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Restorative Possibilities Using Zirconia Ceramics for Single Crowns

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Two clinical cases are presented to explore technical differences and discusses the advantages and disadvantages of using veneered or monolithic zirconia to manufacture posterior single crowns. The first case describes the clinical steps in manufacturing a monolithic crown on a mandibular left second premolar using high translucency zirconia. It shows the use of a conservative tooth preparation based on the superior mechanical properties that this material presents as well as the final optical characteristics achieved by shading and staining. In the second case, a conventional bilayer restorative treatment was made using zirconia framework followed by veneering with feldspar ceramic on a mandibular left first molar. Recent literature indicates that each of these restorative alternatives presents specific advantages and disadvantages. Factors such as mechanical performance, fracture, esthetic characteristics, clinical success, complication rates, adhesion and antagonist wear performance are discussed comparing the two restorative assemblies. The data highlight that monolithic crowns prevent a major problem reported on bilayer restorations: the chipping of veneering ceramic. Monolithic crowns also allow minimally invasive tooth preparations, thus increasing tooth remnant preservation. However, data that support esthetic performance similarity between monolithic and bilayer assemblies are lacking, thus the predictability of use is restricted for the posterior region, as cases demanding high esthetic appeal continue to fundamentally use bilayer restorations. Failures were not found, and patient satisfaction was reported in both techniques after the 12-month follow up.

Key Words: zirconia, veneered crown, monolithic crown.

Introduction

Many all-ceramic materials have been introduced in recent years. One of these is the yttria-stabilized polycrystalline tetragonal zirconia, which became popular in dentistry for its adequate mechanical properties and biocompatibility (1). Zirconia is mainly used as framework for all-ceramic crowns and fixed-partial dental prostheses, usually requiring feldspar ceramic veneering to obtain proper esthetics as it presents high opacity (2).

A systematic review depicted 5-year survival rates of 93.8% for veneered zirconia crowns, where one major failure type reported was veneer chipping (cumulative 5-year complication rate of 3.1%) (3). The risk for chipping is generally attributed to zirconia's inert nature, which impairs limiting chemical interaction with the veneering layer, as well as to internal stresses generated during production, caused by the discrepancy in the thermal expansion coefficient between the zirconia core and veneering ceramic and to technical procedures such as the cooling rate adopted after sintering (4).

Some technical strategies have been developed to reduce the incidence of veneer chipping. Among these is the change in restorative assembly promoted by monolithic restorations. Monolithic restoration prevents veneer chipping (by eliminating the veneer layer) and decreases the removal of sound tooth structures because a more conservative tooth preparation can be performed (1).

To achieve esthetically acceptable monolithic restorations with zirconia, some changes in translucency, color, and the white-opaque appearance of the zirconia were necessary (5). Therefore, changes in the material's composition were realized, including the introduction of smaller crystals, increased yttria content, and cubic crystal structure provided by higher sintering temperatures. This resulted in the material now known as "high translucency zirconia" (6).

Monolithic zirconia restorations were introduced recently, and their manufacturing technique deserves attention. Therefore, this article introduces two clinical cases illustrating the technical differences and discusses the advantages and disadvantages of using veneered or monolithic zirconia for posterior single crowns. The

12-month follow-up is also presented.

Case Report

Two patients with partial loss of coronal dental structure in their posterior teeth were referred for treatment at the Dental School of the Meridional Faculty (IMED, Passo Fundo, Brazil). Clinical and radiographic exams confirmed that single crowns were indicated in both cases. Different materials were used in each case because of their different characteristics. A monolithic zirconia crown was performed on the first patient, because the remaining tooth structure needed to be prepared, and the pattern of destruction suggested preserving as much dental structure as possible. A bilayer crown with zirconia framework veneered with feldspathic ceramic was built for the second patient because the tooth had already been prepared using a more invasive technique.

