



SUBSTRUCTURE FOR OVERDENTURES: FUNDAMENTALS AND RATIONALE

By Michael D. Scherer, DMD, MS

IMPLANT OVERDENTURES have become a staple for restorations in edentulous patients, particularly for the edentulous mandible. Due to their superior retention, stability, and positive impact on oral function compared to conventional complete dentures, the implant overdenture remains a preferred treatment modality for many patients.^{1,2} Restoration using implant overdenture treatment modalities is a predictable clinical procedure that permits a relatively simple workflow for fabricating the restoration.

An implant overdenture is a prosthesis that rests on an edentulous ridge and contains an attachment and housing that helps

secure the prosthesis on the ridge. Two variations of this type of prosthesis occur: 1) an implant-supported prosthesis, and 2) a tissue-supported, implant-retained prosthesis. A bar overdenture is typically classified as the first category and often utilizes a rigid connector with no resiliency or movement of the prosthesis on the arch. The Locator overdenture is classified as the second type because the Locator abutment has slight movement built into the system via a pivoting functionality of the attachment system. Many advocate that this helps it remain compatible with the underlying soft-tissue movement and displacement.

Implant overdentures demonstrate significant enhanced mechanical strength and function compared to conventional dentures without implants. The stress distribution and stabilization provided by the underlying implants and abutments greatly enhance these physical properties.³ The incorporation of an internal metal substructure, also known as a metal framework, further reinforces the prosthesis. Some consider the inclusion of a metal substructure a method to increase the strength of the prosthesis; however, others weigh the factor of increased reinforcement of the prosthesis itself as a factor.⁴ By minimizing flexural deformation and reducing the incidence of fracture, finite analyses and fatigue testing have both shown that overdentures with at least two implants and reinforcement with a substructure

experience substantially lower peak stress values in both the prosthesis and bone.⁵ These advantages contribute to greater longevity, reduced maintenance needs, and increased patient satisfaction.

Understanding the technical factors for substructure designs is key to enhancing the ability of the prosthesis to resist fracture and to impact proper physical properties on implants. This article aims to describe the design parameters and design philosophies for framework design for overdentures.

Rationale of Substructure Reinforcement

The substructure, which is typically composed of metal or a high-performance polymer (HPP) framework and embedded within the poly(methyl) methacrylate (PMMA)/acrylic resin base, plays a pivotal role in distributing occlusal forces evenly across the denture. It also reinforces the acrylic base, preventing mechanical failures and minimizing stress concentrations over the implant sites. In implant positions in lower bone density scenarios, such as in the maxillary arch or mandibular posterior, the inclusion of substructures has been found to be important for the successful fabrication of overdentures (Figures 1 and 2).⁶

Biomechanical studies have demonstrated that unsupported acrylic resin in overdentures is prone to fatigue and crack propagation under cyclic loading. Fracture

About the Authors



Michael D. Scherer, DMD, MS

Fellow, American College of Prosthodontics
Private Practice
Clinical Instructor, School of Dental Medicine,
University of Nevada,
Las Vegas
Las Vegas, Nevada

Assistant Clinical Professor, School of Dentistry, Loma Linda University
Loma Linda, California

Disclosure: Michael D. Scherer, DMD, MS, is Chief Clinical Officer at Zest Dental Solutions.

of the prosthetic base is one of the most common complications encountered with implant overdentures, especially for edentulous arches with at least two or more implants.^{7,8} This tendency is exacerbated in the scenarios where denture bases are thin, especially around Locator housings and where opposing forces are concentrated.⁹ These failures often necessitate repair of the prosthesis, decrease patient satisfaction, and may potentially jeopardize the integrity of the underlying implants.

Technical Rationale

Several technical factors are related to fractures of overdenture restorations:

1. Inadequate acrylic resin base thickness around Locator housings
2. Lack of internal substructure
3. Off angled/malpositioned implants
4. Excessive occlusal forces/para-unction
5. Insufficient restorative space/prosthetic height

Firstly, inadequate acrylic thickness around Locator housings. When PMMA/acrylic resin surrounding the metal housing of the Locator attachment is too thin, it is more prone to fatigue and fracture. Some indicate that the denture base must be at least 2 mm to 3 mm thick for optimal resistance to fracture of the denture base.^{7,10} The Locator attachment system consists of a metal housing and attachment, also known as an abutment. The housing diameter and height and abutment diameter and top remain the same across all implant systems (Figure 3).

