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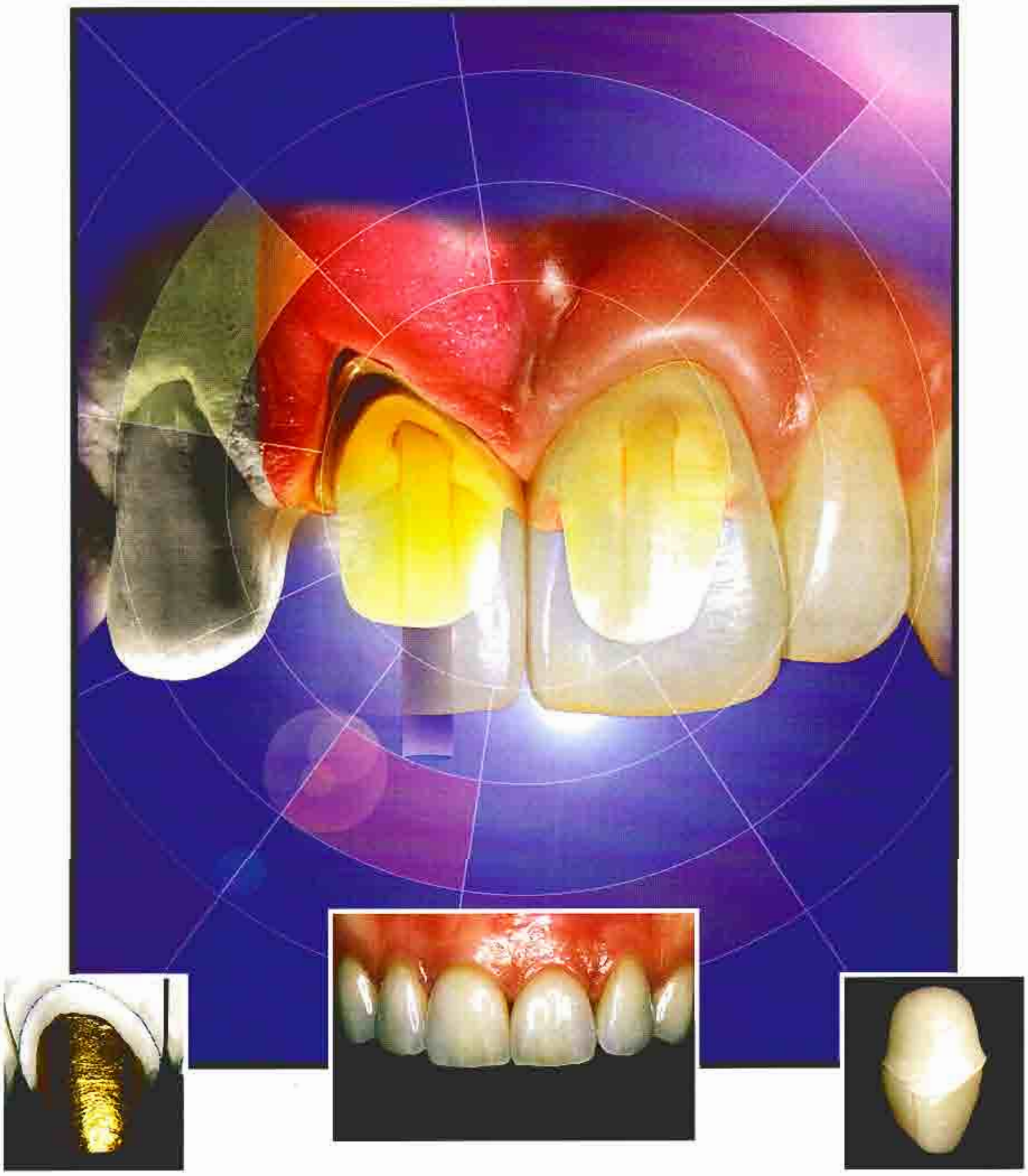

Utilization of Advanced Metal-Ceramic Technology: Clinical and Laboratory Procedures for a Lower-Fusing Porcelain

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Utilization of Advanced Metal-Ceramic Technology: Clinical and Laboratory Procedures for a Lower-Fusing Porcelain

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Metal-ceramic restorations remain the most widely accepted type of indirect restorative modality, and have been applied successfully for years. Recent advances in material science have resulted in the development of a new class of metal-ceramic materials that have been termed lower-fusing ceramics. Following proper procedures for preparation and metal framework design, these metal-ceramic porcelains achieve the aesthetics normally demonstrated by conventional all-ceramic restorations. This article provides an overview of the clinical and laboratory processes utilizing these materials and is illustrated by two case presentations.