Case 1 - Monolithic Zirconia Crown

A 30-year-old male patient was referred due to a dental fracture of the mandibular left second premolar (Fig. 1A). In the clinical and radiographic exam, the tooth presented pulp vitality and a satisfactory structure for receiving a monolithic zirconia crown without needing endodontic or post-treatment. After removing the unsatisfactory restoration (Fig. 1B), the core was restored using self-etching adhesive (Clearfil SE Bond; Kuraray Noritake Dental Inc., Suita, Osaka, Japan) and composite resin (Filtek Z350; 3M ESPE, St. Paul, MN, USA). The tooth was prepared using diamond burs (#3216; #3215; #2200; #3216F; #3215F; KG Sorensen, Cotia, SP, Brazil) and finished with multi-blade carbide burs (H283.314.012 and H283K.314.016; Komet, Gebr. Brasseler GmbH & Co. KG, Lemgo, Deutschland). A minimum space of 0.8 mm for axial walls and 1.0 mm for the interocclusal space was considered. A shoulder finish line was performed (Fig. 1C).

The impression was taken using the double-cord technique (#000 and #0 Ultrapak; Ultradent Products Inc., South Jordan, UT, USA) and polyvinylsiloxane (Express XT; 3M ESPE). An impression was taken of the opposing arch using irreversible hydrocolloid (Hydrogum 5; Zhermack SpA, Badia Polesine, RO, Italy). Photographic images of the shade matching were taken using a VITA classical shade guide as reference. The interim restoration was made using a prefabricated acrylic tooth (New Ace; Yamahachi, Japan) and self-cured acrylic resin (AlikeTM temporary crown and bridge resin; GC Corp., Tokyo, Japan). Special care was given to finishing and polishing the interim crown using rubbers and felt (Fig. 1D).

The impressions were poured with type IV dental stone (Fujirock; GC Corp.) (Fig. 1E). All casts were sent to the dental laboratory to fabricate a monolithic zirconia crown using a CAD-CAM system (Zirkonzahn, Gais, Italy). The casts were scanned in the dental laboratory, using a laboratorial optical scanner (S600 Arti; Zirkonzahn). The restoration was designed using CAD-CAM software (Zirkonzahn.Modellier; Zirkonzahn) with the interim restoration anatomy obtained from a previously scanned cast model. The minimum material thickness was 0.8 mm in the cervical region and 1.0 mm on the occlusal surface (Figs. 1F and G). After finalizing the restoration design, the monolithic crown was milled (M1; Zirkonzahn). The material used was a high translucency zirconia (Prettau Anterior; Zirkonzahn). The restoration was milled with an 20% higher dimension than the final desired restoration to compensate contraction during final sintering (Figs. 1H and I). The restoration was shaded and sintered (Figs. 1J and K) in a suitable furnace (Zirkonofen 600/V2; Zirkonzahn) and stained and glazed posteriorly (Fig. 1L) in a ceramic furnace (EP 5000; Ivoclar Vivadent, Schaan, Liechtenstein) following the manufacturer's instructions during all processing steps.

During the final appointment, the crown's shape and marginal adaptation were evaluated on the master cast. The crown was proved on the tooth preparation and some proximal and occlusal adjustments were made using finishing burs (720F; KG Sorensen), followed by finishing and polishing rubbers (Eve Diapol; Ernst Vetter GmbH, Pforzheim, Germany) using a low-speed hand piece.

The crown's internal surface was sandblasted with aluminum oxide particles (50 µm; BioArt, São Carlos, SP, Brazil) for 20 s at 2.8 bar pressure, a 90º angle, and 10 mm distance from the surface, cleaned with isopropyl alcohol and air-dried, and an MDP-based zirconia primer (Yzap; Yller, Pelotas, RS, Brazil) was applied per the manufacturer's instructions. The tooth preparation was only cleaned with isopropyl alcohol and air-dried. A gingival displacement cord (#000 Ultrapak; Ultradent Products Inc.) was inserted in the gingival sulcus, and the crown was luted using a self-adhesive dual-cured luting agent (RelyX U200; 3M ESPE). After 90 seconds, the material excess was removed and light-cured using a light emitting diode (LED) unit with a 1200 mW/cm^2 irradiance (Radii-Cal; SDI, Bayswater, Victoria, Australia). The final appearance and the following outcomes were assessed through clinical examination: ceramic chipping, ceramic fracture, loss of retention and framework fracture immediately after cementation (Fig. 1M) and after the 12-month follow-up (Figs. 1N and O).