The absence of a substructure reinforcement increases flexural stresses on the acrylic resin base. This occurs notably in the anterior-posterior axis of the mandibular arch during insertion and removal of the prosthesis, and in scenarios of malpositioned or non-parallel implants.^{4,11} In scenarios where more than four implants are placed, such as when implants are widely distributed, it can lead to a highly retentive and stable prosthesis that can be more difficult for patients to remove (Figure 4).

Excessive occlusal forces from para-functional activity and occlusion can also lead to the fracture of denture teeth and/or denture bases around overdentures.⁹ As the patient chews on an overdenture,

TABLE 1: PRACTICAL DESIGN GUIDELINES FOR OVERDENTURE SUBSTRUCTURES
1. Maintain ≥3 mm acrylic base thickness around Locator housings
2. Embed substructures as suspended mesh or bars without impinging on restorative space
3. Standardize substructure thickness to achieve desired mechanical properties
4. Place frameworks between implants, extend distally approximately 10-15 mm, include tissue stops for acrylic resin base processing
5. Provide ≥1 mm relief around Locator housings in all dimensions

TABLE 2: COMPARISON OF SUBSTRUCTURE MATERIALS FOR OVERDENTURES			
Material	Pros	Cons	Recommended Minimum Thickness
Cobalt-Chromium	• Strength & stiffness • Cost-effective • Repairability	• Esthetics/heavier • Risk of sensitivities • More difficult to adjust	≥0.7-1.0 mm
Titanium	• Biocompatibility • Mechanical properties • Machinability	• More expensive • Flexibility/lower rigidity • Porosity/surface roughness	≥1.2-1.5 mm
Polymers	• Biocompatibility • Esthetics/lighter • Ease of adjustment	• Expensive • More difficult to produce • Limited/No repairability	≥2-3 mm
High-Noble Alloys	• Esthetics • Repairability	• Most expensive • Technique sensitive	≥1.2-1.5 mm

the prosthesis may be subjected to high occlusal forces, which, in combination with thinner acrylic resin bases, could lead to fracture through the base above the Locator housing (Figure 5).

Lack of restorative space/prosthetic height can substantially increase the chance of fracture of the prosthesis. Some clinicians and technicians advocate for a minimum required height and width for the prosthesis above and around the Locator housings. Many clinicians advocate for a minimum vertical restorative space of at least 9 mm and a minimum prosthesis height of at least 7 mm to ensure strength in the vertical dimension.¹²⁻¹⁵ Further, many advocate for a minimum prosthesis width of at least 3 mm for zirconia and nano-composite prostheses and at least 4 mm of thickness for PMMA and metal substructure restorations (Figure 6).¹⁰

Design Considerations

Multiple materials have been employed to reinforce overdentures, including metals such as cobalt-chromium (CoCr) and titanium/titanium alloy, polymers such as polyetheretherketone (PEEK) and polyetherketoneketone (Pekkton), fiber-reinforced resin materials such as Trinia or Trilor, and other materials such as nickel-titanium (NiTi). Each of these materials may have similar overall designs, but slightly different recommendations on material properties and thicknesses for use with implant overdenture restorations. However, for all materials, certain practical design guidelines still apply (Table 1).

Material Considerations

Metal-based substructures remain the most popular substructure material employed in clinical and technical practice. Metals

