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A Direct Refractory Die Technique for Cast Gold Restorations

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Clinical Relevance

This direct refractory die technique eliminates wax pattern distortion and facilitates the creation of accurate, precisely fitting cast gold restorations.

ABSTRACT

Fabricating accurate cast gold restorations can be challenging for both clinicians and laboratory technicians. Removing the wax pattern from the master die often distorts the pattern, which, in turn, compromises the overall fit and marginal adaptation of the casting. This article demonstrates a laboratory technique in which the final restoration is cast directly on the refractory die without removing the wax pattern. Thus, distortion of the wax pattern is avoided, enabling the production of superbly fitting gold castings for both intracoronal and extracoronal restorations.

INTRODUCTION

Producing cast gold restorations that are consistently precise and well fitting can be a challenge for both clinicians and dental laboratories. Contributing to this challenge is the issue of wax pattern distortion during the fabrication process.[1-3] Distortion of the wax pattern during removal from the master die and investment is "unavoidable."[3,4] However, use of refractory die techniques can greatly reduce this problem if carefully employed in the process.[5-7] Refractory die techniques have been used for the laboratory fabrication of various dental appliances and restorations for many years.[8-11] Currently, however, a precise and consistent fabrication technique for cast gold restorations on refractory dies has remained elusive and underutilized in restorative dentistry.

Described here is a clinical and laboratory technique for fabricating extremely accurate, smooth, and detailed gold castings for both intracoronal and extracoronal restorations.

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DOI: 10.2341/15-290-T

CLINICAL PROTOCOL

After the tooth preparation has been completed (Figure 1), the gingiva is retracted with a hemostatic-impregnated cotton cord and the preparation cleaned of all debris, then air-dried. A rigid metal check-bite tray (GC America, Alsip, IL, USA) with perforated sidewalls is tried in the mouth. All large open embrasure spaces and undercuts should be blocked out with wax or some other material (in the quadrant to be impressed) prior to the impression procedure. This will minimize the possibility of locking and distorting the impression.

The preparation is impressed with a light/heavy-bodied polyvinyl siloxane impression material sys-

This is the author's manuscript of the article published in final edited form as:
Smith, C., & Diefenderfer, K. (2017). A Direct Refractory Die Technique for Cast Gold Restorations. Operative Dentistry, 42(2), 122–132. https://doi.org/10.2341/15-290-T

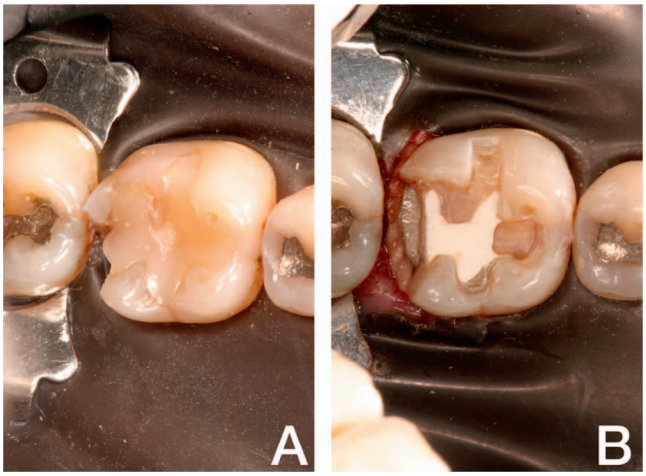


Figure 1. *Number 19 defective resin composite with secondary caries. (A): Pretreatment. (B): Completed cast gold onlay preparation. The DB and DL cusps were judged to have sufficient dentin support to warrant conservative preparation. Note that the interseptal rubber dam has been cut to enable retraction cord placement with the dam in place.*

tem (Aquasil [Dentsply/Caulk, York, PA, USA] is recommended) in the usual manner, ensuring that the patient closes into maximum intercuspation. Support the patient's mandible in the closed position with the loaded impression tray in place. The impression is allowed to set according to the manufacturer's recommendations, but verify that the material exhibits "total rebound to blunt depression" before removing from the mouth.

On removal from the mouth, the impression is rinsed with a surfactant solution (Harvest Surfactant, Harvest Dental, Brea, CA, USA) and dried thoroughly with air. Make sure all the preparation finish lines are well defined and visible, with no bubbles or distortions present in this area (Figure 2).

LABORATORY TECHNIQUE

Die Preparation

The impression is now taken to the laboratory for pouring and mounting. Undercuts or excess impression material are removed with a sharp surgical blade prior to boxing of the impression. The impression is boxed with a polyvinyl siloxane putty on the mesial and distal portions of the tray (Figure 3) to prevent the refractory investment from spilling out over the ends of the tray.

