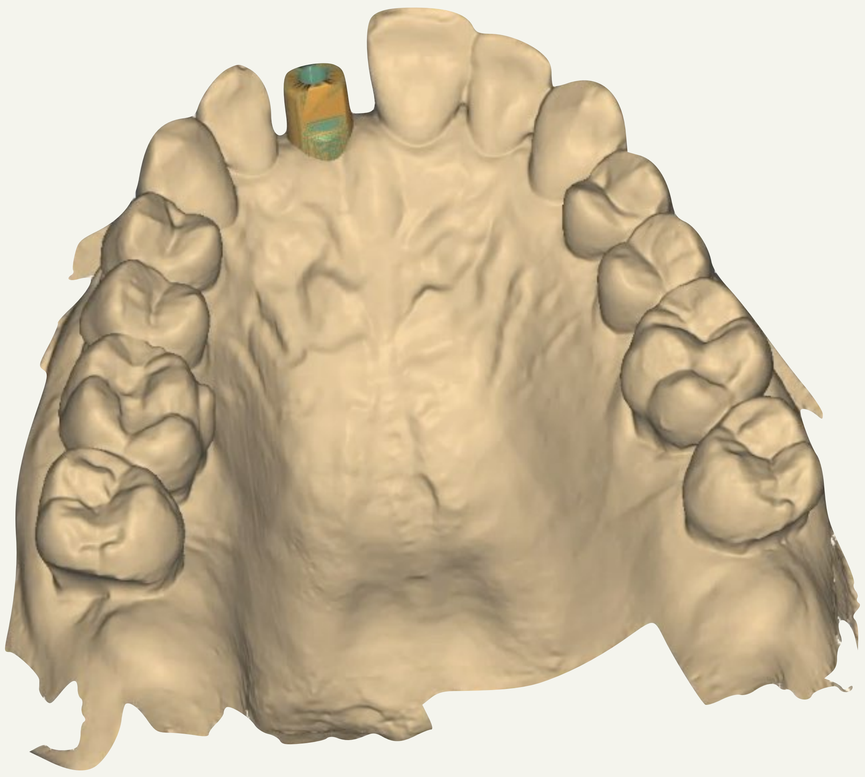


Step 4

Guide is printed and sleeve bonded in.

Step 5

The models are exported from the implant planning software, including the scan body. These files are imported into a laboratory software and a prosthetic is designed. From this information, you can design a custom abutment and final restoration, a TiBase restoration, or a monolithic direct-to-fixture restoration. In this case I designed a screw-retained restoration on a TiBase using a Uris implant and TruAbtument TiBase. I also have the option to print this direct to fixture.



CHAPTER 12: IMPLANT PROVISIONALS

These are the three options for the time of surgery: 1) A printed custom healer that can be delivered in case I do not get torque, 2) A restoration printed monolithic that is designed to be placed direct to fixture, and 3) a restoration that sits on a TruAbtument TiBase. These crowns are fresh off the printer and still wet with resin. After cleaning up the restorations, I decided to go with the direct-to-fixture restoration that had the printed hex included. Many printers will struggle with the accuracy of the hex and the screw channel. If this is the case, the best bet is a fabricate a TiBase restoration.

This restoration has a perfect fit on the TiBase. Notice, that this TiBase is hexed, which means the implant must be placed-timed. If you are concerned you can buy a non-engaging tibase with no hex. However, using a timed guide this should be pretty routine. I will keep this TiBase version as a backup in case the monolithic printed hex fails.

CHAPTER 12: IMPLANT PROVISIONALS

Here you can see the monolithic restoration being fitted on the implant for demonstration purposes. It is important to verify fit and evaluate everything, especially when using new techniques such as this direct-to-fixture printed prosthetic.

On the day of surgery, the guide is placed and verified for fit, which as you can see in this case the guide fits perfectly.

The osteotomy is made through the guide and to depth. Notice the drill has a depth stop drastically lowering the risk of errors during osteotomy preparation.

