

# An Overview of the Current Survival Status and Clinical Recommendation for Porcelain Fused to Metal vs All-ceramic Zirconia Posterior Fixed Partial Dentures

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## ABSTRACT

Porcelain fused to metal (PFM) restorations has shown promising results in terms of longevity over decades. However, due to the paradigm shift with the preferences of both the patients and clinicians toward all ceramic restorations, these prostheses are being increasingly used in posterior region. Zirconia is one of the popular materials in dentistry today; it has good mechanical strength and has shown remarkable results in short-term studies from 3 to 5 years. However, zirconia aging and chipping are most common causes of zirconia failure, besides loss of retention has also been reported in some studies. Nonetheless, there are no substantial studies that decipher the longevity of these restorations over a longer period of time. Moreover, it has been reported that zirconia cannot be used in areas of higher stresses. This review article compares the promising ceramic material zirconia and PFM restorations in terms of longevity and esthetics based on the present studies. An electronic search was conducted across Ovid Medline, complemented by manual search across individual databases, such as Cochrane and Google Scholar for literature analysis on PFM restorations, zirconia crowns, and fixed partial dentures (FPDs). The studies were reviewed and results were compared for the same. This paper summarizes the current scientific and clinical opinion through a brief review regarding the preferred material for posterior crowns and FPDs. It denotes that case selection and certain other factors can play a role in success of the zirconia prosthesis.

**Keywords:** Ceramic, Fixed-partial dentures, Metal ceramic, Restorations, Survival, Zirconia.

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## INTRODUCTION

Porcelain fused to metal (PFM) has been the gold standard restoration in dentistry for many decades.<sup>1</sup> It has been the restoration of choice for mainly posterior fixed partial dentures (FPDs) due to its durability and low fracture rate.

Ceramic fixed dental prostheses (FDPs) are considered an established treatment alternative to metal ceramic FDPs today in daily clinical dental practices.<sup>2,3</sup> The main reason to use all ceramics instead of metal-ceramics is based on the former's more favorable esthetics.<sup>4</sup> Various ceramic materials have been proposed and introduced recently in the market for use in the posterior region. Zirconia [zirconium dioxide (ZrO<sub>2</sub>)] is one of the new ceramic materials introduced in the market that have gained instant popularity. Its mechanical properties are the highest ever reported for any dental ceramics yet, hence, generating considerable interest among the dental fraternity.<sup>5</sup> Zirconia crowns are being increasingly used also in the posterior region today. They are being clinically used in various applications in dentistry from the last 2 decades. However, we need to address the fact that there are only a handful of studies that actually document the clinical outcome and report the clinical performance of zirconia restorations in the long term.<sup>6</sup> It is surprising to know that the zirconia restorations have often been described in the literature not as single crowns, but rather as FPDs, although it is the crowns that constitute the most common fixed prosthodontics treatment in dentistry. The dental community has been "discovering" the mechanical as well as esthetic benefits of zirconia but does not seem to be concerned by its aging problems. The market for zirconia has been increasing by 12% each year, reflecting its considerable demand and popularity.<sup>7</sup> The growing use of zirconia in dentistry warrants much more extensive research and clinical evidence on crowns and FPDs manufactured with this ceramic material.

## PORCELAIN FUSED TO METAL AS THE "GOLD STANDARD RESTORATION"

Since the early sixties, metal-ceramic restorations have represented the "gold standard" in prosthetic dentistry, thanks to their good mechanical properties and

satisfactory esthetic results. Over the last 50 years, these restorations have been very popular and one of the most extensively used materials in dentistry. Porcelain fused to metal restorations have an established and a long history of good clinical success. "Any tooth can be restored with PFM".<sup>8</sup>

Porcelain fused to metals is able to deliver a good marginal adaptation as well as internal adaptation. Many of the few reasons for their staggering popularity are their consistency with positive results, their predictability, accuracy, and its ease with conventional casting procedures. Furthermore, adverse effects reported with the PFM restorations have been extremely rare, hence, their widespread use has been successfully prevalent.