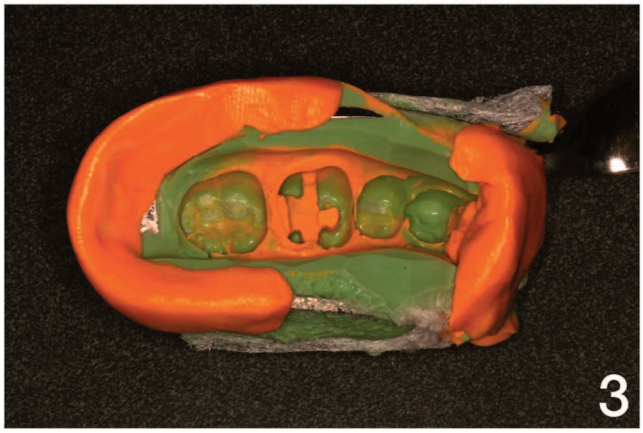


Figure 2. *Final impression must be well defined and clean.*
Figure 3. *The impression is boxed with putty on the mesial and distal of the tray.*

To create the refractory die, the impression is poured using a high heat micro-fine phosphate-bonded investment material (Starvest, Emdin International Corporation, Irwindale, CA, USA) rath-

Table 1: *Powder-to-Liquid Ratios for Gold Castings*[a]

Casting	Starvest Powder (g)	Starvest High-Expansion Liquid (g)	Distilled Water (g)
Inlays (one to four surfaces)	50.000	14.250-14.500	0.400
Onlays and crowns (partial or full)	50.000	14.750-15.000	0.400
Post and cores	50.000	13.850-14.250	0.400

[a] *The ratios may need adjusting according to the lot number of the investment being used at the time. Different lots of the investment can vary in physical characteristics and may have different expansions. Adjust as needed by increasing or decreasing the weight of the expansion liquid (an increase of expansion liquid will cause more expansion of the casting). Keep the weight of H_2O constant. Small incremental changes of the high-expansion liquid can make significant changes in expansions of the castings.*

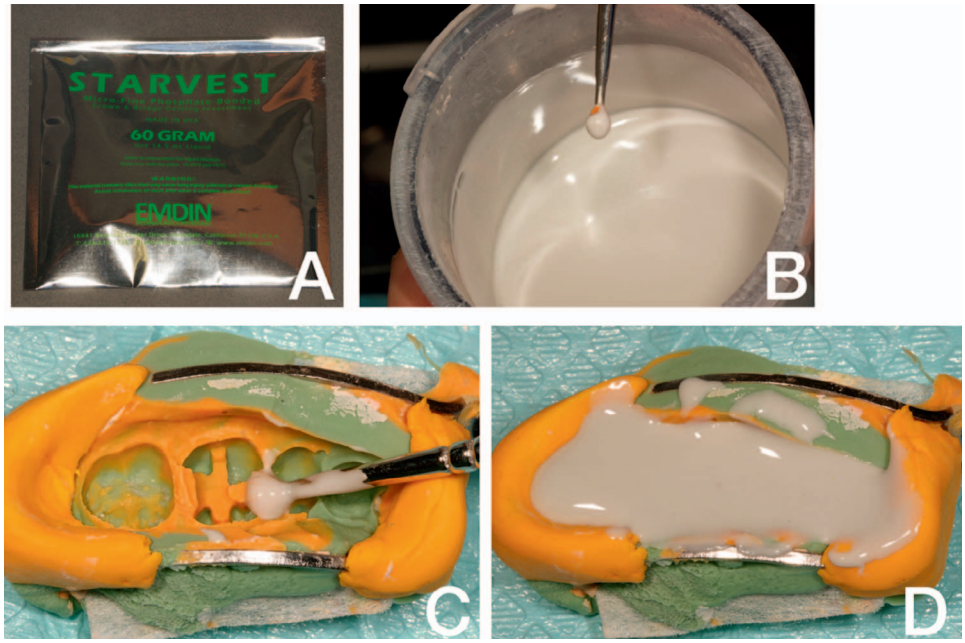


Figure 4. *Starvest phosphate-bonded investment material (A) mixed under vacuum (B) and poured into the impression (C and D).*

er than conventional die stone. This finely ground investment has a powder particle size of 5-7 microns and produces a smoother cast surface, both internally and externally, than was possible in the past with other investments. The older refractory investment powders had a larger particle size, which may result in rougher surfaces and less precise castings.[12] Exactly 50 g of investment powder are weighed out in a plastic container. A predetermined weight of high-expansion colloidal silica mixing solution (Emdin High-Expansion Liquid, Emdin International), combined with a corresponding weight of distilled water, is used for specific preparation configurations (Table 1). The liquid components are weighed to 0.001 g in a tared vacuum-mixing bowl on a digital analytical scale.

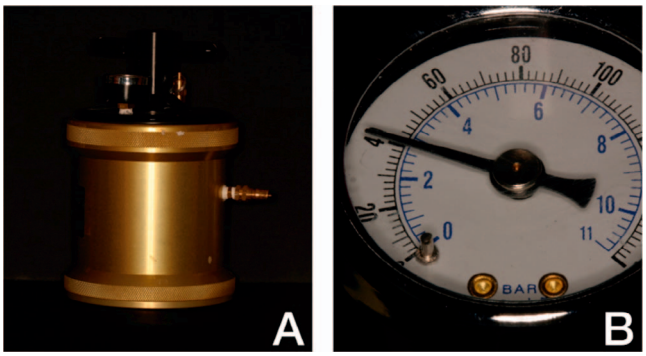
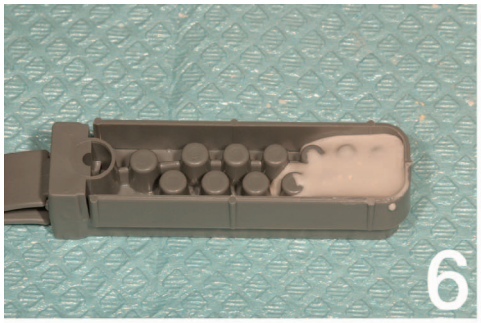


