ISSN 2706-6819 Vol.4, Issue 11: 1-6, DOI: 10.25236/IJFM.2022.041101

Research progress on effect of different materials on the retention rate of Resin-Bonded Bridges

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Abstract: *With the improvement of minimally invasive demand for prosthodontic treatment, resin-bonded bridges are more and more widely used in dentition defects, but the retention rate of resin-bonded bridges limits the popularization and application of this repair method to a certain extent. Resin-bonded bridge repair materials have developed rapidly in recent years, and the retention rate of resin-bonded bridges has increased. This paper summarizes the effect of resin-bonded bridge materials on the retention rate of resin-bonded bridges, in order to provide reference and guidance for clinicians.*

Keywords: *Resin bonded bridges, Restorative material, Retention rate*

1. Introduction

With the increasing economic level in China, people's awareness of self-protection has increased significantly, and the minimally invasive demand for prosthodontic treatment has also been increasing. Resin-Bonded Bridges, in traditional restorative treatment, resin-bonded bridges have less dental tissue preparation, preferential price, short clinical operation time, and less patient discomfort during operation compared with fixed bridge restorations, and patients have the opportunity to choose other restorative methods even after repair failure, which greatly meets people 'needs for minimally invasive surgery [1]. However, the relatively low survival rate and high technical sensitivity of the resin-bonded bridge limit clinicians' choice of the first repair option. Nowadays, with the development of bonding technology and repair materials, the retention rate of bonding bridges has also increased. The bonding bridge can be made of metal materials, ceramic materials and resin materials. Different materials have different repair effects due to different mechanical properties. This article reviews the effect of different materials on the retention rate of resin-bonded bridges in order to provide reference and guidance for clinicians.

2. Manifestation of resin-bonded bridges failure

(1) Shedding and loosening of resin-bonded bridges: The most common cause of failure of resin-bonded bridges is debonding. Debonding is closely related to the choice of adhesive, the pretreatment of adhesive surface, the choice of abutment teeth, the recovery of occlusal relationship and the clinical operation of the physician. (2) Breakage of resin-bonded bridge: The stress of resin-bonded bridge is concentrated in the connector, and the design of connector, the mechanical properties of resin-bonded bridge repair materials, and abnormal force are the causes of resin-bonded bridge breakage. (3) Secondary caries, fracture and shedding of abutment teeth: poor marginal sealing of resin-bonded bridges or resin-bonded bridge retainers and long marginal lines will cause secondary caries of abutment teeth, and reasonable design of resin-bonded bridges will reduce the damage to abutment teeth. (4) Gingivitis: food impaction in poor contact with adjacent teeth, loosening and subsidence of resin-bonded bridges, compression of the gingiva by pontics or accumulation of food debris. (5) Poor aesthetic results: different restorative materials have different aesthetic properties, all-ceramic materials have better aesthetic effects and biocompatibility, while resin materials will show discoloration after a long time, porcelain-fused-to-metal resin-bonded bridges will show porcelain collapse phenomenon, and torqued abutments will show metal color.

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3. Influencing factors of resin-bonded bridges retention rate

3.1. Dentition defect site

Resin-bonded bridges are commonly used in anterior regions with less stress, and Kern [2] recorded the clinical application of cantilever alumina glass-permeable porcelain ceramic resin-bonded bridges in anterior regions over the past 18 years, with 10-year and 15-year survival rates of 95.4% and 81.8%; Kern et al [3] evaluated the 10-year survival rate of 92.0% by applying zirconium oxide all-ceramic cantilever resin-bonded bridges in anterior regions through clinical studies, and also mentioned in the article that the cause of anterior hypodontia had no effect on resin-bonded bridge retention; Thoma et al [4] analyzed a total of 1227 resin-bonded bridges in 18 anterior regions and 11 clinical studies on 602 resin-bonded bridges in posterior regions, and summarized that the deadhesion rate in posterior regions over 5 years was 21.8% (95% CI: 12.1% – 37.5%) higher than 11.2% (95% CI: 7.2% – 17.2%) in anterior regions.

