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ORIGINAL ARTICLE

Influence of attachment and bone loss on the mobility of incisors and canine teeth

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Abstract

Objective. The purpose of this clinical study was to evaluate the correlation between tooth mobility (TM), crown-to-root ratio (CRR) and clinical attachment loss (CAL) in periodontally-compromised participants. ***Materials and methods.*** While slowly biting on a load cell, the mobility of the upper incisors and canine teeth of 20 volunteers was measured using a photogrammetric measurement technique. An automated software program recorded the force-related three-dimensional TM at 3-N intervals. CAL was assessed clinically and CRR values were assessed radiographically. For each contralateral pair of teeth (central, lateral incisor, canine) and for each main level of force, the Pearson product-moment correlation coefficient between TM and CRR and between TM and CAL was computed. Correlations were considered statistically significant at $p < 0.05$. ***Results.*** Statistically significant positive correlations were found between TM and CRR for incisors and canines for each main level of force, whereas canines had the lowest correlation. Statistically significant positive correlations were also found between TM and CAL for the central and lateral incisors at each main level of force. Canines showed no significant correlation between CAL and TM, regardless of force level. ***Conclusion.*** The loss of attachment and bone seem to have more influence on the mobility of incisors than canines.

Key Words: *clinical attachment loss, correlation study, crown-to-root ratio, diagnosis*

Introduction

Numerous scientific investigations have proven that the long-term success of teeth depends on various factors like periodontal status, tooth mobility (TM) and/or oral hygiene [1–4]. Thus, information about TM is of great interest in dental practice. The results of the intra-oral examinations of tooth movements under physiological loadings and clinical attachment loss (CAL) drives decisions about which teeth can be saved and which have an unfavorable prognosis, e.g. for prosthodontic treatment [2,5]. The physiological TM, measured as the total bucco-lingual crown excursion, was determined by several investigators and ranged from 40–120 µm for anterior teeth [6–9]. However, the mobility depends on the quality and quantity of force induction onto the teeth and on different physiological and pathological factors.

Physiological factors include the surface, morphology and number of roots [10]. Additional influence is provided by the connection of the teeth to their bony sockets. The roots of teeth are elastically connected to the alveolar bone via the periodontal ligament (PDL). This complex structure consists of elastic fibers, blood vessels and nerves, enabling the tooth three-dimensional mobility within the socket [11–13]. However, there are pathological factors that cause increased TM. One factor is a widened periodontal ligament. This can appear after dental trauma or mechanical overloading induced by inadequate prosthodontic treatment [14,15].

Another factor is the loss of bone support as a result of vertical or horizontal atrophy. In most cases, infections associated with periodontal disease lead to the destruction of the bone and connective tissues [16,17]. Diagnostic tools to determine the severity of periodontitis include the evaluation of TM,

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probing pocket depth, bleeding indices, bacterial analysis and x-ray analysis.

More useful than probing the pocket depth, the CAL represents the true amount of clinical periodontal breakdown and disease progression [18–20]. For clinicians, evaluating the alveolar bone support is another critical aspect for the prognosis of the longevity of teeth. In a review of the literature, Grossmann and Sadan [21] consider the crown-to-root ratio as a useful aid in predicting the prognosis of teeth. The CRR is defined as 'the physical relationship between the portion of the tooth within the alveolar bone compared with the portion not within the alveolar bone, as determined by radiograph' [22,28]. They found a CRR of 1:2 to be ideal when using the tooth as an abutment for prosthodontic treatment. Shillingburg et al. [23] suggested a 1:1.5 CRR value as optimal for a fixed partial denture abutment or a 1:1 ratio as a minimum. Periodontal bone loss around teeth was also stated to result in an increased CRR that is associated with increased TM [24].

However, in contrast to quantitative measurement techniques, the CRR and CAL analysis that can easily be used in daily practice can not yet provide information about the quantity of TM. Subjective methods where teeth are deflected between two instrument handles are widely accepted, but depend on the experience of the operator [25].

Besides the well known clinical fact that periodontal bone loss results in increased TM, there is a lack of quantitative data for this subject in literature. If a positive correlation between the supporting bone level of teeth and resulting TM can be quantified, analysis of radiographs could give valid information for clinical treatment strategies and for the long-term prognosis of periodontally involved teeth.

