Managing Prosthetic Challenges with a CAD/CAM Zirconia Restoration

From Bilayered to Monolithic

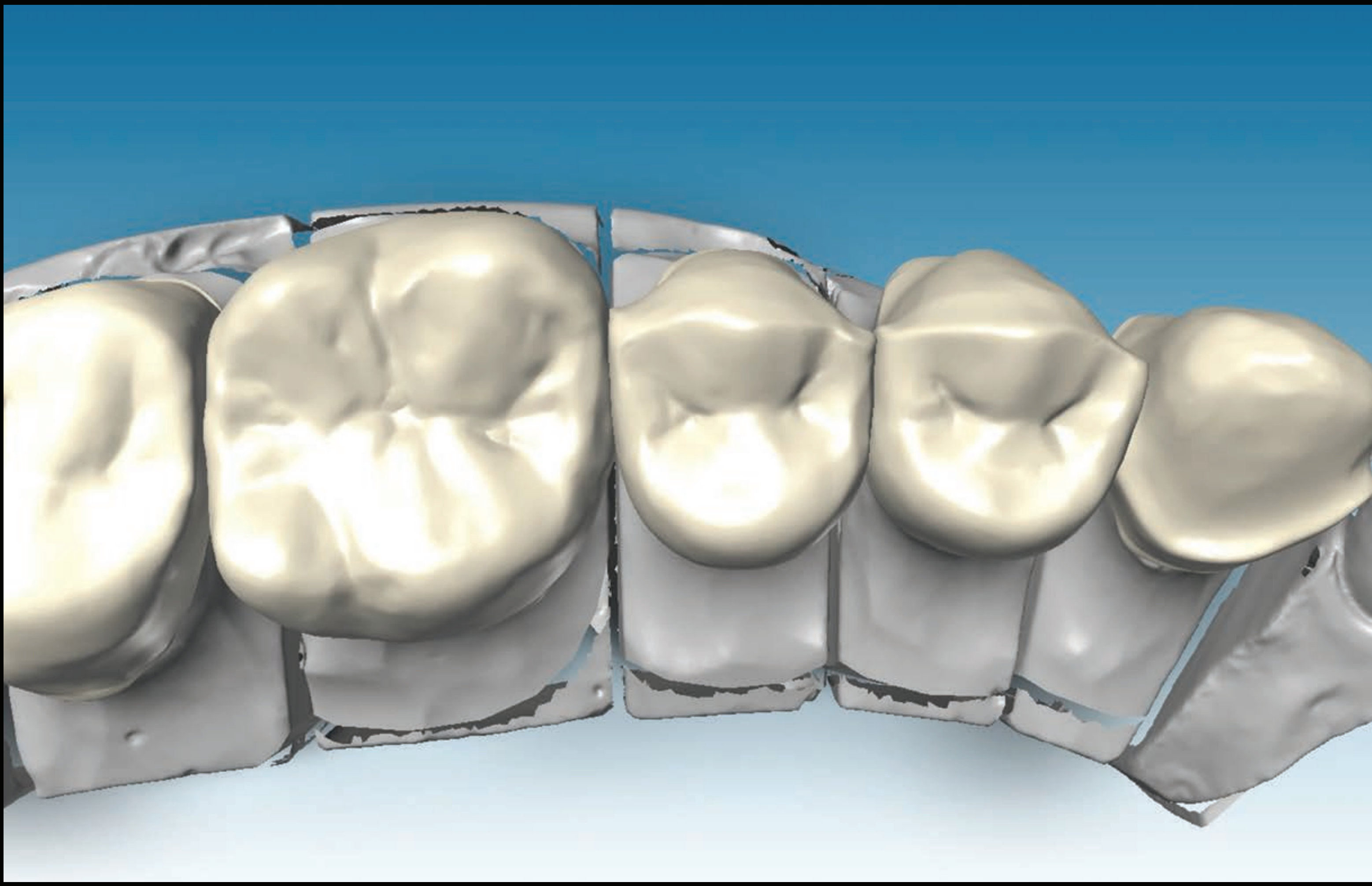
Ariel J. Raigrodski, DMD, MS, FACP

Abstract

The integration of an esthetic restoration with the soft tissue is paramount for a comprehensive esthetic, functional, and healthy restorative outcome. Zirconia may facilitate such an outcome due to its optical properties, which enhance the esthetic integration of the restoration at the soft tissue/restorative interface, while also enhancing soft tissue health due to its unique biocompatibility. This article will demonstrate concepts and procedures for soft tissue management in the case of a full-mouth rehabilitation using CAD/CAM technology and zirconia as a catalyst for an improved soft tissue/restorative integration with crowns and ovate pontic contours.

Key Words: all-ceramic, monolithic restoration, bilayered restoration, hybrid restoration, ovate pontic, CAD/CAM, soft tissue/restorative interface

Zirconia-based restorations are designed and processed via computer-aided design/computer-aided manufacturing technology.