However, one of the major limitations that the material exhibits is the somewhat grayish hue, i.e., reflected from the underlying metal framework. It is a significant limitation especially in anterior region when extremely esthetic results need to be produced, the dark metal collars and grayish hue are unable to produce the translucency, i.e., required to reproduce the translucency of the dental tissues,<sup>9</sup> giving compromising esthetic results.<sup>10</sup> In fact, metal-ceramic restorations can only absorb or reflect light.<sup>11</sup> Furthermore, from an economic standpoint, the cost of precious metals has markedly risen over the years.<sup>12,13</sup>

Although the documented success rate for the PFM over 10 years has been 94%,<sup>14</sup> its limitations with respect to esthetics and biocompatibility have prompted the use of all ceramic restorations. As purported by Brune,<sup>15</sup> the alloy elements from the metal ceramic crowns, that are in close proximity with the gingival tissue, do not get diluted by saliva, hence, may reach higher concentrations in the marginal gingival tissues.<sup>10</sup>

Therefore, all ceramic crowns have been extensively used in prosthodontics in recent years for their superior gingival response and esthetic quality, while achieving similar marginal accuracies when compared to traditional metal-based restorations.<sup>16,17</sup>

Despite the drawbacks, estimates for survival for PFM FDPs are 97% typically over a period of 7 years or more. Thus, a clinical trial in which the well-established PFM restorations are used as the control would perhaps be an excellent method of measuring the performance of all ceramic restorations. Unfortunately, not many studies of this type have been reported. Nevertheless, it is important to evaluate the potential significance of the outcome variables that have been reported.<sup>2</sup>

## STRUCTURAL PROPERTIES OF ZIRCONIA AND CURRENT CERAMIC MATERIALS

The primary shortcoming of the initially introduced ceramics, such as feldspathic porcelain, was its low mechanical stability, which limited the indications for

all ceramic restorations to only anterior regions and to single-unit FDPs. In the last few years, various new dental ceramic materials have been developed with the aim to improve the overall strength and stability of the all ceramic restorations while still maintaining the esthetic benefit. Leucite and lithium disilicate porcelain materials along with the reinforced glass ceramics and oxide ceramics, such as zirconia and alumina, are promising ceramic materials specific to their indications.

Zirconia tends to exist in various forms; it is a polycrystalline ceramics, i.e., devoid of glass phase. It has the superior most mechanical properties when compared to other ceramic materials available in the market. Its other characteristics include low corrosion potential, low thermal conductivity, good radiographic contrast, and good biologic compatibility which have categorized zirconia as the most promising ceramic material in dentistry.<sup>6</sup> Zirconia crystals exist in three different patterns: Monoclinic (M), cubic (C), and tetragonal (T). When zirconia  $ZrO_2$  is mixed with other metallic oxides, e.g., MgO, CaO, and  $Y_2O_3$ , substantial molecular stability can be obtained. One of the most studied zirconia combinations is the yttrium-stabilized zirconia.<sup>18</sup> However, if there is high stress in the material, a crack can propagate through zirconia. The laboratory mechanism of toughening zirconia cannot prevent the crack to progress further. The toughening mechanism just makes it harder for the crack to propagate.<sup>19</sup> Such cracks eventually lead to chipping. The chipping can also be attributed to rapid cooling protocols during fabrication when firing the veneering feldspathic porcelain onto the zirconia substructure. This can be overcome to some extent by ensuring slower cooling when the final restoration is removed from the furnace.

Lava (3M ESPE, St. Paul, Minnesota, USA) is another type of zirconia which uses a framework of Yttria-tetragonal zirconia polycrystal (Y-TZP), with high flexural strength, low elastic modulus when compared to alumina, greater fracture toughness. It also displays transformation toughening, when subjected to tensile stresses.<sup>19</sup>

Zirconia does show properties analogous to stainless steel. However, the physical properties of zirconia tend to modulate through surface treatments. Zirconia aging<sup>18</sup> is one such phenomenon, wherein exposure of zirconia to wet environment for an extended period of time can have deleterious effects on its properties. Furthermore, surface grinding can decrease the fracture toughness of the material.<sup>19</sup> This observation was confirmed by Kosmac, who reported that the mean strength and reliability of zirconia reduce considerably after grinding.<sup>18</sup>

