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Original Article

MMP-13 and IL-17 levels predict orthodontic root resorption

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Abstract: Objective: To investigate the relationship between orthodontic root resorption and matrix metalloprotease-13 (MMP-13) and interleukin-17 (IL-17) levels in gingival crevicular fluid. Methods: Eighty Wistar rats were divided equally into 4 groups. The ELISA method was used to quantitatively detect the changes in MMP-13 and IL-17 levels in the gingival crevicular fluid. Results: On the 1st day, after application of forces, the changes in MMP-13 levels of the gingival crevicular fluid before and after application was statistically significant ($P < 0.05$) in groups B and C; the IL-17 levels in the gingival crevicular fluid were significantly different ($P < 0.05$) in groups A, B, and C at all time points except for the first day. On the 3rd, 5th, and 7th day, the changes in MMP-13 and IL-17 levels in the gingival crevicular fluid of group A (0 g) were significantly different from that of group B (20 g) ($P < 0.05$); the MMP-13 and IL-17 levels of the gingival crevicular fluid in group A (0 g) was significantly different from that of group C (60 g) ($P < 0.05$). Changes in the levels of MMP-13 and IL-17 of group B (20 g) and group C (60 g) were statistically significant on the 5th, 7th, and 14th day ($P < 0.05$). Conclusion: The orthodontic force increases the levels of MMP-13 and IL-17 in the gingival crevicular fluid of rats, suggesting that changes in the levels of MMP-13 and IL-17 in the gingival crevicular fluid can predict the degree of root resorption under orthodontic force.

Keywords: Gingival crevicular fluid, MMP-13, IL-17

Introduction

Root resorption is one of the most common complications of orthodontic treatment. Changes in living conditions and eating habits have caused a corresponding increase in the number of orthodontic patients [1, 2]. The increased incidence of root resorption in orthodontic treatment has also been noted by more orthodontists. However, the specific pathogenesis of orthodontic root resorption is still unclear, and once it occurs, there is no effective treatment [3, 4]. Therefore, early detection of root resorption and prevention of its further development are of crucial importance.

Gingival crevicular fluid, which is secreted by periodontal tissue, penetrates the gingival sulcus from the periodontal ligament through the epithelium of the gingival sulcus [5]. The degree of periodontal inflammation and capillary permeability at the site of inflammation are closely related to changes in specific components and exudation of the gingival crevicular fluid [6]. Mechanical stimulation or inflammation of the periodontal tissue increases the permeability of the surrounding capillaries, and also changes the specific biochemical contents of the gingival crevicular fluid [5, 6]. Current research suggests that the physiological state of periodontal connective tissue is also reflected by the gingival crevicular fluid [7, 8]. Recent studies have shown that matrix metalloproteinase-13 (MMP-13) plays an important role in periodontal tissue remodeling. It has been found that MMP-13 may be released into the gingival crevicular fluid during collagen degradation and protein decomposition [9]. In the sulcus, the expression of MMP-13 in the resorbed root tissue is increased, which may serve as an indicator for root resorption during orthodontic movement [10, 11]. The root resorption caused by orthodontic force is characterized by classical signs of inflammation such as redness, swelling, heat, and pain. This phenomenon, which could be referred to as

orthodontic-related inflammatory root resorption, is of high incidence and severity, and it has been shown that interleukin-17 (IL-17) can effectively mediate the inflammatory response of these tissues [12, 13].

In this study, the changes in MMP-13 and IL-17 levels in the gingival crevicular fluid, before and after orthodontic root resorption, were compared, and the relationship between MMP-13 and IL-17 levels, and orthodontic root resorption was analyzed.

Materials and methods

Grouping and establishment of the rat models

(1) Animal selection: 80 healthy male Wistar rats, 9-10 weeks old, with an average body weight of 220.56 ± 20.45 g, were purchased from the Experimental Animal Research Institute of the Chinese Academy of Medical Sciences, Beijing. They were housed in the animal room at Longhua Hospital which is affiliated to Shanghai University of Traditional Chinese Medicine. They were housed at room temperature (20 ± 2°C) with free access to food and drink.

