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Review Article

Zirconia-Based Restorations: Literature Review

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ABSTRACT

Objective: To review related literature covering different aspects of zirconia-based restoration.

Materials and Methods: Electronic search was performed in PubMed, Scopus and Ovid to identify scientific studies that investigated zirconia-based Restorations. The search included all studies published in English language in peer-reviewed journals in the period from 1983 to June, 2015. The search followed a specific strategy which included combination of the following keywords: zirconia, all-ceramic, glass ceramic, fracture resistance, laboratory simulation, aging, crown, FDPs, FPDs, CAD/CAM, fixed partial denture, fixed dental prosthesis, and bridge.

Results: Search results with abstracts were transferred into Endnote reference system and duplicates were deleted. Articles were then reviewed at three levels (title, abstract, and full text) to further refine the articles.

Conclusions: Yttria stabilized tetragonal zirconia cores veneered with porcelain present a potentially efficient alternative for metal and metal ceramic restorations especially in the posterior region, due to the superior mechanical properties of the zirconia ceramics and the superior esthetic properties of the veneering glass ceramics. The veneering layer is usually applied using the layering technique. Other techniques for the application of the veneering layer include: the overpressing technique and the digital technique. The veneering technique is one of the main factors that can influence the fracture resistance as well as the shade reproducibility of the zirconia-based restoration.

Keywords: Prosthesis, CAD/CAM, Porcelain, Fracture Resistance, Ceramic, Crown.

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INTRODUCTION

Zirconium is one of the transition metals which carries the atomic number 40 and is represented by the Zr symbol. Zirconium has been known as Zircon which probably originated from the Persian word zargun which means golden in color.[1] Zirconium exists in two forms: the crystalline form (soft, grayish-white metal), and the amorphous form (bluish-black powder). Pure Zirconium oxide (Zirconia) was first prepared in 1914 by Hertzfield.[2] Pure Zirconia is a polymorphic material that present in three phases: the cubic phase, the tetragonal phase, and the monoclinic phase. The cubic phase is found at the melting temperature (2680°C), the tetragonal phase is found at temperatures of 2370°C and below, and the monoclinic phase is found at temperatures of 1170°C and below. The transition from the tetragonal to the monoclinic phase involves a 3-5% volumetric expansion, subsequently causing detrimental cracks, which limit the industrial use of pure zirconia.[3]

The addition of metallic oxides such as CaO, MgO, Y_2O_3, and CeO_2 to pure zirconia has been found to retain zirconia in the tetragonal phase in a metastable form at room temperatures; such metallic oxides are known as stabilizers.[4,5] Yttria (Y_2O_3) is the most widely used and studied stabilizer,[3] hence Yttria stabilized tetragonal zirconia (YSTZ) is the only type of stabilized zirconia which reached the status of having a dedicated ISO standard for surgical application[6] and is the main focus of this review. YSTZ was first used as a biomaterial in 1969, when Helmer and Driskell,[7] introduced it as a biomedical implant. Later on, YSTZ was used mainly for total hip prosthesis.[8] It was not before the early 1990s that YSTZ was first introduced in dentistry to be used for endodontic posts,[9] crown and bridge frameworks,[10] and more recently for implant abutments.[11] YSTZ has been shown to possess chemical and dimensional stability,[12] biocompatibility,[13,14] superior physical properties,[15-17] and exceptionally high tolerance to cyclical stresses[18] (Table 1).

