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Anchorage loss assessment of the indirect anchor tooth during adjunctive orthodontic treatment

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Introduction: This study quantitatively assessed movement of anchor teeth connected to a miniscrew (indirect anchor tooth) and investigated factors affecting movement during adjunctive orthodontic treatment. **Methods:** Dental plaster models of 28 patients whose treatment included an indirect anchor tooth on one side were collected before and after treatment. The casts were digitally scanned, and 2 groups were constituted: the indirect anchor teeth (experimental group; n = 52) and the untreated teeth (control group; the first and second premolars opposing the indirect anchor tooth to which no orthodontic force was applied; n = 55). Pretreatment and posttreatment models were superimposed and the amount and direction of indirect anchor tooth movement were evaluated with the use of a univariate linear mixed model. Possible factors affecting movement of the indirect anchor tooth and its significance were also evaluated with the use of a multiple linear mixed model. **Results:** The indirect anchor tooth moved 0.91 ± 0.50 mm and did not exhibit significant differences in the transverse, vertical, or sagittal directions. The location of the indirect anchor tooth affected movement and the tooth moved significantly more in the mandible than in the maxilla. **Conclusions:** The indirect anchor tooth can move during adjunctive orthodontic treatment and thus requires careful monitoring for occlusal changes. (Am J Orthod Dentofacial Orthop 2019;155:347-54)

An orthodontic miniscrew contributes to improving treatment quality by reducing the side effects of orthodontic tooth movement. It is widely used for anchorage enhancement and for movement of the molars,[1,2] which had been considered difficult without extraoral appliances. Furthermore, because it can deliver orthodontic force directly to a target tooth, miniscrew use is helpful in adjunctive orthodontic treatment.

For successful adjunctive treatment, the orthodontic force should be applied to a limited number of teeth to prevent any possible changes in occlusion and to obtain the specific treatment goal. Even though a direct application of force by orthodontic miniscrew is considered first, some anatomic structures make this impossible, such as deficient attached gingiva, a buccal frenum, and narrow interproximal alveolar bone. Therefore, an indirect anchorage system was introduced consisting of a miniscrew and a tooth (Fig 1) adjacent to the target tooth serving as an anchorage.[3,4]

Movement of the miniscrew during orthodontic treatment has been noted by many investigators and systematically reviewed.[5-7] A review of 9 clinical studies found that the miniscrew head moved by 0.23-1.08 mm and that the most frequent types of movement were bodily movement and controlled tipping.[5] In a case report,[3] the maxillary first premolar served as the indirect anchor tooth and showed reciprocal movement during molar distalization. Therefore, when an indirect anchorage system is used, it can be assumed that the indirect anchor teeth where the orthodontic force is delivered directly could move correspondingly instead of the miniscrew. However, there have been few studies that investigated the amount of movement.

Three-dimensional (3D) scanning and superimposition techniques are regarded as accurate and reliable in the comparison of dental study models before and after treatment.[8,9] Therefore, the present study was performed to evaluate the anchorage loss of indirect anchor teeth and to investigate factors affecting

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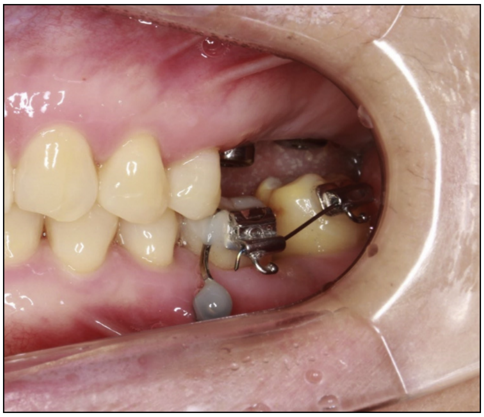

Fig 1. An indirect anchorage system for intrusion of the mandibular left second molar.

movement by superimposing 3D models from before and after treatment for patients who underwent adjunctive orthodontic treatment with the use of an indirect anchorage system.

MATERIAL AND METHODS

We retrospectively selected 28 patients (15 men and 13 women) who visited the Department of Orthodontics at Gangnam Severance Dental Hospital from May 2007 to February 2013 and underwent adjunctive orthodontic treatment with the use of an indirect anchorage system for various reasons. The mean age was 29.9 years (male 28.2 years, female 31.4 years) and the mean treatment duration was 1.1 years (male 1.2 years, female 1.0 years), as seen in Table I. The adjunctive treatment included molar intrusion (n = 11), molar uprighting (n = 7), eruption guidance (n = 5), leveling and alignment of the anterior teeth (n = 4), and molar protraction (n = 1). The number of indirect anchor teeth used in each orthodontic treatment is shown in Figure 2.

