Utilization of Multiple Restorative Materials in Full-Mouth Rehabilitation: A Clinical Report

JUNG NAM, DMD, MS, MSD*
ARIEL J. RAIGRODSKI, DMD, MS†
HARALD HEINDL, MDT‡

ABSTRACT

Many different restorative materials are currently available for use in modern dentistry. Clinicians and dental technicians should be able to choose the most suitable materials for each patient based on research, anecdotal evidence, clinical experience, as well as patient's expectations and desires. The purpose of this article is to share the challenges presented in full-mouth rehabilitation and to describe the considerations in selecting three different restorative materials to achieve a successful restoration in terms of biomechanics, function, and esthetics.

CLINICAL SIGNIFICANCE

Interdisciplinary treatment planning, knowledge of available restorative materials, sequencing treatment modalities, and adequate communication between all parties involved are key to a successful treatment outcome when pursuing full-mouth restorative rehabilitation.

(*J Esthet Restor Dent* 20: 251–265, 2008)

INTRODUCTION

Satisfying patients' high expectations for dental esthetics is one of the challenges in contemporary dental therapy for both clinicians and dental technicians. As part of treatment planning, clinicians should be able to choose the appropriate restorative materials to achieve excellence in natural esthetics as well as proper biomechanics and durability.[1] While treatment planning for restorative procedures, many different factors must be considered. Clinicians should evaluate the prognosis of the individual dentition in terms of gingival and periodontal health, structural compatibility and vitality, and position. In addition, patients must be evaluated comprehensively in terms of parafunctional habits, occlusal wear patterns, existing occlusal schemes, skeletal relationships, inter- and intra-arch relationship, vertical height and horizontal width of the residual alveolar ridges (for implant-supported restorations as well as for pontics), and dentofacial esthetics. Additional factors to be considered are the type of individual restoration required (complete crowns, fixed partial dentures [FPDs], partial-coverage restorations), shade of individual teeth and the harmony of shade between adjacent restorations, the type of foundation restoration if needed, the type of implant abutment and restoration, and the type of pontic. Bearing in mind all of the above considerations and with the ample restorative materials available for indirect restorations, material selection should be customized to the individual needs of the patient while taking into

*Former resident, Graduate Prosthodontics, Department of Restorative Dentistry, School of Dentistry, University of Washington, Seattle, WA, USA; private practice, Seoul, Korea
†Associate professor and director, Graduate Prosthodontics, Department of Restorative Dentistry, School of Dentistry, University of Washington, Seattle, WA, USA
‡Master dental technician, Aesthetic Dental Creations, Mill Creek, WA, USA

DOI 10.1111/j.1708-8240.2008.00188.x

account the materials' mechanical and optical properties, its biocompatibility, and the skills of the dental ceramist and the clinician.

Although gold and metal-ceramics have been used for many years with a high level of clinical success,[2–4] the challenge of achieving ideal esthetics may be facilitated with the use of all-ceramic restorations. With highly translucent teeth, matching the shade and other optical properties to adjacent teeth restored with metal-ceramic restorations may pose a challenge to the dental ceramist and restorative dentist. Therefore, the prospect of using different all-ceramic materials to match in different segments of the mouth, which may require different mechanical properties, may prove advantageous.

There are three major categories of dental ceramic core materials: glass-ceramics, glass-infiltrated ceramics, and polycrystalline ceramics. Each category of ceramic core materials has sub-branches with different chemistry and composition.[5] Clinical studies have demonstrated that different ceramic cores showed different levels of clinical success and longevity. Although some materials' success has been limited to the anterior segment, others have demonstrated clinical success in the posterior segment as well.[6–11] The selection of an all-ceramic system is confounding because of many available different systems and scarcity of information regarding their long-term use in particular for posterior FPDs.[12] On the other hand, clinical studies demonstrated high success rates with metal-ceramics[2–4] and porcelain laminate veneers[13–16] and proved their safety of use.