Thus, the aim of the present analysis was to determine whether the loss of attachment and bone influences the mobility of the anterior teeth. For this purpose, the correlation between the quantitative measurement of TM, CAL and CRR was evaluated.

Materials and methods

Volunteer selection

A group of 20 periodontally-compromised subjects (12 men, age range 47–69 years, mean age 60.8 years; eight women, age range 43–70 years, mean age 54.8 years) participated in this clinical study.

The volunteers were selected from a pool of patients suffering from periodontal disease and scheduled for periodontal treatment. The participants were informed about the study and provided written consent prior to initiation of data collection. The study was independently reviewed and approved by the university's ethical committee (Ethical Committee Re. No. 3673) and the investigation was carried out in accordance with the principles set forth by the Declaration of Helsinki.

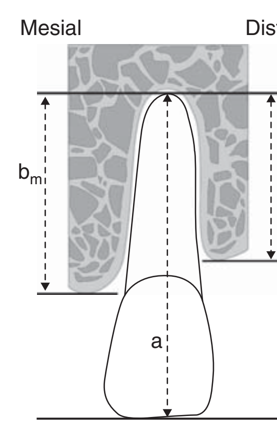
Patients applicable for inclusion had to fulfill the following criteria: A CAL of more than 2 mm and TM grade I or II for at least one maxillary front tooth. Exclusion criteria were enamel cracks, extended carious lesions or fillings, sensitivity to percussion, endodontic treatment and definitive prosthetic restorations at maxillary front teeth. Patients were also excluded if increased tooth mobility due to premature static or dynamic contacts or acute inflammation were detected.

Periodontal parameters were assessed by one experienced operator to verify the diagnosis of a periodontal disease, prior to inclusion. Twelve patients were diagnosed with severe aggressive periodontitis, one patient with moderate chronic and seven patients with severe chronic periodontitis.

Evaluation of attachment loss, crown-to-root ratio and tooth mobility

CAL was assessed by inserting a periodontal probe (Parodontometer PCPUNC 15, Hu-Friedy, Rotterdam, The Netherlands) to the bottom of the probable pocket. The distance from the bottom to the cemento-enamel junction (CEJ) was measured to the nearest millimeter. Measurements were obtained from six sites on each tooth (mesio-buccal, buccal, disto-buccal, mesio-lingual, lingual and disto-lingual) [1,26] and averaged.

CRR was measured by evaluating panoramic radiographs of each participant using specific software (Sidexis next Generation 1.61, Sirona Dental Systems GmbH, Bensheim, Germany). Thereby, the relationship between the portion of the tooth that was within the alveolar bone was compared with the portion not



$CRR_m = (a-b_m)/b_m$

$CRR_d = (a-b_d)/b_d$

$CRR = (CRR_m + CRR_d)/2$

Figure 1. Schematic illustration of the assessment of crown-to-root ratio (CRR).

Table I. Descriptive parameters of crown-to-root ratio (CRR) and clinical attachment loss. (CAL) for the upper central incisors (11, 21), lateral incisors (12, 22), and canine teeth (13, 23).

	CRR			CAL (mm)				
Tooth	*n*	*M*	SD	*n*	*M*	min	max	SD
11	20	0.973	0.305	20	4.62	3.00	6.83	1.24
21	19	0.985	0.283	20	4.57	2.67	10.17	1.76
12	19	1.168	0.421	19	4.81	2.33	7.33	1.42
22	19	1.030	0.369	19	4.42	2.50	8.67	1.71
13	19	0.999	0.256	20	4.55	2.17	7.00	1.42
23	14	0.894	0.211	19	3.89	1.83	5.67	1.02

within the alveolar bone. CRR values were computed for incisors and canine teeth, as described in Figure 1.

To measure tooth displacement, an optical measurement system (Aramis; GOM mbH, Braunschweig, Germany) based on photogrammetrical principles was used as described in previously published articles [27,28].

To induce force on the teeth, the participants were asked to bite on a specific loading device. The loading device contained a load cell (ELFM 250N; Measurement Specialties, Inc, Aliso Viejo, CA) and was calibrated to <1 N accuracy.

While the subject was biting down, voltage signals generated by the loading device were received by an amplifier (Signal amplifier; Scout 55, Hottinger Baldwinn Messtechnik, Darmstadt, Germany), transmitting the signals to an A/D converter (Aramis triggerbox; GOM mbH). The A/D converter released the photogrammetrical system, which automatically took photographs at 3-N intervals.

