Orthodontic treatment of substituting third molars for missing permanent molars

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Introduction: This study aimed to evaluate the orthodontic effect and efficiency of substituting third molars for missing first or second permanent molars systematically. **Methods:** Forty-six patients (69 third molars total) with missing permanent molars replaced by third molars were selected. The angulation, crown-to-root ratio, and periodontal condition of the third molars before and after treatment were compared. The American Board of Orthodontics Objective Grading System was used to evaluate the alignment and occlusion of third molars after treatment. The duration of orthodontic treatment and third molar replacement therapy were also recorded. **Results:** The average orthodontic treatment time was 33.9 ± 5.6 months, and the average angulation change of third molars during treatment was 49.8 ± 29.8°. The average height of mesial alveolar bone increased by 4.8 ± 0.5 mm in patients whose third molars were mesially inclined or horizontally impacted. The root length of adult patients decreased by 0.72 ± 0.02 mm on average, and the average gingival recession was 0.10 mm, both of which were not statistically significant. The average score for each third molar evaluated by the American Board of Orthodontics Objective Grading System was 1.8 ± 0.5 points. **Conclusions:** If the indications and timing of treatment were well-controlled, third molars would be excellent substitutes for missing first or second permanent molars through the orthodontic method. (Am J Orthod Dentofacial Orthop 2023;163:173-80)

The third molars are always the last to erupt in the human oral cavity and are often impacted by limited space. Unlike the other teeth, the eruption of third molars is often accompanied by pain, difficulty in mastication, dysphagia, and acute pericoronitis. Impacted third molars increase risk-related pathologies such as dental caries, periodontal disease, root resorption, and cysts.[1] Studies have shown that mandibular third molars cause mandibular anterior teeth crowding and relapses after orthodontic treatment.[2-4] Therefore, extraction of third molars is recommended for most patients. However, the surgical procedure is not devoid of complications, particularly those of deeply-impacted, wholly-embedded, or severely-angulated teeth.[5] Sigron et al[6] reported that alveolar osteitis, temporary or persistent sensation disorders and abscesses were the top 3 most common complications after removing mandibular third molars.[6] It seems that the third molar is a big nuisance to oral health; however, there may be another side to the story.

In patients with congenitally missing first or second molars, autotransplantation of the third molar is a possible solution.[7] Teeth can be transplanted from one position to another in the same oral cavity with a good long-term prognosis, especially if this is done when the transplanted tooth has approximately two-thirds to three-fourths of its root formed.[8] However, it is really difficult to acquire an intact third molar when it is deeply

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This retrospective study was approved by the biomedical ethics committee of Peking University School and Hospital of Stomatology (PKUSSIRB No. 202058152). Informed consent was obtained from the included subjects at the beginning of treatment.
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impacted, which means that not all third molars are suitable for autotransplantation.[9]

Embryonic stem-cell and tissue engineering technologies may be another solution when acquiring an intact third molar is impossible.[10] Zou et al[11] hypothesized that human third molar buds could be obtained during development, and their germination tissue could then be stored in an embryonic stem-cell bank. When the donor's other teeth are missing, engineering technologies will help the dentist restore the missing teeth.

Third molars become important substitutes when the first or second permanent molar fails.[12] Nonimpacted third molars can be bonded and moved forward to close the space, whereas the impacted third molars require complex tooth movement. Replacing first or second molars with third molars restores dentition with natural teeth, which is different from a fixed bridge or implant. However, few studies have been reported about this type of replacement therapy. Therefore, this study aimed to evaluate the success rate, clinical effect, and efficacy of orthodontic substituting the third molar for missing first or second permanent molars.

MATERIAL AND METHODS

This retrospective study was approved by the biomedical ethics committee of Peking University School and Hospital of Stomatology (PKUSSIRB No. 20205 8152). Informed consent was obtained from the included subjects at the beginning of treatment.

