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Original Article

Identification of key determinant for predicting feasible mandibular molars distalization

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Abstract *Background/purpose:* The distal movement of mandibular molar is effective treatment strategy, while it is still difficult to determine if the posterior available space is sufficient or not for mandibular molar distalization before treatment. Thus, this study aimed to identify the measurement items of lateral cephalograms with the potential to accurately predict the posterior anatomical limit of mandibular molar distalization.
Materials and methods: Cephalometric images of 26 patients were used. We establish five landmarks: the distal contact point (D7), the distal root apex (R7), the distal tooth cervix (TC) of the mandibular second molar, the anterior border of the ramus (ABR) and the external oblique line of the mandible (E). The D7-ABR and the vertical height between TC and E (TC-V), the distal movements of D7 and R7 during treatment (D7D, R7D) were measured. The subjects were divided into bodily-like and tipping movement group, according to the ratio D7D/R7D.
Results: Significant differences in D7D and R7D were found between the bodily-like movement and tipping movement groups ($P < 0.01$). Moreover, TC-V was significantly larger in the bodily-like movement group ($P < 0.01$). A positive correlation was found between TC-V and D7D ($r = 0.68$) and between TC-V and R7D ($r = 0.69$), indicating that TC-V has the potential to make accurate predictions for D7D and R7D. D7-ABR did not show a positive correlation with R7D.
Conclusion: Using TC-V can strengthen the prediction of available posterior space for mandibular molar distalization.

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Introduction

The distal movement of a mandibular molar is often used to correct and relieve mild-to-moderate Class III crowding without adverse arch expansion.[1–4] In order to achieve this movement, various treatments have been developed such as high-pull J-hook headgear and lip bumpers.[5–8] These techniques provide acceptable outcomes; however, they depend on the patient's cooperation. In addition, it is difficult to accomplish sufficient distalization of mandibular teeth with traditional orthodontic technique.[9,10]

Nowadays, temporary anchorage devices (TADs) have been recognized by orthodontists and patients because they are mechanically simple and do not require the patient's cooperation. TADs make it possible to achieve a large distal movement of the maxillary molar without unfavorable side effects.[11,12] For example, distal movements of 3.78 mm (on average) have been reported.[13]

Compared to maxillary molar distalization, the mandible imposes greater anatomical restrictions on the possible amount of distalization.[14] Previous studies regarding this limit have targeted the posterior available space, for example using panoramic radiograph or lateral cephalogram to analyze space discrepancy and predict third molar eruption.[15–20] In most studies, the anterior border of the ramus is regarded as the posterior border of the mandibular dental arch, and the available space for mandibular molar distalization is measured along the occlusal plane. However, 2-dimensional radiographs do not properly reveal the 3-dimensional feature of the mandibular ramus. In a 3-dimensional analysis of computed tomography (CT) scans, the posterior anatomic border appears to be the lingual cortex of the mandibular body. Therefore, CT scans are recommended for patients who require considerable distal movement of mandibular molar.[14,21] However, it is not ethical or necessary to take a CT image of every new patient requiring orthodontic treatment. Like any other radiological investigation, even cone-beam CT is invasive and poses a certain risk to the patients.[22,23]

Hence, this research is aimed to propose lateral cephalograms as an alternative to CT scans for determining the posterior anatomical limit of mandibular molar distalization. We identify the key measurements that can be made to provide a precise prediction.

Materials and methods

This study was performed using a subset of the cephalometric images of 26 patients (21 females and 5 males ranging in age from 14 to 49 years). All patients were in good general health, and had no obvious medical conditions which could affect the alveolar bone and periodontal support of the tooth. In addition, they had no history of trauma, and no previous orthodontic or restorative treatments. As a result of diagnosis, they were treated with bilateral mandibular molar distalization using TADs. The mandibular third molars of the subjects were extracted before treatment. The patients were all treated in the outpatient clinic of the Department of Orthodontics and Dentofacial Orthopedics at Tokushima University Hospital, from 2009 to 2019. This study was carried out following the tenets of the Declaration of Helsinki, and was approved by the Ethics Committee of Tokushima University Hospital (No.2803).