The experimental group was composed of the indirect anchor teeth (n = 52), and the control group was composed of the opposing premolars in the same dental arch (n = 55), to which no orthodontic force was applied (Table II). The target teeth moved by the adjunctive orthodontic treatment were also included in this study to evaluate the effects of different types of target tooth movement.

An orthodontic miniscrew (Orlus; Ortholution, Seoul, Korea) was implanted in buccal or palatal interproximal alveolar bone. Two weeks after implantation, the indirect anchor teeth were connected to the miniscrew with the use of 0.019 × 0.025-inch stainless steel (SS) wire by means of using a flowable resin (Esthet-X Flow; Dentsply, York, Pa) and orthodontic treatment was performed (Fig 1).

Plaster models taken before and after treatment were scanned with the use of a 3D scanner (KOD500; Orapix, Seoul, Korea) at a 1:1 ratio. The scanned models from before and after treatment were aligned with the use of the occlusal plane as the horizontal reference plane. The occlusal plane was determined by 3 points (the mesiobuccal cusp tips of the right and left molars and the contact point of the right and left central incisal edges). The x-axis was set as the line connecting the mesiobuccal cusp tips of both molars. The z-axis was set perpendicular to the x-axis and passed through the contact point of the right and left central incisal edges. The y-axis was set perpendicular to both the x-axis and z-axis at the midpoint of both molars. As a result, the x-, y-, and z-axes were set as the transverse, vertical, and sagittal axes, respectively (Fig 3). The digital models from before and after treatment were superimposed with the use of Rapidform 2006 software (INUS, Seoul, Korea). In the maxilla, the anterior third rugae on both sides, which are known to be the most stable structure,[10-12] were used as a reference for the superimposition. In the mandible, the digital models were superimposed based on the untreated teeth including the control group. After registration, the 2 model images use the same coordinate system.

Each landmark before and after treatment was indicated with only 1 image by hiding the other image. Then we calculated the difference for each coordinate (x, y, and z) of the same landmarks before and after treatment. In addition, we measured the straight-line distances between the same landmarks on the 3D superimposed image to determine the movement of the indirect anchor tooth (Fig 4).

The landmarks used in this study are as follows (Fig 5): the cusp tip of the canine; the buccal and lingual cusp tips of the first and second premolars; the mesiobuccal, distobuccal, and palatal cusp tips of the maxillary first and second molars; and the mesiobuccal, distobuccal, mesiolingual, and distolingual cusp tips of the mandibular first and second molars. If the cusp tip was hard to identify because of restorations or attrition, the most prominent point of the cusp was marked.

This study design was approved by the Institutional Review Board of Gangnam Severance Hospital (3-2017-0276). Because this was retrospective study, written informed consent from the patients was not required.

Statistical analysis

Data are presented as means and standard deviations (SDs) for continuous variables and counts for categoric variables. A univariate linear mixed model was used to

Table I. Demographic features of subjects

Subjects	*Age, y*			*Treatment duration (y, mean ± SD)*
	Mean ± SD	*Minimum*	*Maximum*	
Male (n = 15)	28.2 ± 11.7	15.6	45.1	1.2 ± 0.4
Female (n = 13)	31.4 ± 12.8	13.3	56.0	1.0 ± 0.7
Total (n = 28)	29.9 ± 12.1	13.3	56.0	1.1 ± 0.6

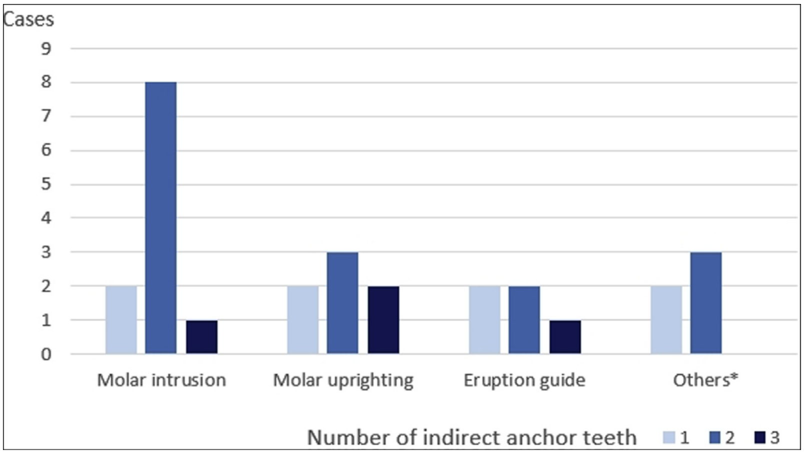

Fig 2. Number of indirect anchor teeth used in each orthodontic treatment. *Others: leveling and alignments of anterior teeth and molar protraction.