Thoma et al [4] summarized and analyzed 14 clinical studies with a total of 795 resin-bonded bridges in the maxilla and 12 in the mandible, and concluded that the debonding rate within 5 years was 12.4% (95% CI: 7.6% – 19.9%) in the maxilla and 18.2% (95% CI: 11.2% – 28.6%) in the mandible, and there was no significant difference between the maxilla and the mandible. Tanoue et al [5] suggested that the survival rate of maxillary resin-bonded bridges was higher than that of mandible.

3.2. Materials

Bonding bridge materials mainly include metal porcelain, all-ceramic and fiber reinforced resin, of which all-ceramic materials include lithium disilicate ceramics, zirconium oxide ceramics, alumina glass penetration porcelain ceramics and so on. Porcelain-fused-to-metal (PFM) resin-bonded bridge has good mechanical properties, high elastic modulus and is not easy to break. The main reason for its failure is debonding. All-ceramic bonding bridges have good biocompatibility and good aesthetic results, but alumina-based glass-penetrating porcelain ceramics have low strength and are prone to fracture; zirconia ceramics have high strength, large elastic modulus, and are not easy to fracture. Fiber-reinforced resin bonding is cheap and beautiful, but the strength is low, and the long-term repair effect cannot be guaranteed.

3.3. Dental adhesives

Choosing proper adhesive can greatly improve the retention rate of bonding bridge, and the commonly used adhesive is mainly divided into resin adhesive, glass ionomer cement and resin cement. Among them, resin cement refers to a class of resin-based composites with adhesive and sealing properties, which are clinically used to cement or bond fixed restorations, and their effects are superior to traditional inorganic cements [6]. The stress distribution is different between different adhesives, and the stress distribution of adhesives is related to the characteristics of adhesives. Penteado et al [7] compared the bonding of seven groups of resin cements to lithium disilicate glass ceramic bonding bridges, and concluded that the stress concentration of the bonding layer was positively correlated with the elastic modulus using three-dimensional finite element analysis.

3.4. Design

The design of the resin-bonded bridges requires consideration of multiple factors, such as patient needs, anatomical limitations, and biomechanics. The bonding bridges are divided into single retainer resin-bondedbridges and double-side retainers resin-bonded bridges according to the number of retainers. single retainer resin-bonded bridge abrades less dental tissue, makes it easier for patients to maintain oral hygiene, has a lower incidence of secondary caries, and has a relatively simpler clinical operation; in the past, double-side retainers resin-bonded bridges were considered to be more firm, and Alraheam et al [8] summarized recent studies that showed that the long-term retention rate of single retainer resin-bonded bridges was higher than that of double-side retainers resin-bonded bridges, and Kern et al [9] concluded through clinical studies that the retention rate within 10 years was 73.9% for double-side retainers resin-bonded bridges and 94.4% for single retainer resin-bonded bridges. Mine et al [10] concluded that the reason for this may be related to the small mobility in different directions of the abutment teeth of the double-side retainers resin-bonded bridge, and the difference in mobility between the two abutments often leads to torsional and shear forces in the retainers on the abutment teeth, which leads to debonding

ISSN 2706-6819 Vol.4, Issue 11: 1-6, DOI: 10.25236/IJFM.2022.041101

of the retainers to teeth with less mobility, and different mobility can lead to difficult to detect debonding and increase their likelihood of caries.

4. Effect of different material on resin-bonded bridges retention rate

4.1. Metallic material

The pretreatment of metal materials greatly improves their bonding efficacy, and in 1979, Tanaka et al [11] provided appropriate surface treatments through pitting corrosion to ensure the improvement of resin surface bonding efficacy. Livaditis and Arora et al [12, 13] also established pretreatment methods combining ultrasonic dispersion, electroplating tin with metal surfaces. The combination of these techniques and materials makes it possible to bond base metal alloys, such as Ni-Cr and Co-Cr alloys. Metallic materials have good mechanical properties, high hardness, strength, high modulus of elasticity, not easy to break, and easily meet the thickness requirements of resin-bonded bridge wing plate. Baran et al. [14] obtained that the in vitro fracture strength of double-ended cobalt-chromium alloy resin-bonded bridges was 637.47 ± 151.91 N by in vitro fracture strength experiments and three-dimensional finite element analysis, and the stress concentration point was the connector body, but abutment fracture eventually occurred.