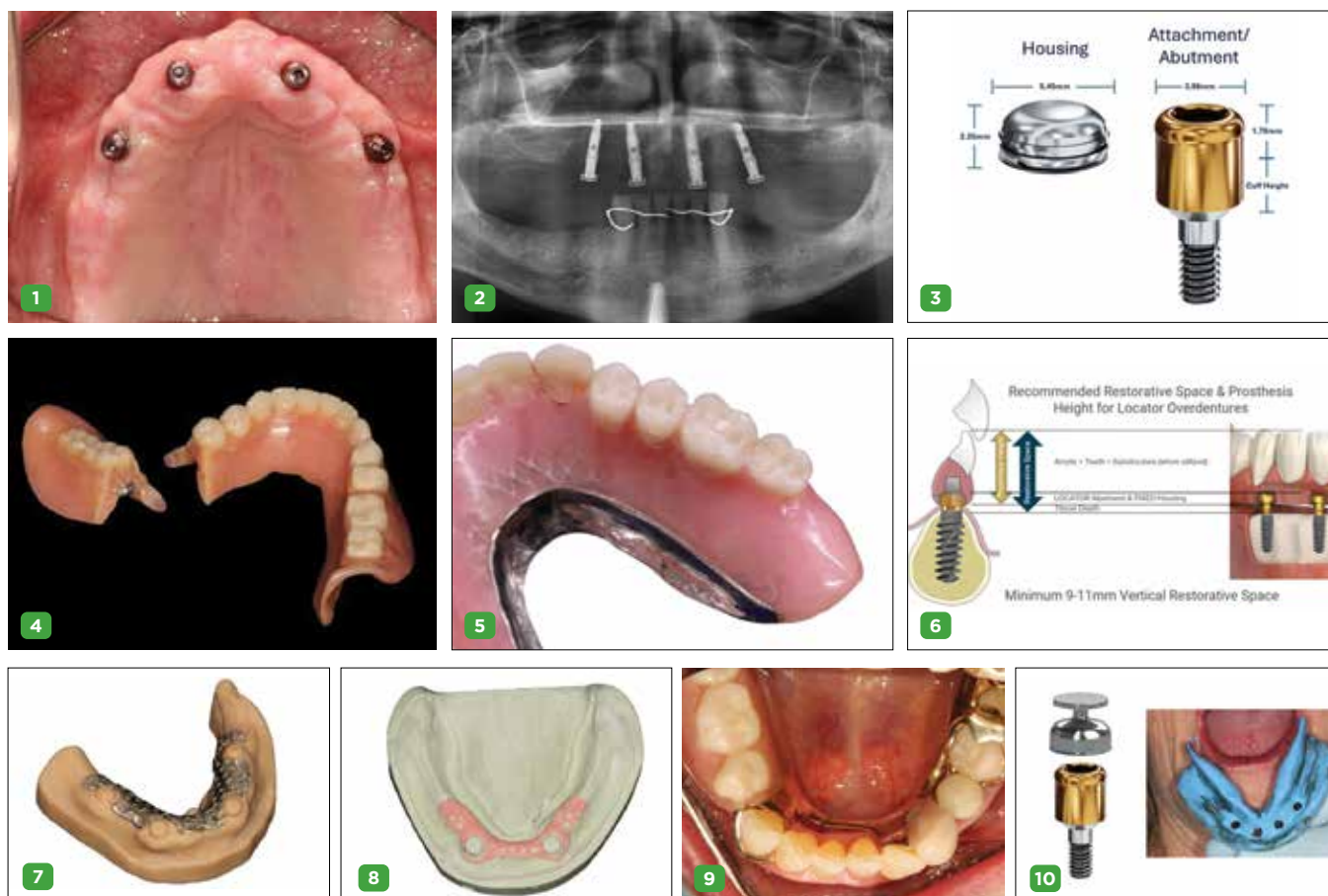


Figure 1: Patient presents with 4 implants on the maxillary arch. **Figure 2:** Panoramic radiograph of the patient illustrating lower bone density. **Figure 3:** The Locator attachment system is comprised of a housing (left) that is embedded within the prosthesis that engages on the abutment (right). Diameters and heights of each are depicted. **Figure 4:** Patient with a 4-implant overdenture without a substructure presenting with a fracture through the posterior implant. **Figure 5:** Patient presents with wear on anterior and posterior teeth of maxillary overdenture restoration; however, the acrylic resin base remains intact due to the presence of the substructure. **Figure 6:** At least 9 mm of vertical restorative space from the surface of the prosthesis to the platform of the implant and 7 mm of vertical prosthesis height from the surface of the prosthesis to the edentulous ridge is recommended. **Figure 7:** SLM-fabricated cobalt-chromium overdenture substructure. **Figure 8:** High-performance polymer overdenture substructure (Trinia) produced via a CAD/CAM milling procedure. **Figure 9:** Patient presented with a mandibular high-noble alloy partial denture. **Figure 10:** Locator impression copings are placed onto Locator abutments (left) and a border-molded PVS impression is made over the copings (right).

typically employed for implant overdentures include cobalt-chromium, titanium, titanium alloy, and high-noble alloys (Table 2). Cobalt-chromium-based remains the most popular of the metal substructure options due to the superior physical properties and cost-effective nature of the materials. Cobalt-chromium substructures contain 60% cobalt (Co) and 25% to 30% chromium (Cr) with small amounts of molybdenum (Mo), nickel (Ni), and iron (Fe). The substructures can be produced via analog methods, such as lost-wax technique casting, or digital production methods such as CAD/CAM milling or 3D printing via selective laser melting/sintering