Case 2 – Veneered Zirconia Crown

A 31-year-old male patient was referred for a fractured acrylic interim crown on the mandibular left first molar. The tooth had been already rebuilt with a glass fiber post in the canal of the distal root and a core built up with composite resin (Fig. 2A). A bilayer crown was planned as restoration using a zirconia framework veneered with feldspar ceramic. The core was finished using diamond bur (#3216F; KG Sorensen) and multi-blade carbide burs. A chamfered finish line was performed. A minimum space of 1.5 mm to the crown material was considered for the axial walls and interocclusal space. The tooth preparation impression, antagonist impression, shade matching, and interim restoration impression were performed as described for the first patient.

The impressions were poured (Figs. 2B and C) and sent to the dental laboratory to fabricate a veneered zirconia crown. The casts were scanned using a laboratorial optical scanner (S600 Arti; Zirkonzahn), and the framework was designed using CAD-CAM software (Zirkonzahn. Modellier; Zirkonzahn) with the interim restorative anatomy from a cast model previously scanned as a

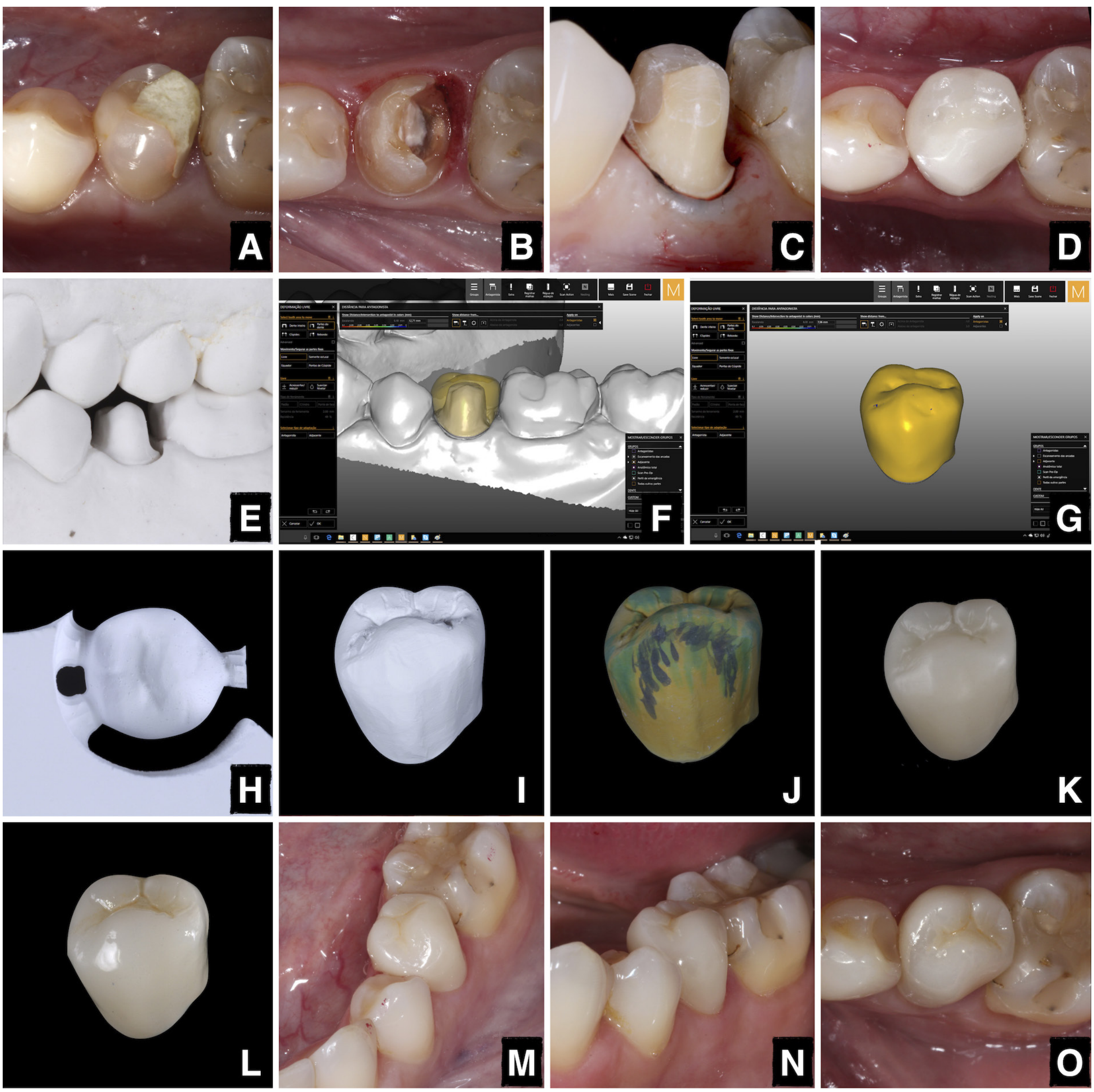

Figure 1. (A): Pretreatment condition. (B): Tooth remnant after removing the provisional restoration (maintenance of glass ionomer restoration on pulp wall). (C): Illustration of the final core prepared for crown manufacturing. (D): Illustration of interim restoration. (E): Casts occluded in maximum intercuspation. (F and G): Restoration design using CAD-CAM software based on the anatomy achieved with the interim restoration. Illustration of the final