Animal grouping: The 80 Wistar rats were divided into 4 groups, with 20 rats per group: group A (0 g), group B (20 g), group C (60 g), and the control group. Their bilateral maxillary first molars were used as the study teeth. Corresponding experimental devices were placed in groups A, B, and C, and the control group was not treated.

Every procedure was approved by the Animal Care and Use Committee of the Beihua university affiliated Hospital and was in conformity with the guidelines of National Institute of Health.

Establishment of a rat model of orthodontic root resorption

a. Anesthesia and initial preparation: The rat was placed supine on the table, injected with anesthetic agent (10% chloral hydrate, 0.3 ml/100 g), and its limbs and head were fixed with a tying rope. The rat's upper jaw was pulled back with a cotton thread, and to prevent the tongue from falling back and suffocating the rat, its tongue was pulled out of its mouth. Maximal mouth opening was achieved with an opener, and to prevent saliva contamination, a dry cotton swab was used to isolate the teeth.

b. Placement of the force-loading device: The maxillary first molars of the rat were disinfected with an alcohol swab, and the gingival crevicular fluid was taken after drying the tooth surfaces. The adhesive surface was completely dried with a small cotton swab on the occlusal surface, and the bonding surface was completely dried with a photocuring lamp for 10 s. For the placement of the force-loading device, one end of a nickel-titanium tension spring was placed on the molar surface, fixed with 3 M resin, and photocured for 20 s. The ligature wire was inserted into the other end of the nickel-titanium tension spring, and the force value of the tension spring was measured by the applied orthodontic force. Finally, the ligature wire was passed through the interdental space of the upper and middle incisors of the rat, fixed and sterilized. To prevent the ligature wire from slipping and enhancing the anchorage, the photocurable resin was fixed onto the neck of the incisor.

c. Postoperative care: At a prescribed time, ground solid food was fed to the rats daily, and the vital signs of each group of rats were observed and recorded. Body weight changes were measured with an electronic scale. The force-loading device was checked regularly and was reinstalled if the device was damaged or detached. Timely treatment of the food residue in the periodontal area and on the force-loading device was done. The soft tissue around the maxillary first molars of the rat was carefully observed for signs of inflammation.

Execution time: After the placement of the force-loading device, 4 rats in groups A, B, C, and control group were executed on the 3rd, 5th, 7th, and 14th day, respectively.

Collection of gingival crevicular fluid and detection of MMP-13 and IL-17

Main reagents and instruments: Rat MMP-13 ELISA kit was purchased from Nanjing Senbega Biotechnology (Serial number SBJ-H1369); rat IL-17 ELISA kit was purchased from Shanghai Aolu Biotechnology Co., Ltd. (Product number F6509.-B); EP tube was purchased from Eppendorf company; and SEL-96 series enzyme

Table 1. Changes in the MMP-13 content (μg/L) of the gingival crevicular fluid of rats of each group before and after compression