Table 1: Physical Properties of YSTZ

Property	Magnitude
Flexural Strength	1200 MPa
Compression Strength	2000 MPa
Fracture Toughness	5-10 MPa*m$^{1/2}$

All ceramic restorations have been used for decades as a replacement for metal and metal ceramic restorations due to the increasing aesthetic demands.[19] YSTZ cores veneered with porcelain present an efficient alternative for metal and metal ceramic restorations especially in the posterior region, due to the superior mechanical properties of the zirconia ceramics and the superior aesthetic properties of the veneering glass ceramics.[19,20] Zirconia ceramics are manufactured with either CAM or CAD/CAM technologies.[21] In order to achieve superior aesthetic results, veneering of the zirconia ceramic with glass ceramic is essential.[21,22]

The veneering ceramic is considered the weakest part in zirconia-based restorations, and it contributes to most clinical failures.[23] These failures have been found to be more of a cohesive nature which indicates a weakness in the veneering layer itself rather than in the bond between the zirconia core and the veneering layer.[24] This cohesive failure presents as chipping of the veneering layer and is the primary concern in zirconia-based restorations.[20,23,25,26] Many factors can contribute to the chipping of the veneering layer including: the support and thickness of the veneering layer,[23,27-29] the design of the zirconia core,[23,27-29] sintering protocol,[30-32] surface treatment of the zirconia core,[33-36] the morphology of the preparation finish line,[37] the adhesive forces between the core and veneering layer,[38,39] the mismatch of the coefficients of thermal expansion between the core and the veneering layer,[30,40] the type of the veneering layer ceramic,[41] and the veneering technique.[21,41-47]

Natural shade reproducibility is a challenge facing any final restoration. This is especially true with zirconia-based restorations as the white, opaque color of zirconia is the main reason behind the application of the veneering layer. Indeed, the white color of the zirconia core might still influence the final shade of the restoration so the application of liners has been proposed.[48,49] Furthermore, the thickness, the shade, the opacity, and the application technique of the veneering layer are all factors that can affect the shade reproducibility of the zirconia-based restoration.[50-52]

The veneering layer is usually applied using the layering veneering technique which have disadvantages such as: the lack of shade uniformity, the formation of microvoids, and the dependence on the skill of the dental technician.[50,53] Using the overpressing technique or the digital technique for the application of the veneering layer have been found to help overcoming the disadvantages of the layering veneering technique.[53,54]

In any material, every pore and imperfection is a potential starting point for cracks. For glass ceramics, the weibull modulus is significantly increased when the material is used in the form of industrial prefabricated blocks and a computer aided subtractive technique is applied.[53] Compared with the layering and the overpressing veneering techniques, the digital veneering technique has shown superior results in terms of fracture toughness.[21,41,55] Moreover, Kim et al.[50] has found that the shade reproducibility of the digital veneering technique is within the clinically acceptable aesthetic standards.

To the best of our knowledge, insufficient research has been conducted about the effect of veneering technique on the fracture resistance and the shade reproducibility of zirconia-based restorations. The aim of this study was to review zirconia-based restorations in terms of material, veneering techniques, fracture resistance and shade reproducibility.

RESEARCH METHODOLOGY

Electronic search was performed in PubMed, Scopus and Ovid to identify in vitro studies that investigated zirconia-based Restorations. The search was carried out by the first two authors of this manuscript (A-S & A-W) and included all studies published in English language in peer-reviewed journals in the period from 1983 to June, 2015. The search followed a specific strategy which included combination of the following keywords: zirconia, all-ceramic, glass ceramic, fracture resistance, laboratory simulation, aging, crown, FDPs, FPDs, CAD/CAM, fixed partial denture, fixed dental prosthesis, and bridge. Search results with abstracts were transferred into Endnote reference system and duplicates were deleted. Articles were then reviewed at three levels (title, abstract, and full text) to further refine the articles.