restoration design, depicting the set thickness (minimum material thickness considered was 0.8 mm in the cervical region and 1.0 mm on the occlusal surface). (H): Monolithic crown milled with high translucency zirconia (Prettau Anterior; Zirkonzahn). (I): Restoration milled with an 20% higher dimension than that of the final desired dimension to compensate contraction during final sintering. (J): Pre-sintering shading technique. (K): Sintered restoration. (L): View after staining and glazing techniques. (M): Final appearance after cementation. (N and O): View after 12 months of follow-up.

reference. A minimal thickness of 0.5 mm was considered (Figs. 2D and E). After finalizing the restorative design, the framework was milled (M1; Zirkonzahn). The zirconia used is indicated for manufacturing bilayer restoration frameworks (ICE Zirkon Translucent; Zirkonzahn). The frameworks were milled with 20% higher dimension than the final desired framework to compensate for contraction during final sintering (Fig. 2F and G). Posteriorly, the restoration was shaded and sintered as indicated by the manufacturer (Zirkonofen 600/V2, Zirkonzahn) (Fig. 2H and I). Afterwards, a compatible feldspar ceramic was applied to the framework per the manufacturer's recommendations (Fig. 2K). The adjustment and luting procedures for the veneered crown were performed as described for the monolithic crown. The final appearance and the following outcomes were assessed through clinical examination: ceramic chipping, ceramic fracture, loss of retention and framework fracture immediately after cementation (Fig. 2L) and after the 12-month follow-up (Fig. 2M and N).