Group	Before pressurization	After pressurization	t	*P*
0 g 1 d	22.240 ± 0.330	22.354 ± 0.290	1.160	0.253
0 g 3 d	20.424 ± 0.221	23.432 ± 0.294	36.570	< 0.001*
0 g 5 d	21.232 ± 0.345	23.601 ± 0.299	23.211	< 0.001*
0 g 7 d	21.093 ± 0.120	23.620 ± 0.324	32.710	< 0.001*
0 g 14 d	21.210 ± 0.433	23.309 ± 0.500	14.190	< 0.001*
20 g 1 d	23.360 ± 0.545	23.887 ± 0.737	2.571	0.014*
20 g 3 d	12.471 ± 0.389	26.149 ± 0.490	97.770	< 0.001*
20 g 5 d	18.303 ± 0.448	27.302 ± 0.557	56.300	< 0.001*
20 g 7 d	22.484 ± 0.870	29.221 ± 0.776	25.840	< 0.001*
20 g 14 d	20.713 ± 0.179	23.445 ± 0.740	16.050	< 0.001*
60 g 1 d	23.544 ± 0.332	23.848 ± 0.444	2.452	0.019*
60 g 3 d	17.320 ± 0.479	30.509 ± 0.382	96.270	< 0.001*
60 g 5 d	12.692 ± 0.556	34.021 ± 0.445	133.900	< 0.001*
60 g 7 d	24.299 ± 0.265	39.200 ± 0.278	173.500	< 0.001*
60 g 14 d	25.475 ± 0.276	34.230 ± 0.499	68.660	< 0.001*

Note: *indicates that the difference in the content of the group before and after the force is statistically significant (P < 0.05).

label analyzer was purchased from Shanghai Precision Instrument Co., Ltd.

Collection and treatment of gingival crevicular fluid

Before using the EP tube to collect the gingival crevicular fluid, the force-loading device was removed to prevent contamination of the gingival crevicular fluid with blood. The collected gingival crevicular fluid was weighed and diluted to a concentration of 0.15 mg/150 μl, and it was spun in a centrifuge at 3500 r/min for 5 minutes, stored in a low-temperature refrigerator at -80°C, and tested for biomarker level within one week of storage.

Manipulation of the MMP-13 and IL-17 ELISA kits for testing of gingival crevicular fluid

Setting of the sample, standard, and blank holes to be tested was done. One hundred microliters of sample diluent were placed in the blank wells and 100 μl of the sample to be tested was placed in the standard well. Both samples were mixed by covering with a sealing plate, and incubated for 30 min at 37°C. The sealing film was carefully removed and the supernatant discarded. The wells were dried and filled with the washing solution, left for 30 s, and supernatant was discarded. This was repeated 5 times, and all wells were consecutively dried. Fifty microliters of the enzyme labeling reagents were added to each well with the exception of the blank well. After incubation at 37°C for 30 min, the wells were washed. Color developer was added to each well, the contents were thoroughly mixed, and the color was allowed to develop at 37°C for 15 min. Subsequently, 50 μl of the stop solution was added to each well, and the optical density (OD) value of each well was immediately measured at 450 nm using an enzyme-label analyzer. The concentrations of MMP-13 and IL-17 were subsequently calculated.

Statistical methods

Statistical analysis was carried out using SPSS 17.0 (Beijing Bo Yi Zhixun Information Technology Co., Ltd.) software system. Measurement data was expressed as mean ± standard deviation, and t-test was used for comparison between the two groups. When P < 0.05, the difference was considered to be statistically significant.

Results

Changes in MMP-13 content of gingival crevicular fluid of rats in each group

Changes in MMP-13 content of gingival crevicular fluid before and after force application in rats of each group: On the first day, there was no significant difference in the MMP-13 content of the gingival crevicular fluid before and after force application in group A (0 g) rats (P > 0.05). There were significant differences in the MMP-13 content of the gingival crevicular fluid in groups B (20 g) and C (60 g) before and after force application (P < 0.05). Changes in MMP-13 content of the gingival crevicular fluid before and after force application on the 3rd, 5th, 7th, and 14th day after the completion of force loading, were compared. The results showed that the MMP-13 content of the gingival crevicular fluid of groups A, B, and C were significantly higher after force-loading. The differences were statistically significant (P < 0.001) (**Table 1**).

