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Zirconium Restorations-A review

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ABSTRACT

Dentistry has evolved over period of time from use of wood for replacement of teeth till use of titanium for dental implants. These journeys have made possible the exposure of much aesthetic material to dentists. As a clinician it becomes extremely difficult to select appropriate materials for intra oral restorations. This article discusses one such material, zirconia which has numerous applications for better restorations in oral cavity.

Key words: Zirconia, Zirconium restorations, Dental implants, Dental abutments

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INTRODUCTION

During tooth restoration, the doctor faces the dilemma: what material to use? [1]. The main factors likely to affect the ultimate selection are the aesthetic and prosthetic strength. Fixed partial metallic ceramic prostheses are regarded as the benchmark in terms of reliable materials [2]. A metal fused to ceramic restoration consists of a metallic crown supporting the overlying ceramic restorations of PFMs have an extensive clinical track record [3]. But the failure rate for fixed PFMS was 4% over five years, 12% over ten years and 32% over fifteen years [4]. The major drawbacks of a PFM restoration is its failure to transmit light which in term adversely affects its aesthetic outcome as the final restoration appears dark in colour [5,6]. This disadvantage is well appreciated at the cervical region of the restoration where at times it is impractical to obtain adequate space. To mitigate this impact, a sufficient measure of the tooth design ought to be eliminated to oblige a material made up of ceramic that can veil the hidden metal without the restoration being over contoured. Another drawback in a PFM restoration is the associated allergic reactions in certain patients to some metallic elements like nickel in metal alloy. Also PFM is known to cause greying of gingival margins [7].

As a result of a growing interest in aesthetics and concerns regarding toxic and allergic reactions to certain alloys, all ceramic restorations were introduced.

LITERATURE REVIEW

History of zirconia

Ceramics have been used in dental practice since 1889, the year Charles HL and copyrighted the crown "jacket" entirely from porcelain [8]. This ceramic crown was introduced in 1990's. This restoration has been widely used as a result of improvements done by EB. Spaulding which was further promoted by Capon WA. Ceramics, on the other hand, are fragile materials so it's easy to fracture [9]. To decrease the risk of fracture, porcelain was fused to metal crowns were introduced in the end of 1950's by Abraham Weinstein [10]. The connection of the metal to the porcelain precluded the formation of stress cracks. Metal copings manufactured with lost wax technique have also solved the problem of marginal fit, associated with conventionally constructed porcelain jacket crowns. Although PFM crowns have a reduction in failures associated with porcelain, the adding an opaque layer of metallic block has decreased the aesthetics of these restoration. A revival of a completely ceramic restoration occurred in 1965 when industrial aluminium porcelain (>50%) was added to fled spathic porcelain during its manufacturing process. McLean W and TH elaborated this new type of the porcelain jacket crown which had an internal aluminium porcelain core which contains 40%-50% aluminium crystals [11]. In spite of having strength twice that of conventional PJC, still it could only be used in anterior region because of its greater opacity [12]. In the 1950s, a further development carried out by the corning glass works led to the development of the Castable Dicor crown system. The glass has been reinforced with various types of mica. Processing complexities and the greater incidence of fracture resulted in the discontinuation of the system [13]. As a result, new

polycrystalline ceramics, like Aluminium oxide and zirconium oxides were proposed [14].

Structural and mechanical properties of zirconia

Zirconia has very good mechanical qualities, with a flexion resistance of 900-1200 MPA and hardness of 1200 MV [15]. These values are nearly identical to those of the metals used for metal ceramic restorations, and clearly superior to the values of any other ceramics used in dental practice. In addition to the lack of an amorphous part, the cause for these excellent mechanical properties resides in the behaviour of zirconia under applied stress. In contrast to other ceramics, that develops cracks due to applied stress which leads to failure of the material, following the development of cracks in zirconium ceramics, these cracks are narrowed and closed with no further progress is made.