Over the last few years, only few studies have reported the long-term results of zirconia restorations, even though its use has been very much prevalent within the dental clinics.<sup>5</sup>

## **SURVIVAL AND LONG-TERM STABILITY FOR PFM VS ALL-CERAMIC FPD**

All-ceramic restorations are indeed controversial for their properties. More so as they are compared to the “gold standard” metal ceramic restorations, which in terms of longevity and long-term predictability offer established results albeit controversy. They are proven to have withstood the test of the time, offering well-established documented and long-term predictable results.<sup>8</sup>

Recently, zirconia has been used to fabricate ceramic FDPs with relatively high strength and good esthetics. Two limitations have been observed clinically. These are veneering porcelain chipping and the possible degradation of zirconia (Zirconia aging), when it is exposed to the moisture of the oral environment. This may lead to decrease in its strength and its plausible deterioration.<sup>12</sup>

The most commonly reported complications with all-ceramic restorations include chipping of porcelain, loss of retention, and endodontic issues. Survival rates of zirconia restorations range from 79 to 100%. The primary cause of clinical failure observed was the chipping of the veneer ceramic.<sup>20</sup> The technical issue of concern was loss of retention which is more frequent with zirconia-based single crowns.<sup>21</sup> Although the use of all-ceramic crowns in posterior region has increased significantly in the last few years, there are not many studies that have documented the clinical outcome of these restorations. It is rather perplexing to know that the zirconia restorations in literature are commonly described in terms of the FPDs and not single crowns, even though single crowns establish the most common fixed prosthodontics treatment.

Various studies have shown that zirconia-based restorations have established survival rates of 100% at 3 or even 5 years. However, most of the studies excluded patients with parafunctional habits. Hence, the results are indeed far-fetched than they appear to be.<sup>22,23</sup>

To date, the comprehensive laboratory testing confirms the marginal fit and strength of the zirconia ceramic restorations; however, the 5 to 10 years clinical studies lack data on success rate and the prime mode of zirconia failure. Studies with long-term clinical evidence on success FPDs with all-ceramic restorations are rare.

## **CRACK PROPAGATION AND FAILURE IN ZIRCONIA**

It is confirmed that zirconia ceramic chipping is principal cause of zirconia failure and continues to be a primary concern.<sup>24</sup> The chipping mechanism is a complex one and not understood very well with respect to dental crowns and bridges.

However, it is known that when tensile stress within the ceramic exceeds the tensile strength of the veneer-

ing ceramic, i.e., when the crack forms and propagates.<sup>25</sup> The tensile stress at a specific location of the ceramic is the sum of external and residual stresses. Residual stresses are simply stresses that are “locked-in” and present within the veneering ceramic and the framework from the time it has solidified. Without the application of any load externally, these stresses persist.<sup>26</sup> These residual stresses, however, can cause immediate or delayed cracking of the ceramic. On the contrary, external stress is formed within the structure by externally applied loads, i.e., mostly during function and mastication. The amount of external stress may vary and is predominated by clinical parameters, such as overloading due to bruxism. Nonetheless, a potential limitation of this all-ceramic system has not clinically been investigated as most of the studies include bruxism in their exclusion criteria.<sup>22</sup>

It is known that the strength of the bond between zirconia and veneering ceramic varies greatly with the type of veneering ceramic used.<sup>27-30</sup> This is probably because different veneering ceramics have different coefficients of thermal expansion, thus causing a mismatch in the coefficient of thermal expansion between the veneering ceramic being used and zirconia.<sup>31</sup> Some researchers have reported that the cooling rate after firing will also affect the bond strength of ceramic-veneered zirconia restorations and thus the cooling rate needs to be set properly to suit the type of porcelain used. It is generally thought that using a porcelain liner at the start of veneering does not lead to improvement in the bond strength.

