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YOUR GUIDE TO:

3D-Printed Flex RPD

By Dr. Wally Renne

INTO THE FUTURE

This book dives into one of the most thrilling and new frontiers of digital dentistry: **3D printed Flex Partial Dentures**. For the first time, clinicians, digital designers, and lab technicians can harness emerging materials and additive manufacturing to produce removable prosthetics that rival , and in many cases surpass traditional methods of flex partial denture manufacturing.

We are standing at the edge of a revolution. New resins and workflows are arriving faster than ever, creating enormous opportunities but also leaving a void of reliable knowledge. How do you properly treatment plan, design, print, and finish these prosthetics with consistency? That is the challenge, and the promise this book intends to answer.

This book doesn't just scratch the surface. It is the most comprehensive guide on flex partial dentures available today, offering practical protocols backed by research and real world experience. It's a rallying call for dentistry to unite behind technology while staying firmly rooted in sound diagnostic principles and timeless design guidelines. Remember, these flex prosthetics are not for every patient and great care must be made in treatment planning and digital design to avoid destruction of the surrounding dentition and periodontium.

Thousands of MOD alumni around the globe are already part of this movement. By becoming a **MOD Pro Member**, you'll unlock access to an entire ecosystem of online courses, in depth videos, and premium resources, including our flagship Flex RPD course.

Dentistry is changing fast. The only question is: will you be leading that change, or following it?
Happy printing,

CHECKLIST - WHEN TO USE FLEX PARTIAL DENTURE

Flex vs Cast Metal

When to pick Flex

Flex RPD

☐ **OCCLUSAL HARMONY**

Flex partial dentures are not supported by the hard tissues as well as cast metal partial dentures, and this can cause damage to the hard and soft tissues with long-span distal extensions.

☐ **HIGH ESTHETIC DEMANDS**

3D-printed flex partial dentures are one of the most esthetic options available for restoring missing teeth with a removable appliance.

☐ **NO MOBILITY**

Because flex partial dentures engage deeper undercuts and rely on lingual plating for rigidity, it is often unwise to use them when mobility exists.

☐ **5 YEAR**

A well-fitting flex prosthesis is essential, as one that fits poorly can be damaging. To expect a prosthesis to fit well in the dynamic environment of the mouth with hard and soft tissue changes beyond 5 years is unreasonable.

Cast Metal RPD

☐ **OCCLUSAL DYSFUNCTION**

Cast metal frameworks with proper guide planes, rest seats, and reciprocation are better suited for patients that have signs of clenching and grinding or other occlusal dysfunction.

☐ **LOW ESTHETICS**

Cast metal frames, cast or wrought-wire clasps, and metal rest seats can be unsightly and are often not accepted by patients.

☐ **MINOR MOBILITY**

Class I mobility is acceptable for a cast metal partial denture. With proper design, it can actually help stabilize and distribute forces across the arch.

☐ **7-10 YEAR**

Some dentists consider it a badge of honor to have old partial dentures in service longer than 10 years. It should not be. Our patients deserve a new custom-fitting prosthesis that is updated to the changes of the dynamic oral environment.

CHECKLIST - WHEN TO USE FLEX PARTIAL DENTURE

Flex Contraindications

When to skip Flex

Flex

- ☐ **LESS THAN 4MM INTEROCCLUSAL**

The lack of interocclusal space in a distal extension will require the base to be ultra thin in order to accommodate both the tooth and the base. Therefore, the material will be too thin and flexible, and this can damage the periodontal and osseous health.

- ☐ **KENNEDY CLASS I WITH SEVERE ATROPHY**

Knife-edge ridges due to severe atrophy are better suited for a rigid frame. The focus over the surface area of the ridge is too great for a flex partial denture and would result in damage to the surrounding tissues and also could accelerate bone loss.

- ☐ **DEEP OVERBITE CASES**

When there is more than 4mm of overbite, the patient can put excessive rotational force on the prosthesis. This will lead to accelerated failure and stress on the surrounding hard and soft tissues.

- ☐ **EXTREME WEAR CASE WITH OCCLUSAL DYSFUNCTION**

Flex partial dentures are not designed to take the extreme forces generated during parafunctional movements, and this can damage the health of the surrounding dentition.

- ☐ **RESIN ALLERGY**

In rare cases, a patient may be allergic to methacrylate-based resins, and thus it would be better to go with a nylon prosthesis.

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CHECKLIST - WHEN TO USE FLEX PARTIAL DENTURE

3D Printed vs Polyamide

When to pick 3D-printed Flex

3D Printed

- ☐ **EASY TO ADJUST**

  3D-printed flex partial dentures are easy to adjust and polish. No special burs are needed and there is no fraying of the material.

- ☐ **HIGH BOND TO TEETH**

  3D-printed teeth bond tenaciously to 3D-printed flex partial denture base material through covalent bonding of the methacrylate groups.

- ☐ **INEXPENSIVE**

  A flex partial denture can be printed in office for $15.

- ☐ **STANDARD HOME CARE**

  No special home care instructions are required for 3D-printed flex partial dentures.

Polyamide (Valplast)

- ☐ **HARD TO ADJUST**

  Special rotary instruments are needed, and even then the staining and fraying of the material makes it difficult to polish.

- ☐ **LOW BOND TO TEETH**

  It is often necessary to have mechanical retention in the denture tooth in order to ensure teeth stay in the base.

- ☐ **EXPENSIVE**

  Lab-made flex partial dentures can cost hundreds of dollars to get fabricated, especially in a timely manner.

- ☐ **SPECIAL HOME CARE**

  A special soaking solution is required for home care that is expensive and not readily available.

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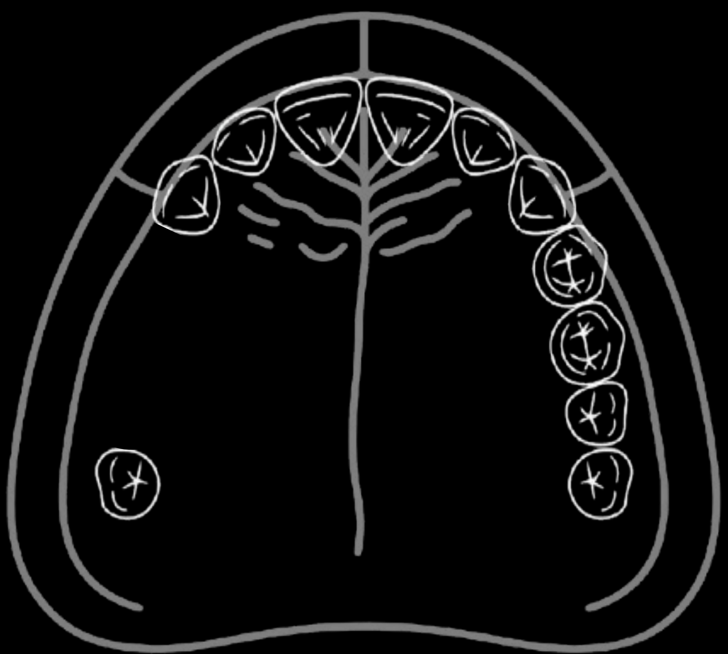
KENNEDY CLASSIFICATION

Design Guide

3D-printed flex partial denture

Class I - bilateral edentulous areas located posterior to all remaining teeth

Class II - unilateral edentulous area located posterior to all remaining teeth



Class III - unilateral posterior edentulous area bounded by teeth

Class IV - anterior edentulous space with no posterior edentulous spaces

APPLEGATE'S RULES

Design Guide

3D-printed flex partial denture

Applegate's Rules for applying the Kennedy Classification

Rule 1: Classification should always be assigned after extractions have been completed, not before.

Rule 2: If a third molar (wisdom tooth) is missing and is not planned to be replaced, it is not included in the classification.

Rule 3: If a third molar is to be used as an abutment tooth, it must be included in the classification.

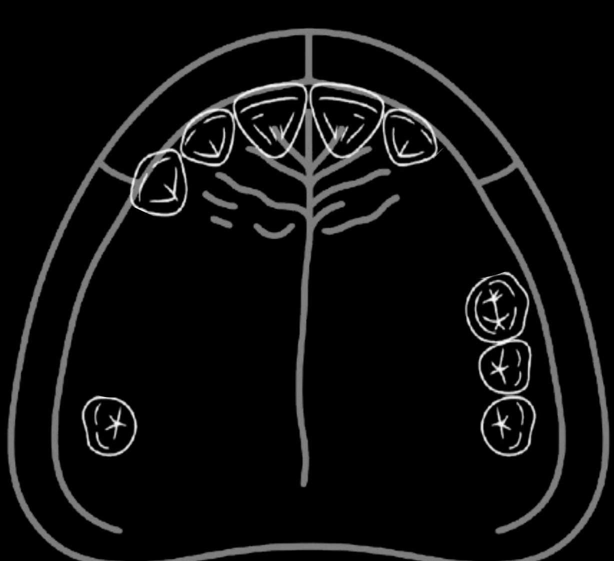
Rule 4: If a second molar is missing and is not going to be replaced, it is not included in the classification.

Rule 5: The classification is determined by the most posterior edentulous area in the arch.

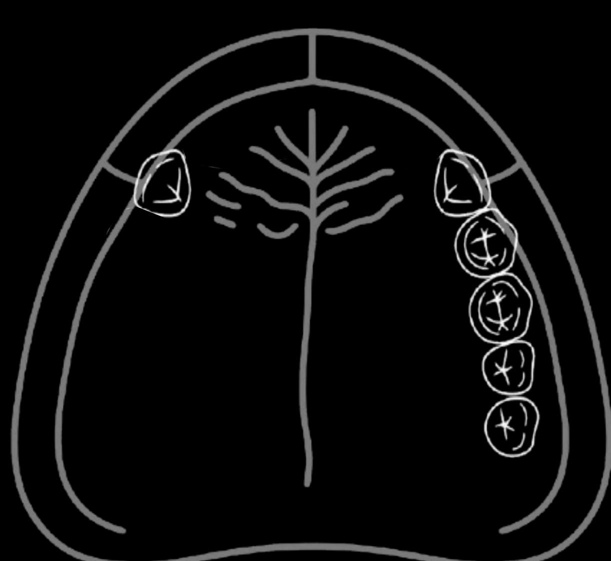
Rule 6: Any additional edentulous spaces, other than the one determining classification, are called *modification spaces*.

Rule 7: The number of modification spaces is considered, but their size or extent is not.

Rule 8: There can be no modification spaces in a Class IV situation.



Class III Mod 1



Class II Mod 1

Class I Mod 1

Design Guide

Background

The advancement of additive manufacturing, or 3D printing, has significantly impacted prosthodontics by introducing new materials and fabrication techniques for dental restorations. Flexible partial dentures, once traditionally made from injection-molded thermoplastics like nylon (e.g., Valplast), can now be 3D printed using flexible, biocompatible photopolymer resins. These materials offer several advantages, including digital design precision, reduced manufacturing time, and material efficiency. The biomechanical behavior of these printed dentures, particularly their flexure under occlusal forces, is a critical factor for clinical success. Unlike rigid materials that behave linearly, the flexibility and non-linear properties of these resins require an understanding of plastic beam flexure.

Fatigue and Creep: In the oral environment, a partial denture is subjected to repetitive, cyclic loading during mastication and placement or removal. This necessitates high fatigue resistance to prevent failure over time. The flexible resins must also exhibit high creep resistance, or the ability to resist deformation under a constant, long-term load to maintain their fit.

Stress-Strain Curve: Flexible denture resins have a characteristic stress-strain curve that includes an initial elastic region, where the material deforms linearly and returns to its original shape. However, as the load increases, the material enters a non-linear or plastic region, where permanent deformation occurs.

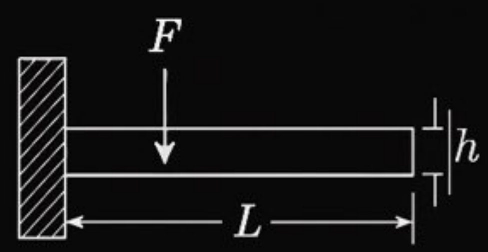
Modeling the Clasp: The retentive clasp of a flexible partial denture can be simplified as a cantilever beam. As the clasp engages an undercut, it bends and stores elastic energy. When occlusal forces exceed the material's elastic limit, the clasp enters the plastic region of flexure. This permanent deformation, while undesirable, is a key consideration in determining the material's fatigue life.

Tuning Flexibility and Rigidity: Digital design allows for the strategic manipulation of material thickness to control the balance between flexibility and rigidity. For instance, retentive clasps can be designed with reduced thickness to increase flexibility and allow for easier insertion and removal, while the major connector can be thicker to provide the required rigidity.

CLASPS

Design Guide

Mathematics



$$\theta_{tip} = \frac{FL^2}{2EI}$$

$$\sigma_{max} = \frac{6FL}{bh^2}$$

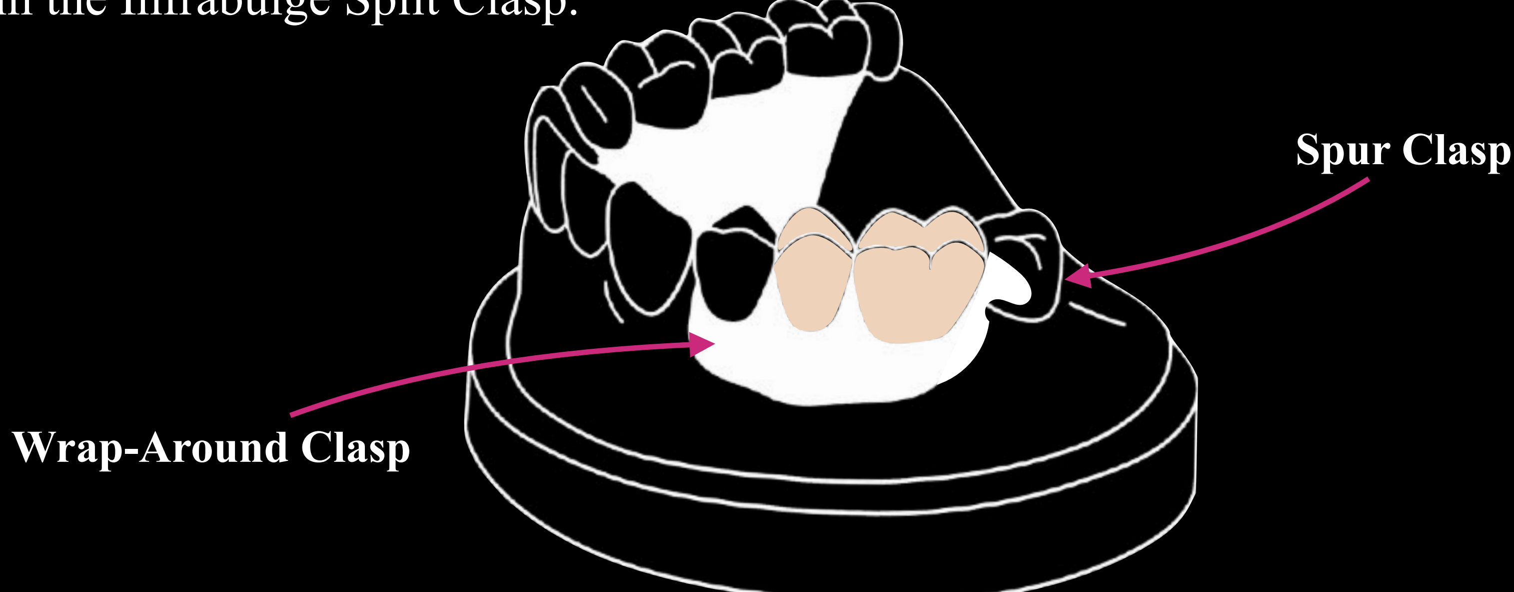
$$d_{tip} = \frac{FL^3}{3EI} \qquad I = = \frac{bh^3}{12}$$

Key Formulas
Tip Deflection: δ_tip = (F L³) / (3 E I)
Tip Rotation: θ_tip = (F L²) / (2 E I)
Maximum Stress: σ_max = (6 F L) / (b h²)
Second Moment of Area: I = (b h³) / 12

Although simple cantilever beam mechanics does not fully explain clasp flexure, it does help. This shows the mechanics of a cantilever beam subjected to a perpendicular point load at the free end. The key geometric parameters are beam length (L), width (b), height (h), and the modulus of elasticity (E). Formulas for deflection, stress, and rotation are included. In dentistry, for clasps we are always bending about the weak axis perpendicular to the clasp arm, and therefore we need to swap b and h in the above formulas where thickness becomes more important than height.
Sensitivity of Parameters deflection of clasps in a buccolingual direction not an occlusogingival direction.

- Deflection grows cubically with length (L^3).
- Deflection decreases cubically with width (b^3).
- Deflection decreases linearly with height (h).
- Material stiffness (E) also reduces deflection linearly.

Here we have two classic styles of clasps: a Wrap-Around Clasp that is long, tall, and thin, and a Suprabulge Spur Clasp that is short and more narrow. We have a few levers to pull to determine clasp flexibility. Thickness is the biggest determinant. However, in dentistry for 3D-printed clasps, we can't get thinner than 1mm due to material properties, and we can't get thicker than 1.5mm as most patients will find 1.5mm to be uncomfortable. Thus, 1mm is the standard clasp thickness. Therefore, we often do not alter thickness of the clasp and instead we alter height and length. If a clasp arm is short then we can make it less high, as both are linear determinants. If a clasp arm is longer, we can make it higher. One trick is to decrease height by including a stress breaker as is seen in the Infrabulge Split Clasp.



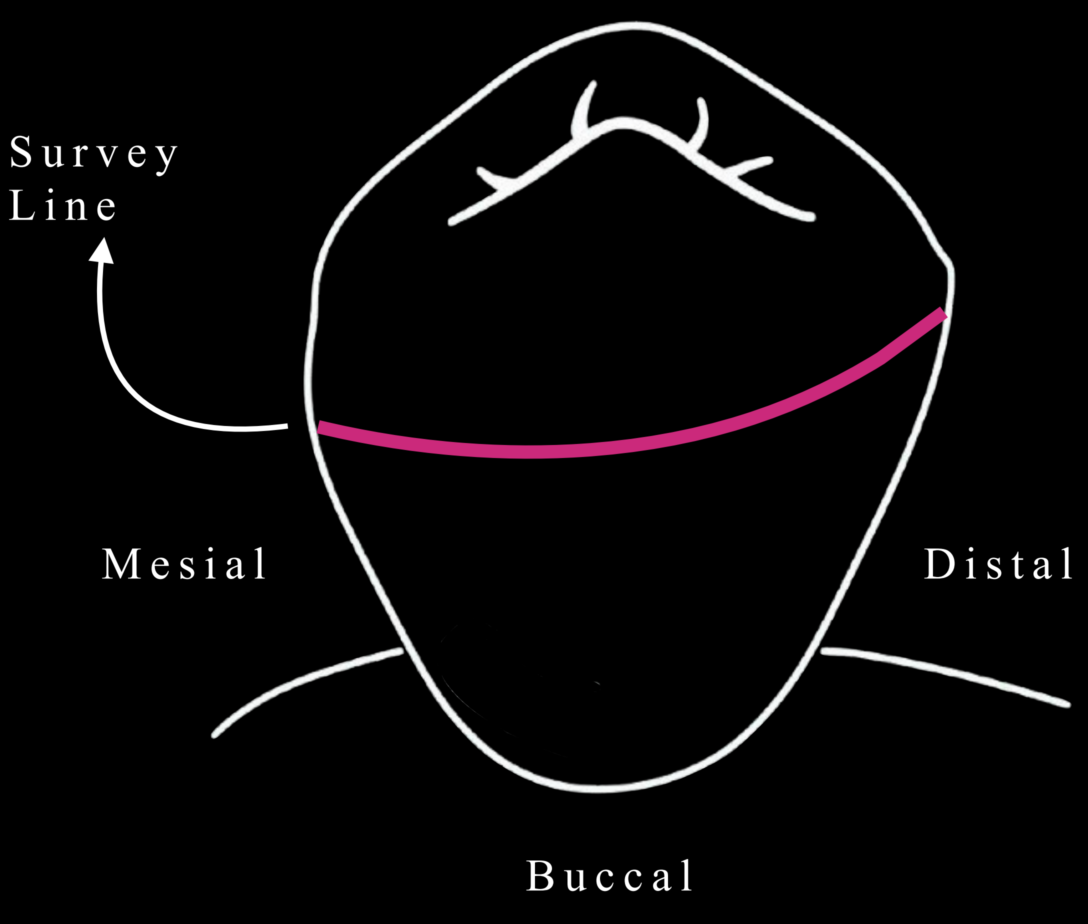
CLASPS

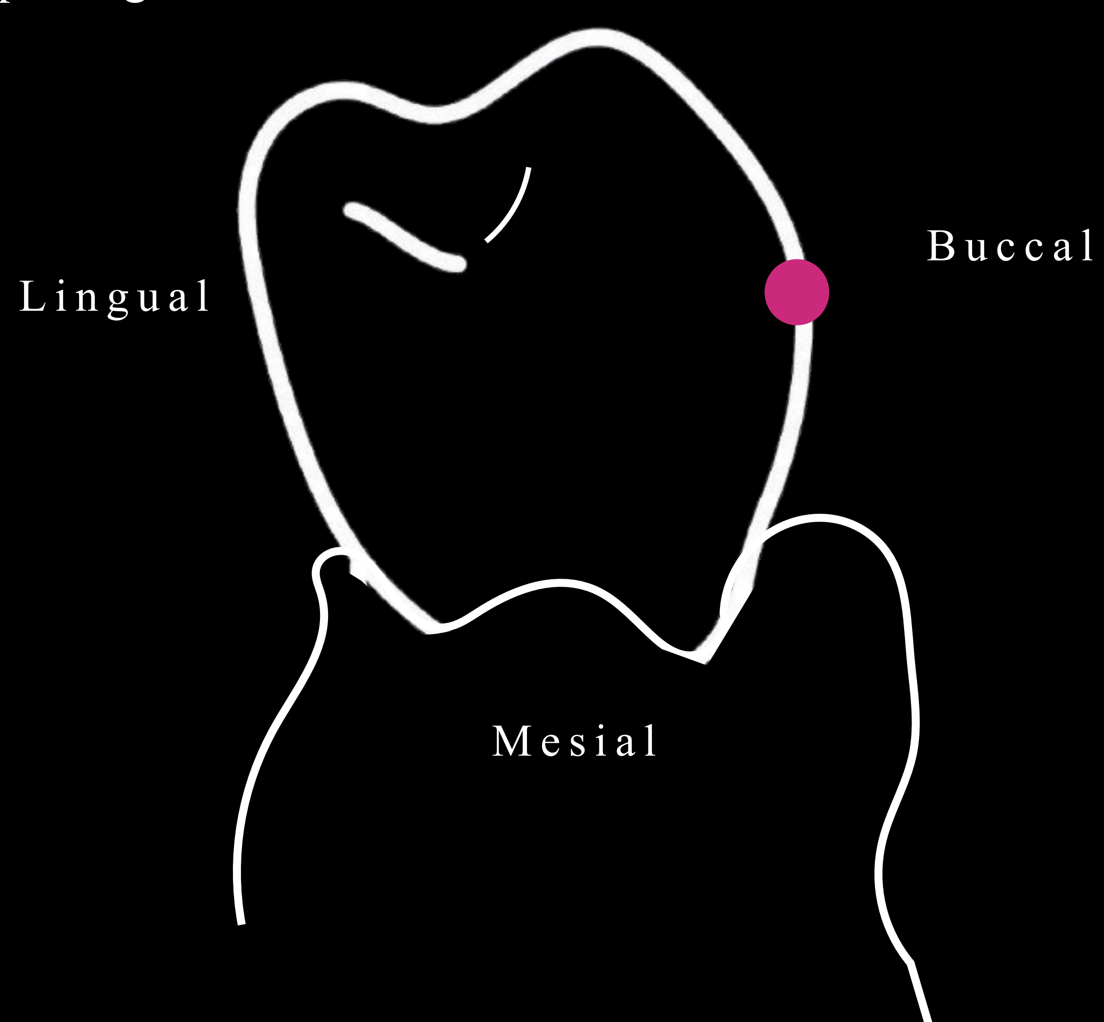
Design Guide

Survey lines

3D-printed resin materials used for flex removable partial dentures (RPDs) have a lower modulus of elasticity compared to most dental alloys used for clasps. Because of this flexibility, it is recommended that clasps made from thermoplastic resins be designed to engage a broader surface area and extend into deeper undercuts on the abutment teeth. However we have to be careful exactly how much undercut we engage because flex resin clasps are susceptible to fatigue-related deformation during repeated insertion and removal. These resins demonstrate significant elastic deformation and are able to rebound back to the original position; however, once a material is repeatedly stressed beyond its proportional limit, its dimensions are permanently altered through a process of plastic deformation. Excessive retentive force on a resin clasp may therefore lead to permanent deformation or even fracture, compromising retention. The biology and health of the clasped tooth must always be considered and of the highest priority. Engaging too severe an undercut can put stress beyond the natural periodontal ligament leeway space and cause permanent damage to the PDL, bone remodeling, and even bone loss.

To prevent this, the design of resin clasps must be guided by the mechanical properties of 3D-printed flex resins and their resistance to deformation. Proper design should include an evaluation of stress distribution, ensuring that the magnitude of the undercut and the blockout width on the abutment tooth are carefully selected to balance retention with long-term durability. To do this in digital design software, we must consider the vertical and horizontal blockout as well as the undercut depth. The Survey Line is determined by the tilt (path of insertion) of the partial denture and is critical for determining clasp design.





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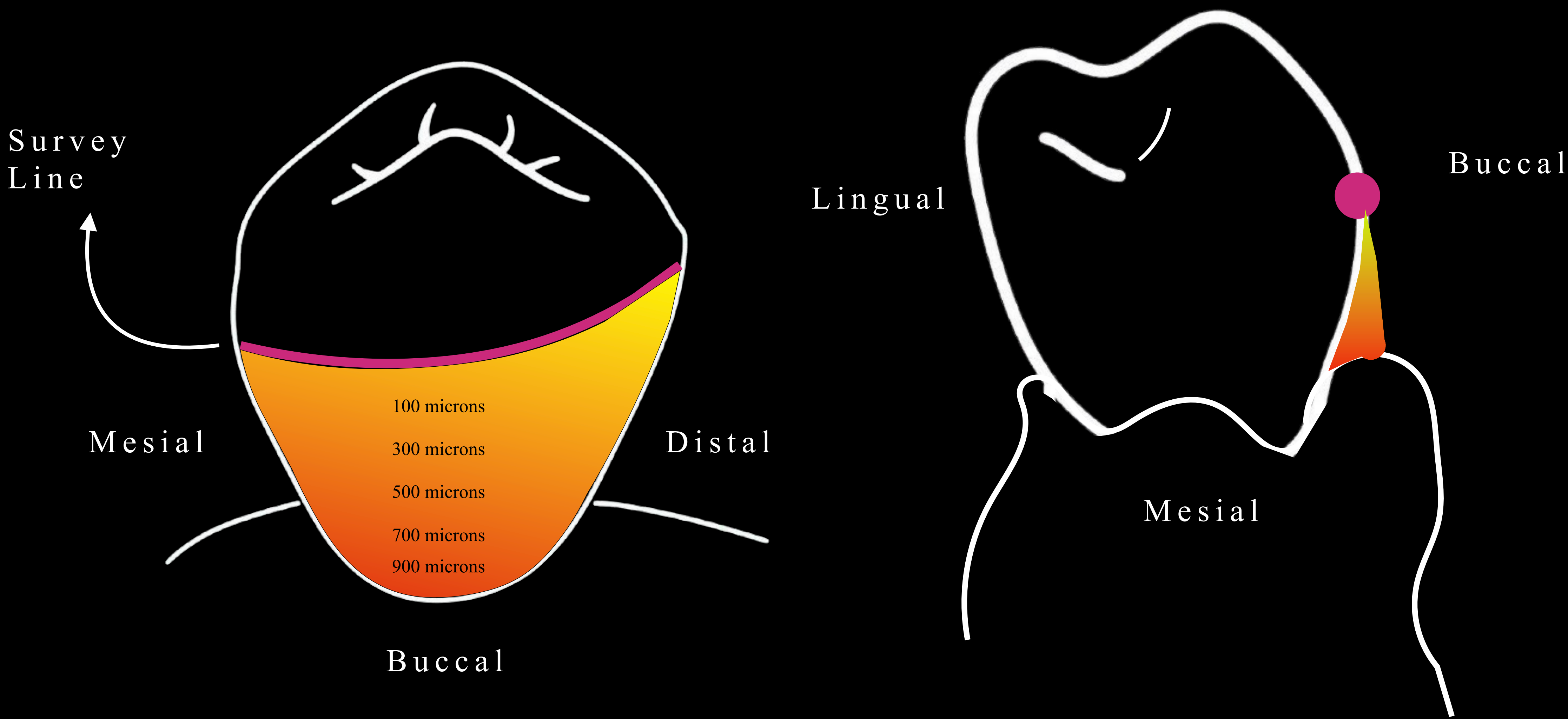
Design Guide

Undercuts



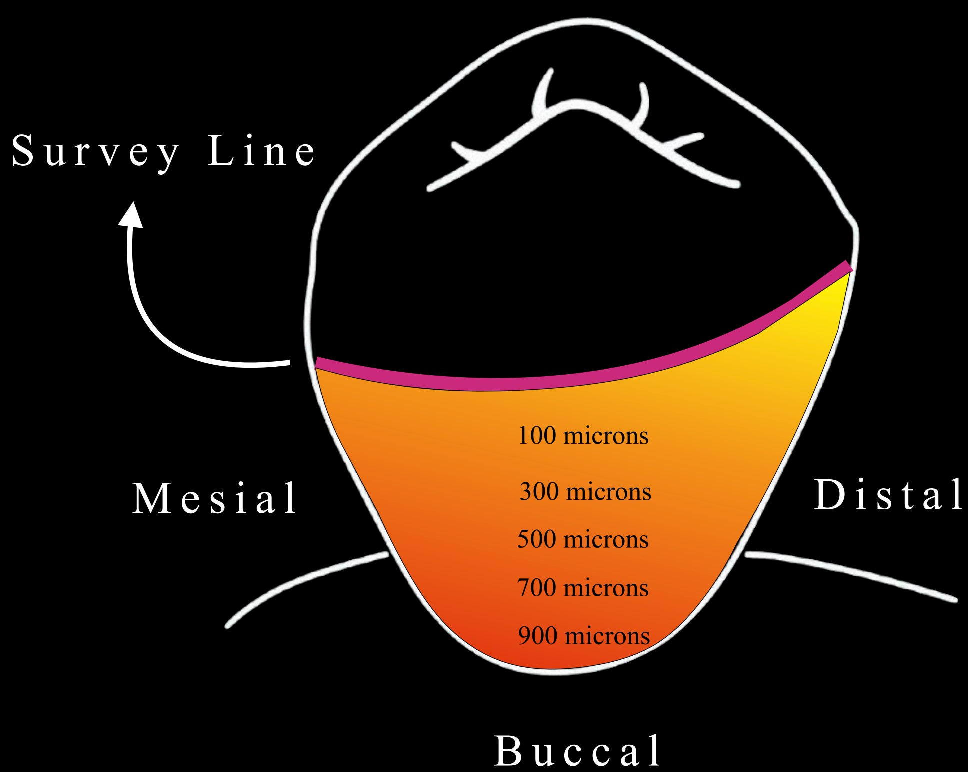
Everything apical to the survey line is considered an undercut. For flex partial dentures, the rules are different compared to cast and wrought-wire clasps. We have to balance retention of the clasp while respecting the tooth integrity and also considering the mechanical properties of the clasp. For example, if we engage too much undercut, we run the risk of deforming the clasp too much at every insertion and removal as it flexes over the survey line. This can lead to increased creep and plastic deformation, causing premature loosening. Furthermore, if too much force is placed on the natural tooth from the clasp flexing over the tooth, we can cause damage to the tooth. Lingual plating and bracing is helpful as it slightly prevents tooth deflection during removal and insertion. If properly designed, when the clasp is flexing over the survey line and the most bulbous area of the tooth, lingual pressure is simultaneously applied through the lingual plating to counteract this deflection. The retention of the clasp during full placement as well as the force placed on the tooth during removal is complex. Many variables must be considered, including the thickness of the clasp; the shape, length, and surface area of the undercut; the depth of undercut engaged; and the modulus of elasticity and flexural strength. Likewise, the clasp must engage enough undercut to retain the partial denture. Typically, 20N of retention force is needed in total for a prosthesis, and this is spread across multiple clasped teeth. In some situations, four teeth might be clasped at 5N each to total 20N, while in other situations two teeth may be engaged at 10N each.