As dental materials continue to evolve, new all-ceramic materials with superior mechanical properties, such as high flexural strength and high fracture toughness, are continuously being introduced to the market.[17,18] Such are the zirconia-based computer-aided design and computer-aided manufacturing (CAD/CAM) systems, which have been introduced recently.[19] These systems are gaining popularity in both the anterior and posterior segments for multiple indications.[20–24]

Zirconia is the strongest and toughest ceramic material available so far.[20] Clinical reports and anecdotal evidence demonstrated that zirconia-based restorations could be used for both anterior and posterior complete crowns and FPDs.[20–22] Moreover, short-term clinical studies demonstrated favorable results on the use of zirconia-based systems for posterior FPDs, which is the ultimate and most challenging mechanical and functional clinical test. In terms of mechanical challenges presented by zirconia-based systems, these studies reported some minor cohesive chipping of the veneering porcelain mainly on the second molars, which did not require the replacement of the restoration. Thus, with these types of restorations, the weak link may be the veneering porcelain.[22–24]

The purpose of this article is to demonstrate and discuss the challenges of material selection for full-mouth fixed rehabilitation. The following clinical report describes the different considerations in selecting different restorative materials to achieve a successful restoration.

CASE PRESENTATION

A 57-year-old Caucasian male patient presented with the following chief complaints: "I would like to have longer teeth and have a better-looking smile." His medical history was noncontributory except for history of gastroesophageal reflux disease (GERD). The patient was referred to the gastroenterology department for evaluation. However, his medical consultation reported that he did not have any current signs or symptoms of GERD.

Extraoral examination indicated relative facial symmetry, straight facial profile, asymptomatic temporomandibular joint (TMJ), and asymptomatic muscles of

Figure 1. An initial frontal view of the patient at rest position.

Figure 2. A frontal view of the patient's dentition in maximum intercuspal position.

mastication and facial expression. Dentofacial analysis demonstrated visually a shortened facial height for the lower third of the face and a slightly enlarged interocclusal space, implying a minor loss of vertical dimension of occlusion.[25] The maxillary dental midline deviated 1.0 mm to the right side as compared with the facial midline. At rest, the patient did not display any portion of his teeth (Figure 1), but in full smile, he displayed about 90% of his maxillary central incisors.[26]

Clinical examination revealed several "cupping" lesions on the occlusal surfaces of his posterior dentition. The patient was recommended the use of fluoride mouth rinse and toothpaste to increase the potential for remineralization and decrease the potential for demineralization.[27] The patient presented with composite-resin and amalgam restorations, missing teeth, a gold onlay, gold crowns, and metal-ceramic crowns. Some of these restorations were failing because of overhanging margins, recurrent caries, and fractures. The majority of the posterior dentition was structurally compromised. Tooth #3 was extracted because of fracture a year prior to the initial examination. Moderate tooth structure loss was noticed in the anterior as well as posterior dentition because of erosion. Although exposed dentin was noticed on the palatal surfaces of maxillary incisors and on some of the occlusal surfaces of premolars and molars, the patient did not report or demonstrate any signs or symptoms of sensitivity. The clinical crown length of maxillary central incisors was 8 mm and that of mandibular central incisors was 5 mm. Thus, in general, the patient displayed short clinical crowns (Figures 2–4).

Periodontal examination was within normal limits, with the patient revealing a thick periodontal biotype. Radiographic examination demonstrated generally adequate bone levels and crown-to-root ratios, with the exception of the endodontically treated tooth #29, which presented minimal bone loss, nonfavorable crown-to-root ratio, and a periapical pathosis (Figure 5).

Diagnostic data collection included clinical examination, full-mouth periapical radiographs, a panoramic radiograph, diagnostic casts, dentofacial analysis, photographic documentation, and a diagnostic wax-up. The dentofacial analysis was made utilizing an indirect acrylic-resin occlusion rim.[28,29] The treatment plan included initial preparation and caries removal and complete-mouth clinical crown lengthening surgical procedures to expose 1.5 to 2 mm of tooth structure circumferentially for adequate ferrule for resistance and retention forms at the posterior segments, and to

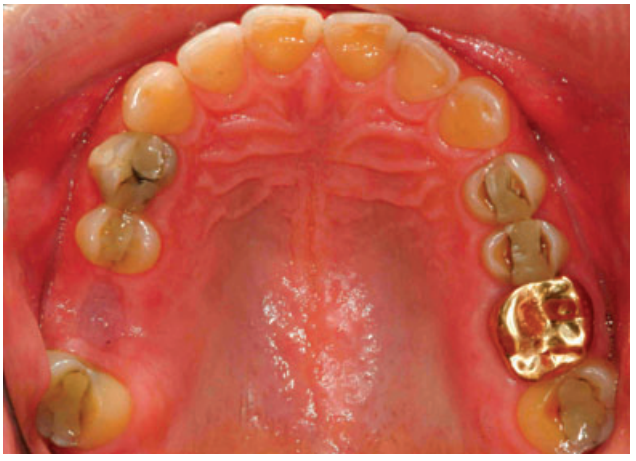

Figure 3. A preoperative maxillary occlusal view. Note the failing restorations and the structurally compromised bicuspids. Cupping lesions can be noted on the bicuspids and second molars as well as wear on the anterior teeth.