Bonding between zirconia and veneering ceramics is still in many aspects a mystery, including the mechanism involved. Recent clinical studies reported that chipping or fracturing of veneering porcelain was observed at a relatively higher rate in zirconia-based FPDs than conventional PFM systems.<sup>18</sup>

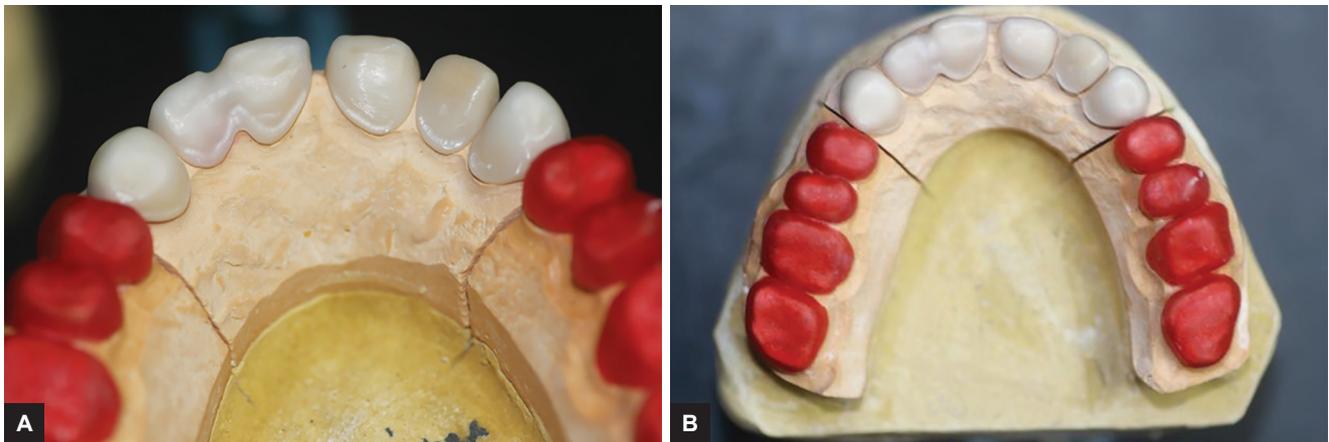
## **CLINICAL RECOMMENDATIONS**

### **Tooth Preparation**

With PFM restorations, dentist is free to be selective with regards to the area of tooth preparation. The areas that will be covered by metal do not require aggressive tooth preparation.

Unlike PFM, the tooth preparation for zirconia ceramic restoration has to be performed in a precise manner following meticulous sequence. Preparation must follow the scallop of the free gingival margin. Tooth preparation for anterior teeth must show reduction as 1.5 mm incisally, at least 1 mm, for esthetic areas, axial reduction up to 1.5 mm can be performed with a 3° taper.

For posterior teeth, 1.5 mm of occlusal reduction, 1 mm of axial reduction, on marginal region is recommended again following the taper of 3°.<sup>18</sup>



**Figs 1A and B:** The resin and coping trials for zirconia restorations fixed partial denture restorations, meticulous steps must be performed to check for marginal adaptation before final finish

The impression technique needs to be accurate, and a silicone impression is required for the master die to be prepared. Followed by which the computer-aided design/computer-aided manufacturing procedure is performed.

Yet, many factors in the hands of the clinicians and technicians can influence the marginal fit of zirconia restorations (Figs 1A and B). It is essential for the preparation to have a linear external line angle to allow adequate scanning.

### **Esthetics vs Strength**

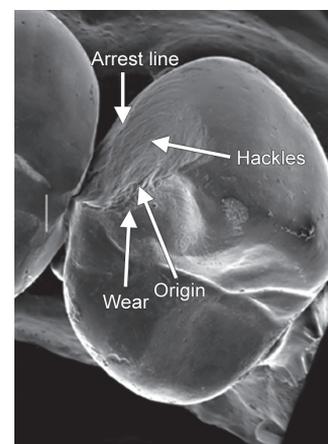
In ideal conditions, without presence of any parafunctional activity and with esthetics as the main concern, leucite-reinforced glass ceramics are the best approaches as all-ceramic restorations.