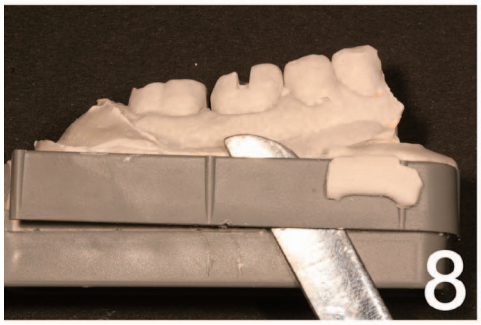
Figure 5. *(A): Lang Investpress. (B): Pressurize to 40 psi.*

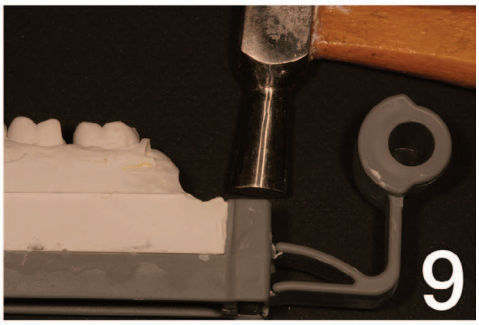
The investment powder is added and the mixture spatulated in a digital vacuum mixer under vacuum for 60-90 seconds at 450 rpm.

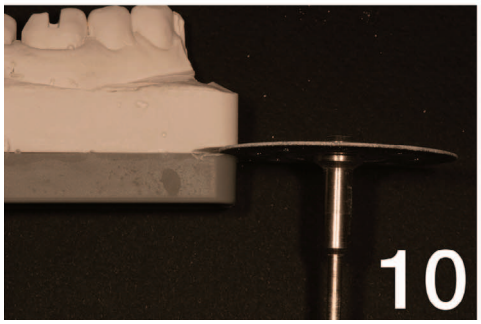
The investment is carefully poured and vibrated into the impression. A small soft brush can be used to paint investment into the preparation (Figure 4); this may be helpful in avoiding bubbles on the refractory die and adjacent surfaces. The remaining investment is added until the preparation is covered with 3-5 mm of investment. The poured impression is immediately placed in a dry pneumatic pressurized curing unit (Investpres, Lang Dental Manufacturing Co, Inc, Wheeling, IL, USA) at a pressure of 40 psi for 30 minutes (Figure 5). Allowing the investment to set under positive pressure results in improved surface smoothness, with fewer and smaller surface voids in the set cast.[13,14] Moreover, in our experience, the refractory dies are more resistant to abrasion by metal waxing instruments, and the subsequent castings appear to be smoother, enabling more efficient polishing.

Following complete setting, the poured check-bite tray impression is mounted on a quadrant articulator (Monotrac V2, Monotrac Articulation, Midvale, UT, USA). The articulator base is first lubricated with a silicone separating medium (MS3 Master Separator, Harvest Dental, Table 2). Next, a second batch of investment material is mixed to a thicker consistency and poured into the articulator









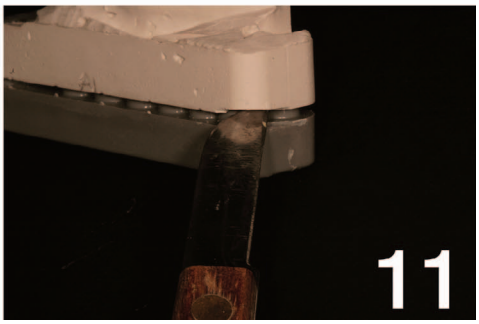


Figure 6. *Monotrac articulator base with a thick mix of investment.*
Figure 7. *Opposing arch poured and mounted after the working arch hardens.*
Figure 8. *Remove the flash and plastic form from the articulator.*
Figure 9. *Lightly tap the base until a small space is formed.*
Figure 10. *Use a separating disc to create a slot in the base.*
Figure 11. *Gently separate the cast from the articulator base.*

base (Figure 6); exact measurement of the liquid-to-powder ratio is not necessary for this step. A portion of this mixture is placed on the exposed hardened side of the investment in the impression. The check-bite tray impression is now placed on the articulator base and stabilized for 30 minutes for hardening. The opposing arch of the impression is then poured in a conventional die stone (Figure 7).

Separation of the refractory model from the impression should be done carefully. First, remove

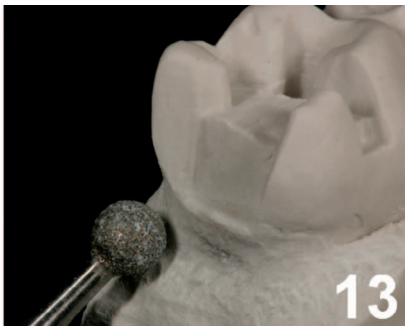


Figure 12. *(A): Make a 4-5-mm-deep cut with a die saw on the proximal. (B): Section the remainder of the base with a separating disc.*
Figure 13. *Trim the die to expose the preparation finish lines and tooth emergence profiles.*

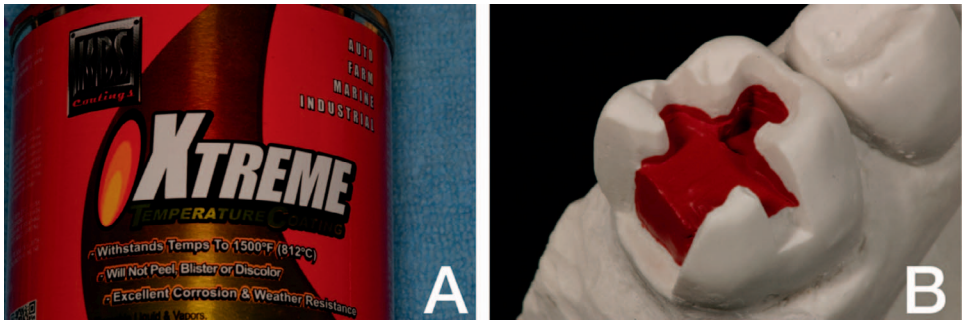


Figure 14. *(A): High-temperature paint for the die spacer. (B): Application of two to three coats creates a matte finish.*