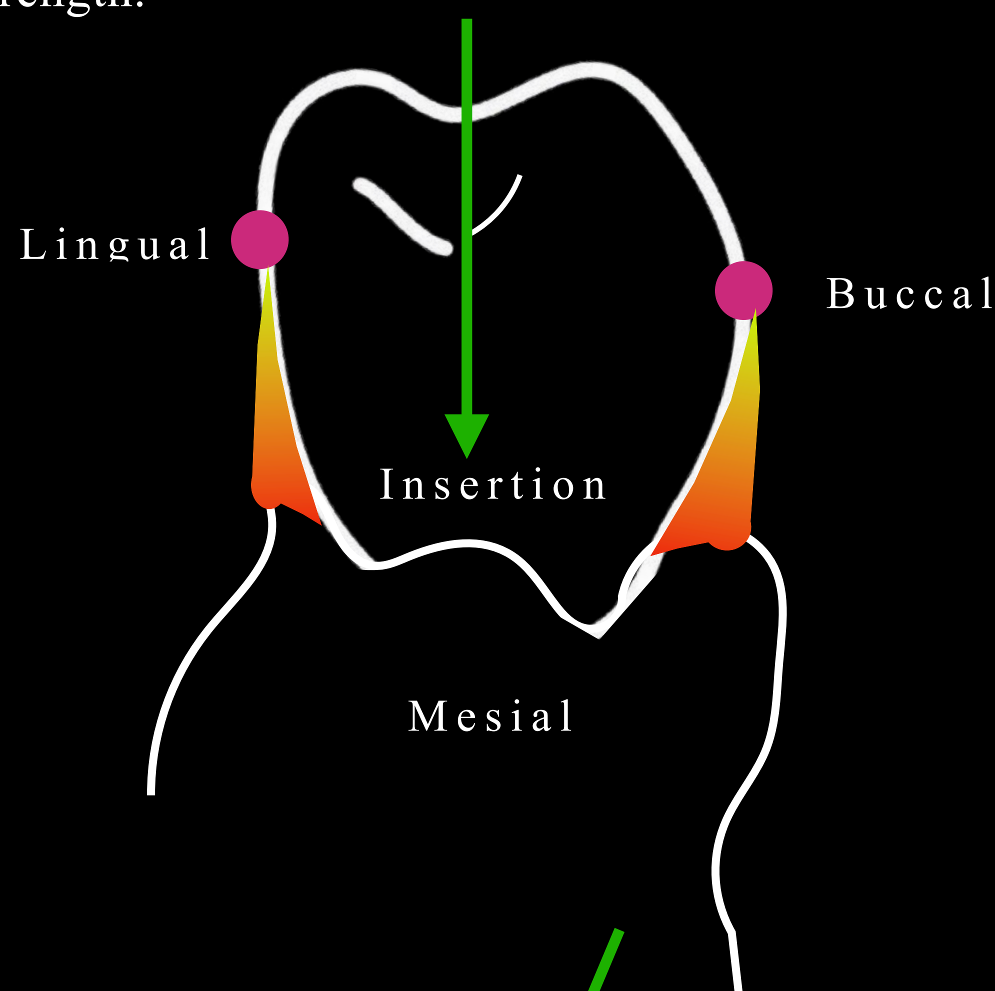
CLASPS

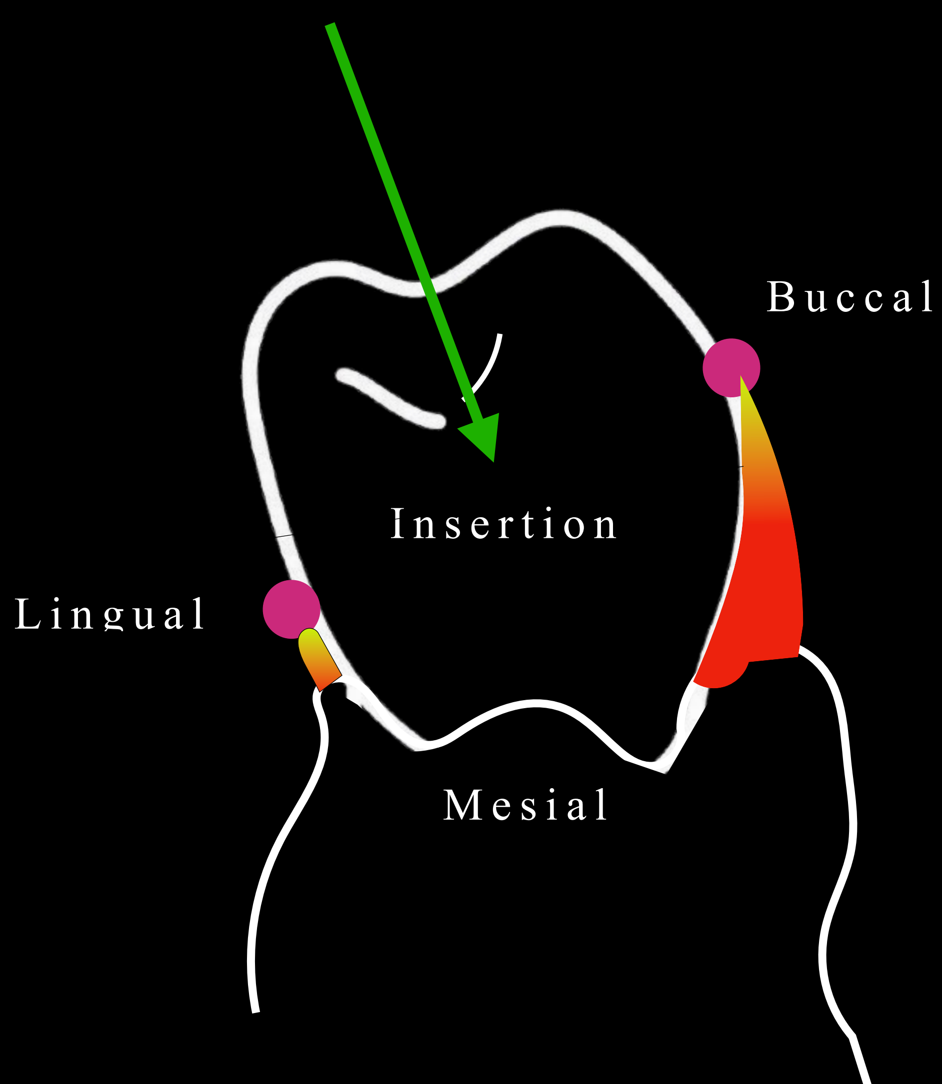
Design Guide

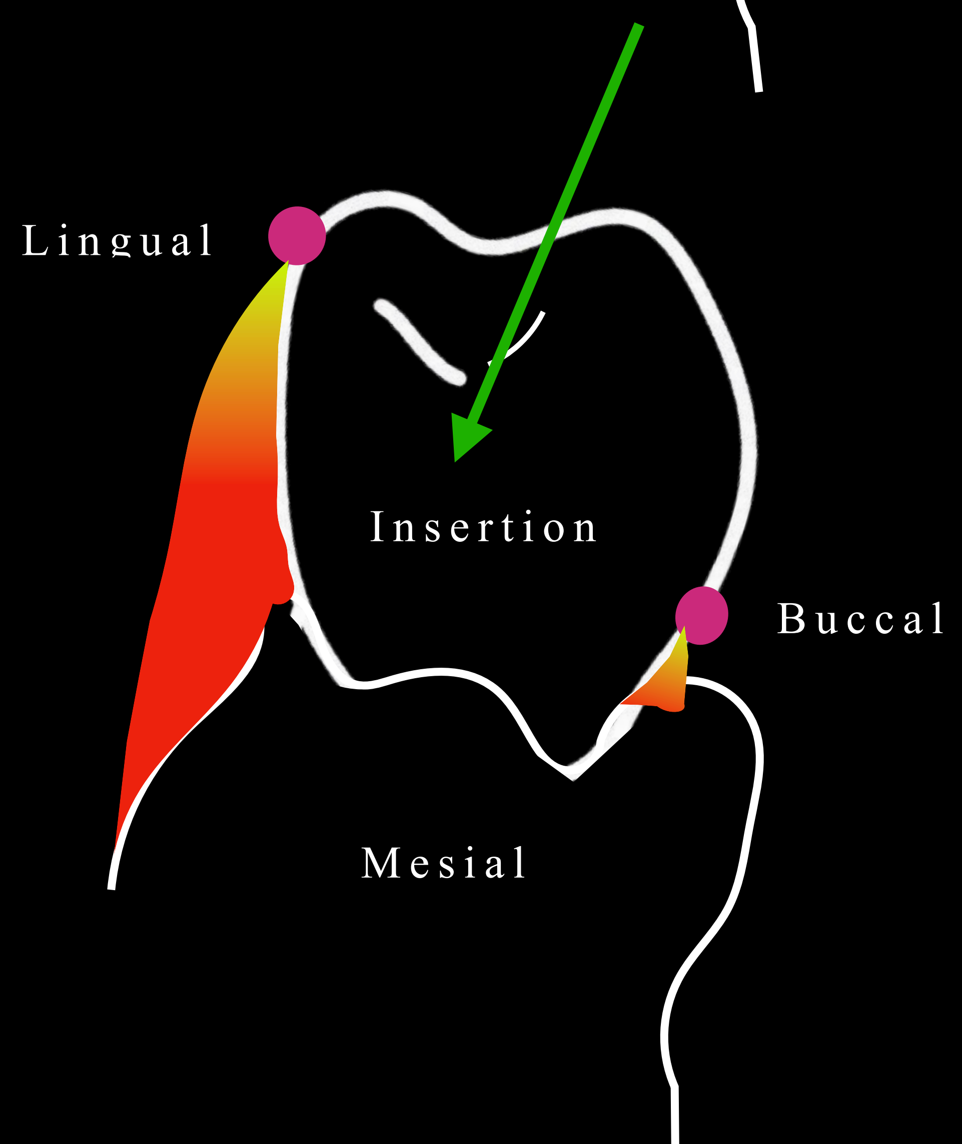
Insertion direction

The tilt of the model is what determines the survey line position and partial denture insertion path. It is the most critical factor to consider early on in design. Let's look at some examples of how changing the tilt alters the undercut location and strength.









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Design Guide

Blockout

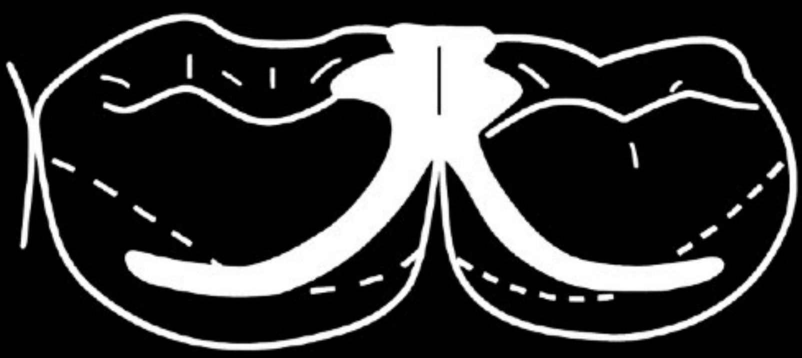
In design software, the entire undercut area apical to the survey line is usually filled in with virtual blockout wax. Using the software remove tools, we edit the blockout wax to the desired vertical and horizontal blockout needed to provide ideal retention and balance forces on the tooth while taking into consideration mechanical properties of the clasp. In RPD design, horizontal and vertical blockout refer to two distinct types of dental undercuts that must be managed during the surveying process. The key difference lies in the orientation of the undercut relative to the path of insertion, which dictates the blockout procedure and its purpose.

Horizontal vs. Vertical Undercuts in Removable Partial Dentures (RPDs)

Aspect	Horizontal Undercut	Vertical Undercut
Orientation	Located on the lateral (buccal or lingual) surfaces of teeth or on soft tissues. Positioned horizontally in relation to the path of insertion.	Found on proximal surfaces, in deep interproximal spaces, or in tissue areas that could interfere with a major connector. Oriented parallel to the path of insertion.
Purpose in RPD Design	Provides direct retention by allowing a flexible clasp arm to engage the tooth and hold the denture securely in place.	Must be mostly eliminated (blocked out) to allow rigid components such as thicker major or minor connectors to seat properly without interference.
Blockout Method	Blockout is applied selectively: non-retentive undercuts are filled in, but the designated retentive area is left open for clasp engagement.	A complete parallel blockout is applied using a dental surveyor to ensure the undercut is removed in line with the chosen path of insertion.
Clinical Considerations	Desirable: Essential for clasp retention, preventing dislodgment. Unwanted: If too deep, the clasp may lack sufficient flexibility, causing excessive stress on the tooth or making engagement impossible.	Potential Issue: If not blocked out, vertical undercuts can prevent the prosthesis from seating correctly and may traumatize soft tissues.

Design Guide

Bracing or Reciprocation



Bracing is the resistance to unwanted orthodontic movement of abutment teeth and is provided by **reciprocal arms** or other plating elements placed against **the contralateral side of the tooth that is clasped**. As the retentive clasp flexes over the height of contour during insertion and removal, it generates lateral forces on the tooth. At this moment, the rigid reciprocal arm must engage the guiding plane, neutralizing these forces and preventing tooth movement.
Stability – The resistance to lateral displacement of the prosthesis is achieved through components such as reciprocal arms and minor connectors, which help maintain the RPD in its intended position during function.

In a traditional cast-metal RPD, **bracing** (or reciprocation) is achieved through **rigid components** (like reciprocating arms, guide planes, and proximal plates). These resist horizontal/lateral forces and prevent tooth movement when the retentive clasp flexes over an undercut.

- **Rigid clasp arms** (on the opposite side of the tooth) provide reciprocation.
- **Guide planes** ensure that movement is controlled during insertion/removal.
- The framework itself distributes forces across the arch.

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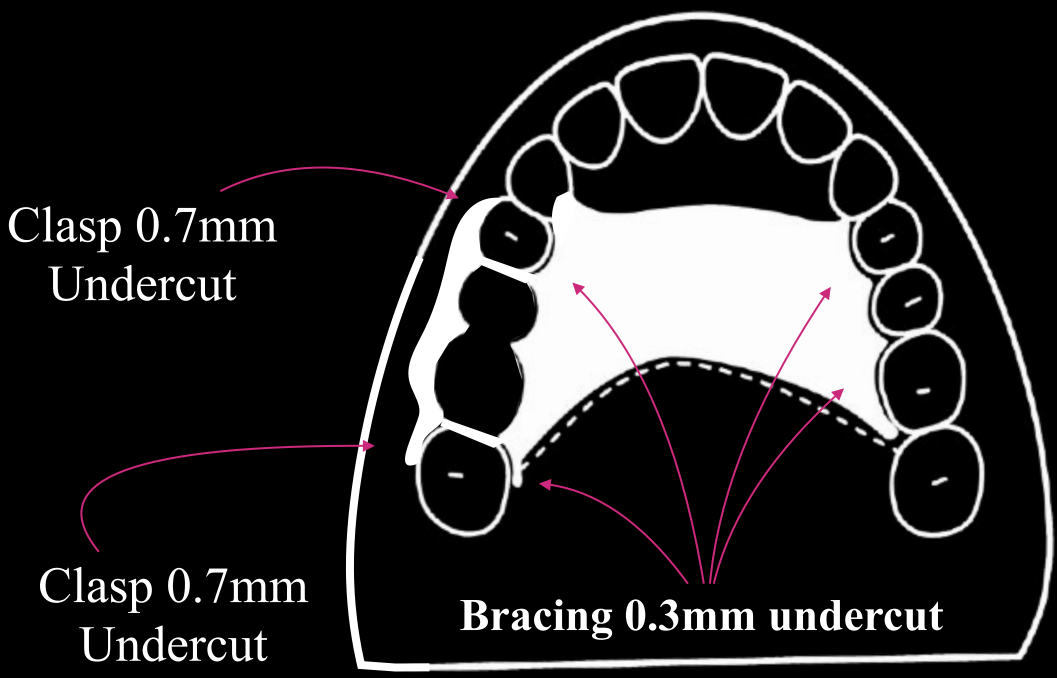
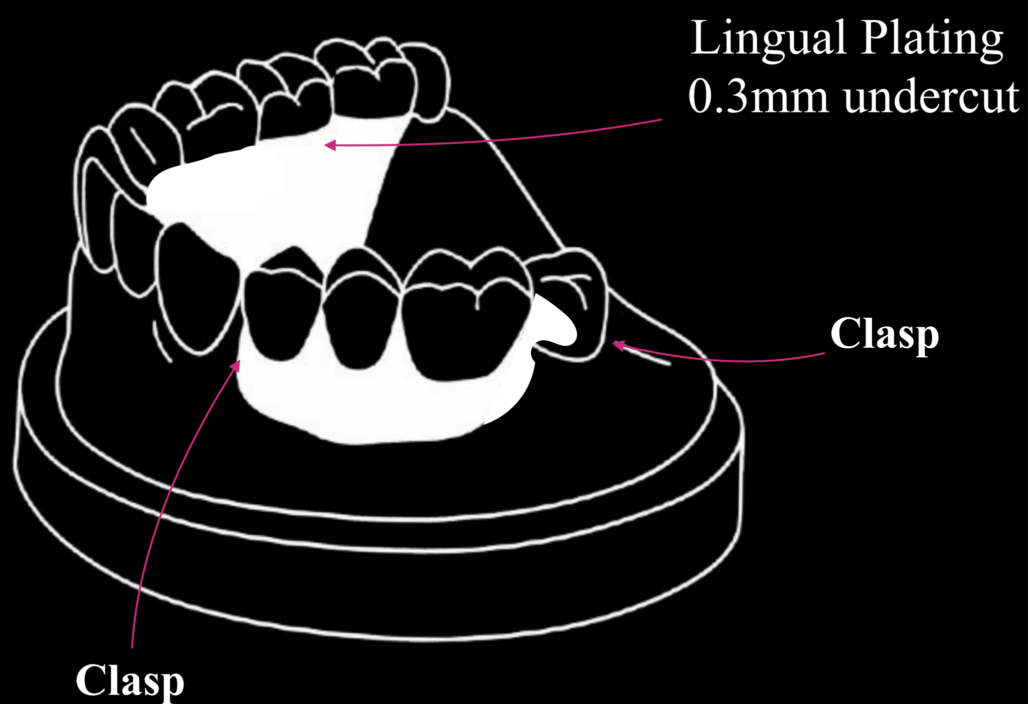
Design Guide

Bracing





The challenge with flexible RPDs is that they are intrinsically too flexible to provide bracing in the traditional manner, but we can design some bracing by focusing on thickness, rigidity, and leveraging special design principles.

1. **Broad Tissue Contact**
    - The flexible saddle/base extends onto keratinized tissue.
    - This wide tissue coverage helps absorb lateral forces instead of transmitting them to abutment teeth.
    - Control the thickness of the tissue to increase rigidity when needed. For example, 2mm-thick resin is rigid enough to offer bracing.

2. **Lingual Plating**
    - Flexible bases can engage natural contours, undercuts, and soft tissue anatomy for indirect stabilization.
    - Example: A high lingual plating can offer lateral resistance and can be designed 1.5–2mm thick depending on desired rigidity.

3. **Strategic Reciprocal Undercut Engagement**
    - Clasps engage deeper undercuts around 0.7mm, but we can also engage minor undercuts on the reciprocal side of the tooth with a flex partial denture. Typically, 0.3mm maximum is engaged, but this helps counteract the lateral forces from the clasp.

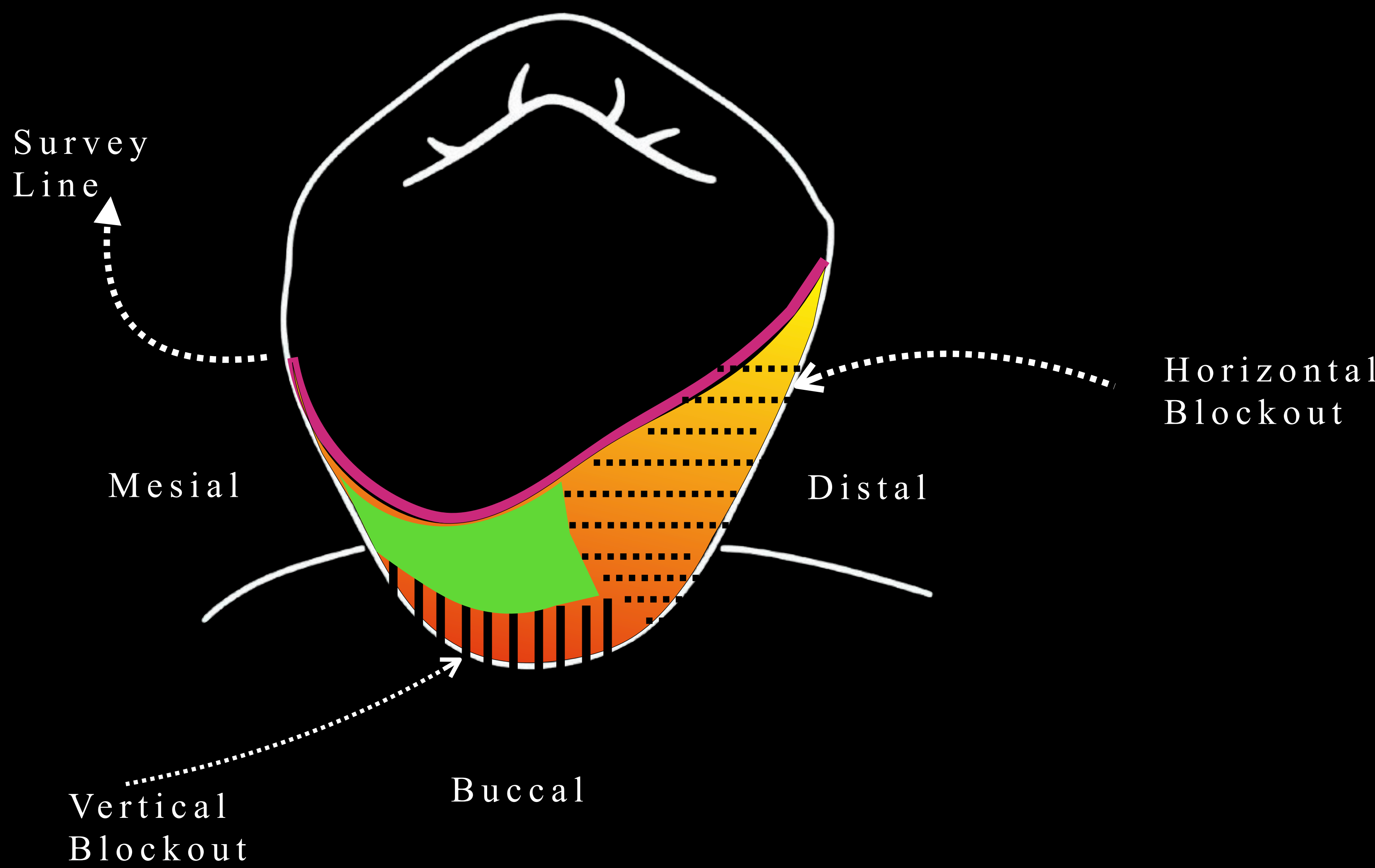
4. **Cross-Arch Stabilization**
    - A flexible RPD tends to flex as a whole. By ensuring **bilateral, cross-arch extension** (not unilateral), bracing is indirectly improved, because forces are spread and counterbalanced across both sides. Broad contralateral tissue contact combined with lingual plating is very beneficial for flex partial dentures.

CLASPS

Design Guide

Undercut engagement through blockout removal

For 3D-printed flex partial dentures, a 0.5–0.75mm undercut is the ideal range for engagement for primary retention. The clasp should be 1mm thick, and where it connects to the major connector should be 5mm incisal-gingivally. The size of the clasp engagement is determined by editing the blockout model, also called the “Virtual Waxup Bottom” in Exocad.



The dotted lines represent horizontal blockout left on the master cast. The vertical lines represent vertical blockout left on the master cast. The green area represents the area where blockout was removed in order to engage the appropriate depth of undercut and surface area. Please note that the clasp might cover the entire area including the blockout area, but only the area in green is retentive and represents where the clasp is actually touching the tooth surface.

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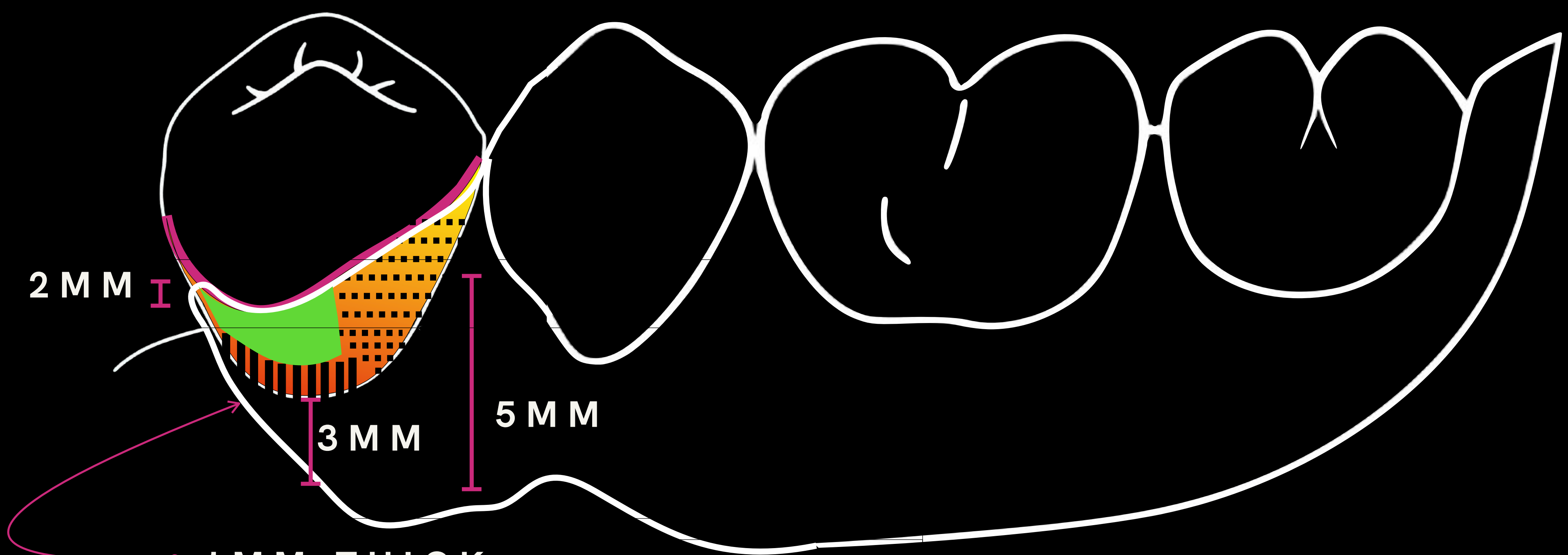
Design Guide

Suprabulge Wrap-Around Clasp



The **Wrap-Around Clasp** is the most common clasp design for flex partial dentures because of its versatility and reliable retention. Ideally, the **occlusal border** of the clasp aligns with the survey line established during diagnostic surveying. When the survey line is positioned too occlusally, however, the clasp may cross into a visible portion of the tooth, leading to an **unfavorable esthetic outcome**, especially in premolar or anterior regions.

The **clasp tip** should measure approximately **2mm in height**, providing adequate retention without excessive bulk. At the junction where the clasp meets the **major connector**, the height should be **5mm**, ensuring strength and resistance to breakage. For added stability, the clasp should extend at least **3mm onto the gingival tissue**, and a **uniform thickness of around 1mm** helps maintain both flexibility and durability.

Retention is achieved by engaging a controlled **undercut of 0.5–0.75mm**. Engagement begins at the **mesial-distal midpoint** of the tooth and extends toward the **embrasure papilla**, distributing forces more evenly. During blockout, wax should be removed from the survey line downward, maintaining a usable undercut depth of up to **0.75mm**. Any undercut deeper than this must remain blocked out to prevent undue stress on the clasp and abutment tooth.

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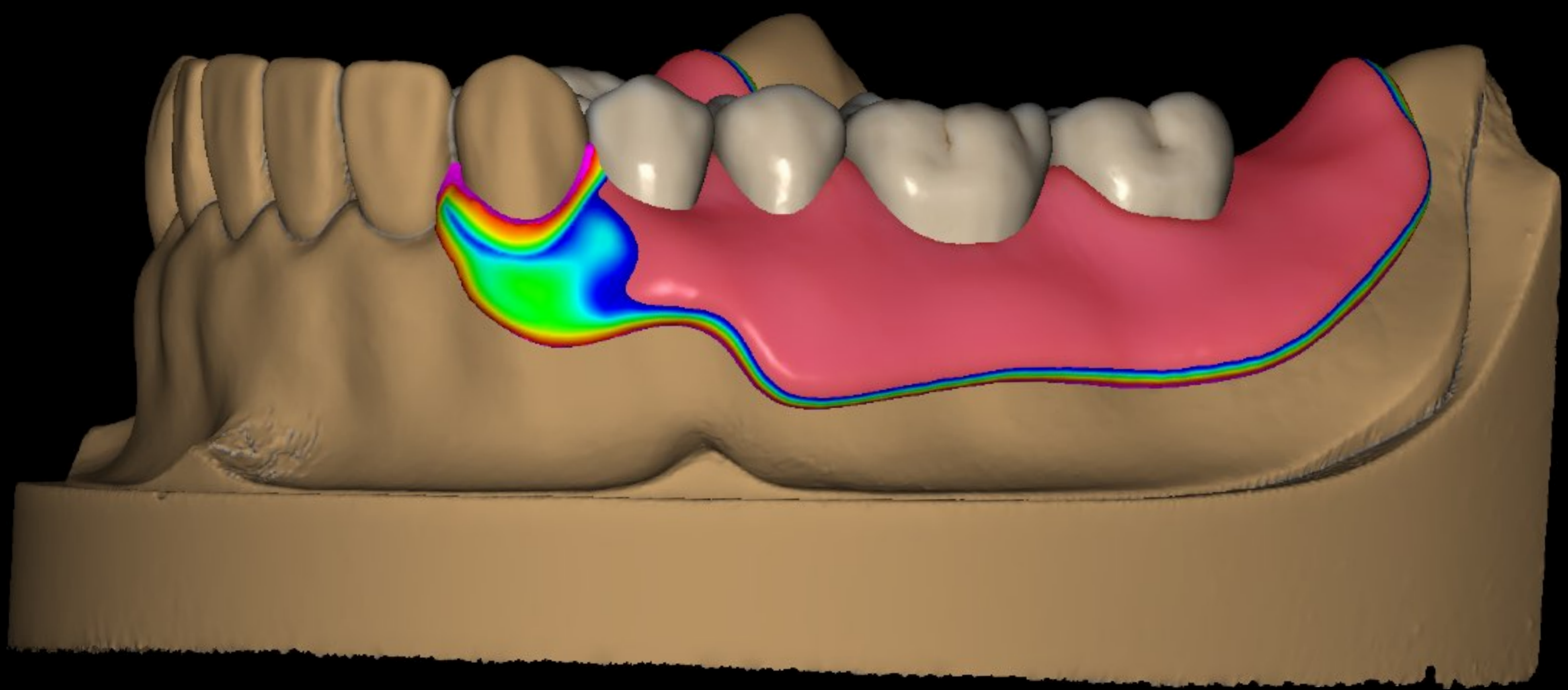
Design Guide

Suprabulge Wrap-Around Clasp



☐ 1MM THICK

The clasp should be 1mm thick, as seen in green. This ensures the print is able to flex while also being strong enough to hold memory over thousands of insertions and removals. The very tip of clasps is 2mm tall but still 1mm thick.

☐ SURVEY LINE

The clasp should start at the survey line. This can be contraindicated if the survey line is very occlusally positioned on the tooth. It drops down to a 0.5-0.75mm undercut.

☐ 5MM JUNCTION

The junction where the clasp meets the major connector must be 5mm tall and 1.5mm thick as seen in blue.

☐ 3MM ON TISSUE

This clasp extends onto the tissue 3mm or more. Therefore, if a large tissue undercut exists, this clasp is contraindicated.

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Design Guide

Infrabulge Split Clasp—My favorite clasp

The **Split Clasp** is indicated in situations where the abutment tooth is **flared or tilted**, creating a pronounced convexity or "high point" that the retentive arm must pass over before accessing the functional undercut. In such cases, the **survey line is positioned more occlusally**, making conventional wrap-around clasp placement challenging. Because of its reduced visibility across the tooth surface, the split clasp is also **well-suited for esthetic cases**, particularly in the premolar or anterior regions.

In design and function, the split clasp bears strong resemblance to the **Roach Clasp** used in traditional cast-metal RPD frameworks. Both rely on the **flexibility of the clasp arm** to achieve retention in areas of complex tooth contour. However, the split clasp adapts this concept specifically to **flexible partial denture design**, where material properties allow it to incorporate flexibility along **both vertical and horizontal axes** at the clasp junction.

This dual-axis flexibility permits the clasp to **deform in multiple directions** during insertion and removal. As a result, it can flex over a prominent bulge without generating excessive stress on the abutment tooth, yet still achieve **secure engagement of the undercut** for reliable retention.

Despite these advantages, the split clasp is **contraindicated in cases with severe tissue undercuts**, as excessive tissue engagement can compromise insertion and removal, reduce patient comfort, and accelerate material fatigue.

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Design Guide

Infrabulge Split Clasp

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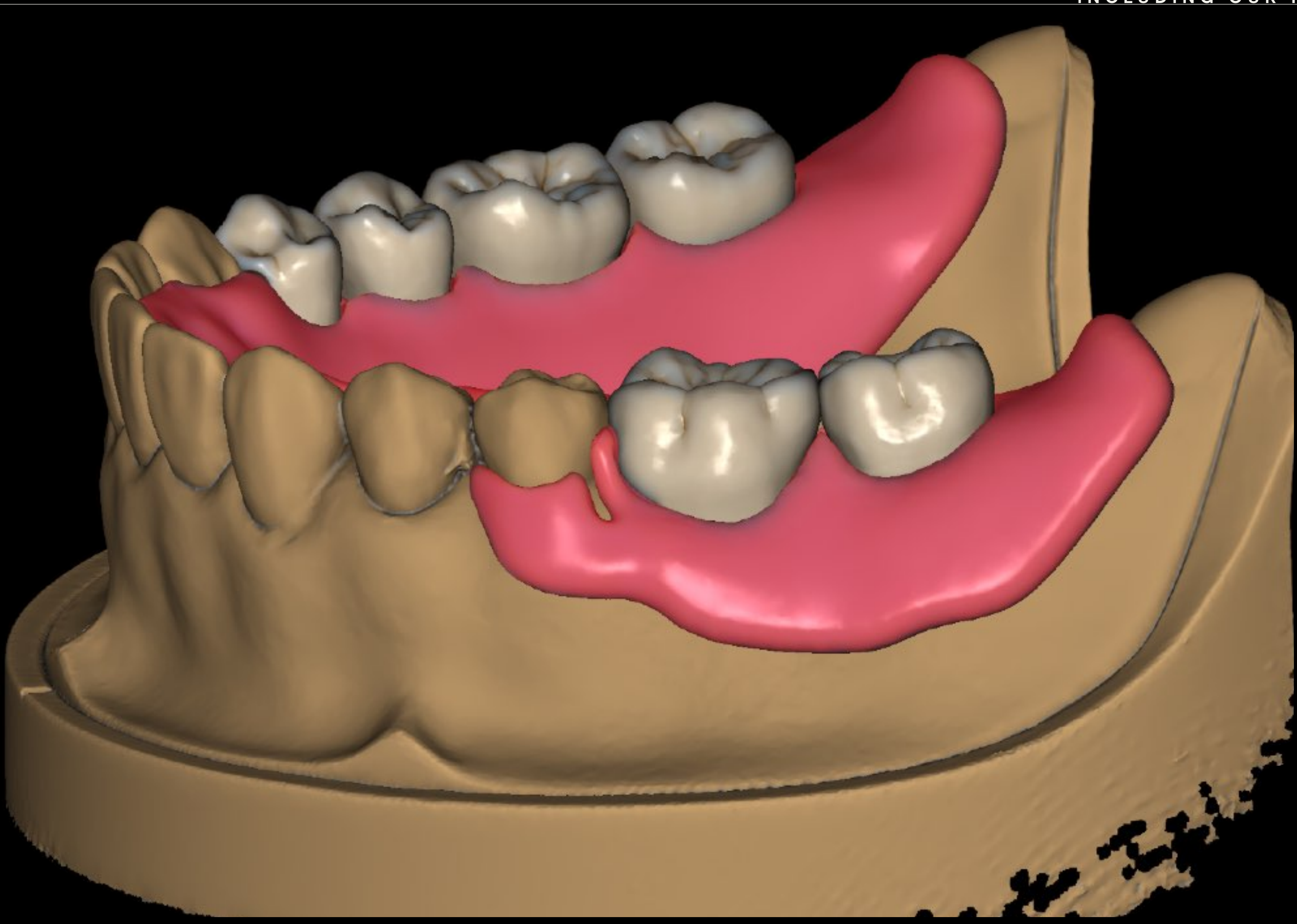


☐ 1MM THICK

The clasp should be 1mm thick. This ensures the print is able to flex while also being strong enough to hold memory over thousands of insertions and removals.

☐ SLIT 1MM WIDE X 3MM

The slit, which imparts greater flexibility to the clasp, is generally 1mm wide and 3mm long starting at the line angle of the tooth.

☐ 4MM JUNCTION

It is very important not to make this too narrow in order to avoid breakage and fatigue with plastic deformation.

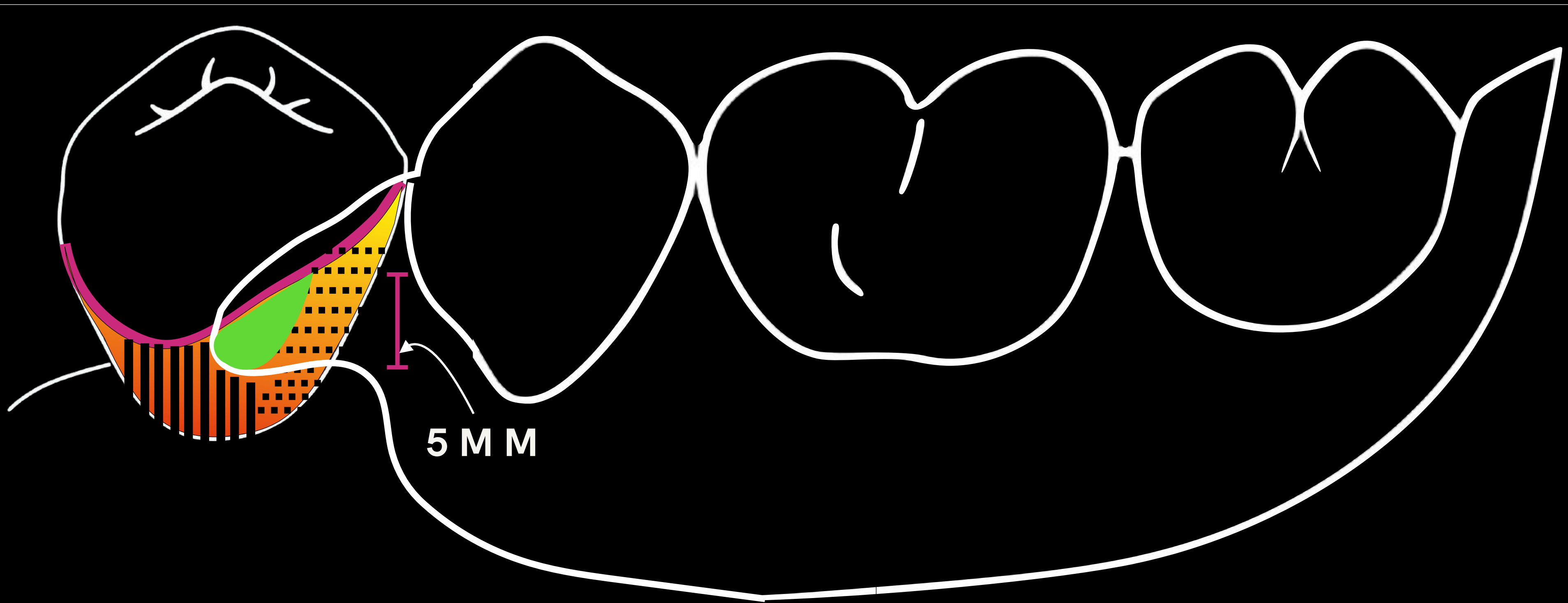
☐ 0.7MM UNDERCUT

It is important to engage the appropriate undercut. Typically, a 0.7mm undercut is engaged in these clinical scenarios.

CLASPS

Design Guide

Suprabulge Spur Clasp



This clasp design is most often indicated in **Kennedy Class III cases** or in situations where a tooth has **rotated or tipped toward the edentulous space**. While it is not considered an esthetic clasp, it remains highly **functional and reliable** in providing retention.

A key feature of this design is that the **clasp originates in the suprabulge region**, located coronal to the survey line. From there, the clasp arm extends to engage a **tear-drop shaped undercut**, typically positioned just apical to the survey line and ends on the mid-position of the tooth mesiodistally. Because the clasp arm is relatively short, it commonly engages only about **0.5mm of undercut**, which is sufficient for retention without overstressing either the clasp material or the abutment tooth.