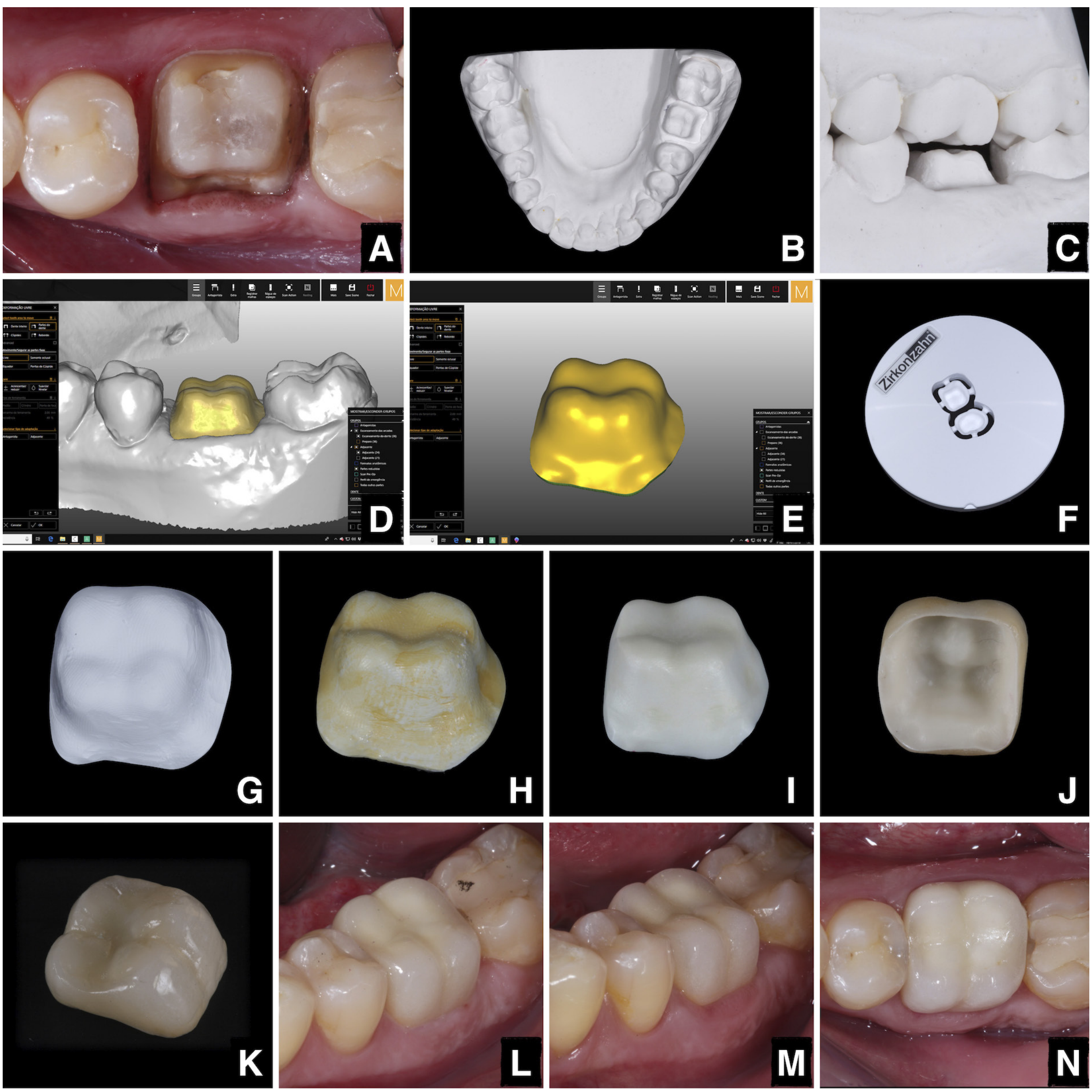

Figure 2. (A): Initial condition. (B): Stone cast with prepared tooth. (C): Casts occluded in maximum intercuspation. (D and E): Illustration of the framework design using CAD-CAM software, with a minimum thickness of 0.5 mm. (F): Framework milled using zirconia indicated for manufacturing restoration frameworks (ICE Zirkon Translucent; Zirkonzahn). (G): Framework milled with a 20% higher dimension than the final desired dimension to compensate contraction during final sintering. (H): Pre-sintering shading technique. (I): Sintered restoration. (J and K): View after veneer feldspar application, firing and posterior glazing. (L): Final appearance after cementation. (M and N): View after 12 months of follow-up

Discussion

All-ceramic crowns are considered an established treatment in clinical practice, and their main advantages are superior biocompatibility and esthetics compared with other materials. A recent systematic review demonstrated that the survival of all-ceramic crowns is related to the type of ceramic used (3). All-ceramic crowns made of leucite, lithium-disilicate reinforced glass ceramic, glass-infiltrated alumina, densely sintered alumina or zirconia present higher 5-year survival rates than feldspathic/silica-based ceramic crowns in posterior regions (3).

