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Case Report

CAD/CAM Zirconia: Case Report and Narrative Review of Present and Future of Dental Restorations in the Aesthetic Zone

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Abstract

Aesthetics is a major concern for dental patients and is a challenge in contemporary dental rehabilitation for clinicians and dental technicians. Discolored frontal maxillary teeth can result in excessive psychological suffering for the affected individual. Here we describe the use of zirconia CAD/CAM restorative materials for the treatment of teeth in the aesthetic zone for a 26-year-old teacher. Maxillary central and lateral individual zirconia crowns were manufactured and cemented with dual-cure resin cement. Harmony with the existing shade of all teeth was achieved. The patient reported improved self-esteem and better relationship with their students as well as social interactions.

Keywords: Maxillary incisors, CAD/CAM, zirconia, aesthetic.

1. INTRODUCTION

Esthetics is a major goal of restorative treatment. Dental ceramics have been applied as restorative materials for decades due to their superiority to other materials in terms of properties and their natural tooth mimicking ability (Choi *et al.*, 2019). Zirconia has been introduced and widely used as an esthetic material in dentistry. Additionally, fixed dental prostheses have been designed as a single-piece zirconia substructure, where veneering porcelain can fire directly. Some reports have documented breakage, fracture, delamination, and chipping of zirconia restorations (Triwatana *et al.*, 2012, Choi *et al.*, 2012). In recent years, monolithic zirconia crowns that are full contour in nature have been popularized since they overcome veneering chipping on zirconia coping. Their popularization had been largely due to their excellent tooth color, minimal wear to the opposing teeth, longevity, conservative tooth preparation, excellent clinical performance, and great flexural strength in the long term (Triwatana *et al.*, 2012).

Maxillary anterior teeth are key to the aesthetics and functional demands of the patient. Here we describe the successful treatment with zirconia all-ceramic crowns of a patient working as a teacher, achieving excellent aesthetics and full competence in function. As a result, the patient feels psychologically and mentally motivated (Al Moaleem *et al.*, 2016). During manufacturing of ceramic crowns, the dentist must know about patients' perception of esthetics; otherwise, both clinical and laboratory efforts would be inadequate to satisfy the symmetry and aesthetic desires of the patient, even if the restoration is technically accurate (Al Moaleem *et al.*, 2017).

In the aesthetic zone, the maxillary incisors – the most visible teeth – must fulfill some essential requirements. The incisal edges of the maxillary incisors must touch the inner edge of the vermilion border of the lower lip with the pronunciation of the 'f' sound. Also, the incisal edges of central incisors should be in the same line as the cusp tips of canines. The midline of the smile should be in harmony with the facial features nearest the mouth (Rosenstiel *et al.*, 2015; Shillinburg *et al.*, 2012).

Most in vivo and in vitro studies, as well as technical case reports, showed that permanent maxillary central and lateral incisors have only one root, with

100% having a single-canal anatomy. Nevertheless, when the pulp canal system is complex, a minimal variation can be suggested to exist; this can be diagnosed with the help of cone-beam computed tomography (Al Ariqi *et al*., 2021).

This case report describes the clinical use of a CAD/CAM zirconia material for a young teacher patient with multiple tooth-colored fillings of the maxillary central and lateral incisors. The narrative review for zirconia is also presented.

2. CASE REPORT

A 26-year-old male teacher patient presented with yellowish discoloration and multiple fillings in his anterior maxillary teeth. A thorough case history was taken with proper extra-oral, intraoral, clinical, and radiographic evaluations. The presence of generalized discoloration and previous composite restoration was diagnosed, and a vitality pulp test was carried out. Alternative treatment modalities discussed with the patient included direct composite veneers, indirect veneers, all-ceramic veneers, and zirconia crowning. The patient requested a long-term solution for his esthetic problem in his maxillary frontal teeth. Following the patient's consent, a treatment plan was finalized that included placing zirconia crowns for the anterior maxillary teeth after elective root canal treatments.