Figure 4. A preoperative mandibular occlusal view. Note the failing restorations and tooth wear.

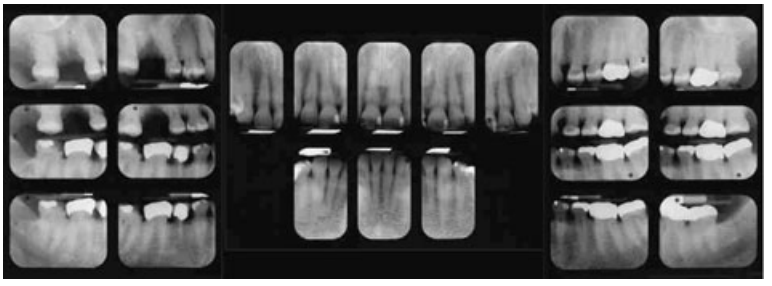

Figure 5. Preoperative full-mouth periapical radiographs.

Figure 6. A frontal view of the diagnostic wax-up.

facilitate esthetic gingival levels anteriorly.[30]

The patient expressed his desire to display more teeth both at rest and smile. As the patient did not display any maxillary teeth at rest, the maxillary incisors were planned to be lengthened 2 mm incisally.[31] Thus, the maxillary central incisors were planned to be lengthened 1.5 mm apically and 2 mm incisally. The vertical dimension of occlusion was planned to be restored by a 3-mm increase at the incisor area in order to gain more space for the restorative materials and to make longer maxillary and mandibular incisors.[25] After an adequate healing period, restorative procedures were planned for the full-mouth rehabilitation, including complete crowns and FPDs and porcelain laminate veneers for the mandibular anterior dentition. Additionally, tooth #29 was planned to be extracted because of poor crown-to-root ratio, poor ferrule, external root resorption, and pathologic mobility.

After the removal of failing restorations and caries removal, esthetic clinical crown lengthening surgical procedures were performed as planned with the diagnostic wax-up (Figure 6). According to bone sounding procedures made prior to surgeries, normal crest dentogingival dimensions were noticed.[32] In addition, the

Figure 7. A frontal view of the patient's dentition in maximum intercuspal position after healing post crown lengthening procedures.

Figure 8. An occlusal view of the maxillary preparations.

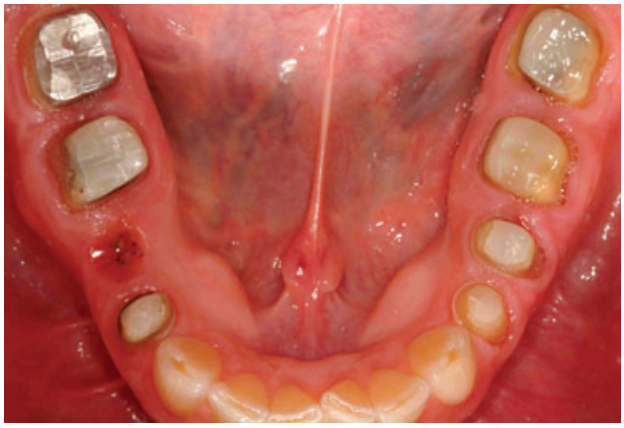

Figure 9. An occlusal view of the mandibular preparations.

Figure 10. A frontal view of the patient's smile with the provisional restorations.

cementoenamel junction (CEJ) was detected 1.5 mm below the free gingival margins. A vacuum-formed surgical template was used as a reference for the prospective desired gingival levels during the surgeries. Full-thickness flaps with scalloped incisions were elevated to preserve interdental papillae.[33,34] Osteotomy was performed according to surgical templates to develop 2.0 mm of biologic width and 1.0 mm of sulcular depth.[35,36]

After 9 months of healing, the gingival tissues were matured and ready for the restorative treatment (Figure 7).[37] The teeth were prepared according to a vacuum-formed preparation guide, and self-cured acrylic-resin shells were clinically relined to fabricate self-cured acrylic-resin interim restorations.[38] The complete crowns and FPDs were prepared and planned to be completed prior to the treatment with porcelain laminate veneers on the mandibular anterior dentition (Figures 8 and 9). The diagnostic interim restorations were modified until the patient was satisfied with phonetics, esthetics, and function (Figure 10). The interim restorations were placed on prepared teeth and functioned for about 4 months to assess the patient's adaptation to the proposed new vertical dimension of occlusion and the new clinical crown lengths. Subsequently, the gingival tissue around the tooth

Figure 11. The mandibular FPD is designed utilizing the CAD unit. Note that an interocclusal record is used to allow for adequate design of the framework to allow for adequate space and support for the veneering porcelain.