Introduction

The success of all-ceramic crowns and fixed dental prostheses (FDPs) is measured not only by achieving adequate function and esthetics in terms of color match with the adjacent and opposing dentition; it is also measured by their integration with the adjacent hard and soft tissues in terms of function, health, and esthetics. Certainly, the optical properties and multiple tooth-colored shades and translucencies presented by all-ceramic materials enhance such integration at the soft tissue/restorative interface.[1]

CAD/CAM Technology

Zirconia-based restorations are designed and processed via computer-aided design/computer-aided manufacturing (CAD/CAM) technology.[1] Clinical studies have shown that these restorations can be used predictably for anterior and posterior crowns and for anterior and posterior FDPs.[2-4] With the advent of CAD/CAM technology, the primary design option for such restorations is the fabrication of a framework/coping that adequately supports the weaker veneering porcelain to minimize the risk for veneering porcelain cohesive failure.[5-7] Recent studies demonstrated similar flexural strength values (70 to 130 MPa) and similar values for fracture toughness (1.2 to 1.7 K1c) for different brands of veneering porcelains for zirconia-based restorations and for high noble alloy-based metal ceramic restorations.[8,9] Such a design is mostly desirable in the anterior segment, where occlusal forces are lower compared to the posterior segments, and esthetics is often the primary consideration. Coping thickness for such restorations is recommended to be a minimum of 0.6 mm in the posterior segments with a thickness of at least 1.5 to 2.0 mm of veneering porcelain, whereas in the anterior segment coping thickness can be reduced to 0.3 mm.[3,10] In addition, developments in CAD/CAM technology have facilitated restoration design flexibility, including the design and processing of monolithic zirconia crowns and FDPs.[11] Although concern has been expressed regarding the effects of aging on zirconia and of the wear properties of zirconia, recent studies have demonstrated that such concerns may be over-emphasized.[12-15] Such restorations may be used in the posterior segments where esthetics is less of a concern; and resistance to fracture, possible lack of interocclusal space, and control of occlusal contacts are of greater concern mainly due to higher occlusal forces compared to the anterior segment. Although clinical evidence is still limited with regard to the minimal thickness of such restorations, an in vitro study demonstrated that monolithic zirconia crowns of 0.6 mm thickness resulted in relatively high magnitude fracture loads.[16] A more recent in vitro study demonstrated that the fracture resistance of monolithic zirconia crowns with 1.0-mm thickness is equal to that of metal-ceramic crowns.[17] Consequently, and since the clinical reality is that minor occlusal adjustments may be needed after the restorations' cementation, it is advisable to use 1.0 mm of occlusal thickness as the guideline for minimal occlusal reduction.

However, in the premolar areas, where esthetics may still be of concern and occlusal forces are increased compared to the anterior segment, a different design can be considered. Termed the "hybrid" design,[18] with such restorations the lingual and occlusal surfaces are still designed for monolithic contours, whereas the buccal aspects can be virtually cut back to the ideal coping thickness and subsequently veneered with the corresponding veneering ceramics to facilitate the esthetic outcome.[18] Such a design can be used in the anterior segments as well, and can be easily achieved via CAD/CAM technology as long as clinicians communicate in detail with the dental laboratory regarding the restoration's design **(Table I)**.

Zirconia Characteristics

In addition, zirconia is presented with multiple tooth-colored shades and different levels of translucency as related to the brand used and to the thickness of the material.[19,20] This may promote favorable integration in terms of color and translucency at the soft tissue/restorative interface, a critical area in terms of soft tissue health and esthetics. These optical characteristics of zirconia are accompanied by excellent biocompatibility and several studies have demonstrated that, compared to titanium, zirconia presents with less bacterial accumulation, less bacterial adhesion, and less inflammatory reaction.[21-23] Thus, zirconia may facilitate adequate soft tissue integration in terms of esthetics and gingival health.

Soft Tissue Integration

Patients restored with FDPs and crowns in areas where esthetics is of paramount significance present with the challenge of having the restorations' contours blend adequately with the free gingival margins and the interproximal papillae. If the patient is missing a tooth that is planned to be restored with an FDP, the goal is to ensure that the pontic blends with the edentulous space and matches the contralateral and opposing soft tissues in terms of emergence profile (including facial and interproximal contours), texture, color, and health.[24,25] Various types of hard and/or soft tissue augmentation procedures, in conjunction with the use of an interim prosthesis to mold the tissue, are utilized to create a healthy concave pontic site at the residual alveolar ridge to facilitate the creation of an adequately matching convex ovate pontic.[26-28] The creation of an ideal convex ovate pontic enhances the pontic's blend with the pontic site, promoting an illusion of the pontic erupting out of the ridge. Moreover, the convex surface of the pontic facilitates the patient's ability to adequately clean the pontic site, while minimizing gingival inflammation.[24,25,29]

This visual essay addresses the use of CAD/CAM technology and zirconia in conjunction with proper clinical procedures, to facilitate not only the restorations' durability and "white component" of esthetics in terms of translucency and shade matching, but also the "pink component" in terms of soft tissue esthetics and health.

Table 1. Advantages and Limitations of Different Designs of Contemporary Complete-Coverage, All-Ceramic Restorations.

