Abstract

Relationship between orthodontically induced

external root resorption and properties of root cementum

2022
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【Introduction】

Orthodontically induced external root resorption (OIRR) is an unpredictable common risk and severe OIRR causes irreversible morphological changes at the root apex. Patient-related factors such as genetics, systemic disease, and abnormal root morphology, as well as treatment-related factors such as appliance type and excessive orthodontic force, may contribute to OIRR. The physical properties and chemical composition of root cementum may affect resistance and sensitivity to OIRR. Furthermore, the diagnosis of OIRR is often made using two-dimensional images such as panoramic radiographs, but it is difficult to accurately identify true root resorption using only two-dimensional information due to distortion. On the other side, dental cone beam computed tomography (CBCT) is widely used in the field of orthodontics in recent years, because it can obtain highly reproducible images without distortion.

The aim of this study was to investigate the relationship between OIRR and three-dimensional tooth movement in orthodontic treatment using CBCT, and to identify new risk factors for OIRR by examining the relationship between OIRR and the physical properties and chemical composition of the root cementum.

【Materials and Methods】

1. Preparation of root cementum specimens

Twenty-seven maxillary first premolars (N=27) were extracted from patients (female, mean age: 20±2.4 years) who visited the Department of Orthodontics, Dental Clinic, Health Sciences University of Hokkaido and required extraction for orthodontic treatment. Randomly selected unilateral extracted teeth were divided into buccal and palatal portions, and further divided into three portions (cervical, central, and apical). The teeth were classified into buccal cervical (BCV), buccal central (BCT), buccal apical (BA), palatal cervical (PCV), palatal central (PCT), and palatal apical (PA) (n=162). The specimens were encapsulated in epoxy resin (Epofix, Struers), and the surfaces were polished to obtain a suitable surface for nanoindentation test.

2. Evaluation of physical properties of the root cementum samples

The physical properties (hardness and elastic modulus) of each root cementum specimen were measured at three locations (inside, center, and outside) on each of the six specimen (BCV, BCT, BA, PCV, PCT, PA) using a nanoindentation testing (ENT-1100A, Elionix). Nanoindentation testing was carried out at 28°C with a peak load of 10 mN (n = 162).

3. Observation and composition analysis of samples by Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray spectroscopy (EDX)

After the nanoindentation test, the specimens were dehydrated in a graded series of ethanol (70 % to 100%) and further dried at 45°C for 48 h. Representative surfaces of cementum specimens were examined with SEM (JMS-7800F, JEOL) and then the composition was analyzed by EDX.

4. Measurement of the amount of tooth movement after orthodontic treatment

Among the patients whose samples were collected, CBCT data were obtained for 8 patients before the start of active treatment (T1) and at the end of active treatment (T2). CBCT data were converted to STL data (mimics, materialize), and a composite model of the cranial bone, maxillary bone, and tooth data to be measured was created for the maxillary superimposition, and a composite model of the mandible bone and tooth data to be measured was created for the mandible superimposition and superimposed at T1 and T2 (3-matic, materialize). The movement of the anterior teeth was measured in the mesial-distal (X-axis), labio-lingual (palatal) (Y-axis), and vertical (Z-axis) directions, and that of the molars in the buccal-lingual (palatal) (X-axis), mesial-distal (Y-axis), and vertical (Z-axis) directions; the Z-axis movement was measured as "+" value for the downward pressure direction and "-" value for the upward movement direction.

5. Three-dimensional evaluation of the amount of root resorption after orthodontic treatment

Using STL data, the amount of root resorption at T1 and T2 was measured as the difference in linear distance and volume. The average values of the movement and root resorption were measured on the left and right sides. The relationship between the amount of root resorption, the amount of movement, and cementum hardness was examined by calculating Pearson's correlation coefficient.

6. Statistical Analysis

Statistical analysis was performed using statistical software (SPSS Statics 26, IBM). One-way ANOVA was used for comparisons among the groups, followed by Tukey's test for multiple comparisons ($P < 0.05$). The relationship between the hardness of the root cementum and Ca/P and Mg/Ca ratios were examined by calculating Pearson's correlation coefficient.

【Results】

1. Evaluation of physical properties of cementum

The hardness and elastic modulus of the root cementum were significantly different, with the BCV having the largest value and the PA having the smallest value. The values were smaller at the center, inside, and outside of the measurement points, but there were no significantly different. The hardness of the root cementum was classified into the Soft, Moderate, and Hard groups based on the mean value of the hardness.

2. Observation of the cementum surface structure and composition analysis

The cementum width became wider in the cervical, central, and apical regions, and there was no significant difference in the surface structure between the hard and soft groups. The Ca/P ratio was significantly lower in the Hard, Moderate, and Soft groups, and a strong positive correlation was observed between the hardness of the root cementum and Ca/P ratio. A negative correlation was observed between the hardness of the root cementum and Mg/Ca ratio.

3. Results of the amount of the root resorption and the tooth movement

The root resorption was greatest in the maxillary central incisors, followed by the maxillary lateral incisors, mandibular canines, mandibular lateral incisors, maxillary canines, and mandibular central incisors. In both the upper and lower jaws, the anterior teeth showed significantly greater values than the molars. The highest amount of movement was observed in the mandibular second premolars, followed by the mandibular first molars on the x-axis, the highest amount in the maxillary central incisors, followed by the maxillary canines on the y-axis, and the highest amount in the mandibular central incisors, followed by the maxillary central incisors on the z-axis.

4. Relationship between the amount of root resorption and tooth movement

There was no correlation between the amount of root resorption on the X and Y axes, but there was a positive correlation on the Z axis.

5. Relationship between the amount of root resorption and the physical properties of cementum

A strong negative correlation was observed between the amount of root resorption and the physical properties of the root cementum.

【Discussion】

The cervical two-thirds of the root cementum was hard cell-free cementum, while the apical one-third was calcified cellular cementum, including the cells themselves. The outer side had Sharpe's fibers that invade the periodontal ligament, while the inner side had a cement dentin border, and the adhesive component other than the hard tissue component was present in the area where the cementum adheres to other structures, which may explain the lower values for the inner and outer sides.

The trend that the amount of root resorption tended to increase with decreasing cementum hardness is considered to be due to the lower Ca/P ratio in the Soft group than in the Hard group. It has been reported that Mg is always involved in bone and tooth calcification, regulates cementum metabolism, and decreases the rate of calcium phosphate degradation. In other words,

the presence of Mg affects the Ca/P ratio and the Mg/Ca ratio, and a low Ca/P ratio may be related to an increase in Mg. Therefore, the Ca/P ratio was lower and the Mg/Ca ratio was higher in the Soft group compared to the Hard group. OIRR is related to the hardness of the root cementum, suggesting that Ca/P ratio and Mg/Ca ratio may be related to the hardness of the root cementum.

【Conclusion】

The physical properties and chemical composition of the root cementum may influence its resistance and susceptibility to OIRR.