Table II. Number of samples in the experimental and control groups

Jaw	*Tooth*	*Experimental group*	*Control group*
Maxilla	Canine	5	
	1st premolar	6	14
	2nd premolar	7	17
	1st molar	6	
	2nd molar	1	
Mandible	Canine	1	
	1st premolar	6	13
	2nd premolar	10	11
	1st molar	10	
	Total	52	55

compare the experimental group with the control group regarding the repeated measurements of teeth. Patients were treated as a random effect, and the group indicator was fixed with the use of a compound-symmetry variance-covariance structure. The experimental group was subdivided into 3 subgroups according to the types of target tooth movement, and each subgroup was compared with the control group with the use of a univariate linear mixed model and the Bonferroni procedure for multiple comparisons. A multiple linear mixed model was used to identify which factors affected the movement of the experimental group after adjusting for sex and age and examining the variance inflation factor to determine if there was multicollinearity among the variables. The variables used in the multiple linear mixed model were as follows: treatment duration, miniscrew location (buccal, palatal, or both sides), the number and location (maxilla or mandible) of the indirect anchor tooth, the relative distance between the miniscrew and indirect anchor tooth (1 was assigned when the miniscrew was located in the interproximal space of the indirect anchor tooth; 2 was assigned when the miniscrew was located in the interproximal space of the tooth next to the indirect anchor tooth), and the amounts and types (molar intrusion, molar uprighting, eruption guidance, and others) of target tooth movement.

One examiner performed all measurements. To evaluate intraclass reliability, the same examiner reanalyzed all measurements in 5 randomly selected patients after a 2-week interval. The intraclass correlation coefficient from the reanalyzed measurements showed high reliability (∼1.00). A 2-sided P value of <0.05 was considered to be statistically significant. All analyses were performed with the use of SAS software version 9.2 (SAS Institute, Cary, NC).

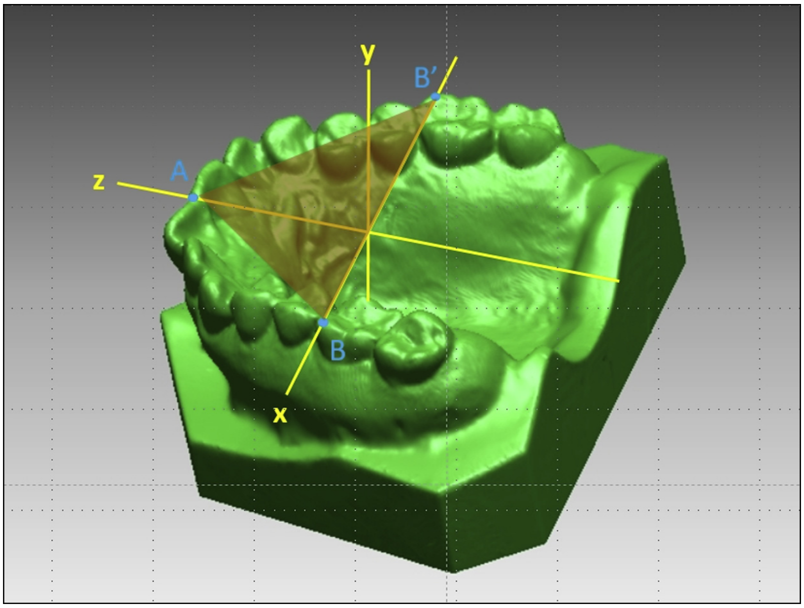

Fig 3. The *x*-, *y*-, and *z*-axes on a 3-dimensional model. *A*, contact point of the right and left central incisal edges; *B* and *B*′, the mesiobuccal cusp tips of the right and left maxillary first molars, respectively.

