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TECHNIQUE

Verifying the seating of a 3D-printed removable die using elastomeric matrices: A dental technique

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Abstract

Computer-aided design and computer-aided manufacturing systems enable digital designing and 3-dimensional (3D) printing of definitive casts with removable dies. However, the fit of the removable dies should be without interferences for their accurate positioning in the cast. Given that the accuracy of additive manufacturing depends on design- and manufacturing-related factors, verifying the accuracy of the position of 3D-printed removable dies in their cast is essential to fabricate positionally accurate definitive prostheses, which would enable minimal or no laboratory and clinical adjustments. This dental technique article presents a straightforward approach to verify the seating of a 3D-printed removable die by using verification matrices made of a polyvinylsiloxane interocclusal registration material.

KEYWORDS

3D printing, Digital Dentistry, Fixed Prosthodontics, Removable dies, Seating

Continuous improvement in technology and workflows has made contemporary computer-aided design and computer-aided manufacturing (CAD-CAM) a valid alternative to traditional dental manufacturing techniques.[1,2] Milling and 3-dimensional (3D) printing enable the fabrication of various dental appliances.[2–4] In particular, 3D-printing technologies have become common for the fabrication of casts for diagnostic and therapeutic purposes in dental clinics and laboratories.[5]

Definitive casts are used to fabricate and adjust prostheses, which can also involve removable dies inserted into their respective space through pins or their conical root portion.[6] When definitive working casts are 3D-printed, removable dies and casts are manufactured separately, post-processed, and assembled to replicate the intraoral situation. Manufacturing parameters such as laser speed, printing orientation, number of layers, shrinkage between layers, amount of supportive material, and postprocessing procedures may affect

FIGURE 1 Typodont used to resemble the proposed clinical scenario.

the fabrication trueness of a 3D-printed object, and deviation values ranging up to 92 μm have been reported depending on the technology.[1,7–10] Given that the deviations that occur during cast and die manufacturing might affect the position of removable dies in their cast, and the accuracy of subsequent definitive prostheses, it is critical to verify the removable dies' position in the cast to prevent complications at later stages.

Elastomeric materials have been used in dentistry for interocclusal registrations[11] as a verification matrix to evaluate the horizontal and vertical restorative space for implant-supported prostheses,[12] porcelain cut-back guide,[13] and as intraoral reference for prosthetically-driven tooth preparations[14] or esthetic direct composite restorations.[15] However, the implementation of polyether or polyvinylsiloxane matrices to evaluate the seating of 3D-printed removable dies has not been described. The presented technique article describes a straightforward method to evaluate the seating of 3D-printed removable dies by using a verification matrix made with a commonly used polyvinylsiloxane interocclusal registration material. This approach allows visual detection of positional discrepancies of removable dies in definitive casts, and thereby, facilitates the confirmation of the position of the die in 3D-printed definitive casts compared with the intraoral position of the prepared tooth.

TECHNIQUE

1. Prepare the abutment tooth for the intended type of complete coverage restoration, ensure adequate gingival retraction and hemostasis, and make the intraoral scans using an intraoral scanner (CEREC Primescan; Dentsply Sirona, Charlotte, NC). Reassess the occlusal clearance of the tooth preparation, and clean any blood precipitates, saliva, or debris that might have formed after scanning (Figure 1).
2. Block out large undercuts adjacent to the prepared tooth with wax (Square Wax Ropes, Hygienic- Coltene Whaledent, Cuyahoga Fall, OH) when necessary.
3. Apply a regular-setting polyvinylsiloxane interocclusal registration material to the finish line and occlusal surface (Futar D, Kettenbach USA, Huntington Beach, CA) under effective gingival retraction. Ensure the finish line, axial walls, occlusal surface, and opposing cusps are clearly defined in the registration (Figure 2a,b). Repeat the interocclusal registration if large imperfections are noticed. Make two interocclusal registrations using the technique described above.