Intraoral examinations showed multiunit composite restoration in relation to teeth #11, 12, 21, and 22 (Figure 1A-B). No pain in the temporomandibular joint was detected. A Class 1 molar relationship and canine guidance occlusion were observed. Mild gingivitis in the interproximal and embrasure areas with melanin pigmentation. A preapical radiographic analysis showed multiunit restorations with the widening of the periodontal ligaments and loss of lamina dura (Figure 1C-E). After examining the patient and collecting data, the treatment plan was discussed with the patient, and he gave his agreement. The treatment was begun by maxillary and mandibular impression with alginate dust-free impression materials. At this visit, scaling and polishing of all teeth were done, including polishing the existing composite restoration. From the alginate impression, a diagnostic cast was poured, then diagnostic wax-up was prepared with the help of the dental technician and ceramist. The rubber base index was prepared from the diagnostic wax-up models (Figure 3A). We built up and performed contorting of maxillary incisors by composite resin (Figure 3B) (Tetric-NCeramic, Ivoclar Vivadent, Lichenestine).

The shade B2 was selected using the vita classic shade guide. Teeth preparations were done using diamond burs as previously described (Rosenstiel *et al*., 2015; Shillinburg *et al*., 2012). All maxillary incisors teeth were electively gone for root canal treatments. After cleaning, shaping, and obturation of the root canal of incisor teeth, their roots received FRC post (Relaxy Fiber Post, 3MESPE, Germany) (Figure 3). The cores of all teeth were built with composite resin (Tetric-NCeramic, Ivoclar Vivadent, Lichenestine) (Figure 4A). The finish line was slightly under the gingiva. When recording the impression, the retraction cord (Medi-Pak 000 knitted nonimpregnated, Medicept dental, India) was positioned in the buccal gingival sulcus for 5 min, then removed. Full-arch impressions for maxillary teeth were made with polyvinyl siloxane (Aquasil soft putty/regular set, Dentsply, Germany) using the putty reline technique (Figure 4B). The maxillary and mandibular impressions were poured in the dental laboratory, dies were formed, and crowns from CAD-CAM FSZ Zirconia (Prettau ,®Anterior, Zirkonzahn, Taufers, Italy) were fabricated.

At the final visit, porcelain try-in of the zirconia CAD/CAM crowns in the patient's mouth was completed, interocclusal adjustment, canine guidance, in addition to protrusive and lateral movements were checked before glazing. Cementations of the glazed zirconia crowns were done with Dual-cure resin cement (Relaxy X^{TM}, Unicem Appli Cap Resin Cement, 3M ESPE, Germany) (Figure 5). All the steps of construction, production, and cementation of all-ceramic zircon crowns following the manufacturer's instructions. A follow-up program was recorded for evaluation of the crowns.

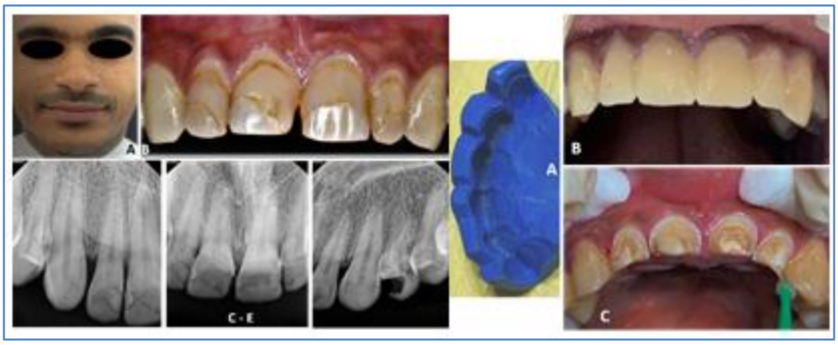

Fig-1: Preoperative intra-oral views, and radiographs

Fig-2: Index for maxillary incisors from the diagnostic wax-up (A), teeth with composite buildup (b), initial preparation for the teeth (C)

Fig-3: During root canal treatments

Fig-4: Teeth after fiber post and composite core build-up and preparations (A), Final impression (B).

3. DISCUSSION

The advantages of CAD/CAM zirconia ceramic prosthesis are tooth-like translucent appearance, good biological compatibility in direct contact with the oral tissues and periodontium, and a wear pattern similar to tooth enamel (Choi *et al*., 2019). These measures are frequently seen by lithium silicate ceramics, which have multi-indications, such as veneers, tabletops, single crowns (as in the present case), and small anterior bridges. Furthermore, suppose we want to increase the indication choices and integrate greater and larger restorations in the posterior region. In that case, this objective is only achievable with CAD/CAM zirconia ceramics restoration materials (Lohbauer *et al*., 2018).