Considering the effect size to be measured at 0.30, the power of the study at 0.80, and an α level of 0.05 and β value of 0.20, the total sample size was calculated to be 64 using G*Power analysis software (version 3.0.1; University of Kiel, Düsseldorf Germany). As a result, 69 third molars from 46 patients (9 males and 37 females, aged 13.0-33.0 years, with an average age of 21.9 $\pm$ 6.9 years) were selected from the Department of Orthodontics, Peking University School and Hospital of Stomatology from September 2011 to October 2017, including 22 patients with an Angle Class I relationship, 15 patients with a Class II relationship, and 9 patients with a Class III relationship. Patients with missing permanent molars and the presence of third molars were the inclusion criterion. Among them, 43 first molars and 26 second molars were missing or extracted, and the corresponding third molars were in normal size and shape. Among the 69 missing permanent molars, 4 were lost prematurely; 42 had residual roots, residual crowns, or severe caries that could not be retained; 12 had secondary lesions after root canal therapy; 9 had resorbed distal roots because of the impaction of third molars; and the remaining 2 were supraerupted and cracked respectively. All patients received fixed appliances to complete the orthodontic treatment. The number of third molars moved forward directly or after surgical exposure and uprighting were 63 and 6, respectively.[13]

The change of angulation, crown-to-root ratio, and height of mesial alveolar ridge reconstruction of third molars before and after treatment was measured on panoramic tomograms. After treatment, the alignment, occlusion, and gingival recession of third molars were measured on study casts.

Considering the distortion of panoramic tomograms and according to Elsey and Rock[14] and the Pell and Gregory classification system,[15] the panoramic images were in the right layer selection as far as possible, and the angulation measurement was based on the specially defined plane. The mesial inferior intersection angle between the long axis of the maxillary third molar and the maxillary palatal plate, which is a horizontal reference plane passing through the bilateral palatal shadow area and perpendicular to the midline reference plane connecting the nasal septum and anterior nasal spine, was recorded as the angulation of the maxillary third molar, and the change in maxillary third molar angulation was calculated by taking the difference between the intersection angle before and after treatment (Fig 1, *A1* and *A2*). The mesial superior intersection angle between the long axis of the mandibular third molar and the mandible plane was recorded as the angulation of the mandibular third molar, and the change in mandibular third molar angulation was calculated by taking the difference between the intersection angle before and after treatment (Fig 1, *B1* and *B2*).

Because of the different magnifications in panoramic tomograms and individual differences, the root length was expressed by the root to crown length ratio, and the difference before and after treatment was recorded as the external absorption amount.

Taking the line connecting the mesial and distal cementoenamel junction of adjacent molars as the reference plane on panoramic tomograms, the lowest point of the mesial alveolar ridge of the mandibular third molar to the reference plane before treatment was recorded as *D1*, whereas the lowest point of the mesial alveolar ridge of the mandibular third molar to the reference plane after treatment was recorded as *D2*. The difference between *D1* and *D2* was counted as the change of mesial alveolar ridge reconstruction height of the mandibular third molar (Fig 1, *C1* and *C2*).

According to the Nagappa and Mukta gingival recession classification,[16] the relative amount of gingival recession was measured on posttreatment study casts, taking the contralateral molar area as a reference standard rather than comparing the gingival state of the