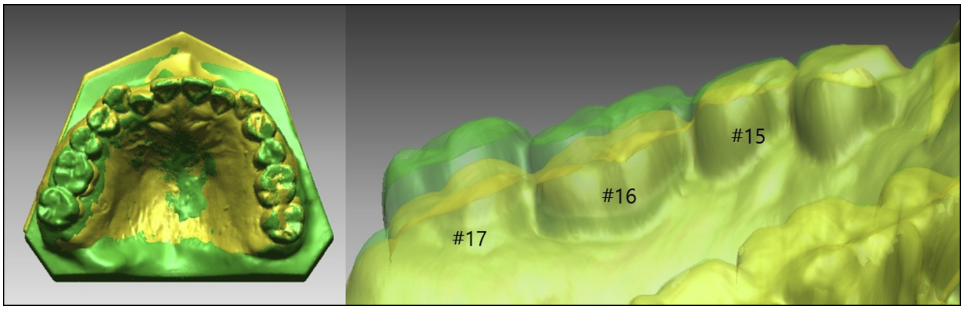

Fig 4. Superimposition of the digital models before and after molar intrusion. *Green*, before treatment; *yellow*, after treatment. The maxillary right first and second molars were intruded with the use of the maxillary right second premolar as an indirect anchor tooth. Note that the indirect anchor tooth (#15) was slightly intruded.

RESULTS

The movement was measured for each individual anchor tooth, regardless of how many indirect anchor teeth were engaged. The mean (±SD) amount of movement was 0.91 (±0.50) mm in the experimental group, which was significantly larger than that in the control group movement of 0.34 (±0.19) mm ($P < 0.001$; Table III). The experimental group moved 0.41-0.50 mm in the transverse, vertical, and sagittal planes, and the control group moved approximately 0.09-0.22 mm in each plane. The comparison between the 2 groups showed significant differences in each plane ($P < 0.001$), whereas comparisons among the 3 planes in the experimental group did not show significant differences ($P > 0.05$; Table IV).

When the experimental group was divided into 3 subgroups according to the movement type of the target teeth, 2 subgroups (molar intrusion and molar uprighting) showed significantly greater changes in the vertical and sagittal planes compared with the control group ($P < 0.01$; Table V); the indirect anchor tooth in the 2 subgroups moved apically and anteriorly during treatment. The eruption guidance subgroup showed greater apical movement than the control group ($P < 0.01$; Table V).

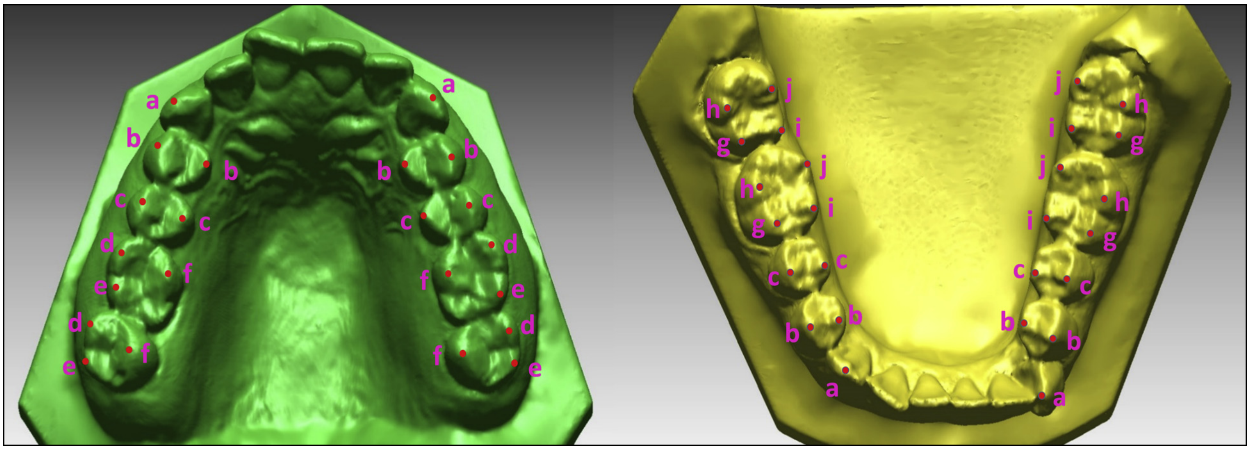

Fig 5. Landmarks on 3-dimensional digital models. *a*, canine cusp tip; *b* and *c*, buccal and lingual cusp tips of the first and second premolars; *d*, *e*, and *f*, mesiobuccal, distobuccal, and palatal cusp tips of the maxillary first and second molars; *g*, *h*, *i*, and *j*, mesiobuccal, distobuccal, mesiolingual, and distolingual cusp tips of the mandibular first and second molars.