Lateral cephalograms were taken both before and after treatment. Each lateral cephalogram was blindly traced on acetate paper by the same examiner (H.T.), in order to avoid inter-operator systematic error. The accuracy of each tracing was confirmed by 2 orthodontic professionals, who joined this study as collaborators. The reliability of individual measurements based on the cephalograms was estimated by measuring all variables twice, 2 weeks apart. A paired t-test for reproducibility showed no significant difference between the two distributions (over all patients for a given variable), indicating that the variables were reproducible. Dahlberg's formula[24] was used to estimate the random error D in individual measurements based on the observed distribution of differences: $D = \text{sqrt}\ (\Sigma d^2/2N)$, where d is the difference between each pair of measurements, and N is the number of measurement pairs. Although the reliability of individual measurements on the cephalograms was sufficient, the mean values of the two measurements were adopted when the conflict occurred between the first and second measurements.

The landmarks and line constructions used for measurements are shown in Fig. 1. Briefly, the measurements are the distal contact point of the mandibular second molar (D7); the distance (D7-ABR, **a** in Fig. 1A) between D7 and the anterior border of the ramus (ABR), measured along the mandibular plane; the tooth cervix (TC); the external oblique line of the mandible (E); the distance (TC-V, **b** in Fig. 1A) between TC and E; And the distal root apex of the mandibular second molar (R7). Please refer to Fig. 1 for details on how these lines and distances are constructed.

Cephalometric tracings pre- and post-treatment were superimposed on the mandibular plane, matching at the menton (Me). The coronal distal movement is defined as the distance (D7D, **c** in Fig. 1B) between point D7 in the pre-treatment and post-treatment cephalograms, measured along the mandibular plane. The root distal movement is defined as the distance (R7D, **d** in Fig. 1B) between point R7 pre-treatment and post-treatment, also measured along the mandibular plane. The ratio D7D/R7D indicates the relative distal movement of the second molar. When this ratio is 1.5 or less, the movement pattern is defined as a bodily-like movement. When it is more than 1.5, the movement pattern is defined as a tipping movement. In cases of double contours, the middle between the two landmarks was used for measurement.

All measurements are presented as mean ± standard deviation (SD, measured across patients). To investigate the correlations of D7D and R7D with TC-V and D7-ABR, regression analyses were carried out. D7D and R7D, TC-V and D7-ABR were statistically evaluated using the Student's *t*-test, to determine the significance of any difference between the groups experiencing bodily-like or tipping motion. Probabilities less than 0.05 were considered significant. All analyses were carried out with statistical analysis software (StatView; SAS Institute, Cary, NC).

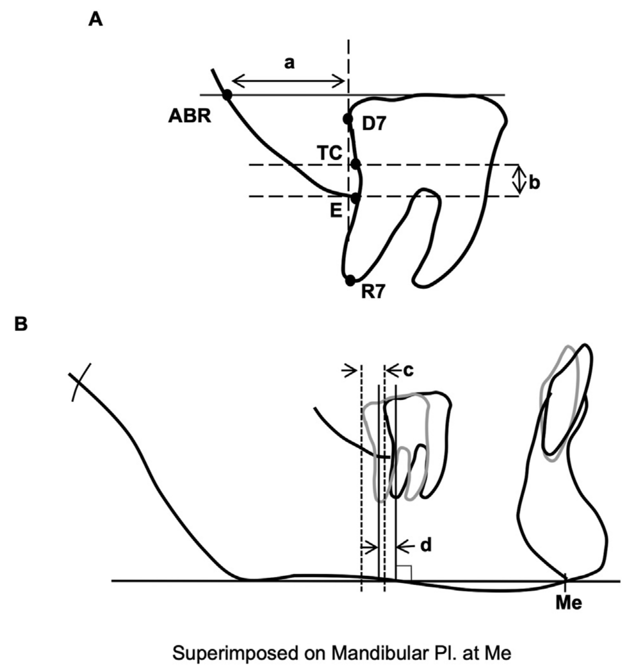

Figure 1 **A**. Construction of landmarks and lines on the lateral cephalograms: D7, the distal contact point of the mandibular second molar; R7, the distal root apex of the mandibular second molar; ABR, the cross point between the occlusal plane and the anterior border of the ramus; TC, the tooth cervix (cement-enamel junction) of the mandibular second molar; E, the cross point between the external oblique line of the mandible and the mandibular second molar. Three lines were drawn using these landmarks. The first line (**a**) is drawn perpendicular to the mandibular plane through D7, then the distance between D7 and ABR is measured along the mandibular plane (D7-ABR). The second and third lines (**b**) are drawn perpendicular to the first line, through TC and E respectively, then the distance between TC and E is measured along the first line (TC-V). **B.** Cephalometric tracings before treatment (black line) and after treatment (gray line) are superimposed on the mandibular plane at the menton (Me). The distance between the point D7 pre-treatment and post-treatment (**c**), measured along the mandibular plane, is defined as the coronal distal movement (D7D). The distance between point R7 pre-treatment and post-treatment (**d**), also along the mandibular plane, is defined as the root distal movement (R7D).