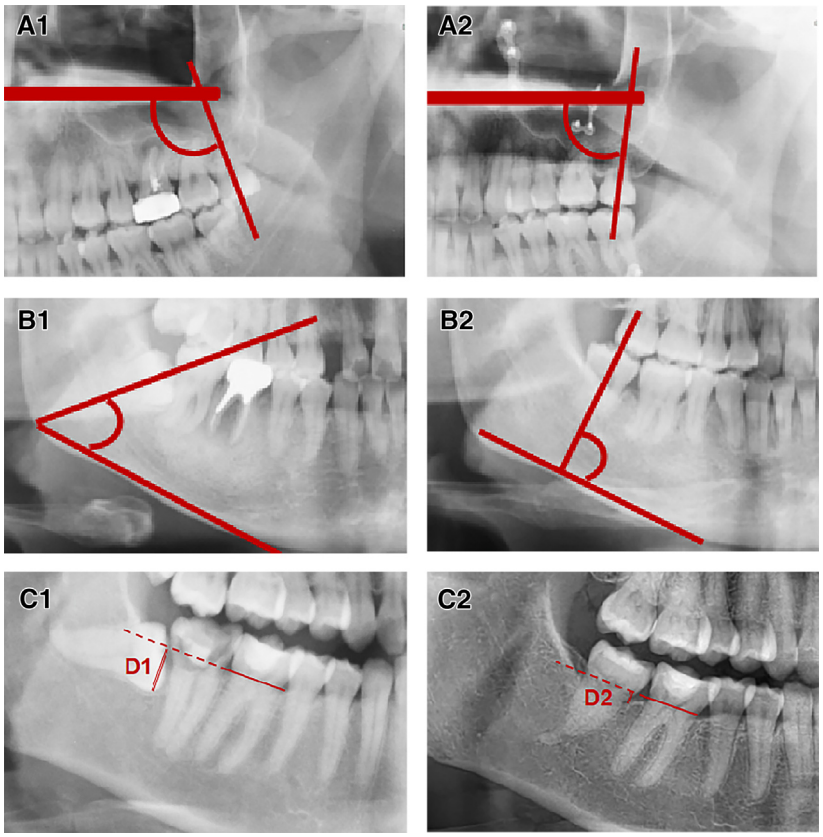

Fig 1. Schematic diagram of the measurement method: **A1,** The mesial inferior intersection angle between the long axis of the maxillary third molar and the maxillary palatal plate before treatment; **A2,** After treatment; **B1,** The mesial superior intersection angle between the long axis of the mandibular third molar and the inferior border of the mandible before treatment; **B2,** After treatment; **C1,** The height of mesial alveolar ridge reconstruction before treatment; **C2,** After treatment. *D1*, distance of the lowest point of the mesial alveolar ridge of the mandibular third molar to the reference plane before treatment; *D2*, after treatment.

moved teeth before and after treatment. The amount of gingival recession was counted at the most severe sites of each molar.

American Board of Orthodontics Objective Grading System (ABO-OGS) was used to measure the molars moved in the study cast objectively,[17] that is, the second and third molars were measured simultaneously when the first molars were missing or extracted, whereas the third molars were measured when the second molars were missing or extracted. The measurement items included alignment, vertical positioning of marginal ridges, buccolingual inclination, occlusal relationship, occlusal contacts, overjet, and interproximal contacts.

The time from the beginning of orthodontic treatment to the removal of the orthodontic appliance is the total duration of orthodontic treatment, and the time from the bonding of the third molar to the closing of the molar extraction space is the duration of third molar replacement therapy.

Statistical analysis

Statistical analyses were performed with SPSS software (version 21; IBM, Armonk, NY). All data were expressed as mean ± standard error of the mean, and the analyses were conducted by t test. The difference was statistically significant with $P < 0.05$. All measurement items were measured 3 times, and each measurement interval was 2 weeks. The intraclass correlation coefficients were calculated, and the measurement results were averaged.

RESULTS

Among the 69 third molars included in the study were 22 maxillary molars and 47 mandibular molars. With respect to the angulation of included third molars, 22 were orthostatic (including 19 maxillary molars and 3 mandibular molars), 44 were mesially inclined or horizontally impacted (which were all mandibular molars

Table I. The duration and times of follow-up visits for first and second permanent molars' replacement therapy

Groups	*Treatment duration*	*Treatment visits*
Loss of first molars (n = 43)	21.2 ± 5.4	20 ± 4
Loss of second molars (n = 24)	19.8 ± 6.1	19 ± 5
t value	1.887	1.857
P value	0.032	0.046

Table II. The duration and times of follow-up visits for maxillary and mandibular molars' replacement therapy

Groups	*Treatment duration*	*Treatment visits*
Maxillary molars (n = 22)	20.0 ± 5.8	19 ± 5
Mandibular molars (n = 45)	22.1 ± 5.5	21 ± 5
t value	1.879	1.727
P value	0.044	0.048

and 6 of which were surgically exposed), and 3 were distally-inclined (which were all maxillary molars). According to Pell and Gregory plane classification, 5 of the 44 mesially inclined or horizontally impacted third molars were in the high position, 39 third molars were in the middle position, and none were in a low position. At the end of treatment, 67 of the 69 third molars included in this study were successfully integrated into the complete dentition, achieving the purpose of orthodontic treatment ultimately. Two molars failed, of which the mandibular molar was extracted because of crown-splitting, and the maxillary molar was ankylosed.