(SLM/SLS) methods. They typically have a high flexural strength (>1000 MPa) and the material has high stiffness and lower flexibility that can permit fabrication in thicknesses as low as 0.7 mm; however, ≥1 mm of thickness is recommended to retain sufficient physical properties required for overdentures (Figure 7).¹⁶

Titanium and titanium alloys are used sparingly for overdenture frameworks because they are traditionally more difficult to manufacture using traditional CAD/CAM milling procedures. In recent years, however, 3D printing technology has evolved, permitting simpler, faster, and

more cost-effective manufacturing methods. Titanium frameworks are substantially lighter than cobalt-chromium, which can improve patient comfort, improve retention, and reduce soft-tissue loading in atrophic edentulous ridges.¹⁷ Due to its lower rigidity and increased flexibility, titanium frameworks should be slightly increased in thickness to at least 1.2 mm to 1.5 mm compared to other materials to maintain similar mechanical properties.¹⁸

HPP-based substructures are a relatively new addition to technical practice, but they are growing in popularity. These substructures typically use fiber-reinforced

composite resins as a backbone and are increasingly used as an alternative to metals. Strength of the prosthesis is achieved by transferring stresses through the fiber bundles embedded within the resin matrix.¹⁹ HPP substructures are less rigid than metals and may flex under load, potentially leading to deformation over time if undersized or poorly bonded. Polymer substructures are also much lighter than metal substructures and offer enhanced esthetics and biocompatibility (Figure 8).²⁰

High-noble metal alloys comprise more than 60% noble metals, such as gold (Au), platinum (Pt), palladium (Pd), and additional trace metals, including silver (Ag), copper (Cu), and others. High-noble alloys are less rigid, and their increased ductility and malleability allow for a very precise cast fit and adaptation on the dentition (Figure 9).²¹ Because of their physical properties, they typically require increased thickness to at least 1.2 mm to 1.5 mm. High-noble metal substructures are also extremely stable, exhibit low

corrosion, and are biologically inert, ideal for patients with allergies and/or metal sensitives.²² Although high-noble alloys historically permitted technicians to fabricate restorations successfully, the extremely high cost of fabrication often precludes its use in standard practice.

Analog Method of Fabrication

The traditional analog method for fabricating overdenture substructures involves multiple manual steps, each critical for ensuring a passive fit, appropriate reinforcement, and sufficient space for attachments. These methods employ techniques that have been used for years and remain viable in many dental laboratories, especially where digital resources are limited.

The impression of the overdenture is typically made utilizing the impression copings that are specific to that system. In Figure 10, the Locator impression coping is placed on top of the Locator abutment and the clinician fabricates an impression. Many clinicians prefer to utilize elastomeric-based

impression materials, typically with poly(vinyl) siloxane (PVS) or polyether-based materials.

After the impression is received from the dental office, Locator analogs are placed into the impression copings, and a master cast is poured in dental stone (Figures 11 and 12). Any dental gypsum stone can be utilized; however, some prefer to use a type 4 die-stone or a type 3 model material. The technician may also choose to place a gingival mask or moulage around the Locator analogs before pouring the laboratory stone to help simulate gingival resiliency and ensure a passive fit of the substructure.

A bead is prepared in the areas of any tissue contact, such as in the case of the maxillary arch. Wax is applied to the areas of the edentulous arch, notably in areas around undercuts. The model is duplicated utilizing hydrocolloid or silicone-duplicating materials and poured into the dental stone. The overdenture substructure is designed using pre-formed wax patterns with typical features including: metal mesh