The measurement was stopped if the test subject experienced discomfort that prevented further loading or the pre-defined threshold of 60 N was reached. Images were taken by two synchronized high-resolution digital cameras (Unifoc, Componon-S 2.8/50, Schneider, Kreuznach, Germany) arranged at a 30° angle. Three measurements of each tooth were performed, with an intervening time period of 120 s to assure realignment [29].

The images were processed and correlated using a special software system that produced three-dimensional images of the teeth during all load steps (Aramis software; GOM mbH) [30–32]. A 4-mm^2 area on the tooth's surface 2 mm from the incisal edge of each tooth was defined for further analysis. The maximum calculable pixel number on this area was averaged. The first image taken without loading was used as the baseline. Tooth displacement was recorded in three dimensions (*x*-, *y*- and *z*-axes). Using the Pythagorean Theorem, an absolute displacement vector (u) was calculated.

All statistical analyses were performed with IBM SPSS Statistics Software (Version 19 and 20, SPSS Inc., Chicago, IL). In order to find out whether the measurements of symmetrically-positioned teeth could be combined, paired *t*-tests were performed for the following pairs of teeth: 11 + 21, 12 + 22 and 13 + 23 according to the corresponding levels of force applied.

If the combination of symmetrically-positioned teeth was proven correct, the arithmetic mean values of tooth movement together with the corresponding 95% CI of the mean were calculated. The force applied was categorized into three main levels; low (3–9 N), medium (12–21 N) and high (24–30 N).

For each pair of teeth and for each main force level, the Pearson product-moment correlation coefficient between TM and CRR was computed as well as the correlation coefficient between TM and CAL. Correlation coefficients were considered statistically significant at $p < 0.05$.

Results

The basic descriptive parameters of CRR and CAL measurements for the six upper teeth are shown in Table I. Pooled data from three measurements of TM were used in the subsequent statistical analysis. The results of force-related TM are shown in Table II. The force applied to measure tooth movement ranged

Table II. Mean tooth mobility values for each tooth in µm.

	Tooth					
Force (N)	11	12	13	21	22	23
3	72.6	71.8	80.5	78.6	82.2	58.3
6	87.9	90.5	90.7	98.2	100.7	64.3
9	101.9	107.9	98.5	99.6	115.7	71.5
12	116.8	123.9	107.4	115.3	130.9	81.6
15	128.7	140.3	118.4	127.2	144.8	82.7
18	141.1	158.6	124.9	134.4	158.7	87.4
21	160.5	172.3	131.2	151.2	185.4	91.5
24	164.7	200.6	143.0	166.4	185.5	96.7
27	163.3	216.2	150.1	156.3	203.3	90.9
30	148.6	213.4	157.8	143.1	198.6	95.1

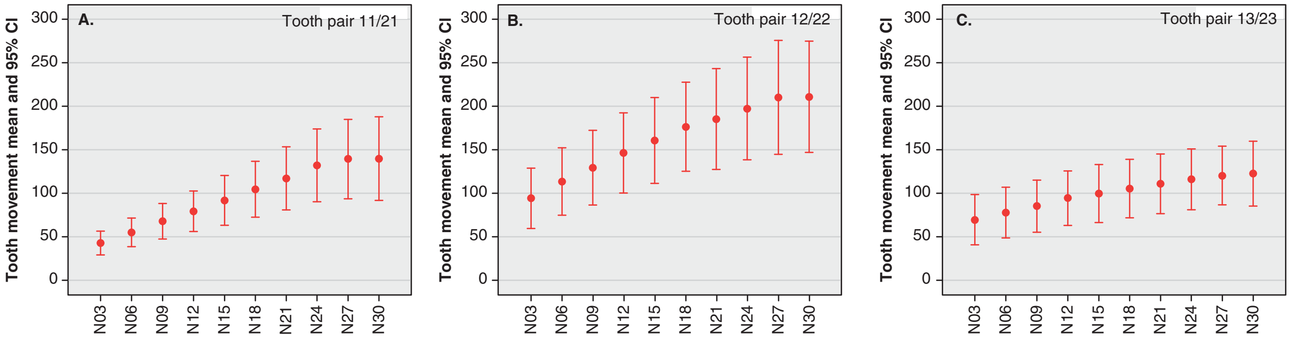


Figure 2. Tooth mobility (TM) corresponding to force (mean and 95% CI) for tooth pairs (A) 11+21, (B) 12+22, and (C) 13+23.

from 3–48 N. Forces of 33 N and above were partly applied to fewer than five patients. This sample size was considered insufficient for statistical analysis. The effective range of forces analyzed comprised the range from 3–30 N.