All measurement items were measured 3 times, and the intraclass correlation coefficients for angulation, crown-to-root ratio, mesial alveolar ridge height, the relative amount of gingival recession, and ABO-OGS scores ranged from 0.86 to 0.92.

Throughout the treatment process, the average treatment duration was 33.9 ± 5.6 months (range, 16.0-54.0) and the average number of follow-up visits was 32 ± 4 (range, 16-52). The average treatment duration of replacement therapy for patients with missing first molars and second molars were 21.2 ± 5.4 (range, 12.0-33.0) months and 19.8 ± 6.1 (range, 10.0-33.0) months, respectively. The average follow-up visits for patients with missing first molars and second molars were 20 ± 4 times and 19 ± 5 times, respectively. By *t* test analysis, the differences between the 2 groups were statistically significant (Table I). For patients with missing maxillary molars, the average treatment duration of replacement therapy was 20.0 ± 5.8 (range, 10.0-33.0) months, and the average number of visits was 19 ± 5 times. For patients with missing mandibular molars, the average treatment duration of replacement therapy was 22.1 ± 5.5 (range, 12.0-33.0) months, and the average number of visits was 21 ± 5. The differences between the 2 groups were statistically significant by *t* test analysis (Table II).

Before treatment, the average angulation of third molars was 59.8 ± 29.9°, and the average change of angulation after treatment was 49.8 ± 32.8°. The average angulation change of maxillary and mandibular molars, which were inclined, was 31.2° ± 10.1° and 51.0° ± 30.2°, respectively.

Taking age as a stratification factor, the number of adolescent and adult third molars was 24 and 45, respectively. The crown-to-root ratio of third molars in the adolescent group before and after orthodontic treatment was 1.08 ± 0.30 and 1.52 ± 0.22, respectively. The crown-to-root ratio of third molars in the adult group before and after treatment was 1.72 ± 0.32 and 1.62 ± 0.51, respectively. As a result, The root length of third molars in the adolescent group increased after orthodontic treatment, and this difference was significant by *t* test analysis. Correspondingly, the root length in the adult group decreased, but no significant difference was determined. The average crown length of third molars in permanent teeth in Chinese patients was 7.1-7.3 mm.[18] Therefore, it can be estimated that the average root length of the adolescent group increased by 3.17 ± 0.44 mm, and the average root length of the adult group decreased by 0.72 ± 0.02 mm (Table III). Furthermore, the change in the crown-to-root ratio of maxillary and mandibular third molars after treatment was 0.20 ± 0.06 and 0.22 ± 0.08, which showed no significant difference by *t* test (Table IV).

In patients with orthostatic or distally-inclined third molars before treatment, the height of the mesial alveolar ridge had no change after treatment; in patients with mesially inclined or horizontally impacted third molars before treatment, which were all mandibular third molars, the height of mesial alveolar bone increased by 4.2-5.2 mm, with an average increase of 4.8 ± 0.5 mm. By *t* test analysis, this difference was statistically significant.