Figure 12. An occlusal view of the maxillary zirconia-based copings on the maxillary definitive cast.

preparations had matured and was ready for making the master impressions using polyvinylsiloxane impression material (Imprint III light body & Imprint II Penta Heavy body, 3M ESPE, St. Paul, MN, USA). The double-cord technique was utilized to retract the tissues to expose preparation finish lines. First cord, a #00 (Ultrapack, Ultradent, South Jordan, UT, USA), was used, and the second cord was selected as needed among #0, 1, and 2 (Ultrapack, Ultradent). A centric relation record was made, utilizing the anterior interim restorations as an anterior reference point and silicon interocclusal record material in the posterior segments (Jet-bite, Coltène/Whaledent, Altstatten, Switzerland).

In choosing the restorative materials, zirconia-based crowns and an FPD (Lava, 3M ESPE, St. Paul, MN, USA) were selected, excluding teeth #'s 2-p-4, 15, 17, 22 to 27, and 31 (Figures 11–13). The mandibular anterior dentition was planned to be restored with feldpathic porcelain laminate veneers, and teeth #'s 2-p-4, 15, 17, and 31 were planned to be restored with metal-ceramic crowns and an FPD. Zirconia-based restorations were selected because of the patient's expectations and demands of high esthetics, metal-free oral environment, high biocompatibility, proper function, and longevity in both the anterior and posterior segments and for FPDs as initially demonstrated in clinical studies. An additional consideration was the ability to use one all-ceramic system that could be delivered using conventional luting procedures because of the patient's gingival health, which was less than perfect. Metal-ceramic restorations were selected for the second molars and for the FPD with the second molar retainer because of reports of chipping of veneering porcelain mainly on the second molars in clinical studies evaluating posterior zirconia-based FPDs. After the definitive cast was fabricated and sectioned, a definitive full-contour wax-up was completed and tried in the patient's mouth to verify esthetics (Figure 14). The dies were scanned for the fabrication of the all-ceramic copings and the FPD framework.

Lava Ceram Overlay Porcelain (3M ESPE) was selected for layering porcelain of the zirconia-based all-ceramic restorations, and IPS D-Sign (Ivoclar, Schaan, Liechtenstein) was selected for the metal-ceramic restorations, with high

Figure 13. An occlusal view of the mandibular zirconia-based copings and the FPD framework on the mandibular definitive cast.

Figure 14. A frontal view of the full-contour wax-up.

Figure 15. An occlusal view of the maxillary restorations on the definitive cast.

Figure 16. An occlusal view of the mandibular restorations on the definitive cast.

noble alloy (Aquarius XH, Ivoclar Williams, Amherst, NY, USA), and for the porcelain laminate veneers. Porcelain butt margins were used on the facial aspect of tooth #4 retainer of the metal-ceramic FPD. A silicone-based disclosing agent (Fit Checker, GC, Tokyo, Japan) was utilized for fit verification and as try-in paste prior to the definitive cementation for final esthetic evaluation and initial occlusal adjustments. The teeth were air-particle abraded with 50 μm Al_2O_3 prior to the cementation procedures. The definitive complete crowns and FPDs of the maxillary arch and the mandibular posterior segments were ready for cementation (Figures 15–18). Because of the excellent mechanical properties of zirconia, a conventional cementation technique was selected. A self-etching, self-adhesive, dual-cured composite resin cement (RelyX Unicem, 3M ESPE) was used for all crowns and FPDs. A translucent shade was used for the zirconia-based crowns and FPD.