The retention rate of metal resin-bonded bridges varies greatly in different articles, and Thoma et al [4] analyzed that the 5-year retention rate is 91.3% and the 10-year retention rate varies from 18% [15] to 88% [16], which may be related to the evaluation method or failure criteria. In addition, several other variables, such as the resin-bonded treatment method and the metal alloy used, may also influence the retention rate. Yoshida et al [17] collected and observed patients who underwent double-ended metal pterygium resin-bonded bridges as well as fixed denture restorations from 1990 to 1994 and found that the 15-year cumulative survival rates were 66.5% and 61.6% in the metal pterygium resin-bonded bridge and fixed denture restorations groups, respectively, and recommended the preferred resin-bonded bridge restorations for patients with mild or no caries in abutment teeth. Tanoue et al [18] evaluated the retention of 311 metal-resin-bonded bridges in 266 patients between 1983 and 2013, with a retention rate of 41.2% ± 6.5%. Saker et al [19] conducted a 60-month comparative study of 20 alumina-based glass-permeable porcelain bridges and 20 traditional porcelain-fused-to-metal bridges in the anterior region and found that the 5-year retention rate of porcelain-fused-to-metal bridges was 100% and 90% for alumina-based glass-permeable porcelain bridges, and concluded that there was no significant difference in the effect of metal materials and all-ceramic materials on the retention rate of resin-bonded bridges, but the authors also stated their study limitations, the sample size was small, and the observation period was short

According to a certain amount of literature, the author thinks that the main reason for the failure of metal bonding bridge is debonding, and the pretreatment of metal surface is the key to ensure its bonding strength. Generally, the methods used include electrolytic etching method, alumina sandblasting method, silicon film method, chemical etching method and tin plating method. However, the economy of pretreatment methods is relatively poor, coupled with poor metal aesthetics, more and more clinicians and patients currently prefer to use all-ceramic material resin-bonded bridges, and with the development of all-ceramic materials, more and more studies [20] have shown that the retention rate of all-ceramic material resin-bonded bridges is even higher than that of metal material resin-bonded bridges.

4.2. All-ceramic material

With the advent of Land [21] 's first long stone all-ceramic crown in 1904, this nonmetallic material with good biocompatibility is increasingly popular with clinicians and patients. In 1965, Mclean [22] pioneered the addition of Al2O3 to feldspar ceramic materials to improve mechanical and physical properties. Today, prosthodontic ceramics have been combined from low-strength ceramics and low-adhesives to modern high-strength ceramics and improved bonding techniques, which can be applied in a variety of clinical cases. The brittleness, tensile strength, wear resistance and edge sealing of ceramic materials have always limited the application of ceramics in the oral cavity. With the development of ceramic technology, these problems have also been solved. Ceramic materials for all-ceramic bonding bridges include CAD/CAM zirconia, alumina-based glass penetration porcelain, and hot die-cast lithium silicate glass ceramic. Among them, zirconia has excellent strength, fracture resistance and toughness [23] and is widely used in resin-bonded bridges; hot pressing lithium silicate glass ceramics have transparency and refractive index close to natural enamel, and cast porcelain restorations have realistic color and good marginal adaptation, which is currently recognized as the all-ceramic restorative material with the best aesthetic effect [24]. All-ceramic resin-bonded bridges can take into account excellent aesthetic conditions while minimizing the amount of tooth preparation, and on this basis, improved positioning splints can be used to ensure accurate bonding, reduce technical sensitivity, and make the restorative effect as optimal as possible [25].