Table 2. Comparison of the MMP-13 content (μg/L) of the gingival crevicular fluid of rats in different groups at different time points

Group	Group A (0 g)	Group B (20 g)	Group C (60 g)	P1 (Group A and Group B)	P2 (Group A and Group C)	P3 (Group B and Group C)
1 d	0.114 ± 0.759	0.527 ± 0.853	0.304 ± 0.644	0.114	0.399	0.357
3 d	3.008 ± 0.366	13.678 ± 2.003	13.189 ± 2.024	< 0.001	< 0.001*	0.447
5 d	2.369 ± 0.509	8.999 ± 3.425	21.329 ± 2.324	< 0.001	< 0.001*	< 0.001*
7 d	2.527 ± 0.196	6.737 ± 0.901	14.901 ± 2.112	< 0.001	< 0.001*	< 0.001*
14 d	2.099 ± 1.309	2.732 ± 1.544	8.755 ± 1.706	0.1701	< 0.001*	< 0.001*

Note: *indicates that the difference in the content of the group before and after the force is statistically significant (P < 0.001).

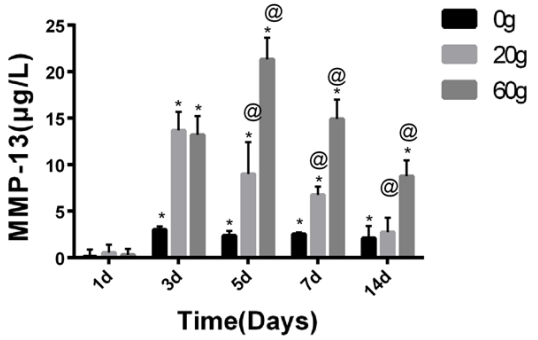

Figure 1. Comparison of changes in the MMP-13 content of gingival crevicular fluid in each group. The anterior-posterior changes in MMP-13 content of gingival crevicular fluid were detected by ELISA. *There was significant difference between group A (0 g) and the other two groups, and the difference was statistically significant (P < 0.05); @ indicates group B (20 g) was significantly different from group C (60 g), and the difference was statistically significant (P < 0.05).

Comparison of MMP-13 content of gingival crevicular fluid in rats of different groups at different time points

On the third day after the completion of force-loading, the MMP-13 content of the gingival crevicular fluid in group A (0 g) was increased. On the 5th, 7th, and 14th day after completion of force-loading, the MMP-13 content of the gingival crevicular fluid in group A (0 g) was maintained at a relatively stable level. At the beginning of the day, the MMP-13 content of the gingival crevicular fluid in group B (20 g) rats was significantly increased, but was gradually decreased on the 5th, 7th, and 14th day after the completion of force-loading. On the third day after completion of force-loading, the MMP-13 content of the gingival crevicular fluid in group C (60 g) was gradually increased, hit a maximum peak on the fifth day, and began to gradually decrease on the 7th and 14th day. According to the statistical results, the changes in the MMP-13 content of the gingival crevicular fluid in group A (0 g) on the 3rd, 5th, and 7th day differed from that of group B (20 g), and this was statistically significant (P < 0.05). Group A (0 g) was also significantly different from group C (60 g) on the 3rd, 5th, 7th, and 14th day (P < 0.05). The difference in MMP-13 content of the gingival crevicular fluid on the 5th, 7th, and 14th day was statistically significant (P < 0.05) (**Table 2**, **Figure 1**).

Changes in IL-17 content of the gingival crevicular fluid in rats of each group

Changes in IL-17 content of the gingival crevicular fluid before and after force application in each group of rats: With the exception of the first day, there were differences in the IL-17 content of the gingival crevicular fluid in groups A, B, and C, before and after force application (P < 0.05). On the first day of force-loading, the rats in groups A, B, and C showed no significant difference (P > 0.05) in the IL-17 content of the gingival crevicular fluid, before and after force application. The IL-17 content of the gingival crevicular fluid was measured before and after force application, on the 3rd, 4th, 5th, and 7th days. The results showed that the levels of IL-17 in the gingival crevicular fluid of groups A, B, and C were significantly higher after force loading. The differences were statistically significant (P < 0.001) (**Table 3**).