With the aid of a silicone matrix made of the diagnostic wax-up, A2 shade light-cured direct composite resin buildups (Filtek Supreme Plus Universal Restorative, 3M ESPE) were completed for the mandibular

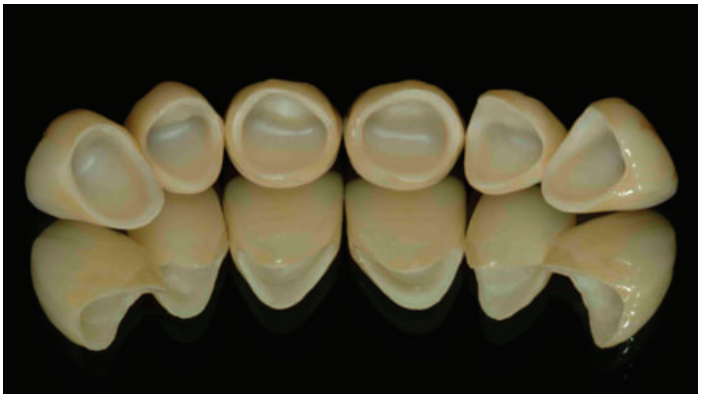

Figure 17. A view of the intaglio surface of the maxillary anterior restorations with zirconia margins.

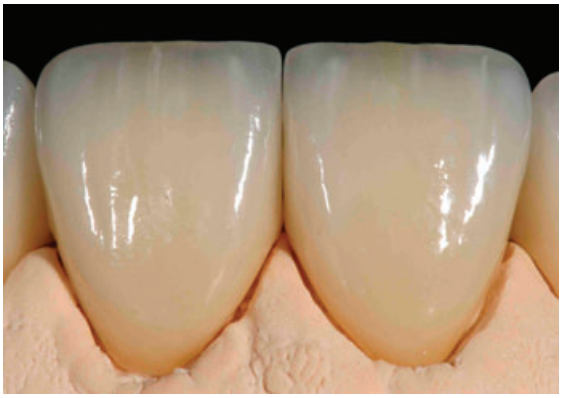

Figure 18. A close-up of the maxillary central incisors definitive restorations. Note the detailed characterizations.

Figure 19. An occlusal view of the mandibular veneer preparations.

Figure 20. A postoperative frontal view of the patient's restoration in maximum intercuspal position.

anterior teeth right after the completion of the cementation procedures for the crowns and FPDs. This allowed the clinicians to provide the patient with the desired new anterior guidance immediately on the day of cementation. The composite resin build-ups were also utilized as preparation guides for the prospective porcelain laminate veneers.

Subsequently, the mandibular incisors and canines were prepared for feldspathic porcelain laminate veneers (Figure 19) and provisionalized utilizing an indirect bis-GMA (Synfony, 3M ESPE), which was temporarily cemented with flowable composite resin after spot etching. Feldspathic porcelain laminate veneers were fabricated using the refractory die technique. IPS D-Sign porcelain (Ivoclar Vivadent, Amherst, NY, USA) was used for the veneers' fabrication. Once tried in, the porcelain laminate veneers were bonded with a translucent shade of light-cured composite resin cement (RelyX Veneer, 3M ESPE) (Figures 20–22). A heat-processed hard occlusal guard (Lucitone Clear, Dentsply, York, PA, USA) was delivered for managing clenching habit, providing the patient with a mutually protected occlusion (Figures 23–25).

DISCUSSION

Loss of tooth structure presented with this patient was attributed to the erosion caused by GERD.

Figure 21. A postoperative lateral view of the patient's left side in left laterotrusive movement.

Figure 22. A postoperative lateral view of the patient's right side in right laterotrusive movement.

Figure 23. A close-up of the patient's smile. Note the blending between the zirconia-based crowns and the feldspathic porcelain laminate veneers.

Figure 24. A postoperative view of the patient's full face smile.

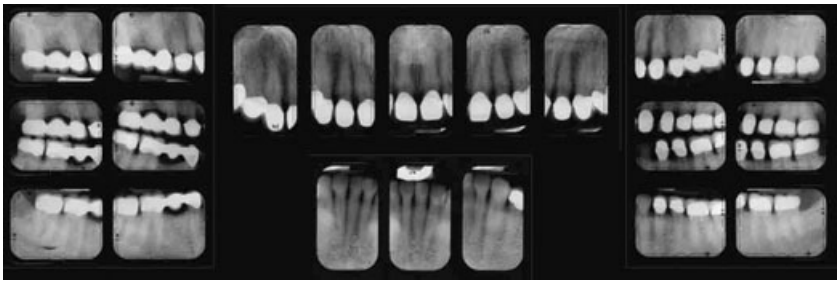

Figure 25. Postoperative full-mouth periapical radiographs.