By combining strategic origin, precise undercut engagement, and minimal arm length, this clasp provides a **stable and conservative option** in cases where rotation or tipping of abutments complicates conventional clasp placement.

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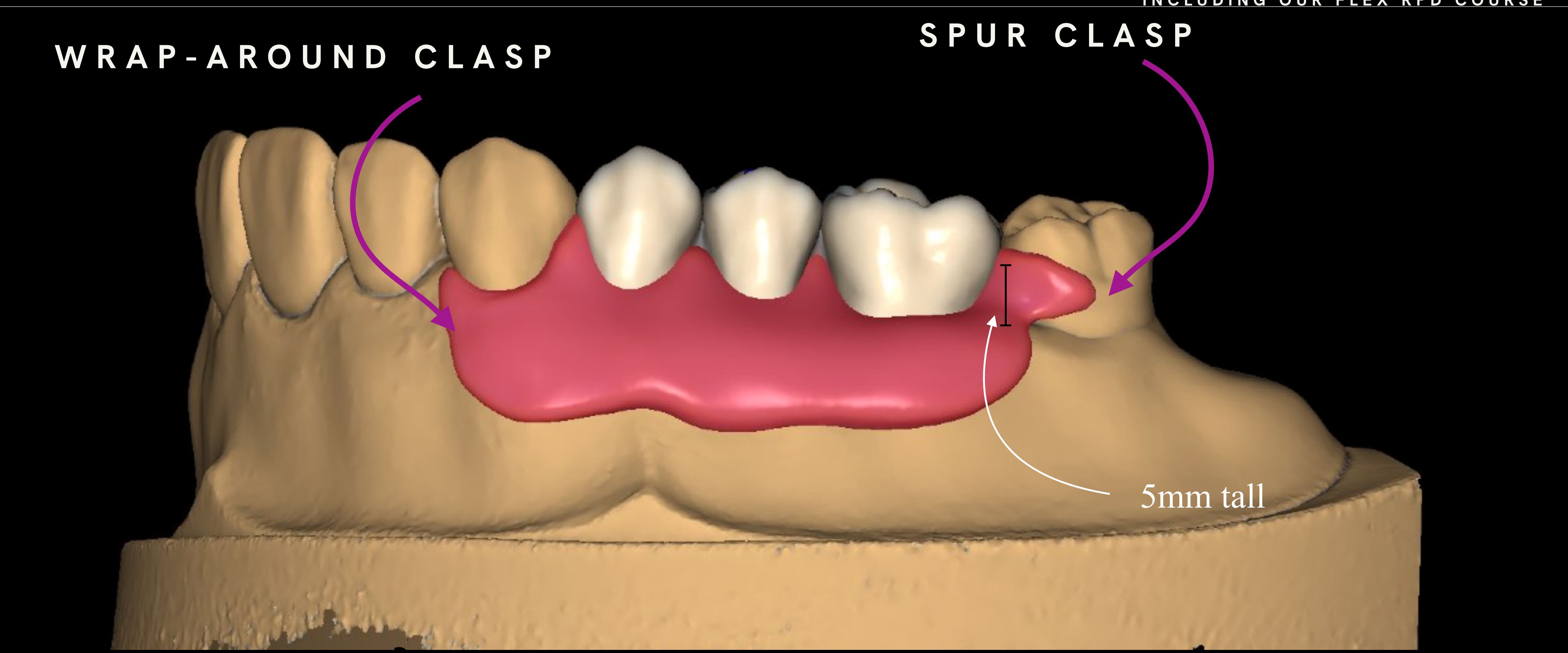
CLASPS

Design Guide

Suprabulge Spur Clasp



☐ 1MM THICK

The clasp should be 1mm thick. This ensures the print is able to flex while also being strong enough to hold memory over thousands of insertions and removals.

☐ 0.5MM UNDERCUT

Due to the short lever arm, it is important to engage only a 0.5mm undercut.

☐ 5MM JUNCTION

It is very important not to make this too narrow in order to avoid breakage and fatigue with plastic deformation.

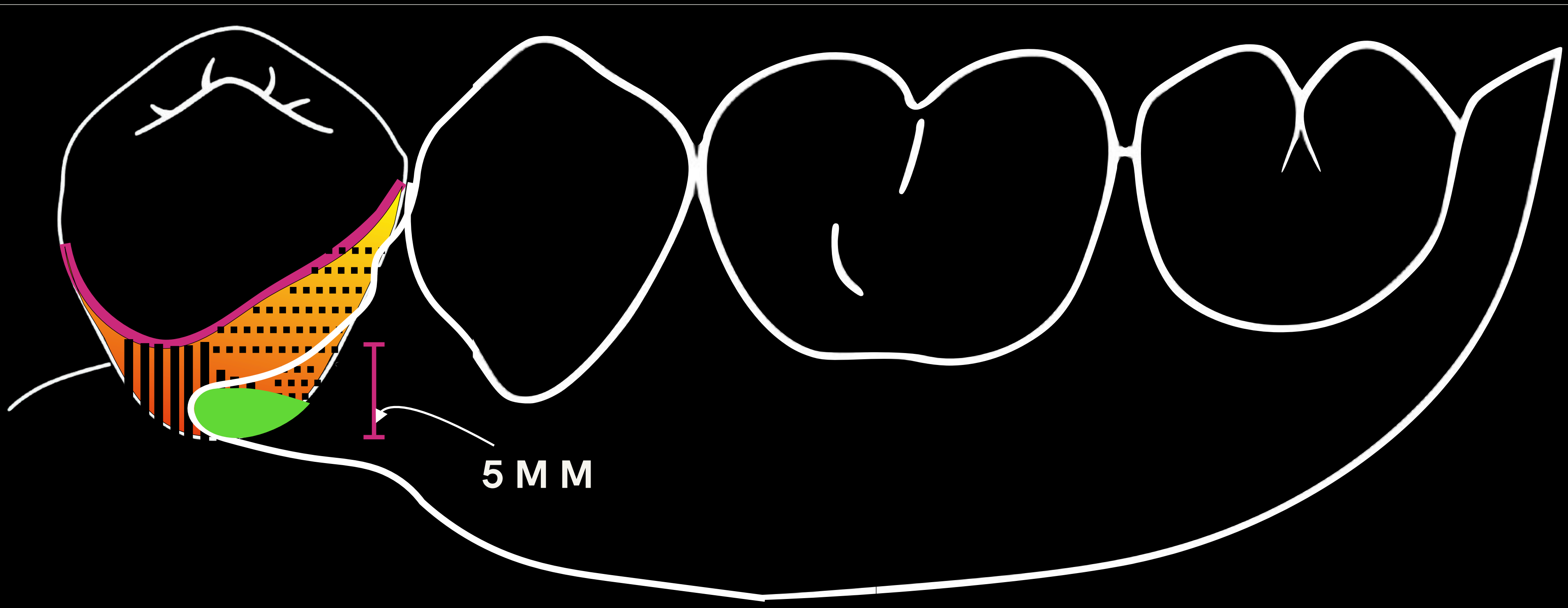
☐ TEAR DROP

The area that is relieved of blockout wax is a tear drop area located apical to the survey line and on the side of the edentulous space.

CLASPS

Design Guide

Infrabulge Spur Clasp



The **Infrabulge Spur Clasp** is primarily indicated for the **anterior region** in cases where a pronounced tissue undercut prevents the use of a conventional clasp arm along the gingiva. Its design makes it more **esthetic** than the Suprabulge Spur Clasp, since it can be shaped to mimic a natural extension of the papilla, blending into an area that is already visually concealed.

The clasp typically **originates from the papilla area**, taking advantage of the relief created by blockout wax on the edentulous side. This hidden origin point allows for both functional retention and an esthetically discreet appearance, making it especially suitable in cases with a high smile line where traditional clasping would be objectionable.

Because the clasp has a **short lever arm**, its flexibility is limited compared to longer clasp designs. As a result, only a **0.5mm undercut** is usually engaged. This depth balances retention with material limitations, ensuring that the clasp does not fracture or place undue stress on the abutment tooth.

Clinically, the Infrabulge Spur Clasp is best suited for situations where **esthetics and tissue preservation** are priorities, such as in patients with thin biotypes or large tissue undercuts in areas such as the anterior mandible.

CLASPS

Design Guide

Infrabulge Spur Clasp

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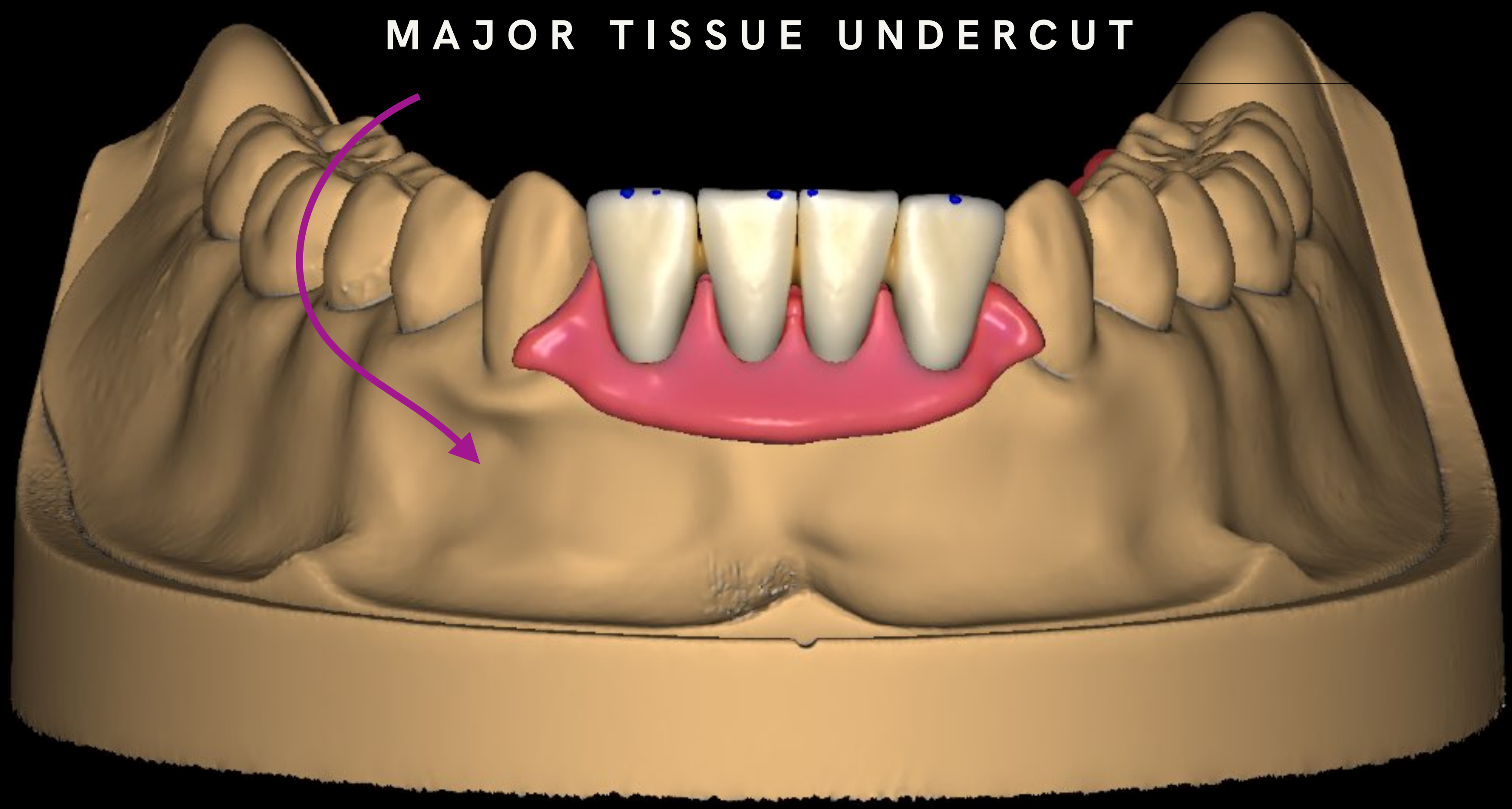
MAJOR TISSUE UNDERCUT



☐ 1MM THICK

The clasp should be 1mm thick. This ensures the print is able to flex while also being strong enough to hold memory over thousands of insertions and removals.

☐ 0.5MM UNDERCUT

Due to the short lever arm, it is important to engage only a 0.5mm undercut.

☐ 5MM JUNCTION

It is very important not to make this too narrow in order to avoid breakage and fatigue with plastic deformation.

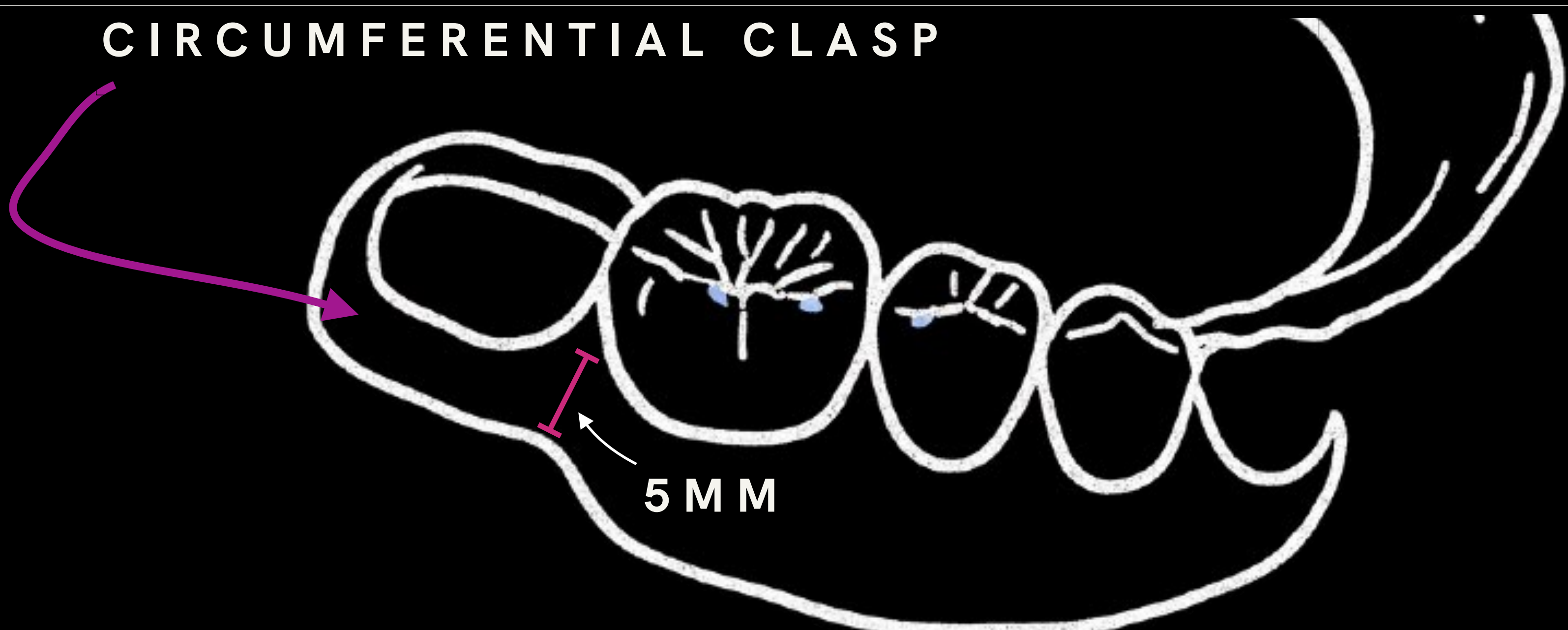
☐ TEAR DROP

The area that is relieved of blockout wax is a tear drop area just coronal to the tissue and on the side of the edentulous space.

CLASPS

Design Guide

Circumferential Clasp



The circumferential clasp was first introduced by Dr. Paul Kaplan, a U.S. Army prosthodontist, in his 2008 *Dentistry Today* article, "Flexible Removable Partial Dentures: Clasp & Design Concepts." This clasp was developed specifically for use with flexible removable partial dentures, where conventional cast-metal clasp designs are not always directly transferrable due to differences in material properties.

Indications

- Free-standing distal abutments: Ideal when a terminal abutment tooth supports the end of a free-end saddle (Kennedy Class II MOD 1 situations).
- Rotational control: Particularly beneficial when rotational forces are expected, since the encircling design distributes stress more evenly around the tooth.
- When esthetics are less critical: Because the clasp fully encircles the tooth, more of the clasp may be visible compared to other designs.

Biomechanical Advantages

- Provides maximum tooth coverage and therefore enhanced retention compared to a single-arm clasp.
- Offers stability against dislodging forces from multiple directions.
- Reduces the risk of clasp "popping off" during functional movement, as the encirclement creates a secure retentive effect.

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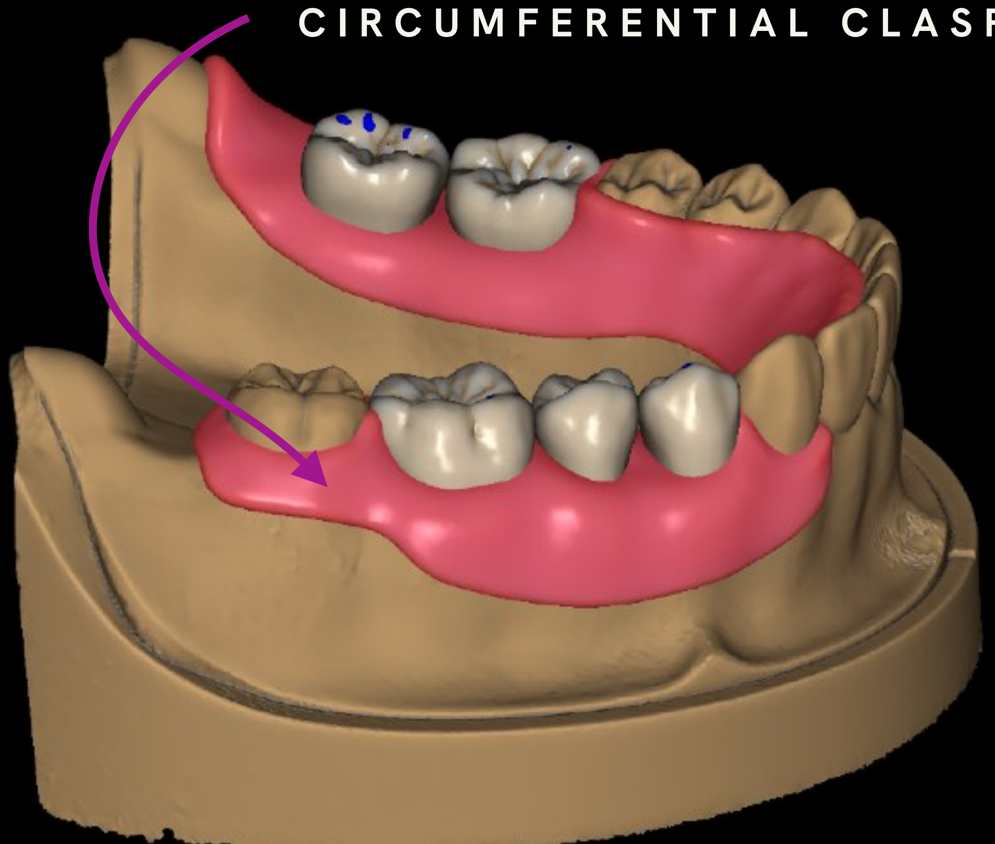
CLASPS

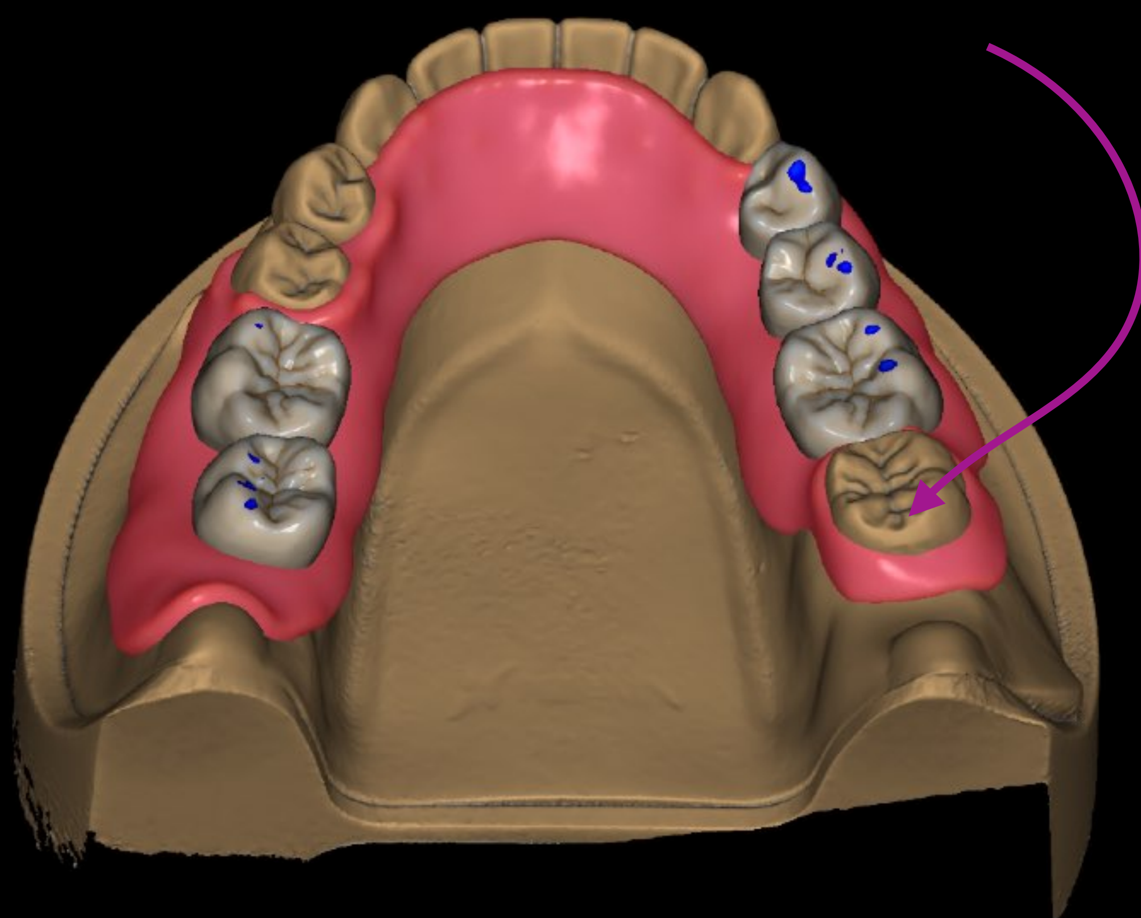
Design Guide

Circumferential Clasp

CIRCUMFERENTIAL CLASP



CIRCUMFERENTIAL CLASP



☐ 1MM THICK

The clasp should be 1mm thick. This ensures the print is able to flex while also being strong enough to hold memory over thousands of insertions and removals.

☐ 0.5MM UNDERCUT

The clasp typically engages one surface of the tooth (usually the lingual or buccal) at 0.5mm. The rest of the tooth is engaged at 0.3mm maximum.

☐ 5MM-TALL CLASP

It is very important not to make this too narrow in order to avoid breakage and fatigue with plastic deformation. The clasp should be 5mm tall circumferentially with a portion on the tissue as well as the tooth.

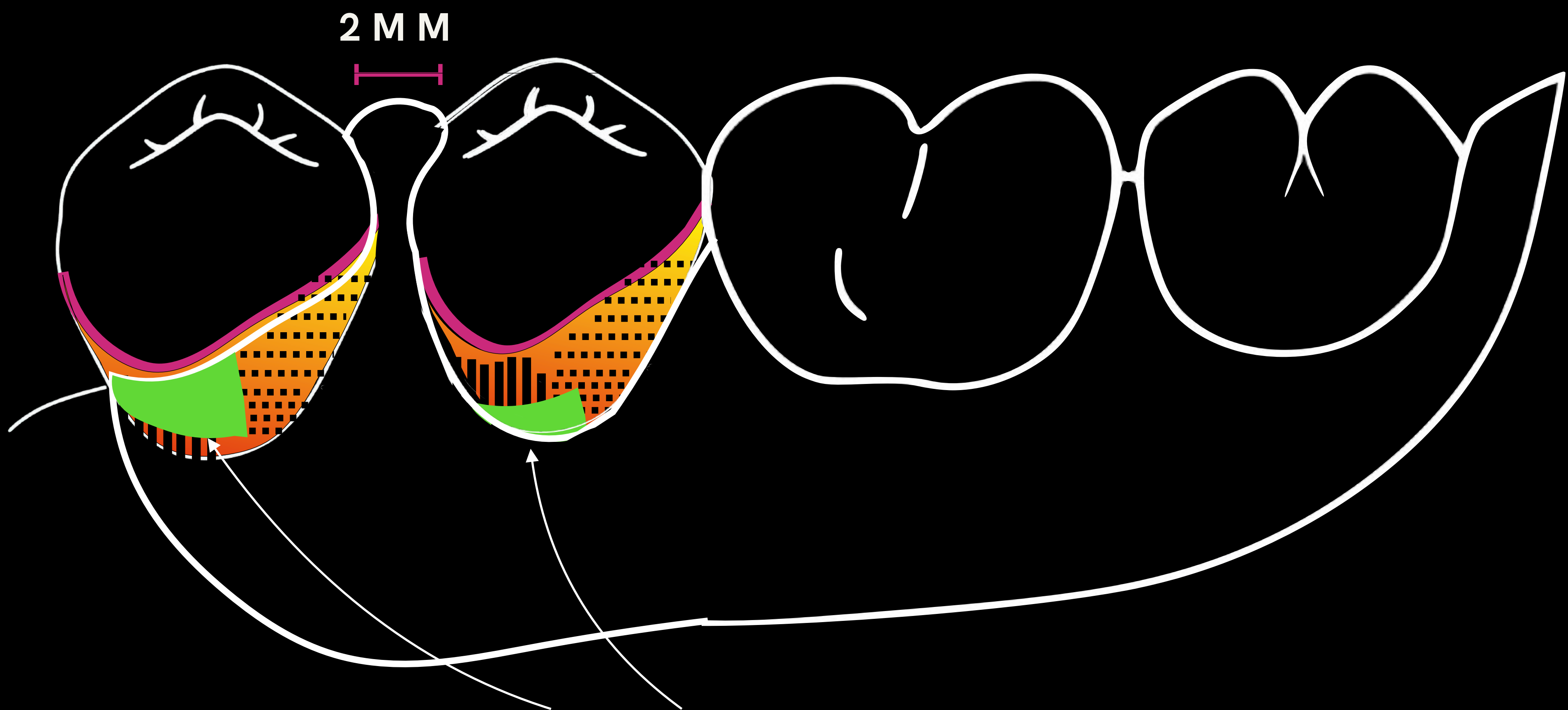
☐ SURVEY LINE

The clasp extends just coronal to the survey line circumferentially and ends on the tissue at least 2mm. Where it meets the major connector, it must also be 5mm tall at a minimum.

CLASPS

Design Guide

Embrasure Combination Clasp



Double undercut engagement

This clasp design represents a **hybrid between the wrap-around clasp and the circumferential clasp**, combining features of both. It joins the palatal/lingual and buccal components by crossing over the **occlusal table**, creating a continuous element that unites the two sides. This configuration provides **greater overall retention** and improved **stability for free-end saddles**, making it more effective than a conventional wrap-around clasp in certain clinical situations such as long distal extensions.

Because of its path across the occlusal surface, proper placement usually requires **selective tooth preparation** to achieve adequate seating, clearance, and function. The recommended tooth reduction in the **embrasure space** is approximately **1mm on each adjacent tooth**, which allows room for a clasp that is about **2mm wide and 1mm tall**. This ensures sufficient material thickness while maintaining a balance between durability and flexibility.

However, due to the inherently **thin dimensions** of the embrasure clasp, this design is more **fragile** compared to broader clasp types. Careful attention to surveying, blockout, and finishing is essential to reduce the risk of deformation or fracture during function. I find this best used when opposing a denture because the embrasure clasp can be made thicker and therefore offers better rigidity.

CLASPS

Design Guide

Embrasure Combination Clasp

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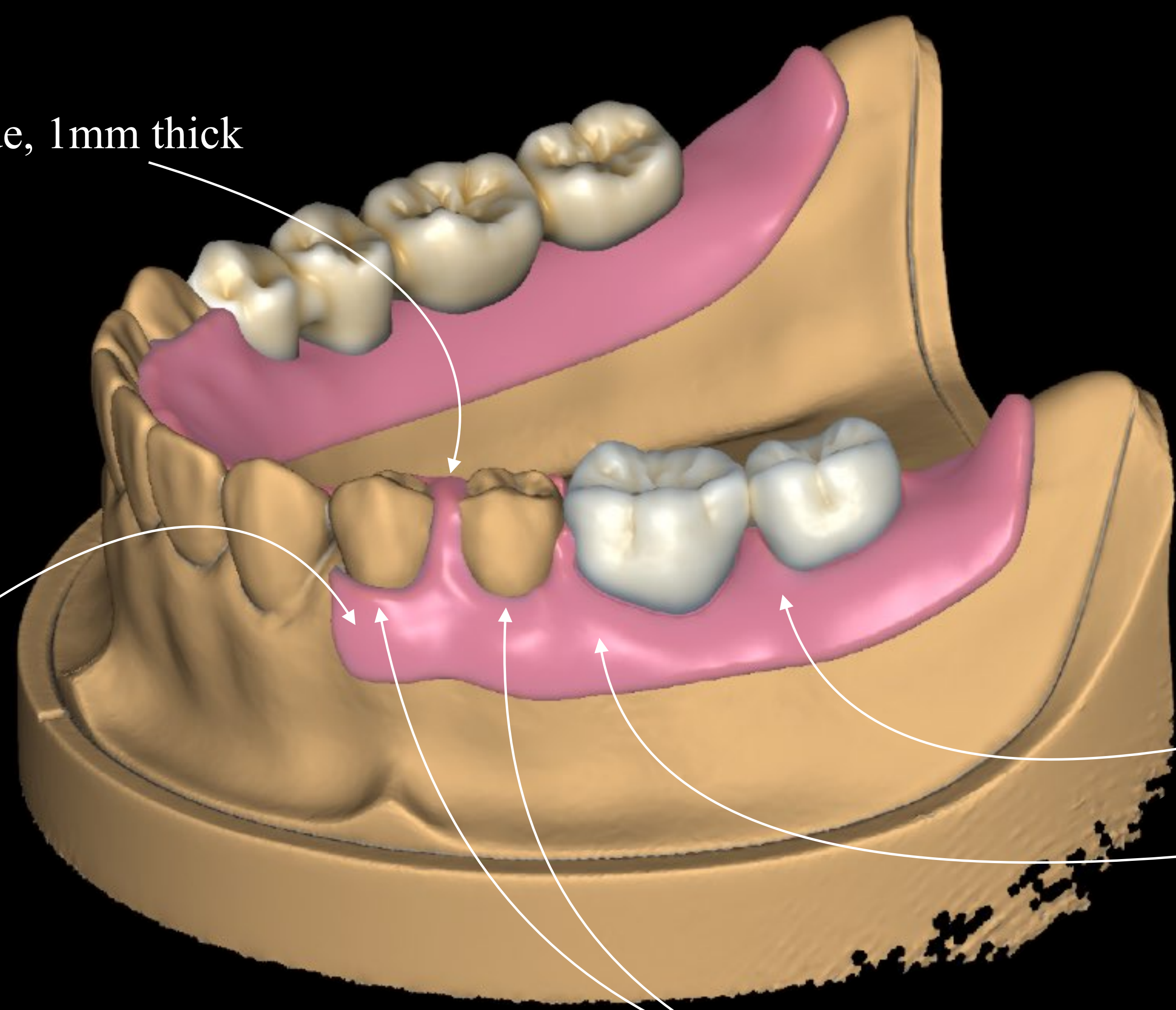


☐ 1MM THICK

The clasp should be 1mm thick. This ensures the print is able to flex while also being strong enough to hold memory over thousands of insertions and removals.

☐ 0.5MM DUAL UNDERCUT

Double undercuts are engaged on the two clasped teeth. This is one of the more retentive clasps.

☐ 5MM JUNCTION

It is very important not to make this too narrow in order to avoid breakage and fatigue with plastic deformation.

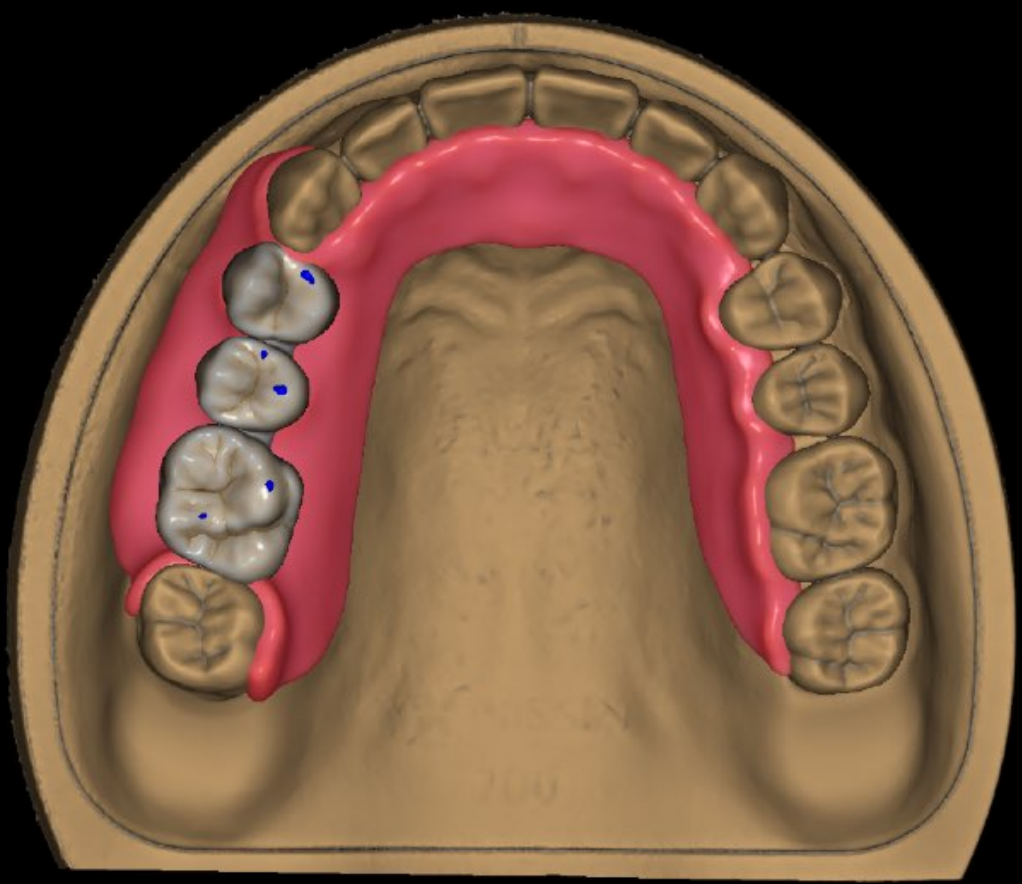
☐ TOOTH REDUCTION

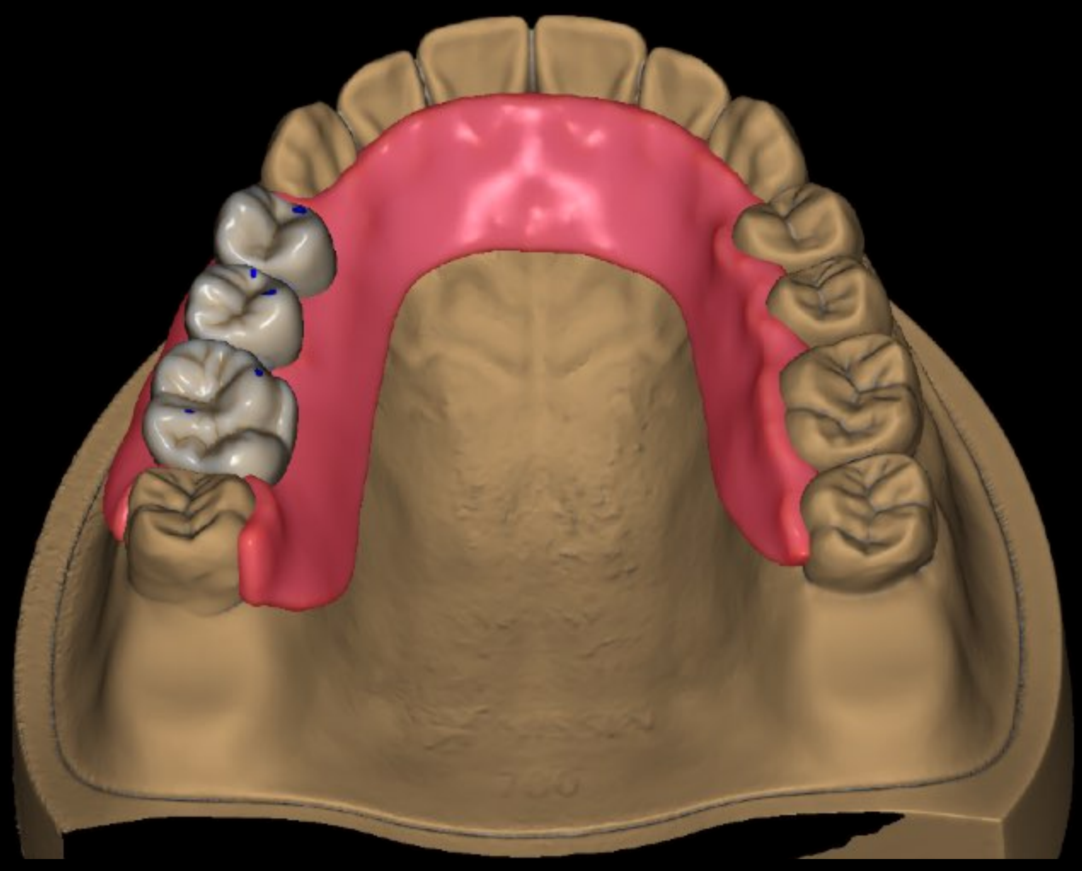
1mm in depth and width is removed from each marginal ridge to give a 2mm-wide minor connector in the embrasure and a 1mm-tall minor connector.