The increased patient demand for aesthetics has resulted in the widespread application of porcelains as veneering materials.[1,2] Over the past decade the interest in dental aesthetics has increased exponentially. Consequently, patients desire full- or partial-coverage restorations that are indistinguishable in appearance from the natural dentition. Porcelain has proven to be highly biocompatible, which favors a healthy gingival response, and is frequently used in veneer restorations for teeth, metal, or high-strength ceramic copings.[3]

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Metal-ceramic restorations have been utilized in dentistry for over 35 years, since high expansion porcelains were developed by the formation of leucite within the material.[4] The crystal leucite is included within the glass matrix to raise the thermal coefficient of the parent feldspar glass to match that of casting alloys. This procedure allows porcelain to fuse with metal without thermally induced cracking. The feldspar glass has a coefficient of thermal expansion (CTE) of only 7.7×10^{-6} C°, whereas leucite has a CTE of approximately 25×10^{-6} C°. The incorporation of leucite crystals increases the CTE of the entire system. The crystals in conventional metal-ceramic systems are arranged in clusters, leaving large areas of the amorphous glass crystal free. Due to this irregular arrangement of crystals and discrepancies in the CTE values, tensile cracks are more likely to form in the glass

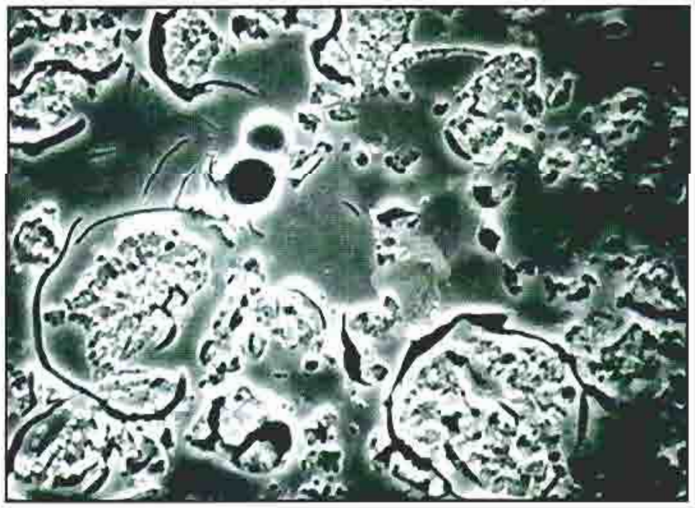

Figure 1. Scanning electron microscope (SEM) image of conventional porcelain, demonstrating the large and uneven distribution of leucite crystals with tensile cracks apparent in the glass matrix.

phase (Figure 1), and relatively low flexural strengths (60 MPa to 80 MPa) for unsupported conventional metal-ceramic porcelains have been reported.[5]

Recent advances in ceramic science have resulted in the awareness that improved physical properties can be obtained by the manipulation of the leucite crystalline phase. The objective of this research was the development of a finer and more evenly dispersed crystalline phase within the glassy matrix of the ceramic material. Several all-ceramic systems (eg, IPS Empress, Ivoclar Williams, Amherst, NY; OPC, Jeneric/Pentron, Wallingford, CT) incorporate this optimized leucite phase, which results in significantly improved flexural strengths.[6]

New Class of Metal-Ceramic Porcelains

Research and development has also resulted in the evolution of metal-ceramic materials (Omega 900, Vident, Brea, CA; Duceragold, Degussa, South Plainfield, NJ) that capitalize on this optimized leucite phase.[7] In contrast to conventional metal-ceramic porcelains, the leucite crystals in these products are more evenly dispersed and of much smaller size. The increased homogeneous nature of the crystalline phase raises the CTE of the material to achieve that of the casting alloys, and no tensile cracks occur since the absolute tensile stresses between the crystals and the glass matrix are negligible (Figure 2). The homogeneous nature of the crystalline phase significantly improves the physical properties of these ceramic materials, and