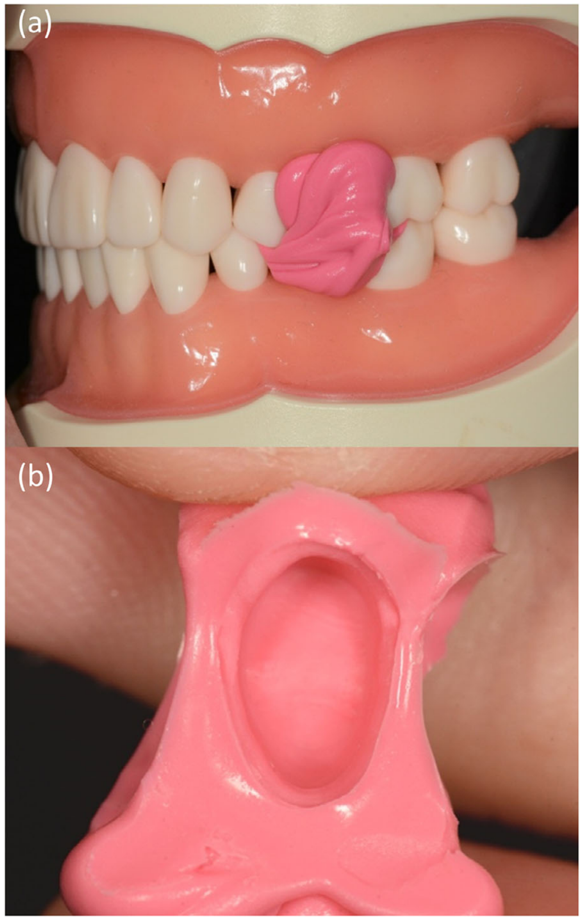

FIGURE 2 Intraoral registration using elastomeric interocclusal registration material. (a) Intraoral application of the elastomeric interocclusal registration material. (b) Close-up photograph of the interocclusal registration. Note clear reproduction of the finish line, occlusal anatomy, and axial walls.

4. Fabricate the removable die and the cast using a 3D printer (Form 3; FormLabs, Somerville, MA) and a dental model resin (Model V2; FormLabs, Somerville, MA). The removable die and the cast in the present technique were printed with a layer thickness of 25 μm. The supports were automatically generated at the root portion of the removable dies, orate the cast base, and the appliances were arranged and manufactured with their apex or base parallel to the build platform. Subsequently, post-process the die and the cast following the manufacturer's recommendations, and carefully remove the supports from the root portion of the removable die by using a dental laboratory carbide bur (H79EF.11.040 HP EF Cutter Carbide, Brasseler, Savannah, GA). Trim the

