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The types and application progress of fixation for tooth dislocation injury

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Abstract: *Tooth dislocation injury is a more common type of dental trauma, which is commonly caused by sports accidents, traffic accidents, falls, family accidents and increasingly common attacks. The purpose of treatment is to restore function by splinting in time. Splint will fix the injured tooth and the healthy teeth on both sides into a whole, so that the force is dispersed on a group of teeth, so that it forms a multi-rooted tooth. After dislocation injury, the displaced tooth must be restored to the normal position as soon as possible and fixed in time. Elastic and semi-elastic splints are mostly used in clinical fixation. The update and development of materials make the selection of fixation diversified. This paper will review the types and research progress of splint materials that meet the indications of tooth dislocation injury, in order to provide reference and guidance for clinical work.*

Keywords: *Tooth dislocation injury; Elastic splint; Half-elastic splint; fixation*

Tooth trauma refers to a disease that causes acute damage to hard tissue, pulp or periodontal tissue of teeth under sudden external force [1]. Maxillary central incisor teeth are most commonly involved [2]. The international classification of dental trauma [3-4] falls into three categories: fracture injury, dislocation injury and avulsion injury or complete dislocation. The more common type of dental trauma in clinic is dislocation injury, and the affected tooth with dislocation injury should be immobilized in time. Evidence-based medicine has also confirmed that dental trauma immobilization is the most commonly used method to treat the injured tooth and promote periodontal healing, and can also maximize the preservation rate of the injured tooth in the oral cavity [5-6].

The history of splints is based on the principle of jaw fracture, and rigid fixation increases the incidence of pulp necrosis and root resorption [7]. Later scholars also confirmed in animal experiments that semi-elastic splints and elastic splints are more able to provide functional movement for teeth [8-9]. The continuous improvement of materials makes splint materials and retention methods gradually diversified, but they all maintain the same functional requirements: fixing displaced teeth and optimizing the healing effect of pulp and periodontal ligament [10]. In this article, the types and application of fixation methods for tooth dislocation injury are reviewed.

1. Semi-elastic splint

1.1 Titanium chain splint

Titanium chain splints are end to end metal chains made of pure titanium, with a thickness of 0.2mm. The operator can easily bend them to fit the profile of the dental arch, and then fix them on the damaged teeth and adjacent teeth using a light curing resin [11]. In order to improve the periodontal reattachment healing ability of the affected tooth, the titanium chain should be fixed on the crown away from the gum, and the amount of resin used to fix the splint should be kept to a minimum [12]. The titanium chain is flexible in all directions due to its unique diamond-shaped network structure design, which also enables the titanium chain splint to provide physiological tooth movement without transferring orthodontic force on the affected tooth and adjacent teeth [13].Mazzoleni compared the axial stress of resin splints, wire composite splints, button support splints and titanium chain splints and found that the titanium chain splints have the lowest axial stress.

It shows a low energy change required for splint deformation, indicating that titanium chain splint has the highest flexibility [14]. The clinical use of titanium chain splint has also confirmed its advantages

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of small stimulation of oral mucosa and high comfort for patients [15]. For the operator, the finished titanium chain reduces operation time. The disadvantage is that the unique cavity design needs to be filled with resin materials, and the oral hygiene of patients is challenging and unattractive. Because of its high cost compared with other splints, it is rarely used in clinical practice.

1.2 Orthodontic splint

Orthodontic splint, also known as orthodontic wire bracket fixed splint, is a more traditional fixing method, which meets the mechanical requirements of the affected tooth, adjacent tooth and alveolar bone, and plays a good role in protecting the periodontal tissue. Some scholars found in animal experiments that the root absorption rate of orthodontic splints was much lower than that of wire splints [16], which also confirmed the above statement. The force exerted by the orthodontic wire bracket on the affected tooth and bone tissue is gentle and gradual, and such splints are controllable for the orthodontist [17]. Through clinical observation, domestic scholars [18] found that the use of orthodontic brackets to fix children with dislocation injuries effectively improved the treatment effect and reduced complications, and suggested that orthodontic splints could be used as the preferred fixation method for children with dislocation dental injuries. The disadvantage is that the dentinal bracket device fixed on the tooth surface is irritating to the oral mucosa [19], and this fixation method has high technical requirements for the operator [20], which is easy to cause the displacement of the affected tooth due to iatrogenic differences [21]. Some scholars [22] have treated periodontal diseases with orthodontic brackets combined with periodontal splints, and found that the effect is more ideal than that of using periodontal splints alone, with higher patient satisfaction. Li Luoyu et al. [23] also used the combination of the two methods in the treatment of alveolar process fractures and achieved good therapeutic effect and reduced oral adverse events. Polizzi et al. [24], in a review of the defining non-surgical methods proposed for the treatment of mandibular fractures, found that most orthodontists would prefer the direct bonding technique of the orthodontic bracket, especially for children. Although more convenient and beautiful new splints have gradually emerged in recent years, orthodontic bracket fixation has not been completely replaced.