Dallak *et al*. (2020) reviewed the original studies and case reports addressing the root canal morphology of permanent maxillary anterior teeth among the Saudi Arabian population. These authors concluded that Type I Vertucci's classification of canal configuration is the most common type in maxillary central and lateral teeth (one canal with one root and canal configuration). Also, Al Ariqi *et al*. (2021) found that maxillary central incisors have some variations other than Type I Vertucci's classification; this was obvious during elective root canal treatments of maxillary central and lateral teeth.

Predominantly confusing is the widely varying indication range for the new 5th generation mixed zirconias and the most used generation (third) with graded translucency within a milling block CAD. For this generation, the indication range varies from only small three-span bridges in the anterior region (Kuraray Noritake Europe., 2017) up to the approval of 14-unit bridges (Ivoclar Vivadent, 2020) (maximum of two teeth per dental gap replaced). Therefore, the concept of a single "zirconia" material is no longer useful; rather, there are many material variants that can be created for individualized applications.

In their clinical and radiographical study, Al Moaleem *et al*. (2017) found that the behavior of anterior maxillary teeth (in the aesthetic zone) restored with CAD/CAM zirconia crowns after RCT were equal or higher in survival rate compared to other all-ceramic materials tested namely porcelain fused to metal, and e.max ceramic over the recall period.

The clinical outcomes for our patient were masking of the discoloration with durable and biocompatible crowns. Also, the color matching resulted in a boosted self-esteem, with improved social communication, particularly in his profession as a schoolteacher. Also, the smile line and the degree of arrangements during smiling and speaking were in harmony.

4. Review of zirconia

The advent of computer-aided manufacturing and computer-aided design (CAD/CAM) has brought many advances in clinical dentistry (Uzun 2008). The CAD/CAM technology is crucial in developing highly strong polycrystalline ceramics, including stabilized zirconium dioxide. Initially, stabilized zirconium dioxide could not be processed using outdated laboratory systems. CAD/CAM systems are used initially to develop ceramic inlays, onlays, crowns, and veneers (Sundaram and Varghese 2020; Sajjad 2016).

The in-ceramic system was first used for the initial-ceramic core materials for three-unit anterior fixed partial dentures and crowns in the European market in 1989 (Sundaram and Varghese 2020). Subsequently, in 1993, all-ceramic restorations based on procera were introduced (Nobel BiocareAB, Gothenburg, Sweden). These restorations were made up of more than 99% $A1_20_3$ (high purity aluminum oxide) which was sintered densely and veneered using a compatible lowly-fused dental porcelain (Naji *et al*. 2018).

As a well-known ancient gemstone, zirconia is referred to chemically as zirconium oxide and is technically a ceramic material. Zirconium oxide forms about 0.02 % of the earth's crust (Tong *et al*., 2016) and is relatively abundant in nature. A German chemist named Martin Heinrich Klaproth identified zirconia as a metal dioxide (Zr02) in 1789 during a chemical reaction involving gems exposed to heat. For a long time, Zirconium oxide has been viewed as a pigment for ceramic in the presence of other rare earth oxides (Deany IL, 1996). In 1999 during a global symposium, zirconium oxide was considered to have fulfilled the criteria for a proper restorative material in clinical dentistry due to its mechanical, chemical, and dimensional properties. Zirconia is being applied extensively in dentistry due to these and many other properties (Touati *et al*., 1999).

Clinical trials have shown that prostheses based on zirconia can function as viable long-term restorations (Miyazaki *et al*. 2013. Larsson and Wennerberg., 2014;). Technical problems, however, related to the clinical effectiveness of zirconia fixed dental prostheses and crowns have been reported, notably the chipping and loss of retention of veneered porcelain in the case of zirconia framework structures (Miyazaki *et al*. 2013., Larsson and Wennerberg., 2014). Steps to reduce the veneering porcelain's chipping by milling the frameworks and veneers and stressed with either fusing firing with CAD on or luting agent have not addressed the problems with chipping. Zirconia formed as fully anatomical monolithic contoured prostheses has been proposed as an alternative route to reducing the challenges of veneer chipping. In prosthodontics, these are generally known as monolithic zirconia crowns (Deany IL, 1996).