Complications such as framework fracture, ceramic fracture, ceramic chipping, marginal discoloration, loss of retention (debonding), and poor esthetics are technical problems reported in clinical studies associated with single crowns (3). Ceramic chipping is a common problem in bilayer single crowns, independent of the ceramic used; however, some studies demonstrated considerable incidence of veneer chipping in veneered zirconia crowns (7,8). Zirconia optical characteristics were improved by developing ceramic blocks with different color shades, allowing manufacturing restorations using only this material, thus eliminating the veneering ceramic (7). High translucency zirconia was recently introduced, including fully stabilized cubic and tetragonal zirconia. The increased translucency has been achieved by materials with a high percentage of isotropic cubic phase with a smaller grain size (9).

In addition, using monolithic restorations enables tooth reminiscent preservation in accordance with the minimally invasive restorative concept. Considering an unavoidable restorative cycle that will result in more invasive restorations with time, choosing the most conservative available option will grant a longer final lifetime for the tooth (10). Thus, clinicians must always consider and evaluate the specific situation presented to the clinic and choose the best restorative option (less invasive) that will lead to the best lifetime predictability possible for the patient. Thus, monolithic restorations should be considered as a potential option.

The first case report presented a possibility of an all-ceramic crown, without veneering ceramic, made with a monolithic zirconia marketed as Prettau Anterior (Zirkonzahn GmbH). The manufacturer indicates this material for inlays, onlays, veneers, fixed partial prostheses (maximum 3-unit), and single crowns and describes an alleged flexural strength higher than 670 MPa (11), which, in accordance with ISO 6872:2015, classifies this material as a Class V rank and corroborates the manufacturer's indications for use (12). In the second case report, a zirconia indicated for framework with ceramic veneering was used, marketed as ICE Zirkon Translucent (Zirkonzahn GmbH). For this material, the manufacturer reports a flexural strength higher than 1.400 MPa (13), which, in accordance with ISO 6872:2015, classifies this material as a Class VI rank and corroborates the manufacturer's indications for use as even substructures/frameworks for prostheses involving four or more units (12). In vitro literature corroborates both manufacturers' allegations of flexural strength measurements (14-15).

Focusing on optimizing the monolithic restorations' optical performance, different methodological approaches have been considered to enhance zirconia's translucency, including increasing final sintering temperature, yttria content and zirconia grain size, decreasing the number of grain boundaries, and reducing the alumina content (6,10,15). These modifications present significantly decreased mechanical properties (e.g., strength and toughness) as a disadvantage of the material (6), which inherently impact the material's indication as only being for single crowns, and, at most, three-unit fixed partial dentures are indicated.

In manufacturer reports, Prettau Anterior (Zirkonzahn) alleges similar translucency to that of lithium disilicate-based ceramics (11). However, studies have also shown lower translucency than the lithium disilicate when the same layer thickness is adopted (IPS e.max CAD; Ivoclar Vivadent) (6). The main difference in applying these two materials is that monolithic crowns of lithium disilicate require at least 1.5 to 2.0 mm occlusal thickness (16), whereas, monolithic zirconia may be successfully used for monolithic restorations with lower occlusal thickness (0.8 mm), thus promoting less tooth reduction during preparation (6,17). Therefore, in accordance with the minimally invasive concept, monolithic restorations seem to be the least invasive approach currently available for full anatomic crowns.

The main difficulty involving rehabilitating esthetically and functionally compromised teeth is to mimic all characteristics observed with natural dentition. A conventional fixed dental prosthesis that uses porcelain as a veneering material presents a greats advantage in this regard. Additionally, the use of a whitish framework (characteristics typically observed in zirconia-based frameworks) improves the masking ability of any darkened substrate present and provides a skilled technician with an acceptable scenario for using different feldspar ceramic shades combined with the recent advances in processing technologies for generating almost unrecognizable restorations (18). Therefore, the conventional bilayer restorative assembly presents a great advantage, although monolithic materials show promising results (6). This material is adequate for restorations made in the posterior region where the esthetic demand is lower, while more studies are needed for the anterior region to corroborates a generalized use.

Manufacturers indicate that another possibility for enhancing the optical properties of monolithic restorations is that when preparing a monolithic restoration, the potential aesthetic areas involved in the restoring tooth (facial portion) may be defined, and the restoration can be reduced in such areas after performing a porcelain veneering increment in the area (19). As those areas are uninvolved in functional movements, they should not impair the longevity of such restorations and should not lead to a higher risk of chipping of such areas. However, scarce data are available to corroborate such statements, and this assembly was not considered in the present report.

