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ZIRCONIA RESIN BONDED BRIDGES: AN INNOVATIVE APPROACH FOR MINIMALLY INVASIVE DENTAL PROSTHESES

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Resin-bonded bridges (RBBs) are considered one of the most minimally invasive treatment modalities for the replacement of missing teeth. In an era of metal-free natural-coloured dental restorations, zirconia resin-bonded bridges (ZrRBBs) are an innovative approach for patients requiring a high aesthetic demand where other options are challenging. In addition to the aesthetic appearance, various investigations demonstrated several benefits of using ZrRBBs over other types of framework materials such as low incidence of framework fracture and ceramic chippings. However, debonding could be an issue if the case is not well-planned. Even though long-term randomised clinical trials are rare, the current evidence has shown short- to medium-term high survival rate for cantilevered ZrRBBs that have been cemented using Panavia resin cement. Careful case selection, detailed examinations, and appropriate treatment planning ensure reliable restorations and predictable consequences. The literature also has reported some factors that increase survival rate of ZrRBBs such as retentive tooth preparation confined to the enamel, mechanical treatment of the retainer fitting surface with an air-abrasion of 50 µm alumina particles with a pressure of 0.25 MPa or less, and chemical treatment of the retainer fitting surface with adhesion promoting agents containing an MDP monomer or phosphorylated methacrylates containing a primer in addition to silane.

INTRODUCTION

A resin-bonded prosthesis is defined in the glossary of prosthodontic terms as a fixed partial denture that is luted to tooth structures, primarily the enamel, which has been etched to provide micro-mechanical retention sites for the resin luting agent [1]. This prosthesis has been used in recent decades as a reliable minimally invasive fixed option to replace short span edentulous areas with no or less destructive interventions on the supporting teeth. The resin bonded bridge (RBB) technique was introduced by Rochette in the 1970s as a perforated metal periodontal splint [2]. Since then, a variety of methods have been described in the literature to develop this type of conservative restorative treatment modality. In 1977, Howe and Denehy [3] further described the possible use of an acid-etched cast metal framework to replace missing anterior teeth. The design of the retainer was modified at this stage by using a non-perforated framework to increase the prosthesis retention. However, the long-term survival was not expected as RBBs were considered temporary indirect restorations. “The Maryland bridge” was then developed in 1982 [4]. A metal framework made of nickel-chrome alloys was treated with an electrolytic etching technique to allow resin cement to bond micro-mechanically to the fitting surface of the Maryland bridge. Moreover, the evolution at that period started to involve the replacement of missing posterior teeth with the same design [5]. Several techniques and modifications have been tested over the past 50 years that have resulted in the current effective use of RBBs with different material and design options in specific and carefully selected cases.

Since the first RBB pioneered in 1973, there have been tremendous changes in the design, materials used, and clinical techniques that increase the overall survival of RBBs. Careful treatment planning and improved clinical skills are required for a successful treatment outcome. It has been shown that the replacement of missing teeth with RBBs is a predictable alternative to conventional fixed partial dentures if some favourable prognostic factors are considered such as using Panavia resin cement, retentive tooth preparation, preparation confined to the enamel, silicoating the retainers, supra-gingival margins, Ni-Cr or Co-Cr alloys, and no occlusion on the pontic in lateral excursions [6].

The treatment modality of restoring dental spaces with RBBs has various advantages over conventional fixed bridges. It has been shown that RBBs offer a conservative and cost-effective approach to the replacement of missing teeth compared to conventional bridgework [7]. One of the main advantages of RBBs is its low invasive nature, as minimal or no tooth preparation is needed at all. This reduces risk of biological complications, such as endodontic problems and adverse soft tissue interactions related to the abutment teeth [7, 8]. Consequently, unfortunate catastrophic failures and loss of the abutment teeth can be avoided in many prosthodontic cases. Furthermore, RBBs may be used as an alternative treatment option to implants in juvenile patients and in cases of anatomical limitations [9]. Treatment reversibility and ease of retrievability are also some of the important RBBs benefits that make this restorative technique viable and a must to offer while discussing treatment options with the patient [10]. Moreover, the literature has reported patients' high satisfaction with RBBs [11].

Despite the several benefits of RBBs reported in the literature, there are some major disadvantages of using this type of bridgework as a permanent dental solution. A systematic review published in 2017 shows that the debonding of the restoration is the most common type of failure [6]. This causes RBBs to have a lower survival rate [12] when compared to conventional forms and implant-supported single crowns [13]. Additionally, the greying effect of the metal retainer showing through the abutment teeth is considered a fundamental aesthetic limitation that may prevent some dentists providing their patients with this kind of conservative restoration.