TRANSFORMATION TOUGHENING

A valuable property of YSTZ is the transformation toughening, in which the tetragonal crystals transform to the monoclinic phase when subjected to cracks caused by stressful surface stimuli such as diamond surface grinding,[56] sandblasting,[56] or thermal aging.[57] This transformation can lead to localized compressive stresses around the crack tip, retarding the crack propagation increasing the strength of the zirconia structure.[58] However, if the surface stimulus was severe such as severe grinding causing deep flaws, it will not be counteracted by the compressive stresses of the transformation toughening and will reduce the strength of the zirconia structure.[59]

LOW THERMAL DEGRADATION

A major issue concerning zirconia ceramics is the susceptibility to low thermal degradation (LTD),[3,60,61] in which zirconia structure tends to transform from the tetragonal to the monoclinic phase (T→M) at fairly low temperatures (65°-400°C) in the presence of water leading to relative expansion accompanied by micro and macro cracking which ultimately leads to surface roughening and deteriorates the mechanical properties.[60]

Several theories have been proposed to explain the LTD phenomena including: Sato et al.[62] theory which explains LTD by the formation of Y-OH bonds when water reacts with Zr-O bonds at the crack tip leading to strain release and the acceleration of (T→M) transformation, Yoshimura et al.[63] theory which is similar to Sato et al. theory except that Yoshimura et al. suggested a four-step degradation process in which the Zr-OH bonds form stress sites and as more OH groups diffuse through the surface stress sites turn into nucleation sites for subsequent (T-M) transformation, Lange et al.[64] theory which explains LTD by the reaction between water and Y_2O_3 forming crystallites of $Y(OH)_3$ leading to the depletion of Yttrium from the surrounding zirconia grains which are free to undergo transformation (T→M), and

Chevalier et al.[65] theory in which the O_2 originating from the dissociation of water is responsible for destabilizing the zirconia grains and hence LTD.

Regardless of the mechanism, LTD is most pronounced between 200° and 300°C,[3] the (T→M) transformation starts at the surface and proceeds into the bulk, the (T→M) is slowed down by decreasing zirconia grain size and increasing the stabilizer content, and LTD results in a decrease in strength, toughness, and density.[66]

ZIRCONIA MANUFACTURING TECHNIQUES

A computer aided subtractive technology is necessary in order to produce zirconia-based restorations. Two techniques have been introduced for this purpose: the CAM only technique in which the restoration is designed by conventional wax-up procedures and the CAD/CAM technique where the restoration is designed using a computer graphics software.

In comparison between the two techniques, studies have found that the CAD/CAM technology exhibited smaller marginal discrepancies,[67-69] was less complex, and produced more consistent restorations.[68]

Dental CAD/CAM technology has been used to produce YPSTZ restorations since the 1990s.[10] YSTZ can be manufactured using the CAD/CAM technology in two forms: In the first form, or the partially sintered form, the zirconia block is machined in a partially sintered state (soft machining) and then fully sintered after machining.[70] In the second form, the zirconia block is machined in a fully sintered state (hard machining).[71]

Hard machining has been reported to have better marginal fit than soft machining,[71] because no sintering process is needed after milling and therefore no shrinkage is expected. However, hard machining has been found to have detrimental effects on the mechanical properties of zirconia.[59] As a result, soft machining has been recommended as it shortens the milling time and reduces the wear on the milling tools.[69] Because the final sintering of the partially sintered zirconia leads to 20-25% shrinkage, partially sintered zirconia has to be milled in enlarged form as compensation, and this requires a high level of accuracy of the CAD/CAM system.[24]

ZIRCONIA VENEERING TECHNIQUES

The veneering ceramic is usually applied with the layering technique similar to the fabrication of metal ceramic restorations, other techniques for the application of the veneering layer include: the overpressing technique and the digital technique.

THE LAYERING VENEERING TECHNIQUE

The veneering ceramic is typically applied with the layering (conventional) veneering technique which involves compaction, firing, and glazing.[72] Compaction involves mixing of a porcelain powder with sculpting liquid and binder to form a paste which is painted over the zirconia core by vibration, spatulation, or brushing techniques.[72]

Usually, two layers are added: dentine layer and enamel layer. A firing procedure is required for each layer that is added, two types of firing are available: vacuum firing and air firing. The firing procedure initially involves slow heating of the crown to drive off excess water, and then binders are burnt out. After that, porcelain particles start to fuse and some contraction occurs, but the ceramic layer remains porous at this stage. With time, more fusion takes place as the molten glass flows between the ceramic particles and more contraction occurs resulting in a non-porous ceramic layer. Cooling is done at a very slow rate to avoid cracking or crazing.[72] Finally, glazing is done in order to eliminate residual porosity and produce a smooth and shiny surface.[72]