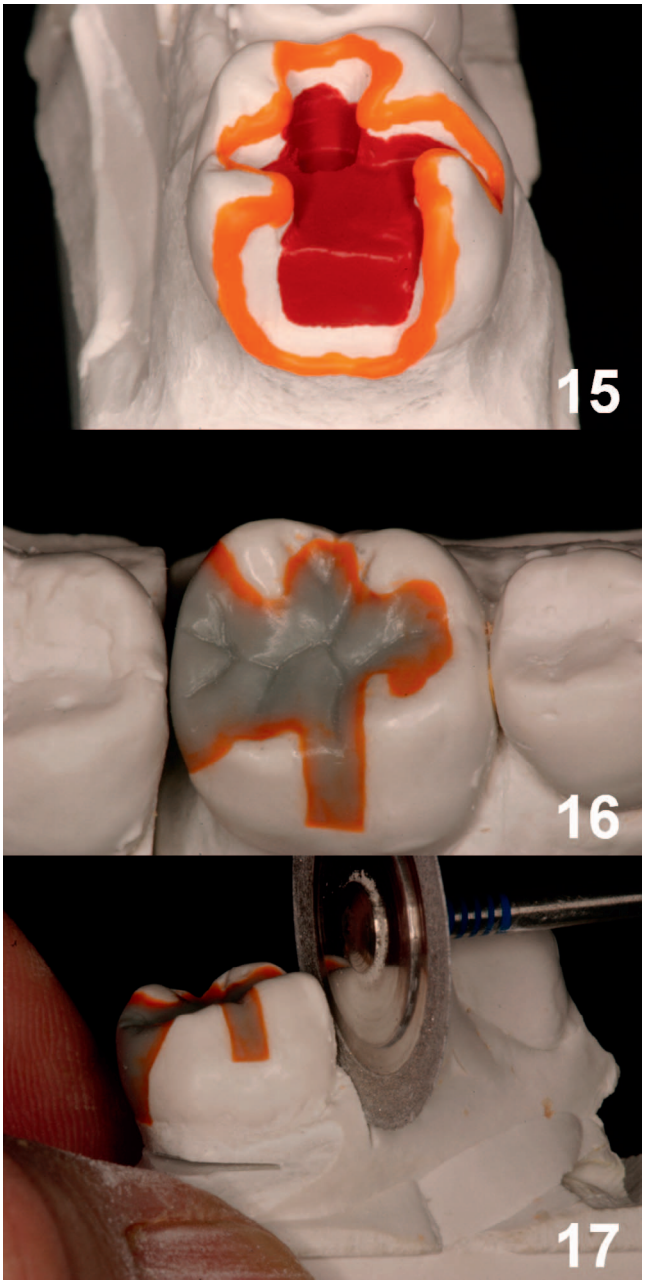


Figure 15. *Contrasting bright opaque wax margin is applied first.*
Figure 16. *Final wax-up.*
Figure 17. *Section the refractory die and wax pattern from the base.*

the distal of the impression tray from the refractory investment die/base. This will decrease the potential for distortion of the metal tray and impression. Break off the excess refractory investment and plastic form from the articulator (Figure 8). Tap with a small hammer lightly on the plastic base near the articulator hinge to create a thin space between the refractory investment base and the plastic base (Figure 9). Next, use a large diamond separating disc (Brasseler USA, Savannah, GA, USA) to place a horizontal slot in the front of the refractory die base where the plastic base and the investment meet (Figure 10). Insert a Buffalo knife blade into the slot and gently rotate back and forth to loosen and separate the refractory die base from the articulator base (Figure 11).

Remove the refractory die base from the articulator base. Make a 4-5-mm-deep saw cut in the proximal(s) (Figure 12A) and section the remaining portion with a diamond- or glass-reinforced separating disc (Dynex disc, 40 mm × 0.5 mm, Renfert, Hilzingen, Germany) from the underside of the base (Figure 12B). Trim the die with a mounted diamond stone and appropriate instruments to expose the preparation finish lines and tooth emergence profiles (Figure 13). Clean dies and models with pressurized air to remove all refractory residue.

A high-temperature automotive paint (XTC, KBS Coatings, Valparaiso, IN, USA; Figure 14A) is an ideal die spacer. Mix 10%-20% refractory investment powder thoroughly into the paint and apply to the appropriate surfaces (pulpal floor and axial wall[s] for inlays; pulpal floor, axial walls, and occlusal portion for onlays; and the occlusal and axial walls for extracoronal preparations]. Two or three coats should be applied and allowed to dry completely; this should produce a smooth matte rather than a glossy finish (Figure 14B) and should provide approximately 25 microns of die relief, which is adequate space for the luting agent (the material can also be used as a block out for undercuts). It is not always necessary