In an era of rapid development of metal-free dentistry and an increase in the patients demanding of natural-coloured dental restorations, several trials have been conducted to investigate the possibility of obtaining the combined benefits of minimally invasive RBBs made of aesthetic metal-free all ceramic materials. Thus, the aim of this article was to review the studies that examined the survival, complications, and clinical application of zirconia resin bonded bridges (ZrRBBs) as aesthetic minimally invasive dental prostheses.

THEORETICAL

Dental Ceramics

Different classifications of dental ceramics have been proposed according to the clinical indications, fracture resistance, ability to be etched, processing methods, firing temperatures, translucency, and composition. However, the most recent, comprehensive, and composition-based classification has been suggested by Gracis et al. [14] in which dental ceramics and ceramic-like materials are divided into three families: glass-matrix ceramics, polycrystalline ceramics, and resin-matrix ceramics. The classification was according to whether a glass-matrix phase is present (glass-matrix ceramics) or absent (polycrystalline ceramics) or whether the material contains an organic matrix highly filled with ceramic particles (resin-matrix ceramics). Manufacturers' recommendations supported by clinical trials have guided the clinical indications of each type of dental ceramics which showed that no single universal ceramic material has been proven to suit all clinical scenarios. Thus, a thorough understanding of the material properties is crucial for both the clinician and dental technician to provide the best dental ceramic restoration that meets the patient needs.

Since the first use of ceramic materials in dentistry, various advances in mechanical properties have improved brittle ceramics to reliable materials with superior strength, fracture resistance, and toughness. Due to their mechanical properties and bonding mechanism, etchable ceramics, such as lithium disilicate, can be considered a successful material for single crowns that restore anterior and posterior teeth [15]. However, no conclusive evidence exists yet regarding the suitability of lithium disilicate ceramics as a material of choice for conventional fixed bridgework to restore edentulous areas especially in the posterior region [16, 17]. On the other hand, non-etchable polycrystalline ceramics, specifically zirconia, can be utilised as single crowns and short- and medium-span fixed bridgeworks even though the opacity and chipping of the veneering ceramics are some limitations that should be considered before providing such treatments [18-20].

All-ceramic RBBs

Trials have not limited the application of ceramic materials in only conventional fixed partial dentures, but have also extended their use to include RBB treatment modality. Since they were introduced in 1991 as an aesthetic alternative to traditional ceramometal RBBs [21], all-ceramic RBBs have been increasingly utilised as conservative indirect prostheses to mainly replace single missing teeth. As a result of the recent technological advancements in resin and ceramic materials, certain clinical situations that indicate use of a non-surgical, but minimally invasive, intervention with a high aesthetic outcome can be managed using an all-ceramic RBBs treatment approach. The early two-retainer design of all ceramic RBBs in the 1990s was associated with a high rate of fast unilateral retainer fractures, mainly at the connector. Nevertheless, the fractured part of the bridgeworks that stayed on the abutment teeth remained bonded for 5 to 10 years [22, 23]. The results of studies since then have supported using a cantilever design for all-ceramic RBBs to reduce the complications and achieve long-term success [24, 25]. In a systematic review and a meta-analysis conducted in 2016, it was demonstrated that cantilever RBBs had lower clinical failure rates compared to two-retainer RBBs [26]. However, evidence has still shown that traditional ceramometal RBBs are the gold-standard treatment modality in such cases, although several studies reported relatively high success rates associated with all-ceramic RBBs [25-28]. A review by Miettinen and Millar reported an estimated annual failure rate of 11.7 % for all-ceramic RBBs, while metal-retainer RBBs had a failure rate of 4.6 % [10].

Due to differences in the study designs, sample selection, and teeth and framework preparation, the survival rate of all-ceramic RBBs varies broadly in the literature - from 73.9 % [23] to 100 % [29]. Moreover, the survival and complication rates differ according to the used ceramic materials, including glass-infiltrated alumina, lithium disilicate, and zirconia. Because of the mixture of the relatively aesthetic appearance of infiltrated glass with the improved strength of alumina, RBBs made of glass-infiltrated alumina were used in the earlier generations of all-ceramic RBBs. It was shown, in a study carried out by Kern [30], that the success rate was 92.3 % in the single-retainer glass-infiltrated alumina group and 67.3 % in the two-retainer group over 5 years. In a recently published study that evaluated the long-term survival of anterior glass-infiltrated alumina cantilever RBBs, it was reported that the 10-year and 15-year survival rates were both 95.4 % and dropped to 81.8 % after 18 years [25]. Nevertheless, one of the major limitations of this study is the small sample size. Likewise, another long-term clinical trial conducted to examine anterior glass-infiltrated alumina RBBs revealed a success rate of 85.18 % at 8 years [27]. However, most of the studies investigating these types of all-ceramic RBBs reported some complications and failures which included debonding and the fracture of the porcelain that decreased their survival rate [23, 25, 27, 30].