POWER
ACCURACY
SPEED

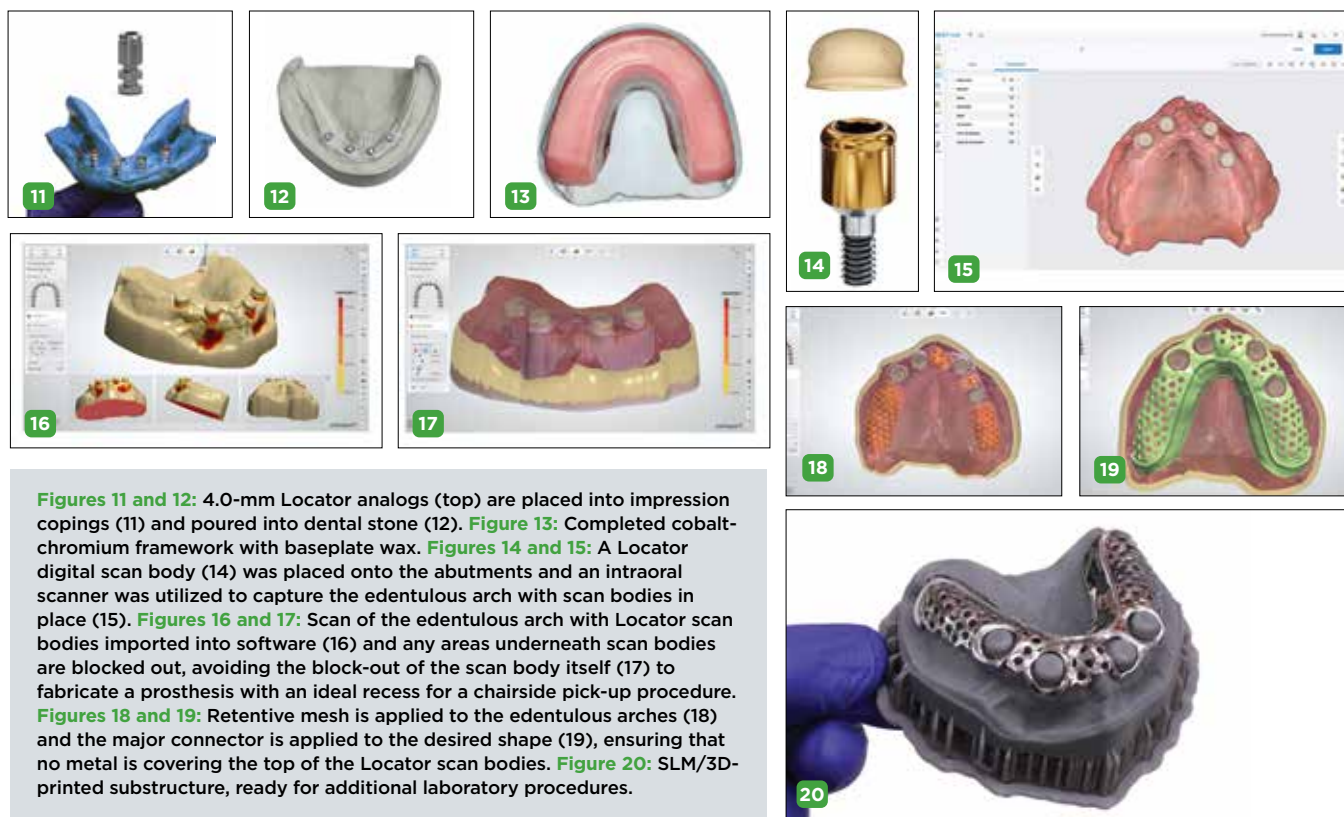


(425) 227-4333

3DBioCAD.com info@3DBioCAD.com

VISIT OUR
WEBSITE!





Figures 11 and 12: 4.0-mm Locator analogs (top) are placed into impression copings (11) and poured into dental stone (12). **Figure 13:** Completed cobalt-chromium framework with baseplate wax. **Figures 14 and 15:** A Locator digital scan body (14) was placed onto the abutments and an intraoral scanner was utilized to capture the edentulous arch with scan bodies in place (15). **Figures 16 and 17:** Scan of the edentulous arch with Locator scan bodies imported into software (16) and any areas underneath scan bodies are blocked out, avoiding the block-out of the scan body itself (17) to fabricate a prosthesis with an ideal recess for a chairside pick-up procedure. **Figures 18 and 19:** Retentive mesh is applied to the edentulous arches (18) and the major connector is applied to the desired shape (19), ensuring that no metal is covering the top of the Locator scan bodies. **Figure 20:** SLM/3D-printed substructure, ready for additional laboratory procedures.

or bar connecting the implant sites, relief of 1.5 mm to 2 mm above the crest of the ridge in critical areas, and tissue stops to stabilize the framework during processing. The wax-up is sprued using standard dental sprue wax or rods and invested in a phosphate-bonded investment material. The wax is then eliminated from the mold using high heat, and the metal is cast into the mold using centrifugal- or induction-casting techniques. After cooling, the metal is divested, cleaned via air abrasion, and finished using carbide burs, rubber wheels, and polishing compounds.

The completed framework is placed onto the master cast and baseplate wax is applied to the retentive mesh forming a wax rim (Figure 13). The substructure is returned to the dentist, who will complete the necessary records and send it back for tooth setup. Once confirmation of the tooth setup is complete, the case is processed with conventional methods using the stone cast. If the clinician prefers to use a chairside housing attachment method, a Locator processing spacer is applied before processing the acrylic resin. If the clinician prefers to

have the laboratory process the housing, the Locator housing is placed onto the analog on the cast prior to acrylic resin processing.