MAJOR CONNECTORS

Design Guide

Maxillary Horseshoe





A **flexible partial denture with a “horseshoe” design** provides minimal palatal coverage and increased patient comfort. Because the flexible resin base is restricted to a U-shaped band along the alveolar ridge, it avoids extensive contact with the palate. This design is especially indicated in patients with a **palatal torus** where traditional broad coverage would cause discomfort, or in patients highly sensitive to changes in taste and temperature perception. The reduced palatal surface enhances **oral proprioception** and **tongue freedom**, allowing for a more natural feel when eating and swallowing. However, the horseshoe design sacrifices **rigidity** and **stress distribution**, leading to greater flexure under functional load. This can translate into uneven force transfer to abutment teeth and soft tissue, making it better suited for short-span edentulous areas where minimal support is required. One way we overcome these shortcomings is through lingual plating. This increases rigidity and also adds hard tissue stops, which can act as minor bracing and subtle reciprocation in some instances. Therefore, it is essential to utilize lingual plating when employing this style of major connector.

Design Guide

Maxillary Horseshoe design parameters

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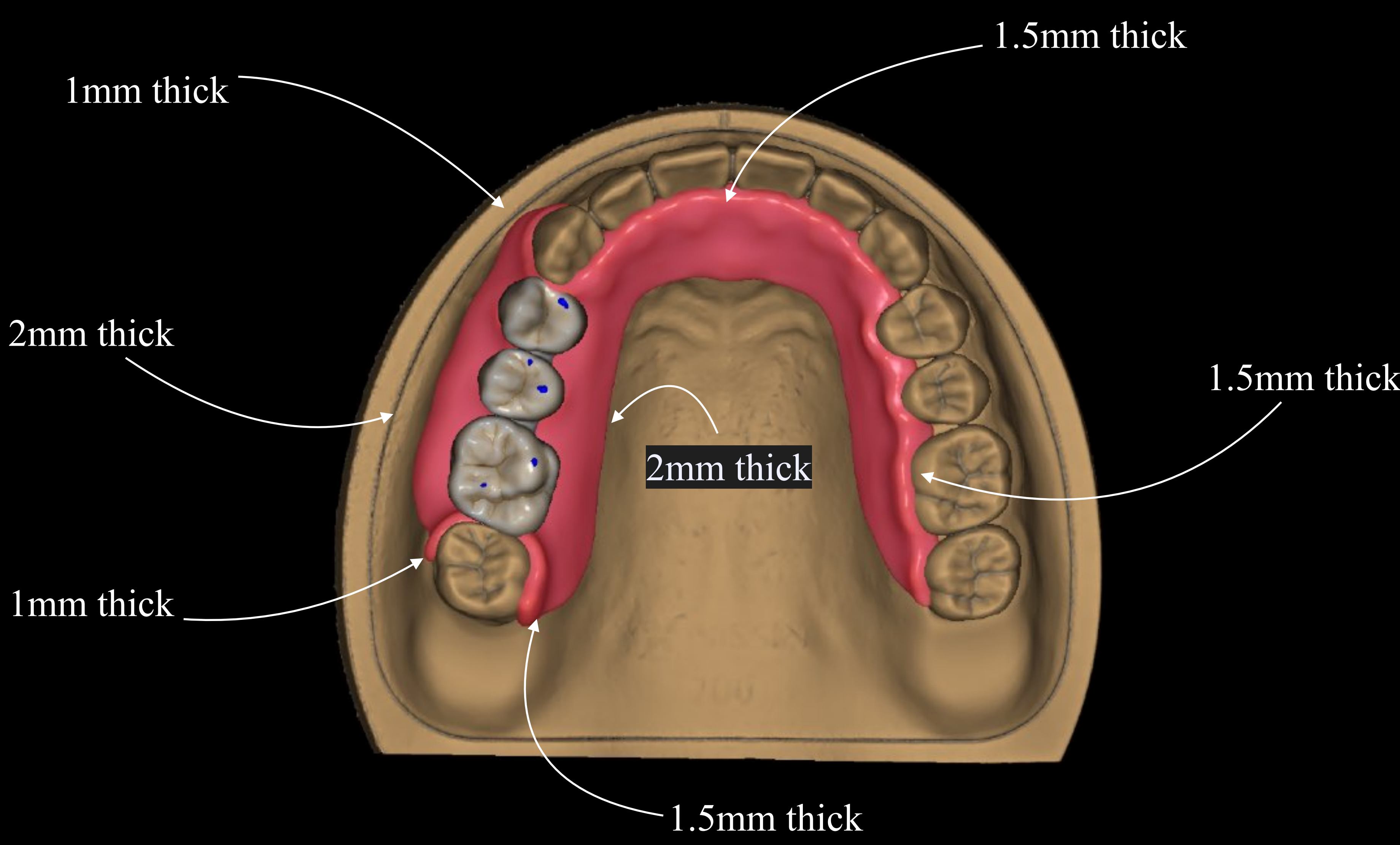
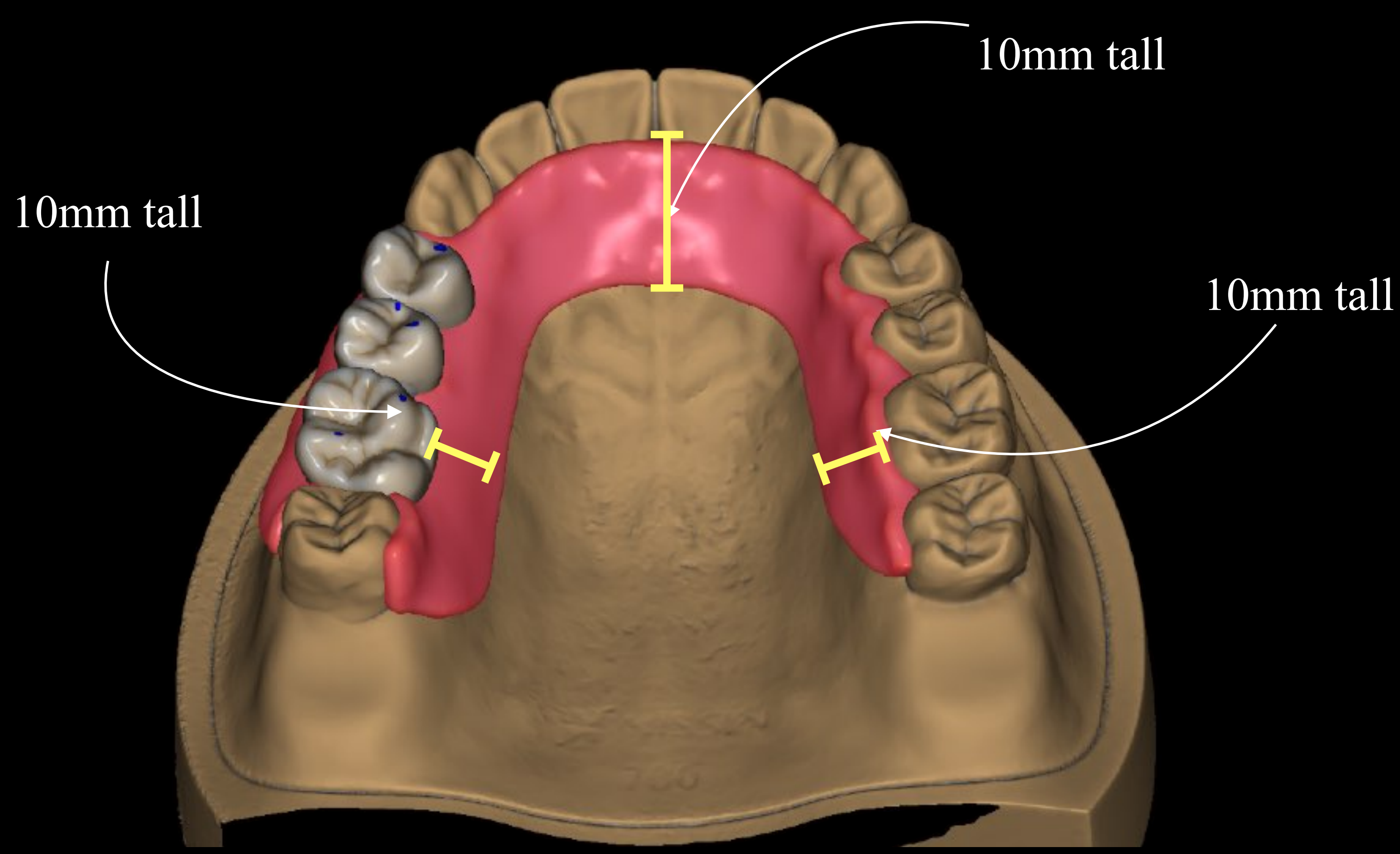
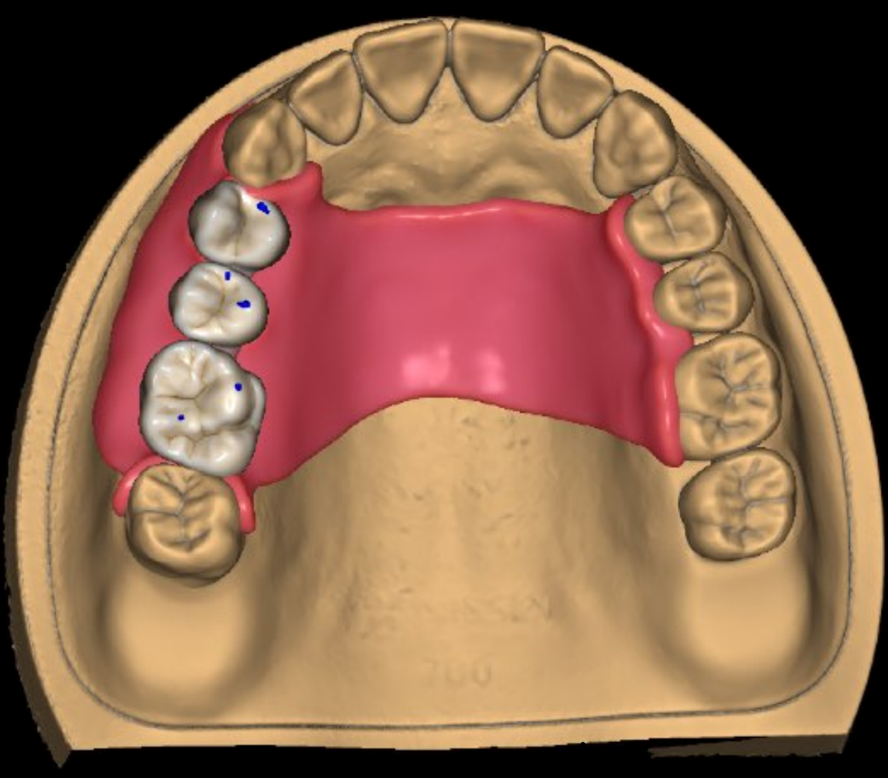


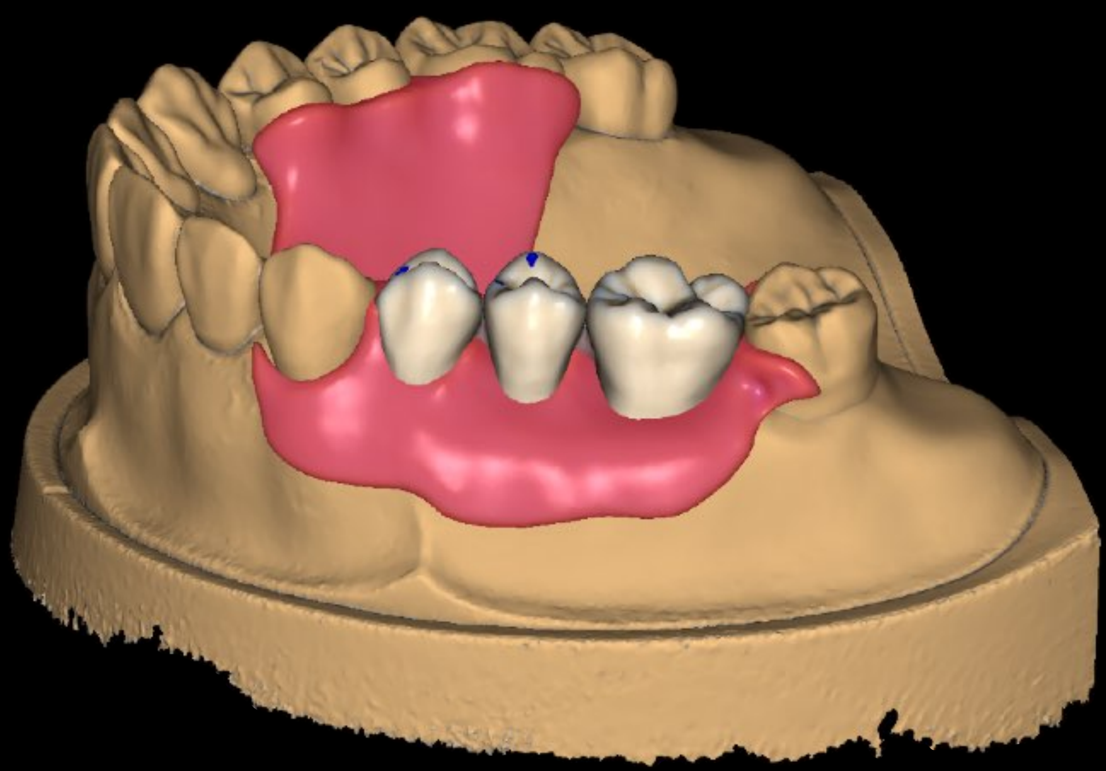


MAJOR CONNECTORS

Design Guide

Maxillary Palatal Strap





The **palatal strap design** incorporates a wide band of material across the hard palate, providing **excellent cross-arch stability and rigidity**. By engaging a larger surface area of the palate, occlusal forces are better distributed, reducing torque on abutment teeth and improving the prosthesis's long-term prognosis. This design is particularly advantageous in Kennedy Class I and II situations where distal extension saddles demand additional support and resistance to flexure. The trade-off, however, is that the strap interferes more with **tongue action** and may initially feel bulky to patients. Speech adaptation may take longer, and some patients may report a slight reduction in palatal sensitivity or altered phonetics, especially with lingual sounds. Despite these drawbacks, the palatal strap is often considered the **most biomechanically sound design** for long-term function, especially when combined with cross-arch lingual plating as shown here. It is usually contraindicated when large palatal tori exist.

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Design Guide

Maxillary Palatal Strap design parameters

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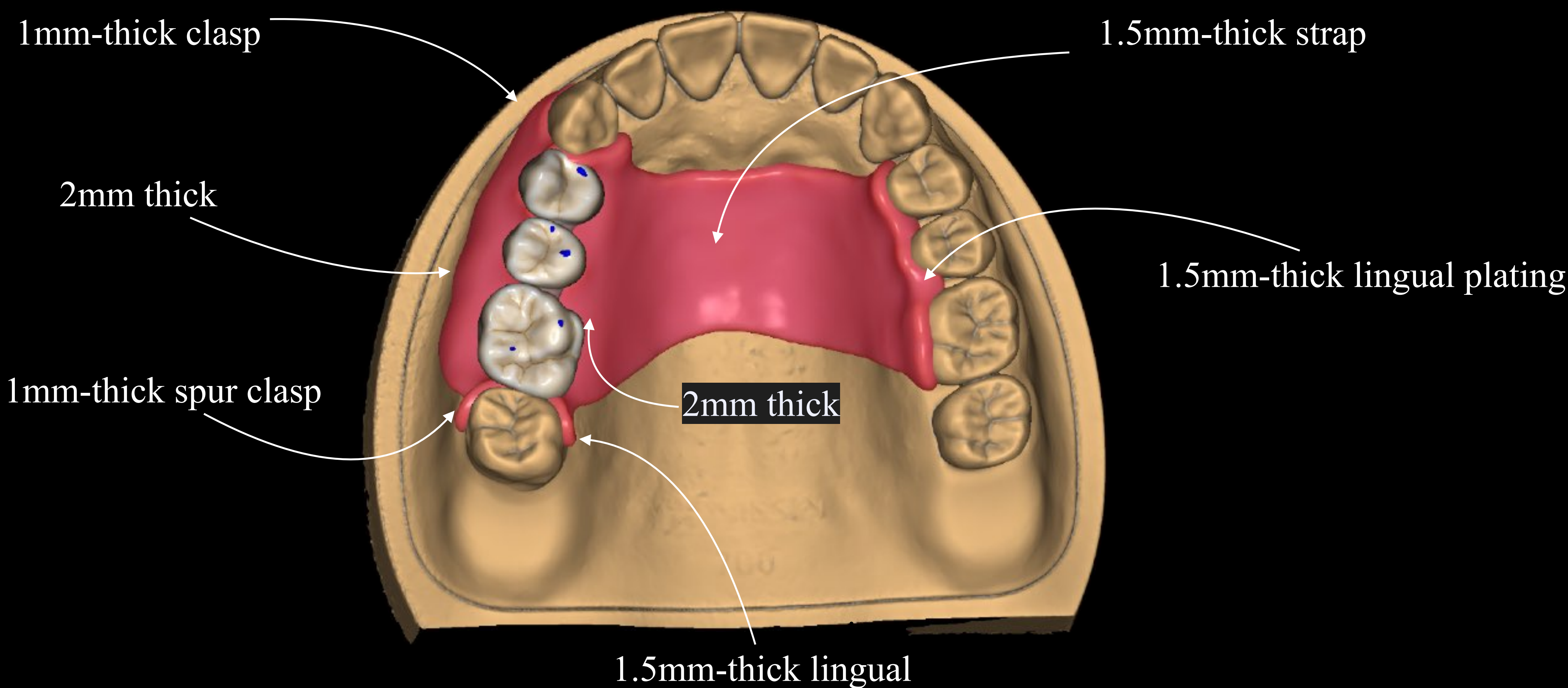

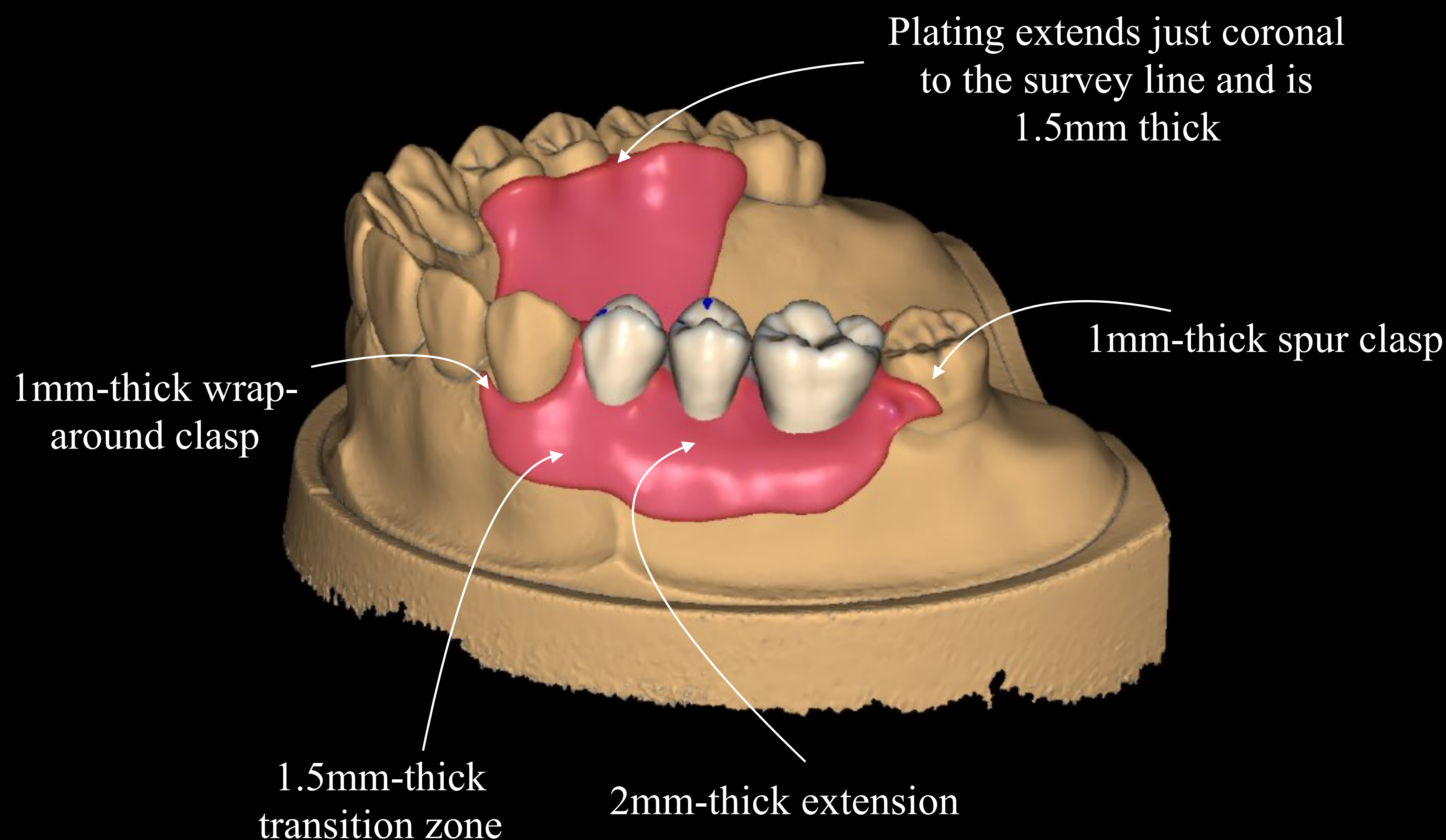

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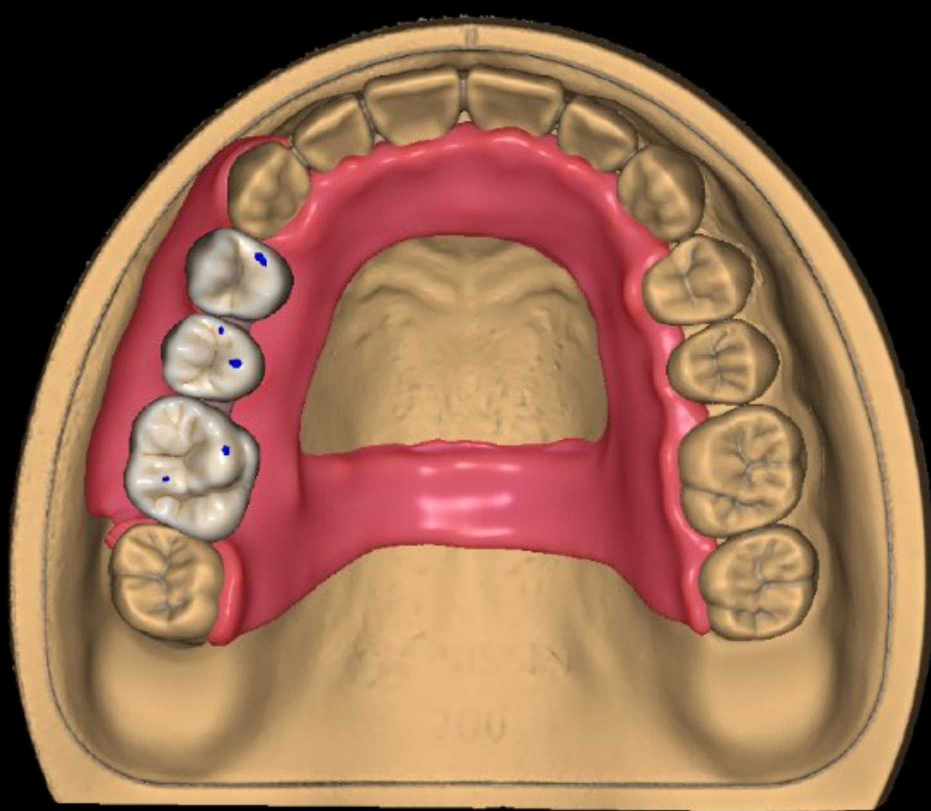
Design Guide

Maxillary AP Strap design



A **flexible partial denture with an "AP Strap" design** can be thought of as a modified horseshoe major connector, reinforced with an **additional posterior palatal strap**. Unlike a traditional cast metal framework, the AP strap in flexible partial dentures is not simply duplicated in metal thickness and proportions. Instead, the **strap thickness and width are carefully optimized** for flexible resin materials, strategically placed to increase rigidity without adding excessive bulk or palatal coverage. This design is particularly advantageous in cases with a **palatal torus**, since the posterior strap can often be positioned **posterior to the torus**, avoiding interference while still maintaining structural support. The horseshoe portion preserves tongue space and taste perception, while the posterior strap provides a cross-arch bracing effect that resists flexure and improves stress distribution during function. For optimal performance, the AP strap design should be **combined with lingual plating** on the anterior teeth. Lingual plating not only enhances **rigidity** by splinting multiple teeth together, but also improves **retention and stability**, preventing rotation of the denture during mastication. This synergy between the anterior horseshoe band, posterior strap, and lingual plating creates a balanced design that maximizes both **biomechanical efficiency** and **patient comfort**. Clinically, the AP strap is best indicated in **Kennedy Class I and II cases**, especially when palatal tori are present, or in patients who cannot tolerate the bulk of a full palatal strap but require more rigidity than a simple horseshoe design can provide. The result is a design that blends the **comfort of minimal coverage** with the **functional strength of reinforced support**, making it a versatile option in flexible partial denture therapy.

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Design Guide

Maxillary AP Strap design

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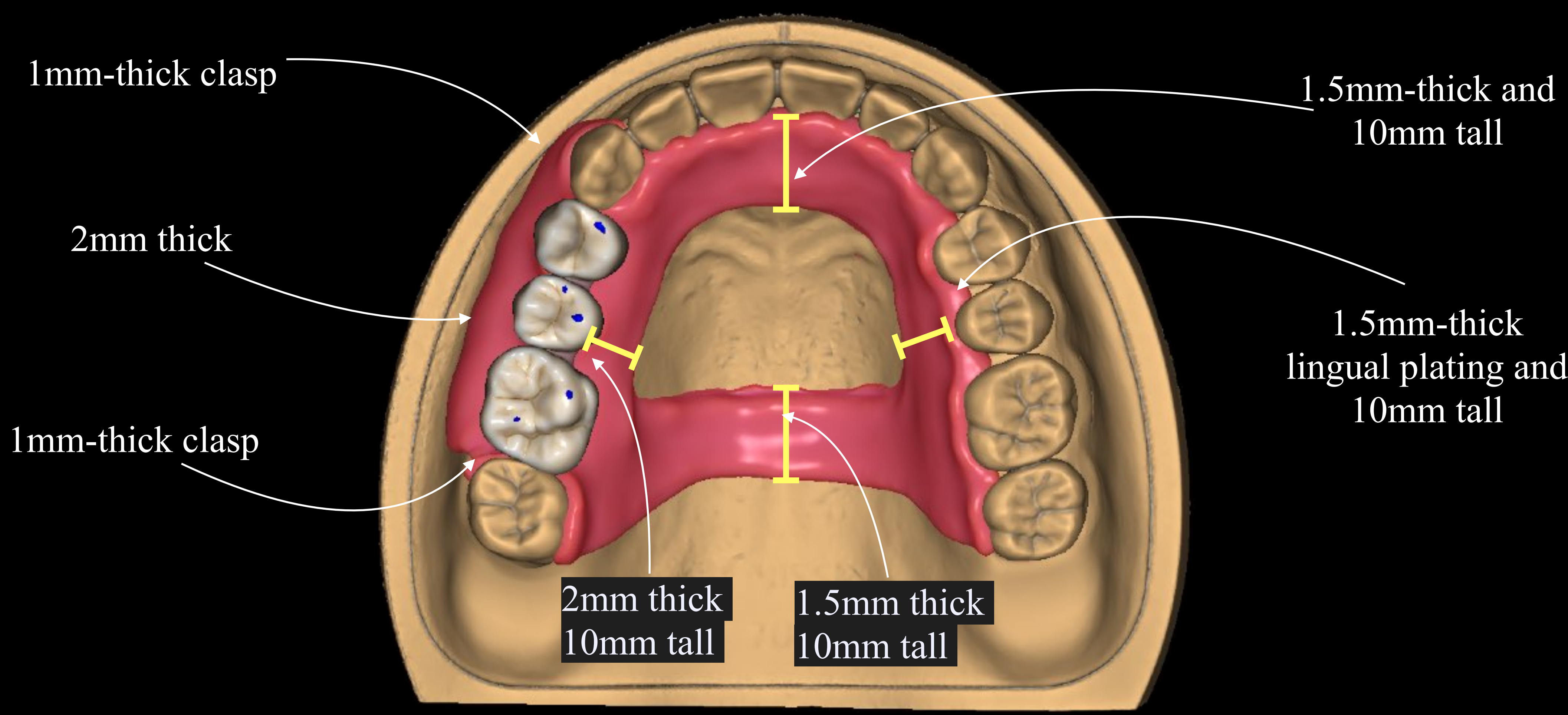
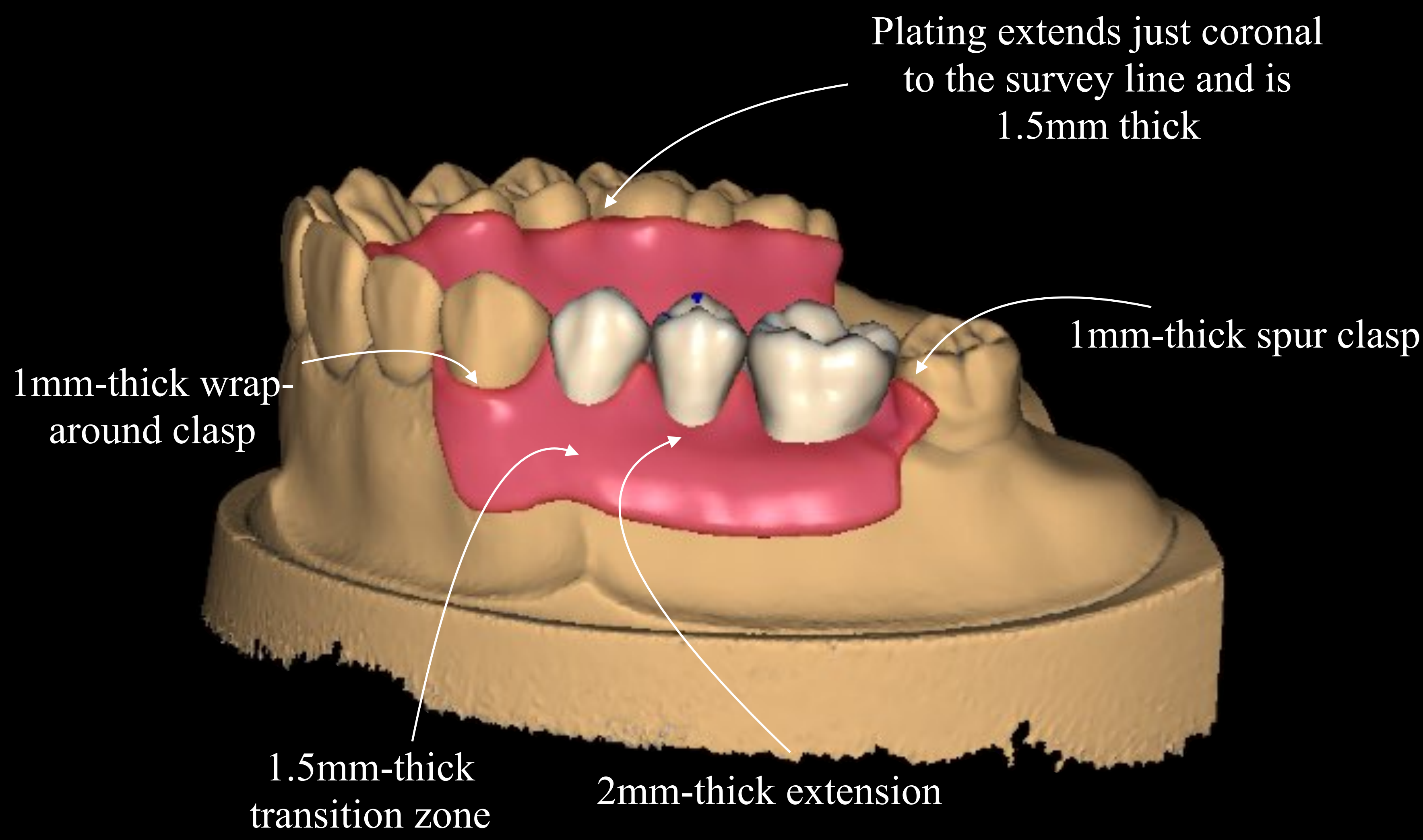
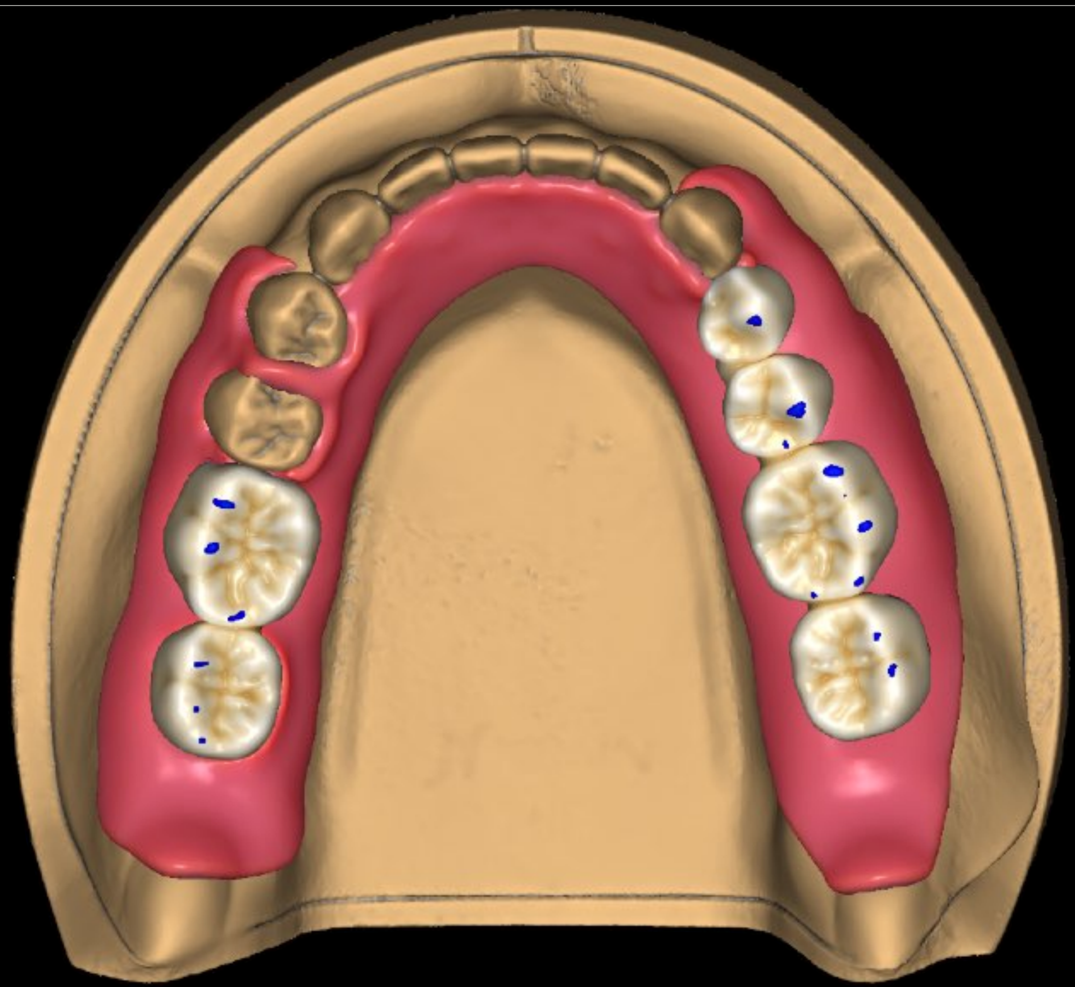


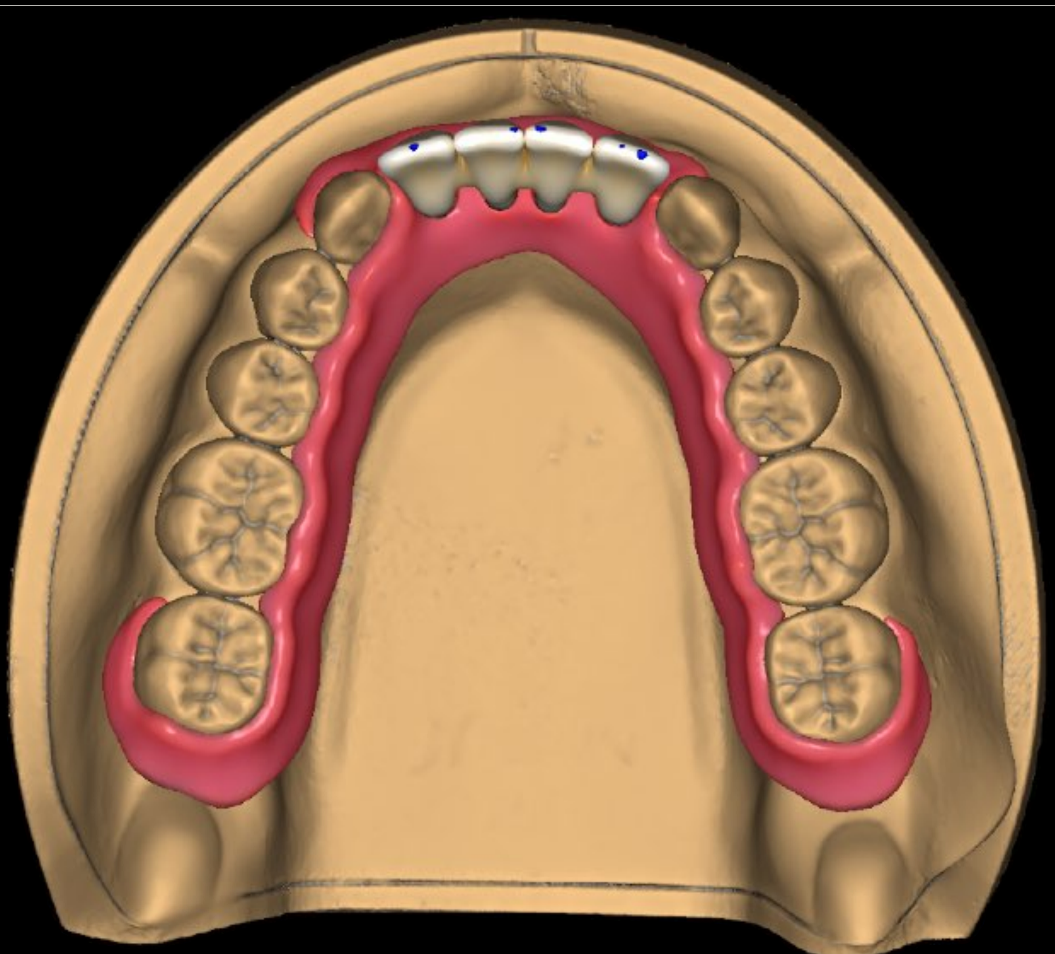


MAJOR CONNECTORS

Design Guide

Mandibular Lingual Plating





For the **mandible**, there is essentially only **one sound option** when designing a flexible partial denture: **lingual plating**. Unlike cast metal frameworks, a **lingual bar design is not feasible** in flexible resin. The reason is that the material would be too thin, flexible, and structurally weak to provide adequate rigidity and cross-arch stability in the bar form. Without reinforcement, such a design would compromise both function and longevity.