With regard to RBBs made of lithium disilicate ceramics, various studies have investigated the survival and complications of such a treatment modality. Lithium disilicate glass ceramic ($Li_2Si_2O_5$) is a type of all-ceramic material that is currently used in the fabrication of single and multi-unit dental indirect restorations because of its colour being similar to natural teeth and its high mechanical properties [14]. In a case series study published in 2013, a 100 % success rate of cantilevered RBBs up to 5 years was reported although there are limitations associated with the small number of patients [31]. Similarly, a clinical study conducted by Sailer et al showed a 100 % success rate over a 6-year follow-up period using the cantilever design [32]. An 88.5 % success rate was reported in another observational study with a follow-up period of 3 years [33]. Thus, it was concluded in a recent systematic review that the 5-year estimated survival rate of glass-ceramic RBBs was 89.8 % [34]. The review also stated that the mid- or long-term clinical results of glass-ceramic RBBs could be lower than the current survival and complication rates presented in the review [34].

As a result of the reported complications of using glass-infiltrated alumina and lithium disilicate ceramics in the fabrication of RBBs; and due to the dramatic increase in the patients' demand for non-metallic appearance restorations, ZrRBBs have been utilised in the last few decades trying to limit the complications associated with all-ceramic RBBs and to achieve high satisfaction and a better quality of life for the patients.

Zirconia RBBs (ZrRBBs)

Zirconium oxide (ZrO_2), or zirconia, is a heterogenous, highly-resistant, polycrystalline ceramic. It has excellent mechanical properties due to a unique phenomenon known as transformation toughening. Pure zirconia exhibits a monoclinic crystal structure at room temperature, but when heated to 1170 °C it transforms to a tetragonal structure. Upon cooling, the transformation from a tetragonal phase to a monoclinic phase induces an approximate 4.5 % volume increase which could produce catastrophic failure, so it is stabilised with oxides such as magnesia (MgO), yttria (Y_2O_3), and calcium oxide (CaO) [35]. Yttria is the most well documented dopant for inducing transformation toughening that helps to block or at least hinder the crack propagation and fractures. Zirconia is mainly used in the form of an yttria-stabilised tetragonal phase (Y-TZP) as a dental prosthetic material for indirect restorations.

In contrast to glass-ceramics, such as lithium disilicate, zirconia cannot be acid etched due to the lack of silica and glass phase within the ceramic and, thus, does not have the advantage of conventional adhesive bonding techniques. On the other hand, unlike glass-ceramics, larger connector dimensions are not required in bridgeworks made of zirconia as it has superior toughness and flexural strength comparing to glass-ceramics [26]. Additionally, zirconia shows excellent biocompatibility and low plaque retention, the same as other ceramic materials [36].

To overcome complications, such as the fracture of ceramics associated with early all-ceramic RBBs, zirconia was introduced and increasingly utilised in the recent years as a strong alternative to glass-infiltrated alumina and lithium disilicate ceramics

Survival of ZrRBBs

Studies in this field defined survival in different ways with many terms such as "complete survival" and "functional survival" [23, 29]. However, the most relevant and best clinically applicable definition of survival is stated as "all-ceramic RBBs remaining in situ for the follow-up time without multiple debondings" [34].

In a recent systematic review reporting the survival rate of all-ceramic RBBs, some benefits of using zirconia to fabricate RBBs have been reported [34]. According to the Chen et al. [34] review, framework fractures mainly occurred in the group of RBBs made of glass-ceramic such as silicate ceramics and alumina-infiltrated ceramics. The results also confirmed that failure events were mainly reported in the group of glass-ceramics [34]. The high survival rate of ZrRBBs reported in the Chen et al. [34] study was in agreement with the results of two studies [29, 37]. The first one conducted in 2014 by Sasse and Kern [29] reported an overall survival rate of 100 % after six years. The other investigation was a retrospective clinical trial carried out by Sailer and

Hämmerle [37] in which the 4-year survival rate was 100 % as well, even though the follow-up in this study was not long enough for other outcomes to occur.