The implant is placed through the guide and to depth with special attention being placed on the timing of the implant (where the vertical notch on the sleeve aligns with the vertical notch on the implant driver).

The restoration is then screwed into place. In this case, a roll graft was utilized to gain keratinized tissue thickness on the facial.

This is the patient 6 months later ready for final restoration. You can see very little wear on the printed restoration with the color and texture being nearly identical to when the restoration was originally placed.

CHAPTER 13

Quick Reference

This chapter is a quick guide to many of the concepts mentioned in the book.

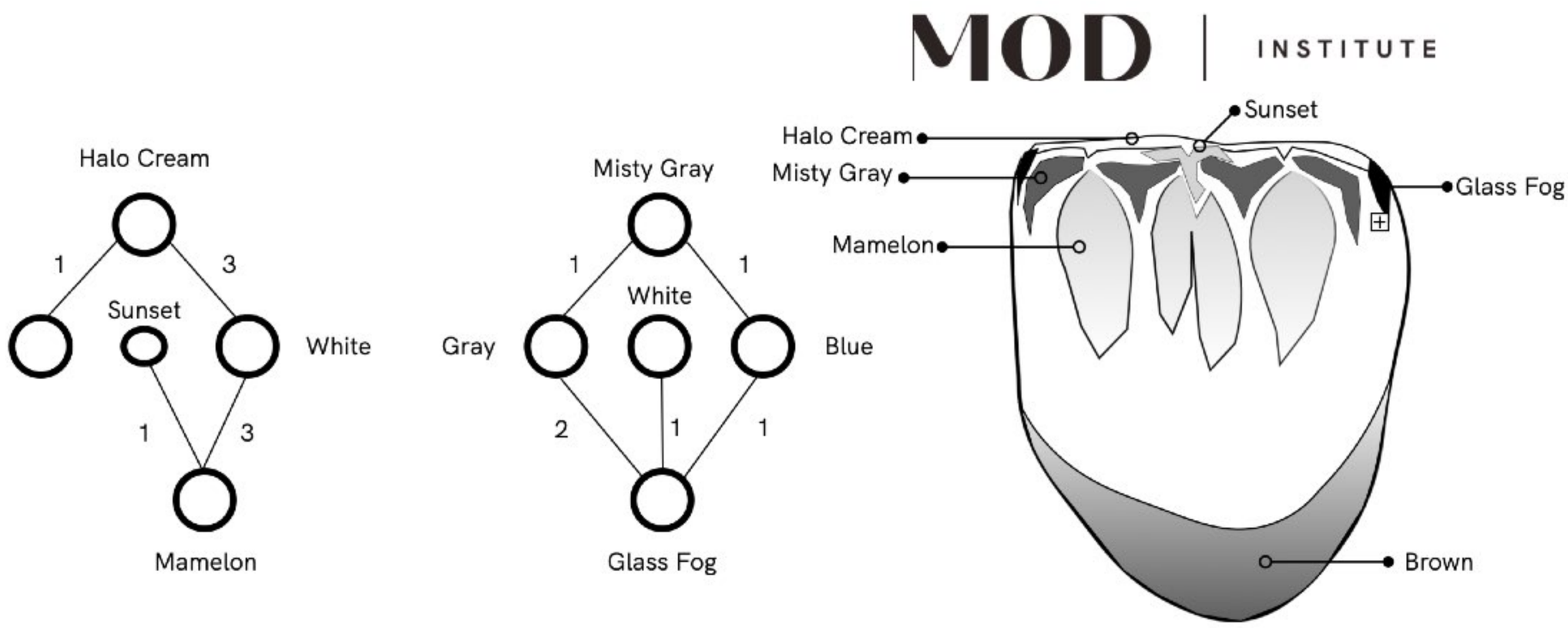
Finishing of Printed Restorations:

1. Hand Polish
2. Stain and glaze

1. Hand Polish

To hand polish you must cure the resin appropriately to hand polish otherwise the surface hardness is too soft and they will not shine.