Comparison of IL-17 content of the gingival crevicular fluid in rats of different groups at different time points: On the third day after completion of force-loading, the IL-17 content of the gingival crevicular fluid of group A (0 g) was increased. On the 5th, 7th, and 14th day after completion of force-loading, the IL-17 content of the gingival crevicular fluid in group A (0 g)

Table 3. Changes in the IL-17 content (pg/ml) of the gingival crevicular fluid of rats in each group before and after compression

Group	Before pressurization	After pressurization	t	*P*
0 g 1 d	16.013 ± 2.341	16.121 ± 1.977	0.158	0.876
0 g 3 d	14.599 ± 1.550	17.566 ± 1.799	5.588	< 0.001*
0 g 5 d	15.900 ± 0.899	18.377 ± 1.150	7.589	< 0.001*
0 g 7 d	16.399 ± 1.456	18.663 ± 0.956	5.813	< 0.001*
0 g 14 d	16.057 ± 2.902	18.226 ± 3.628	2.088	0.044*
20 g 1 d	15.890 ± 1.505	16.508 ± 1.145	1.462	0.152
20 g 3 d	14.323 ± 1.409	27.982 ± 1.903	25.800	< 0.001*
20 g 5 d	15.919 ± 1.383	25.912 ± 2.879	13.990	< 0.001*
20 g 7 d	14.605 ± 1.492	21.267 ± 2.001	11.940	< 0.001*
20 g 14 d	15.793 ± 1.160	18.693 ± 1.689	6.330	< 0.001*
60 g 1 d	14.341 ± 0.464	14.637 ± 0.639	1.676	0.102
60 g 3 d	16.814 ± 1.296	29.803 ± 3.033	17.610	< 0.001*
60 g 5 d	15.700 ± 1.988	37.716 ± 2.166	33.490	< 0.001*
60 g 7 d	15.608 ± 0.785	29.909 ± 3.435	18.150	< 0.001*
60 g 14 d	15.535 ± 0.609	24.159 ± 1.003	32.870	< 0.001*

Note: *indicates that the difference in the content of the group before and after the force is statistically significant (P < 0.001).

was maintained at a relatively stable level. On the 3rd day after completion of force-loading, the IL-17 content of the gingival crevicular fluid in group B (20 g) rats was significantly increased. On the 5th, 7th, and 14th day after completion of force-loading, the content was gradually decreased. The IL-17 content of the gingival crevicular fluid in group C (60 g) rats was gradually increased on the 3rd day after completion of force-loading, reached a peak on the 5th day, and steadily decreased on the 7th and 14th day. According to the statistical results, the changes in IL-17 content of the gingival crevicular fluid in group A (0 g) differed from that of group B (20 g) on the 3rd, 5th, and 7th day, and this was statistically significant (P < 0.05). The IL-17 content of the gingival crevicular fluid in group A (0 g) was significantly different from that of group C (60 g) on the 3rd, 5th, 7th, and 14th day (P < 0.05). The difference between the IL-17 content of the gingival crevicular fluid of groups B and C was statistically significant on the 5th, 7th, and 14th day (P < 0.05) (**Table 4**, **Figure 2**).

