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# Research progress of posterior tooth onlays restoration after root canal treatment

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***Abstract:*** *Pulp diseases and periapical diseases developed from caries can cause large area of tooth defects, and root canal treatment is the most effective treatment for them. The loss of tooth tissue during treatment will lead to the reduction of tooth flexural strength, which will affect the long-term repair effect. The posterior tooth is the most frequent tooth position for root canal treatment, and the repair method after the posterior tooth root canal treatment is the focus of clinical attention.With the development of repair technology and materials, and the popularity of minimally invasive concept, onlays have been widely used in the restoration of posterior tooth defects. In this paper, the materials and design methods of onlay restoration are discussed in order to provide reference for clinical work.*

***Keywords:*** *Onlay, Resin, Ceramics, Design method*

Onlay is a type of restoration that covers one or more tooth cusps and is embedded inside the tooth to restore the shape and function of the tooth, so as to preserve the healthy tooth tissue to the greatest extent [1]. Posterior tooth are prone to fracture after root canal treatment due to their special anatomical morphology, function and location [2]. With the development of repair technology and materials, which meet the minimally invasive concept, more and more onlays are applied to the restoration of posterior tooth after root canal treatment, which can avoid the root fracture disadvantages caused by post crown restoration[3]. It has a better protective effect on the tooth root after treatment[4]. In this paper, the effects of different materials and different onlay design methods on the fracture properties of posterior tooth were reviewed.

## 1. Onlay restoration materials

### *1.1. Metal materials*

Metal onlays usually use precious metal alloys,gold alloy is one of the commonly used materials with good ductility, wear resistance, edge sealing property and low expansion rate, but the price is high. The retention rate of gold alloy onlays can reach 94.9% in 30 years of clinical observation[5]. Non-precious metal onlays often use cobalt-chromium alloy, high strength, high corrosion resistance, and low price are its excellent characteristics, but poor ductility, potential sensitization, so it is often used for temporary repair[1]. At present, with the increase of people's aesthetic requirements for restorations and the development of restorative materials, the application of metal materials has gradually decreased.

### *1.2. Resin materials*

Composite resin onlay is a kind of in vitro curing indirect resin repair. The main material is composite resin containing dimethacrylate group. The composite resin has an elastic modulus similar to that of natural dentin, is easy to adjust and trim, has good fracture resistance[6], and is not easy to wear the opposite jaw teeth[7]. With the development of materials science, the physical and mechanical properties of composite resin fillers can be enhanced with the increase of content [8]. However, the low wear resistance of the composite resin makes the later restoration prone to edge micro-leakage or fracture[9], resulting in repair failure. Later resin aging discoloration, restoration and natural tooth color difference affect the appearance. Therefore, composite resin onlay restoration may be more suitable for

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the restoration of teeth with less occlusal burden and deciduous teeth[10]. Resin nano-ceramics (RNC) or nanoparticle filler resins are nano-ceramic particles embedded in highly cross-linked resin substrates, such as 3M's LavaUltimate, Cerasmart, and UpceraHyramic. In the classification of materials science, resin nano-ceramics also belong to composite resins[11]. LavaUltimate, also known as superior toughness porcelain, contains 80% ceramic filler composed of silica and zirconia, 20% resin matrix, bending strength of 204MPa, elastic modulus of about 12.8GPa, good fracture toughness, the restoration is not easy to break and collapse porcelain, low wear resistance, not easy to wear the jaw teeth or restorations, a study shows. The two-year retention rate of LavaUltimate onlays is 100%, which is not significantly different from the clinical performance of direct repair with composite resin[12], but it lacks long-term clinical observation, and the problem of easy wear of the prosthesis still needs to be solved[13]. The bending strength of Cerasmart is about 217MPa, which is higher than LavaUltimate[14].

UpceraHyramic is a resin nano-ceramic independently developed in China. 82% of it is inorganic filler, composed of progressive fine structure barium glass powder and silicon oxide nano-powder[15], and its bending strength is higher than LavaUltimate within 2mm thickness. It is basically stable, has slightly stronger fracture toughness than LavaUltimate, and is not easy to break porcelain. However, when the thickness is limited, it is not recommended for clinical repair in patients with complex occlusal relationship[16].

### *1.3. Ceramic materials*

Some scholars[17]classify ceramics into three categories based on their composition: glass-matrix ceramics, non-glass-matrix ceramics (polycrystalline ceramics) and polymer-impregnated ceramics.

#### *1.3.1. Glass-base ceramics*

According to the production method, it can be divided into filled glass ceramics and glass impregnated ceramics. Filled glass ceramics can be divided into low filled glass ceramics, medium filled glass ceramics and high filled glass ceramics according to the percentage of added particles.

##### *1.3.1.1. Filled glass ceramics*

Low-filling glass ceramics: the main component is glass, containing a trace amount of added particles, less than 17% of the added particles, known as feldspar porcelain, its main components contain silica and alumina based feldspar, good aesthetic performance, bending strength is the lowest among ceramic materials, 60-70MPa, low mechanical properties, poor folding resistance[18]. In clinical practice, Vita's VM13 and Degudent's AllCeram are mainly used, and VitaBlocksMarkI and MarkII are often used in the restoration of posterior onlays[19,20].