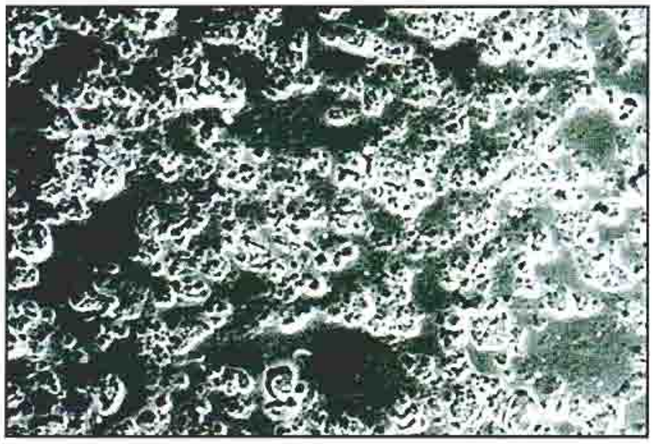

Figure 2. SEM of metal-ceramic porcelain (Omega 900, Vident, Brea, CA). The average leucite crystal size of 3 μm, with a more homogeneous distribution, is apparent. No tensile cracking is present.

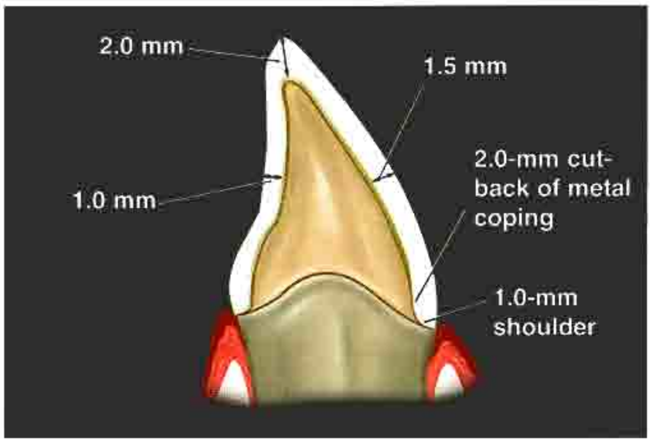

Figure 3. Diagram depicts the optimal preparation that results in maximum aesthetics for metal-ceramic restorations.

Figure 4. Metal coping demonstrates the ideal 2-mm cutback for aesthetic framework design.

flexural strengths twice that of conventional metal-ceramic porcelains have been reported.[7] These developments have not only enhanced the physical and mechanical properties of the metal-ceramic materials, but the optical properties as well.

The abrasion potential of conventional metal-ceramic porcelains has remained a concern for several years. This is presumably due to the rather large (30 μm) average particle size of the leucite crystals. One of the primary benefits of the fine crystalline structure is the decreased potential for abrasion, which can be attributed to a significantly smaller particle size of approximately 3 μm.[8] It is the size and shape of particles on the surface of the dental ceramic rather than the hardness of the material that appears to be the critical factor for abrasion of the opposing dentition.[9,10]

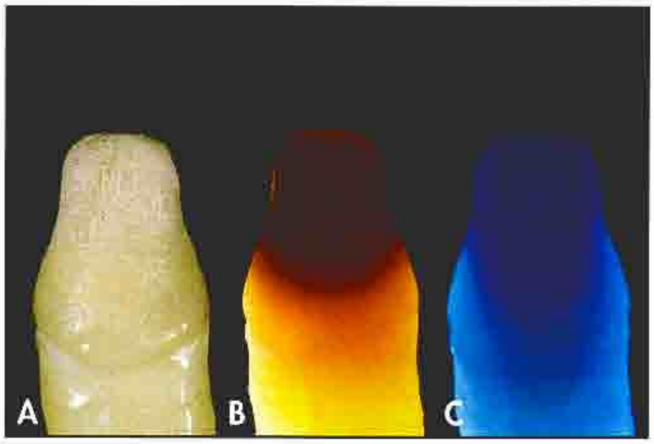

Figure 5A. Fluorescent shoulder materials are fired and exhibited under reflected light. 5B. The material is shown under transmitted light. 5C. The shoulder materials are revealed under fluorescent light.

