

Research Progress of Ceramic and Resin Onlays in the Restoration of Tooth Defects

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Abstract: As the concept of minimally invasive repair has gradually become the mainstream, onlays have attracted more and more attention from clinicians. Ceramic and resin are two kinds of materials that are mainly used to make onlays. This article will review the physical properties, bonding properties and clinical applications of the two materials, in order to provide reference for clinical practice.

Keywords: Ceramic Materials; Resin Material; Onlay.

1. Introduction

There are various methods to restore tooth defects. In the past, it was believed that full crown had good retention and was more conducive to protecting the remaining tooth tissue, while post-core crown was more commonly used in endodontically treated teeth. With the popularization of minimally invasive concept, the preservation of more healthy tooth tissue and better protection of periodontal tissue health have become the focus of people's attention in tooth defect restoration. Because of the small amount of tooth preparation, in vitro fabrication of onlays can better restore the tooth shape and adjacent relationship, and has gradually become a new choice for the restoration of primary and permanent tooth defects. Composite resins and ceramics are commonly used in onlay fabrication. This review will focus on the physical properties, bonding properties and clinical applications of the two materials.

2. Physical Properties

Wear is the process of material loss due to mechanical friction or chemical corrosion. Abnormal wear of dental restoration materials may lead to occlusal problems, affect the masticatory function of patients, and even lead to the failure of aesthetic restoration.

Ceramic materials have high hardness and good wear resistance, but their wear on teeth is large. Lee [1] et al. studied the case of glass ceramic and gold alloy grinding with enamel, and the results showed that the wear amount of enamel and gold alloy grinding was less than that of glass ceramic grinding. A study [2] compared the wear of 9 kinds of ceramic materials, and the results showed that the latest low-melting titanium alloy and gold alloy ceramics had the best wear resistance, which was close to that of natural teeth. Liu Yi-hong [3] et al used zirconia balls with different surface treatment methods to ground natural enamel, and the results showed that the width of the wear spot on the enamel surface was as follows: glazing group > rotary grinding group > untreated group > 106-125 μm emery rubber wheel polishing group > 20-30 μm emery rubber wheel polishing group > 1 μm emery polishing group. It is suggested that fine polishing can be used to reduce the wear property of the implant in clinical work, but it can not completely eliminate it.

The poor wear resistance of composite resin materials has

always been a problem, but its wear on natural teeth is small. Some studies have shown [4] that the friction properties of composite resin and enamel are similar and will not lead to excessive abrasion of natural teeth. The wear resistance of composite resin is determined by the composition and content of filler, bonding state of matrix and filler, and curing condition. Some scholars believe [5] that the higher the content of filler per unit volume of composite resin, the higher its mechanical strength and hardness, but the size and nature of filler particles have no significant effect on the wear behavior of composite resin. Jin Jie [6] et al. found that the wear depth of Z350 resin is greater than that of other resins with higher filler content, and material loss occurs mainly in the form of friction and wear. However, CLEARFIL MAJESTY Posterior (CMP) resin showed better wear resistance due to its higher filler ratio.

At the same time, the temperature and PH value in the oral system are constantly changing, and these factors will also directly or indirectly affect the wear properties of composite resin. Some studies [7] used FiltekTMP60 resin to conduct wear experiments and found that, when the test load was constant, lower PH value could lead to increased wear degree of composite resin material and decreased wear resistance and microhardness. This may be due to the occurrence of chemical corrosion, which affects the wear resistance of the material [8].

Resin materials are not wear-resistant, while porcelain materials, although better wear resistance, are prone to chipping. In recent years, with the development of materials science, a new type of ceramic toughening resin material has emerged, which is composed of composite resin and ceramic particles heterogeneous mixing [9]. Wu Chuanxing [10] used two kinds of ceramic resin composite materials (Vita Enamic and Lava Ultimate) and two kinds of glass ceramic materials (IPS e.max CAD and IPS Empress CAD) to ground ultra-thin inlays with talc porcelain. The results show that Lava Ultimate not only wears itself the least, but also causes the least damage to the abrasive material among the four materials. Jae-Won Choi [11] et al. conducted in vitro experiments to compare the grinding of five materials with primary teeth, and the results showed that the wear resistance of resin ceramic material Vita Enamic was higher than that of the other four materials, but the abrasion of primary teeth was higher. Therefore, in clinical work, composite resin inlays should be the main method for repairing large area defect of

primary teeth. At present, resin ceramic composites are not widely used, and the research on their properties needs to be improved.