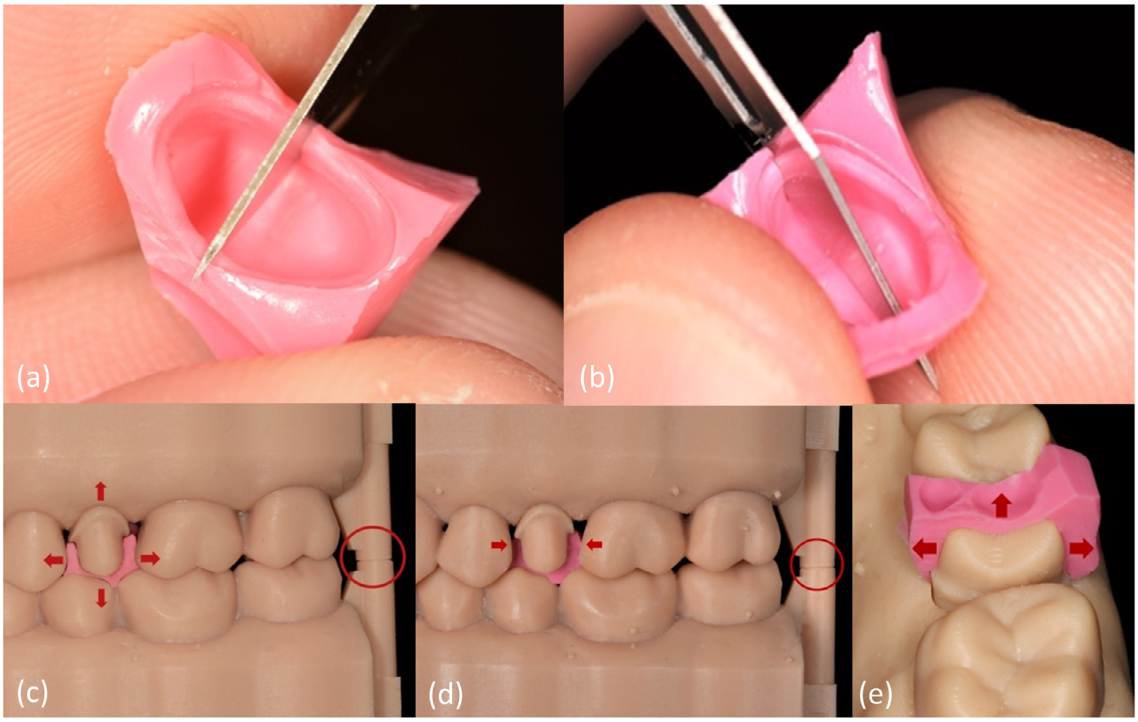

FIGURE 3 Visual evaluation of die's positional trueness. (a) First interocclusal registration with mesiodistal cut. (b) Second interocclusal registration with buccolingual cut. (c) Buccal view of first interocclusal registration. Red arrows indicate the direction of the vertical and mesiodistal displacement. Note slight separation between vertical support poles of 3D-printed casts and interproximal flaring of interocclusal registration with minimal finger pressure suggesting incomplete seating of removable die. (d) Buccal view of first interocclusal registration after minor adjustments to the apical portion of the removable die. Red arrows indicate intimate and passive adaptation of interocclusal registration to axial walls of tooth preparation, suggesting complete seating of removable die. Note contact between ends of vertical support poles of 3D-printed casts after adjustments. (e) Distal view of second registration after sectioning. Red arrows indicate the direction of buccolingual and vertical displacement evaluated with second interocclusal registration.

registration material by using a sharp laboratory blade. Conservatively trim the buccal surface and preserve the interocclusal registration material extending beyond the mesiolingual and distolingual line angles of adjacent teeth (Figure 3a).

5. Position the interocclusal registration on a 3D-printed cast and evaluate its seating on the removable die; trim the excess material apical to the finish line to ensure proper seating. After the registration seats passively, evaluate the interocclusal relationship of opposing casts; if needed, carefully trim the occlusal surface of the interocclusal registration leaving only the indentations of the opposing cusps. Adjust the registration as needed until maximum intercuspation and the contact between the vertical support poles of the 3D-printed casts is achieved.
6. Cut the interocclusal registration longitudinally (mesiodistally) (Figure 3b) and position the lingual portion of the registration onto the removable die. Hold the interocclusal registration steadily with moderate pressure against adjacent teeth, assess the extent of vertical and mesiodistal displacement, and corroborate the vertical seating (Figure 3c). If separation of the vertical support poles of the maxillary and mandibular 3D-printed casts, or distortion of the sectioned interocclusal registration in the form of interproximal flaring is noticed when minimal vertical pressure is applied to approximate the casts; verify that the interocclusal registration is properly seated. When needed, adjust the apical portion of the removable die until the registration precisely adapts to the axial walls of the removable die's coronal portion (Figure 3c). Cut the second interocclusal registration buccolingually and use it to evaluate any buccolingual displacement (Figure 3d,e)
7. Use one registration at a time and evaluate the correspondence of the removable die with the occlusal clearance and interproximal relationships observed intraorally. Assess the extent of the vertical displacement by using the interocclusal registration (Figure 3c). If significant vertical or horizontal displacement is noticed, evaluate the root portion of the removable die and the cast for areas of abrasion prevailing after the initial adjustment, untrimmed supports, debris, and resin residues inside the die space of the cast (Figures 4a,b), and proceed to adjust them carefully. If the 3D-printed cast incorporates a horizontal verification window, use it to evaluate the seating of the apical portion of the removable die after every adjustment.
8. When significant discrepancies exist between the removable die and the intraoral registration, or excessive movement or rotation of the die is noticed; manufacture a new removable die before proceeding to definitive prosthesis fabrication.