2. Elastic splints

2.1 Elastic fiber composite resin splint

The commonly used elastic fiber composite resin splints are mostly glass fiber and ultra-high strength polyethylene fiber, which have good flexural strength and bonding properties. The properties of fibers, geometric arrangement and different resin materials covered make the types of fibers diversified. Baena et al. [25] conducted experiments on five sets of fixed splints using a universal testing machine and polarizing mirror, and observed that the glass fiber had better stress distribution around the affected teeth under different occlusal loads, and it could better distribute and absorb the occlusal stress from the center and edge. In clinical practice, some scholars [26-27] have confirmed that fiberband composite resin splint has a good effect on gingival index, plaque index, gingival crevicular bleeding, and the imaging examination of postoperative two-year follow-up. Zhu Wenting et al. [28] found in the clinical observation of 320 cases of permanent anterior teeth that fiber composite resin has strong aesthetics and comfort, is easy to maintain good oral hygiene, and can ensure high bonding strength even if the adjacent teeth of the affected teeth are primary teeth. In addition, the operation time of fiber composite resin splint in the patient's mouth is short, and it is more suitable to be used for post-traumatic examination and treatment of children in a state of fear [29]. Zhang Xiaxia et al. [30] compared traditional fixation splint with fiber composite resin splint and concluded that fiber composite resin splint was more convenient for extraction and did not affect pulp testing and root canal treatment during fixation. Most studies have shown that fiber composite resin splints can be used as the first choice in the treatment of tooth dislocation injury.

2.2 Wire-resin composite splint

Wire-resin composite splint is a splint formed by fixing metal wires on the injured tooth surface and adjacent undamaged adjacent teeth with resin materials. According to the guidelines of the International Association of Dental Traumatology, it is recommended to use metal wires with a diameter of less than 0.4mm for dislocated dental trauma [31].Vilela et al. [32] created four splint models for dislocated tooth injury by using three-dimensional finite element method, and applied horizontal and vertical loads to them. The results showed that the activity of affected teeth under horizontal load of 0.9mm wire resin splint was 10% lower than that under 0.4mm wire resin splint, and the vertical load was 5% lower. The 0.9mm metal wire is more rigid, which is more suitable for the treatment of alveolar process trauma.

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Paz et al. [33] created a fracture model of alveolar process using a cattle incisor tooth to simulate the maxillar incisor tooth, and used a deflection meter to measure displacement in the fractured and adjacent central incisor area under functional cycle and static load. It was found that using a wire of at least 0.9mm could effectively reduce the displacement of the fractured alveolar process to a level similar to that of adjacent teeth. Wire resin splints are easy to use, easy to place, especially in uncooperative pediatric patients [34], and have minimal physical barriers to aesthetics, pronunciation, and chewing function. In clinical trials, Lv Yunsong et al. [35] concluded that wire resin splint was superior to traditional dental arch splint in terms of peridental microecological indicators and aesthetic effects. However, for patients with mixed dentition, composite resin splint was more unstable than orthodontic splint with mechanical and adhesive fixation [36], which was the same as the conclusion of clinical studies by domestic scholars [18].

2.3 Nylon wire splint

Nylon wire splints also rely on the bonding of resin materials to achieve fixation. Nylon wire, also known as fishing line, is commonly used with a diameter of 0.13-0.25mm and a low elastic modulus. Studies have shown that nylon wire has high flexibility and aesthetics [37]. Baena et al. [25] also proved through universal testing machine that in the case of external biting of injured teeth, Nylon wire splint shows the characteristics of no stress distribution. The activity of nylon wire under horizontal load is 82% higher than that of 0.4mm metal wire, and that under vertical load is 84% higher. The low value of induction force indicates the high elasticity of the material. However, the induction force value of nylon wire is the highest when the root tip area changes, which is speculated to be the insufficient distribution of force leading to the overload of the force of the affected tooth. IADT suggested that the diameter of nylon wire should be 0.13-0.25mm, and it is not recommended for children with only a few permanent teeth [31]. However, some scholars [38] concluded through three-dimensional finite element model experiments that 1mm nylon wire may be suitable for fixing avulsion teeth in the mixed dentition stage. Although there are different opinions on nylon splints, they all agree that nylon splints are more flexible and stable to the peridental tissue of the affected tooth. Zafar et al. [39] made a model of tooth dislocation injury with 3D printing technology, and asked students to fix and remove wire resin splints and nylon resin splints. After completing a questionnaire survey after simulation training, 38% of students believed that wire was easier to place than nylon wire, and 52% of students agreed that nylon splints were easier to remove. In another simulation training [40], two materials were added: twisted wire and power chain to simulate the treatment, and 56.2% thought that the power chain was the easiest to place and the nylon splint the easiest to remove.