Lingual Plating Design Principles: Lingual plating provides the necessary **support, rigidity, and splinting effect** in flexible partial dentures. The plating is extended from just coronal to the survey line down to the lingual tissues at least 3mm, creating a vertical wall of material that averages 8–10mm in height. Combined with a 1.5mm thickness, this configuration achieves the **ideal balance: rigid enough to resist flexure under functional loading, yet still comfortable and non-invasive to surrounding soft tissues**. Importantly, this **avoids any traumatic encroachment on the periodontal tissues**, which can occur if the major connector is too flexible.

Management of Distal Extension Cases: In long-span distal extension cases (**Kennedy Class I or II**), the design must **account for increased stress and leverage forces**. Here, the denture base should be extended fully to the retromolar pad, **ensuring optimal tissue support**. In addition, the distal extension areas are thickened to ~2mm to provide **extra rigidity and resistance to bending**, which is critical in preventing deformation of the prosthesis under occlusal load.

Terminal Clasping: Terminal clasps are incorporated on the most distal abutment molars whenever possible. This **enhances retention and helps counteract rotational forces**. Terminal clasping is particularly important in **anterior modification spaces and Kennedy Class IV scenarios**, where prosthetic stability is challenged by missing anterior teeth and increased leverage across the arch.

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Design Guide

Mandibular Lingual Plating

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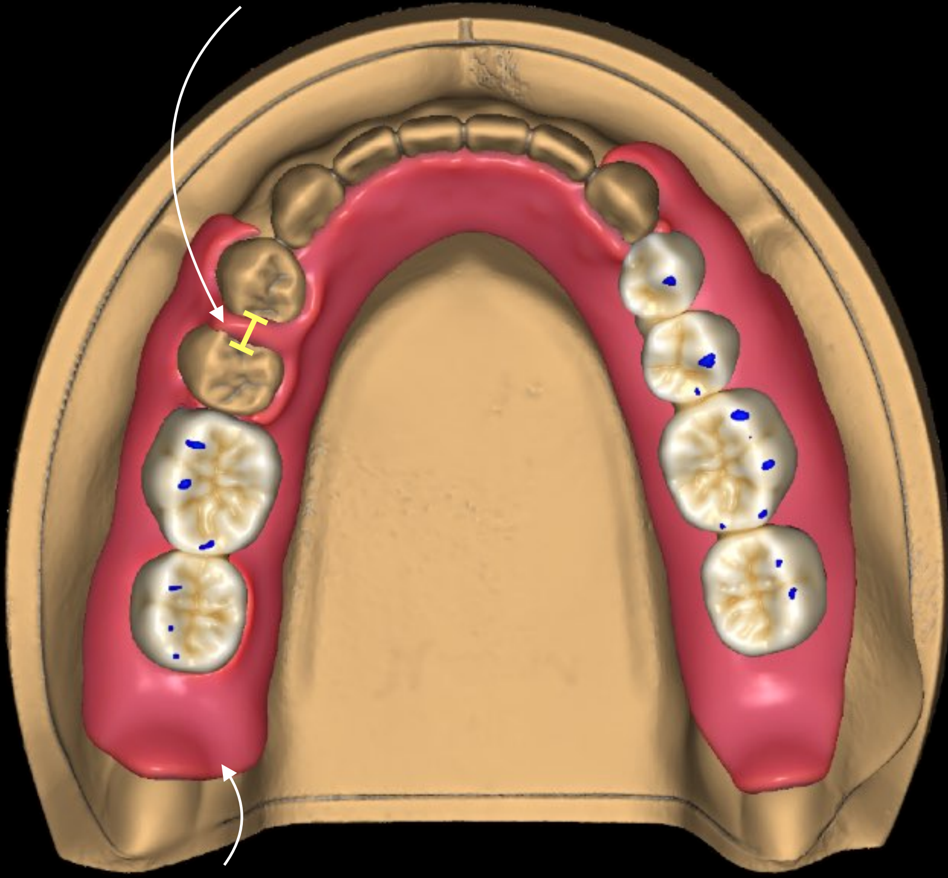

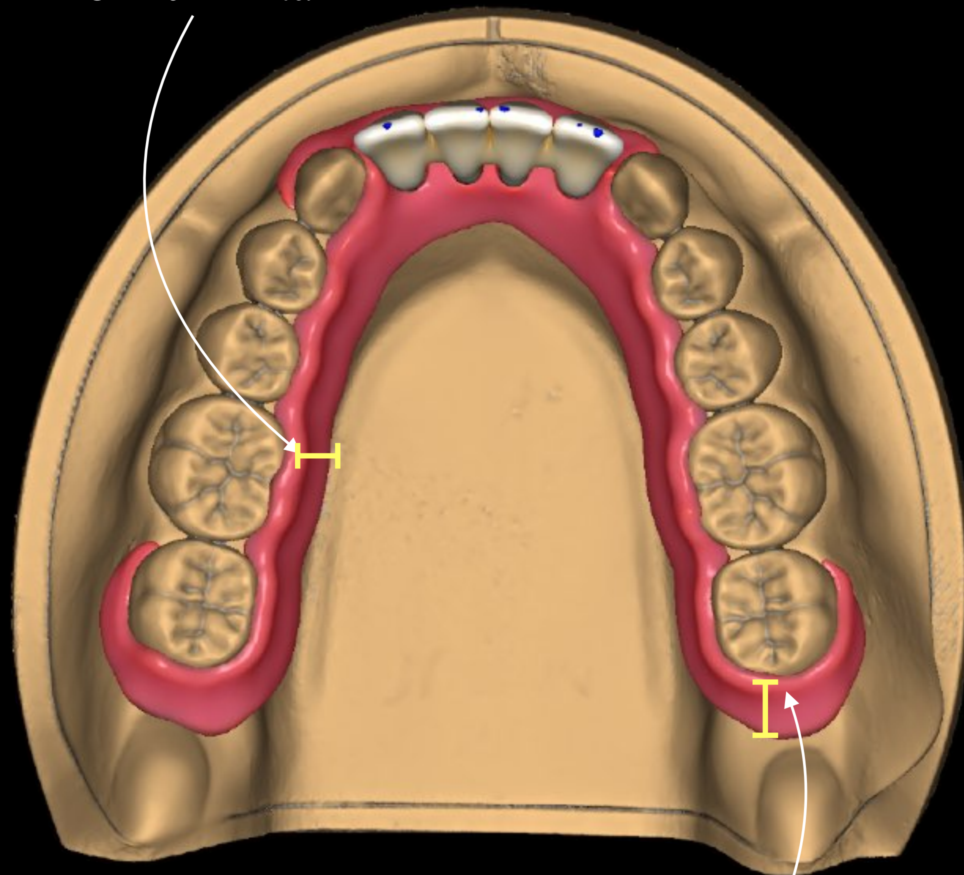

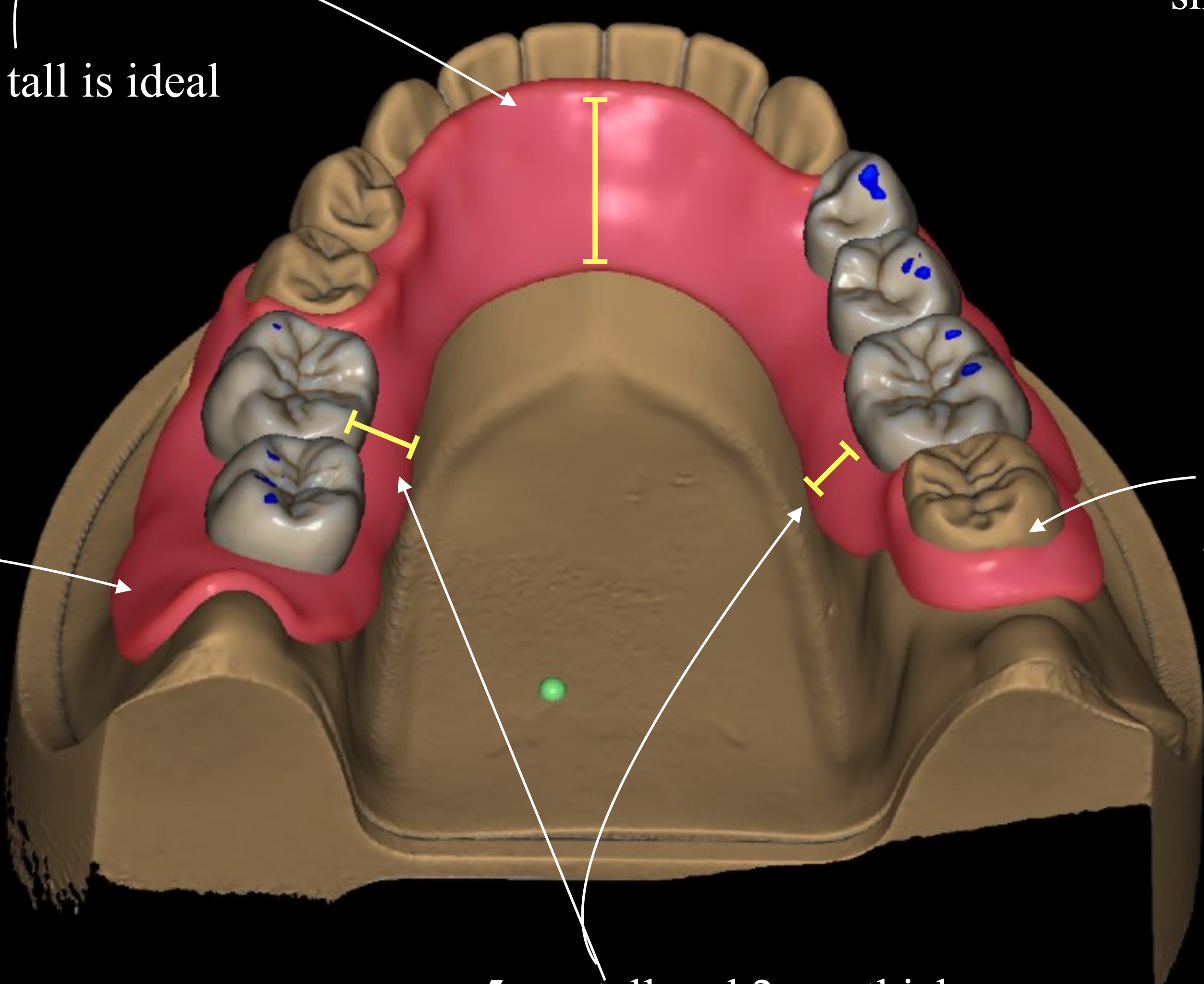

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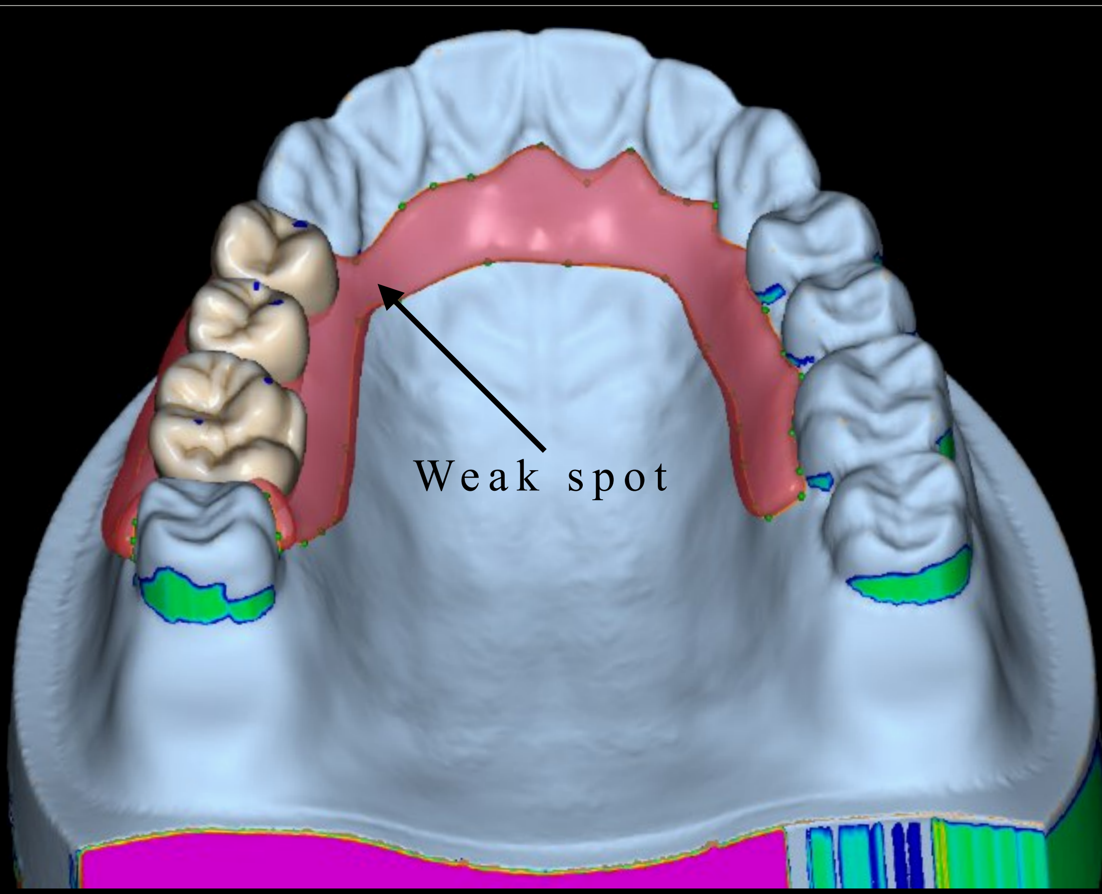
Design Guide

Mandibular Lingual Plating common mistakes



By far the **most common error** seen in flexible partial denture designs is the creation of prostheses that are **too thin, fragile, and excessively flexible**, with little to no lingual plating. While patient comfort is always an important goal, **comfort cannot come at the expense of mechanical soundness**. A successful design must carefully **balance flexibility with rigidity**, ensuring proper support, stability, and longevity.

In the example noted above, the design **did not follow any of the fundamental rules for a horseshoe major connector**. Instead of providing broad coverage and strategic reinforcement, the framework was left narrow and unsupported.

The **absence of lingual plating** is one of the most serious design flaws. Without plating, the denture lacks the ability to effectively **distribute functional flexural forces across to the contralateral teeth**. This leaves the prosthesis vulnerable to uneven stress concentrations, resulting in increased torque on the abutments nearest the edentulous span. Over time, this can accelerate periodontal breakdown and loss of abutment support.

A narrow, unreinforced **horseshoe configuration** introduces another predictable point of failure. Flexible partial dentures designed this way almost always **fracture at the weakest zone**, typically in the **cuspid (canine) region adjacent to the edentulous space**. The reason is that this is where functional stress is concentrated during mastication, and without sufficient cross-arch rigidity, the material cannot withstand repeated flexural loading.

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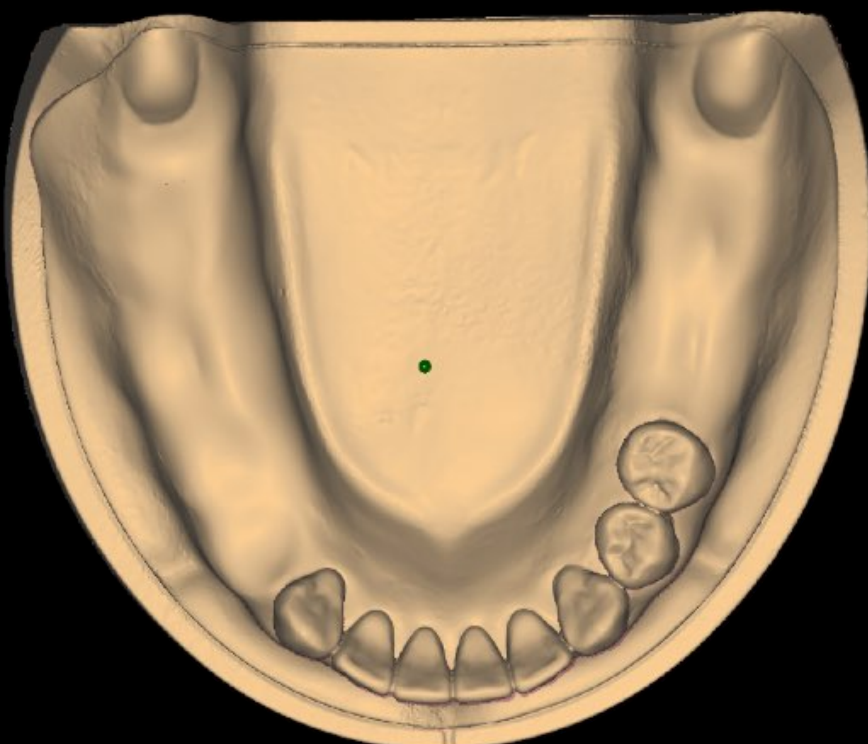
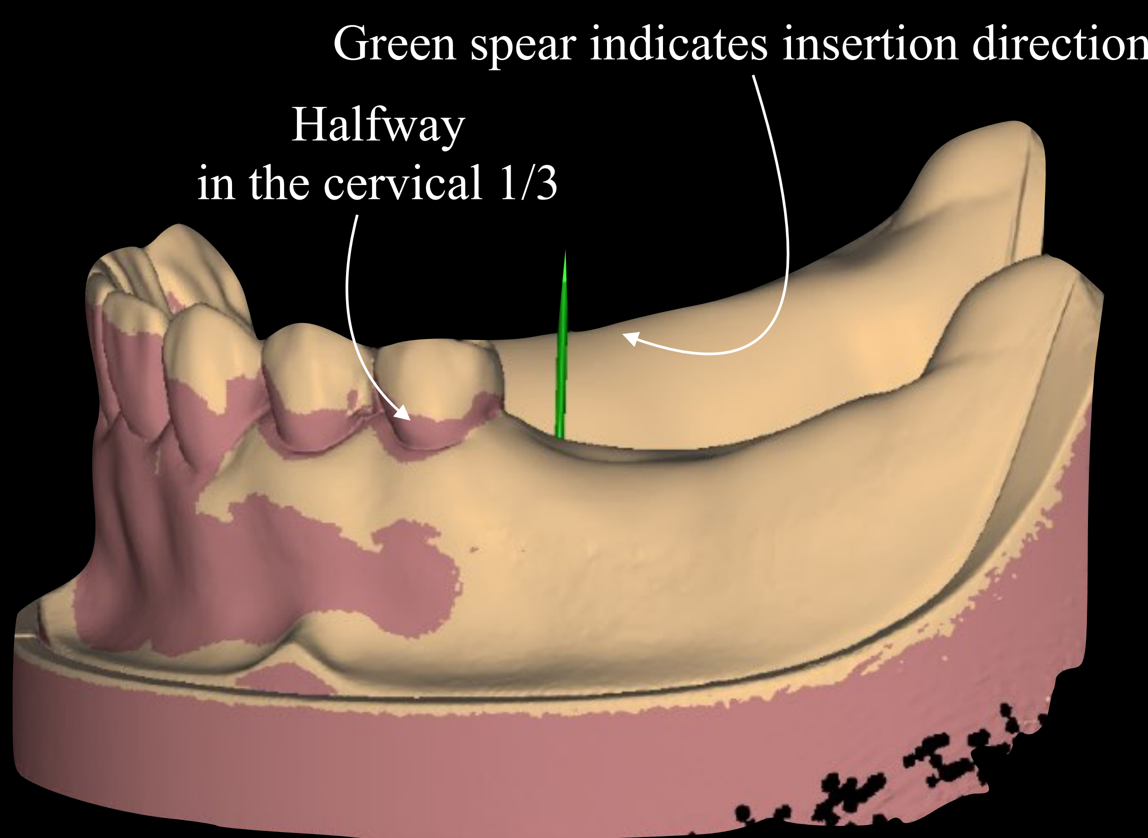
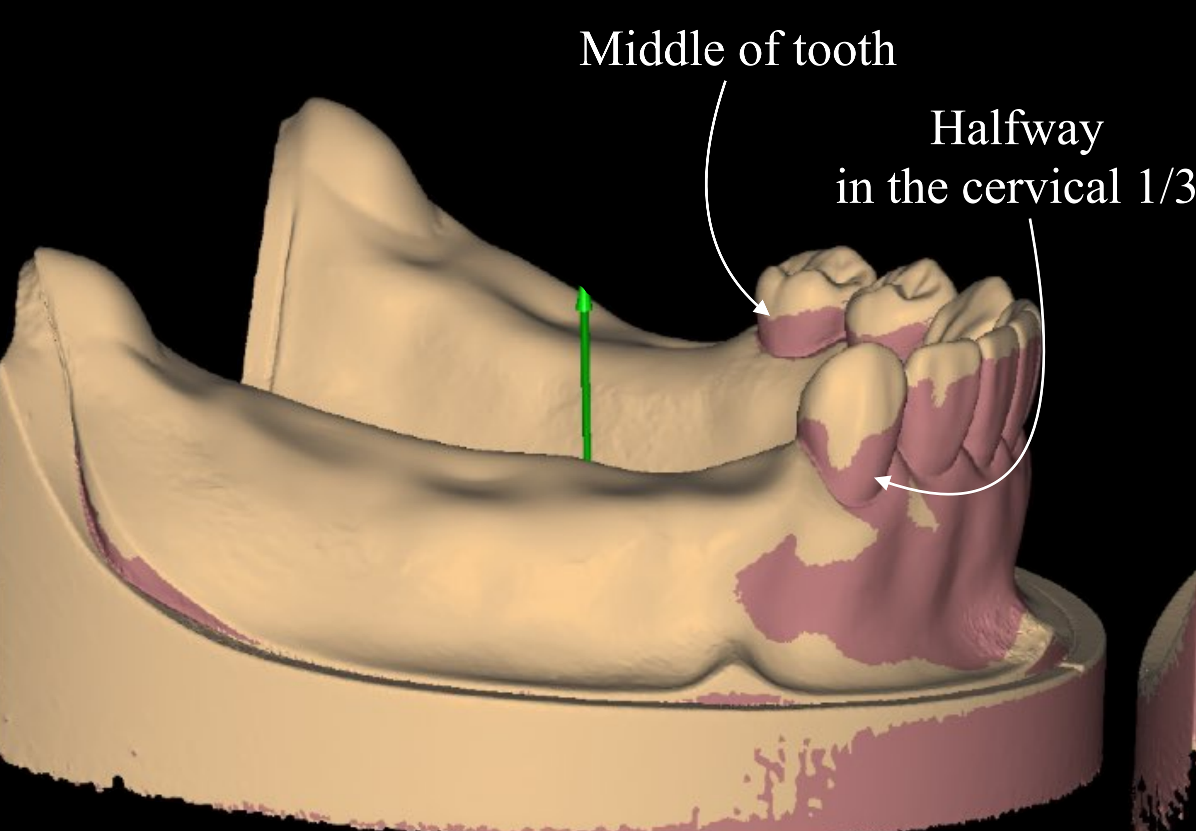
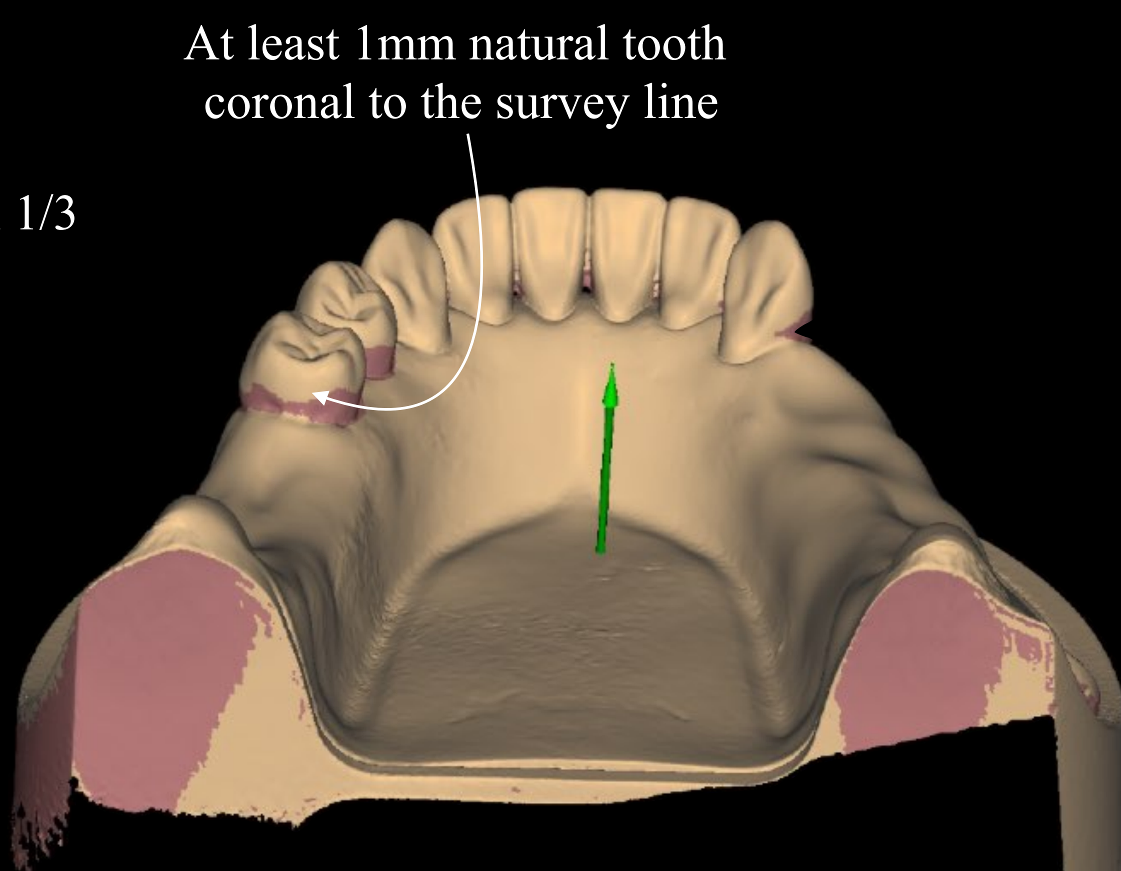
Design Guide

Exocad Design Steps - Determine path of insertion









The first step is determining the **tilt, or path of insertion**. You rotate the model and select **“set from view”**; this adjusts the survey line. The survey line is indicated in **salmon color** and also highlights all the areas **apical to the survey line that are undercut in relation to it**.

For **clasped teeth**, you ideally want the survey line in the **cervical third** of the tooth, if possible. On the **guide plane areas**, ensure that there is at least a **1mm band of tooth structure coronal to the survey line**. For **lingually plated teeth**, the survey line should ideally be located in the **middle third of the tooth**.

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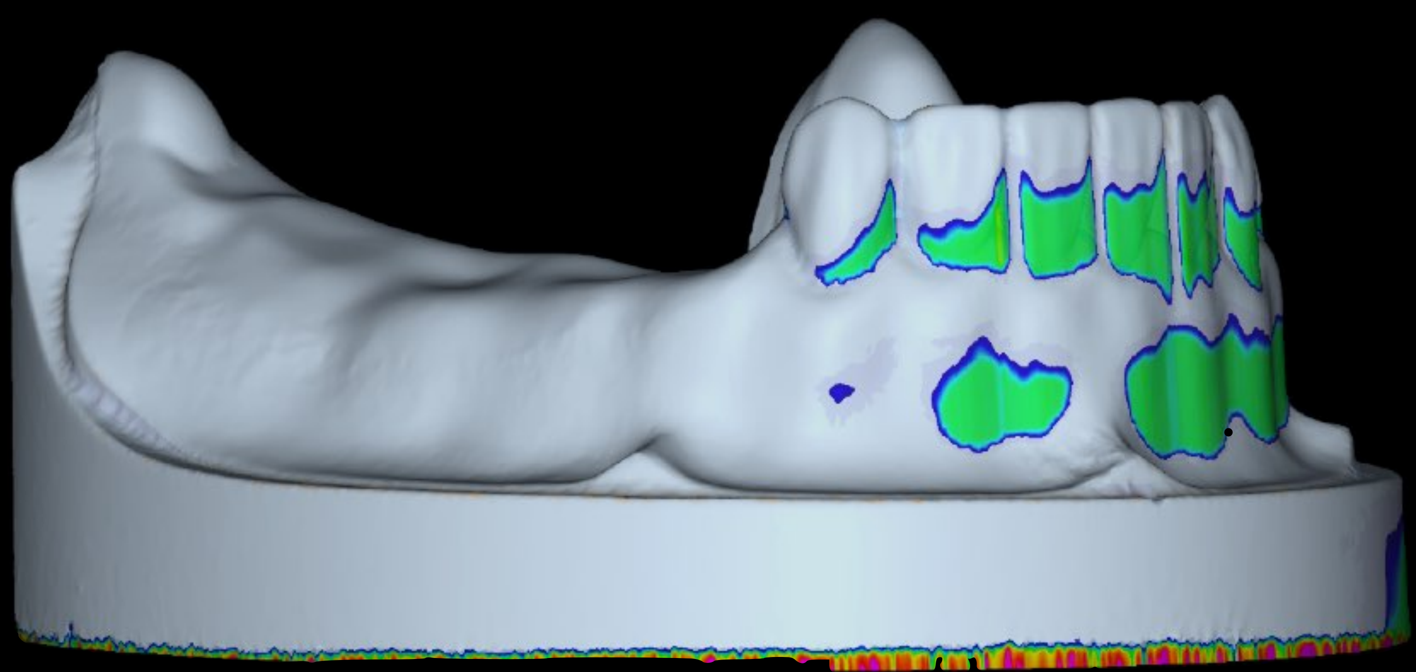
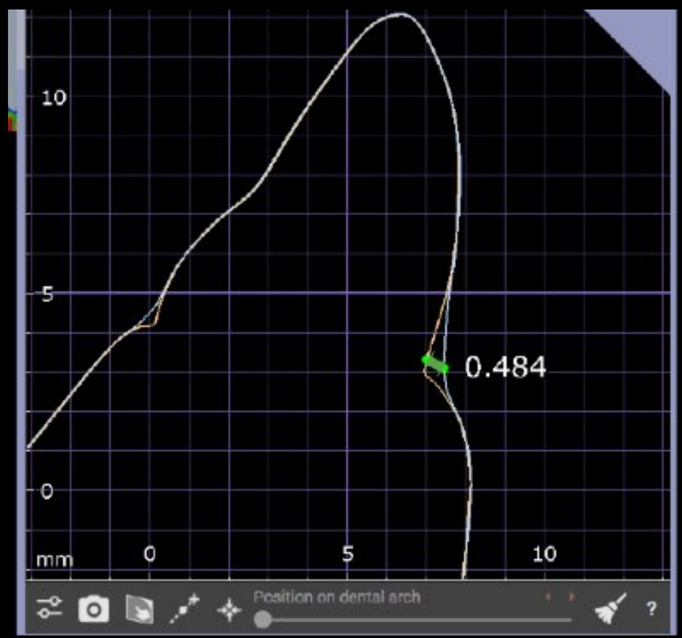
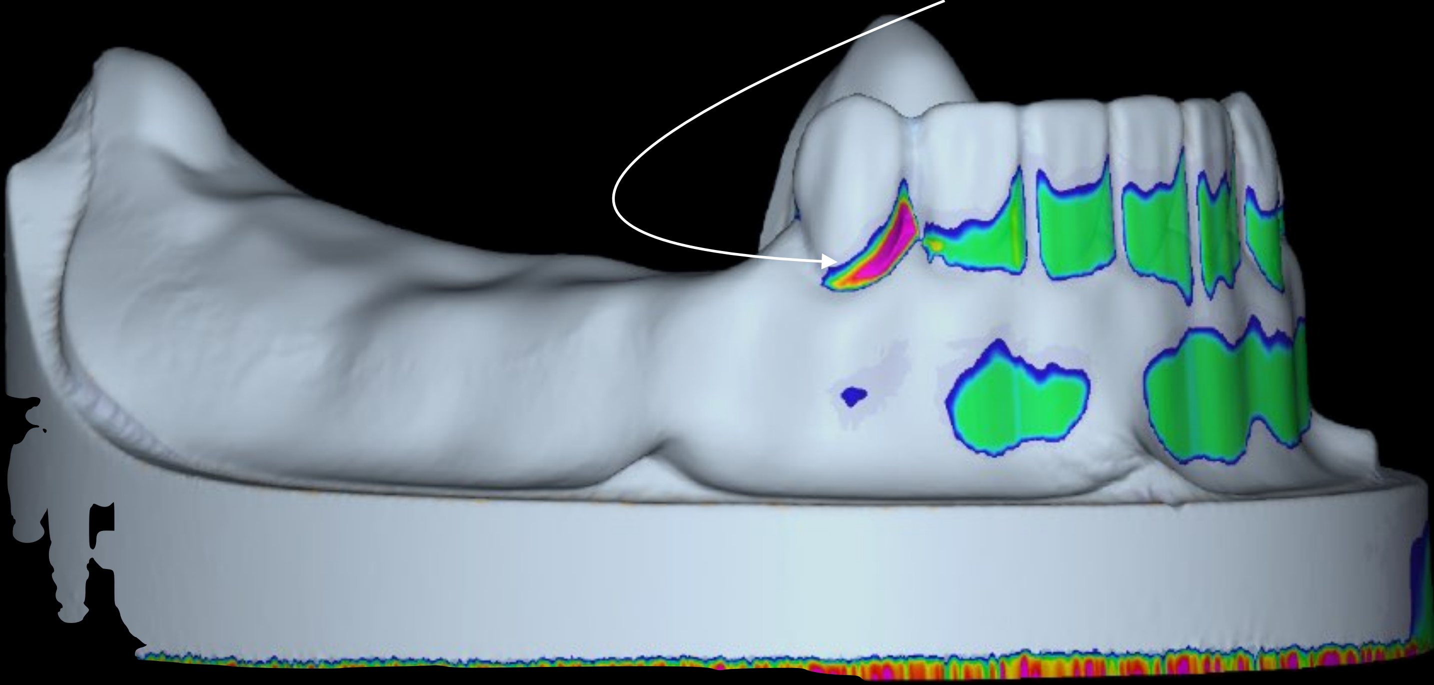
Design Guide