Table 1 Linear measurements of orthodontic patients treated with mandibular molar distalization.

Case no.	D7D (mm)	R7D (mm)	D7/R7	TC-V (mm)	D7-ABR (mm)
1	2.8	0.7	4.0	0	7.0
2	2.7	0.1	27.0	1.1	9.5
3	0.2	0.1	2.0	−0.7	4.5
4	2.1	1.9	1.1	2.1	4.9
5	2.1	0.2	10.5	−2.0	7.3
6	4.4	4.0	1.1	5.2	7.4
7	1.0	0.2	5.0	−1.8	2.0
8	3.3	2.2	1.5	3.5	9.4
9	1.2	0.7	1.7	−3.0	2.0
10	2.0	0.8	2.5	−0.7	2.7
11	2.6	1.0	2.6	1.6	6.0
12	1.0	0.6	1.7	−0.2	3.8
13	2.5	1.0	2.5	−1.2	3.3
14	3.0	1.5	2.0	1.6	7.0
15	1.9	1.8	1.1	0.5	4.7
16	1.5	0.1	15.0	−1.6	2.8
17	3.4	2.4	1.4	2.5	11.3
18	2.3	1.1	2.1	−1.1	6.1
19	2.8	1.1	2.5	−0.8	2.0
20	2.0	0.5	4.0	0	5.0
21	2.0	1.0	2.0	−3.0	0
22	3.0	3.0	1.0	1.0	2.0
23	3.0	2.5	1.2	0	2.0
24	2.5	2.0	1.3	1.0	2.0
25	2.2	2.0	1.1	0	2.0
26	4.0	3.1	1.3	1.0	3.5

D7D, The coronal distal movement of the second molars; R7D, The root distal movement of the second molars; D7/R7, The ratio of D7D and R7D; TC-V, The distance between the tooth cervix (TC) and the external oblique line of the mandible (The value is shown as minus when TC located below the external oblique line of the mandible); D7-ABR, The distance between the distal contact point of the mandibular second molar and the anterior border of the ramus (ABR).

Results

The movements D7D and R7D show great variety: D7D ranges from 0.2 mm to 4.4 mm, and R7D ranges from 0.1 mm to 4.0 mm. The ratio D7D/R7D also has a large variation, ranging from 1.0 to 27.0 (Table 1). According to the definition given above, 10 subjects were in the bodily-like movement group and 16 subjects were in the tipping movement group. The mean values of D7D were 3.0 ± 0.8 mm and 2.0 ± 0.8 mm for the bodily-like movement and tipping movement groups, respectively. The difference between the two means is significant ($P < 0.01$) (Table 2). The mean values of R7D were 2.5 ± 0.7 mm and 0.7 ± 0.4 mm in the bodily-like movement and tipping movement groups, respectively. The mean value of R7D in the bodily-like movement group was significantly larger than that in the tipping movement group ($P < 0.01$) (Table 2).

Positive correlations were found between TC-V and D7D ($r = 0.68$) and between TC-V and R7D ($r = 0.69$). There was a weak positive correlation between D7-ABR and D7D ($r = 0.39$), while there was no positive correlation between D7-ABR and R7D ($r = 0.079$). The correlation coefficients are higher with respect to TC-V than D7-ABR, indicating that TC-V provides a more accurate prediction of D7D and R7D (Fig. 2).

In the bodily-like movement group, the mean values of TC-V and D7-ABR were 1.7 ± 1.7 mm and 4.9 ± 3.4 mm, respectively. In the tipping movement group, the mean values of TC-V and D7-ABR were -0.7 ± 1.4 mm and 4.4 ± 2.5 mm, respectively. TC-V in the bodily-like movement group was significantly larger than that in the tipping movement group ($P < 0.01$); however, no significant difference in D7-ABR was found between the bodily-like movement and tipping

Table 2 Means and standard deviations of D7D and R7D in the bodily-like and tipping movement groups.

	D7D (mm)	R7D (mm)	TC-V (mm)	D7-ABR (mm)
Bodily-like movement	3.0 ± 0.8 *	2.5 ± 0.7 *	1.7 ± 1.7 *	4.9 ± 3.4
Tipping movement	2.0 ± 0.8	0.7 ± 0.4	-0.7 ± 1.4	4.4 ± 2.5

D7D, The coronal distal movement of the second molars; R7D, The root distal movement of the second molars; TC-V, The distance between the tooth cervix (TC) and the external oblique line of the mandible (The value is shown as minus when TC located below the external oblique line of the mandible); D7-ABR, The distance between the distal contact point of the mandibular second molar and the anterior border of the ramus (ABR). Data are expressed as mean ± SD. *: $P < 0.01$ by *t*-test.

