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Abutment Tooth and Periodontal Tissues with Unilateral Mandibular Dissociation and Loss by Precision Extracoronal Attachment

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ABSTRACT
In order to explore the application of the precision extracoronal attachment based on three-dimensional finite element stress model in the repair of unilateral mandibular dissociation and loss, the stress distribution of the butment and periodontal tissues when the precision extracoronal attachment was used in unilateral mandibular dissociation and loss was analyzed, so as to provide reference for the application of materials in clinical repair. In this study, the biomechanics of oral cavity and its attachment were analyzed to provide theoretical basis for model construction. Because the degree of periodontal tissue absorption and the number of abutment teeth affected the restoration effect of the coronal precision attachment, the models were established from these two perspectives. The results showed that when the periodontal tissue absorption of both abutment teeth exceeded 1/3, the method of double abutment restoration was not recommended. When three abutments were used, there was a significant decrease compared with the absorption of the periodontal tissue of the double abutment. In clinic, the stress distribution of the distal abutment teeth and its periodontal tissues can be improved by increasing the number of abutment tooth. However, since increasing the number of abutments required an increase in the amount of healthy tooth tissue, it couldn't be blindly selected in the clinic. After comprehensive consideration, it is appropriate to choose two abutment teeth for restoration.

Keywords: Precision extracoronal attachment, Unilateral dissociation and loss, Abutment tooth, Periodontal tissue, Stress model

1. Introduction

Dentition defect is a common disease in the department of stomatology, which would cause the decreased chewing function, periodontal tissue lesions, temporomandibular joint disorders, and facial changes. As the disease progresses, it will gradually affect the articulation clarity of patients, among which, free end loss is the most common (Wang et al., 2017; Siriwardana et al., 2017; Team, 2017). Attachment is a special device widely used in the process of denture repair. Generally, it is divided into two groups, Yin type and Yang type, which are matched with each other and connected by different mechanical means (Raymond et al., 2018). Precision attachment is an imbedded locking retainer, one part of which is fixed on the crown, root or implant in the mouth and the other part is connected with the denture and retainers the denture through the high chimerism of the two. It has the advantages of conforming to biological principles and aesthetic appearance of the prosthesis and can better protect abutment and enhance the retention and stability of denture (Smith et al., 2017).

Currently, the most commonly used type of denture is removable partial denture (RPD). However, the traditional removable denture repair would expose the metal clasp and affect the aesthetics, and its retention stability is not good, resulting in a greater impact on the denture chewing (Beloborodov et al., 2018). The precision attachment has special advantages in repairing the defect of free end. Due to the lack of abutment support in the distal segment of the free end denture, the stress distribution under bite force is relatively complex. It is not only necessary to bear partial bite force of the denture, but also subject to certain torsion force, which is easy to cause abutment damage (Chapel et al., 2017).

In the process of precise attachment restoration, the main factors affecting abutment teeth and dentinal ridge stress are the choice of attachment and abutment teeth. With the development of science and technology and the wider application of computer, the advantages of three-dimensional finite element calculation have become increasingly prominent, and the computer-aided design and production of restoration has a broad development prospect (Yang et al., 2017). In this experiment, CT images of adult mandibular alveolar bone and isolated teeth were mainly selected for analysis. MIMICS biological modeling software was used to establish a complete three-dimensional finite element model of distal dissociation and absence of the unilateral first and second molars of the mandible. The stress distribution of the abutment tooth and periodontal tissues in the unilateral mandibular dissociation and loss with the precision extracoronal attachment was analyzed to provide a reference for the clinical application of materials.

2. Biomechanics of oral cavity and its attachment

2.1. Analysis of oral biomechanics

Oral biomechanics is a subject that applies mechanics principle and engineering technology to analyze the physiological and pathological changes of oral maxillofacial region. The research contents of oral biomechanics include the biomechanics of dental body and periodontal tissue, the biomechanics of temporomandibular joint, the biomechanics of oral denture repair and the biomechanics of the correction of maxillofacial deformity (Seedat et al., 2017; Cotti et al., 2017; Kuo et al., 2016). Dental tissue biomechanics mainly studies the strength, elastic modulus, Poisson ratio and other mechanical properties of the dental tissues. Periodontal tissue mainly includes periodontal membrane and alveolar bone, which plays an important role in the transmission and dispersion of supporting teeth and biting force.

Stress analysis of oral biomechanics is a method of stress analysis of components with physical models or objects. The combination of basic theory and engineering technology is used to analyze the stress, strain and displacement of oral components, which is the necessary means to study the basic theory of composite mechanics. The commonly used methods include resistance strain measurement, photoelastic stress analysis, laser holographic interferometry, moire method and so on. Theoretical stress analysis is the theoretical solution to the stress distribution obtained by the theories of material mechanics, elastic mechanics and basic physics. Generally, it needs to deal with a large number of complex data in an acute manner. At this time, computer-aided numerical analysis is needed, including finite element analysis method and infinite element analysis method. The principle of finite element analysis method is to discretize the continuous solution region into a group of finite elements which are connected in a certain way. Compared with the traditional experimental stress analysis method, the finite element analysis method can model complex objects and obtain the stress and displacement state of any part of the model (Said et al., 2017). After the biomedical model is transformed into a mathematical mechanical model, the mechanical parameters can be changed according to needs, and the stress size and distribution changes can be analyzed without changing the geometric shape of the model. With the development of computer technology and the further development of large-scale finite element software, the finite element analysis method, especially the three-dimensional finite element analysis method, has been widely used in the clinical and research fields of oral prosthodontics, orthodontics, implants and so on.