Restoration or residual tooth tissue fracture is a major cause of restoration failure. The disadvantage of composite resin is its poor fracture resistance due to its own composition. Improving the fracture resistance of composite resin is one of the goals of the development of dental restorative materials. Xu Wenjing [12] compared the fracture resistance of three different resin inlays through in vitro experiments, and found that Z350 resin showed excellent fracture resistance. This is due to the higher filler content of Z350 resin, which increases its hardness, and the combination of filler and matrix increases its surface area, thereby enhancing its stress transfer ability. The experimental study of Ning Hongliang et al. [13] found that SureFli SDR resin with higher filler content has better fracture resistance than Z350 resin. The experimental results are in agreement with the above theory. Vasiliki Tsertsidou et al. [14] used four different resin inlay materials to repair molar MOD holes and detected the fracture peak and fracture behavior through in vitro experiments. The results showed that the fracture peak of resin inlay restoration was significantly higher than that of direct resin filling restoration. In the resin inlay restoration group, the fracture peak of the short fiber composite resin inlay group was the highest, and the fracture mode was mainly characterized by reparable crown fracture. This short fiber composite resin is made by adding polyethylene fiber reinforcing agent to the composite resin to enhance its performance. When the restoration is loaded by these fibers, the stress can be effectively dispersed to reduce the occurrence of fracture of the restoration and the remaining tooth tissue [15]. However, due to its high technical sensitivity and lack of evidence-based medicine guidance, this material is rarely used in clinical practice.

Ceramic inlays are better than resin inlays in fracture resistance, which can better protect the remaining tooth tissue and is widely used in clinical practice [16]. Zhan Quanhua [17] et al. used a universal mechanical testing machine to compare the fracture resistance of lithium disilicate ceramic inlays and zirconia inlays and found that zirconia inlays had better fracture resistance. However, the results of a meta-analysis [18] showed that lithium disilicate ceramic inlays had stronger fracture resistance than other ceramic inlays. This difference may be related to whether the experimental teeth were treated with root canal treatment and the different experimental methods in vivo and in vitro.

At the same time, the base material is located between the ceramic inlay and the remaining tooth tissue, and its elastic modulus is quite different from the two, which affects the stress and fracture strength of the ceramic inlay. Zhang Dan [19] et al., using the method of three-dimensional finite element analysis, found that the stress distribution of inlays in the base group and the non-base group was almost the same, but the maximum principal stress value of the base group was lower than that of the non-base group. At the same time, this study believed that the selection of base materials with high elastic modulus and close to the elastic modulus of dentin could increase the fracture resistance of the inlays and the remaining tooth tissue. This is consistent with the findings of Saridag[20] et al.

3. Performance of Bonding

The retention of onlays mainly depends on the bonding of enamel and dentin [9]. The commonly used adhesives for

resin onlays and porcelain onlays are resin adhesives. The difference between the two mainly lies in that resin onlays do not need restoration treatment, while porcelain onlays need corresponding pretreatment of the restoration surface to obtain satisfactory bonding effect.

Sandblasting and acid etching are common surface treatments for ceramic onlay. Wang Danyang [21] found through in vitro study that the best bonding effect could be obtained by etching IPS E. Max Press ceramic onlays with 5% hydrofluoric acid for 60s or 10% hydrofluoric acid for 20s, and the etching time could be shortened if combined with coupling agent. Zhang Jie [22] applied 9% hydrofluoric acid to treat the polymeric porcelain surface and tested its shear strength, and the results showed that the maximum shear strength could be reached when hydrofluoric acid was used to etch for 30s. Hydrofluoric acid can dissolve silica, thus forming pores and increasing the bonding area [23, 24]. At present, it is clear that the pretreatment of ceramic onlays with hydrofluoric acid can promote the bonding of ceramic onlays. The treatment effect is related to the concentration and time of hydrofluoric acid. It is generally believed that 2.5%-10% HF acid etching for 20 seconds to 1 minute can form a suitable roughness on the surface of ceramic [21]. It is recommended to use a lower concentration of HF and pay attention to the proper disposal of wastewater after use. Since zirconia ceramic cannot be acid-etched by hydrofluoric acid, sandblasting is needed to increase its surface roughness and obtain a larger bonding area to improve its bonding performance. With the emergence of silane coupling agents, some scholars [25] believe that sandblasting combined with silane coupling agents can obtain ideal and stable bonding effect on the inlay surface.