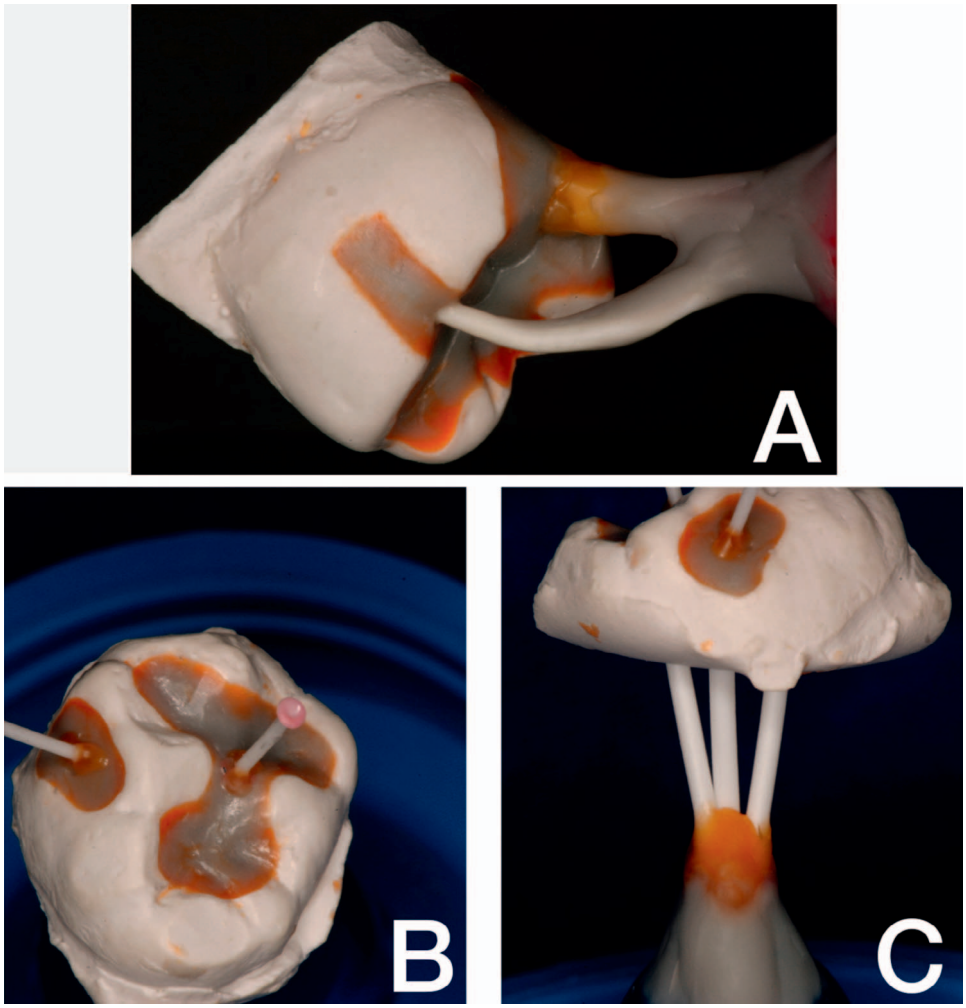


Figure 18. *(A): Sprue the wax pattern and refractory die. (B and C): Sprue through the die for one-surface inlays.*

to place a die spacer in refractory inlay dies. When carefully executed, manual relief of the inlay casting axial walls and pulpal floor with a white stone can provide space for a luting agent and relieve undercuts on cast inlays.

Wax-Up

Begin the wax-up by applying a thin line of bright-orange–colored contrasting wax (Consequent, Yeti Dental, Engen, Germany) to all finish lines of the preparation (Figure 15). This is a block-out wax, but works well to highlight the margins during the wax-up of the restoration. The refractory die material is very white, and most buildup waxes are too translucent to enable detection of overextended wax margins. This results in castings with overextensions of gold on the margins. Next, apply a sculpting wax (Thowax, Yeti Dental) to the remainder of the die. Finalize all external contours of the wax pattern. Remove all excess wax at the cavosurface margins with a wax-carving instrument (DPT Carver, Hu-Friedy, Chicago, IL, USA). Gently smooth the wax pattern with an artificial soft sable brush and carefully polish the axial surfaces and margins with a microfiber lens cleaning cloth to finish the wax pattern (Figure 16).

Investing the Wax Pattern

Using a diamond- or glass-reinforced separating disc, section and cut the refractory die, with its wax pattern in place, from the base 3 mm below the existing margins (Figure 17). Keep the wax pattern and die free of the refractory die residue by frequently cleaning with pressurized air. If refractory residue is left on the wax pattern, a rough surface will be produced on the casting. The wax pattern is sprued on the contact areas or cusps of full crowns, onlays, and multiple-surface inlays