In order to understand the excellent mechanical properties of zirconia, one must understand the fundamental structure. Zirconium dioxide is a poly crystalline material that occurs naturally in mineral form [16]. In addition to its higher mechanical properties, zirconium dioxide possesses beneficial biological properties such as low corrosion potential, cytotoxicity, and minimum adherence to microorganisms zirconia occurs in 3 crystal forms according to surrounding pressure and temperature, monoclinic, cubic, and tetragonal [17-19]. The monoclinic structure much stable at standard room temperature and pressure. This is the form found in naturally occurring deposits. The monoclinic form transforms in to a tetragonal form at 1170°C, with 4-5% reduction in volume. The tetragonal shape decreases more as it becomes cube shaped at 2370°C [20]. The cubic shape is less frequently found in biomedical application. The reduction in size of ceramic during heating is uncommon therefore; partly zirconia is unusual as a biomedical material. The above mentioned phases occur within a common ZrO_2 crystal [21]. This alteration between phases is reversible and on cooling it returns back to the monoclinic phase. Along with the alteration, change in the volume of crystalline grains also occurs, and precisely this change of volume has been used to achieve an outstanding mechanical properties. In order to obtain a stable material which can be used during the dental procedures zirconia is stabilized by mixing 3 to 5% Y_2O_3 in the tetragonal phase. These little quantities of Y_2O_3 prevents (t) to (m) alteration below 1170°C which allows the tetragonal phase to remain present at standard room temperature [22,23]. Yttrium Partially Stabilized Zirconium dioxide (Y-PSZ) has superior mechanical properties as compared to other combinations though sintering is much harder; it is the primary type of zirconia used for current clinical use.

The optical properties of conventional dental ceramics are comparable to those of dental hard tissues. That's why ceramics is the preferable material dental restoration in areas where aesthetic is the main concern. Aesthetic appearance of ceramics is controlled by its translucency. More stable the ceramic, more opaque is its crystalline structure. According to this difference in optical properties, the appropriateness of a given ceramic material is decided by the site of restoration, the stump shade and area required for the restoration. The translucency of ceramic materials of characterized thicknesses can be positioned as follows; Veneering ceramics (0.5 mm)>Empress I (0.5 mm)>In Ceram Spinel (0.5 mm)>Empress II (0.5 mm)>Empress I (0.8 mm)>Procera Al,0, (0.5 mm)>Empress II (0.8 mm)>ZrO_2, (1 mm)>In Ceram Alumina (0.5 mm)>In Ceram Zirconia (0.5 mm) [24-26].

Dental applications of zirconia

The distinctive blend of mechanical resistance, biocompatibility, and low deterioration potential of zirconium has made it a particularly attractive material for dental application especially where aesthetics is the prime concern. The earliest mention of use of zirconium in dental practice goes back to the 1970's [27]. Zirconia was used for the first time as an endosseous dental implant in 2008 [28]. Nowadays it has been largely suited for many dental applications, but mainly for:

- Zirconia endosseous dental implant
- Zirconia based implant abutments
- Zirconia based crown and bridges
- Zirconia based dental posts
- Zirconia based aesthetic orthodontic bands and brackets
- Monolithic zirconia crowns

All these applications are further discussed in detail in the article one by one.

Zirconia endosseous dental implant

An endosseous dental implant is the part of tooth restoration which is supported by implant and is inserted within the maxilla or mandible, it straight away associates with the hard and soft tissues, and here it is attached to the implant abutment. It imparts a base for both functional and aesthetic demands of a clinical situation. A broad range of dental materials are used for fabricating implants over years but so far the most successful material is titanium alloy [29,30]. In spite of having a clinical success rate of 92 to 98% after 10 years, they are still deficient in the form as implant. Toxic allergic reactions to metals, lower aesthetics, greater wear of the alloy and biological accountabilities following its wear are the areas of concern with titanium alloys, which led to the research of ceramic materials likely to be used as endosseous implant [31-33]. Al_2O_3 ceramic was the earliest material used as implant in orthopaedics in 1930s and in dental clinical use in 1980s, but later its use was reduced due to its low survival rates because of its inadequate osseointegration and high fracture [34]. Further introduction of Y-TZP in the early 2000s, reawakened the use of ceramic as implant due to its superior properties. According to research, Y-TZP has sufficient mechanical strength to withstand masticatory forces without fracture [35].