GERD is one of the intrinsic causes of dental erosion. Patients with GERD present with delayed acid clearance. Tests such as endoscopic examination and 24-hour esophageal pH monitoring are used for accurate diagnosis. Avoiding fatty and spicy foods and elevating the head of the bed is part of the treatment being rendered. Histamine-2 blockers and proton pump inhibitors as well as medications to enhance gastric motility are prescribed to treat GERD. The physiologic type of GERD may be temporary and thus may not require medications. The treatment of dental erosion resulting from GERD must be multidisciplinary and should include the physician, gastroenterologist, restorative dentist, and dietary consultant.[27] The patient did not show any signs or symptoms of parafunctional habits or nocturnal bruxism except for self-reporting of minor clenching habits during the day. The restoration was built with mutually protected occlusion.[39]

Clinical crown lengthening procedures were performed prior to the restorative procedures in order to minimize the duration of the interim restorative phase, thus reducing the prospects of provisional cement wash out and the development of recurrent caries.[40]

The restorations differed between the maxillary anterior dentition and the mandibular anterior dentition. Restoring the maxillary anterior teeth required the use of complete crowns because of the exposure of dentin on the palatal surfaces and the prospect of increasing the vertical dimension of occlusion. However, porcelain laminate veneers were selected to restore mandibular anterior dentition, thus allowing predictable conservative restorations with relatively less invasive clinical procedures.[41] Complete crowns and FPDs were completed prior to treatment with porcelain laminate veneers. This was done because of the challenge of predictably maintaining interim veneers during the relatively extended interim restorative phase. Zirconia-based restorations were selected for the crowns and an FPD, excluding the second molar restorations where metal-ceramics restorations with porcelain occlusal surfaces were utilized because of the overriding considerations of managing higher occlusal forces[42] and the evidence of longevity.[2–4]

Zirconia was selected from a variety of different all-ceramic core materials because of its unique properties. Zirconia presents with high biocompatibility, facilitating gingival response,[43,44] less framework distortion during firing cycles,[20] and adequate marginal fit.[20] In addition, the recommended size of posterior connectors for a zirconia FPD framework is 9 mm^2, which may provide better esthetic results with an ideal embrasure form and a better periodontal response as compared to other all-ceramic core materials.[23] Moreover, most zirconia-based systems allow for shaded copings and frameworks as related to the prospective color of the restoration, while allowing some level of light transmission similar to alumina-based ceramic systems.[45] With its superior mechanical properties in terms of flexural strength and fracture toughness as compared to other all-ceramic materials, zirconia-based restorations may serve as a restorative alternative for both the anterior and posterior segments.[22–24,46,47]

The integration of different types of restorative materials in complex full-mouth rehabilitations can be a challenging task for the dental technician. It requires thorough knowledge, understanding, and creativity to match the shades and handle the different materials. Various veneering porcelains and different types of core materials exhibit different optical properties, light reflection, and light absorption. Thus, the ceramist must take several steps in order to compensate for the color discrepancies of different types of ceramic cores.

A careful selection of the veneering porcelains under the aspect of

color matching is a necessity. A comparison of the individual shade tabs of the porcelain systems is required to translate shade from one porcelain system to the other. In the presented patient, a superior harmony of the dentins and effect enamels used with metal-ceramic porcelain and the veneering porcelain for the zirconia framework facilitated an adequate translation from one system to the other in terms of shade matching.

It is imperative to follow a strict layering protocol throughout the porcelain stratification. Such layering protocol is the blueprint for the porcelain buildup process and derived from the buildup concept of suitable single-tooth restorations certainly in accordance with the patient's wishes and preferences. The shade properties of the feldspathic porcelain laminate veneers for the mandibular anterior teeth are influenced to a certain degree by the color of the underlying tooth structure. The zirconia framework is a substructure with a relatively high value and a whitish appearance in strong contrast to the metal framework, which exhibits an unfavorable gray opaque color. The gray color of the metal substructure must be compensated by certain measures. Thus, the value of the metal-ceramic restorations must be slightly elevated to compensate for the metal's lower value. With the presented patient, a material with a high value was placed underneath the dentin buildup to obtain the desired effects and color match. This measure is also recommended to achieve better harmony between the feldspathic porcelain laminate veneers and the metal-ceramic restorations. The utilization of the same veneering material is clearly indicated. The intense chroma of the prepared teeth required a slight compensation with an opaceous ceramic material.

CONCLUSIONS

A successful esthetic result using three different restorative materials was achieved in the presented full-mouth rehabilitation. The use of three different restorative materials and different techniques posed a challenge in achieving natural esthetic appearance, and in satisfying biomechanics and function as well as the patient's ultimate desires. However, although technically challenging, this approach facilitated a more conservative treatment in terms of using conservative porcelain laminate veneers in the mandibular anterior segment and achieving esthetics in both the anterior and posterior segments utilizing selectively both all-ceramics and metal-ceramics without neglecting biomechanical considerations. Interdisciplinary treatment planning, adequate treatment sequencing, excellent communication between all members of the treatment rendering team, and a good understanding of the materials in terms of their mechanical and optical properties by both clinicians and dental ceramists are key to a successful result of this type of comprehensive therapy.