5. Generation of zirconia in dentistry

The first-generation tetragonal zirconia polycrystals (3Y-TZP) are made up of 3 mol% or 5.2 wt% Y_2O_3 dopants and 0.25 wt% Al2O3. 3Y-TZP has a small grain size (0.3–0.5 µm), elevated crack durability (9-10 MPa.m1/2), increased flexural strength (900–1200 MPa), and an elastic modulus of 210 GPa at room temperature (De Angelis *et al*. 2021; Zhang *et al*. 2014). The material is sintered at a moderately decreased temperature relative to the second and third generations. The grain size is fundamental in determining 3Y-TZP's mechanical properties. Research studies have shown that over basic grain size, the 3Y TZP is not so much stable but rather more prone to change. However, lowering the grain size below 1 µm is associated with a lower transformation rate, to the point where transformation is impossible when the grain sizes were less than 0.2 µm, resulting in decreased zirconia fracture toughness (Behr *et al*., 2020).

The sintering conditions are an important factor that impacts the grain size and, therefore, affects zirconia's mechanical properties. Higher sintering temperatures and longer sintering times increase grain size (Ebeid *et al*., 2014). Cercon (Dentsply Prosthetics), DC Zirkon (DCS Precident, Schreuder and Co), In-Ceram YZ (Vita Zahnfabrik), Magma (3M ESPE) are examples of the first generation 3-YTZP. Progressed conventions have been created to lessen zirconia's opacity, making it clearer by intensifying the heat treatment conditions (Zhang *et al*., 2014).

The second generation, partially stabilized zirconia (3Y-PSZ), comprises tetragonal found in a cubic stabilized zirconia matrix. The material is doped with Y2O3 at 3 mol%, yet the sintering aid (0.25 wt% Al2O3) is eliminated, and the sintering temperature and duration are expanded. 3Y-PSZ's grain size is increased between 0.5 and 0.7 µm, and the content in the cubic stage increased from 6 and 12% to 20 and 30%. As an outcome, the translucency parameter is increased to 24–31, and the biaxial strength is diminished to 900–1150 MPa (Zhang *et al*., 2014). An extra methodology that can be utilized is to supplant tetragonal zirconia grains with zirconia particles that are optically isotropic cubic. This should be possible by increasing the yttrium substance to lessen the grain limit light dissipating to yield fully stabilized zirconia (Cho *et al*., 2021). This material's generation has a larger grain size, which is related to the porosity presence and, therefore, wears.

The cooling phase of this material must be controlled because of the requirement for elevated sintering temperature ranging between 1680 and 1800°C.

The third generation, 4-5Y-PSZ, consolidates all the more optically isotropic cubic zirconia (50-80%), has a grain size ranging from 1 to 4 µm, and is created by increasing the Y2O3 dopants to 5 mol% and expanding the sintering temperature or potentially term more than that of the previous generation (Ahmed *et al*., 2020). Although aesthetics is enhanced, cubic zirconia is weaker than its tetragonal zirconia. There is an increase in translucency parameter to 30–43, and the biaxial strength is diminished to 450–740 MPa, more in the scope of lithium disilicate (Cho *et al*., 2021, Ahmed *et al*. 2020). The fourth generation 4Y-TZP increased the flexural strength to 750 MPa (by 10%) and the material became more translucent. While the fifth generation 3Y/4Y/5Y-TZP further increased flexural strength (550–1200 MPa) and translucency (matching multilayer zirconia). However, this advantage of increased translucency is counterbalanced by the disadvantage of reduced flexural strength, diminishing the clinical indication choices of this type of zirconia. In fact, the indication range for 5Y-TZP zirconia hardly differs from that of lithium disilicate ceramics (Rosentritt *et al*., 2020).