2.4 Occlusal splint of full arch

Occlusal splint of full arch is elastic fixation, which is suitable for multiple damaged teeth with mixed dentition. The use of full dentition occlusal pad can effectively eliminate occlusal trauma [10], but the patient's comfort and eating are affected, and the operation process is complicated. Tu Shanshan et al. [41] analyzed the effect of orthodontic appliance combined with dental pad on teeth with dislocation injury compared with that of wire resin splint, and the results showed that the former was superior to the latter and worthy of clinical application. Zhu Yuanbing et al. [42] established bionic dentition and tooth dislocation injury models, and measured the motion of affected and adjacent teeth by pruning full dentition pads in the range of lip incisal gingiva and proximal distal dental surface coverage, and found that the fixation effect would be affected to a certain extent, and suggested that the extension range of dental pads should be designed according to the degree of tooth trauma loosening.

3. Other types of splints

3.1 Composite resin material

Composite resin splint is a single resin composite material. After the acid etching of the tooth surface, the resin forms a mechanical bond with the tooth enamel to bond the affected tooth and adjacent tooth. Due to its easy operation and strong aesthetics, it is widely used in clinical practice [43].Zhou Yanping et al. [44] used composite resin splint and fiber composite splint for fixation and followed up for 6 months, and concluded that composite resin splint was superior in periodontal index and subjective satisfaction of patients, although both had positive effects on loose teeth. Junichiro et al. [45] tested the influence of four splint materials on the deflection force and resistance of tooth models with different mobility in vitro, proving that composite resin splint has the highest resistance in different mobility models and provides the greatest resistance to tooth mobility within the range of splint. It is suggested that composite resin splint is more suitable for severe damaged teeth with high

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activity, and fiber composite resin splint is an ideal material for mild to moderate damaged teeth with similar physiological movement to adjacent teeth. Composite resin materials have strong stiffness and poor flexibility, and have higher fracture risk compared with fiber composite resin splints [46]. Because the material is directly connected to the affected tooth and the loose tooth as a whole, this method is not suitable for patients with missing teeth within the fixed range.

3.2 Power Chain

Power Chain is a rubber chain used in orthodontic closed gap, which contains a porous structure, similar in appearance to titanium chain splint, and mechanically fixed on the tooth surface using composite materials. However, there are relatively few historical studies on this material in the field of splint fixation [47]. Meshari et al. [48] compared the stiffness, beauty, operation time and cost of the power chain and five other commonly used splints after fixing them with the upper jaw standard model, force measuring element, linear variation transformer and splints. The results showed that the material with the lowest stiffness was nylon wire (5.7Nm-1) and power chain (6.3Nm-1), and the data were almost the same. The most easily operated splints are power chains and fiber splints, the most beautiful material is nylon wire splints, and the cost gap of other materials is not large in addition to titanium chains, and it is predicted that the power chain will become a substitute for new splints materials due to high flexibility.

4. Conclusion

Since the occurrence of trauma is often accompanied by oral soft tissue injury, the use of resin composite adhesive splints has little impact on the soft tissue and will not interfere with subsequent examination and treatment [34]. Except composite resin materials used for splints alone, splints can be fixed on adjacent teeth near the gap and still achieve good fixing effect when adjacent teeth are missing [49]. The above mentioned materials have been described in terms of aesthetics, ease of operation, influence on periodontal tissue, rigidity and so on. As for the resin materials used to fix splints, some scholars [50] proposed that when applying splints with lower rigidity, the stress concentration between the affected teeth and neighboring teeth would be reduced, and adhesives with higher elastic modulus should be used. Resin composite splints have a common disadvantage: the hard tissue of the teeth is irreversible when the splints are removed, and more tests and studies are needed for this unsolvable problem. The rapid development of materials science has brought about the diversity of materials and the diversity of reported results among clinical studies of fixed methods, and the systematic evaluation of different fixed methods is also challenging. Combined with clinical practice, it is not difficult to find that the mainstream method for dislocation injury is elastic splint. Clinical trials can evaluate aesthetics, cost and operational difficulty, and in vitro trials can evaluate the stiffness of splint materials. However, oral mastication and occlusion are complex and dynamic processes, and the effects of splint fixation with various materials on periodontal tissue cannot be visually quantified in clinical and in vitro studies. The three-dimensional finite element model and universal testing machine can determine the displacement and strain of different materials on tooth or bone tissue through the measured stress and displacement values. The results of the above materials in different experiments can be considered to meet most of the requirements of the best splint. With the continuous development of materials, more splint materials will be studied and enter the clinic.

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