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Research progress of crown -root ratio in orthodontics

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Abstract: *Different types of malocclusion have different craniomaxillofacial morphology and occlusal contact, and the crown-root ratio of teeth is closely related to them. Unhealth crownl-root ratio will affect the long-term stability of teeth. Studies at home and abroad suggest that crown-root ratio has ethnic and gender differences. In orthodontic treatment design, orthodontists should analyze the changes in crown length and crown-root ratio according to the patient's gender, ethnicity and other comprehensive judgments, so as to better estimate the treatment risk, maintain the health of periodontal tissues, and then establish a good occlusal relationship, maintain arch stability, and finally obtain a good treatment effect.*

Keywords: *Crown-root ratio; malocclusion; CBCT*

Crown-Root Ratio (C/R) study has important meaning for Clinical Medicine of Stomatology, and is a very important treatment reference index. Patients with different malocclusion types have different craniomaxillofacial morphology and occlusal contact, and the tooth crown-root ratio is closely related to it[1] , poor crown-root ratio will affect the long-term stability of teeth, especially in the case of massive adduction of anterior teeth during tooth extraction treatment, Patients with malocclusion have root resorption , shorter root length , poor crown-root ratio, or desire to use tooth extraction treatment before the start of orthodontic treatment, have a greater risk of severe root resorption in maxillary incisors or root resorption after orthodontic treatment, When the anterior teeth have great impact on facial esthetics and the roots are single roots, there is an increased risk of extraradicular resorption during orthodontic treatment when the current crown-root ratio is relatively high, affecting the long-term stability of orthodontics . Therefore, the orthodontist needs to refer to the patient's crown-root ratio to plan treatment and determine prognosis [2] .

1. Measurement method of crown- root ratio

There are two clinical definitions of the crown-root ratio, which are defined mainly by the different delineation of the dividing line. First, anatomically, the crown-root ratio is the ratio of tooth crown to tooth root length obtained by taking enamel and cementum junction as the demarcation line. The second is the clinical crown-root ratio, which is "the ratio of the crown oriented portion of the tooth to the root-oriented portion of the tooth at the top of the alveolar ridge on imaging "[3] . Because the growth and development or resorption of alveolar bone leads to the change of alveolar crest level, which cannot truly reflect the change of crown-root ratio of teeth in development and exercise function, excluding the effect of individual periodontal level on the experimental data, most studies use enamel cementum boundary as the measurement standard to exclude the effect of individual periodontal level on the experimental data.

1.1 Measurement of ex vivo teeth

In real life, the tooth is embedded in the alveolar fossa, so it is impossible to directly measure the length of the crown and root. However, ex vivo tooth measurements are hardly used in clinical practice presently since ex vivo tooth measurements cannot determine root resorption and crown wear before tooth loss[4] ,.

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1.2 X-ray and pantomogram

Most studies in the past used X-ray or pantomogram for measurement, but due to the different inclination angles of the teeth, the positioning and measurement of crowns and roots lacked some accuracy[5] . Because the accuracy of crown-root ratio is highly dependent on crown length and root length, an error of one millimeter may result in a significant difference in this ratio even when finely determining the crown root cross-sectional points at position. It has been shown that difficulties in identifying reference points are the main cause of vertical measurement errors in X-ray and pantomogram[6] . However, X-ray and pantomogram are relatively inexpensive and part of the examination in most patients and relatively easy to obtain. Although there are some limitations in measurement accuracy compared to cone-beam CT (CBCT), it can also provide sufficient information to be more practical in some treatments and not require additional radiation[7] .

1.3 Cone beam CT (CBCT)

With the development of imaging technology, CBCT has gained popularity in stomatology. CBCT has accurate resolution ability for hard tissues, greatly reduces errors, and has the advantages of wide development range, low radiation dose, high spatial resolution, and good three-dimensional images of hard tissue structures. It can clearly and accurately show the shape of crown and roots, accurately measure the length of crown and roots before and after orthodontic treatment, determine the degree of root absorption of teeth after orthodontic treatment, and has high accuracy of measurement results[8] .