Figure 6. The opacious dentin layer is built up and fired separately to control shrinkage.

High Gold Metal-Ceramic Alloys

Due to increased aesthetic demands, it is desirable to use metal-ceramic restorations with a high gold content, which creates a warmer appearance in the definitive restoration. Conventional metal-ceramic porcelains have a sintering temperature of approximately 950°C, with opaquing porcelains being 30 to 50 degrees higher.[11] In order to use high gold alloys with these systems, the addition of higher fusing platinum and palladium are required to raise the solidus temperature. This procedure results in the fabrication of a silvery or pale yellow alloy that produces a dark oxide upon firing.

Lower firing materials, which allow sintering on alloys that maintain a warm gold color, have also been recently developed. High gold alloys contain reduced amounts of nonprecious elements that can easily oxidize and increase the likelihood of corrosion. Corrosive products can infest the surrounding tissues, causing local toxic reactions and aesthetic compromise.[12]

Alternative Alloys

The CTE of the Duceragold porcelain is approximately 16×10^{-6} C°, which limits its use to a single alloy (Degunorm, Degussa, South Plainfield, NJ), that has a coefficient of 16.8×10^{-6} C°.[13] The CTE of Omega 900 is 13.8×10^{-6} C°, which allows it to be used on high-gold and conventional metal-ceramic alloys, as necessary.

Chemical Solubility

One concern expressed for lower firing porcelains is the potential for increased solubility in the oral environment. The test for chemical solubility requires the ceramic to be stored in a 4% acetic acid solution at 80°C for 16 hours. The limit of acceptable material loss is 100 $\mu g/cm^2$. Conventional metal-ceramic materials fall within the range of 10 $\mu g/cm^2$ and 50 $\mu g/cm^2$. Both the Omega 900 and the Duceragold materials have solubility values of less than 20 $\mu g/cm^2$,[7] which is considered a low degree of solubility compared to that of conventional metal-ceramic porcelains.

Clinical Technique

The clinical techniques used with this class of metal-ceramic materials are identical to those utilized with

Figure 7. The dentin layer is built up incrementally in the same manner as conventional porcelain materials.

conventional metal-ceramic systems. While the teeth can be prepared with traditional margin designs, aesthetic metal-ceramic restorations require a 1-mm shoulder margin.[14] A minimum of a 270° or 360° shoulder preparation on teeth in the anterior region facilitates optimal aesthetics (Figure 3). As in conventional metal-ceramics, facial reduction of 1.5 mm is necessary for these new materials. Accepted tissue management and impression making procedures should be followed. Due to its improved rheologic properties, the author prefers a new polyvinylsiloxane impression material (Imprint II, 3M, St. Paul, MN) that contains synthetic fillers.

Laboratory Technique

Standard laboratory techniques for the fabrication of metal frameworks using the lost wax technique can be utilized. Investing and casting parameters are specified by the manufacturer's directions for the indicated alloy. Alternate alloy systems such as capillary casting technology (Captek, Precious Chemicals, Longwood, FL) can be used with the Omega 900 system.[15] Due to its high CTE, only the Degunorm alloy can be used with the Duceragold system.

Framework design should allow for maximum thickness of porcelain (within the accepted limits) to minimize susceptibility to fracture. Once casting is completed, the frameworks for single anterior teeth can be safely thinned to 0.15 mm without an increased potential for ceramic fracture.[16] This framework would severely compromise the success of all-ceramic restorations.