Zirconia based implant abutments

Implant abutments are the intervening piece which connects the body of the implant to the crown [36,37]. They are made from a variety of alloys, out of which titanium is most commonly used. But a prefabricated titanium abutment has many aesthetic restrictions such as the shape of the alloy does not correlate with the natural anatomic tooth form, greying of gingiva etc.

In order to solve the problems related to prefabricated titanium abutments, alumina ceramics were introduced in early 1990's. Zirconia provides advantage over alumina due to its ideal colour, good tissue compatibility, lower plaque accumulation, customizability, allows prosthetic flexibility because of veneering, accurate fit, permits radiographic monitoring because of its radiopacity [38,39].

Zirconia based crown and bridges

Alloy ceramic crowns and FPDs are used in dental clinics since 1960's to restore absent teeth where aesthetic is the prime concern [40]. PFM were the standard material for such purpose but due to its low aesthetics as it was hard to hide metal component and it also causes allergic reactions in some patients which is why zirconia is preferred over PFMs. Solid or monolithic zirconia contains more stabilizers, which makes them more durable to withstand heavy chewing and grinding therefore they are recommended for posterior crowns. On the other hand, Layered zirconia's had more translucencies and is opalescent unlike monolithic zirconia which is why they are primarily used for anterior crowns. A zirconia crown has promising survival rates ranging from 89 to 100% with an average follow up time of 3.7 years [41-43].

Zirconia based dental posts

Dental posts are manufactured by a variety of materials such as metals (gold and titanium) ceramics (zirconium), fibre reinforced materials. The demand for more aesthetic posts, especially during all ceramic restoration has led to the development of new materials for dental posts. While performing an all ceramic restoration in the anterior region post made up of metal can lead to unfavourable aesthetics such as greyish discoloration of semi-transparent all ceramic crown and the adjoining gingiva [44]. Moreover they also cause complications such as burning sensation, pain, sensitization, metallic taste, and other allergic reactions [45]. These issues resulted in the growth of zirconia posts. Posts made from zirconium are biocompatible offers better aesthetics and they also showed a high success rate [46].

Zirconia based aesthetic orthodontic bands and brackets

Apart from the applications mentioned above zirconia is also used for manufacturing of aesthetic orthodontic brackets [47]. Brackets made up from polycrystalline zirconia are used in place of alumina ceramic brackets as they have highest toughness [48]. Polycrystalline zirconia brackets are cheaper as compared to the ones made up from mono crystalline alumina ceramics. In addition to this, polycrystalline ceramic brackets are more opaque and they give away intrinsic colours thus decreasing its aesthetic appearance. It exhibits good sliding property with stainless steel as well as nickel titanium archwires with reduction in plaque accumulation, bond failure at bracket/adhesive attachment [49].

Monolithic zirconia crowns

Development of CAD/CAM technologies allows processing of one piece zirconia crowns. They do not require a 2nd veneering layer above the core made from zirconia. By knocking out the second layer it decreases the incidence of chipping of the veneering ceramic. Apart from this, monolithic zirconia crowns has showed low wear rates on the opposite natural tooth as compared to the crowns made from veneering ceramics which shows enamel wear.

DISCUSSION

Dental ceramics and treatment technologies have developed considerably over the last decade; much of the evolution is linked to new microstructures and CAD-CAM methods. The new generation of ceramic materials offers exciting possibilities, both in terms of material selection and manufacturing techniques. The success of ceramic restorations depends on many factors such as the choice of materials, the design of the restoration, occlusion and cementing media. The information presented is important because a good knowledge of the different ceramic materials makes it possible for the dentist to select the most suitable material.

CONCLUSION

The need of patients for better appearance will continue to rise. As a clinician, we need to identify and select appropriate materials for restoration of missing tooth or teeth. The zirconia has expanded applications of aesthetic restorations in both, anterior and posterior region of oral cavity. Now it is our role for provision of better services to restore or to enhance smiles of patients. For this to be achieved we must understand these newer materials which are available in the market.

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