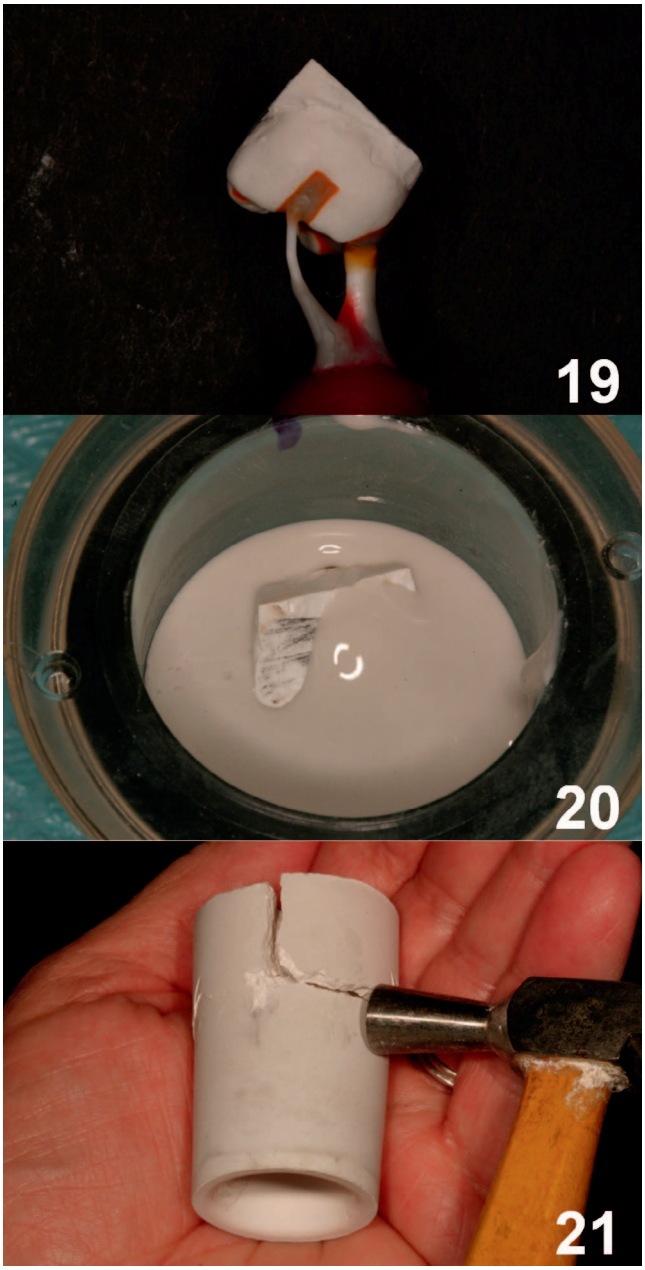


Figure 19. *Attach the wax pattern and refractory die to the sprue base.*
Figure 20. *Cover the refractory die and wax pattern with a second (identical) mix of Starvest phosphate-bonded investment.*
Figure 21. *Break out the casting from the investment.*

(Figure 18A). Single-surface wax patterns are often sprued through the refractory die to the bottom of the wax pattern (Figure 18B). This is accomplished by boring a small hole(s) through the underside or side of the refractory die to the underside of the wax pattern. Attach the wax pattern/refractory die to a 3-5-mm length on a sprue base (Figure 19), then place the investment forming ring on the sprue base, orienting the angle of wax pattern/refractory die to be in the trailing position of the centrifugal casting machine's rotation. Index this position on the ring former and the hardened investment for orientation in the cradle of the centrifugal casting machine.

The wax pattern/refractory die is now invested, using the same phosphate-bonded investment material (Starvest) as used for the refractory die. Mix this investment using the same liquid:water:-powder ratio and mixing protocol as used to make the refractory die. If the component proportions differ from that of the refractory die, the expansion rates of the two investments will differ, possibly producing cracks in the investment. Gently vibrate and pour the investment into the ringless investment ring at an angle, covering the wax pattern/die with 3-5 mm of investment (Figure 20). Place the ring assembly into a dry Lang Investpres to a pressure of 40 psi for 60 minutes. Setting of the investment material under positive pressure may result in the production of fewer surface irregularities in the final casting.[15] Remove the ring assembly from the Lang Investpress and remove the base and plastic ring former from the hardened investment ring.

Burnout and Casting

Check to see that no flakes or residue of investment are embedded in the sprue wax button on the underside of the investment ring before placing the investment ring into a calibrated room-temperature burnout furnace. Place the orientation mark on the investment facing toward the oven door. Set the temperature rate at 7°F per minute to rise to a final temperature of 1350°F. After reaching the temperature of 1350°F, hold the temperature for 30 minutes before casting. The total burnout time is approximately three hours and 30 minutes.

Cast and allow the invested casting to bench cool before divesting. Do not divest the casting with an air abrasion unit. Break out the casting with a small hammer in the palm of the hand or on a soft surface (Figure 21). Place the casting in a plastic sealed container containing a solution of 38% hydrofluoric acid or substitute hydrofluoric acid (Figure 22). Place the container in an ultrasonic cleaner and vibrate until the investment is dissolved away. Check the casting under magnification for any bubbles, undercuts, and artifacts; these can be carefully removed with a white stone.