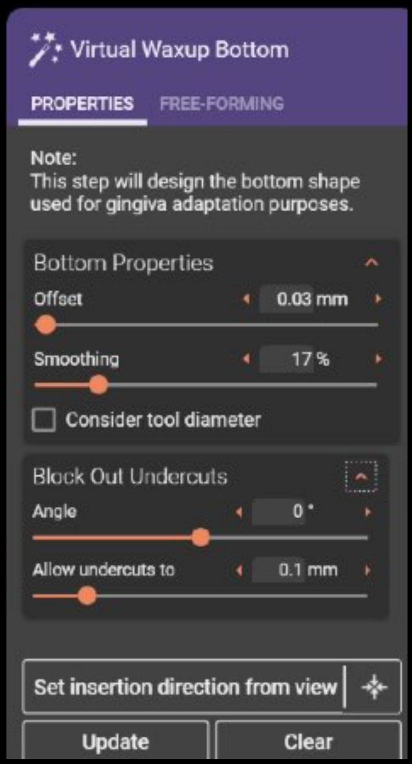
Exocad Design Steps - Edit the blockout model





Remove wax to expose 0.5mm–0.7mm undercut





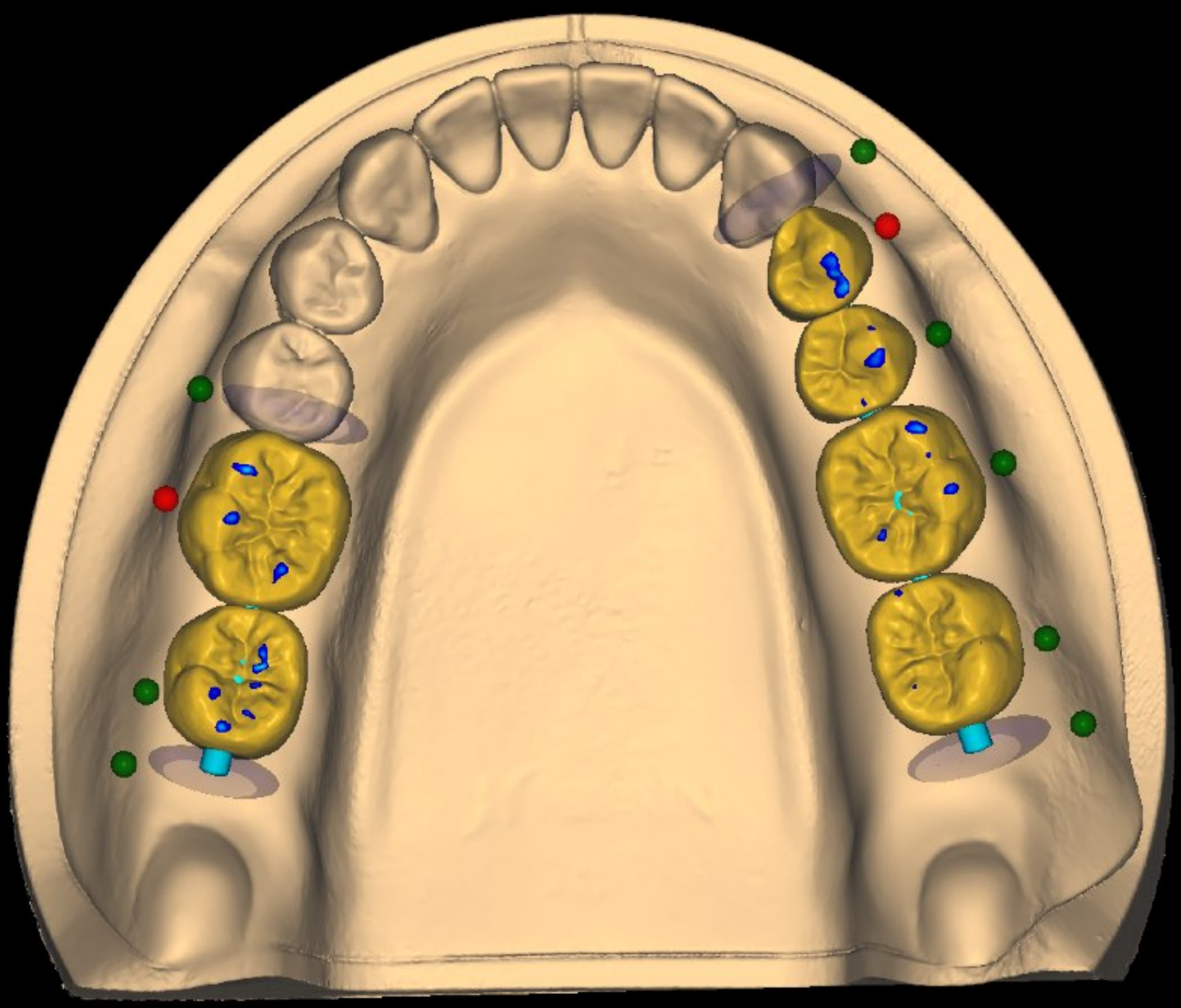
After hitting **Apply** to lock in the desired path of insertion, you will see the undercuts displayed. The **green areas** represent undercuts apical to the survey line. By default, Exocad allows **100 microns of undercut (green)**, meaning blockout wax is essentially applied everywhere apical to the survey line.

We then need to **edit the wax**. Go to **Freeform** at the top of the wizard box and selectively remove the blockout. Use the **slice tool** to identify the point on the blockout area that corresponds to **0.5mm**, and remove wax in this region all the way down to the natural tooth surface.

This is how we control both the **amount of clasp engagement with the tooth** and the **exact undercut depth**. Remember, for **wrap-around clasps** we aim for **0.5–0.7 mm of engagement**.

Design Guide

Exocad Design Steps - Set the teeth



Click the mesial contact point and then gingival areas to set the teeth. Don't worry too much about their exact location at first, since we have many tools to adjust them later. Once the teeth are placed, go to **Chain Mode** and deselect any **red dots**. You can now move the entire segment of teeth together.

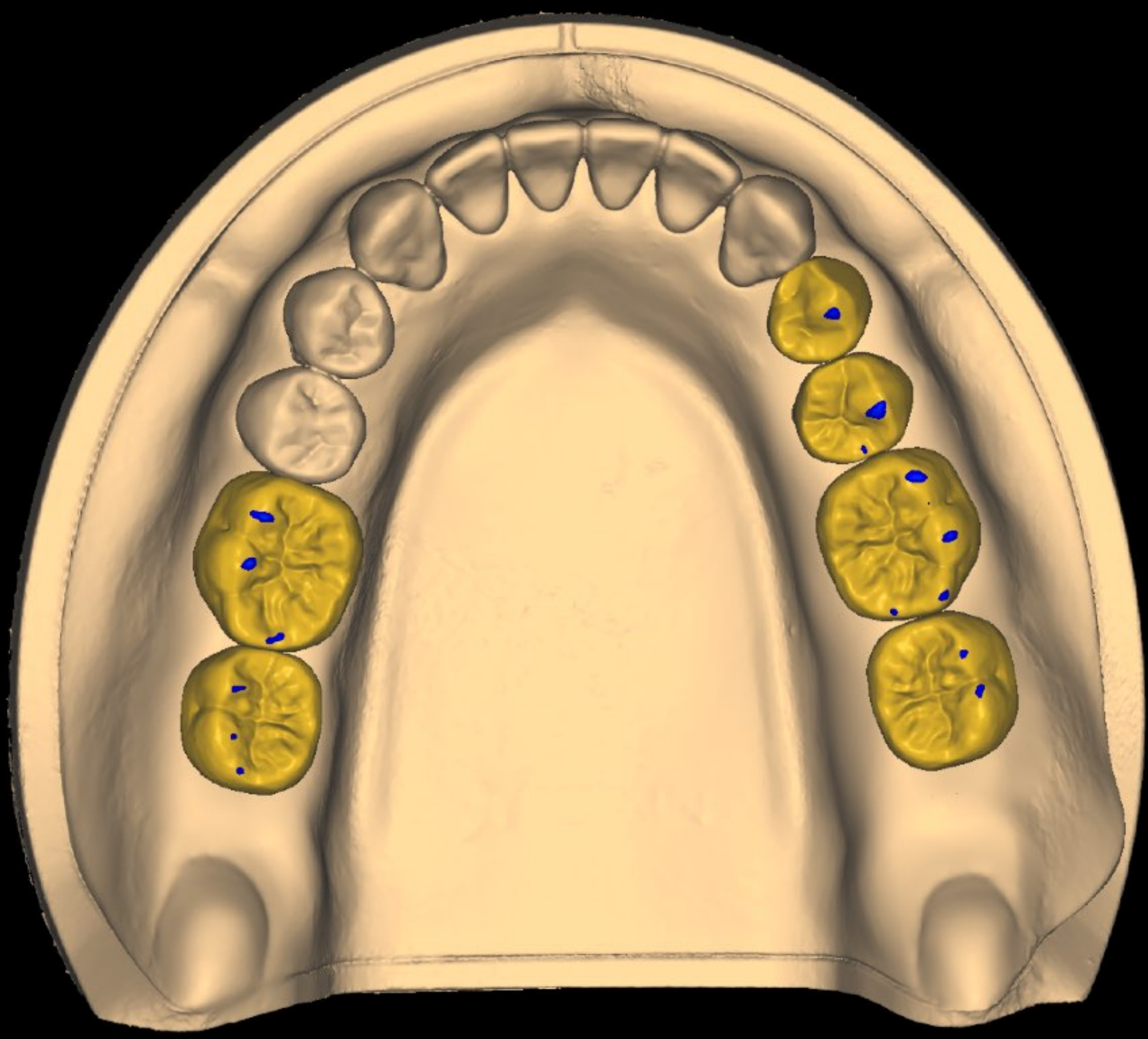
After positioning the **most anterior tooth correctly**, lock it by clicking a green dot (which will turn red). Then proceed to position each tooth **one by one**.

In **Exocad 3.3 or later**, you can enable **Instant Anatomic Morphing**, which automatically equilibrates occlusion while you move the teeth, streamlining the process.

MAJOR CONNECTORS

Design Guide

Exocad Design Steps - Edit with Freeform



Very little work should be done in Freeform. Use the add/remove tools to fine-tune occlusal contact locations. Maintain flat contacts with no contacts on incline planes, which would cause sliding. Make sure to cut all intersections to include Basal, Static Occlusion, and Approximal.

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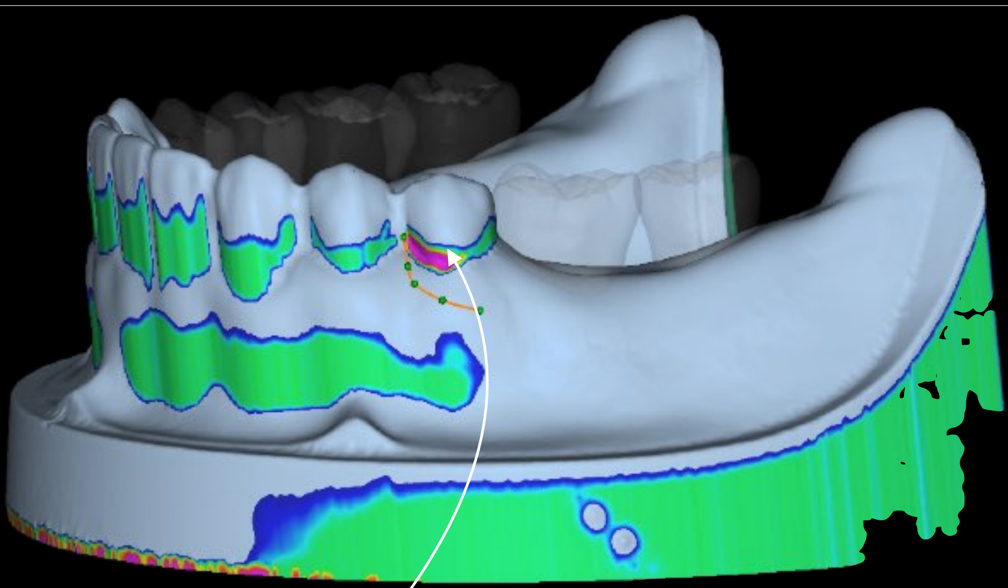
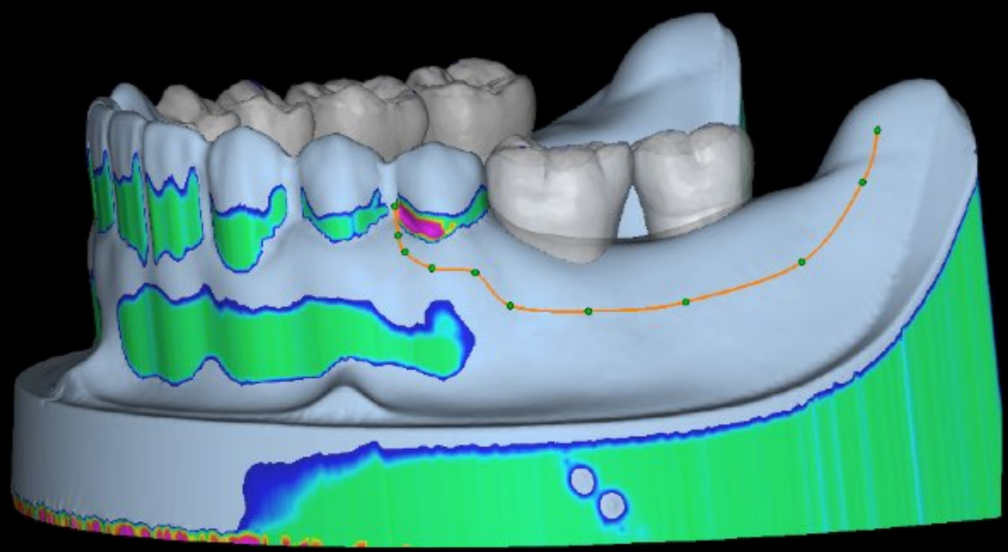
MAJOR CONNECTORS

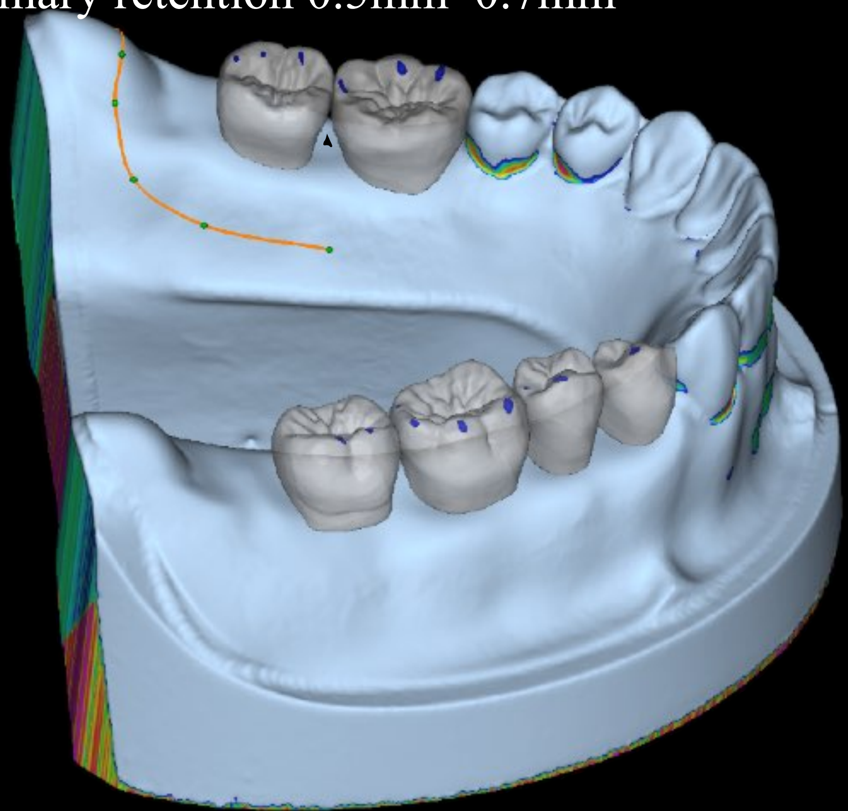
Design Guide

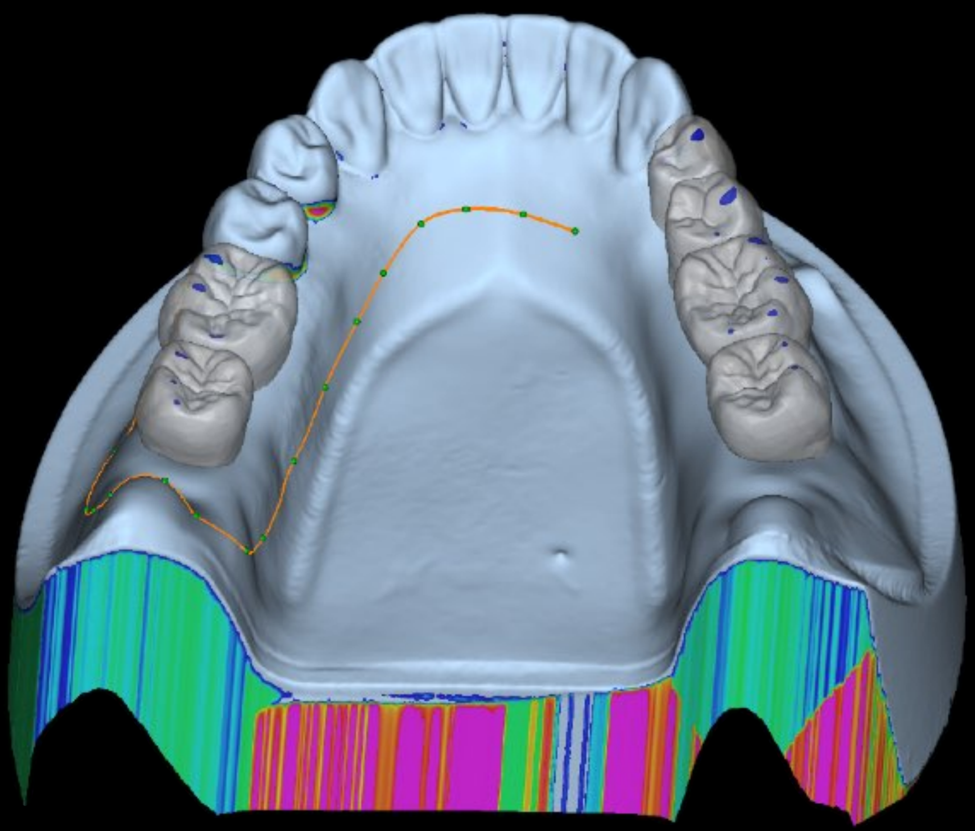
Exocad Design Steps - Draw design on tissue



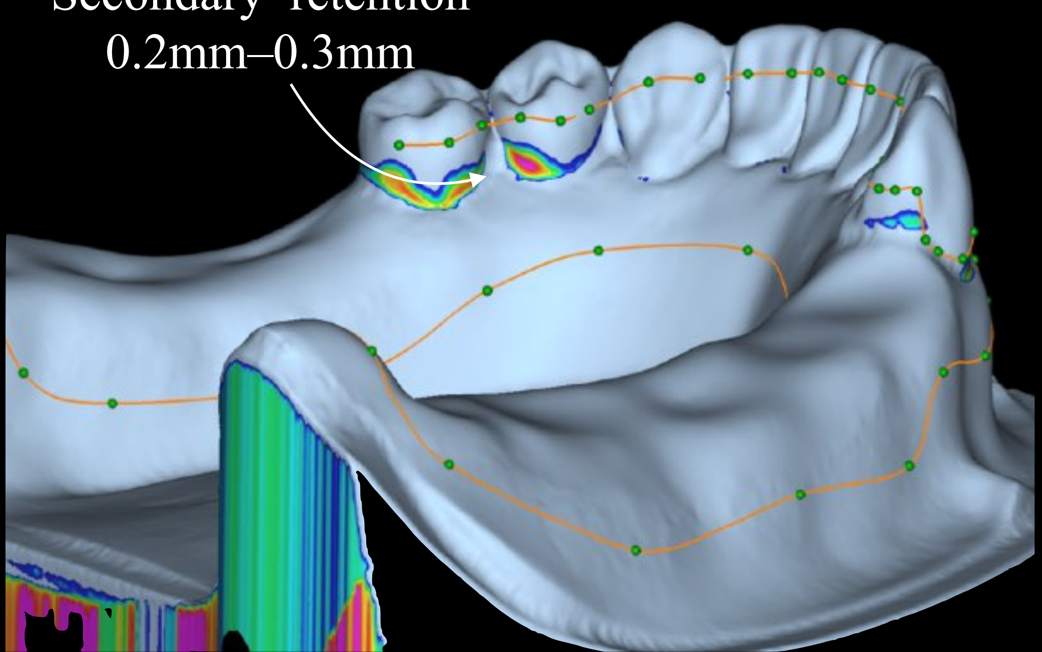


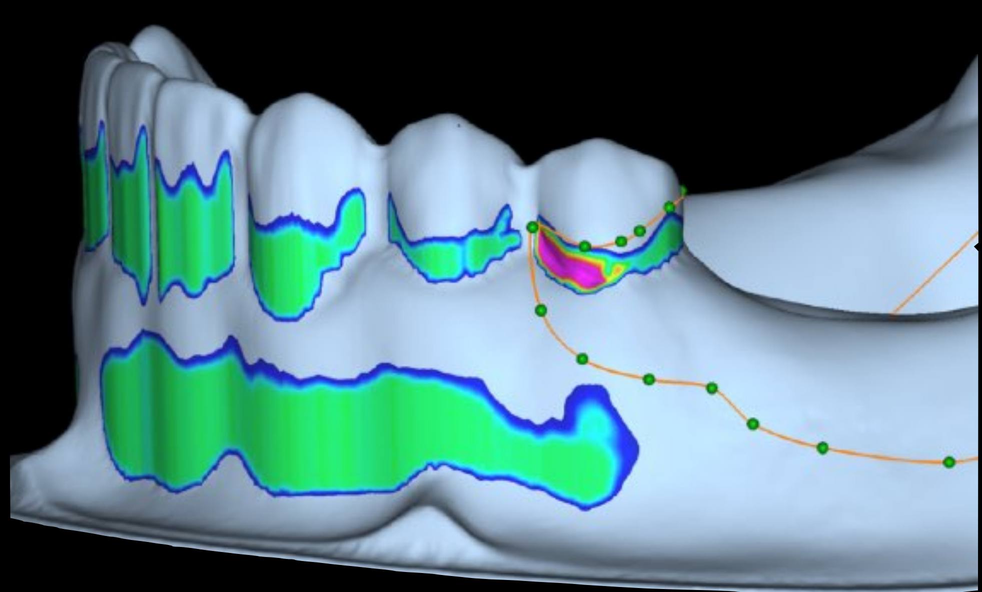
Primary retention 0.5mm–0.7mm





Secondary retention 0.2mm–0.3mm

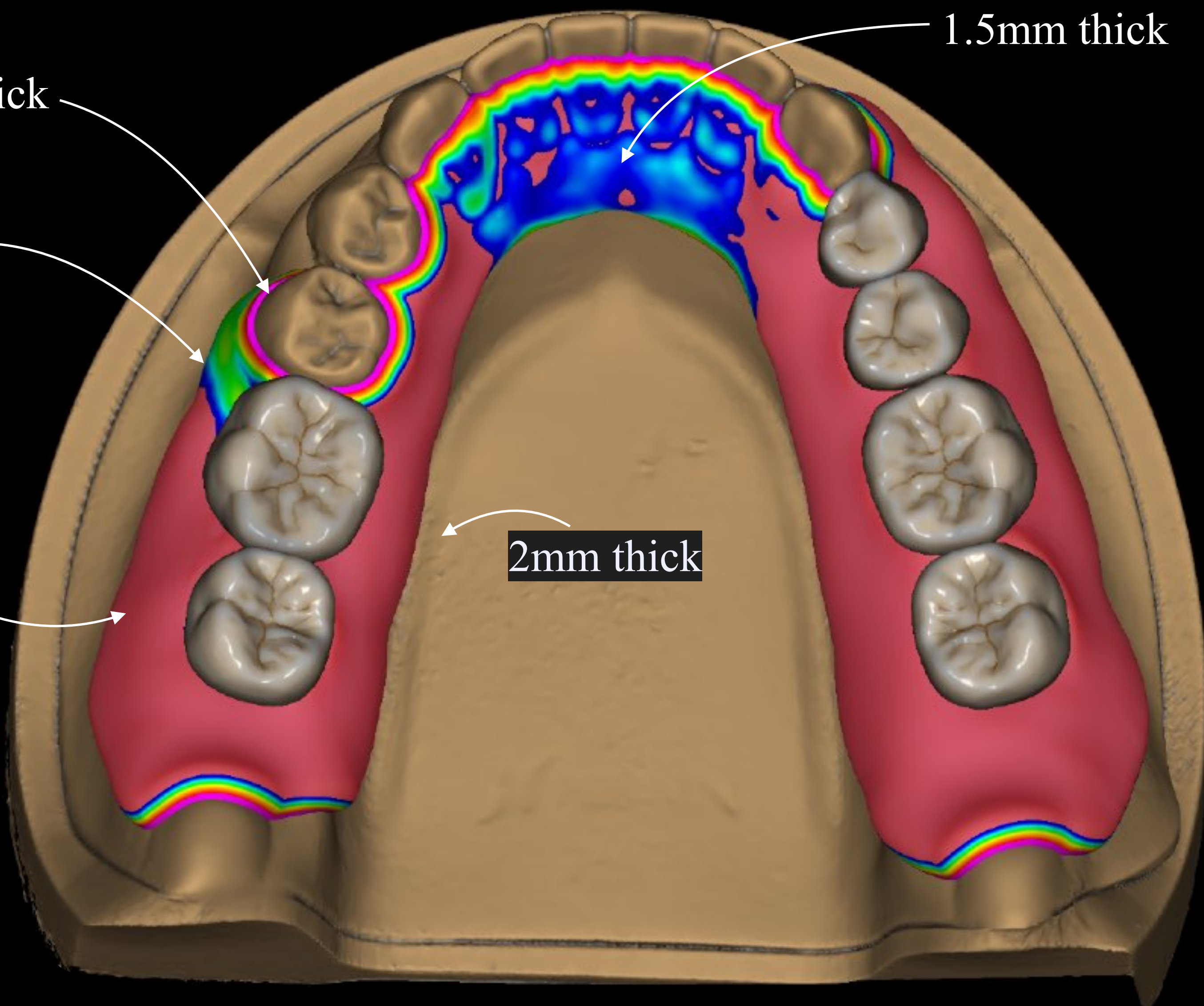


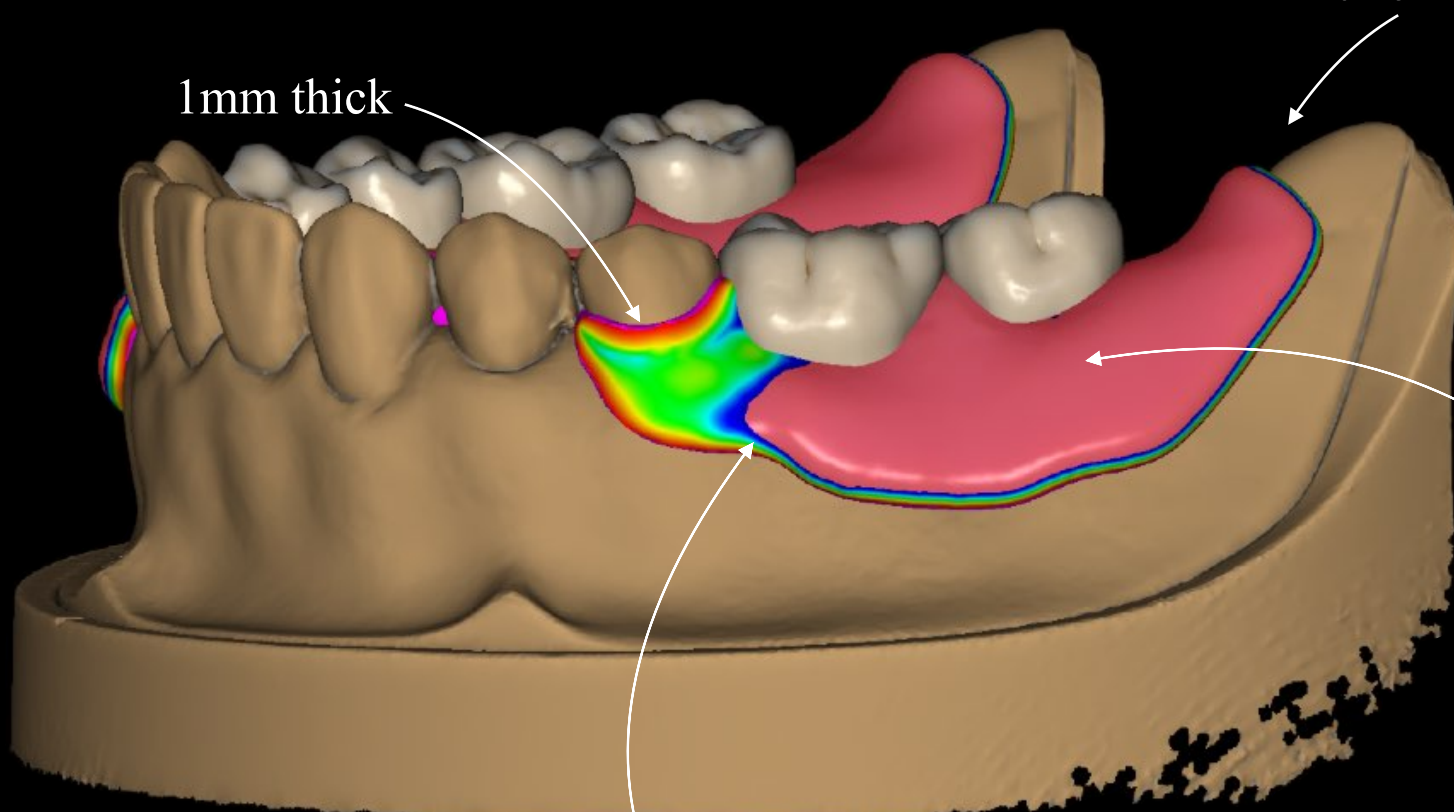


MAJOR CONNECTORS

Design Guide

Exocad Design Steps - Freeform tissue





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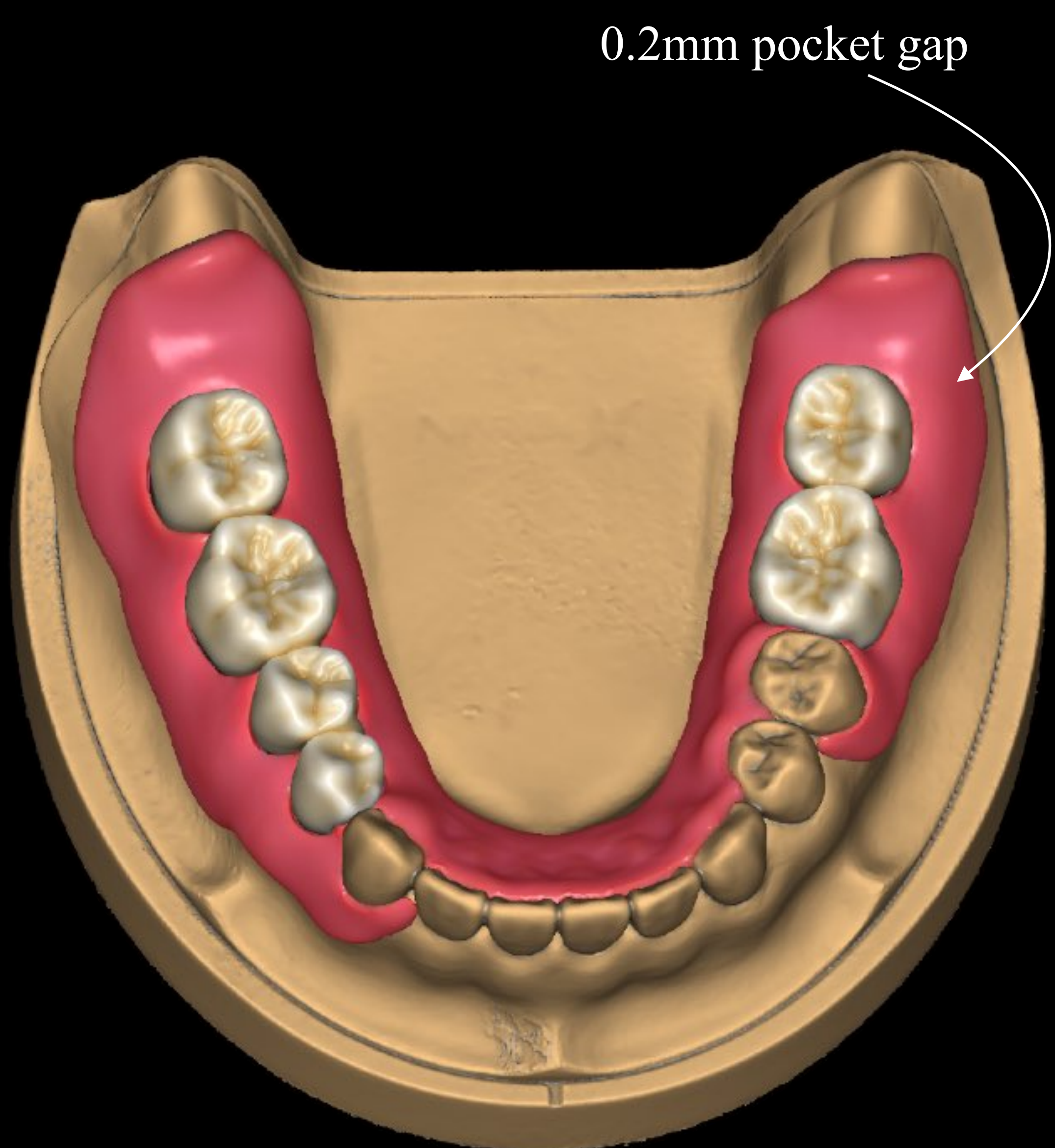
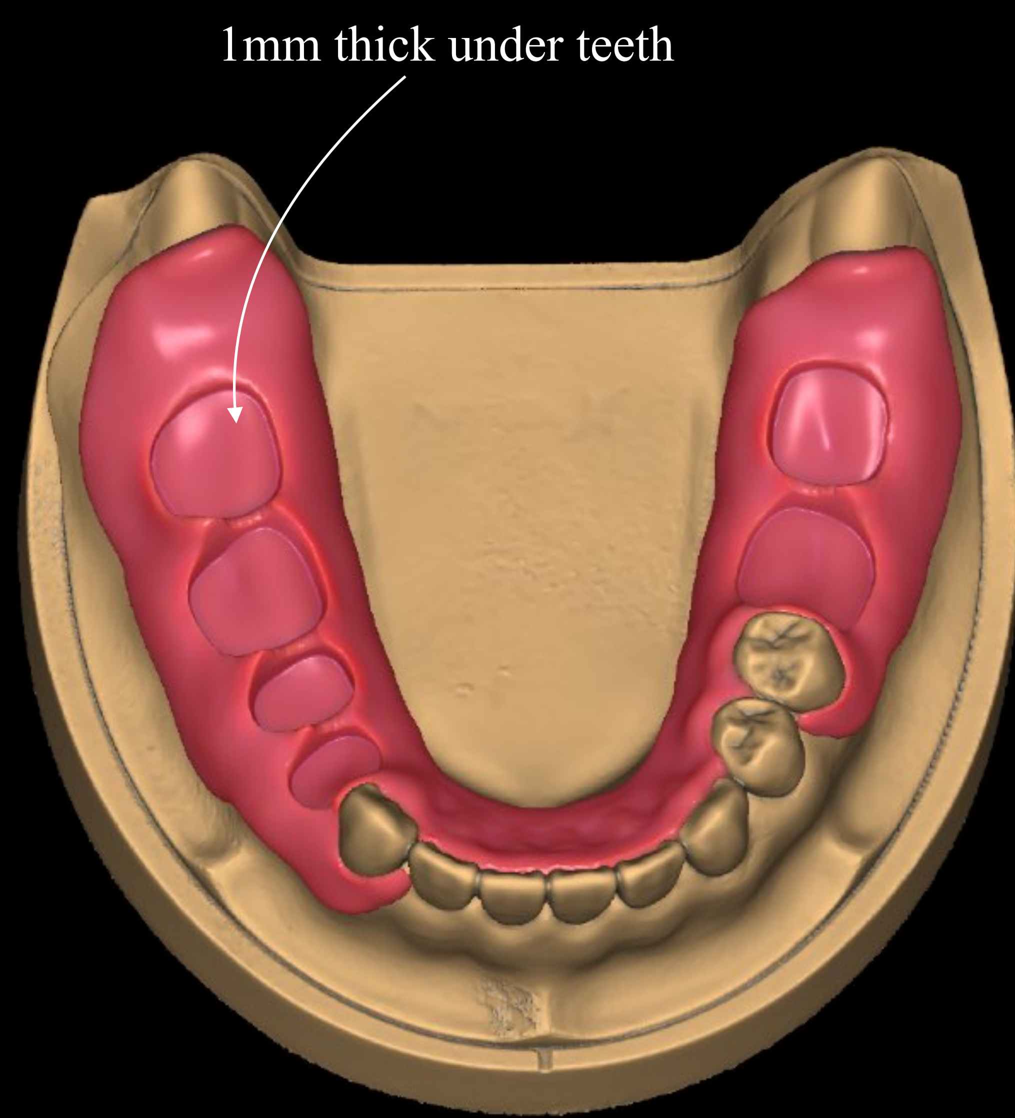
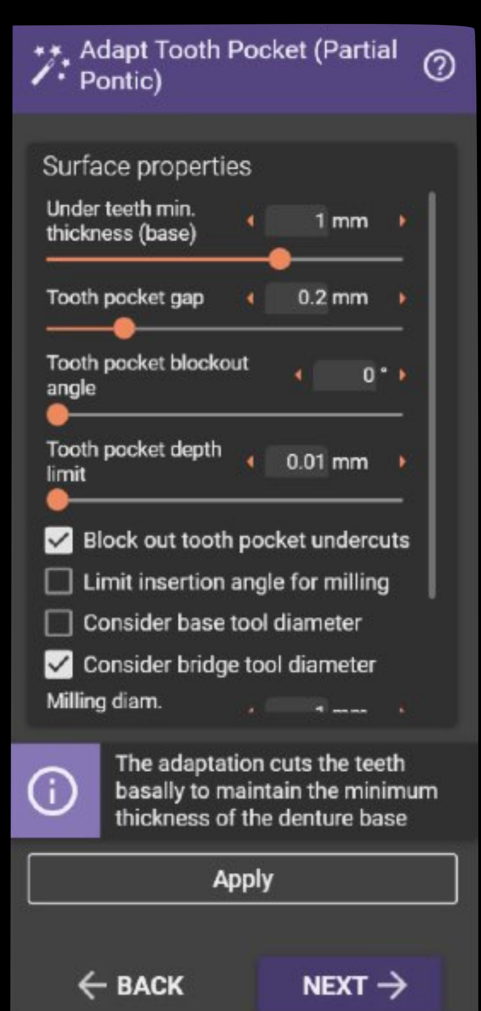
MAJOR CONNECTORS