Table III. Comparisons of measurements (mm) between the experimental group and the control group

Jaw	*Experimental group*	*Control group*	*Significance*
Maxilla	0.80 ± 0.56	0.37 ± 0.23	$P < 0.001$
Mandible	0.98 ± 0.44	0.30 ± 0.11	$P < 0.001$
Total	0.91 ± 0.50	0.34 ± 0.19	$P < 0.001$

Table IV. Movement (mm) of the indirect anchor tooth and untreated tooth on the transverse, vertical, and sagittal planes

Direction	*Indirect anchor tooth*	*Untreated tooth*	*Significance*
x (transverse)	0.50 ± 0.41	0.18 ± 0.16	$P < 0.001$
y (vertical)	0.41 ± 0.40	0.09 ± 0.08	$P < 0.001$
z (sagittal)	0.50 ± 0.37	0.22 ± 0.16	$P < 0.001$
Significance	NS	NS	

The multiple linear mixed model revealed that no variable affected the movement of indirect anchor teeth except the location of the indirect anchor teeth. Indirect anchor teeth in the mandible moved significantly farther than those in the maxilla ($P < 0.05$; Table VI).

DISCUSSION

The miniscrew as a direct anchorage system is considered to be reliable by both orthodontists and patients for various orthodontic cases.[13,14] However, secondary displacement of the miniscrew of ~0.2-1.1 mm was reported during orthodontic treatment. The insertion site, loading duration, and length of the miniscrew were factors affecting its displacement.[5,6,15]

Compared with the multitude of studies on the stability of miniscrews themselves, there have only been a few studies that evaluate the stability of indirect anchorage systems.[7,16,17] Some studies have reported the possibility of high loads around the indirect anchor tooth[16] and significant movements of the indirect anchor tooth,[18] but others have shown nonsignificant anchorage loss of the indirect anchor tooth in canine retraction.[19]

The present study demonstrates that the indirect anchor tooth moved ~0.9 mm, and especially more in the mandible, which was significantly greater than that of the tooth that did not undergo orthodontic treatment. Because the indirect anchorage system consisted of a miniscrew and connecting wire, each component can affect anchorage loss in the system.

A miniscrew in an indirect anchorage system could move under orthodontic loading. However, according to this study, the amount would be little, if any, considering that the orthodontic force was not applied directly to the miniscrew in the indirect anchorage system and the force magnitude was smaller than in previous studies.[20,21] Further radiographic and superimposition analyses performed before removal of the miniscrew would be helpful to investigate miniscrew movement.

The connecting wire and its points of connection to either a tooth or a miniscrew can affect stability. The connecting wire is made of 0.019 × 0.025-inch SS, which barely deforms during adjunctive orthodontic treatment.[22-24] The bending and torsion of the wire could be ignored because the length of the connecting wire is relatively short and the orthodontic force is not applied directly to the wire.

Table V. Direction of indirect anchor tooth movement (mm) followed by different types of orthodontic treatment

	Indirect anchor tooth			
Direction	*Molar intrusion (n = 21)*	*Molar uprighting (n = 14)*	*Eruption guidance (n = 9)*	*Untreated tooth (n = 55)*
x (transverse)	−0.01 ± 0.75	0.08 ± 0.60	−0.06 ± 0.37	−0.02 ± 0.24
y (vertical)	−0.29 ± 0.55*	−0.35 ± 0.51*	−0.36 ± 0.39*	0.00 ± 0.12
z (sagittal)	0.20 ± 0.59*	0.36 ± 0.54*	−0.20 ± 0.47	−0.03 ± 0.27

Univariate linear mixed model and Bonferroni procedure were performed to compare indirect anchor tooth and untreated tooth for each type of orthodontic movement. Positive values indicate buccal, occlusal, and anterior movement on x-, y-, and z-axes, respectively, and negative values indicate lingual, apical, and posterior movement on x-, y-, and z-axes, respectively.
*$P < 0.01$.