The layering veneering technique is susceptible to the formation of microvoids and flaws which can form due to air trapping during the compaction or firing stages,[72] this can affect the translucency, shade uniformity, and/or surface characteristics of the veneering ceramic layer.[50,72]

In addition, these microvoids and flaws can form a starting point for cracks later on.[53] In order to reduce these complications, a highly skilled laboratory technician,[53] and a properly controlled compaction and vacuum firing,[72] are needed.

THE OVERPRESSING VENEERING TECHNIQUE

In order to overcome the complications of the layering veneering technique, veneering zirconia cores with a glass ceramic using the overpressing technique was proposed.[42] The overpressing technique involves forming a wax pattern for the veneering ceramic layer over the zirconia core followed by spruing, investing, and using a piston to force a heated ceramic ingot into the mold. After the ceramic material cools and hardens, the investment is broken apart and the crown is stained and glazed in a conventional furnace.[73]

Studies comparing between the layering and the overpressing veneering techniques in terms of physical properties found conflicting results. Some studies[39,42] found that applying the overpressing veneering technique can improve the physical properties of the zirconia-based restoration. Chaar et al.[42] found that the overpressing veneering technique can reduce the effect of aging on the fracture resistance of zirconia-based fixed dental prosthesis (FDP), as they recorded a mean load to failure of 1897 N for aged overpressed zirconia-based FDP compared with 1769 N for aged layered FDP.

On the other hand, Guess et al.[45] recorded a mean load to failure of 1100 N for overpressed veneered zirconia-based crowns compared with 1317 N for layered crowns when 0.5 mm uniform thickness cores were designed, while the mean load to failure recorded was 1500 N for the overpressed veneered zirconia crowns and 1103 N for layered crowns when anatomical cores were designed.

In another study, Pries et al.[21] compared between overpressed veneered and layered crowns and recorded lower failure loads for overpressed crowns using both uniform thickness (Overpressed: 1529 N / Layered: 1842 N) and anatomical (Overpressed: 1690 N / Layered: 2253 N) cores. In agreement with Preis et al., Al-Wahadni et al.[46] also recorded a lower mean load to failure for overpressed veneered zirconia-based crowns compared with layered crowns (Overpressed: 857 N / Layered: 1200 N).

Another group of studies,[74-77] found no significant difference in the physical properties of the zirconia-based restoration when applying either the layering or the overpressing veneering techniques.

Guess et al.[76] for example, recorded a mean single load to failure of 825 N for overpressed veneered zirconia-based specimens compared with 803 N for layered specimens, and the difference was found to be statistically not significant.

THE DIGITAL VENEERING TECHNIQUE

Due to the significant advancement in CAD/CAM technology over the last decades, it became possible to use ceramic materials of high homogenous quality for dental restorations.[78] The application of CAD/CAM technology has broadened to include not only high strength ceramic oxide materials, but also a variety of glass ceramic materials.[41] Tinschert et al.[53] found that using glass ceramic materials in the form of prefabricated blocks and applying a computer aided milling technique significantly increases their weibull modulus.

In recent years, a new technique has been introduced for veneering zirconia cores in zirconia-based restorations, in which the veneering glass ceramic layer is fabricated using the CAD/CAM technology.[41] The significance of this technique lies in overcoming the drawbacks of the layering and the overpressing zirconia veneering techniques presented in microvoid formation, the lack of shade uniformity, multiple delicate laboratory procedures, and the dependence on the skill of the laboratory technician.[43,50,53] Moreover, the fabrication of the zirconia veneering layer by the CAD/CAM technology can increase the cost effectiveness,[41] reduce the laboratory working time,[79] and optimize controlling the design and shade of the zirconia-based restoration.[50]