Restoration Design	Advantages	Limitations
bilayered	most esthetic potential	least functional potential due to weaker veneering porcelain (risk of cohesive chipping), and due to an interface between the veneering porcelain and the core material (risk of adhesive delamination)
monolithic	most durability and functional potential	least esthetic potential (relatively monochromatic)
hybrid	most esthetic potential in low-function areas while maintaining durability in high-function areas	requires detailed communication with the ceramist

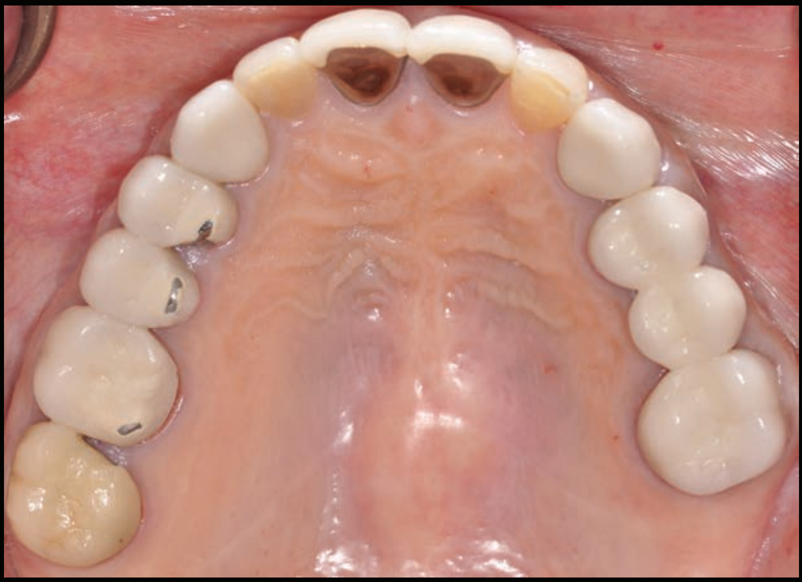


Figure 1a: Preoperative maxillary occlusal view of a patient with a failing full-mouth rehabilitation. The patient had been experiencing symptoms of malocclusion, which were translated to wear and fracture of some of her restorations. Note the wear and the fractures of the porcelain on ##2-5, and missing #15.

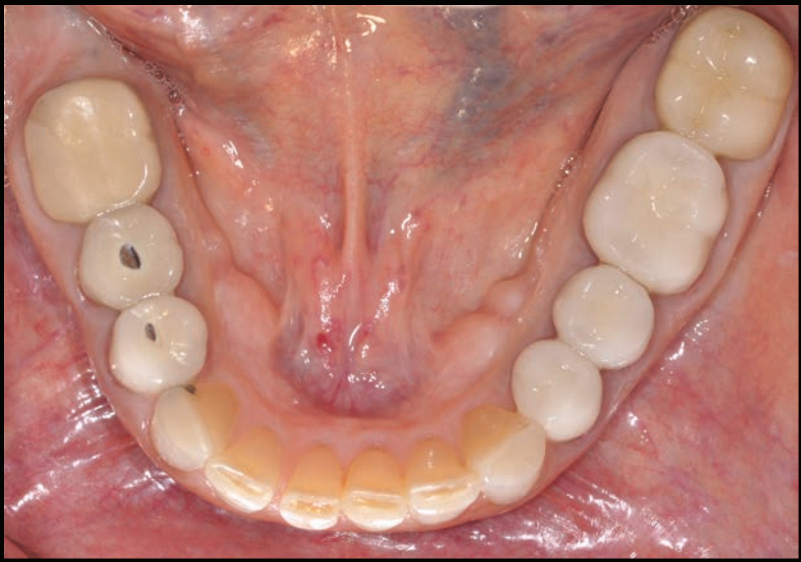


Figure 1b: Preoperative mandibular occlusal view of the patient. Note the wear on the occlusal aspect of the restorations and the anterior teeth, and missing #31.

Figure 2: Preoperative frontal retracted view of the patient in maximal intercuspal position. Note the color match discrepancies of the restorations with the remaining dentition. The patient presented with 4. 0-mm overbite, 3.0-mm overjet, gingival recessions, and opaque restorations. She expressed her satisfaction with the shade of her maxillary lateral incisors (which were relatively intact, excluding a mesial and distal direct composite resin restorations on #7). Therefore, a joint decision was made with the patient to use the maxillary lateral incisors as a guide for shade matching along with the mandibular anterior teeth. This decision increased the challenge the dental ceramist faced while fabricating the definitive restorations.

Figure 3a: Right lateral view of the patient in maximal intercuspal position. She presented with an Angle Class II dental relationship and demonstrated initial group function transitioning to right canine guidance in right lateral movement.

Figure 3b: Left lateral view of the patient in maximal intercuspal position. She demonstrated initial group function transitioning to left canine guidance in left lateral movement.