2.2. Biomechanical analysis of oral attachments

According to the different processing precision of oral attachment, it can be divided into precision attachment and semi-precision attachment. Precision attachment is made of special alloy by machining, while semi-precision attachment is usually cast by preformed plastic and wax mold. The precision extracoronal attachment has the advantages of not being limited by the volume of the crown and retaining the external shape of the dental crown. At the same time, the tissue of the cutting tooth is less, which is convenient for the patient to wear. There are also some shortcomings, for example, plaque is not easy to control and can't be used in the case of too narrow space between missing teeth (Rocha et al., 2017).

When attachment is used to repair, with the increase of abutment number, the bite force can be gradually evenly distributed, so as to reduce the pressure borne by alveolar crest, while with the increase of abutment tooth, excessive dental tissues have to be worn off. Previous clinical studies have shown that the poor health of the abutment tissues near the missing tooth area often occurs during the restoration of dentition defects, including different degrees of periodontal tissue absorption, abutment loosening, etc. (Kim et al., 2017). When the periodontal tissue is absorbed, the periodontal condition of abutment teeth should be fully considered, so as to minimize the adverse effects on the alveolar bone of abutment teeth while the prosthesis is well retained.

3. Finite element model of abutment teeth and periodontal tissues

3.1. Finite element models of different degrees of periodontal tissue absorption

Based on the special anatomical structure of alveolar bone, the constant changes of metabolism, and the changes of alveolar bone with age, it is a very special tissue in the skeletal system of the whole body. The alveolar bone is characterized by absorption after pressure, so when there is a defect of dentition, the alveolar bone loses functional stimulation and is repaired. Alveolar bone is directly subjected to different types of forces from the direction and causes tissue absorption other than physical bone resorption, resulting in a slow, progressive and irreversible change in bone tissue. However, the absorption of alveolar bone would reduce the area of periodontal membrane, which is an important factor leading to the failure of oral repair.

In this experiment, the two-abutment model of the second premolars and the three-abutment model of the second premolars when the periodontal tissue absorbs 1/3 and 1/2 respectively are established. The overall shape of the three-abutment model and the alveolar bone meshing of the second premolar periodontal tissue absorbed by 1/2 are shown in Figure 1 and Figure 2.

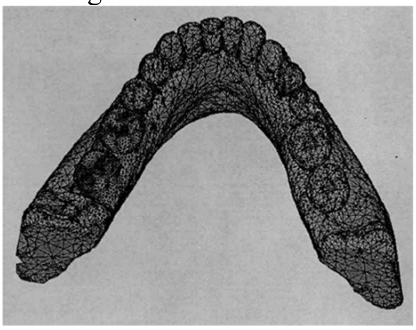


Fig. 1. Three-base dental model of the second premolar periodontal tissue absorbed by 1/2

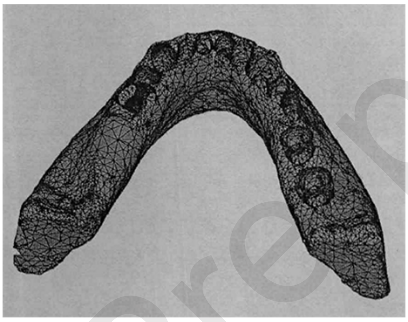
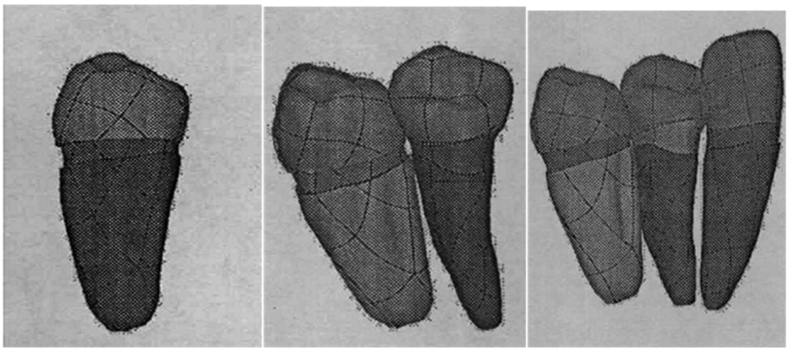


Fig. 2. The alveolar bone meshing of the second premolar periodontal tissue absorbed by 1/2

As can be observed from the figure that when the periodontal membrane of the second premolars was absorbed to different degrees, the stress distribution at the lingual side of the periodontal membrane of the first premolars was more complex, while the stress distribution at the buccal side was more regular and the root was smaller. When the periodontal tissues of the second premolars were absorbed to different degrees and repaired by two abutments, the overall stress distribution of the periodontal membrane of the first premolars did not change significantly, and high stress areas appeared in the mesial surface. When the third abutment was added, the stress distribution of the periodontal membrane of the first premolar was significantly improved.