The phenomenon of bacteria, liquid, molecules or ions infiltrating into the gap between the tooth and the restoration is called microleakage [26]. The selection of appropriate adhesives and the application of correct bonding methods are the key to reduce the occurrence of microleakage and prevent restoration failure. Chen Liang [27] et al. conducted an in vitro study on the bonding properties of ceramic onlay, and the results showed that the shear strength and compression strength of self-adhesive resin were higher than those of total etch resin. At the same time, the patients were followed up for 6 months, and the results showed that the ceramic inlays bonded with the two adhesives had satisfactory bond strength and microleakage resistance. The study by Seisuke[28] et al. also supports this view. This view is also applicable to the bonding of resin onlays. Shen Bao-lian [29] compared the bonding performance of four different adhesives to resin inlays, and the results showed that the microleakage value of self-adhesive resin PULPDENT Embrace was lower than that of other three adhesives, and had the highest shear strength value. The study of Gao Kai [30] et al. can also confirm this view.

Some studies [31] compared the microleakage of porcelain resin inlays, all-ceramic inlays and composite resin inlays, among which the microleakage value of porcelain resin inlays were the smallest, followed by composite resin inlays, and the microleakage of porcelain inlays was the most serious. Bao Pingping [32] et al. also obtained a similar conclusion in their experimental study. The reason may be related to the different adhesives and bonding methods used in the three material inlays. The composition of resin inlays and resin cement is similar, and the formation of chemical bond is easier. However, porcelain inlays need pre-treatments such as

sandblasting and acid etching to achieve the chemical bond between porcelain materials and resin cement, so resin insets can achieve better bonding effect. Wang Qianxia [33] 's experiment also confirmed that the microleakage value of composite resin insets was smaller than that of porcelain insets. Meanwhile, the study also found the influence of saliva PH value on microleakage: the smaller the saliva PH value, the greater the microleakage value of the insets. Similar to the mechanism by which saliva PH affects the wear properties of materials, it may be related to chemical corrosion.

4. Clinical Application

Considering the above properties of ceramic inlay and resin inlay, composite resin inlay has lower wear resistance but less microleakage. Therefore, composite resin inlay is suitable for the restoration of small tooth defects or parts with small bite force, such as children's primary teeth. Porcelain inlay is more suitable for the restoration of permanent teeth, especially teeth with large area defect or root canal treatment, because of its better wear resistance and fracture resistance.

Due to the characteristics of the anatomical structure of primary molars, when a large area of caries occurs, due to the narrowing of the tooth neck and the thin enamel-dentine junction, it is easy to cause the filling material to fall off and even the tooth fracture. At this time, metal prefabricated crown can be used to repair the defect of filling treatment [34], but the type of prefabricated crown is fixed, which is different from the shape of the child's teeth. It cannot restore a good occlusal relationship and adjacent relationship, and is prone to the loss of prefabricated crown, abrasion and perforation, and secondary caries [35]. Moreover, the composite resin embedding system is simple to manufacture, short production cycle, and easy to be cooperated with by children, so it is widely used in clinical practice. Li Yanfan et al. [36] respectively applied the methods of superporcelain inset, metal prefabricated crown and direct filling to repair large area defect of primary teeth, and found that superporcelain inset had excellent performance in the aspects of restoration integrity, marginal fitness, gingival reaction, secondary caries, wear degree and adjacent relationship during the observation period of long-term curative effect. This is consistent with the conclusion of Mittal et al. [37], who observed the long-term efficacy of resin inlaid and metal prefabricated crowns in repairing large defects in primary molars. Huang Xuemei et al. [38] showed that the clinical effect of resin inlays restoration in children's primary teeth was better than that of direct filling, which was conducive to improving the masticatory function of children and the children had a high degree of cooperation.