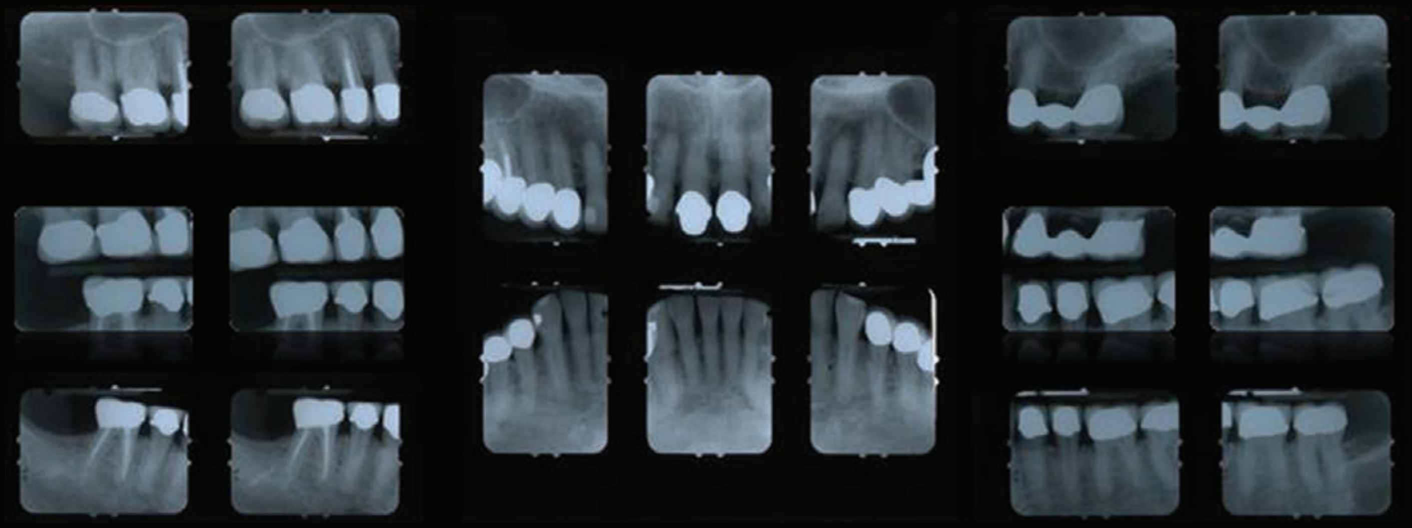


Figure 4: A full-mouth periapical radiograph showed adequate crown-to-root ratio, and mild bone loss around the anterior mandibular dentition. The patient was diagnosed with the following: mild localized periodontitis, acquired horizontal and vertical ridge deficiencies, partial edentulism, bilateral Angle Class II malocclusion with fractured restorations, and bruxism and clenching (by report).
Treatment objectives were to resolve the patient's chief complaints; this included addressing her malocclusion while also improving her chewing ability as well as esthetics. Therefore, she was given an anterior deprogrammer to eliminate any posterior teeth contact and interferences that might cause muscle disharmony and preclude adequately recording centric relation (CR) position (which was to be used as a reference for designing the definitive occlusal scheme). It was decided to provide the patient with long-term provisional restorations, which would be used as trial prostheses to ensure adequate function and esthetics. In addition, it was decided to use monolithic zirconia full-coverage restorations on the molars to address the patient's complaint of porcelain chipping and zirconia-based restorations elsewhere. Such an approach will facilitate the esthetic result, in particular at the soft tissue/restorative interface, while providing the patient with restorations that can be predictably conventionally luted since her gingival health was questionable.