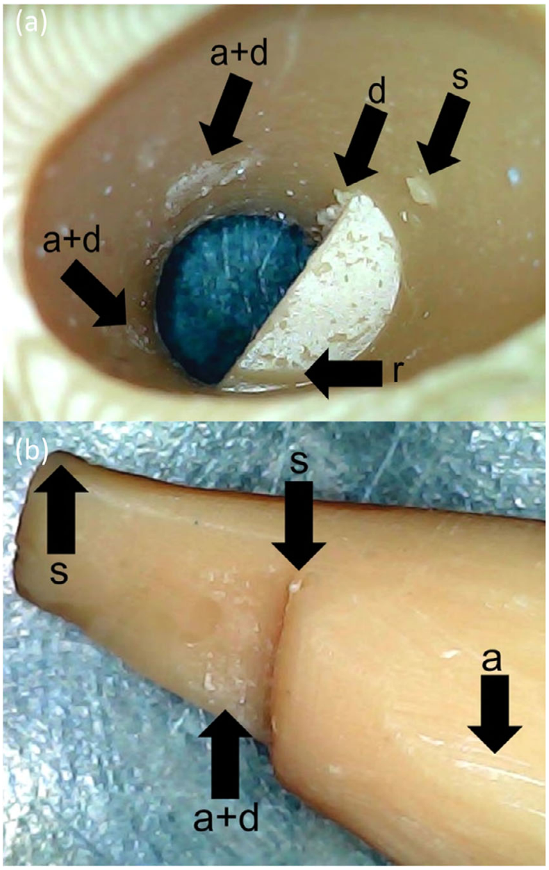

FIGURE 4 Digital microscope (Microdirect 1080p HD digital microscope, Celestron LLC, Torrance, CA) images of possible causes of positional inaccuracies taken under 10× magnification. (a) Die space of 3D-printed cast. (b) Apical portion of the 3D-printed die. Note the presence of minuscule residues of support insertions (s), polymerized resin (r), abrasions (a), and debris (d) after single insertion of the 3D-printed die in the model's die space.

DISCUSSION

The presented technique described an approach to evaluate the seating of 3D-printed removable dies by using matrices made with polyvinylsiloxane interocclusal registration material. Research suggests that modern 3D printers can fabricate accurate dental appliances adequate for clinical and dental laboratory use.[1,3,5,16] However, despite the satisfactory precision of most contemporary systems, the accuracy of 3D-printed objects depends on several design and manufacturing factors.[1,16] These factors play an important role when the desired object has a complex geometry or involves multiple components such as 3D-printed casts with removable dies.[5]

Several removable die designs are available in contemporary CAD software programs; each with different root geometries and retentive mechanisms.[5] Commonly, supports are placed on the root portion of 3D-printed removable dies to prevent any adjustment to the crown portion of the die. However, this approach might potentially lead to interferences between the die and the cast given that the removal of the supports is subjective. Like conventional stone casts, even the slightest discrepancy between the matching surfaces of the 3D-printed removable die and the cast might lead to unfavorable interocclusal relationships, inaccurate fabrication, and further adjustment of the definitive prostheses. Therefore, a straightforward approach, like the one described in the present technique can be implemented as a precautionary step to validate the position of the removable dies after manufacturing, thus increasing the efficiency of prostheses fabrication. Furthermore, it can be adapted by the clinician to more complex situations involving fixed partial dentures, multiple adjacent tooth preparations, and tooth preparations with limited interocclusal space that demand more attention to the space between the abutments and their related structures.

Elastomeric interocclusal registration materials should have acceptable rigidity, dimensional stability, fine detail reproduction, satisfactory deformation recovery, and favorable working time.[11] Similar to the other elastomers used intraorally, their accuracy depends on precise application on a dry and clean field. Therefore, the present technique has limitations related to intrinsic features and handling of the interocclusal registration material. In case of insufficient material, slow application, or poor application technique, the registration will not be accurate and its use as a verification device will be compromised. Additionally, in clinical situations where there are no teeth adjacent to the one prepared, interocclusal registration material should be supported with an interim carrier in autopolymerizing resin (Alike, GC America) or prefabricated celluloid crowns (Crown Forms, 3 M America) with an occlusal opening to record the opposing occlusal contacts. These carriers, however, should be easily removed preceding the transverse and longitudinal sectioning of the interocclusal registrations. In addition, a polyvinylsiloxane interocclusal registration material was used, and polyether or bisacrylic interocclusal registration materials may affect the outcome of this technique. Additionally, the die and cast presented in this technique were fabricated using a stereolithography-based 3D printer. However, 3D printers based on different technologies that enable cast and removable die fabrication may also be used to implement this technique. Also, this technique should be considered as an auxiliary means to visually identify substantial positional discrepancies; therefore, its implementation should always be accompanied by careful inspection of matching surfaces of the 3D-printed dies and models, and sound clinical judgment based on diagnostic information gathered during clinical appointment such as intraoral photographs and clinical measurements. Future studies should also corroborate the feasibility of this technique for different indications that involve multiple removable dies to substantiate its reliability.