However, the application of composite resin inlay in the restoration of primary teeth also has its disadvantages [39], such as poor cooperation of children, difficulty in impression making and wet isolation. The pulp Angle of primary teeth is relatively high, and the inlay needs a certain thickness, which may expose the pulp Angle during the preparation of the cavity. During the clinical operation, the inlay restoration should be selected according to the condition of the child's tooth defect and the cooperation.

The hardness of porcelain inlays is higher and the amount of tooth preparation is larger than that of composite resin inlays. Therefore, porcelain inlays are widely used in the restoration of permanent teeth and young permanent teeth. According to the study of Nie Dezhou et al. [40], both composite resin inlaid restoration and metal prefabricated

crown restoration of young permanent teeth with large defects can achieve good results, but the crown continued to elongate after 2 years in the metal prefabricated crown restoration group, which may be related to the continued eruption of the teeth, and may increase the incidence of gingival inflammation, secondary caries and other complications. Sun Hao et al. [41] studied the process of adolescent tooth eruption and restoration of the first molar with composite resin filling and porcelain inlaid restoration. One year after restoration, the measurement of the affected teeth showed that the opposite teeth in the resin filling group had a tendency to elongate, which indicated that the resin restoration had excessive wear, while the cusp of the porcelain inlaid restoration group had little change. This study suggests that porcelain inlays may be more beneficial to the occlusal establishment and facial shape development of young permanent teeth with large area defects. Dilisa et al. [42] conducted a 5-year follow-up study on 42 young permanent first molars with large defects restored by porcelain inlaid. During the follow-up period, the pulp vitality of the restored teeth was normal, there was no postoperative sensitivity, and the restoration performed well.

In clinical practice, porcelain onlay is more commonly used to restore pulpless teeth than vital pulp teeth. Zhang Fengjuan et al. [43] evaluated the restoration effect of 90 pulpulent molars restored with CAD/CAM all-ceramic onlay, and the follow-up results showed that the restoration margin fitness, integrity, secondary caries of abutment teeth, gingival condition, interproximal relationship and abrasion of the corresponding teeth could achieve good satisfaction immediately after restoration, 6 months and 12 months after restoration. Wang Litao [44] randomly divided 120 patients with large tooth defects after root canal treatment into two groups, using composite resin filling and super ceramic inlay restoration, respectively. After 1-year follow-up and observation of various indexes, the incidence of complications within 1 year in super ceramic inlay restoration group (6.4%) was lower than that in composite resin filling group (20.7%), and the incidence of complications within 1 year in super ceramic inlay restoration group was lower than that in composite resin filling group (6.4%). The success rate (95.16%) was higher than that of composite resin group (81.03%). The results of a meta-analysis by Naik, V. B et al. [45] showed that the performance of porcelain inlays was better than that of resin inlays in the follow-up observation of 5 to 10 years, and the performance of feldspar ceramics was better than that of glass-matrix ceramics in the porcelain inlays.

Onlays made of resin ceramic composites have also been used in clinical practice [46]. Hua Weixiao et al. [47] used resin super porcelain inset to repair large area defect of vital pulp posterior teeth. The follow-up results after 1 year showed that the success rate and satisfaction of resin super porcelain inset restoration were higher than those of resin inset restoration group, and the incidence of adverse events was also lower. Compared with traditional composite resins, ceramic toughened resin materials have superior physical properties. Compared with porcelain materials, the hardness is slightly lower, but the toughness is strong and not easy to break [48].

5. Conclusion

In conclusion, resin onlay is the first choice for primary teeth, and porcelain onlay is the first choice for permanent

teeth. However, the choice of restoration material is not a single fixed one. The oral environment of the patient, the cooperation of the children and their families, the economic status of the patient and the tooth defect condition should be considered comprehensively to select the most suitable restoration method to obtain the best restoration effect.

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