In posterior region for single crowns, the ideal choice among ceramic restorations would be lithium disilicate full coverage restorations. They provide both adequate strength and esthetics.

The use of zirconia in posterior region is recommended when the conditions are favorable for the same, i.e., adequate crown height, enough tooth structure for retention of the restorations, and no parafunctional activity.

### **High Stress Areas and Parafunction/BruXism**

All-ceramic restorations are not highly recommended in areas of high stresses. The mechanically weaker ceramics, like the feldspathic or silica glass-ceramics, can be recommended only in anterior regions with low functional load. Lithium disilicate can be suggested for premolar and first molar crowns only. Zirconia is not recommended in regions with higher occlusal loads, for example, the second molar region when there is not enough room for ceramic restorations. They are also not indicated for patients with parafunctional habits, such as bruxism<sup>32</sup> due to their potential for chipping and fracture under



**Fig. 2:** Fractographic analysis of the Y-TZP zirconia framework shows that the crack origin was located on a rough area corresponding to the strong occlusal contact point with tooth # 46<sup>22</sup>

high abnormal loads (Fig. 2). In such patients, it is ideal to have metal on the occlusal surface, as even the veneering ceramic of the PFM restoration could fracture under high occlusal. If the patient insists on having metal free restoration, informed consent decision must be made with the patient for the same.<sup>24</sup> It is then also recommended to use occlusal night guard with zirconia restorations to reduce their fracture rate.<sup>22</sup>

Fractographic analysis of the Y-TZP zirconia framework shows that the crack origin was located on a rough area corresponding to the strong occlusal contact point with tooth 46.<sup>22</sup>

### **Tooth Wear**

Current studies suggest that highly polished zirconia exhibits the least wear of antagonist teeth among various other dental materials including enamel. However, the more surface roughness of zirconia, the larger was the wear of the opposing enamel. "Therefore, surface finishing and polishing procedure of zirconia full-contoured restorations was critical for obtaining clinical success."<sup>28</sup>

## Height of Abutment

Specifically for the posterior teeth that have very short clinical crowns, minimal tooth reduction can be done occlusally which can be kept as metal and buccal surface can have porcelain veneer facing.<sup>8</sup> For ceramic FPDs to be used, the height of the connecting surface has to be at least 6.25 mm. Hence, ceramic FPDs are indicated only when the distance between the marginal ridge and the interproximal papilla is at least 4 mm, thus height of the abutment plays a crucial role to ensure adequate mechanical resistance with correct shape and dimensions for all zirconia restorations. This aspect has to be considered carefully when considering a metal-free FPD. Further research is indicated to consider the reliability of zirconia for greater extensions.<sup>18</sup>

## Number of Firings

It is suggested that it is preferable to avoid increasing the number of firings with porcelain as increase in number of firings of porcelain beyond a certain number can bring about a change in the crystalline structure with some veneering porcelains.

With layering technique, the greater the number of firings, the higher is the bond strength. However, a few reports suggest that bond strength of porcelain can reduce beyond six firings.<sup>33-35</sup>

## CONCLUSION

It has been suggested that zirconia-based single crowns did not perform well in the clinics, in spite of the considerable mechanical stability of zirconium oxide ceramic. Failure due to the extensive fracture of the veneering ceramic and loss of retention were frequently found technical problems for this type of ceramic crowns, occurring more often with the zirconia-based FPDs than with PFM fixed partial restorations.

Subsequently, zirconia-based single crowns should not be considered as the primary treatment option for now, and patients must be informed thoroughly about the current limitations. Another factor influencing the choice of the material for single crowns in daily clinical practice is the biologic outcome of the reconstructions. Zirconia shows better biocompatibility with oral tissue than other restorations. This establishes itself as one of the main decisive factors in choosing zirconia restorations over the PFMs.<sup>4</sup>

Thus the above limitations with zirconia must first be overcome by further refinements of the production technology. Further research with long-term trials is essential to gauge the long-term effects of zirconia restorations.<sup>4</sup>

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