In order to determine whether the measurements of symmetrically-positioned teeth could be combined, paired *t*-tests were performed for the following pairs of teeth: 11 + 21, 12 + 22 and 13 + 23. In all comparisons, the null hypothesis of a mean difference of zero could not be rejected at the significance level of alpha = 5%. This result provides the justification for combining the measurements of TM, CRR and CAL for contralateral teeth.

Figures 2A–C show the relationship between tooth movement and force applied for the tooth pairs 11 + 21, 12 + 22 and 13 + 23. As the overlapping 95% CI indicates, directly adjacent levels of force imply no significant change in tooth movement. Therefore, it seemed reasonable to combine the force levels into three categories; low force (3–9 N), medium force (12–21 N) and high force (24–30 N).

The scattergrams (Figures 3A–C) with interpolation lines for the three levels of force indicate a positive correlation between TM and CRR for all teeth. All correlations were significant ($p < 0.05$) (Table III). For teeth 12 and 22, the correlations were highly significant at $p < 0.01$. For the tooth pair 13 + 23, the observed correlation is smaller than for the other pairs of teeth (Figure 3C, Table III).

Correlating TM and CAL, significant correlations were shown for the central and lateral incisors at three levels of force (Figures 4A and B and Table IV). However, no significant correlation between TM and CAL was found for the tooth pair 13 + 23, regardless of level of force (Figure 4C and Table IV).

Discussion

In this clinical study, the correlation between force-related TM, CRR and CAL was evaluated. The volunteers were selected from a group of patients with increased CRR and CAL values resulting from periodontal disease. The volunteers showed different degrees of severity of periodontal disease. All measurements in the present study were performed before an initial periodontal therapy.

TM was assessed by an optical measurement system, which has proven to be applicable for the quantitative analysis of intraoral micromovement [27,28,33]. Contrary to other measurement techniques for evaluating TM [34–36], the optical system allows a non-contact recording of three-dimensional TM. However, the current technique is limited to

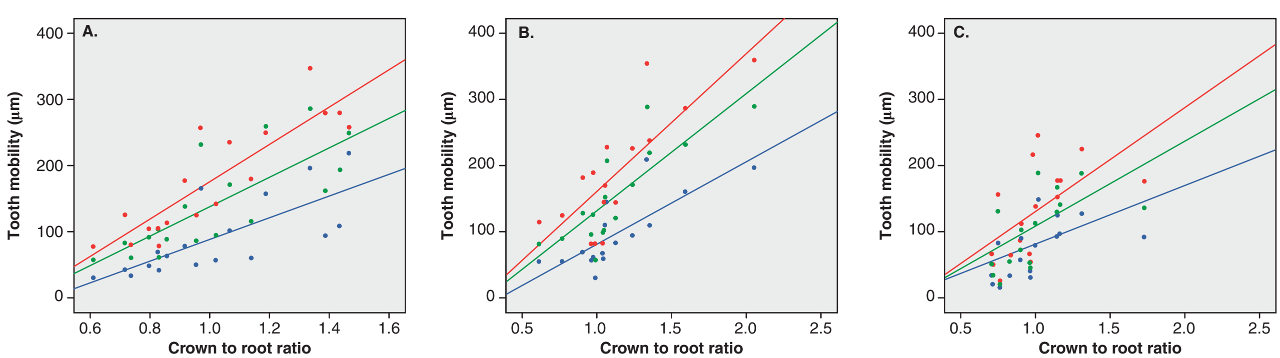


Figure 3. Scattergram with interpolation lines for the three levels of force for tooth pairs (A) 11+21, (B) 12+22, and (C) 13+23: Tooth mobility (TM) in relation to crown-to-root ratio (CRR) for three levels of force. Red = high force (24 N to 30 N), green = medium force (12 N to 21 N), blue = low force (3 N to 9 N).