SUMMARY

The present technique article described a straightforward approach to verify the seating of a 3D-printed removable die using verification matrices made from a polyvinylsiloxane

interocclusal registration material. Elastomeric matrices can be sectioned longitudinally and transversely to identify potential positional inaccuracies of 3D-printed removable dies, compared with the position of the prepared tooth relative to adjacent and opposing teeth. These auxiliary appliances should be meticulously manufactured and used in conjunction with careful inspection of 3D-printed casts and removable dies.

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REFERENCES

1. Revilla-León M, Özcan M. Additive manufacturing technologies used for processing polymers: current status and potential application in prosthetic dentistry. J Prosthodont. 2019;28:146–58.
2. van Noort R. The future of dental devices is digital. Dent Mater. 2012;28:3–12.
3. Azpiazu-Flores FX, Knobloch LA, Larsen PE. Interdisciplinary management of a patient with dentinogenesis imperfecta type ii using a combination of CAD-CAM and analog techniques: a clinical report. J Prosthodont. 2022;31:647–54.
4. Revilla-León M, Zeitler JM, Kois DE, Kois JC. Utilizing an additively manufactured Kois deprogrammer to record centric relation: a simplified workflow and delivery technique. J Prosthet Dent. 2022. doi: 10.1016/j.prosdent.2022.04.034
5. Yilmaz B, Donmez MB, Kahveci Ç, Cuellar AR, de Paula MS, Schimmel M, et al. Effect of printing layer thickness on the trueness and fit of additively manufactured removable dies. J Prosthet Dent. 2022;128:1318.e1–e9.
6. Magne M, Bazos P, Magne P. The alveolar model. Quintessence Dent Technol. 2009;32:39–46.
7. Maneiro Lojo J, Alonso Pérez-Barquero J, García-Sala Bonmatí F, Agustín-Panadero R, Yilmaz B, Revilla-León M. Influence of print orientation on the accuracy (trueness and precision) of diagnostic casts manufactured with a daylight polymer printer. J Prosthet Dent. 2023. doi: 10.1016/j.prosdent.2023.01.033
8. Revilla-León M, Piedra-Cascón W, Methani MM, Barmak BA, Att W. Influence of the base design on the accuracy of additive manufactured casts measured using a coordinate measuring machine. J Prosthodont Res. 2022;66:68–74.
9. Sim JY, Jang Y, Kim WC, Kim HY, Lee DH, Kim JH. Comparing the accuracy (trueness and precision) of models of fixed dental prostheses fabricated by digital and conventional workflows. J Prosthodont Res. 2019;63:25–30.
10. Emir F, Ayyildiz S. Accuracy evaluation of complete-arch models manufactured by three different 3D printing technologies: a three-dimensional analysis. J Prosthodont Res. 2021;65:365–370.
11. Chai J, Tan E, Pang IC. A study of the surface hardness and dimensional stability of several intermaxillary registration materials. Int J Prosthodont. 1994;7:538–42.
12. Zafiropoulos GG, Rebbe J, Thielen U, Deli G, Beaumont C, Hoffmann O. Zirconia removable telescopic dentures retained on teeth or implants for maxilla rehabilitation. Three-year observation of three cases. J Oral Implantol. 2010;36:455–65.
13. Lund PS. A dual purpose impression and porcelain cutback guide. J Prosthet Dent. 1992;67:41v2.
14. Meereis CT, de Souza GB, Albino LG, Ogliari FA, Piva E, Lima GS. Digital smile design for computer-assisted esthetic rehabilitation: two-year follow-up. Oper Dent. 2016;41:E13–E22.
15. Bailey O, McGuirk C, O'Connor C. Matrix transfer techniques for direct paste composite resins. Br Dent J. 2022;233:91–98.
16. Anadioti E, Kane B, Zhang Y, Bergler M, Mante F, Blatz MB. Accuracy of dental and industrial 3D Printers. J Prosthodont. 2022;31:30–37.

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