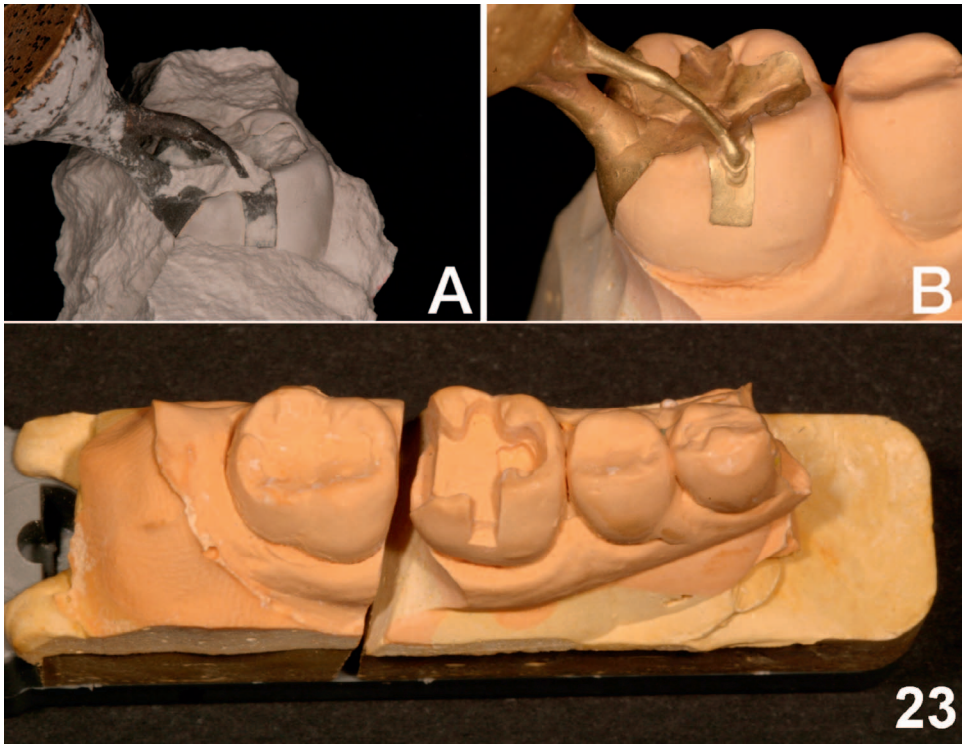


Figure 22. *Casting before (A) and after (B) acid divestment.*
Figure 23. *Working die.*

A second pour of standard die stone is made to fabricate the working master cast for fitting and finishing of the casting (Figure 23). GC Fujirock golden tan (GC America) is the preferred material for this important step because it produces extremely accurate dies consistently across product lot numbers, as verified by evaluations using machined metal standardization dies (C. T. Smith, unpublished data) and its proven record of success over years of use in R. V. Tucker Study Club sessions. Mix 30 g of stone with 6.4 g of distilled water for 30 seconds under vacuum using a digital vacuum mixer. Pour and mount the impression on a Monotrac Articulator. After the stone has set, separate the master model from the impression. Section and trim the master die to expose margins and emergence profiles as needed. The casting should be gently tried on the master die. Evaluate the casting and master

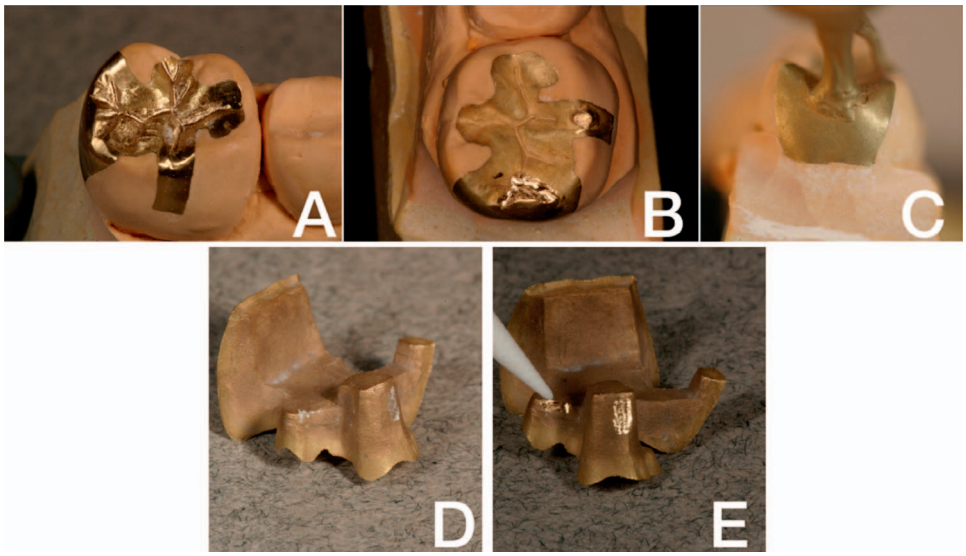


Figure 24. *(A-C): Try the restoration on the working die. (D and E): Adjust the rubs and pressure points.*