Table III. Pearson product-moment correlation coefficients between crown-to-root ratio (CRR) and tooth mobility (TM) for three levels of force.

Tooth movement at force level	CRR central incisors			CRR lateral incisors			CRR canines		
	Pearson correlation	*p*-value	*n*	Pearson correlation	*p*-value	*n*	Pearson correlation	*p*-value	*n*
Low	0.533	0.015	20	0.762	0.000	19	0.451	0.053	19
Medium	0.745	0.000	20	0.779	0.000	19	0.567	0.011	19
High	0.874	0.000	18	0.795	0.000	16	0.587	0.013	17

the intra-oral anterior region because measurement objects must be positioned in the camera's field of view.

To acquire information about the bony support and periodontal situation of the measured teeth, CRR values were assessed. The CRR, as reviewed by Grossmann and Sadan [21], might be a valuable benchmark to obtain information about bone support. CRR values were performed by calculating the arithmetic mean from the mesial and distal bone height of every anterior tooth. However, the buccal and palatinal bone support could not be taken into account. Furthermore, Grossmann and Sadan [21] stated that the CRR evaluation might under-estimate the severity of bone loss around the abutment. A more precise examination would have been digital volume tomography to evaluate the bony support of the teeth.

To acquire further clinical diagnostic tools to judge the attachment of the teeth, CAL was assessed. CAL was measured with a periodontal probe and is an important benchmark for assessing periodontal status [20,37]. Especially for periodontally-compromised teeth, the use of the CAL, measured from the cemento-enamel junction (CEJ) to the base of the sulcus, reflects the real attachment loss compared with probing pocket measurements.

Compared with previously published results, investigating the three-dimensional TM of periodontally-healthy volunteers [28], evident differences could be seen.

Periodontally-healthy subjects induced higher axial forces while biting on a load cell (up to 81 N), as did the periodontally-compromised volunteers. Other authors also reported higher force values between 94 N for females and 146 N for males for the central incisor [38]. In contrast, none of the volunteers reached the pre-defined threshold of 60 N in the present study. Fewer than five participants reached forces of 33 N and higher.

The force levels of 33–60 N were considered statistically insufficient for further analysis and rejected. An explanation for the reduced bite forces might be that the volunteers were asked not to overload their periodontally-compromised teeth. Furthermore, the three-dimensional tooth displacement values differed between the periodontally-compromised and healthy participants. In the present investigation, the TM of the right central incisor ranged between 72.6 μm at 3 N to 148.6 μm at 30 N. Compared with a previous study [28] that included periodontally-healthy subjects, the much higher displacement values (displacement of a right central incisor: ca. 70 μm at 27 N) are in accordance with previously published results in the dental literature [39,40].

Persson and Svensson [40] compared the initial TM of subjects with healthy periodontal conditions and subjects with periodontal disease. They found that the displacement of the central incisors was much greater for the group with periodontal disease (55 μm at 0.8 N) compared with the periodontally-healthy