Discussion

Gingival crevicular fluid is an inflammatory exudate that can be released by the epithelium of the gingival sulcus and its surrounding capillaries. Immune response changes in the gingival crevicular fluid is closely related to the development of periodontal disease [14, 15]. These immune response changes are mediated by biomarkers such as MMP-13 and IL-17 [10, 16]. It has been reported that the role of MMP-13 and IL-17 in stimulating osteoclast activity is related to the occurrence of root resorption during orthodontic treatment [17, 18]. As a matrix metalloproteinase, MMP-13 plays an important role in periodontal tissue remodeling [19]. To a certain extent, the MMP-13 levels can reflect the degree of periodontitis, root resorption, and other periodontal diseases that may occur during orthodontic treatment [20, 21]. IL-17, an early promoter of induced inflammatory response, amplifies existing inflammatory responses by promoting the release of pro-inflammatory cytokines and participating in the host's immune responses [22, 23]. Increased levels of IL-17 is significantly correlated with gingival index, probing depth and attachment loss, and plays an important role in the occurrence and development of early lesions in periodontal tissues [24, 25]. At present, there are reports that the concentration of IL-17 in the gingival crevicular fluid of teeth under orthodontic pressure is significantly higher after force application. It is believed that IL-17 may be involved in the process of orthodontic-induced osteoclast differentiation and root resorption [26]. Currently, there are few studies on the relationship between orthodontic root resorption and changes in the level of MMP-13 and IL-17 in the gingival crevicular fluid. Therefore, this study measured the changes in MMP-13 and IL-17 levels of the gingival crevicular fluid before and after orthodontic root resorption in an animal model. By analyzing the relationship between changes in MMP-13 and IL-17 and orthodontic root resorption, a simple and sensitive detection index, useful in the clinical diagnosis of root resorption, was formulated.

In this study, we first observed the changes in MMP-13 content of the gingival crevicular fluid of rats in each group, then we analyzed the changes in MMP-13 before and after force application, and last we compared the changes in MMP-13 content of the gingival crevicular fluid

Table 4. Comparison of changes in the IL-17 content (pg/ml) in the gingival crevicular fluid of rats in each group at different time points

Group	Group A (0 g)	Group B (20 g)	Group C (60 g)	P1 (Group A and Group B)	P2 (Group A and Group C)	P3 (Group B and Group C)
1 d	0.108 ± 0.799	0.618 ± 0.894	0.296 ± 0.733	0.065	0.443	0.221
3 d	2.967 ± 0.575	13.659 ± 2.017	12.989 ± 2.013	< 0.001	< 0.001*	0.300
5 d	2.477 ± 0.516	9.993 ± 2.387	22.016 ± 2.301	< 0.001	< 0.001*	< 0.001*
7 d	2.264 ± 0.903	6.662 ± 0.800	14.301 ± 2.988	< 0.001	< 0.001*	< 0.001*
14 d	2.169 ± 1.258	2.900 ± 1.602	8.624 ± 1.694	0.117	< 0.001*	< 0.001*

Note: *indicates that the difference in the content of the group before and after the force is statistically significant (P < 0.001).

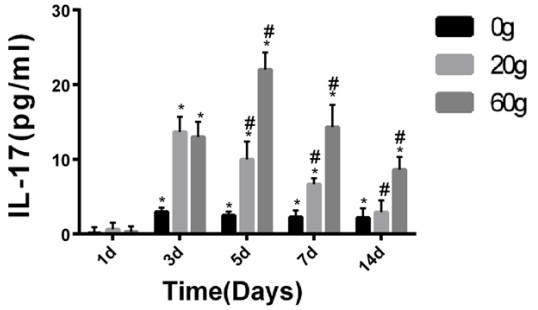

Figure 2. Comparison of changes in the IL-17 content of gingival crevicular fluid in each group. The ELISA method was used to detect the changes in IL-17 content of gingival crevicular fluid; *indicates that group A (0 g) was significantly different from the other two groups, and the difference was statistically significant (P < 0.05); #indicates group B (20 g) was significantly different from group C (60 g), and the difference was statistically significant (P < 0.05).

of rats in different groups at different time points.