Margin design can be a conventional metal margin (collar), or the metal framework can be cut back to establish a porcelain butt margin. By using the vertically reduced metal framework espoused by Geller and Winter, state-of-the-art metal-ceramic restorations can achieve the aesthetics demonstrated by all-ceramic restorations.[17] In this technique, the framework is reduced up the axial wall a minimum of 2 mm (Figure 4). This reduction allows for increasingly translucent porcelains to be used in the marginal area, improving the optical properties in this region. As long as the margin design is a shoulder with a 90° exit angle, this amount of cutback does not affect the strength of the cemented restoration.[18]

Figure 8. Facial view of the restoration following the firing of the translucent materials. The porcelain buildup is prepared for correction.

Figure 9. The definitive restoration is placed on the master cast to verify surface texture.

Figure 10. View of the definitive restoration following the completion of glazing and polishing.

Figure 11. Preoperative facial view of a patient who presented for restoration of a maxillary anterior 3-unit fixed partial denture.

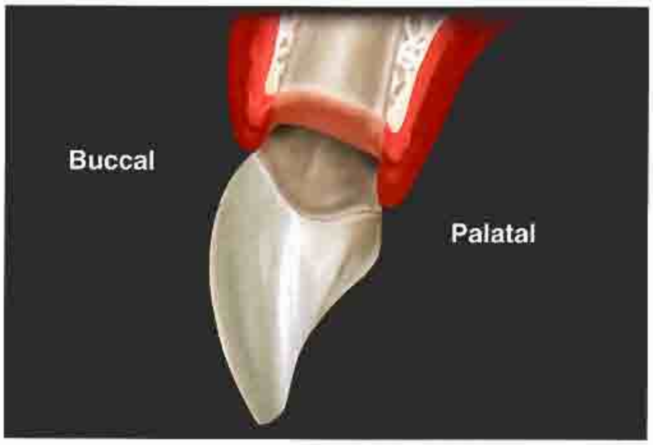

Figure 12. Diagram demonstrates pontic design for natural contour as the tooth emerges from the soft tissue.

Figure 13. Cast demonstrating necessary contouring of stone in pontic area to achieve natural emergence profile.

One of the benefits of using yellow-gold alloy systems is that they generally require a single coat of opaque porcelain only, which conserves vital space for the more translucent dentin and incisal porcelains. Following the opaquing procedure, fluorescent porcelain materials are built up and fired (Figure 5). In one variation of the use of conventional metal-ceramic porcelains, the author demonstrated a highly effective process to build up and fire the opacious dentins separately from the dentin and incisal materials (Figure 6). Due to the minute grain size of the Omega 900 porcelains (Vident, Orange, CA), this material exhibits a tendency to shrink slightly more than conventional metal-ceramic porcelain upon firing. In order to provide a degree of control over this process, the layers of the opacious dentin may be fired separately. The dentin and translucent layers can be built up in the conventional manner (Figure 7), or a more sophisticated aesthetic approach using specialized layering techniques can be utilized.[19,20] Corrections are made as necessary (Figure 8). Contouring, staining, and glazing are accomplished by the same techniques utilized for conventional metal-ceramic materials (Figures 9 and 10).

Try-In and Cementation

The crown and/or fixed partial denture restorations are tried in to verify complete seating. A fit-checking medium (Fit Checker, GC America, Chicago, IL) can be used to highlight binding areas, which are subsequently adjusted. Once complete seating is obtained, the restorations are thoroughly cleaned with a slurry of pumice or an intraoral air abrasion unit. While maintaining proper porcelain margins, the interior of the restoration is carefully air abraded with aluminum oxide particles. It is recommended to etch the porcelain margin with a hydrofluoric acid-etching gel. This procedure will increase the surface area and create micromechanical retentive areas for enhanced adhesion. Depending on the clinical requirements, either conventional or chemical-cure resin cements can be used. In the author's clinical experience, opaque cements (eg, zinc phosphate) limit the aesthetic success achieved with a vertically reduced metal framework. In the anterior regions where aesthetics are paramount, it is preferable to use cements that exhibit greater translucency.

Several resin-modified glass-ionomer cements (eg, Vitremer, 3M, St. Paul, MN) have moderate translucency and are effective in these regions. For maximum translucency, the author prefers to use self-curing resin cement (Panavia 21, J. Morita, Tustin, CA). This cement, as with all resin cements, is significantly more technique sensitive and requires the use of dentin bonding agents.