Because the addition of alumina improved physical properties, Galiatsatos and Bergou [26] conducted an 8-year study and found that the retention rate of alumina glass permeable porcelain resin-bonded bridges in the anterior region was 85.18%.Kern [27] evaluated the long-term retention rate of glass-permeable porcelain bond bridges with double retainer and single retainer alumina base, and found that the retention rate of bond bridges was 92.3% in the single retainer group and 67.3% in the double retainer group. The study also showed that bond bridge breakage was the most common cause of failure in 5 of 37 bond bridges. Saker et al [19] conducted a 60-month comparative study of 20 alumina based glass permeable porcelain bridges and 20 traditional porcelain-fused-to-metal bridges in the anterior region and found that the number of shedding of porcelain-fused-to-metal bridges was less than that of the all-ceramic group, with 3 cases of debonding and 2 cases of fractures in the all-ceramic group. In Chen et al [28] 's systematic review on the retention rate of all-ceramic resin-bonded bridges, some advantages of using zirconia all-ceramic materials to fabricate resin-bonded bridges were reported, and it was concluded that stent fractures mainly occurred in glass-based ceramics such as silicate ceramics and alumina glass-permeable porcelain resin-bonded bridges, and zirconia all-ceramic resin-bonded bridges showed superior retention rate. This is consistent with what has been described in a review by Thoma et al [4] on bond bridge retention, particularly with glass-based ceramic junctions and scaffold fractures being the most common. Compared with glass ceramics (such as lithium disilicate), zirconia is not acid-etched due to the lack of silica and glass phase in ceramics, so it does not have the advantages of traditional bonding techniques. On the other hand, unlike glass ceramics, zirconia scaffolds have smaller linkers and therefore have better toughness and bending strength compared to glass ceramics [29].

Thus, the main reasons for the failure of all-ceramic resin-bonded bridges are the fracture and debonding of resin-bonded bridges. In clinical application, glass-based all-ceramic resin-bonded bridges are mainly used for the loss repair of anterior teeth, with greater force on the posterior teeth and more applications of zirconia all-ceramic resin-bonded bridges.

4.3. Fiber-Reinforced Composites

Fiber-reinforced composite resins (FRCs) have a color very similar to teeth, a modulus of elasticity similar to teeth, and good resin-bonded properties. With the increasing demand for metal-free cosmetic restorations in modern times, fiber-reinforced composite resin materials have been widely used in the oral cavity. Fiber-reinforced composites can be made of carbon graphite fibers, aramid fibers, polyethylene fibers, and glass fibers [14], and polyethylene fibers and glass fibers are mainly cited in the dental field. Filip et al [30] investigated the biomechanical behavior of bond bridges of direct fiber-reinforced composites, indirect fiber-reinforced composites, gold alloys, lithium disilicate glass ceramics, and zirconia by everStick (Stick Tech, Finland), and also found that the stress concentration at the junction, but those with fiber enhancers could significantly disperse the stress, and the stress of everStick materials was the smallest and the performance was the best compared with the two reinforced fibers. Tezvergil-Mutluay et al [31] found that everstick has firm chemical binding and high flexural strength, and the microcrack mechanism of the internal structure of the material can simulate stress interruption in the periodontal ligament and has a significant periodontal protective effect.

Kumbuloglu and özcan [32] found that fiber-reinforced composite resin-bonded bridges generally failed due to prosthesis debonding or veneer composite delamination, but almost all complications were minor and all restorations remained functional after physician intervention, except for one initial restoration. After 4.8 years of follow-up, the survival rate of fiber-reinforced composite resin bonded bridges was 97.7%. In a review, Mendes et al [20] concluded that the retention rate of fiber-reinforced composite resin bonded bridges within 5 years was 81.7%. Several studies by Van Heumen et al [33-35] showed that the retention rate of dimensional reinforced composite resin bonded bridges was 60% -80% within 5 years. In order to prolong the service life of fiber-reinforced composite resin bonding bridge, Chen et al [36] studied the fracture factors of fiber-reinforced composite resin bonding bridge. Through multiple load-failure tests, it was concluded that the main factors affecting its performance were fiber volume, fiber position and fiber arrangement direction. Brunner et al [37] investigated the bearing capacity of resin-bonded bridges of different materials under cyclic loading, in which the bearing capacity of fiber-reinforced composite resins was significantly smaller than that of metal materials and zirconia all-ceramic materials, but not significantly different from lithium disilicate glass ceramics.

ISSN 2706-6819 Vol.4, Issue 11: 1-6, DOI: 10.25236/IJFM.2022.041101

5. Conclusion

There are relatively few literatures on the effect of different repair materials on resin-bonded bridges at home and abroad, and the opinions are not uniform, and no accurate conclusion can be drawn. Because the mechanical properties of resin-bonded bridges are changed greatly by different repair materials, three-dimensional finite element analysis has become a trend to study the biomechanical properties of resin-bonded bridges. It is believed that with the development of computer technology, restorative materials and stomatology technology, resin-bonded bridges will be widely used.

Acknowledgements

The manuscript was totally drafted and written by the authors, without including any external individual.

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