Digital Method of Fabrication

Digital methods for fabricating overdenture substructures leverage intraoral scanning, computerized software, and CAD/CAM production methodologies such as milling or 3D printing. The goal of the digital approach to substructure design is to improve precision, reduce turnaround times, and enhance biomechanical performance.

In a digital workflow, the impression is typically taken with an intraoral scanner. The clinician places Locator scan bodies on top of the abutments and scans the scan bodies and the edentulous arch in a single scan. Key to this technique is ensuring that the entire arch is captured—including all details of the Locator scan bodies—while stabilizing the soft tissues during scanning to accurately capture properly extended or slightly overextended borders, as well as all relevant details of the arch's soft-tissue anatomy. A scan of the opposing arch is captured; however, no bite scans are required

for fabricating overdenture frameworks using this approach. The scans are post-processed and sent to the dental laboratory.

The digital scan files are imported into digital design software and a virtual model base is created (Figures 14 and 15). Any necessary adjustments to the model—such as adding a small bead around the periphery of the design—are made to improve the soft-tissue seal. The path of insertion is set according to the arch, following the best pathway for balancing undercuts across the arch. Before proceeding with the design, the technician confirms with the clinician whether the housings will be attached within the denture base by a technician in the laboratory or chairside by the clinician. With the laboratory-based approach, the scan bodies are converted to analogs for model printing. After the denture base is processed, the technician manually lutes the housings to the processed denture. In the chairside processing scenario, the technician uses the scan bodies as a physical reference on the model and designs directly over them—without any block-out (Figures 16 and 17). The Locator scan body is larger than the housing, following its shape closely

in the design creates an ideal recess in the processed resin base for accurate housing pick-up at the time of delivery.

The substructure's retentive mesh is designed based on anatomical features in the edentulous areas to guide the positioning of support elements. For example, in mandibular arches, the retentive mesh should include the residual ridge and the areas between Locator attachments, whereas in maxillary arches, it should include the residual ridge and small portions of the hard palate between Locator abutments. In this example, the edentulous spans distal to the patient's right and left posterior segments, extending to the tuberosities, are designed with retentive mesh. A moderate amount of relief is provided underneath the retentive meshwork to permit the flow of acrylic resin during processing; this example uses a 0.60-mm relief beneath the retentive meshwork. The major connector is designed as a horseshoe with an open palate, as outlined with the beading area (if designed) and engaging the portion of

the retentive mesh. While there are no firm guidelines as to where to terminate the edge of the major connector, many advocate for engaging as much of the hard palate as possible. Emphasis is placed on not covering the top of the scan bodies (Figures 18 and 19); however, additional mesh or a retentive matrix can be applied to the facial aspects of the substructure for added strength.

The substructure is finalized with an acrylic resin finish line in the area that corresponds with the retentive meshwork, stippling is applied (if preferred), and 3.0-mm tissue stops are added in edentulous areas to permit acrylic resin flasking/processing procedures. The completed substructure design is output from the software in a printable/machinable file format, such as STL or PLY. The substructure is manufactured either by 3D printing the design in wax, followed by investment/casting, or by direct fabrication via SLM/SLS 3D-printing procedures with a metal 3D printer (Figure 20).

The completed framework is placed onto a 3D-printed resin cast and a wax baseplate is applied to the retentive mesh, forming a wax rim. Traditional wax procedures, as described earlier, are completed and returned for tooth setup. Once the patient approves the tooth setup, the case is processed through conventional methods. Many technicians prefer to duplicate the 3D-printed model into stone or gypsum to permit easier acrylic resin processing. After processing, the completed prosthesis is returned to the clinician with pre-prepared recesses that precisely match the shape of the scan bodies. These recesses allow for simplified chairside acrylic resin processing and facilitate accurate attachment placement.

REFERENCES ONLINE

To view the references for this article, go to insidedentaltech.com/go/idt1396



This article was double-blind peer reviewed by members of IDT's Editorial Advisory Board

Adventure Awaits...



When you need a vacation, your refining return can help get you there. Refine your dental scrap with Cora and let the fun begin.



High payments for scrap with settlements among the highest in the industry



Quick turnaround for dental scrap (including platinum and palladium alloys with cobalt/chrome)



Seamless experience with high-quality customer service



Scan here for a free refining kit



CORAREFINING

www.corarefining.com • 800.844.2040