Case Presentations

Case 1

A 34-year-old female patient presented with significant aesthetic compromise on teeth #6 through #8, which had been previously restored with a maxillary 3-unit fixed partial denture (Figure 11). Due to the minimal space for connector dimensions, it was deemed contraindicated for an all-ceramic fixed partial denture. The ridge was prepared to receive an ovate pontic with significantly less curvature than is traditionally performed (Figures 12 and 13). As described previously, a 360° shoulder preparation with 1.5 mm of facial reduction was subsequently performed. Impressions were taken utilizing polyvinylsiloxane (Imprint II, 3M, St. Paul, MN), and provisional restorations were fabricated utilizing a new cold-cure methylmethacrylate material (Zeta, Vident, Brea, CA).

The 3-unit fixed partial denture was fabricated of a metal ceramic (Omega 900, Vident, Brea, CA) with a gold composite alloy framework (Captek, Precious Chemicals, Longwood, FL) and a 360° porcelain margin on both abutments. The cast was tried in and fit was verified utilizing fit-examining material (Fit Checker, GC America, Chicago, IL). The cast was cemented with a resin-reinforced glass ionomer (Vitremer, 3M, St. Paul, MN). The patient was pleased with the aesthetics restored by the metal-ceramic fixed partial denture (Figures 14 through 16).

Figure 15. Reflected postoperative facial view of the metal-ceramic porcelain restoration exhibits enhanced aesthetics that are indistinguishable from the natural dentition.

Figure 16. Postoperative facial view of the definitive metal-ceramic porcelain (Omega 900, Vident, Brea, CA) restoration. Note the improved optical match of the restoration to the adjacent teeth.

Figure 14. Postoperative view exhibits the ability of the modified ovate pontic design to impart a natural appearance to the restoration.

Case 2

A 68-year-old male patient presented with a recently restored mandibular arch with an anterior fixed partial denture and a posterior removable partial denture (Figure 17). The patient had undergone treatment to place 8 maxillary posterior implants, which were awaiting uncovering. The patient requested a nonremovable treatment option.

Figure 17. Preoperative facial view of a patient with a restored mandibular arch and an anterior fixed partial denture. A fixed metal-ceramic prosthesis was indicated for the posterior region.

Figure 18. A provisional restoration fabricated to duplicate the aesthetics and function of the definitive prosthesis.

Upon implant uncovering, a provisional restoration was fabricated from methylmethacrylate to approximate the desired definitive restoration (Figures 18 and 19). Only at this stage was it possible to determine if the implant placement was adequate for a fixed restoration. Custom abutments were milled and secured to the implants. Definitive impressions were taken utilizing polyvinylsiloxane in a custom tray.

The fabrication of large metal-ceramic prostheses has traditionally been a challenging procedure, and conventional metal-ceramic porcelains fired on long-span metal frameworks have often caused framework distortion due to sag. Consequently, the restorations would no longer fit following the porcelain firings. A low-firing porcelain material (Omega 900, Vident, Brea, CA) can be fired on higher-fusing alloys used for conventional porcelains, reducing the possibility of metal sag due to the greater difference between the sintering temperature of the porcelain and the solidus temperature of the alloy. The prosthesis, a 13-unit fixed partial denture, was fabricated on a high palladium alloy (Cerapall 6, Metalor Dental, North Attleborough, MA) using a metal-ceramic porcelain (Omega 900, Vident, Brea, CA) with gingival porcelains to duplicate the lost soft tissues (Figure 20). The prosthesis, cemented with a noneugenol cement (TempBond, Kerr/Sybron, Orange, CA) on the custom abutments, demonstrates the versatility and aesthetic potential of these new restorative materials (Figures 21 and 22).

Conclusion

Due to the relative infancy and technique sensitivity of all-ceramic restorations, metal-ceramic restorations remain the restoration of choice for full-coverage aesthetic posterior applications, particularly for fixed partial denture applications. The ultimate objective of aesthetic dentistry must also address biological and long-term functional requirements. Materials and techniques that incorporate these two inseparable issues are essential for true excellence. New metal-ceramic systems with improved optical and physical properties, combined with aesthetic designs for metal framework fabrication, can achieve

Figure 19. Facial view of the seated provisional restoration. Note the adaptation of the prosthesis to the existing hard and soft tissues.