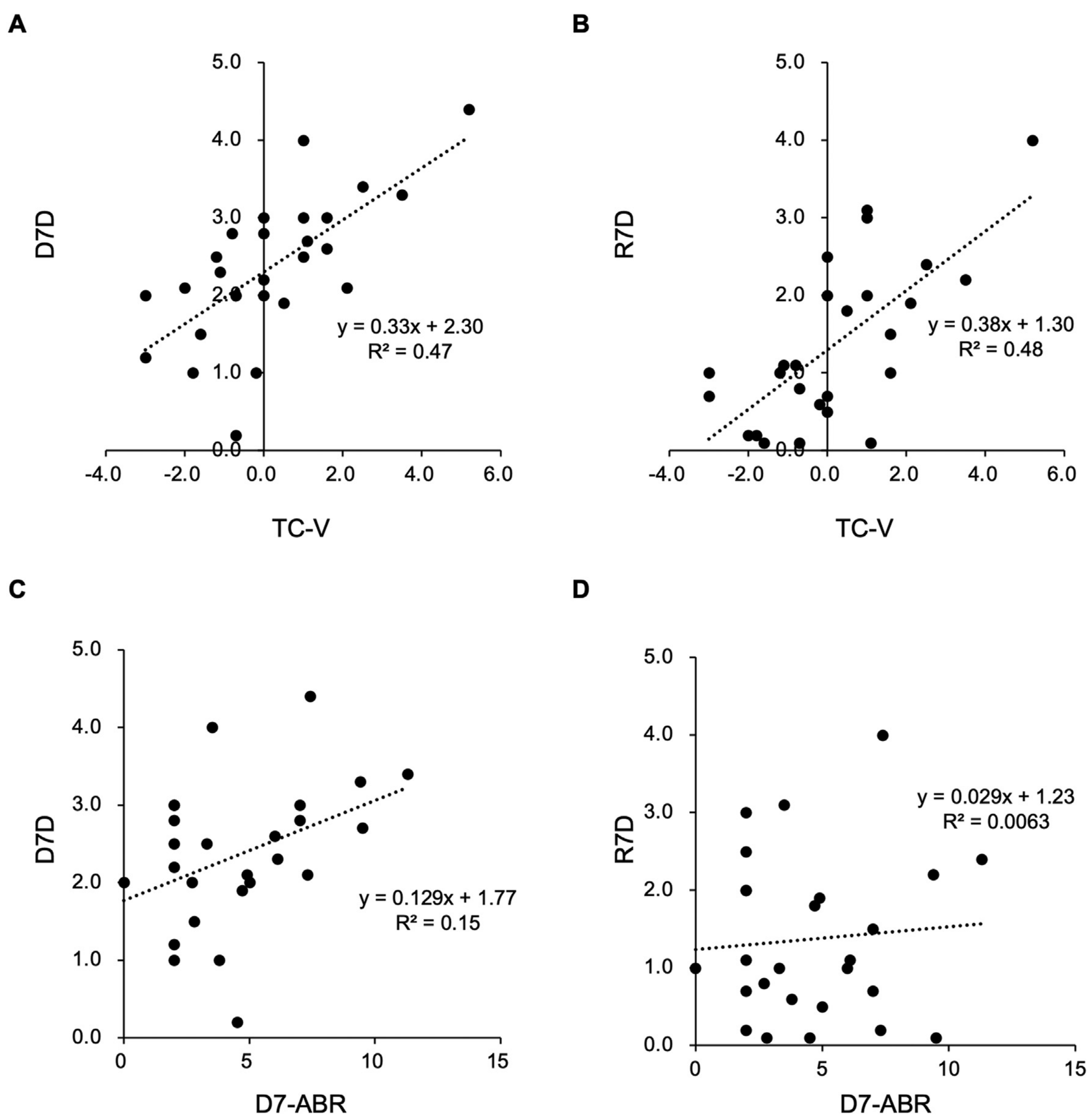

Figure 2 Relationship between TC-V, D7-ABR and molar distalization. Correlation coefficients between D7D and TC-V (**A**), between R7D and TC-V (**B**), between D7D and D7-ABR (**C**), and between R7D and D7-ABR (**D**).

Table 3 Means and standard deviations of TC-V and D7-ABR in the bodily-like and tipping movement groups.