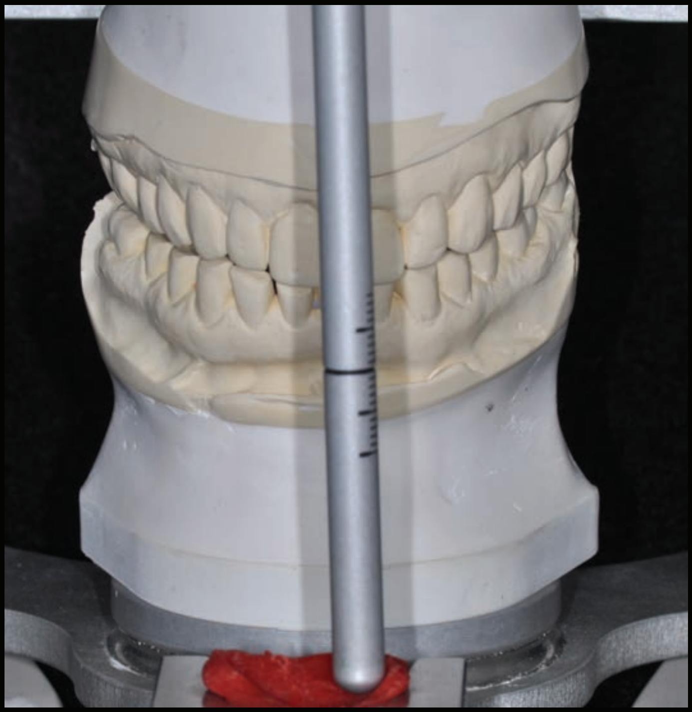
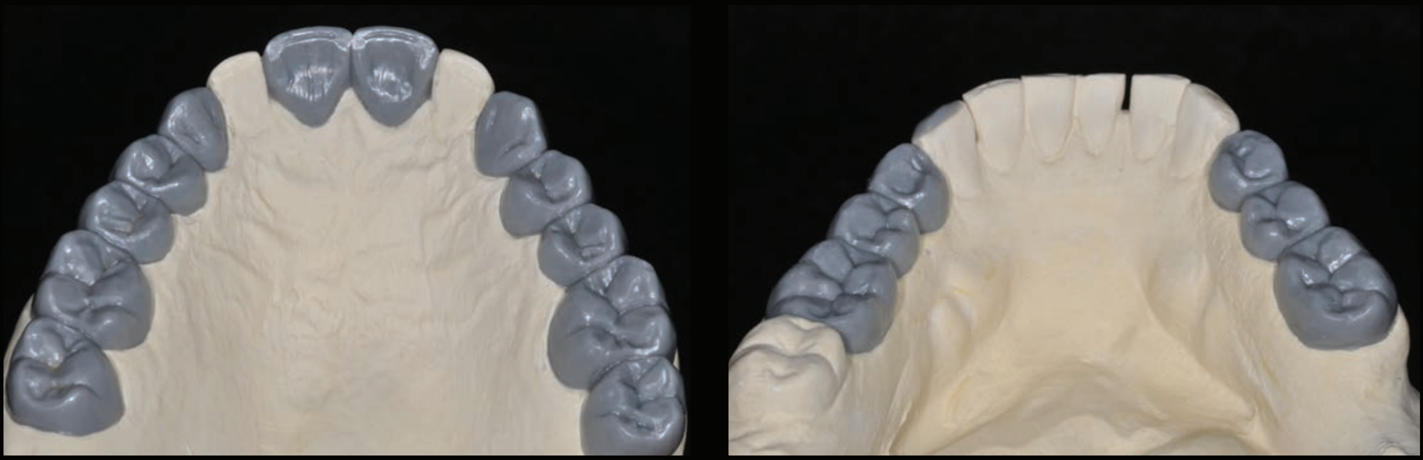
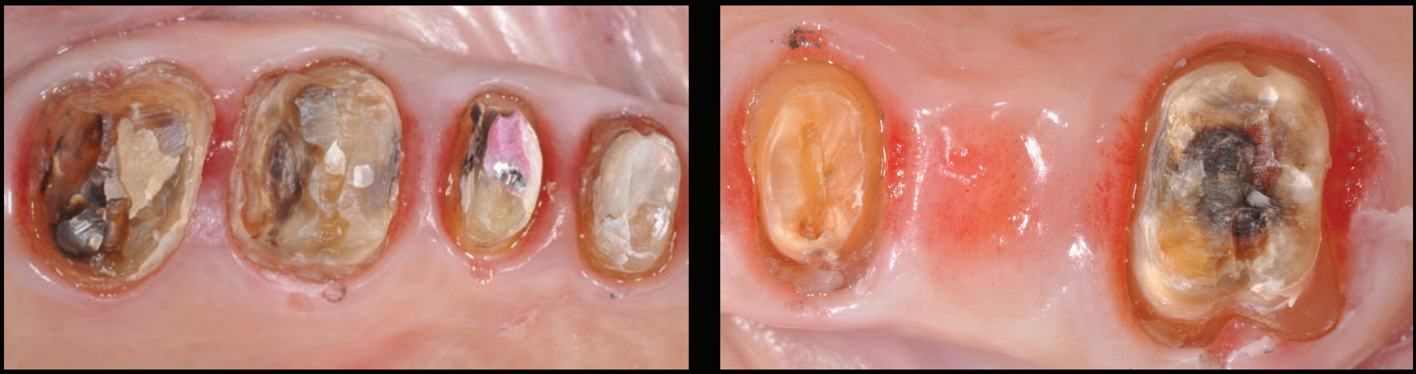


Figure 5: Diagnostic impressions were made and the patient was provided with an anterior deprogrammer for three months. Once centric relation was confirmed, a facebow record was made and the maxillary cast was mounted on a semi-adjustable articulator. A CR record was made and the mandibular cast was mounted while opening the vertical dimension of occlusion by 2.0 mm at the incisal area. A custom incisal guide table was made and was used in fabricating the diagnostic wax-up while providing the patient with mutually protected occlusion.

Termed the “hybrid” design, with such restorations the lingual and occlusal surfaces are still designed for monolithic contours, whereas the buccal aspects can be virtually cut back to the ideal coping thickness and subsequently veneered with the corresponding veneering ceramics to facilitate the esthetic outcome.



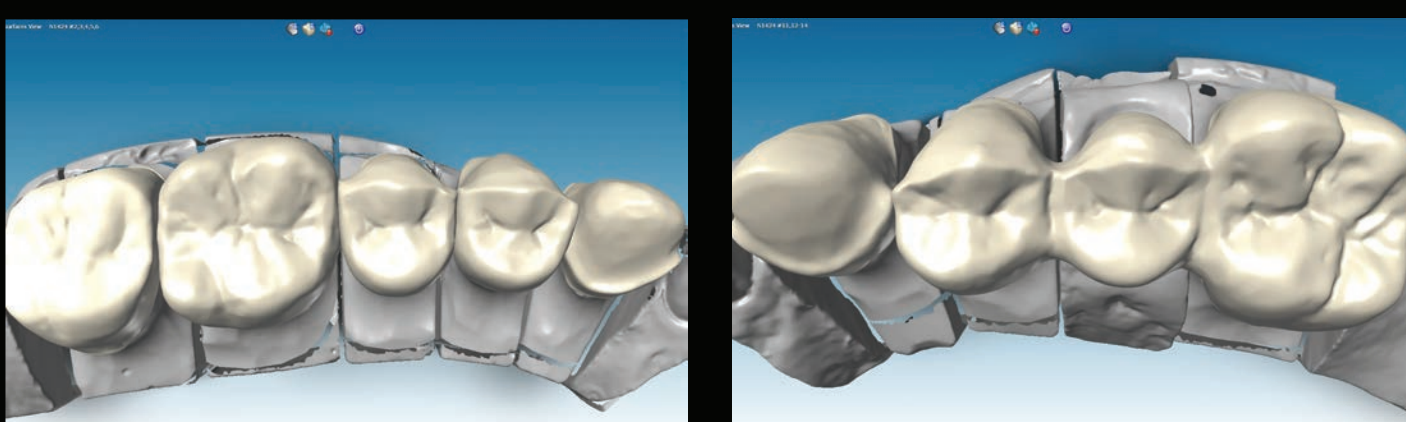
Figures 6a & 6b: Occlusal views of both the maxillary and mandibular wax-ups showing the palatal aspects of the maxillary central incisors and the maxillary canines, as well as the incisal aspects of the mandibular canines. All were designed to ensure that the anterior and canine guidance would immediately disocclude the posterior dentition in excursions.