The results showed no significant differences in the MMP-13 content of the gingival crevicular fluid in group A (0 g) rats, before and after force-loading on the 1st day of the device application (P > 0.05). There were statistically significant differences in the MMP-13 content of the gingival crevicular fluid of rats in groups B (20 g) and C (60 g), before and after force-loading on the 1st day of device application (P < 0.05). The changes in MMP-13 content of the gingival crevicular fluid, before and after force-loading on the 3rd, 5th, 7th, and 14th day after the completion of force-loading, were compared. The results showed that the MMP-13 content of the gingival crevicular fluid in groups A, B, and C was significantly higher after force loading, ad this was statistically significant (P < 0.001). The results of comparison between different groups showed that changes in the MMP-13 content of the gingival crevicular fluid in group A (0 g) was statistically different from that of group B (20 g) on the 3rd, 5th, and 7th day (P < 0.05). Group A (0 g) was significantly different from group C (60 g) on the 3rd, 5th, 7th, and 14th day (P < 0.05). Compared with group C (60 g), the difference in the MMP-13 content of the gingival crevicular fluid in group B (20 g) on the 5th, 7th, and 14th day was statistically significant (P < 0.05). Some studies have reported changes in MMP-13 content of the gingival crevicular fluid before and after force-loading [27, 28]. Although the above-mentioned related reports focused on the diagnostic value of MMP-13 for periodontitis, they all found that the concentration of MMP-13 in the gingival crevicular fluid of orthodontic teeth is significantly higher than that before the force-loading, which is consistent with our study, and provides excellent evidence that MMP-13 may be involved in the-orthodontic root resorption.

Simultaneously, we observed the changes in IL-17 content of the gingival crevicular fluid in each group, analyzed the changes in IL-17 content of the gingival crevicular fluid before and after force-loading in each group, and compared the changes in IL-17 content of the gingival crevicular fluid in rats of different groups at different time points. The results showed that the IL-17 content of the gingival crevicular fluid, before and after force-loading, was increased in groups A, B, and C. With the exception of those on the first day, the differences of IL-17 levels in the gingival crevicular fluid at other time points were statistically significant (P < 0.05). The results of comparing different groups showed that the change in IL-17 content of the gingival crevicular fluid in group A (0 g) was significantly different from that of group B (20 g) on the 3rd, 5th, and 7th day (P < 0.05). The IL-17 content of the gingival crevicular fluid in group A

(0 g) was significantly different from that of group C (60 g) on the 3rd, 5th, 7th, and 14th day ($P < 0.05$). The difference in IL-17 content of the gingival crevicular fluid between group B (20 g) and group C (60 g) was statistically significant on the 5th, 7th, and 14th day ($P < 0.05$). Related studies demonstrated differences in the IL-17 content of the gingival crevicular fluid in rats before and after application of the orthodontic rat model. It was found that the concentration of IL-17 in the gingival crevicular fluid was significantly higher after the orthodontic load was applied [29]. Unlike our research, this report focused on IL-17 as a possible marker of preterm birth in patients with chronic periodontitis, which varies in gingival crevicular fluid and placental tissue. This report also found that the concentration of IL-17 in the gingival crevicular fluid was significantly higher than that before the force-loading, which was consistent with our experimental results. It is suggested that the detection of the IL-17 levels in the gingival crevicular fluid could be used as a suitable evaluation of the orthodontic force value, which could guide clinical treatment. And, some other clinical reports indicated that in orthodontic treatment, the level of IL-17 in the gingival crevicular fluid of patients undergoing orthodontic root resorption is often higher when compared to patients with normal periodontal health, which is in tandem with the results of this paper [30].

In this study, the difference in the expression levels of the monitoring factors in rats and humans was not excluded and may be affected by the regional environment and experimental methods; the fear and anxiety responses of the rats in the experiment, for example, will have a negative impact on the experimental results. The study did not observe the changes of MMP-13 and IL-17 at other time points on the same day, which may lead to some confounding factors in the results.

Therefore, we will continue to increase the number of animal models as the study progresses, and we will pay attention to the relevant reports on orthodontic root resorption, in order to continuously improve the research.

In summary, under the action of orthodontic forces, the levels of MMP-13 and IL-17 in the gingival crevicular fluid of rats were increased, suggesting that changes in the levels of MMP-13 and IL-17 in the gingival crevicular fluid can predict the degree of root resorption under orthodontic force.

Disclosure of conflict of interest

None.

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