In another systematic review reporting a mean observation period of at least 5 years, ZrRBBs resulted in significantly higher survival rates compared to metal-ceramics, metal-acrylics, glass-infiltrated ceramics, glass-reinforced ceramics, and composites [38]. This is also demonstrated by a study recently published in 2020 which reported a 100 % survival rate of ZrRBBs after a mean follow-up of 10 years even though the small number of patients is considered as a major limitation of the study [39]. Similarly, but with a larger sample size of one hundred and eight ZrRBBs, the Kern et al. [40] trial showed a 10-year survival rate of 98.2 %. Furthermore, a randomised clinical trial examined thirty ZrRBBs during a mean observation time of 41.7 months showed a 100 % survival rate [28].

Hence, literature has agreed that ZrRBBs appear to be very promising and perform best when compared to other RBBs made of different materials.

Debonding as a possible technical complication of ZrRBBs

Despite the high survival rate reported by several studies, some complications have been reported in the literature associated with replacing missing teeth with ZrRBBs. In general, one of the most common complications of RBB treatment modality is debonding [38]. This is particularly more prominent with RBBs made from zirconia due to the unpredictable resin bonding to the fitting surface as a result of the unique physico-chemical properties of zirconia [41].

According to a systematic review conducted by Chen et al. [34], the overall estimated 5-year debonding rate of all-ceramic RBBs was 12.2 %. When the incidence of debonding was further investigated based on the framework ceramic materials, a statically significant difference in the estimated 5-year debonding rate between the group of glass-ceramic RBBs (1.6 %) and ZrRBBs (5.5 %) was found. Another systematic review showed that the studies included in the review reported a high incidence of framework debonding of ZrRBBs with an annual rate of 1.42 [38].

On the contrary, the results of a ten-year study that investigated the survival of one hundred and eight cantilever ZrRBBs showed only six debondings - three of them were caused by traumatic incidents and all six restorations were successfully rebonded and remained functionally and aesthetically successful [40]. The outcome of this long-term clinical study, besides results of other studies [26, 29, 42, 43], challenge the idea of debonding being a major common complication of ZrRBBs and illustrate that debonding might not be an issue if the case is carefully selected and the success criteria are considered.

Advantages of ZrRBBs

Various investigations demonstrated several benefits of using ZrRBBs over other types of framework materials. Subsequently, this could increase patient satisfaction with the aesthetics and function of such minimally invasive treatment modality. In addition to the highly aesthetic appearance of the ZrRBBs that is an inherent property of all-ceramic materials, some other advantages were reported in the literature, such as the low incidence of framework fractures and ceramic chippings.

Based on the findings of a systematic review conducted by Thoma et al. [38], it was stated that the incidence of RBBs lost due to material fractures was material dependent. None of the RBBs made of zirconia were lost due to material fractures. The same systematic review also concluded that the chipping rate was also dependent on the material used. The lowest annual chipping rate of zero was reported for ZrRBBs. Findings of this systematic review are supported by a prospective study in which no fracture of ZrRBBs occurred after 5 years [42], by a randomised clinical trial with a mean observation time of 41.7 months that showed no fracture or chipping of ceramic occurred [28], and by a ten-year clinical trial that reported no ZrRBB framework fractures occurred, but only 3 minor chips of the veneering ceramic were recorded [40].

Also, it has been reported in various trials that ZrRBBs have an extremely rare incidence of biological complications related to the abutment teeth and surrounding tissues, such as dental caries, loss of vitality, and periodontal diseases [34, 38, 39].

Criteria for success

To provide more predictable long-term ZrRBBs with less complications and high patient satisfaction, multiple factors should be considered and explored starting from early on at the case history taking stage.

Successful ZrRBBs require careful case selection, detailed examinations, and appropriate treatment planning. Occlusal and periodontal stability are key roles for the clinical longevity of ZrRBBs. A thorough occlusal analysis is advised to be carried out in the first visits with the help of dental records such as articulated casts and wax-ups. Adequate edentulous and interocclusal spaces in addition to the absence of malaligned and tilted surrounding teeth are critical for the sufficient connector height and framework rigidity of ZrRBBs. This is also important to avoid any occlusal interferences that could cause debonding of the restoration. More importantly, a detailed occlusal assessment and careful planning are crucial for patients with parafunctional habits who are planned to receive ZrRBBs as the best available treatment option [44]. Likewise, successful ZrRBBs necessitate a good periodontal status with minimal teeth mobility. It was revealed that predictable bridgeworks can be expected in well-motivated patients, with plaque control compatible with good periodontal health [45]. Furthermore, a sufficient enamel structure as well as absence of carious lesions and pre-existing restorations in the abutment teeth are fundamental for optimal results [46].