Figures 7a & 7b: All maxillary full-coverage restorations were removed. In the occlusal view of the maxillary posterior dentition immediately after removal of the preexisting restorations, note a relatively healthy gingiva traumatized by the procedure. Also, note the pontic area, which will be manipulated for an ovate pontic site with the provisional restorations. The mandibular preexisting restorations were removed as well. Foundation restorations were replaced and the tooth preparations were refined. The patient declined any new metal or metal-ceramic restorations. Since her gingival health was questionable (which might compromise bonding procedures of bondable all-ceramic restorations), a posterior FDP was part of the rehabilitation, and matching of all the restorations was of primary importance to the patient, it was decided to select zirconia-based restorations with various restoration designs.

Figures 8a & 8b: Maxillary and mandibular views of the provisional restorations. The diagnostic wax-ups were duplicated in dental stone, impressions of these new casts were made, and shells with contours of the diagnostic wax-up were made of bis-acryl material (Protemp Plus, 3M ESPE; St. Paul, MN). Maxillary and mandibular provisional restorations were placed following the occlusal scheme developed on the articulator using the shells, which were relined with autopolymerized acrylic-resin (Jet, Lang; Wheeling, IL) in the patient's mouth. The pontic site was trimmed with a high-speed, super-coarse, football-shaped bur and direct composite resin was added to the cervical part of the pontic to mold the tissue at the pontic site to an ovate pontic shape.
The patient functioned with the provisional restoration for more than three months and did not report any sensitivity, discomfort, or pain. During that period the provisional restoration on #19 cracked once. However, there was no additional loss of retention, cement wash, or fracture.

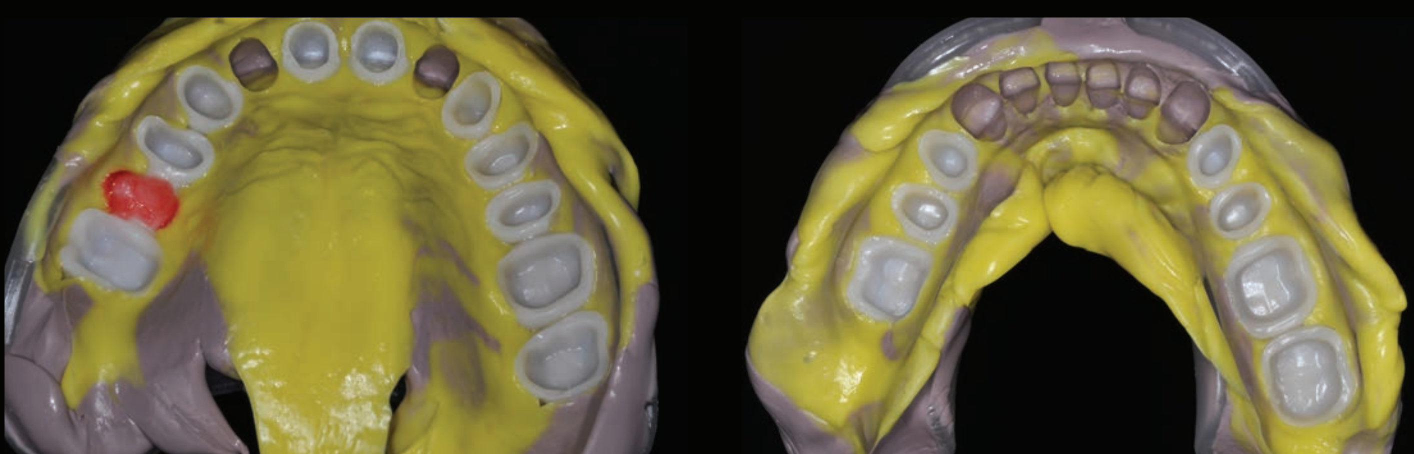
Figures 9a & 9b: Occlusal views of the maxillary and mandibular teeth preparations. Subsequently, master impressions of the prepared teeth on both arches were made with polyvinyl siloxane (PVS) (Imprint 3, 3M ESPE); impressions of the provisional restorations were made as well. Interocclusal records were made to allow for cross mounting of the definitive casts to the provisional restorations. Care was taken not to compromise the soft tissue and to avoid prospective recessions.