A number of digital zirconia veneering systems have been introduced including: "IPS e.max CAD-on" system by Ivoclar Vivadent Company,[41] "Lava Digital Veneering System (DVS)" system by 3M ESPE Company,[80] and "VITA Rapid Layer Technology" by Vita Zahnfabrik Company.[80]

THE CAD-ON SYSTEM

The CAD-on system was developed by Ivoclar Vivadent Company in 2009, in order to produce an efficient CAM technique, which provides strong anterior and posterior zirconia-based restorations without aesthetic compromise. In the CAD-on technique a zirconia-based core (IPS e.max ZirCAD) is fabricated and a CAD/CAM processed lithium disilicate veneering layer (IPS e.max CAD) is milled and attached to the core by means of a low fusing glass ceramic (IPS e.max CAD Crystall./Connect) in a conventional ceramic furnace.[81]

In 2009, Beuer et al.[41] introduced the CAD-on digital zirconia veneering technique and compared it with the overpressing and the layering veneering techniques, and he found that the fracture resistance under static loading for the CAD-on technique is significantly higher than the other techniques, with a mean failure load of 6262 N compared with 3700 N for the layered veneered zirconia-based crowns, and 3523 N for the overpressed veneered crowns. In agreement with Beuer, Kanat et al.[50] tested the CAD-on technique and found similar results (CAD-on: 4408 N / Layered: 4323 N / Overpressed: 2507 N). Schmitter et al.[82] compared between CAD-on veneered zirconia-based crowns and layered veneered crowns in terms of fracture resistance with and without artificial aging, and found that CAD-on veneered crowns were non-sensitive to artificial aging and recorded higher failure loads compared with layered crowns.

LAVA DIGITAL VENEERING SYSTEM (DVS)

The DVS system was developed by 3M ESPE Company in 2010, in order to produce an efficient CAM technique, which provides high quality zirconia-based restorations. In the DVS system a zirconia-based core (Lava Frame) is fabricated and a CAD/CAM processed glass ceramic veneering layer (Lava glass ceramic block) is milled and attached to the core by means of a low fusing glass ceramic (Lava Fusion powder) in a conventional ceramic furnace.[83]

Choi et al.[55] compared DVS veneered zirconia-based crowns with overpressed and layered veneered crowns and recorded a higher mean failure load for DVS crowns compared with other crowns (DVS: 6242 N / Layered: 4264 N / Overpressed: 5071 N). In agreement with Choi et al.,[24] Preis et al.[21] recorded a higher mean failure load for DVS veneered zirconia-based crowns when compared with layered and overpressed crowns (DVS: 2372 N / Layered: 2253 N / Overpressed: 1690 N). In spite of these satisfying results, the DVS system was pulled off the markets, but no reason was specified by 3M ESPE Company.

VITA RAPID LAYER TECHNOLOGY SYSTEM

The Rapid Layer Technology system was developed by Vita Zahnfabrik Company in 2010, in order to provide high quality anterior and posterior zirconia-based restorations. In Rapid Layer technology, a zirconia-based core (VITA In-Ceram YZ) is fabricated and a CAD/CAM processed feldspathic ceramic veneering layer (Vita Triluxe forte) is milled and cemented onto the zirconia core by means of resin cement (Panavia F 2.0) in an attempt to reduce stresses between the core and the veneering layer.[84]

Brawek et al.[80] compared between the DVS and the Rapid Layer digital zirconia veneering techniques in terms of marginal and internal fit and reported that the DVS technique had a better fit than the Rapid Layer technique. However, both techniques were found to have satisfying marginal and internal fit. In another study,[85] it was found that the Rapid Layer veneering technique is less sensitive to artificial ageing, but it showed lower failure loads compared with the layering veneering technique (Rapid Layer: 395 N, Layering: 1166 N). In their recent study, Al-Wahadni et al.[52] compared Rapid Layer veneered zirconia-based crowns to layered and overpressed veneered crowns and recorded a lower mean failure load for Rapid Layer veneered crowns compared with other crowns (Rapid Layer: 638 N / Layered: 1200 N / Overpressed: 857 N). In agreement with Al-Wahadni et al., Kanat et al.[86] compared Rapid Layer veneered zirconia-based crowns to layered and overpressed veneered crowns and found similar results (Rapid Layer: 1900 N / Layered: 6102 N / Overpressed: 4117 N).