With regard to preparing abutment teeth, there is conflicting evidence in relation to the consequences. Some studies suggest no benefit of an extensive abutment preparation on the overall success of ZrRBBs and this may lead to increased biological complications. It was stated that a significant preparation is associated with an increased risk of failure [46]. A prospective study demonstrated that bridges made with minimal preparation are shown to be superior in terms of longevity than those for which other types of tooth preparation is made [47]. Ibbetson, in his review, showed that the preparation should only be undertaken after due thought as to its consequences, and any significant degree of preparation is likely to penetrate the dentine which may lead to technical and biological complications [48]. On the other hand, several studies have reported the most superior results with preparation and modification of the teeth. A systematic review showed better survival rates of RBBs, in general, where the retentive tooth preparation confined to the enamel is performed [6]. Another systematic review by Thoma et al. found that the debonding rate could be decreased by improved abutment teeth preparation designs [38]. In the same way, studies focused only on RBBs made of zirconia demonstrated that some preparation designs such as lingual veneers, small proximal boxes, pin holes, guiding planes, and cingulum grooves improved the seating and retention of the framework and resulted in decreased debondings and a higher survival rate [23, 40, 42, 49]. It is recommended to perform anatomic, rounded, and well-finished preparations where needed to ensure adequate support for the ceramic material and to avoid any unfavourable technical or biological consequences [18]. However, ZrRBBs can also survive without any tooth preparation [50].

Based on the findings of most of the studies in this field, the cantilever design is considered essential for successful and long-lasting ZrRBBs. Wei et al. conducted a systematic review and meta-analysis on the clinical performance of different framework designs and found that the cantilever design demonstrated lower clinical failures than the two-retainer design [26]. This finding is supported by another systematic review that stated RBBs with one retainer tooth showed the highest survival rate [38]. To elaborate further, recently published systematic review papers specifically studied the survival and complication rates of all-ceramic RBBs showed that cantilevered all-ceramic RBBs had a higher survival rate and lower debonding and fracture rates compared with the two- retainer design [34, 50].

Due to the absence of a glass phase, bonding to non-etchable zirconia has been challenging and unpredictable since its first use as a framework for RBBs. Hence, a variety of bonding methods and fitting surface treatment techniques have been suggested in several laboratory and clinical trials. While most of the reported methods and techniques have been tested in the laboratory, only a few bonding methods were clinical-based trials. Additionally, some of the reported techniques are time consuming, complicated, and technique sensitive [43]. One of the clinically suggested techniques for a zirconia fitting surface treatment is air-abrasion. Even though the effect of air-abrasion on the mechanical strength of zirconia appears controversial, there are no controlled clinical trials showing a negative effect of air-abrasion with moderate pressure on the clinical outcomes of ZrRBBs. Thus, it is recommended to use 50 μm alumina particles with a pressure of 0.25 MPa or less to minimise the zirconia subsurface damage, but to provide the required micro-roughening and cleaning of the bonding surfaces leading to improved bonding and, subsequently, the survival of the restorations [43]. The chemical treatment of the fitting surface is advised in addition to the mechanical treatment with the air-abrasion. Adhesion promoting agents containing a Methacryloyloxydecyl dihydrogen phosphate (MDP) monomer or phosphorylated methacrylates containing a primer with silane could result in the significantly improved adhesion to the bridge retainer [36]. With regard to the most successful luting cement, the Panavia resin cement reported the highest survival rate [6].

In summary, an appropriate case selection, adequate treatment plan, and paying close attention to the clinical and laboratory details are crucial elements for the clinical longevity of ZrRBBs.

CONCLUSIONS

Innovative ZrRBBs have shown very promising outcomes in the recent years for replacing anterior short span edentulous areas with high aesthetic results, minimal teeth destruction, and less technical and biological complications. Careful case selection, detailed examinations, and appropriate treatment planning ensure reliable restorations and predictable consequences. The current evidence has shown short- to medium-term high survival rates for cantilevered ZrRBBs that have been cemented using Panavia resin cement. The literature also has reported some factors that increase the survival rate of ZrRBBs such as the retentive tooth preparation confined to the enamel, the mechanical treatment of the retainer fitting surface with air-abrasion of 50 μm alumina particles with a pressure of 0.25 MPa or less, and the chemical treatment of the retainer fitting surface with adhesion promoting agents containing an MDP monomer or phosphorylated methacrylates containing a primer in addition to silane. Nevertheless, more long-term randomised clinical trials are essential to investigate the accurate longevity of ZrRBBs, patients' satisfaction and improvement of their quality of life, and alternative simple and less technique sensitive bonding methods and framework fitting surface treatment techniques.

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