DISCLOSURE AND ACKNOWLEDGMENTS

The authors thank Drs. Simone Verardi and Byung-Do Ham for the periodontal surgeries presented in this case and to Ms. Daniela Heindl for the metal framework fabrication presented in this case.

The authors do not have any financial interest in the companies whose materials are included in this article.

Some of the photos as well as some of the information in this manuscript were published in Materials Selection for Complete-Coverage All-Ceramic Restorations—Ariel J. Raigrodski in "Interdisciplinary Treatment Planning: Principles, Design, Implementation" Editor: Michael, Cohen. Permission for use was given by Quintessence Publishing, Carol Stream, IL, USA.

REFERENCES

1. Cortellini D, Canale A, Giordano A, et al. The combined use of all-ceramic and conventional metal-ceramic restorations in the rehabilitation of severe tooth wear. Quintessence Dent Technol 2005;28:205–14.

2. Walton TR. A 10-year longitudinal study of fixed prosthodontics: clinical characteristics and outcome of single-unit metal-ceramic crowns. Int J Prosthodont 1999;12:519–26.

3. Walton TR. An up to 15-year longitudinal study of 515 metal-ceramic FPDs: part 1. Outcome. Int J Prosthodont 2002;15:439–45.

4. Rosenstiel SF, Land MF, Fujimoto J. Contemporary fixed prosthodontics. 4th ed. St. Louis (MO): Mosby Elsevier; 2006. p. 258–85.

5. Raigrodski AJ. All-ceramic full-coverage restorations: concepts and guidelines for material selection. Pract Proced Aesthet Dent 2005;17:249–56.

6. Moffa JP, Lugassy AA, Ellison JA. Clinical evaluation of castable ceramic material. Three year study. J Dent Res 1988;67:118.

7. Hankinson JA, Cappetta EG. Five years' clinical experience with a leucite-reinforced porcelain crown system. Int J Periodontics Restorative Dent 1994;14:138–53.

8. Segal BS. Retrospective assessment of 546 all-ceramic anterior and posterior crowns in a general practice. J Prosthet Dent 2001;85:544–50.

9. Oden A, Andersson M, Krystek-Ondracek I, Magnusson D. Five-year clinical evaluation of Procera AllCeram crowns. J Prosthet Dent 1998;80:450–6.

10. Lehner C, Studer S, Brodbeck U, Scharer P. Short-term results of IPS-Empress full-porcelain crowns. J Prosthodont 1997;6:20–30.

11. Fradeani M, Redemagni M. An 11-year clinical evaluation of leucite-reinforced glass-ceramic crowns: a retrospective study. Quintessence Int 2002;33: 503–10.

12. Sorensen JA, Cruz M, Mito WT, et al. A clinical investigation on three-unit fixed partial dentures fabricated with a lithium disilicate glass-ceramic. Pract Periodontics Aesthet Dent 1999;11:95–106.

13. Friedman MJ. A 15-year review of porcelain veneer failure—a clinician's observations. Compend Contin Educ Dent 1998;19:625–32.

14. Dumfahrt H, Schaffer H. Porcelain laminate veneer. A retrospective evaluation after 1 to 10 years of service: part II-clinical results. Int J Prosthodont 2000;13:9–18.

15. Peumans M, De Munck J, Fieuws S, et al. A prospective ten-year clinical trial of porcelain veneers. J Adhes Dent 2004;6:65–76.

16. Fradeani M, Redemagni M, Corrado M. Porcelain laminate veneers: 6- to 12-year clinical evaluation—a retrospective study. Int J Periodontics Restorative Dent 2005;25:9–17.

17. Raigrodski AJ. Contemporary materials and technologies for all-ceramic fixed partial dentures: a review of the literature. J Prosthet Dent 2004;92:557–62.

18. Raigrodski AJ. Contemporary all-ceramic fixed partial dentures. Dent Clin North Am 2004;48:531–44.

19. Witkowski S. CAD/CAM in dental technology. Quintessence Dent Technol 2005;28:169–84.

20. Sorensen J. The lava system for CAD/CAM production of high-strength precision fixed prosthodontics. Quintessence Dent Technol 2003;26:57–67.