In patients with missing first molars, the average amount of gingival recession of the second and third molars was 0.13 ± 0.02 mm. In patients with the loss of second molars, the average amount of gingival recession of the third molars was 0.10 ± 0.01 mm. There was no significant difference between the 2 groups. Meanwhile, the average gingival recession of the moved

Table III. Changes in the crown-to-root ratio

Groups	Crown-to-root ratio (≤18 y, n = 25)	Crown-to-root ratio (>18 y, n = 42)
Before	1.08 ± 0.30	1.72 ± 0.32
After	1.52 ± 0.22	1.62 ± 0.51
t value	2.232	2.004
P value	0.027	0.052

Table IV. Comparison of maxillary and mandibular molars' change of crown-to-root ratio, gingival recession, and ABO-OGS cast scores

Groups	Crown-to-root ratio	Gingival recession	ABO-OGS scores
Maxillary molars (n = 22)	0.20 ± 0.06	0.11 ± 0.02	1.5 ± 0.3
Mandibular molars (n = 45)	0.22 ± 0.08	0.13 ± 0.01	1.3 ± 0.4
t value	1.923	1.989	1.936
P value	0.056	0.052	0.055

ABO-OGS, American Board of Orthodontics Objective Grading System.

maxillary and mandibular molars were 0.11 ± 0.02 and 0.13 ± 0.01 mm, respectively, which showed no significant difference (Table IV).

The ABO-OGS cast scores of patients with missing first molars were higher because the third molars mainly focused on the vertical positioning of marginal ridges, buccolingual inclination, occlusal relationship, occlusal contacts, and interproximal contacts, and the average score for second and third molars was 1.5 ± 0.4 points. For the patients with missing second molars, the scores of third molars were mainly focused on the vertical positioning of marginal ridges, buccolingual inclination, occlusal relationship, and occlusal contacts, and the average score of each third molar was 1.0 ± 0.2 points. The 67 third molars scored 118 points, averaging 1.8 ± 0.5 points per tooth (Table V). The ABO-OGS cast scores of the moved maxillary molars and mandibular molars were on average 1.5 ± 0.3 and 1.3 ± 0.4 points, respectively, which all mainly focused on the vertical positioning of marginal ridges, buccolingual inclination, occlusal relationship, and occlusal contacts and showed no significant difference (Table IV).

DISCUSSION

There are many reports about replacing missing molars by erecting and moving third molars forward.[19,20] However, the main purpose of these studies is to introduce the technical methods of orthodontic treatment, and they lack the evaluation of clinical results. Therefore,

Table V. The ABO-OGS cast scores of 7 measurement items

	Loss of first molars (n = 43)		Loss of second molars (n = 24)
Items/scores	Second molars	Third molars	Third molars
Alignment	0	3	1
Vertical positioning of marginal ridges	3	13	4
Buccolingual inclination	8	23	5
Occlusal relationship	7	21	6
Occlusal contacts	7	20	6
Overjet	1	3	1
Interproximal contact	10	10	2

ABO-OGS, American Board of Orthodontics Objective Grading System.

with the 46 patients and 69 third molars, the clinical effect of third molars replacing missing molars in terms of change of the angulation, root length, height of mesial alveolar ridge reconstruction, and gingival morphology, as well as the objective scores of ABO-OGS after treatment, were evaluated respectively.

In this retrospective study, 67 of the 69 third molars achieved good contact with adjacent teeth, root parallelism, stable occlusal contacts, and normal gingival morphology, which meant that the success rate was 97.1%. This pertained even to the severely impacted third molars. Therefore, with careful orthodontic design and experienced operation, the angulation of third molars would not affect the final orthostatic effect. As we all know, root resorption is a common phenomenon in orthodontic treatment,[21-23] shortening in root length of adult third molar roots was detected after treatment in this study, but no statistically significant differences were found, which corresponded to the result of Wang et al.[24] The onset and progression of root resorption are associated with risk factors such as the duration of treatment, the magnitude of the force applied, the direction of the tooth movement, the method of force application (continuous vs intermittent) and the shape of the root. In this study, Nitinol wires were used, and light force was applied to move the third molars. In addition, the roots of the third molars were moved to the area without cortical bone. Thus, little root resorption was found in the third molar of adult patients.