Zirconia-toughened ceramics and alumina toughened zirconia are two other types of zirconia. Furthermore, graded zirconia and nanostructured zirconia have been developed as experimental novel zirconia types with improved translucency (Kontonasaki *et al*. 2019). Zirconia toughened alumina has been introduced as a relatively new generation of common tough ceramic and is used broadly, mostly as oxide ceramic structural composites (Zhang and Lawn., 2018). The material's mechanical properties depend on its microstructure and can easily be controlled by densification and powder preparation processes.

6. PROPERTIES OF ZIRCONIA

Biocompatibility

Biocompatibility refers to a material's ability to offer a host of effective and positive clinical services without creating any allergic or toxic responses or adverse systemic reactions in the surrounding intro-oral tissues (Choi *et al*., 2019). Zirconia ceramics do not have harmful or genotoxic impacts and have satisfactory responses in oral tissue. In vivo and in vitro evaluations have been conducted on the biocompatibility of zirconia. An in vitro study concluded that zirconia does not have a toxic effect on cell cultures when interacting with blood cells (Choi *et al*., 2012). In vivo research has assessed the biocompatibility of zirconia with soft tissue and bone, showing no cytotoxicity (Alghazzawi *et al*., 2012).

Zirconia Optical Properties

Zirconia is a monochromic, opaque material; the aesthetic properties of the zirconia restorations are associated with its optical properties, including contrast ratio, translucency, opalescence, and color (Tong *et al*. 2016; Zhang *et al*. 2014). New ultra-translucent and multicolor monolithic zirconia ceramics present considerably improved aesthetics and translucency, similar to those of the more translucent lithium disilicate ceramics (Rinke *et al*., 2013). Although a significant increase in translucency has been achieved, new translucent monolithic zirconia ceramics need to be further evaluated in vitro and in vivo for their long-term potential to preserve their outstanding properties (Elsaka *et al*., 2019).

Microstructural Properties

Zirconia exists in three forms: the monoclinic phase (stability up to 1170℃ at optimal temperature), the tetragonal phase (stability between 1170℃ and 2370℃), and the cubic phase (stability from 2370℃ and 2680℃ at the melting point). These transformations are two-way, temperature-driven in the third phase, and are followed by mechanical property changes, such as higher strength in the second tetragonal phase followed by the third cubic phase (Kontonasaki *et al*., 2019). The stabilization of tetragonal zirconia is necessary for dental prosthesis applications. The cooling process to optimal temperature is related to a 4 to 5% volumetric expansion that leads to severe cracking, ultimate catastrophic material failure, and the need for restoration. As a result, the process of mixing zirconia with a stabilizing oxide has been identified to cause stabilization of zirconia at room temperature in the cubic or tetragonal stages. Also, the procedure maintains the enhanced mechanical, electrical, and thermal properties, which enable its application in clinical dentistry. Yttrium (yttrium oxide or Y2o3), Ca0 (calcium oxide), Ce203 (cerium oxide), and Mg0 (magnesium oxide) are effective dopants (Muñoz *et al*. 2017).

Zirconia Fracture Toughness

Zirconia is considered one of the most rigid materials existing and the toughest ceramic-like materials used in dentistry. The phase transformation observed from tetragonal to monoclinic has benefits that, ironically, the outcome in the enlargement generates cracks and retard its growth, thus, improving the material's fracture strength. The process minimizes the stress of the crack area, leading to the generation of layers with compressive stresses that then dissolve the power of the crack (Kontonasaki *et al*., 2019). During dental use, zirconia is sintered at high temperatures. When cooled to room temperature, residual stresses occur; rapid cooling rates between each of the other veneering materials with a variation in thermal expansion coefficient leads to greater residual stresses. The process of milling zirconia and adjustment of its occlusal or intaglio surfaces found on the prosthesis before the insertion process is another factor that leads to the tetragonal to monoclinic transformation (Wongkamhaeng *et al*., 2019). Although the self-toughening mechanism of zirconia is considered beneficial to stop serious fractures due to stress, the transformation process (t-m) is observed to be irreversible. It weakens the material with effects that are unpredictable in the long term. The transformation stage is considered the main challenge of the zirconia material. In addition to localized stress, a state referred to as hydrothermal aging or LTD (low-thermal degradation) can also cause phase transformation (Wongkamhaeng *et al*., 2019).