Design Guide

Exocad Design Steps - Cut Pockets





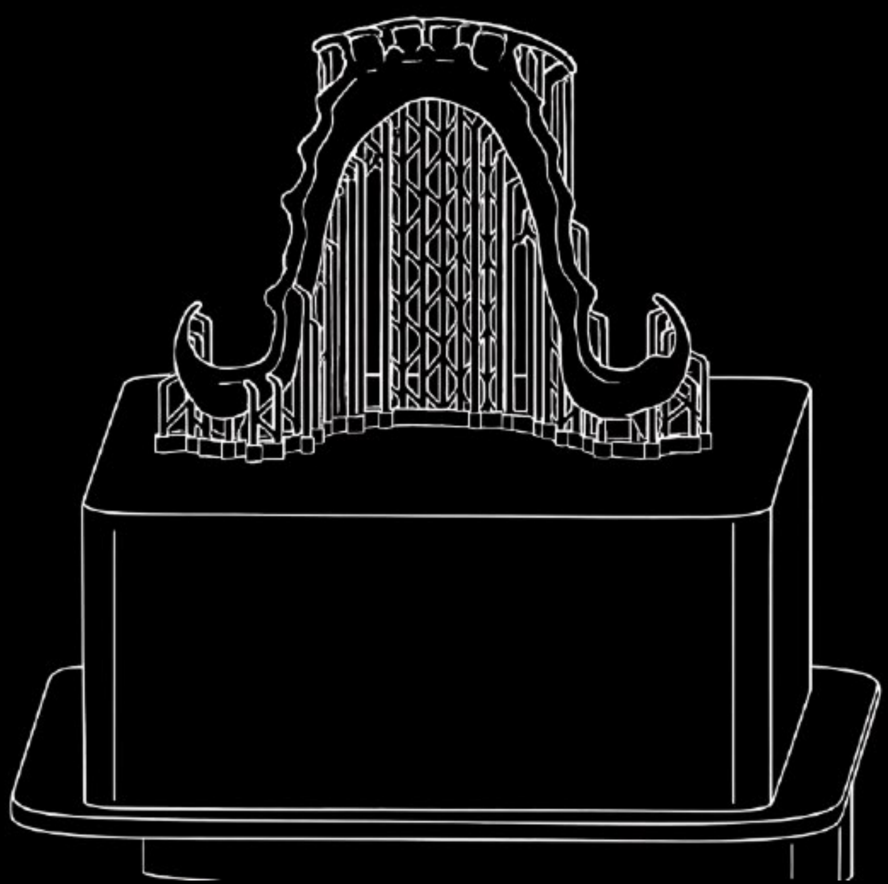


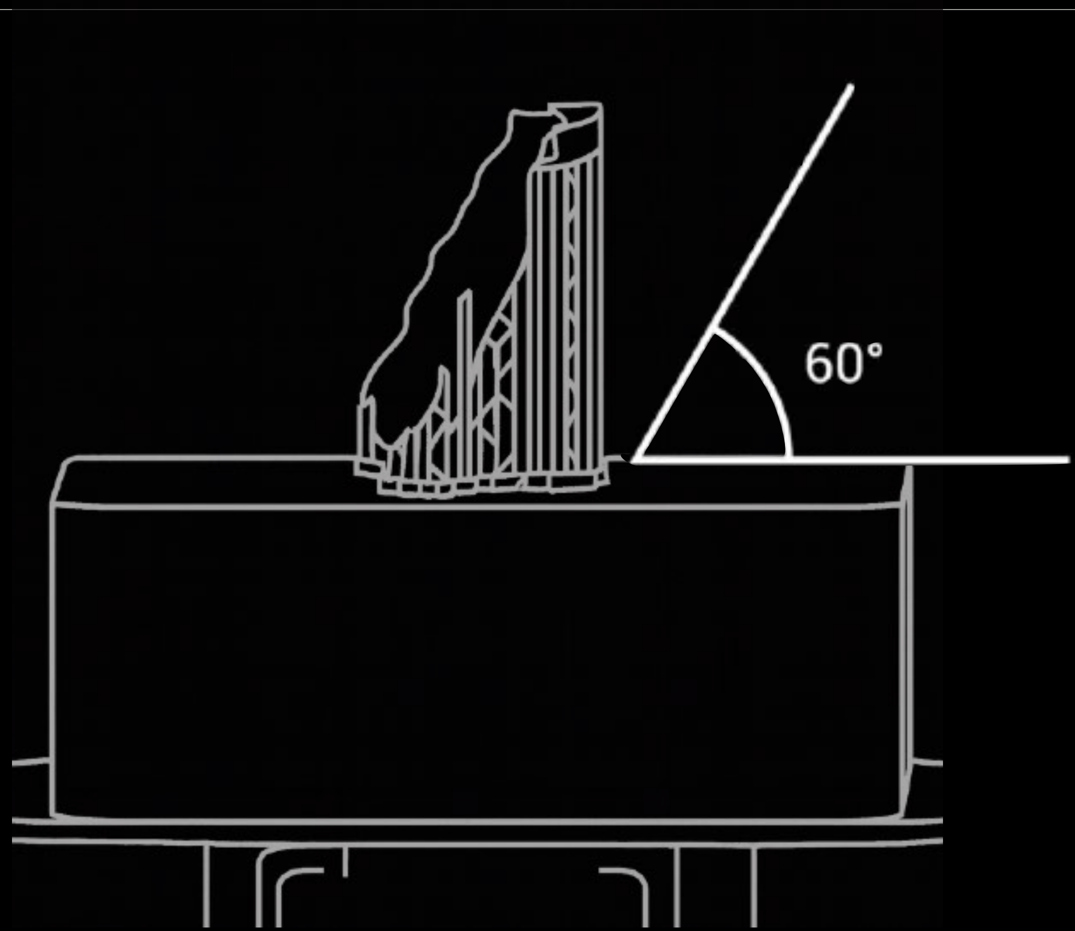
Pocket settings are important. The most important setting is the 1mm thickness under the tooth socket. Then the gap of 200 microns helps with seating of the teeth in the sockets, especially if you have support tips in your socket. Set a 200 micron pocket gap, 1mm thickness under teeth, and Consider tool diameter to 0.2mm for printing. Hit next and you are all done with design!

NESTING

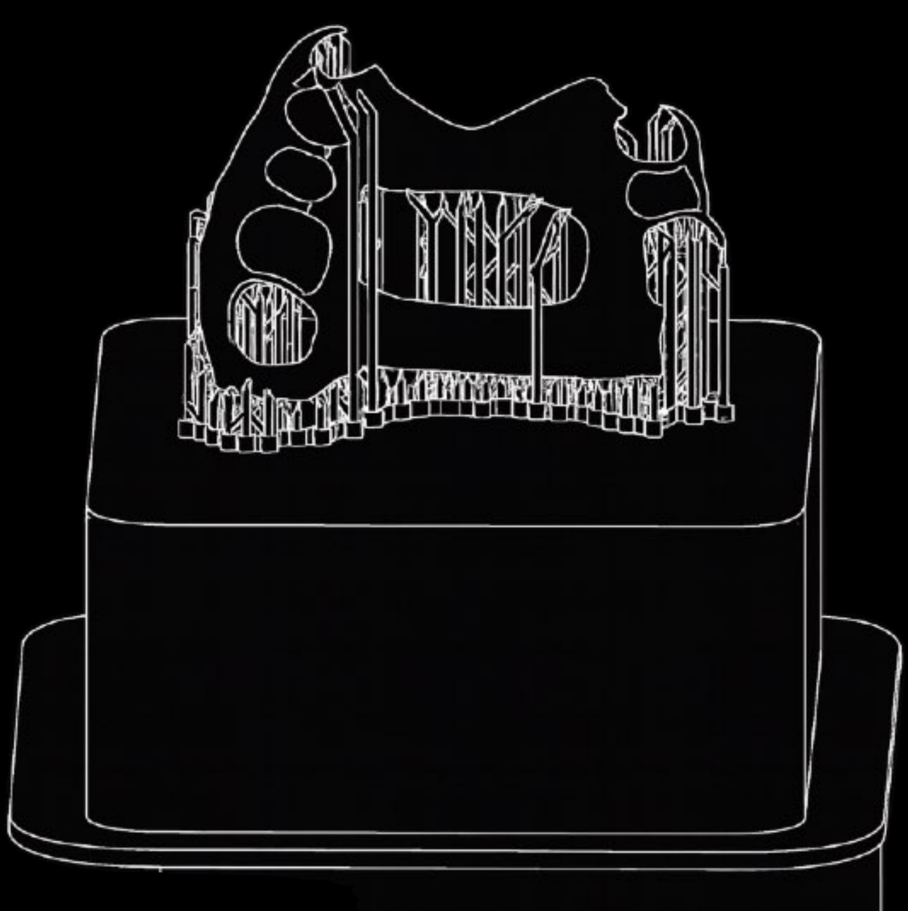
Print Finishing

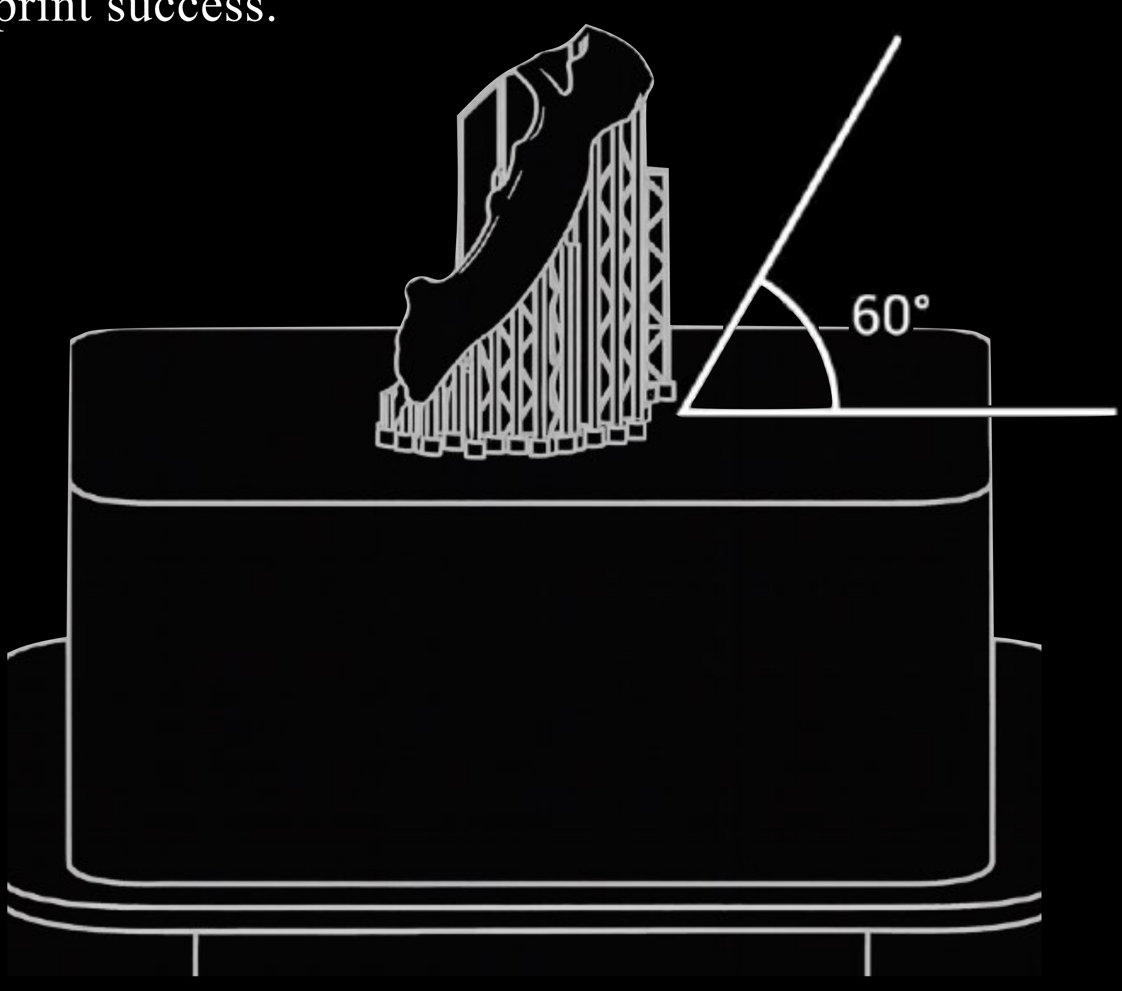
Nesting is key!





Because of the rather complex designs of flex partial dentures, with various clasp shapes and major connector shapes, the nesting can be difficult. It is recommended to nest at a 60-degree angle with the intaglio surface facing the plate. This minimizes support tips in the sockets and prevents overcure in thin socket areas. Additionally, peel forces are minimized due to small cross-sections being cured, which helps with print success.





NESTING

Print Finishing

Nesting is key!

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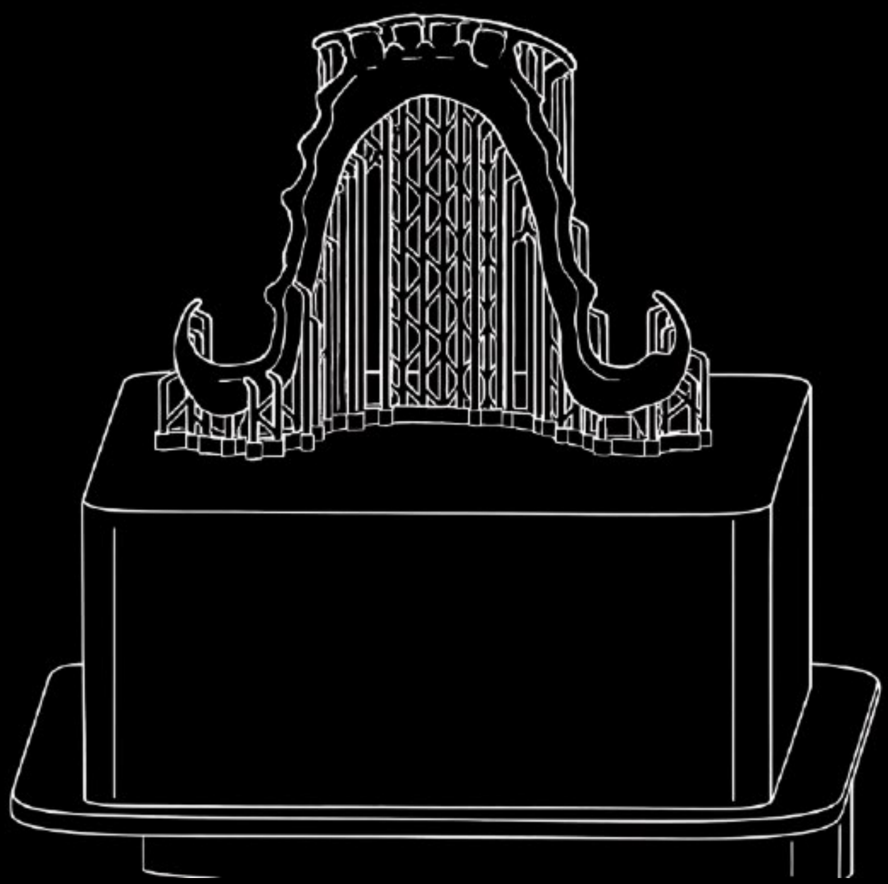
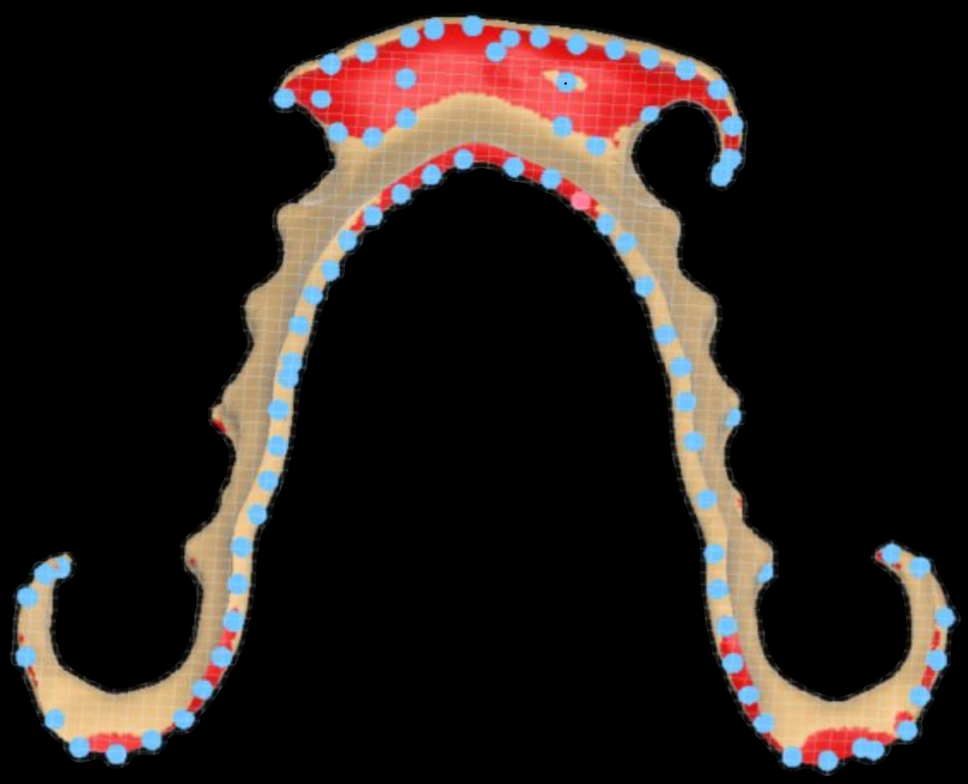
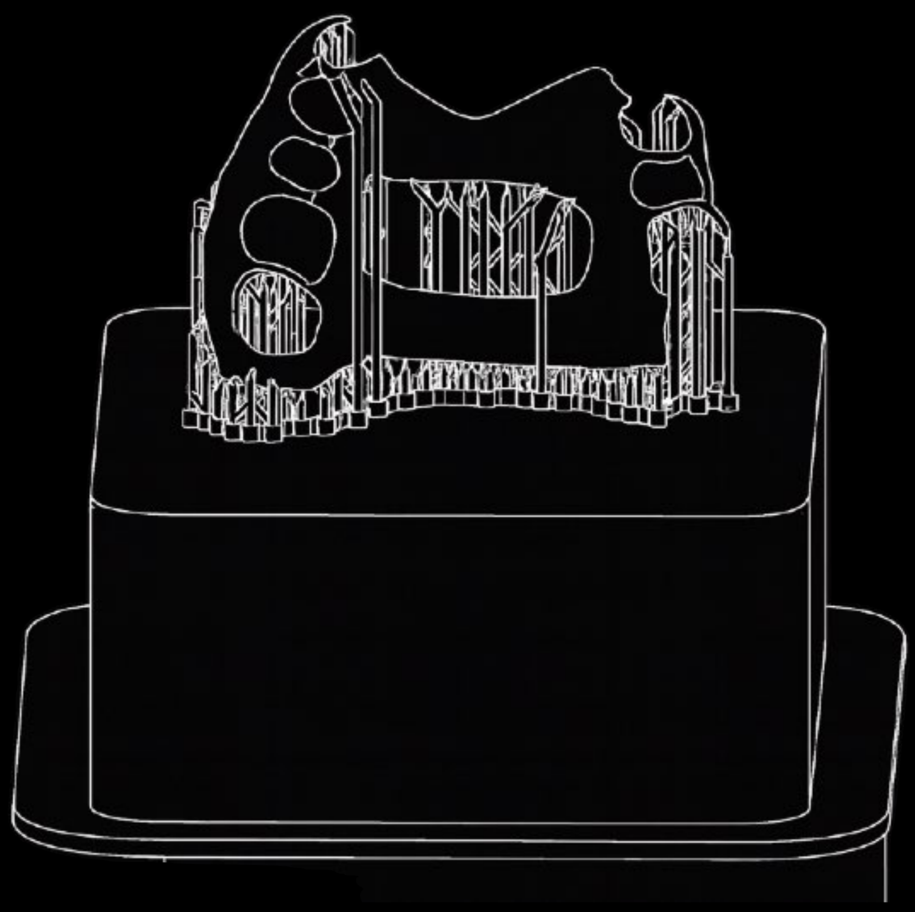
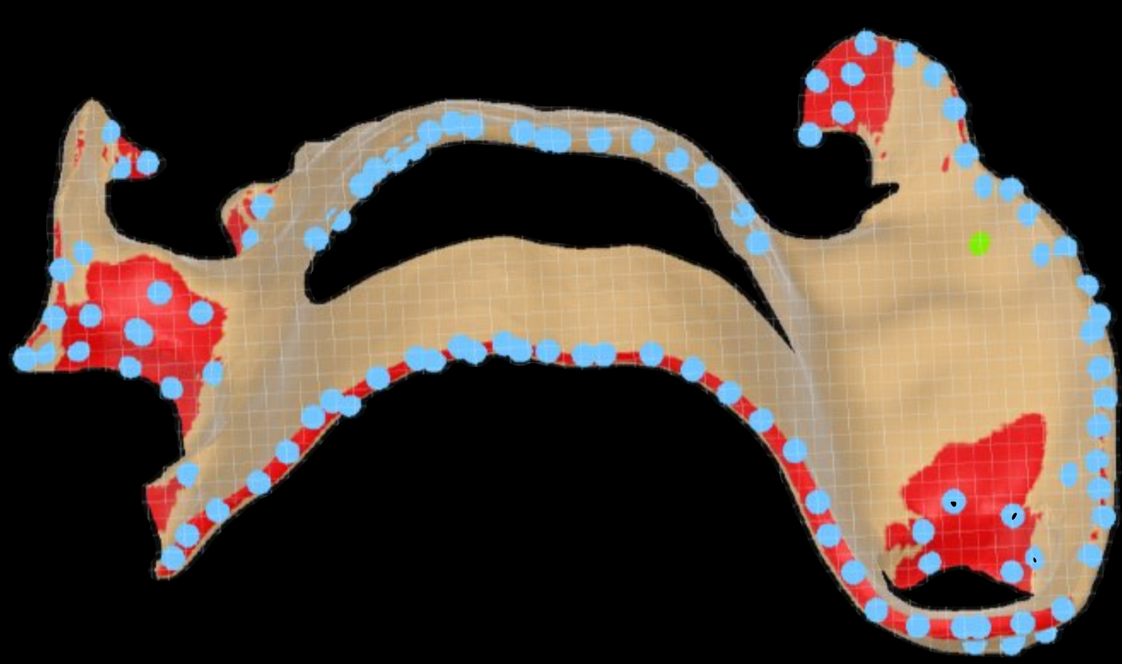




Support density is high. A dense band of supports should follow the outline of the prosthesis on the border surfaces closest to the plate. Ensure that a support is on the tip of each clasp. If you have an open printer, the support tip diameter should be 0.35mm and the penetration 0.3mm, with a 2mm base diameter.

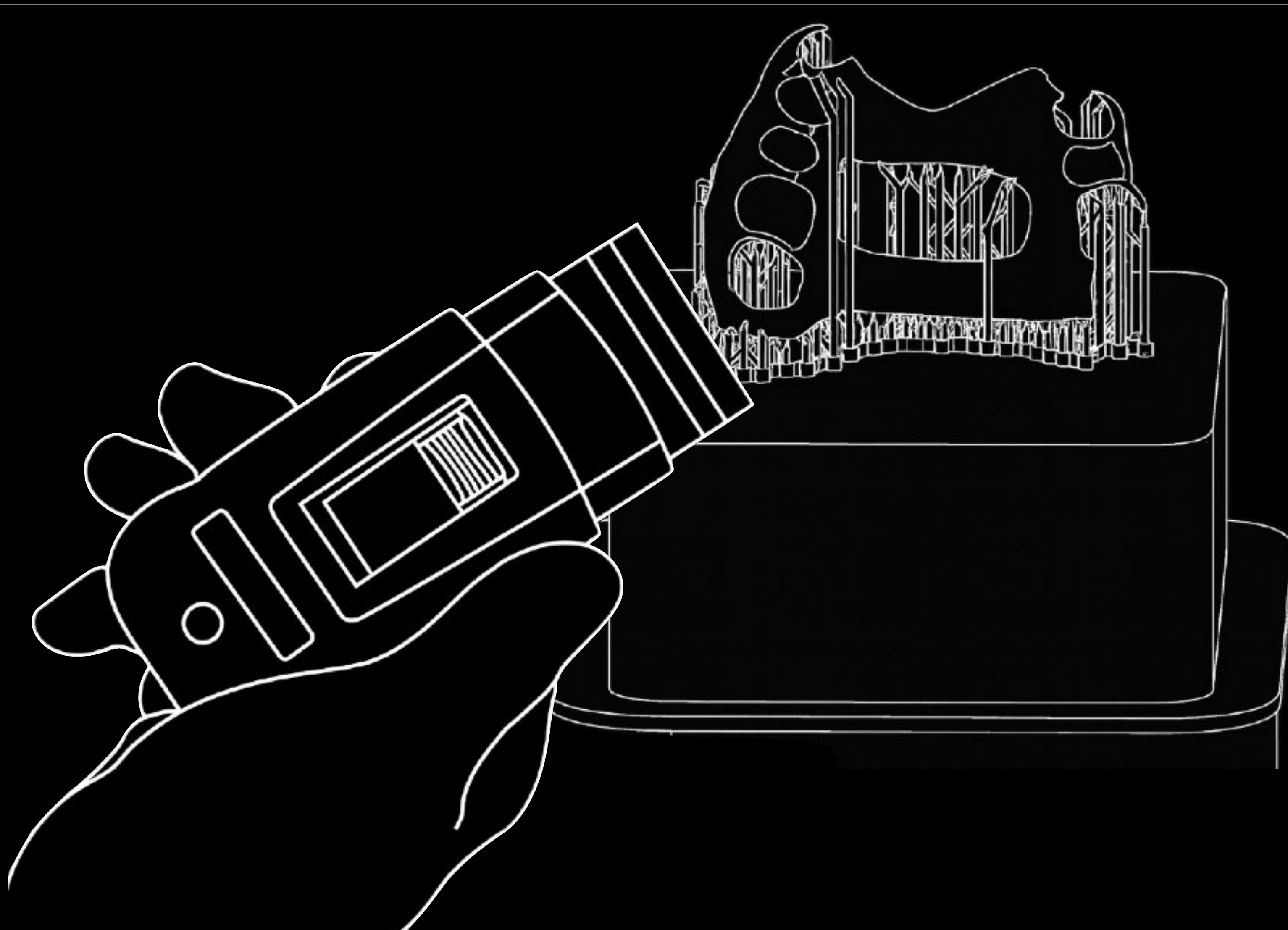




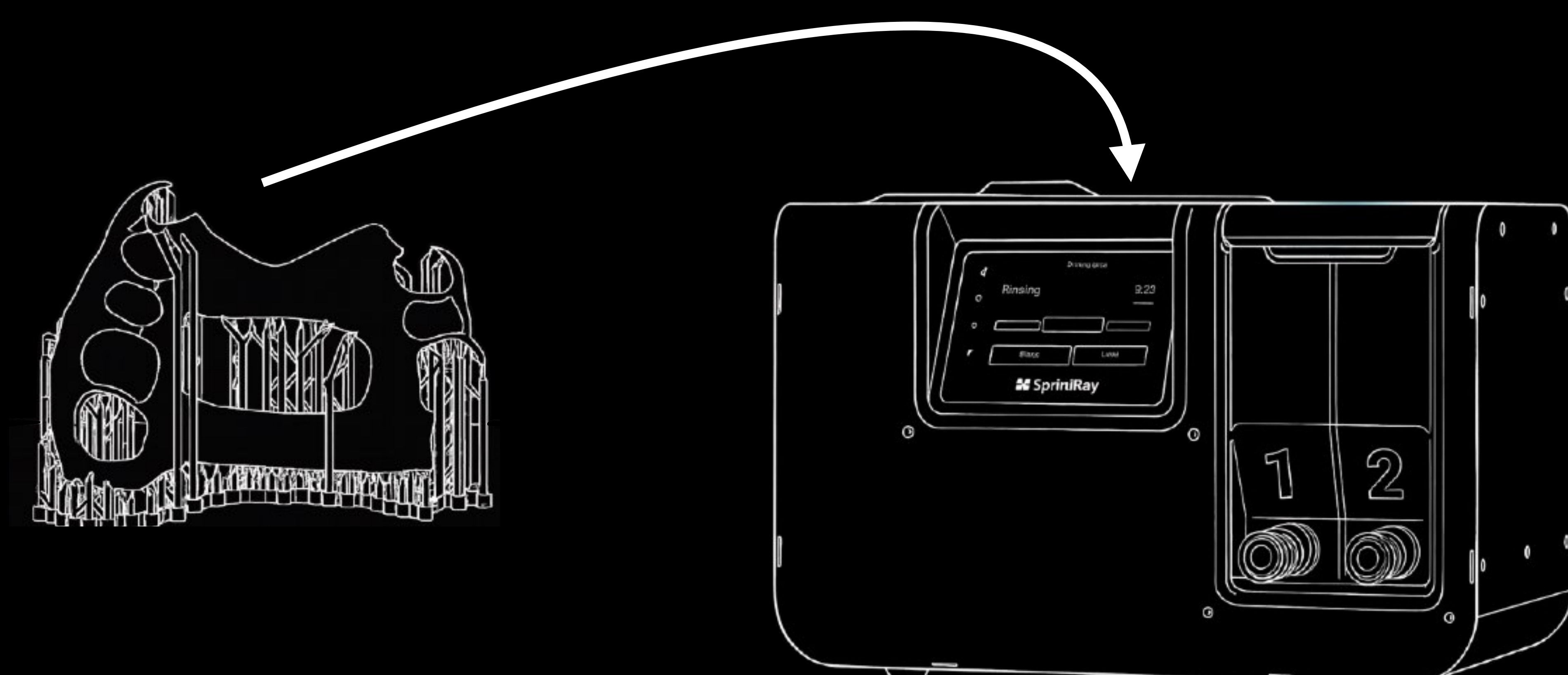
WASHING

Print Finishing

Cure and Finish.



You must be extremely careful when removing the flex partial denture from the build plate because any rough handling could easily distort it. Remember, it is in the uncured state and must be treated very gently. The best tool to use is an ultra-sharp razor. Once removed, place the partial denture in the wash unit with clean alcohol. If you have dirty alcohol, the finish will not be as nice.