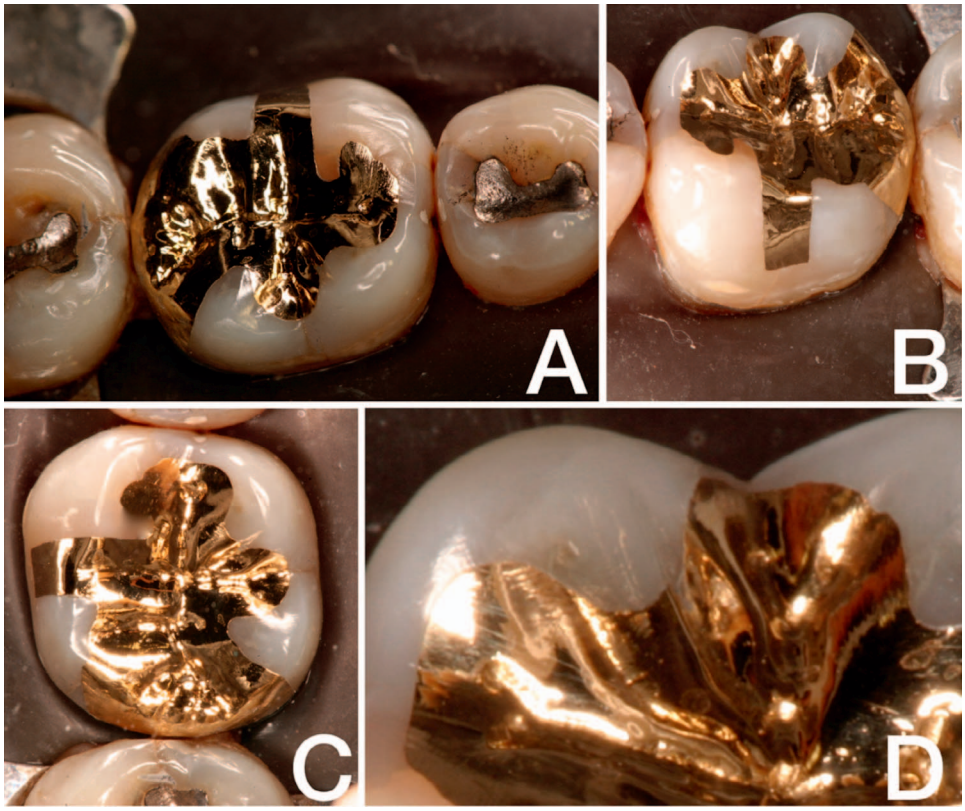


Figure 25. *(A): Initial try-in of the casting before cementation. (B-D): Finished restoration.*

die for minute rubs or powder streaks, which indicate small undercuts or pressure points on the surfaces of the casting and die. These areas on the casting are relieved with the Shofu Dura-White stone (CN1 HP) and lightly abraded with a 27-μm aluminum oxide air abrasive. The casting is placed again on die with gentle pressure, and the sequence of fitting, relieving, and air abrading of the internal surface of the casting is repeated until the casting seats completely and passively on the master die (Figure 24).

When the casting has been completely seated on the working model die, the proximal contact(s) can now be adjusted to final form and fit. The final finish and polish are completed. The casting is now ready for clinical try-in, finishing, and cementation procedures (Figure 25). Table 2 lists the materials and equipment used throughout these procedures.

SUMMARY

The clinical and laboratory techniques described here result in accurate, precise-fitting, and smooth gold castings. Distortion of the wax pattern has been eliminated because there is no removal of the wax pattern from the die once it is waxed.[5] The molten gold alloy is cast directly onto the refractory die, resulting in a casting that is the exact mirror image of the die and tooth preparation. Every bur mark, undercut, and detail will be reproduced on the casting due to the micro-fine particle size of the investment. Ultimately, when this technique is utilized properly, a very predictable, consistent, and precise casting will be obtained. This will save chair-side time, reduce remakes and operator anxiety, and increase both the quality of treatment and patient satisfaction. In addition, the long-term prognosis of the restoration is enhanced due to the precise fit and marginal adaptation of these restorations.[16]

This technique has been successfully employed in several Tucker Study Club sessions, during which various configurations of cast gold restorations are prepared, fabricated on-site, and delivered over a three-day period. The technique has demonstrated the potential to enable operators of varying experience to efficiently produce and deliver extremely precise, conservative restorations with a very long functional prognosis (Figure 26).

Table 2: *Materials and Equipment*

Product	Manufacturer
Aquasil Ultra Heavy Type 2 Heavy Body PVS impression material Aquasil Ultra XLV Light Body PVS impression material	Dentsply Caulk York, PA, USA www.dentsply.com
Harvest Dental MS3 Master Model Separator and Surfactant	Harvest Dental Brea, CA, USA www.harvestdental.com
Starvest Phosphate Bonded Investment (High-Expansion Green Liquid/Powder)	Emdin International Corporation Irwindale, CA, USA www.emdin.com
Investpres Pneumatic Pressurized Curing Unit	Lang Dental Manufacturing Co, Inc Wheeling, IL, USA www.langdental.com
Monotrac V2 Quadrant Articulator	Monotrac Articulation Midvale, UT, USA www.monotrac.com
Diamond Separating Disc	Brasseler USA Savannah, GA, USA www.Brasselerusadental.com
Dynex Glass-Reinforced Separating Discs (40 × 0.5 mm)	Renfert Hilzingen, Germany www.renfert.com
XTC Xtreme Temperature Coatings High-Temperature Automotive Paint	KBS Coatings Valparaiso, IN, USA www.KBS-Coatings.com
Consequent Orange Wax Grey Thowax (sculpturing wax)	Yeti Dental Engen, Germany www.yeti-dental.com
DPT Carver	Hu-Friedy, Inc Chicago, IL, USA https://www.hu-friedy.com
COE CheckBite Trays GC Fujirock Golden Tan Die Stone	GC America Alsip, IL, USA www.gcamerica.com
Dura-White Stones (CN1 HP)	Shofu Dental Corporation San Marcos, CA, USA www.shofu.com
Elite HD soft putty	Zhermack SpA Badia Polesine, Italy www.zhermack.com
Practicum 200-Gram Digital Analytical Balance	Sartorius Göttingen, Germany www.sartorius.us
Whipmix/Jelrus Infinity L30 Digital Burnout Furnace Whipmix VPM Digital Vacuum Mixer Whipmix 60-Gram Ringless Formers and Bases	Whip Mix Corporation Louisville, KY, USA www.whipmix.com

Acknowledgements

All clinical and laboratory procedures and all photographs were completed by the first author. The authors express their deepest gratitude to Drs Warren K. Johnson and Melvin R. Lund for reviewing this manuscript and, most importantly, for their invaluable friendship, support, mentorship, inspiration, and encouragement.

Figure 26. *Additional examples.*

Conflict of Interest

The authors of this article certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

(Accepted 21 February 2016)

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