	D7D (mm)		R7D (mm)	
TC-V >0	3.0 ± 0.8	*	2.0 ± 1.0	*
TC-V ≤0	1.9 ± 0.8		0.8 ± 0.7	

D7D, The coronal distal movement of the second molars; R7D, The root distal movement of the second molars; TC-V, The distance between the tooth cervix (TC) and the external oblique line of the mandible (The value is shown as minus when TC located below the external oblique line of the mandible). Data are expressed as mean $\pm$ SD. *: $P < 0.01$ by *t*-test.

movement groups (Table 3), suggesting that it was difficult to predict D7D and R7D by D7-ABR.

Discussion

The use of TADs to distalize molars has enhanced the possibility of camouflaged treatment for mild-to-moderate Class III patients.[25–27] In these cases, the distal movement of the mandibular molar requires accurate prediction before treatment.[28] However, it is often difficult to determine whether there is enough space for the desired movement.[29] Up to now, few methods have been available to make this prediction.[1,14,30] Kim et al.[14] investigated the mandibular posterior anatomical border for molar distalization using a lateral cephalometric analysis. They demonstrated that the threshold value of the distance between the distal surface of mandibular second molar and the ABR ($Ceph_{OL}$) was 3.9 mm. This result indicates that a mandibular second molar with $<$3.9 mm of a $Ceph_{OL}$ value is likely to have a root in contact with the inner lingual cortex. In addition, the percentage of correctly identified cases based on this threshold alone was 66.2%. Nevertheless, Kim et al.[14] recommended CT scans for patients who require significant mandibular molar distalization.

Our study aims to develop an accurate indicator of the available posterior space for mandibular molar distalization using lateral cephalograms, which are commonly used in orthodontic clinic. We select some landmarks that are easy to identify and measure. For example, the tooth cervix (TC) of the mandibular second molar is easy to distinguish and any orthodontist can easily plot it. In the present study, we examined 26 patients treated in our clinic whose mandibular second molar was distalized using TADs. In the bodily movement group, the values of TC-V show $>$0 mm in all the cases. In addition, the positive correlations were found between TC-V and D7D and between TC-V and R7D. However, there was no positive correlation between D7-ABR and R7D. Taken together, these results indicate that the simple threshold TC-V $>$ 0 mm is useful for the determination of possibility to achieve a large amount of bodily-like mandibular molar distalization. Our results suggested that TC-V is more suitable on the possibility of mandibular molar distalization than D7-ABR. This may be related to the fact that the D7-ABR is affected by the angle of the external oblique line and does not necessarily represent the size of the distal region inside the alveolar bone.

To confirm the effectiveness of TC-V on the prediction of posterior available space, we conducted a preliminary study of anatomic analyses carried out with CT scans using the same methods as Kim et al.[14] reported (Supplemental Figure 1). We selected 52 patients (37 females and 15 males ranging in age from 16 to 46 years) in our clinic, and performed a lateral cephalogram and a CT scan at the same time. To conduct a discriminant analysis with TC-V as an available variable for prediction, we divided the patients into two groups: those with TC-V $>$ 0 mm (TC located above the external oblique line of the mandible), and those with TC-V $<$ 0 mm (TC located below the external oblique line of the mandible). Interestingly, the distances between the distal root of the mandibular second molar and the mandibular inner cortex on the CT were significantly different in the two groups: 4.0 $\pm$ 2.5 mm for the subjects with $>$0 mm of the TC-V and 1.1 $\pm$ 2.5 mm for the subjects with $<$0 mm of the TC-V (Supplemental Table 1). The *t*-test shows a significant difference between the two distributions ($P < 0.05$). These findings imply that TC-V might be an available indicator for feasible distalization of mandibular molar.

This study has developed an easy and clinically applicable method for evaluating the feasible distal movement of a mandibular second molar based on simple measurements of TC-V on a lateral cephalogram. Even so, we must make some critical remarks. The sample size of this study is small, but the measurements are apparently normally distributed. Therefore, we expect that a larger sample size would not appreciably change the results. Furthermore, we confirmed that the sample size is appropriate to detect the valid results using the power analysis. Nevertheless, higher quality clinical research on much more samples is required to estimate the accuracy of any formula based on TC-V for clinical applications.

In conclusion, the use of TC-V strengthens the prediction of available posterior space for mandibular molar distalization. A new formula for calculating the feasible distal movement of the mandibular second molar was made and a graph constructed for easy assessment.

Declaration of conflicts of interest

The authors declare no conflict of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jds.2022.05.009.

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