It is worth noting that the measurement of crown-root ratio also has some drawbacks. For example, in microdontia, while maintaining the same crown-root ratio, the length of the crown and root is smaller than in normal teeth , while the crown-root ratio is approximately the same as the crown-root ratio value of normal teeth, so the crown-root ratio does not completely reflect the appropriate size of the crown and root of the tooth, i.e. Crown and root length are required to determine whether a tooth can provide adequate stress support[9] .

2. Gender and ethnic differences in crown-root ratio

In studies by foreign scholars, there are gender and ethnic differences in crown- root ratio[10] . In a study of African, Hispanic, and White Americans' crown-root ratio in the United States, sex differences were noted in crown-root ratios in central incisors, with females having greater crown-root ratio (0.55) than males'(0. 5 1). The mean crown-root ratio of teeth was greater in Hispanic populations compared to Caucasians and African-Americans. There were also significant differences in crown-root ratio between African-Americans and Caucasian for upper jaw lateral incisors, lower jaw central incisors, and lower jaw first premolars[11] . In Hungarian, Japanese and German studies of crown-root ratio in permanent dentition[10] : Japanese and Germans showed differences in crown-root ratio on all teeth, and Hungarians also showed differences in crown-root ratio on individual tooth positions with Japanese and Germans.

In a panoramic radiometric study based on permanent dentition in Iranian population, the mean crown-root ratio was 0.46 and 0 .47 in males and females, respectively, and the crown-root ratio was smaller in all teeth (except maxillary central incisors and mandibular first molars) in males than in females[12] . This is similar to the Finnish population while another study of Finns showed crown-root ratio of maxillary central incisors between 0.49 and 0.59 in males and 0.52 and 0.66 in females, with males having overall smaller crown-root ratio than females[9] . However, in a study of crown-root ratio in permanent dentition in Saudi Arabia, males had significantly greater crown-root ratio than females in maxillary second premolars, mandibular lateral incisors, mandibular premolars, and mandibular molars[13] .

Korean scholars[14 -15] found that the crown-root ratio of incisors was between 0.77 and 1.10 in individual positive often populations, the mean crown-to-root length of males was less than that of females, and the crown-root ratio of mandibular central incisors was less than that of females, and suggested that the roots of Caucasians were longer than those of Koreans.

Domestic scholars[16] concluded in the study that in addition to canines and second premolars, the crown-root ratio of adult maxillary teeth in men is greater than that in women in Shanghai. Gender differences were observed in the ratio of mandibular lateral incisors, first premolars, second premolars, first molars, and second molars. Xu Hong[17] et al measured the crown-root ratio of maxillary and mandibular teeth in patients with malocclusion by pantomogram to obtain crown-to-root length and crown-root ratio of left and right corresponding-teeth no difference, but there are differences in upper and lower corresponding-teeth, and there are gender differences .

3. Different types of malocclusion have different crown-root ratios

Patients with skeletal Class II malocclusion or deep overjet had longer root lengths and smaller crown-root ratio in mandibular incisors compared with other patients[14]. And the crown-root ratio of the maxillary anterior teeth was greater in skeletal Class II division II than in skeletal Class I, skeletal Class II division I and individually normal[18 -19] , while there was no significant difference in the crown-root ratio of maxillary incisors between Class II division I patients and individual normal populations, It may be related to the fact that the anterior teeth of Class II dichotomized patients are medially inclined resulting in their roots being close to their labial cortex and limiting length development, In closed mouth movement and functional movement, over-tight occlusal contact of maxillary and mandibular incisors produces large forces, which affect the development of roots under the action of certain inflammatory factors, ultimately resulting in relatively high crown-root ratio of maxillary incisors in such patients. The crown-root ratio of skeletal Class III upper and lower incisors was greater than that of skeletal Class II and skeletal Class I[20] , it has been suggested that skeletal Class III malocclusion, anterior crossbite are more likely to develop short root anomaly than other malocclusion, which suggests that there is some association between skeletal Class III malocclusion and short root anomaly. Due to the compensatory mechanism of skeletal Class III malocclusion, the labial apical region of the upper anterior teeth is close to the palatal bone cortex, the lingual apical region of the lower anterior teeth is close to the labial bone cortex, the apex is too close to the maxillary palatal and mandibular labial bone plates, so there is insufficient space to accommodate the continued growth of the root and limit the root length . Secondly, the occlusal force of anterior teeth in patients with bone type III is weak, and the stimulating effect on alveolar bone is small. The reduced occlusal function can cause progressive atrophic changes in periodontal tissues, such as the reduction of adult dentin cells and differentiation ability during tooth development, thus affecting the root length.