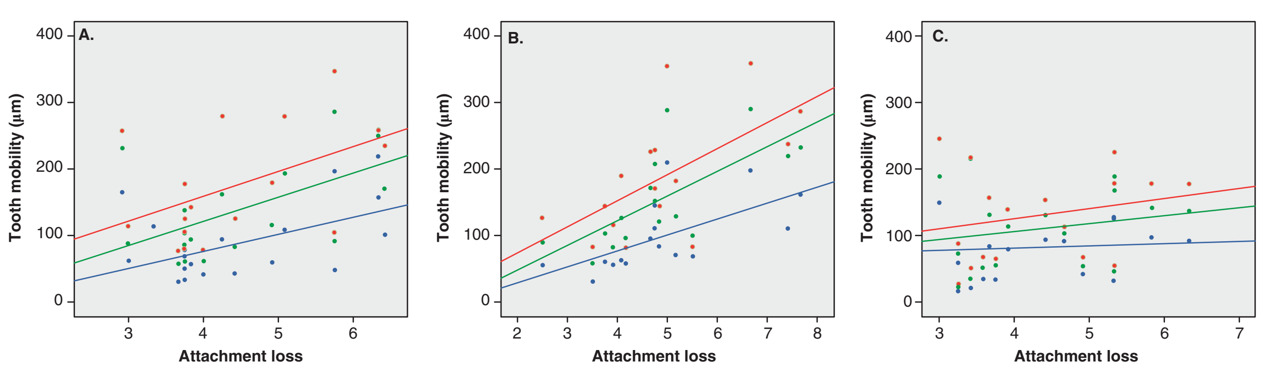


Figure 4. Scattergram with interpolation lines for the three levels of force for tooth pairs (a) 11+21, (b) 12+22, and (c) 13+23: Tooth movement in relation to clinical attachment loss (CAL) for three levels of force. Red = high force (24 N to 30 N), green = medium force (12 N to 21 N), blue = low force (3 N to 9 N).

Table IV. Pearson product-moment correlation coefficients between clinical attachment loss (CAL) and tooth mobility (TM) for three levels of force.

	CAL central incisor			CAL lateral incisor			CAL canines		
Tooth movement at force level	Pearson correlation	*p*-value	*n*	Pearson correlation	*p*-value	*n*	Pearson correlation	*p*-value	*n*
Low	0.600	0.005	20	0.659	0.002	19	0.135	0.582	19
Medium	0.494	0.027	20	0.744	0.000	19	0.265	0.274	19
High	0.509	0.031	18	0.615	0.011	16	0.225	0.386	17

group (26 μm at 0.8 N). The lower absolute displacement values might be related to the lower forces that were applied in a horizontal direction onto the tooth. These values reflect the initial TM within the horizontal plane. Because of the higher forces applied in an axial direction, the present results might provide information about both the TM within the PDL and the deformation of alveolar bone.

In accordance with the former study [28], statistical tests showed that the TM of contralateral teeth could be pooled for further analysis. Even the CRR and CAL values could be pooled for analogous teeth because no statistically significant differences were found.

The correlation between CRR and TM was statistically significant for the central and lateral incisors and canine teeth (Table III). However, using the current measurement technique with high bite forces, it must be considered that only the secondary TM could be evaluated. At low force levels, the behavior of the elastic fibers in the PDL might be decisive for tooth displacement [41]. Inducing higher force (>1 N), the PDL is completely compressed and the distortion of the alveolar bone around the teeth becomes more important for the amount of TM [39,42].

Comparing the strength of correlations between central and lateral incisors and canine teeth, differences can be seen. The upper incisors showed high correlation values that were highly significant. The observed correlation between CRR and TM was smaller for canine teeth. A reason for this could be that the incisors have a smaller root surface and thus smaller bone support compared with canines [43]. If there is comparable bone loss on canine teeth and incisors, the higher root surface of canines might provide more resistance against force impact. Thus, the loss of bony support on canines might have less influence on TM than it would on incisors. This finding could be of interest for treatment strategies and prognosis of periodontally compromised teeth.

Correlating TM and CAL, statistically significantly positive correlations were found for the central and lateral incisors for each main level of force. Comparable to the correlation of CRR and TM, the level of attachment influences the mobility of incisors.

No significant correlation between CAL and TM was found for the canine teeth, regardless of force level. This result seems to be comparable to the CRR to TM correlation, where only small correlations were found for canine teeth. Again, the greater root surface of canines connected to the alveolar socket might enable a greater resistance against force impact, even when attachment loss can be measured.

One point of critic of the present investigation may be the relatively low size of the study cohort ($n = 20$). Due to the exploratory pilot character of this study and the general aim to provide first quantitative data of correlations between TM, CRR and CAL, the sample size can be justified. However, future prospective clinical trials with larger cohorts and larger follow-up periods are necessary to assess not only the clinical situation but also the impact of various therapeutic strategies on the long-term outcome of periodontally involved patients.

As described previously, the TM measurement is limited to the anterior region of the upper jaw. Further clinical studies are necessary to obtain information about correlations between TM and bone support for the posterior teeth. Another point of interest could be the biomechanical behavior of osseointegrated dental implants in correlation to different supporting bone levels.

Conclusions

Within the limitations of this clinical study, the following conclusions can be drawn:

(1) Statistically significant correlations between TM and CRR were found for upper incisors and canine teeth, whereas the canines showed the lowest correlations.
(2) CAL and TM are correlated for incisors, whereas there was no significant correlation for canine teeth.
(3) The loss of attachment and bone seemed to have limited impact on the mobility of canines.

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