Periodontal condition is another concern for orthodontists, so we evaluated the height of mesial alveolar ridge reconstruction of impacted mandibular third molars and gingival recession of the moved molars. In this study, the reconstruction of the mesial alveolar ridge was active, and the height of the mesial alveolar ridge

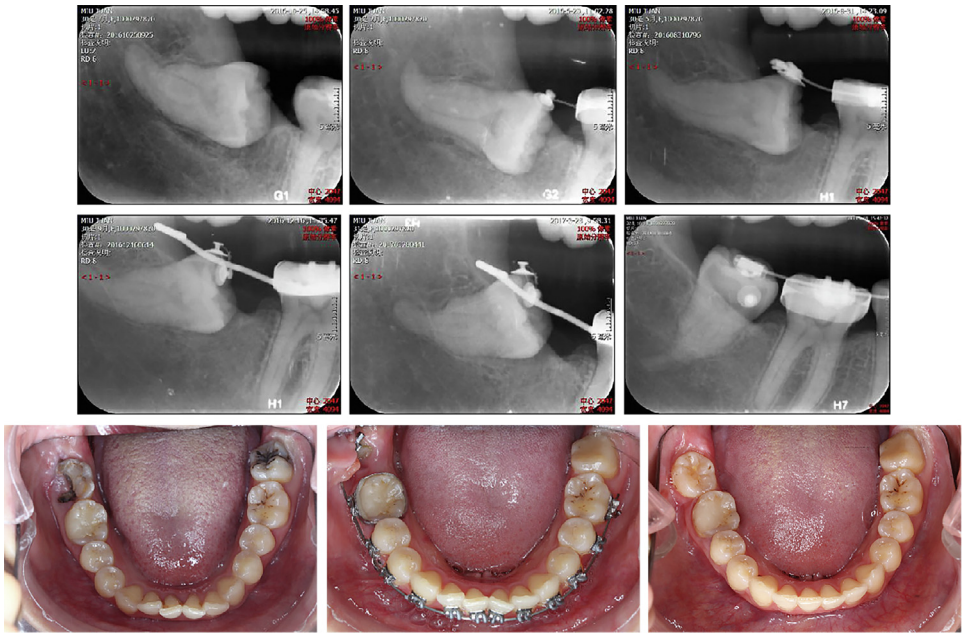

Fig 2. Periapical radiography and intraoral photography of the treatment process.

increased after treatment. In addition to the benign change of the alveolar ridge, the gingival morphology and the height of the gingival covering the root surface of most third molars were not affected by orthodontic force. Joss-Vasselli et al[25] reviewed the clinical situation of gingival recession after orthodontic treatment and found no significant correlation between the gingival recession and orthodontic treatment.

In addition, good alignment and occlusion are significant to oral health and function; as a result, ABO-OGS was used to objectively evaluate the alignment and occlusion of third molars after treatment in this study, which is widely used to evaluate the effect of orthodontic treatment, especially the occlusal condition of posterior teeth.[26,27] The results of this study showed that although the third molars were located at the end of the dental arch, the total average score of the 7 measurement items was about 1.8 points per tooth, which can be considered that 67 third molars integrated into the dentition had a good adjacency relationship with the adjacent teeth and had a good occlusion relationship with the opposite teeth. What matters is that this is the first study to evaluate the alignment and occlusion of third molars after treatment with ABO-OGS.

For patients with missing permanent molars and the presence of third molars, orthodontic treatment can replace prosthetic treatment. However, the indications and opportunities for orthodontic treatment should be strictly controlled. First, the obvious absorption of alveolar bone does not indicate third molars replacement therapy, which lacks adequate periodontal supporting tissue. Of course, if sufficient alveolar support can be provided through bone augmentation surgery, it can be considered a relative indication.[28] In addition, the innovative technology of periodontal accelerated osteogenic orthodontics can increase the alveolar bone width and posttreatment stability, shorter treatment time, and decrease the amount of apical root resorption, which is a clinical procedure that combines selective alveolar corticotomy, particulate bone grafting, and application of orthodontic forces.[29,30]