FRACTURE RESISTANCE OF ZIRCONIA-BASED RESTORATIONS

Zirconia-based restorations have been long known for their superior mechanical properties. Many studies,[16,19,20] showed that zirconia-based restorations have the ability to withstand the mechanical loads of the posterior regions, and to be a good alternative for other all ceramic, ceramic fused to metal, and all metal restorations. Most studies which evaluated the fracture resistance of zirconia-based restorations found favorable results compared with other all ceramic restorations.[25,61,87-89] However, chipping of the veneering layer is still a major concern regarding zirconia-based restorations.[20,23,25,26] Several factors were reported to adversely affect the fracture resistance of zirconia-based restorations including: weakness of the veneering layer,[24,90] weakness of the veneer-core interface,[35] thermal and mechanical ageing,[60] surface treatment,[33-36] and thickness of the zirconia core.[23,27-29] Single cycle (static) loading to failure is regarded an excellent measure for the fracture resistance of any dental restoration.[30] The static loading machine comprises an indenter that can be subjected against a specimen with a gradual rise in the loading strength until the specimen fails, the specimen can be mounted in different angulations varying from 90-130 degrees with the horizontal plane to best mimic the angulations of the biting forces.[91,92] Although static loading shows no clinical relevance, it provides the maximum force that a material can withstand before failure, thus it may be helpful for comparing tested specimens.[21]

Zirconia-based crowns have recorded single cycle load to failure ranging from 346 to 6263 N.[41,54] This wide range can be attributed to several factors including: physical and chemical composition of the restoration, cementation technique, anatomic differences in shape and thickness, and loading conditions.[47]

It is worthy to mention however, that failure modes recorded under static loading such as bulk fractures were significantly different from those observed clinically such as cohesive veneering layer chipping originating from occlusal adjustment areas or wear facets.[20,93] In addition, static loading doesn't provide an insight into the fracture initiation and propagation patterns of the restoration in the oral environment.[23]

In the oral environment, dental restorations are subjected to moisture, thermal and mechanical fatigue causing temporary deformations and internal stresses, which can significantly affect the fracture strength of the restoration.[94] In order to best simulate clinical conditions, thermal and mechanical cycling devices started to emerge representing the natural chewing cycle and the alternating rise and fall in the temperature of the oral environment.

Chewing simulators can represent the natural chewing cycle through repetitive vertical and horizontal controlled forces, which can also be applied in a watery environment.[85] Zirconia-based restorations recorded only a 48% survival rate of a 200 N load for 50,000 cycles,[95] and a 90% veneer chipping under 100,000 cycles of 200 N load,[96] which is more representative of the failures that are recorded clinically for zirconia-based restorations. Furthermore, cyclic loading improved the ability to understand the clinical behavior of zirconia-based restorations through the ability to observe the fracture modes and crack initiation points and propagation patterns.[23] The combination of thermal and mechanical cycling has been proposed to best represent the oral environment, and a thermal cycling of 3000 cycles between 5° and 55° of 2 minutes each, combined with mechanical cycling of 1.2 million cycles of 50 N load has been proposed to represent a five year clinical fatigue for ceramic restorations.[97] With more research conducted with thermal and mechanical cycling, the detrimental effects of fatigue on the fracture resistance of zirconia-based restorations are being appreciated.[61]