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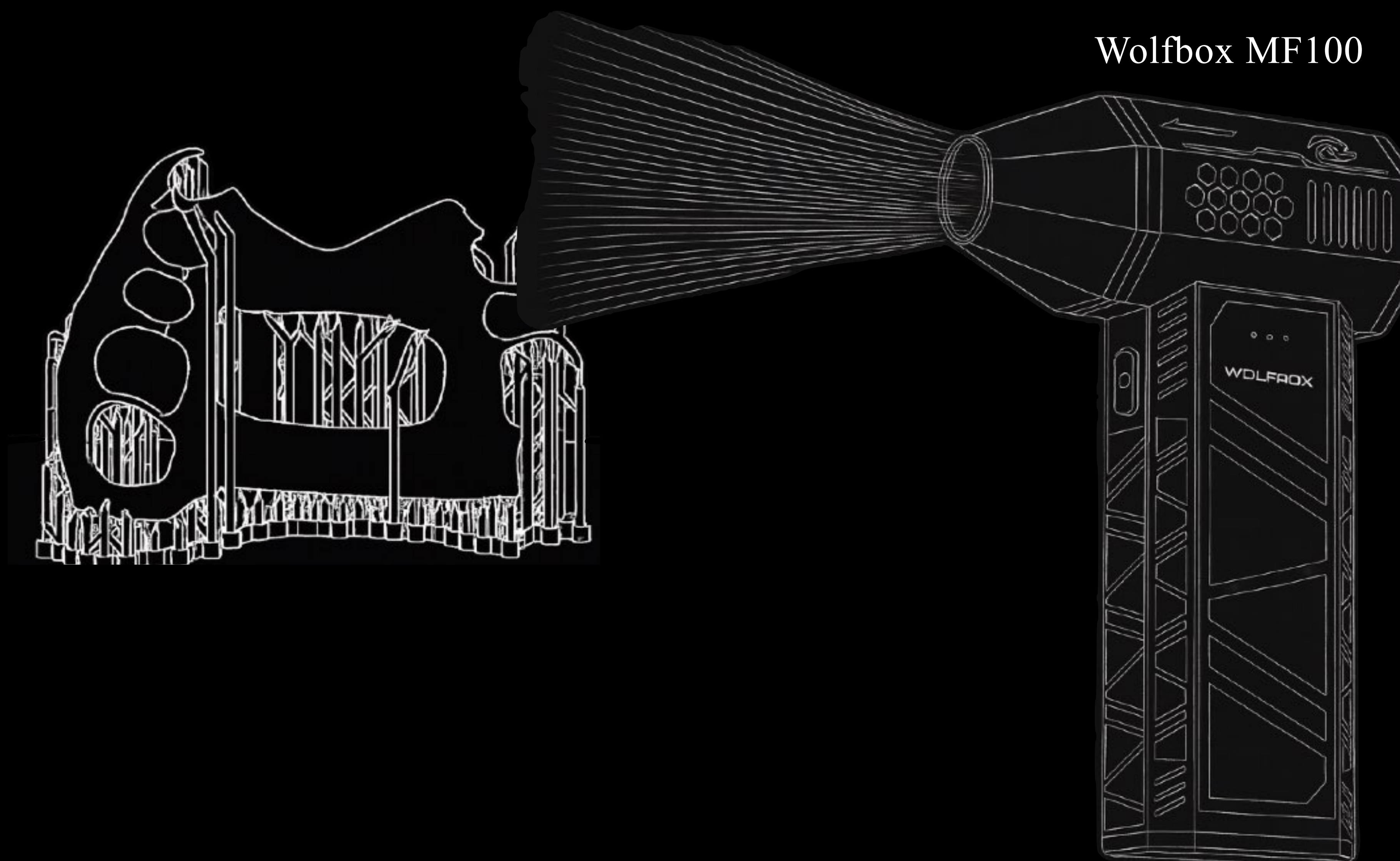
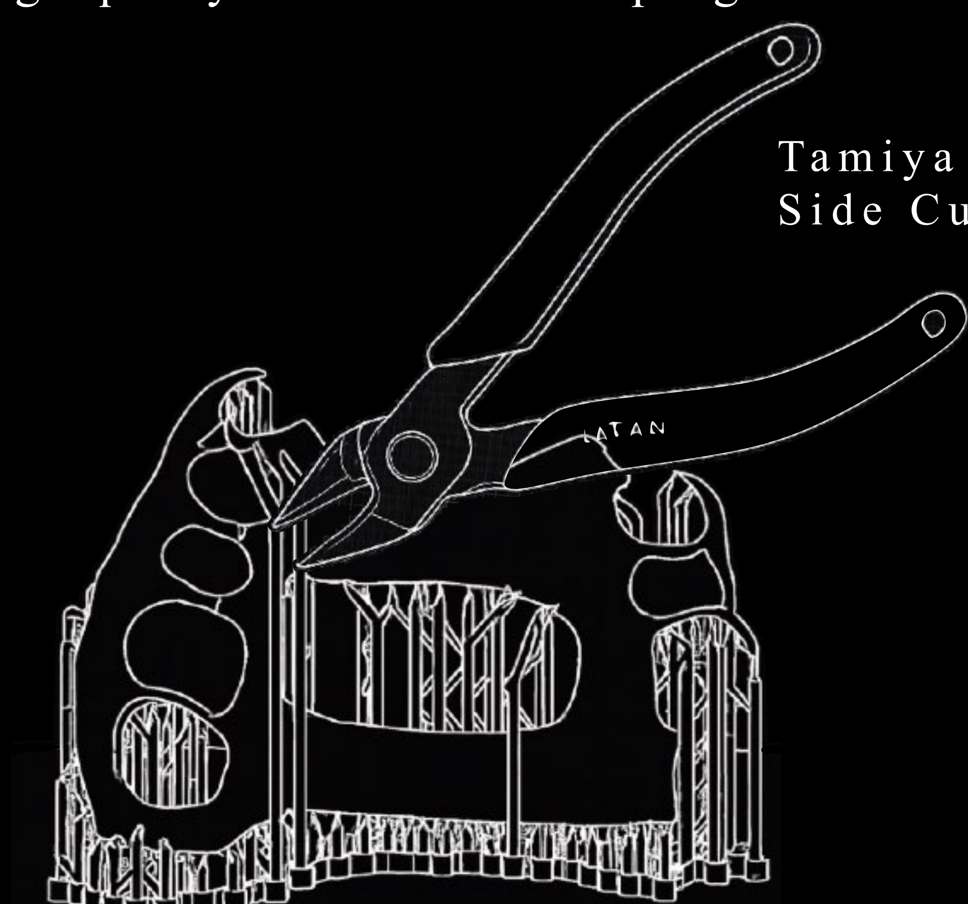
POST WASH

Print Finishing

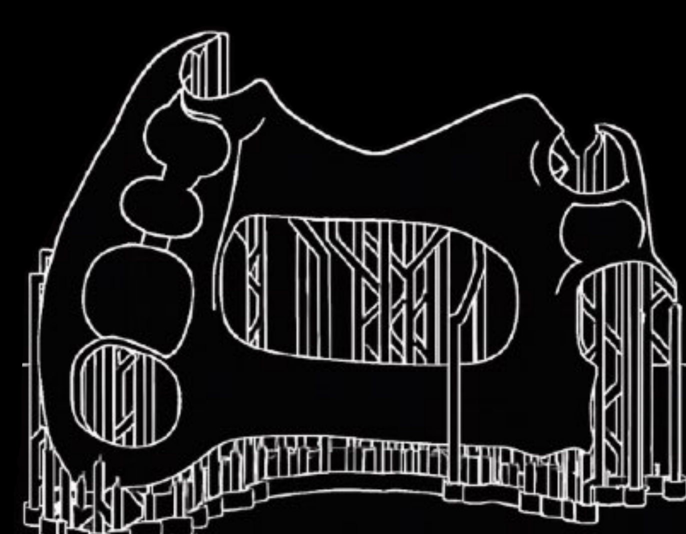
Cure and Finish.



Air drying is essential after the wash. If any residual alcohol is left during the bonding of the teeth and finishing, you can have a weak prosthesis. After it is completely dry, remove the supports using a high-quality flush cutter. Be super gentle so as not to distort the prosthesis at this time.



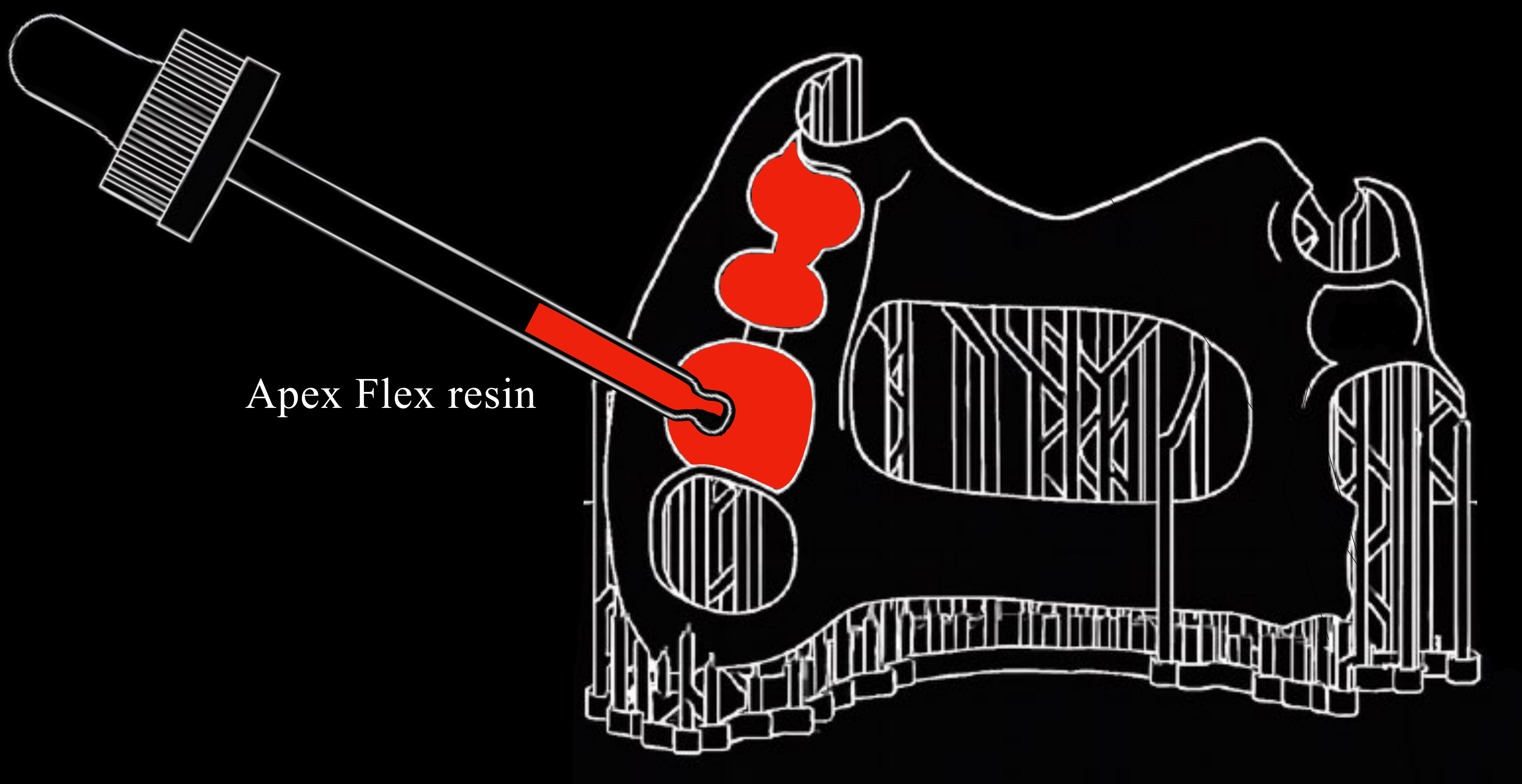
Tamiya Sharp Pointed
Side Cutter No. 123



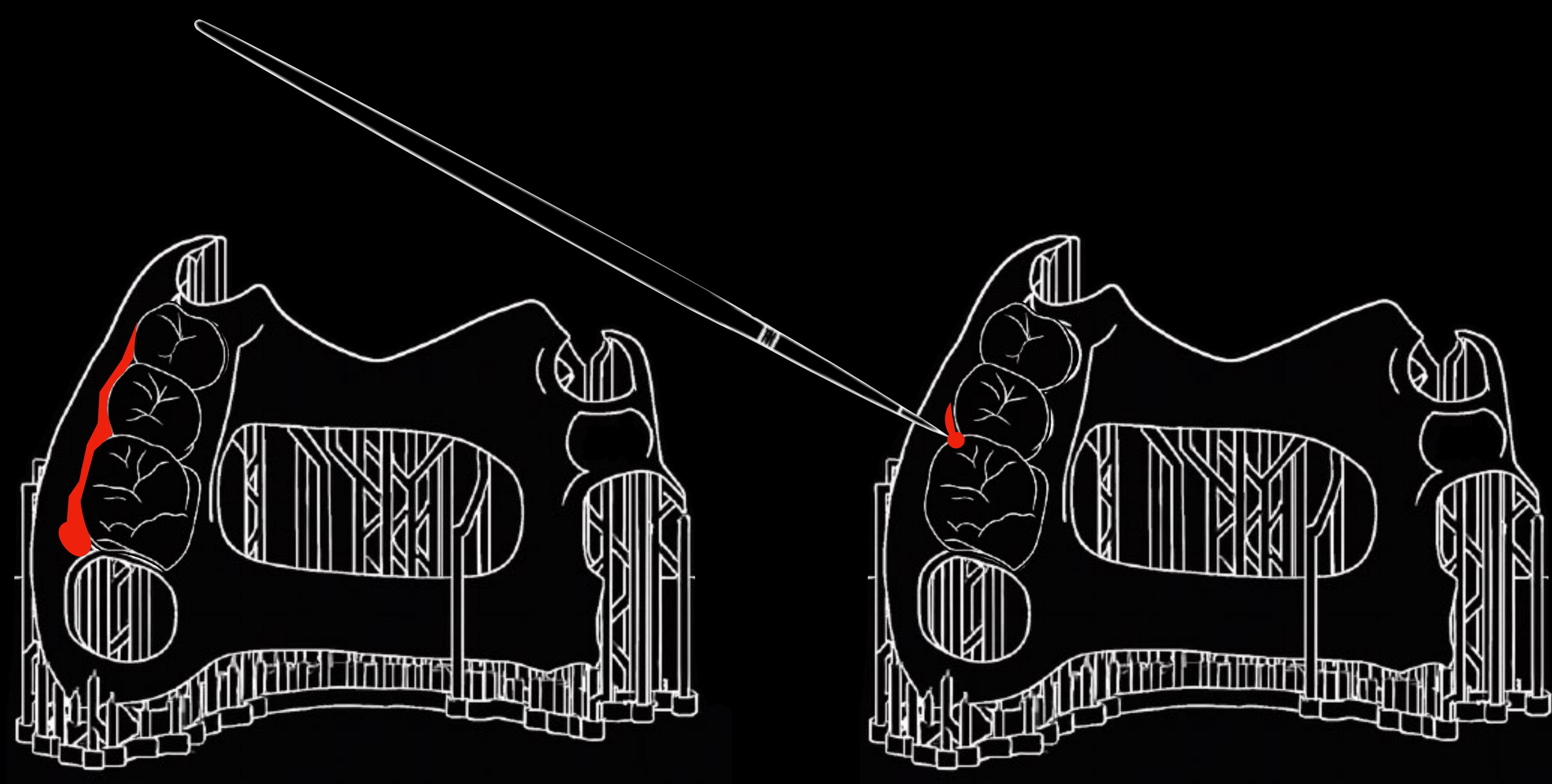
TOOTH BONDING

Print Finishing

Bonding the Teeth



To bond the teeth in the flex denture base, simply fill the tooth sockets with liquid flex resin. I use a dropper and keep the flex resin in a small amber glass dropper bottle to have handy at the workbench. Hold the teeth in place. Clean the excess resin with a brush or microfiber cloth.



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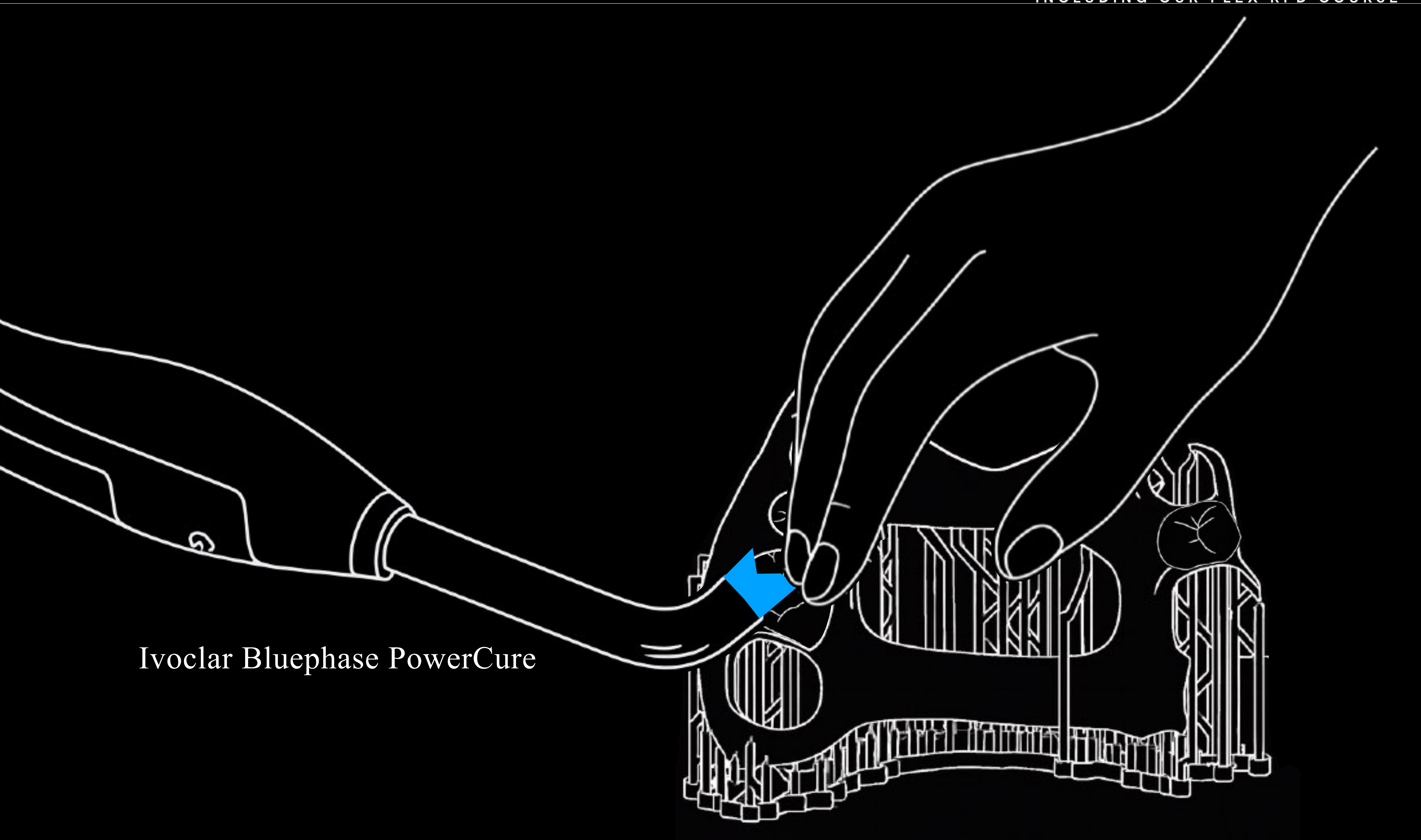
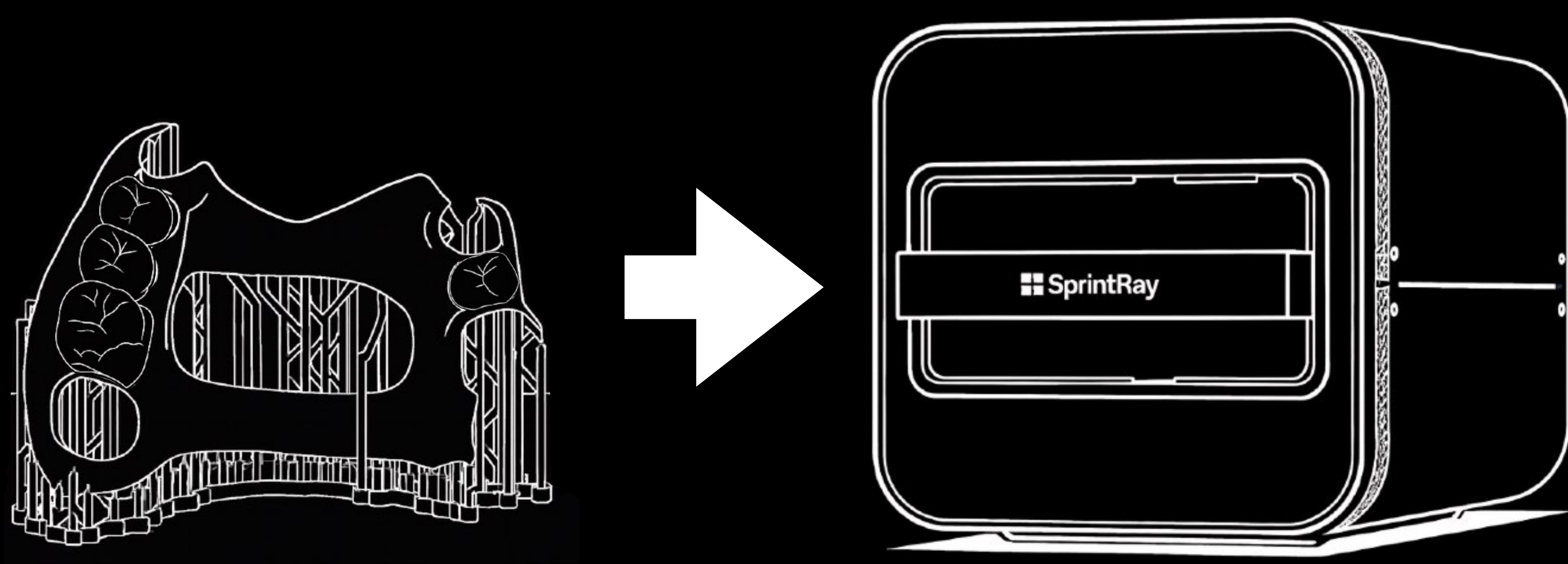
TOOTH BONDING AND CURE

Print Finishing

Cure and Finish.



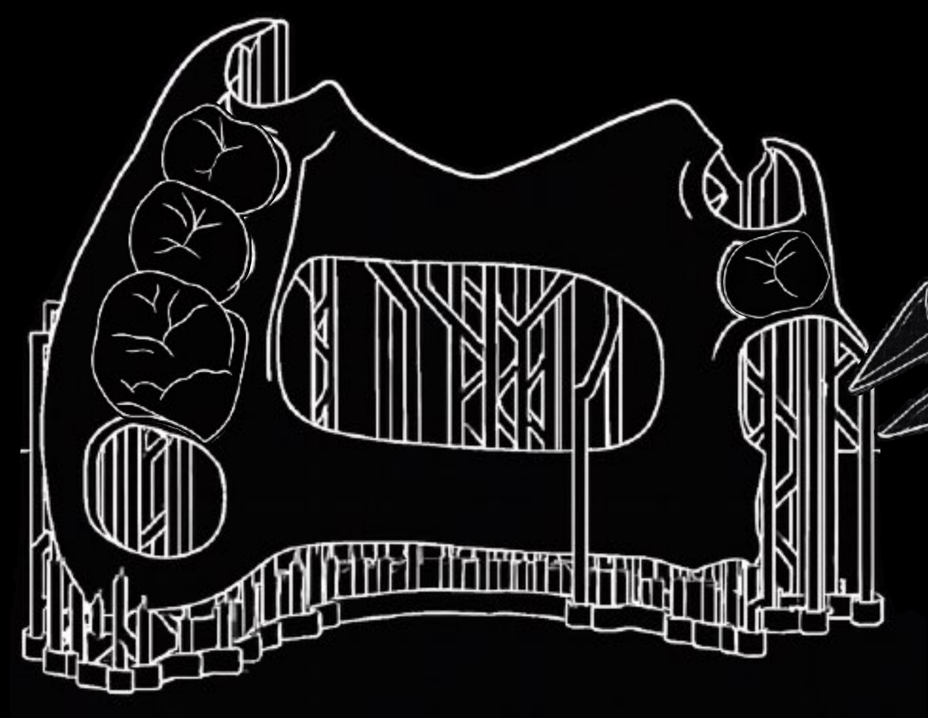
Spot-cure the teeth in place. It is important to maintain gentle finger pressure on the teeth when wiping the excess. Please note that the supports are still on the prosthesis. This prevents warping and distortion during the curing process. Put the whole complex in the nanocure and cure for the full time.

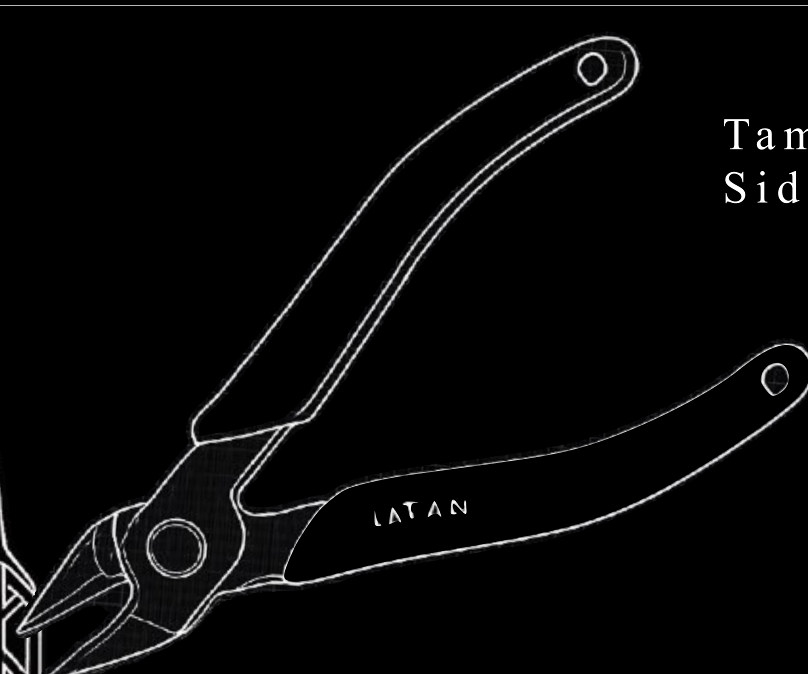


SUPPORT REMOVAL

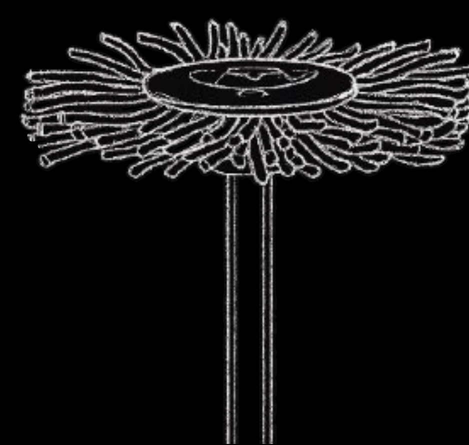
Print Finishing

Cure and Finish.



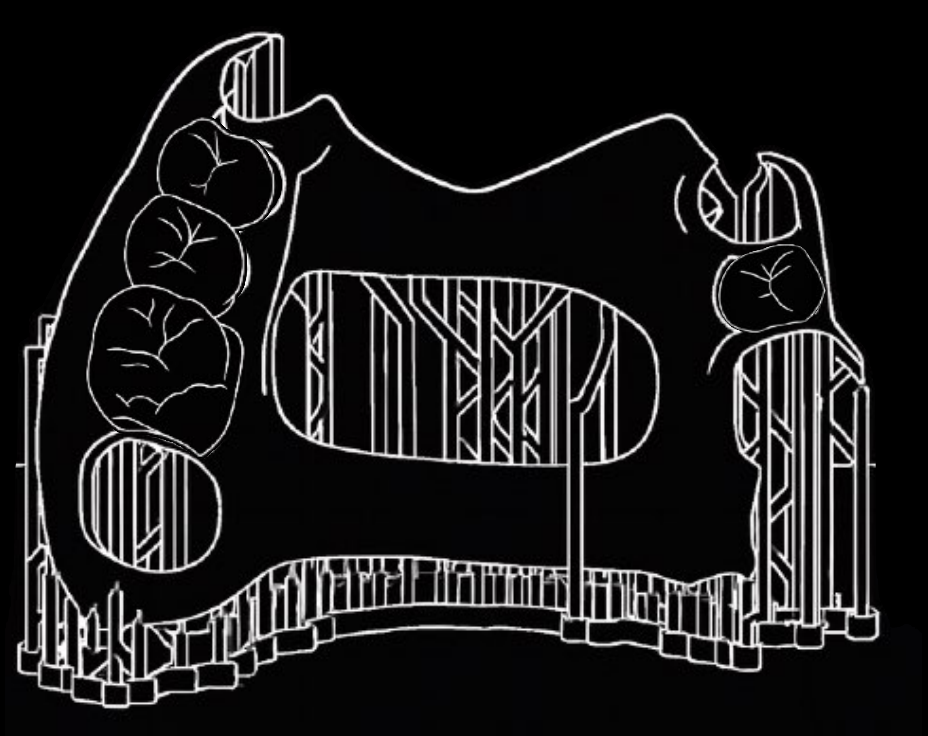


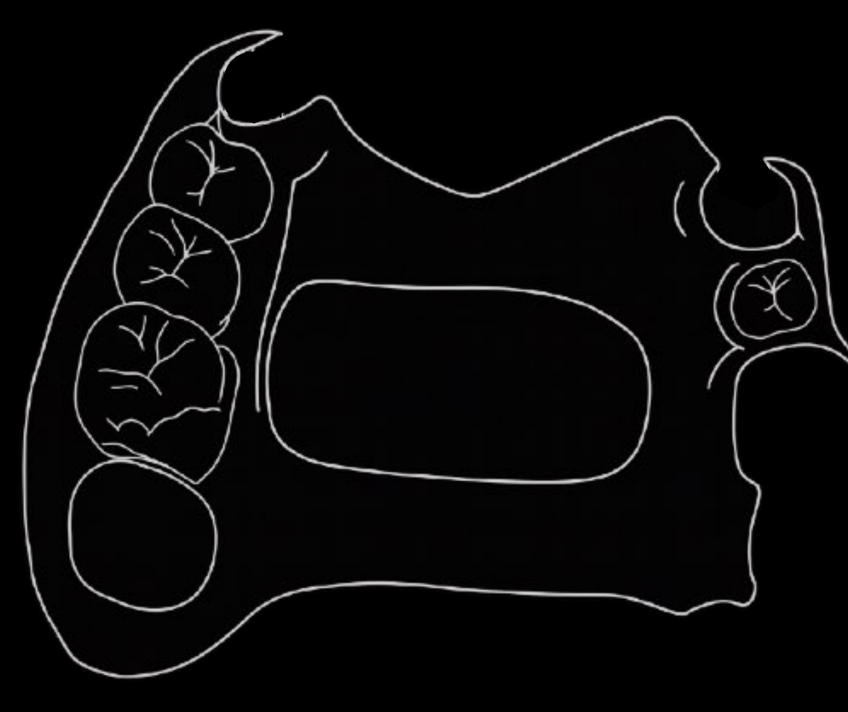
Tamiya Sharp Pointed Side Cutter No. 123



MEISINGER 402-220-HP

Let the prosthesis cool completely before removing the supports, as otherwise warpage can occur. Remove the supports using a high-quality flush cutter. Once the supports are removed, the small residual bumps can be smoothed down with a polishing wheel such as the Meisinger 402-220.





HIGH SHINE

Print Finishing

Cure and Finish.

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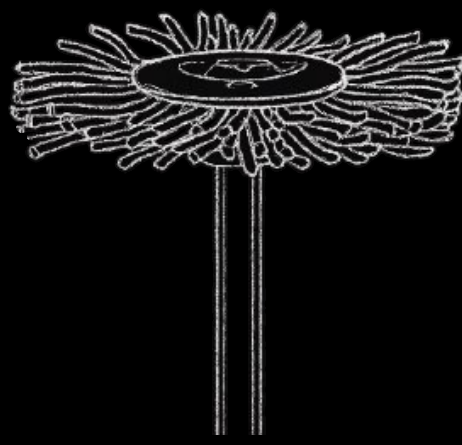
Use your favorite fine polishing paste on a lathe or lab handpiece and work the polish into the surface with a fine bristle brush (such as a #11 Robinson), and end with a high-thread-count cotton buff. The last step is to use food-grade mineral oil and repeat the polishing steps.

GET THE GOODS

Print Finishing

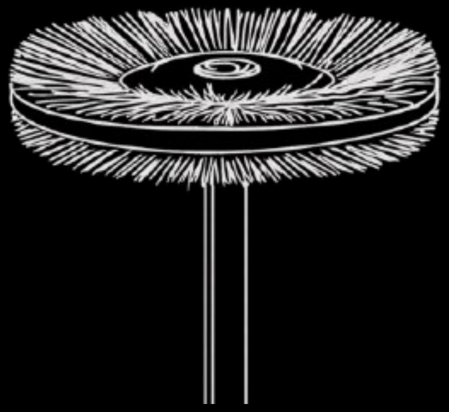
Favorite Burs

Support Bump Removal and smoothing:

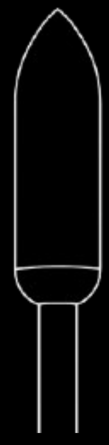


MEISINGER 402-220-HP

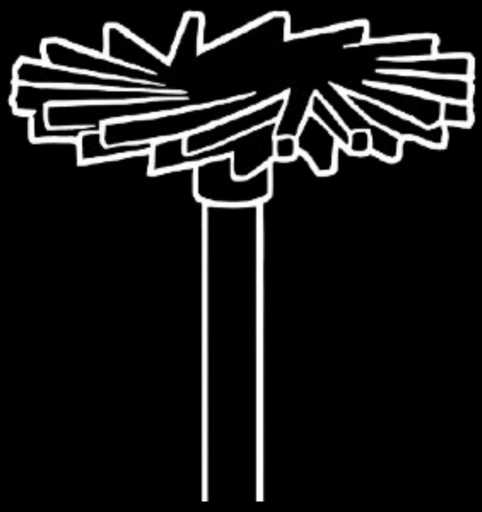
Shine with fine diamond paste and end finalize with mineral oil polish.



MEISINGER 130-220-HP



MEISINGER 9791-050



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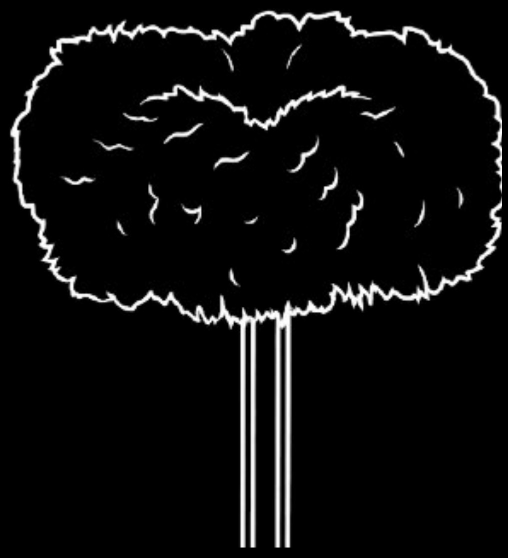

MEISINGER150-220-HP

GET THE GOODS

Print Finishing

Favorite Burs

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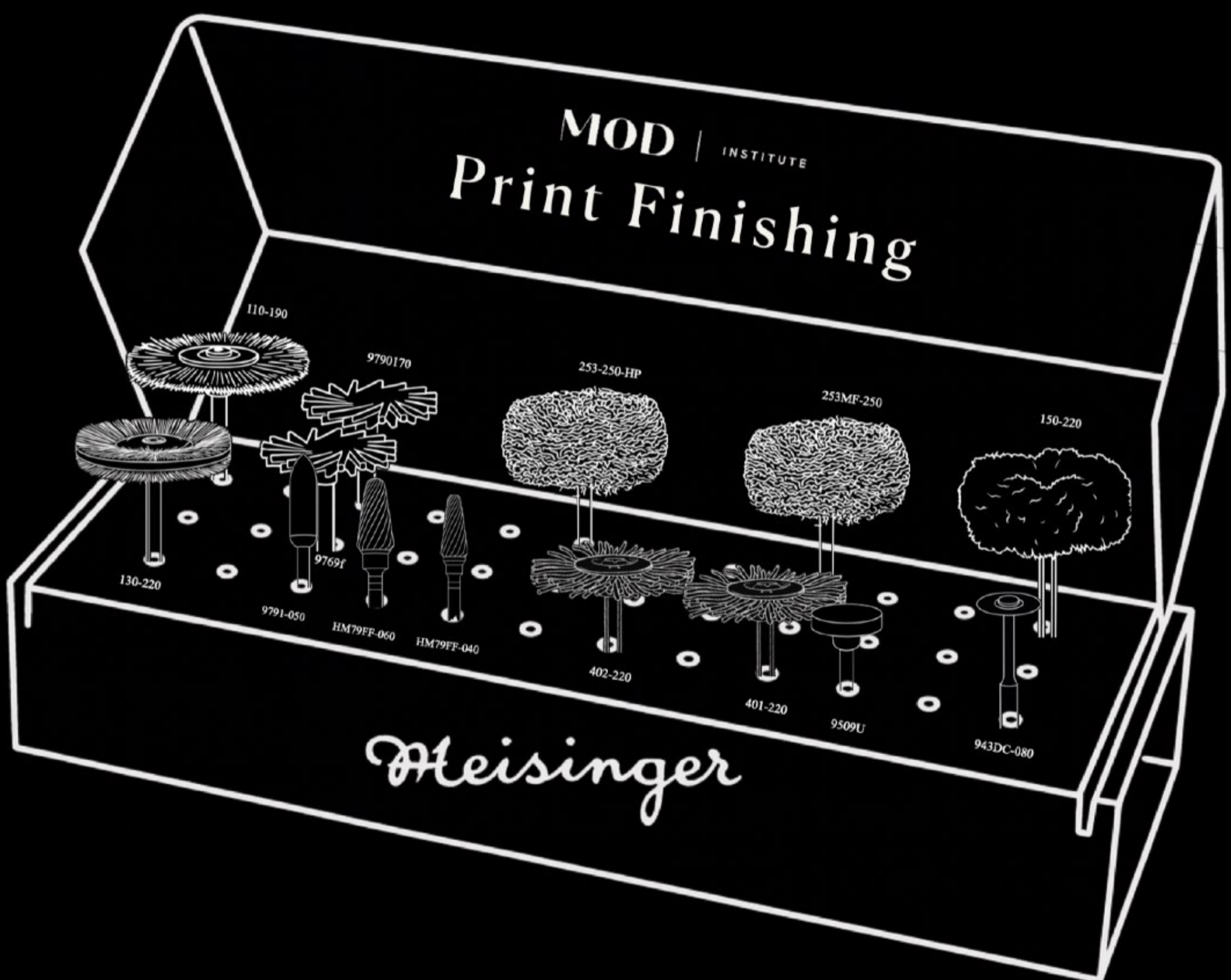

LIT IS GOOD FOR THE SOUL

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3D-Printed Flex Partial Denture

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