Second, the size and shape of third molar crowns should be normal to function as normal molars. Traditionally, panoramic tomograms are used to observe the crown size and root morphology of third molars from a 2-dimensional perspective. However, it seems that the third molars with normal crown size from the 2-dimensional direction still have the possibility of developmental deformity. Even if the third molars are pulled to the target position, they may also have problems with loose occlusal contact and poor contact with adjacent teeth. At this time, the examination of cone-beam computed tomography is particularly important,[31-33] which can reconstruct the 3-dimensional shape of third molars and carry out virtual tooth arrangement to predict the alignment and occlusal relationship after treatment. Therefore, it is suggested that the replacement therapy of third molars should be designed after a 3-

dimensional analysis. In terms of orthodontic opportunity, the earlier extraction time of the first or second permanent molars, the more conducive to the automatic adjustment and mesial movement of third molars, thus reducing the difficulty of follow-up treatment.

The first and second permanent molars are susceptible to pathologic factors in the oral cavity and are often extracted when serious lesions occur. These missing teeth could be restored with removable dentures, fixed bridges, implants, autogenous tooth transplantation, and embryonic stem-cell and tissue engineering technologies. In addition, the therapeutic possibility presented in this study on replacing missing first or second molars with third molars can be an excellent option, which has the following advantages:

First, there are no strict requirements for the positions of third molars. Our results showed that orthostatic and impacted third molars could be used to replace the extracted molars as long as there is no tooth ankylosis. The figure shows a 29-year-old woman whose residual crown of the mandibular right second molar could not be restored, and the distal third molar is horizontally impacted with its apex close to the mandibular nerve canal. Despite the complex position of this third molar, we successfully erected and moved it forward (Fig 2).

Second, there is no requirement for the state of root development. Both adolescents and adults can move the third molars to the targeted position with orthodontic treatment. Furthermore, any third molars in the early stage of root development can be adjusted automatically after the second molar is extracted.[34]

Third, no surgery or only minimal crown exposure is usually required. Impacted third molars can be exposed and bonded with orthodontic appliances and then adjusted to erupt into the space created after the extraction of mesial molars.

Finally, for the third molars close to the mandibular nerve canal, orthodontic traction and movement can avoid surgical extraction, which may cause dry sockets, temporary or persistent sensory disturbance, and alveolar abscesses.[35] It is particularly important that third molars are used in orthodontic treatment, and the integrity of natural dentition and oral health and function are restored with autogenous teeth. Compared with the teeth from autogenous transplantation, the pulp and periodontal conditions of these moved teeth are better.[36]

Although the advantages of third molars replacement therapy are significant, there are still some shortcomings. For example, when the third molars are severely impacted, erecting the third molars often takes longer, which will prolong the treatment duration. In this study, the average time of third molars replacement therapy for erecting and moving forward was 20.8 $\pm$ 4.6 months, and the average time of the whole orthodontic treatment duration was 33.9 $\pm$ 5.6 months, which is a little longer than the conventional orthodontic duration.[37] Second, the requirement for the technique level of orthodontists is very high. Different mechanical designs and appliance devices are needed for different impacted third molars. Therefore, for general practitioners and junior orthodontists, impacted third molars with greater difficulty may be challenging.

This study is a retrospective study. The changes in angulation, crown-to-root ratio, and height of mesial alveolar ridge reconstruction before and after treatment were measured on panoramic tomograms. The problems of image deformation and magnification exist, resulting in measurement inaccuracies. In addition, this study does not evaluate pulp activity or periodontal probing. Therefore, the author hopes that orthodontic academia can see the importance of the clinical orthodontic effect and conduct more in-depth clinical research to provide a more systematic and scientific basis for orthodontic treatment in the future.

CONCLUSIONS

In most patients, when the indications and timing of treatment are well-controlled, the orthodontic replacement of the first or second permanent molars with third molars will have a very high success rate. This method can restore defect dentition with natural teeth and repair the morphology and function of the oral and maxillofacial system.

AUTHOR CREDIT STATEMENT

Huan-Huan Chen contributed to data curation, formal analysis, investigation, and original draft preparation; Gui Chen contributed to conceptualization, funding acquisition, project administration, and manuscript review and editing; and Hong Su contributed to conceptualization, funding acquisition, and manuscript review and editing.

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