3.2. Finite element model with different numbers of abutment tooth

In the department of stomatology, the absence of distal free end teeth is common. Due to the particularity of the free end, the abutment tooth selected in the restoration is limited to one end of the side of the missing tooth, while the other end is in the free state, which results in the cantilever beam's force mode and certain rotating force. In this research, MIMICS software was used to analyze two-dimensional CT images of adult mandibular alveolar bone and isolated teeth and obtain three-dimensional reconstruction models of alveolar bone and each tooth. Three models with complete periodontal tissue were established, with the second premolar as abutment teeth, the first premolar and the second premolar as abutment teeth, and the first premolar, the second premolar and the canine teeth as abutment teeth. The abutment teeth, baked porcelain crown, and periodontal membrane models of the three models are shown in Figure 3. The material properties of each part of the model are shown in Table 1.



(a) Abutment teeth 1 (b) Abutment teeth 2 (c) Abutment teeth 3

Fig. 3. The abutment teeth, baked porcelain crown, and periodontal membrane models of the three models

Table 1
Characteristics of materials in various parts of the model

Material Science	Modulus of Elasticity (MPa)	Poisson ratio
Periodontal ligament	69.0	0.45
Natural teeth	20289	0.3
Nickel-chromium alloy	188050	0.28
Alveolar bone	13800	0.3
Porcelain	84000	0.28
Artificial teeth	3000	0.3

It was found that the change of abutment teeth number had little influence on the stress distribution of alveolar crest in the missing tooth area. When the number of abutment teeth was different, the stress distribution of alveolar crest in the missing tooth area was relatively consistent, and the stress in the distal and proximal middle of alveolar crest in the missing tooth area was relatively large. The change of abutment teeth number had a significant effect on the stress distribution of abutment alveolar socket. When selecting the single abutment teeth, abutment teeth would produce a force in the distal middle direction, which would lead to uneven horizontal component of the force, and abutment would tend to tilt toward the distal center. When the second abutment teeth were added, the effect of sharing of partial bite force, abutment teeth restoration in adjacent missing tooth area and improvement of periodontal tissue distribution were all obvious. Due to the increase of the second abutment tooth, the stress distribution of the periodontal membrane of the second premolar was significantly improved and the stress value decreased. As the abutment increased, the fulcrum of the denture moved forward, resulting in an increase in the stress of the alveolar bone in the apical region of the distal abutment. When the third abutment teeth were added, the change of stress in the distal abutment and periodontal tissues was not obvious. It can be concluded that there was no proportional relationship between the increase of abutment number and the decrease of force of distal abutment periodontal membrane. At this time, the stress of the first premolar body and periodontal tissues would be improved to some extent due to the increase of abutment teeth. When the fangs became abutments, the stress on the periodontal membrane and alveolar socket of the fangs would increase continuously.

4. Discussion

Dentition defect is one of the common diseases in oral prosthodontics. It is mainly caused by dental caries, periodontal disease, periapical disease and developmental disorder. The application of attachment in the restoration of oral dentition defect has a long history, but there is no effective way to solve the edentulous defect, especially the restoration of multiple posterior teeth. As the structure of teeth, periodontal membrane, alveolar bone and prosthesis in the maxillary tissues is complex and diverse, and the force is irregular, the establishment of a complete finite element model is the basis of three-dimensional finite element analysis, and also the premise of a comprehensive understanding of biomechanical behavior. The stress and displacement of any part of the model can be obtained by the finite element method, and there would be visual display of data and images.

In this experiment, stress analysis was carried out on the models after the restoration of the precision attachment outside the crown, which were respectively based on the finite element models with different degrees of periodontal tissue absorption and the finite element models with different abutments. The results showed that when the two abutments were used for repair, the stress of the distal abutment periodontal tissue increased with the increase of the degree of periodontal tissue absorption. When the periodontal tissue absorbed 1/3 of the length of the tooth root, the stress of the periodontal tissue increased significantly compared with that of the normal one, while the 1/2 of the length of the periodontal tissue didn't change significantly compared with l/3. As the increase of overall stress of periodontal tissue caused by periodontal tissue absorption would affect the periodontal tissue, it was not recommended to adopt double abutment restoration when the periodontal tissue absorption of two abutments exceeded 1/3. When three abutments were used, there was a significant decrease compared with the absorption of the periodontal tissue of the double abutment. For patients with missing distal dentition and periodontal tissue absorption, the three-abutment restoration program is more reasonable. In clinic, the stress distribution of the distal abutment teeth and its periodontal tissues can be improved by increasing the number of abutment tooth. However, since increasing the number of abutments required an increase in the amount of healthy tooth tissue, it couldn't be blindly selected in the clinic. After comprehensive consideration, it is appropriate to choose two abutment teeth for restoration. In addition, it is found that finite element analysis is a practical, advanced and effective stress analysis method in stomatology research, which is worthy of promotion in scientific research and clinical evaluation.

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