Medium filled glass ceramics: Such ceramics can contain 17-25% particles, and the increase of filled particles improves the mechanical properties of glass ceramics, but the aesthetic properties are lower than that of low-filled glass ceramics. Common clinical materials include Vita's VMK95, Dentsply's Ceramco II and Ivoclar Vivadent's IPS d.SIGN[13].

High fill glass ceramics: Its particle percentage can reach 45-70%, leucine and lithium disilicate are commonly used as filling particles, and the bending strength of glass ceramics based on leucine can reach 120-160MPa, mainly including IPS Empress Aesthetic of Ivoclar Vivadent. Optec OPC by Jeneric Pentron, Authentic by Jensen and Finesse All-Ceramic by Dentsply.IPS Empress CAD of Ivoclar Vivadent is a glass ceramic with leucite crystals added, and its bending strength is 160MPa, which has good polishing and aesthetic properties[21].The bending strength of lithium disilice-based ceramics ranges from 300 to 500MPa, including IPS Empress II, IPS e.max Press and IPS e.max CAD from Ivoclar Vivadent, and 3G from Jeneric Pentron. Vita Suprinity of Vita and Celtra Duo of Dentsply are zirconia reinforced lithium silicate glass ceramics. The bending strength of Vita Suprinity is 420MPa and the elastic modulus is about 70GPa. The bending strength of Celtra Duo is 370MPa[22], and zirconia reinforced lithium silicate glass ceramics have better semi-transparency and polishing properties than lithium disilicate glass ceramics[23], but it is more difficult to process than lithium disilicate glass ceramics[24].

Low-filled glass ceramics have low flexural strength and great limitations in clinical application. The mechanical strength of medium filled glass ceramics is better than that of low filled glass ceramics, but its aesthetic effect is not good, and its clinical application is not wide. The mechanical properties of high-fill glass ceramics have been greatly improved, the aesthetic performance is good, the operation beside the chair is convenient, and it has been widely used, but some materials lack long-term clinical

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effect observation.

#### *1.3.1.2. Glass impregnation ceramics*

This kind of ceramic is a glass-impregnated ceramic material formed by impregnating glass into a porous ceramic structure, which belongs to In-Ceramic ceramic materials. They include In-CeramAlumina, which has a purity of 99.99% aluminum oxide, a bending strength between 236 and 600MPa, and a fracture toughness between 3.1 and 4.6 mpam 1/2; In-CeramSpinell, the main body is magnesium aluminate spinel, adding trace alumina, better semi-transparent than In-Ceramspinell, bending strength of about 350Mpa; And Vita's In-CeramZirconia, 35% partially stabilized zirconia is added to the In-Ceram alumina powder composition to significantly improve the fracture toughness, as well as improve the bending strength, with a bending strength of 513-620 mpa and its lowest transparency. This kind of ceramic has high mechanical strength, but poor transparency, low aesthetic performance and limited clinical use[25].

### *1.3.2. Non-glass Matrix Ceramics (polycrystalline ceramics)*

Non-glass matrix ceramics do not contain glass components, are containing alumina and zirconia based ceramics, both of which have high mechanical properties, the bending strength of alumina is about 650MPa, while the bending strength of zirconia is in the range of 800 to 1500MPa. This kind of ceramics has stronger mechanical properties and is more robust than glass-base ceramics, but it is less transparent than glass-base ceramics and slightly weaker aesthetic properties[26].

### *1.3.3. Polymer Impregnated Ceramics (PICN)*

Polymer impregnated ceramic (PICN Polymerinfiltratedceramicnetwork) is a kind of organic - inorganic compound material, under high pressure condition, dipping polymer (organic phase) to the part of the mesh structure of sintering ceramics[27]. At present mainly VitaEnamic, feldspar porcelain, 86% from 14% glycol dimethyl acrylic resin polymer, the bending strength of about 150-160 mpa, modulus of elasticity is about 27 gpa, material hardness, toughness and bending strength is more close to natural tooth tissues[20], excellent fatigue resistance, on the fracture toughness, Better than lithium disilicate based, leucite based and feldspathic based glass ceramics. It also has excellent bonding and polishing ability[28]. Spitznagel et al. proved that the success rate of VitaEnamic as onlay reached 95.6% in a 3-year clinical study[29]. Ceramic contents would be degraded in acidic solution, so Vitaenamic should be avoided in patients with gastroesophageal reflux disease[30].

## 2. High onlay design method

The amount of residual tooth tissue is closely related to the tooth flexural resistance. Reducing the reserve of natural tooth tissue and preparing sufficient repair space to ensure the resistance of the prosthesis is one of the keys to successful restoration of the affected tooth. The following will be elaborated from five aspects: onlay thickness, tooth axis wall, maxillofacial coverage, retention depth, and edge design.