Figures 10a & 10b: The definitive casts, the casts of the provisional restorations, and interocclusal records were scanned with the Lava scanner (3M ESPE). Zirconia-based restorations (Lava Plus, 3M ESPE) were designed to allow for adequate support of the veneering porcelain at areas where esthetics is critical. Monolithic zirconia restorations were designed for the molars, where the likelihood of heavy occlusal forces is higher and to reduce the incidence of mechanical complications.

Figures 11a & 11b: Lateral views of the framework try in. The proximal contacts and internal fit were assessed using a silicone disclosing agent (Fit Checker, GC America; Alsip, IL). Afterwards, the occlusal contacts were evaluated and the occlusal surfaces of the posterior teeth were slightly adjusted with a high-speed fine diamond bur and ample water. In addition, the intaglio surface of the FDP framework pontic was coated with autopolymerized acrylic resin (GC Pattern Resin, GC America) to record the ovate pontic contours to facilitate the fabrication of a natural-looking ovate pontic for #13.

Figures 12a & 12b: Intraoral occlusal views of the maxillary and mandibular zirconia copings and FDP framework secured on the prepared abutment teeth. Note the monolithic design of the molar restorations, the coping design for the bilayered maxillary canines and central incisors crowns, and the hybrid design for the premolar restorations.



Figures 13a & 13b: Maxillary and **mandibular pick-up impressions were made with Imprint 3 PVS to ensure an accurate transfer of the soft tissue contours around the abutment teeth, in particular at the pontic site. This facilitated the creation of adequate blending of the restorations in terms of contours at the soft tissue/restorative interface.**

Figure 14: The zirconia copings and frameworks were layered, and stained and glazed as needed. A monolithic approach was used for the design and fabrication of the functional occlusal aspects of the posterior crowns and FDP; this helped to ensure optimization of the mechanical properties of the restorations' occlusal contacting areas. The facial and incisal aspects of the crowns that were visible at smile were conventionally layered to facilitate internal characterization, translucency, and esthetics using corresponding layering ceramics (Noritake CZR, Kuraray Noritake; Tokyo, Japan). The intaglio surface of the pontic was layered as well, to match the contours of the pontic site.

Figures 15a & 15b: The restorations were tried in the patient's mouth to assess color match and esthetics, proximal, internal, and marginal fit, and to assess occlusal contacts. Functional and esthetic integration with the adjacent and opposing dentition as well as integration at the soft tissue/restorative interface were noted. Once verified, the restorations were conventionally cemented with self-etching, self-adhesive, dual-cured composite-resin cement (RelyX Unicem 2, 3M ESPE).

Figures 16a-16c: The patient was provided with a mutually protected occlusion with canine guidance in right lateral excursion, anterior guidance in protrusive movement, and canine guidance in left lateral excursion.

Figure 17: Excellent marginal integrity and excess cement removal were confirmed. The ceramist layered the facial and incisal aspects of the anterior restorations to provide characterizations and translucency to the patient's satisfaction.

Figure 18: Postoperative full-mouth radiographs. Note the excellent marginal integrity of the definitive restorations.

Figure 19: A hard occlusal guard with a mutually protected occlusion was provided for the patient to wear while sleeping and when feeling the urge to clench while awake. This left lateral view taken several months after delivery demonstrates esthetic and functional integration with the soft tissue around the teeth, in particular at the ovate pontic restoring #13.

Acknowledgments

The author thanks master ceramists Nori Kajita, RDT, CDT, and Masayuki Saito, RDT (Cusp Dental Research; Malden, MA), for fabricating the restoration presented in this article.

References

1. Raigrodski AJ. Contemporary materials and technologies for all-ceramic fixed partial dentures: a review of the literature. J Prosthet Dent. 2004 Dec;92(6):557-62.
2. Raigrodski AJ, Hillstead MB, Meng GK, Chung KH. Survival and complications of zirconia-based fixed dental prostheses: a systematic review. J Prosthet Dent. 2012 Mar;107(3):170-7.
3. Raigrodski AJ, Yu A, Chiche GJ, Hochstedler JL, Mancl LA, Mohamed SE. Clinical efficacy of veneered zirconium dioxide-based posterior partial fixed dental prostheses: five-year results. J Prosthet Dent. 2012 Oct;108(4):214-22.
4. Monaco C, Caldari M, Scotti R. Clinical evaluation of 1,132 zirconia-based single crowns: a retrospective cohort study from the AIOP clinical research group. Int J Prosthodont. 2013 Sep-Oct;26(5):435-42.
5. Rosentritt M, Steiger D, Behr M, Handel G, Kolbeck C. Influence of substructure design and spacer settings on the in vitro performance of molar zirconia crowns. J Dent. 2009 Dec;37(12):978-83.
6. Guess PC, Bonfante EA, Silva NR, Coelho PG, Thompson VP. Effect of core design and veneering technique on damage and reliability of Y-TZP-supported crowns. Dent Mater. 2013 Mar;29(3):307-16.
7. Mahmood DJ, Linderoth EH, Vult Von Steyern P. The influence of support properties and complexity on fracture strength and fracture mode of all-ceramic fixed dental prostheses. Acta Odontol Scand. 2011 Jul;69(4):229-37.
8. Ishibe M, Flinn BD, Spiekerman C, Raigrodski AJ. Flexural strength of pressed and layered ceramics. Presented at: 91st General Session of the International Association for Dental Research; 2013 Mar 20-23; Seattle, WA (abstract 44).
9. Ansong R, Flinn BD, Chung KH, Mancl L, Ishibe M, Raigrodski AJ. Fracture toughness of heat-pressed and layered ceramics. J Prosthet Dent. 2013 Apr;109(4):234-40.
10. Raigrodski AJ, Dogan S, Zhang H. Five year follow-up of anterior maxillary crowns with customized zirconia copings. Presented at: 91st General Session of the International Association for Dental Research; 2013 Mar 20-23; Seattle, WA (abstract 1737).
11. Beuer F, Stimmelmayr M, Gueth JF, Edelhoff D, Naumann M. In vitro performance of full-contour zirconia single crowns. Dent Mater. 2012 Apr;28(4):449-56.
12. Flinn BD, deGroot DA, Mancl LA, Raigrodski AJ. Accelerated aging characteristics of three yttria-stabilized tetragonal zirconia polycrystalline dental materials. J Prosthet Dent. 2012 Oct;108(4):223-30.
13. Flinn BD, Singh A, Mancl LA, Raigrodski AJ. Low temperature degradation of three zirconias. Presented at: 90th General Session of the International Association for Dental Research; 2012 Jun 20-23; Iguaçu Falls, Brazil (abstract 198).
14. Rosentritt M, Preis V, Behr M, Hahnel S, Handel G, Kolbeck C. Two-body wear of dental porcelain and substructure oxide ceramics. Clin Oral Investig. 2012 Jun;16(3):935-43.
15. Janyavula S, Lawson N, Cakir D, Beck P, Ramp LC, Burgess JO. The wear of polished and glazed zirconia against enamel. J Prosthet Dent. 2013 Jan;109(1):22-9.