Table VI. Contributing factors to the movement (mm) of indirect anchor tooth

Factors	*Variables*	*Number of indirect anchor tooth*	*Movement of indirect anchor tooth*	*Significance*
Treatment duration, y	<0.5	6	0.53 ± 0.30	NS
	0.5-1.0	9	0.97 ± 0.66	
	1.0-1.5	27	0.90 ± 0.47	
	>1.5	10	1.10 ± 0.36	
Miniscrew location	Buccal	38	0.90 ± 0.45	NS
	Palatal	6	0.57 ± 0.27	
	Both	8	1.17 ± 0.67	
Number of indirect anchor tooth	1	8	0.84 ± 0.62	NS
	2	32	0.89 ± 0.45	
	3	12	1.04 ± 0.46	
Location of indirect anchor tooth	Maxilla	25	0.80 ± 0.56	$P < 0.05$
	Mandible	27	0.98 ± 0.44	
Distance between miniscrew and indirect anchor tooth	1*	44	0.87 ± 0.47	NS
	2†	8	1.01 ± 0.45	
Amount of treated tooth movement	Continuous variable	52		NS
Movement type of treated tooth	1. Molar intrusion	21	0.96 ± 0.50	NS
	2. Molar uprighting	14	1.00 ± 0.41	
	3. Eruption guidance	9	0.70 ± 0.43	
	4. Others	8	0.76 ± 0.69	

NS, not significant.
*Miniscrew is located at the interproximal space of the indirect anchor tooth; †Miniscrew is located at the interproximal space of the tooth next to the indirect anchor tooth.

The connecting area between the tooth and wire may be relatively stable because of the resin bonded to the tooth's surface. On the other hand, the connecting area between the miniscrew and wire seems to be the weakest part, because they physically contact at the neck of the miniscrew with flowable resin sealing the gap. Therefore, when orthodontic force is delivered to the indirect anchor tooth, the connecting wire can rotate around the miniscrew neck owing to the low adhesion strength between the sealing resin, miniscrew, and connecting wire.[25,26] In addition, as the stress applied to the miniscrew is concentrated in the neck area,[27] the connection between the miniscrew and wire can be broken. Depending on the measurement method, Monga et al[18] demonstrated that an indirect anchor tooth in the maxilla moved 0.83 mm or 1.27 mm and an indirect anchor tooth in the mandible moved 0.87 mm or 1.07 mm, which is similar to the results of the present study. However, they inserted a 0.017 × 0.025-inch SS wire into an auxiliary slot in the first molar tube without any bonding materials, which could allow the indirect anchor tooth to move. It is supposed that gaps in any part of the indirect anchorage system could cause movement of the indirect anchor tooth.

The multiple linear mixed model showed that there were no specific factors affecting movement except the location of the indirect anchor teeth: Teeth in the mandible exhibited greater movement than those in the maxilla. It might be supposed that greater movement of the miniscrew under orthodontic force in the mandible led to greater movement of the indirect anchor tooth. However, this assumption is contrary to some investigators who reported a smaller amount of miniscrew movement in the mandible.[28] Moreover, movement of the miniscrew could not be identified in our study.

The different superimposition bases in each jaw are also considered to affect indirect anchor tooth movement. Whereas the anterior third rugae were used as a stable superimposition base in the maxilla, teeth not subjected to any orthodontic force were used in the mandible. Although the basal bone surface and lingual or mental foramens were reported to be stable superimposition bases in the mandible,[29-31] we could not use them, because this study was performed on dental casts.

In the present study, we found that the indirect anchor tooth moved in the opposite direction of the target tooth's movement except in molar intrusion cases. In molar intrusion cases, which can be assumed to be geometry I,[32] the indirect anchor tooth is expected to move in the occlusal and anterior directions but actually moved in the apical and anterior directions. This could result from the additional force applied to the target tooth. In many molar intrusion cases in this study, direct orthodontic force from the elastomeric chain had been additionally applied to the target tooth because it is difficult to maintain a light and continuous force with brackets and wires only. The directly applied force might contribute to the apical movement of the indirect anchor tooth along with the target tooth. It would be necessary to establish a coherent design for an indirect force system without any additional forces to determine the movement of the indirect anchor tooth.

Maintenance of occlusion, except for that of the target tooth, is critical in adjunctive orthodontic treatment. In the present study, we found that the indirect anchor tooth moved during treatment and that the movement was not predictable in terms of the amount or direction of movement or the design of the indirect anchorage system, but not in terms of the location of the indirect anchor tooth. Therefore, close monitoring of occlusion should be performed even when using an indirect anchorage system including a miniscrew.

CONCLUSION

An indirect anchorage system can be used effectively in adjunctive orthodontic treatment. However, careful monitoring of changes in occlusion is required because just less than 1 mm of movement of the indirect anchor tooth is anticipated, especially in the mandible.

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