### *2.1. High onlay thickness*

The thickness of the onlay is one of the important factors affecting the resistance of the prosthesis. Only when the prosthesis reaches a certain thickness can it have enough resistance to resist the occlusal stress and recover the masticatory function. Abduo[31] et al believe that adequate resistance can be obtained if the thickness of the restoration reaches 2mm. She Yahu et al.[32] analyzed tooth tip thickness models with different thickness of 2, 3 and 4mm by using three-dimensional finite element method, and found that increasing the tooth tip covering thickness of all-porcelain onlays could reduce the risk of breakage of all-porcelain onlays, but it might lead to the loss of onlays and palatal dentine fracture. Zeng Zhiwei et al.[33]conducted in vitro experiments on molars designed for 2mm, 4mm and 6mm onlay restoration, and found that the thicker the onlay, the higher the loading force, but in the aging experiment with 2mm thickness, the edge tightness was the best.

### *2.2. Axial wall of tooth body*

Kassis et al.[34]found that when the remaining tooth wall thickness is greater than 2mm, the bending resistance of onlays is the highest. Yang Xinyu[35]analyzed the 2.2mm and 2.5mm gingival wall width defect models of MOD cavities in maxillary first premolars by three-dimensional finite element method,

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and found that the dentine stress increased with the increase of gingival wall width. Chen Mengxiao et al.[36-37]prepared maxillofacial cavity shape (0 cavity shape), distal proximal maxillofacial defect cavity shape (DO cavity shape) and proximal distal proximal maxillofacial defect cavity shape (MOD cavity shape) on the maxillary first premolars through in vitro experiments, and found that the flexural O cavity shape >DO cavity shape >MOD cavity shape. In other words, the greater the number of remaining axial walls of maxillary first premolars, the stronger the tooth flexural resistance, the greater the axial wall width, and the greater the dentine stress.

### *2.3. Maxillofacial coverage*

In vitro experiments, only functional tip coverage and full tip coverage were prepared for maxillary first premolars, and it was found that the tooth tip coverage type had a significant impact on the tooth flexural performance after restoration, and the full tip coverage group had a stronger flexural performance than the functional tip coverage group. YANGH[38]found that compared with partially covered onlays, the stress level generated in the enamel layer was lower, and the risk of stress concentration and tooth fracture was not easy to occur. Deng Zhipeng[39]found that some occlusal surface overlay onlays had serious tooth damage during 2-year clinical observation. In a 2-year clinical observation, Yu Jian et al.[40]found that the comprehensive performance of full occlusal surface covering onlays was good, and it was a good choice for the repair of light and moderate molar defects after root canal treatment.

### *2.4. Retention depth*

An onlay is a prosthesis embedded in the tooth, and its retention depth in the tooth has not yet been determined. Yang Xinyu[35]set the distance between the pulp wall and the gum wall in the MOD cavity of the maxillary first premolar by three-dimensional finite element method, and found that the stress value decreased with the increase of the distance of 0.5, 1.0 and 1.5mm. Chen Mengxiao et al.[36]found that the retention depth of 2.0mm or 3.0mm had no significant difference on the flexural resistance of teeth. HAYESA et al·[41]showed that prosthesis with a retaining depth of 4mm pulp cavity showed higher fracture resistance, and the fracture mode of teeth at this time was mostly reversible crown fracture rather than irreversible root fracture, which was more clinically acceptable. Pedrollo et al. [42]found through the three-dimensional finite element method that the fracture load of the inner crown of lithium disilsilicate with a depth of 5mm was significantly higher than that of the inner crown with a depth of 2.5mm. The retention depth of 2.5mm was more prone to repairability failure, while that of 5mm was more prone to complete irrepairability failure. Dartora et al.[43]found through the three-dimensional finite element method that samples with 5mm retention depth had better fracture resistance than samples with 3mm and 1mm. In conclusion, it can be seen that the increase of retention depth increases the flexural resistance of the prosthesis, but it also increases the possibility of irreparable failure after dental restoration.

### *2.5. Edge design*

The edge design of onlay has an important influence on its long-term retention rate. Currently, the common edge designs in clinic include concave shoulder table, plane butt and inclined plane. It is believed that the type of onlay edge is closely related to the thickness and stress distribution of porcelain, which may ultimately affect the long-term repair effect and edge tightness[44]. Chen Gang et al.[45]conducted a clinical study on onlays with concave shoulder and planar joint. During the 12-month observation period, the three cracked onlays all occurred at the functional tips of the concave shoulder group, while no cracked onlays were found in the planar joint group, suggesting that the design of concave shoulder had a large amount of wear in the tooth tip area, which weakened the tooth tip's folding resistance. The planar butt joint has a certain protective effect on dental tissue, and has more advantages in the preservation of dental tissue and clinical convenience. Therefore, when the bucco-lingual wall of the remaining teeth is thin, the butt edge design is reliable.

## 3. Conclusions

In summary, high onlay has become a good repair method for premolar defects. With the development of oral materials and repair technology, the success rate of high onlay repair is getting higher and higher. Considering aesthetics, strength, biocompatibility and other aspects, polymer

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impregnated ceramics have excellent performance in high onlay repair, but lack of long-term clinical observation. However, there is no systematic conclusion on which tooth preparation form can better retain the remaining tooth tissue and restore the function and aesthetic shape of the tooth, and the preparation design of onlays still needs further research.

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