16. Baladhandayutham B, Beck P, Litaker MS, Cakir D, Burgess J. Fracture strength of all-ceramic restorations after fatigue loading. Presented at: 41st Annual Meeting & Exhibition of the American Association for Dental Research; 2012 Mar 21-24; Tampa, FL (abstract 24).

17. Sun T, Zhou S, Lai R, Ma S, Zhou Z, Longquan S. Load-bearing capacity and the recommended thickness of dental monolithic zirconia single crowns. J Mech Behav Biomed Mater. 2014 Jul;35:93-101.

18. Raigrodski AJ. Concepts of design for contemporary anterior all ceramic restorations. J Cosmetic Dent. 2013 Winter;28(4):46-58.

19. Baldissara P, Llukacej A, Ciocca L, Valandro FL, Scotti R. Translucency of zirconia copings made with different CAD/CAM systems. J Prosthet Dent. 2010 Jul;104(1):6-12.

20. Dogan S, Flinn BD, Toivola RE, Heindl H, Chu SJ, Raigrodski AJ. Translucency measurement of zirconia and lithium-disilicate using densitometry and spectrophotometry. Presented at: 89th General Session of the International Association for Dental Research; 2011 Mar 16-19; San Diego, CA (abstract 1651).

21. Josset Y, Oum'Hamed Z, Zarrinpour A, Lorenzato M, Adnet JJ, Laurent-Maquin D. In vitro reactions of human osteoblasts in culture with zirconia alumina ceramics. J Biomed Mater Res. 1999 Dec;47(4):481-93.

22. Rimondini L, Cerroni L, Carrasi A, Torricelli P. Bacterial colonization of zirconia ceramic surfaces: an in vitro and in vivo study. Int J Oral Maxillofac Implants. 2002 Nov-Dec;17(6):793-8.

23. Scarano A, Piattelli M, Caputi S, Favero GA, Piattelli A. Bacterial adhesion on commercially pure titanium and zirconium oxide disks: an in vivo human study. J Periodontol. 2004 Feb;75(2):292-6.

24. Abrams L. Augmentation of the deformed residual endentulous ridge for fixed prosthesis. Compend Contin Educ Gen Dent. 1980 May-Jun;1(3):205-13.

25. Garber DA, Rosenberg ES. The edentulous ridge in fixed prosthodontics. Compend Contin Educ Dent. 1981 Jul-Aug;2(4):212-23.

26. Dylina TJ. Countour determination for ovate pontics. J Prosthet Dent. 1999 Aug;82(2):136-42.

27. Howard WW, Ueno H, Pruitt CO. Standards of pontic design. J Prosthet Dent. 1981 May;47(5):493-5.

28. Abrams H, Kopczyk RA, Kaplan AL. Incidence of anterior ridge deformities in partially edentulous patients. J Prosthet Dent. 1987 Feb;57(2):191-4.

29. Zitzmann NU, Marinello CP, Berglundh T The ovate pontic design: a histologic observation in humans. J Prosthet Dent. 2002 Oct;88(4):375-80. **jCD**

Patients restored with FDPs and crowns in areas where esthetics is of paramount significance present with the challenge of having the restorations' contours blend adequately with the free gingival margins and the interproximal papillae.

Dr. Raigrodski is a professor, Department of Restorative Dentistry, University of Washington (UW), in Seattle. He also is an adjunct professor, Department of Materials Sciences and Engineering, UW College of Engineering. He has a private practice in Kenmore, Washington.

Dr. Raigrodski can be contacted at draigrod@comcast.net or at (206) 234-3340.

Disclosure: The author did not report any disclosures.