Wear of Zirconia and Antagonists

Y-TZP was found to have twice the hardness of most porcelains so that the full-contoured zirconia restorations can create wear of the antagonists (Miyazaki *et al*., 2013); this is dependent on both the environmental factors in the area, and the material applied. The materials' internal pores, surface defects, and fracture toughness can increase the antagonist's wear (Stober *et al*., 2016). Also, the surface texture plays a significant role in prolonged stability and safety of the occlusion; the impact on abrasion of the antagonist's teeth due to full zirconia restoration is an issue when zirconia is applied on the occlusal surface (Kontonasaki *et al*. 2019). Thus, adjustment of the occlusion is a crucial step during the cementation of zirconia restorations. Al Moaleem *et al*. (2020) concluded that polished zirconia specimens demonstrated a higher effect on the surface roughness of samples immersed in khat than glazed specimens. Generally, polished monolithic zirconia led to a slightly lower level of wearing on both the enamel antagonists and the substance itself than glazed monolithic specimens (Esquivel-Upshawa *et al*. 2019).

Low Thermal Degradation (LTD) or Hydrothermal Aging

Hydrothermal aging can be defined as the natural alteration that takes place at low temperatures and with liquids being present. In such a case, phase alteration or changes does not occur due to local stress at the proceeding crack's tip. The hydrothermal degradation of zirconia can be minimized using the selection of particular pre-sintering temperatures and optimized solutions (Alessi *et al*., 2014).

Studies have evaluated the aqueous attack of Y-TZP ceramics and described the method by which the hydrothermal aging phenomenon takes place. Earlier, Swain and Rose (1986) proposed that water vapor diffusion creates stress accumulation, thus breaking the bond in Zr0 and inducing lattice defects to act as nucleating agents for the subsequent t-m transformation. Recently, El-Ghany and Sherief (2016) have argued that oxygen atoms originating from water desiccation fill vacancies created by oxygen in zirconia grains. This is assumed to be the reason for destabilizing and altering the parameters of the lattice. In addition, zirconia material has shown better strength and fracture strength in short-term laboratory studies (Choi *et al*., 2021). The LTD is influenced by several factors, including the form and content of the stabilizer, residual stress, and grain size (Choi *et al*., 2012). Several approaches to minimizing the LTD of 3Y-TZP have been suggested, including the addition of small amounts of silica (Choi *et al*., 2012), using yttrium coating in place of co-precipitated powder, and the reduction of particle size (Choi *et al*., 2019). Also, the increase of the stabilizer's content or the composite formation alongside Al_2O_3 cooping by liquid infiltration of cenitrate (Daou EE., 2014). Finally, hydrothermal degradation of zirconia was minimized using the selection of particular pre-sintering temperatures and optimized solutions.

7. CONCLOUSION

CAD/CAM zirconia restorative material protheses have excellent biocompatibility, and result in minimal wearing of opposing teeth, provide long-term aesthetics with stable color. These properties mean that CAD/CAM zirconia restorative prostheses can increase the patient's self-esteem and confidence, hence promoting a return to a satisfactory social life. Zirconia-based restorations are a promising prosthodontics alternative material to other restorations and show excellent clinical, mechanical, and chemical performance.

Limitation

This study was conducted among Taif University students, and outcomes cannot be reached rates of smoking among university students in other parts of Saudi Arabia.

RECOMMENDATIONS

Anti-smoking policies in public places must be implemented, as well as smoke-free policies inside all university campuses, to decrease the smoking prevalence among students. There is also a need for a mental health practitioners' therapy service for both students and their peers who smoke to help them stop smoking.

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Author's contributions

First author is the main author who planned the research and prepares the patient and follow the treatment plan, questionnaire and revises the final version. Second author revise the literature and write the draft as well as submission of paper. Third author literature collection and data collection, fourth, fifth, sixth and, seventh author share in data analysis data collection phase and revise the draft.

Informed consent

The written and verbal informed consent was obtained from all participants before enrolment in the study.

Ethical approval

Ethical approval Directorate of Health Affairs in Taif city approved this study (Ethical approval number: IRB KACST 114/2020). The procedures followed were in accordance with the Helsinki Declaration of 1975 that was revised in 2013.

Conflict of interest

The author declare that they are no conflict of interest

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