21. McLaren EA, Giordano RA. Zirconia-based ceramics: material properties, esthetics, and layering techniques of a new veneering porcelain, VM9. Quintessence Dent Technol 2005;26:99–111.

22. Vult von Steyern P, Carlson P, Nilner K. All-ceramic fixed partial dentures designed according to the DC-Zirkon technique. A 2-year clinical study. J Oral Rehabil 2005;32:180–7.

23. Raigrodski AJ, Chiche GJ, Potiket N, et al. The efficacy of posterior three-unit zirconium-oxide-based ceramic fixed partial dental prostheses: a prospective clinical pilot study. J Prosthet Dent 2006;96:237–44.

24. Sailer I, Feher A, Filser F, et al. Five-year clinical results of zirconia frameworks for posterior fixed partial dentures. Int J Prosthodont 2007;20(4):383–8.

25. Kois J, Phillips K. Occlusal vertical dimension: alteration concerns. Compend Contin Educ Dent 1997;18:1169–77.

26. Tjan AH, Miller GD, The JG. Some esthetic factors in a smile. J Prosthet Dent 1984;51:24–8.

27. Barron RP, Carmichael RP, Marcon MA, Sandor GK. Dental erosion in gastroesophageal reflux disease. J Can Dent Assoc 2003;69:84–9.

28. Phillips K, Morgan R. The acrylic occlusal plane guide: a tool for esthetic occlusal reconstruction. Compend Contin Educ Dent 2001;22:302–6.

29. Magne P, Belser U. Novel porcelain laminate preparation approach driven by a diagnostic mock-up. J Esthet Restor Dent 2004;16:7–17.

30. Magne P, Gallucci GO, Belser UC. Anatomic crown width/length ratios of unworn and worn maxillary teeth in white subjects. J Prosthet Dent 2003;89:453–61.

31. Vig RG, Brundo GC. The kinetics of anterior tooth display. J Prosthet Dent 1978;39:502–4.

32. Kois JC. Altering gingival levels: the restorative connection part I: biologic variables. J Esthet Dent 1994;6: 3–9.

33. Cattermole AE, Wade AB. A comparison of the scalloped and linear incisions as used in the reverse bevel technique. J Clin Periodontol 1978;5:41–9.

34. McGuire MK. Periodontal plastic surgery. Dent Clin North Am 1998;42:411–65.

35. Vacek JS, Gher ME, Assad DA, et al. The dimensions of the human dentogingival junction. Int J Periodont Rest Dent 1995;14:154–65.

36. Gargiulo AW, Wentz FM, Orban B. Dimensions and relationships of the dentogingival junction in humans. J Periodontol 1961;32:261–7.

37. Pontoriero R, Carnevale G. Surgical crown lengthening: a 12-month clinical wound healing study. J Periodontol 2001;72:841–8.

38. Yuodelis RA, Faucher R. Provisional restorations: an integrated approach to periodontics and restorative dentistry. Dent Clin North Am 1980;24: 285–303.

39. Parker MW. The significance of occlusion in restorative dentistry. Dent Clin North Am 1993;37:341–51.

40. Ramirez OI, Schuler RF, Heindl H. Treating complex cases using an interdisciplinary approach for predictable aesthetic and functional outcome. Pract Proced Aesthet Dent 2005;17:275–81.

41. Dietschi D. Bright and white: is it always right? J Esthet Restor Dent 2005;17:183–90.

42. Mansour RM, Reynik RJ. In vivo occlusal forces and moments: I. Forces measured in terminal hinge position and associated moments. J Dent Res 1975;54:114–20.

43. Warashina H, Sakano S, Kitamura S, et al. Biological reaction to alumina, zirconia, titanium and polyethylene particles implanted onto murine calvaria. Biomaterials 2003;24:3655–61.

44. Cales B, Stefani Y. Yttria-stablilized zirconia for improved orthopedic prosthesis. In: Wise DL, editor. Encyclopedic handbook of biomaterials and bioengineering. New York (NY): Marcel Dekker; 1995. pp. 415–52.

45. Edelhoff D, Sorensen J. Light transmission through all-ceramic framework and cement combinations. IADR 2002 (abstract 1779).

46. Hauptmann H, Suttor D, Frank S, Hoescheler H. Material properties of all-ceramic zirconia prostheses. J Dent Res 2000;79: 507.

47. Suttor D, Hauptmann H, Frank S, Hoescheler S. Fracture resistance of posterior all ceramic zirconia bridges. J Dent Res 2001;80: 640.