Figure 20. The finished prosthesis was fabricated of a high-fusing palladium alloy and a metal-ceramic porcelain (Omega 900, Vident, Brea, CA) and prepared for cementation.

Figure 21. Facial view of the 13-unit fixed partial denture, which has been cemented on custom-milled abutments.

Figure 22. Magnified postoperative view of the fixed partial denture following cementation. Note the integration of the denture with the existing restorations.

the same aesthetic quality as all-ceramic restorations. The capacity to apply established clinical and laboratory techniques while utilizing these lower-fusing ceramic materials qualifies them as an acceptable choice for aesthetic metal-ceramic indications, particularly when considering the decreased potential for abrasion.

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References

1. Kelly JR, Nishimura I, Campbell SD. Ceramics in dentistry: Historical roots and current perspectives. J Prosthet Dent 1996; 75(1):18-32.
2. Anusavice KJ. Recent developments in restorative dental ceramics. J Am Dent Assoc 1993;124(2):72-84.
3. 1990 survey of dental restorations. In: Survey of Dental Services, 1990. Chicago, IL: ADA Survey Center, 1990.
4. Weinstein M, Katz S, Weinstein AB. Fused porcelain to metal teeth. US Patent 3,052,982. 1962.
5. Seghi RR, Daher T, Caputo A. Relative flexural strength of dental restorative ceramics. Dent Mater 1990;6(3):181-184.
6. Seghi RR, Sorensen JA. Relative flexural strength of six new ceramic materials. Int J Prosthodont 1995;8(3):239-246.
7. Kappert HF. Modern metal-ceramic systems with Omega 900. Zahnnarztl Mitt 1996;18:1-8.
8. Heinzman JL, Krejci I, Lutz F. Wear and marginal adaptation of glass ceramic inlays, amalgam, and enamel. J Dent Res 1990; 69:423(Abstract No. 161).
9. Reeves N, Gore K, Meters JC, Kelly JR. Enamel wear against In-Ceram and Vitadur-N with various surface finishes. J Dent Res 1993;72:187(Abstract No. 665).
10. George LA, Eichmiller FC. Wear of enamel against glass-ceramic, porcelain, and amalgam. Proceedings of biomedical and biological applications of ceramics and glass symposium. In: Rusts R, Fischman G, eds. Ceramic Transactions, Biological and Biomedical Applications of Ceramics and Glasses. Westerville, Ohio: American Ceramic Society, 1995.
11. Binns D. The chemical and physical properties of dental porcelain. In: McLean JW. Dental ceramics: Proceedings of the First International Symposium on Ceramics. Carol Stream, IL: Quintessence Publishing; 1983:41-46.
12. Chiche G, Pinault A. Esthetics of Anterior Fixed Prosthodontics. Carol Stream, IL: Quintessence Publishing; 1994:53-73.
13. Meier B, Komma O, Kempf B, et al. A new metal-ceramic system: Some aspects of materials technology. Dent Lab 1993;9:1-6.
14. Goodacre CJ, van Roekel NB, Dykema RW, Ullman RB. The collarless metal-ceramic crown. J Prosthet Dent 1977;38(6): 615-622.
15. Giordano RA. Dental ceramic restorative systems. Compend Cont Educ Dent 1996;17(8):779-794.
16. McLean JW, Sued IR. Reinforcement of aluminous dental porcelain crowns using a platinum alloy preformed coping technique. Br Dent J 1987;163:347-352.
17. Winter RR. Achieving aesthetic ceramic restorations. J Calif Dent Assoc 1990;18(9):21-24.
18. Lehner CR, Mannchen R, Scharer P. Variable reduced metal support for collarless metal-ceramic crowns: A new model for strength evaluation. Int J Prosthodont 1995;8(4):337-345.
19. Sieber C. Variations in light and conduction and light intensity. QDT 1994;17:95-101.
20. Aoshima H. Aesthetic all-ceramic restorations: The internal live stain technique. Pract Periodont Aesthet Dent 1997;9(8):861-868.