In patients with open bite , the root length of maxillary central incisors was shorter than that of normal bite, the crown-root ratio of mandibular incisors was higher than that of normal occlusion and deep overjet[21] , and showed that the length changes of roots of maxillary and mandibular central incisors and lateral incisors were basically in line with the trend of gradually longer roots and gradually lower crown-root ratio as the overjet deepened. In patients with open bite, the crown-root ratio was unsatisfactory from incisors to premolars, and the roots of some teeth were short, and these results were analyzed to be possibly related to the loss of occlusal contact. Some scholars have proposed that the crown-root ratio is related to the mandibular plane angle angle, and the roots of patients with high mandibular plane angle opening are shorter than those of other opening patients. Patients with high-angle open bite tend to present with weak occlusal force, thus causing occlusal dysfunction and affecting root length. This suggests that short roots in patients with open jaws may also be associated with a higher proportion of patients with high mandibular angles in this population. This is consistent with domestic scholars' results in a comparative study of the crown and root length of incisors in patients with deep overjet[22] . The results showed that the crown-root ratio of upper and lower incisors was related to the individual craniofacial type and the arrangement pattern of upper incisors, which could provide a reference for clinical diagnosis and treatment.

4. Factors Affecting Crown-Root Ratio

4.1 Heredity and growth

As mentioned earlier, crown-root ratio has ethnic differences. The reason for this is the fundamental problem of genetics and development. For example, the reduction of odontoblasts and the decrease of differentiation ability during tooth development affect root length[23] . It has been shown that the Y chromosome promotes root growth more than the X chromosome[24] , which may be responsible for the longer roots in men than in women.

4.2 The teeth are arranged in different ways and the height and thickness of alveolar bone

Because the teeth are arranged in different ways and the lip inclination is different, the position of the roots in alveolar bone is different. Root growth and development is limited by the height and thickness

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of the labial lingual lateral bone cortex , and the apical close to the labial lingual lateral bone cortex, so there is insufficient space to accommodate the continued growth of the root, which limits root length[25-27] .

4.3 Root resorption

Root resorption occurs in almost all malocclusion patients regardless of orthodontic treatment[28 -29] . In particular, patients with concomitant trauma[30] have increased root resorption in response to certain inflammatory factors, resulting in shorter roots. It has been shown that the risk and degree of root resorption are different in patients with different types of malocclusion, patients with class II malocclusion have a significant trend of severe root resorption than those with Class I malocclusion, Class II classification has a higher risk trend of root resorption among the four occlusal types, and maxillary incisor area is more likely to have root resorption than mandibular incisor area[31] .

4.4 Occlusal contact

Decreased occlusal function may reduce the possibility of incisal wear and reduce the irritating effect on alveolar bone, resulting in atrophic changes in the periodontal ligament and root resorption, such as the reduction of odontoblasts and decreased differentiation during tooth development, thus affecting root length. In an experiment on the effect of occlusal stimulation on alveolar bone, extraradicular resorption was significantly greater during molar tooth movement in rats without occlusal contact than in normal occlusion [32], It suggests that reduced occlusal function also increases the risk of extraradicular resorption.

4.5 Age

It has been shown that the crown length of maxillary and mandibular central incisors decreases with increasing patient age; this may be due to age-related physiological attrition, in particular the crown length of mandibular incisors decreases with increasing age, and crown-root ratio decreases significantly with increasing age[14] **.**

5. Conclusion

In clinical practice, shorter root resorption leads to an increase in the crown-root ratio, a shift of the center of resistance of the tooth toward the crown side, an increase in root stress for the same magnitude of chewing force, and an increased risk of tooth loosening[33]. In orthodontic clinic, crown-root ratio has certain significance in the development of treatment plan, selection of orthodontic tooth movement mode, and long-term stability after treatment. Orthodontists should analyze the changes of crown length and crown-root ratio according to patient gender, ethnicity and other comprehensive judgments during orthodontic treatment, so as to better estimate the treatment risk, maintain the health of periodontal tissues, and then establish a good occlusal relationship, maintain dental arch stability, and finally obtain a good therapeutic effect.

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