SHADE REPRODUCIBILITY OF ZIRCONIA-BASED RESTORATIONS

Natural shade reproducibility is a challenge facing any final restoration. In order to produce dental restorations with accurate shade matching of natural teeth, a thorough understanding and assessment of the different color elements has to be established.[98] Variable color elements such as hue, chroma, and value; translucency and opacity; light transmission and scattering; and metamerism and florescence, can influence the shade reproducibility of any dental restoration.[49,98]

For zirconia-based restorations, the concern regarding natural shade reproducibility lies in the opaque white color of zirconia. Zirconia has been found to be completely opaque with a contrast ratio of 1.00 at 0.5 mm thickness.[99,100] Attempts have been made to produce esthetic full contour zirconia restorations.[101,102] However, as discussed above, veneering zirconia with a glass ceramic layer has been found necessary to provide superior esthetic results.[21,22]

From an esthetic point of view, translucency doesn't always have a positive effect, as a restoration with good masking ability is sometimes required, especially for discolored teeth.[61] On the other hand, due to the high translucency of Zirconia veneering materials, the white color of the zirconia core might still influence the final shade of the restoration so the application of liners,[48,49] and the use of colored zirconia cores,[38] have been proposed.

Another factor that can affect the shade reproducibility of zirconia-based restorations is the veneering technique.[22,52] Luo et al.[22] compared between the layering, the overpressing, and the combined overpressing and layering zirconia veneering techniques in terms of translucency and shade reproducibility, and found that the overpressing technique had the highest translucency (transmittance value of 1.64), followed by the layering technique (transmittance value of 1.54), while the combined zirconia veneering technique had the lowest translucency (transmittance value of 1.47), they also found that the overpressing technique had the highest (L) values (the lightest) with 87.5, followed by the layering technique with 84.2, and the combined technique had the lowest (L) value with 82.1. This was explained by the difference in infrastructure, homogeneity, and porous volume between pressed and veneered ceramics.

In another study, Kim et al.[50] compared between the layering and the digital zirconia veneering techniques in terms of shade reproducibility, and found that the mean shade difference values between the two techniques were within the clinically acceptable limits (ΔE values from 1.03 to 2.44), although the digital veneering technique had higher (L) values and lower (a) and (b) values, Kim et al. explained these findings by the differences in crystal size and transparency between the digital and the layering veneering ceramics.

In a recent study, Al-Wahadni et al.[52] compared between layered, overpressed, and digitally veneered zirconia-based crowns in terms of shade reproducibility using a Vita shade tab as a control. Applying two shade evaluation formulas (CIE Lab and CIE 2000), they recorded the lowest mean shade difference values for the layered veneered crowns and the highest values for the digitally veneered crowns (Layered: 2.3 ΔE Lab, 1.4 ΔE 2000 / Overpressed: 3.5 ΔE Lab, 2.1 ΔE 2000 / Digital: 4.0 ΔE Lab, 3.1 ΔE 2000). These results were explained by: First, the highly saturated monochromatic nature of the ceramic ingots produced for the overpressing veneering technique. Second, the high homogeneity and the proportional distribution of the ceramic crystals in the CAD/CAM glass ceramic blocks for the digital veneering technique.

Other factors that can contribute to the shade reproducibility of zirconia-based restorations include: thickness of the zirconia core and the veneering layer,[51,103] shade of the zirconia core and the veneering layer,[38,50] brand of the zirconia core,[4249] and the firing procedures.[104,105]

CONCLUSIONS

YSTZ cores veneered with porcelain present a potentially efficient alternative for metal and metal ceramic restorations, due to the excellent mechanical properties of the zirconia ceramics and the superior esthetic properties of the veneering glass ceramics. The veneering layer is usually applied using the layering technique, other techniques for the application of the veneering layer include: the overpressing technique and the digital technique. The veneering technique is one of the main factors that can influence the fracture resistance as well as the shade reproducibility of the zirconia-based restoration. It is important to note however that insufficient research has been conducted regarding the influence of the veneering technique on the fracture resistance and shade reproducibility of the zirconia-based restoration.

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