- Komet 9845C
- Komet 9845M
- Komet 9489M
- Komet 9489F
- If you have a lathe, polish the teeth with a clean polish rag wheel with nothing on it using a light touch. This will finalize the high shine.
- After polish cure for another 1000 - 1800. flashes or follow IFU



This represents the MOD Cheat Code for coloring any tooth.

2. Stains & Glaze

Do not cure in a manufacturers curing unit before characterization this way.

I recommend using IPS Empress Direct resin stains with the candy coating technique. First paint a thin coat of native print resin onto the restoration and leave unpolymerized. Apply your stains as seen above. These are light cured tacked into place with the Ivoclar Vivadent Powercure hand held light. (You must have a hand held curing light with a 385nm bulb). After cured with the hand held light you now must put the teeth in the manufacturers recommended curing unit in glycerin or follow IFU. The restoration can then also be hand polished.

Finishing a Split File Denture

To hand polish you must cure the resin appropriately to hand polish otherwise the surface hardness is too soft and they will not shine.

1. Hand Polish
2. Stain and glaze

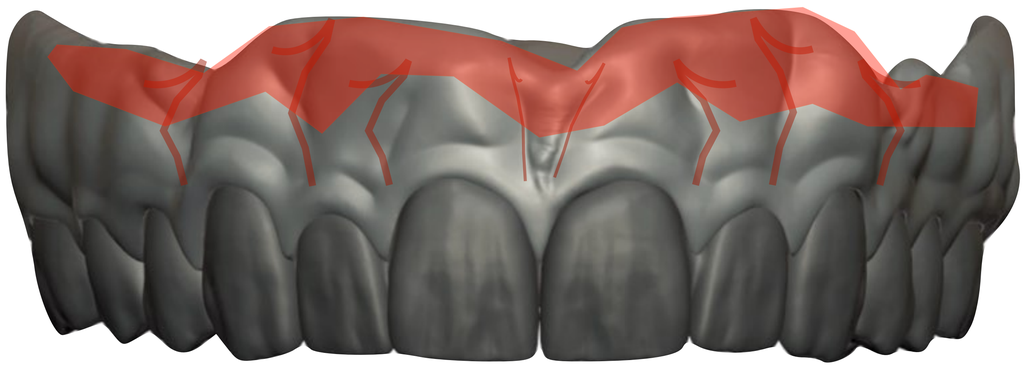
1. Hand Polish

To hand polish you must cure first following IFU . The best way to polish base after curing:

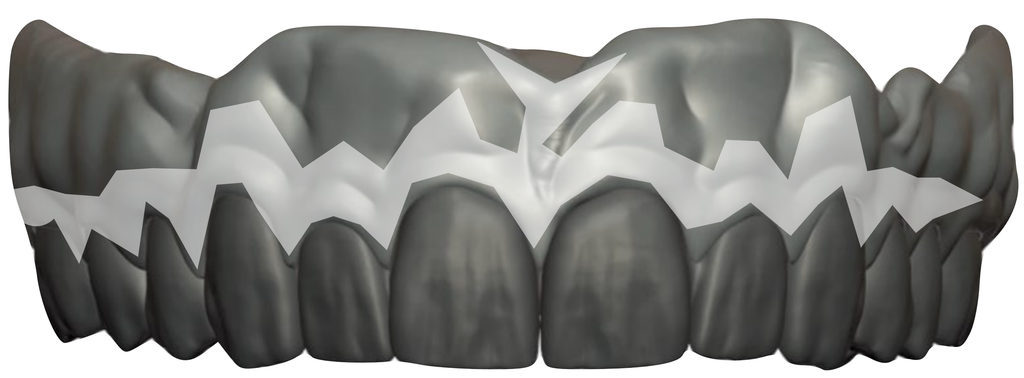
- Fine grit polish paste using a lathe and light pressure on a horse hair lathe brush.
- Follow up with a fine rag wheel with nothing on it with a light touch to create a high shine.

2. Stains

To stain you must not precure.



1. Add Anax Gum Red Paint to deep areas and borders



2. Add Light Pink Flow to the attached tissues

Recommended Reading

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