In addition to the factors discussed above, another important complication reported in using zirconia-based restorations is the loss of retention. Sailer et al. (3) reported a 4.7% 5-year complication rate. In vitro studies that evaluate approaches for promoting enhanced bond strength to zirconia substrate have shown that using an air-abrading strategy is mandatory with aluminum oxide particles or silica-coated aluminum oxide particles, followed by primers that facilitate both micromechanical interlocking of resin cement and chemical interactions with the involved substrates (20). Clinicians should be cautious in choosing the least aggressive protocol available for this, as a hazardous protocol may impair mechanical performance and predispose ceramic fracture (21). These were the reasons that we pretreated both zirconia restorations presented here by air-abrading with aluminum oxide, then applied an MDP-based primer and resin cement for luting.

Regarding the antagonist wear promoted by veneered and monolithic restorations, a systematic review of in vitro studies revealed that polished zirconia showed a favorable wear behavior opposing natural teeth (22). Other recent clinical studies showed that the wear of opposed enamel caused by monolithic zirconia crowns was approximately twice that of natural teeth after 2 years (23). However, other dental ceramics (lithium disilicate and feldspar ceramics) have greater mean values of enamel wear than do monolithic zirconia crowns (2,23,24).

Therefore, all acquired scientific knowledge on fracture mechanics in bilayer zirconia in clinics calls attention to the demand for following strict processing guidelines and matching material characteristics to assure enhanced performance of such restorations, thus reducing the risk of chipping (25). Regarding monolithic zirconia, improvements in the optical characteristics and mechanical properties of the available materials may yield promising clinical outcomes. In the current case reports, failures were not found, and the patient satisfaction were reported in both cases after the 1-year follow-up. However, more clinical randomized trials comparing the performance of monolithic restorations and conventional bilayer zirconia restorations are required to fully comprehend this thematic (wherein, a randomized clinical study comparing these treatment options in single crowns is being conducted, in which the case reports will be included). Monolithic crowns using high translucency zirconia appears to be an adequate restorative alternative for manufacturing single crowns in the posterior region, thus increasing tooth remnant preservation. However, the predictability of esthetic performance mimicking the characteristics of natural dentition remains higher using veneered bilayer assembly. After the 12-month follow-up, failures were not found, and patient satisfaction was reported using both techniques.

Resumo

Dois casos clínicos são apresentados para explorar as diferenças técnicas e discutir as vantagens e desvantagens de se utilizar zircônia com cerâmica estratificada ou monolítica para confeccionar coroas unitárias. O primeiro caso descreve os passos clínicos na confecção de uma coroa monolítica no segundo pré-molar esquerdo utilizando uma zircônia altamente translúcida. Neste caso é apresentado a confecção de um preparo conservador devido as propriedades mecânicas deste material bem como suas características ópticas encontradas com a pigmentação e maquiagem. No segundo caso, um tratamento restaurador convencional de estratificação foi realizado utilizando uma infraestrutura de zircônia seguido pelo recobrimento com cerâmica feldspática em um primeiro molar inferior esquerdo. A literatura recente indica que cada uma dessas alternativas restauradoras apresenta vantagens e desvantagens específicas. Fatores como desempenho mecânico, fratura, características estéticas, sucesso clínico, taxas de complicações, adesão e desgaste do antagonista são discutidos comparando as duas possibilidades restauradoras. Os achados da literatura destacam que coroas monolíticas impedem um grande problema relatado em restaurações estratificadas: o lascamento da cerâmica de recobrimento. Coroas monolíticas também permitem preparos dentários minimamente invasivos, aumentando assim a preservação do remanescente dentário. No entanto, dados suportando um desempenho estético similar entre coroas monolíticas e estratificadas são inexistentes, assim a previsibilidade de uso é restrita para a região posterior, pois casos exigindo alta demanda estética restaurações estratificadas continuam ser principalmente utilizadas. Falhas não foram encontradas e a satisfação do paciente foi relatada em ambas as técnicas após o acompanhamento de 12 meses.

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