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Original Article

Orthodontic Forces Interrupt Root Formation in Immature Teeth: Myth or Fact? A Pilot Study

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Main Points

- Root dimensions do not differ between the treated and untreated groups.
- Post-treatment changes include a reduction in the distobuccal and palatal root length of molars.
- Developing roots achieve normal length after rapid maxillary expansion and fixed orthodontic treatment.

ABSTRACT

Objective: To assess the effects of rapid maxillary expansion (RME) and orthodontic treatment with fixed appliances on the developing roots of anchor teeth compared with completely formed roots.

Methods: Pre- and post-treatment cone-beam computed tomography (CBCT) scans of 19 patients (mean pre-treatment age 10.9±1.3, mean post-treatment age 13.66±1.29) with incompletely formed roots who had undergone RME and orthodontic treatment with fixed appliances were selected. In addition, 15 CBCT scans of age- and sex-matched untreated controls (mean age 13.69±1.08) with completely formed roots of the same teeth were obtained. Pre- and post-treatment CBCT records of the experimental group were segmented and reconstructed to obtain linear and volumetric measurements of the roots for comparison with the control group. Changes in the root dimensions were analyzed using the paired t-test; Independent Student's t-test was used for comparisons between the groups.

Results: All premolars in the experimental group showed a statistically significant increase in root length and volume post-treatment ($p<0.05$), with the greatest increase seen in the second premolar. The distobuccal and palatal root lengths of the molars decreased significantly after treatment in the experimental group. The comparison of post-treatment root dimensions between the experimental and untreated control groups showed no significant difference.

Conclusion: The teeth with developing roots attain normal root length after RME and orthodontic treatment with fixed appliances, with no significant differences in root length and volume compared with teeth with completely formed roots.

Keywords: Maxillary expansion, orthodontic treatment, developing teeth, root formation

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INTRODUCTION

Dental root development is a complex process that initiates after crown formation and continues for two to three years after the eruption of teeth in the oral cavity.[1,2] Thus, root elongation and apex formation are susceptible to intrinsic and extrinsic factors like trauma and mechanical force application, potentially leading to short and malformed roots.[3,4]

One of the commonly used orthodontic treatment modalities during the developmental stages of teeth is rapid maxillary expansion (RME).[5] In this treatment method, heavy orthopedic forces are transmitted to the bone with anchorage from the posterior teeth.[5,6] Although this procedure successfully corrects transverse discrepancy, some adverse effects on the buccal cortical bone and roots of the anchor teeth have been reported.[7,8] Resorption of the completely formed roots of the anchor teeth is one of the potential side effects of RME.[7,9] It is associated with radicular volume loss, especially on the buccal aspect of roots.[7,8,10,11] Additionally, root resorption is also a possible consequence of fixed orthodontic treatment due to factors such as treatment duration, direction, magnitude of force, and amount of tooth movement.[12,13] This side effect of orthodontic treatment on completely formed roots leads to the suggestion that it could also disrupt the root development process in developing teeth.[7]

Some radiographic studies evaluated the effect of orthodontic treatment on developing teeth and showed less root resorption and achievement of normal root length after completion of treatment.[14,15] In contrast, another study reported that RME and reverse headgear treatment at an early age can inhibit maxillary and mandibular root development.[16] These studies primarily utilized either periapical or panoramic radiographs. However, a separate study using CBCT in patients with clefts found no significant changes in the root length of developing roots after RME.[17]

Three-dimensional evaluation with CBCT provides high-definition images and produces multiplanar reformatted images allowing 2D views in all three dimensions.[18] Additionally, it enables the estimation of changes in root dimensions occurring over a period of time compared with other methods.[7] Despite this advantage, there is a paucity of literature exploring the effect of orthodontic treatment on developing dental roots using CBCT.

Whether orthodontic treatment disrupts root formation and affects the morphology and length remains unclear. Therefore, the objective of this retrospective pilot study was to three-dimensionally evaluate the effects of RME and orthodontic treatment with fixed appliances on the length and volume of the developing roots of anchor teeth by comparing them with an untreated control group. The null hypothesis was that RME and orthodontic treatment had no significant effect on the length and volume of developing roots of anchor teeth.

METHODS

This retrospective pilot study was conducted at the Department of Orthodontics, Boston University Henry M. Goldman School of Dental Medicine. CBCT records were collected from the department repository, and ethics approval was granted by the Institutional Review Board of Boston University (approval no.: H-32515, date: 10.12.2018). A sample of patients for the experimental group was selected based on the following inclusion criteria: aged 8-12 years, good quality pre (T1) and post-treatment (T2) CBCT records of patients treated with RME, no history of craniofacial anomaly or syndrome, no history of craniofacial trauma or surgery, no amalgam restorations or root canal fillings, and no extracted premolars or molars. Patients had maxillary constriction with unilateral or bilateral posterior crossbite or transverse discrepancy, as diagnosed with compensated molar inclination.[19] The treatment method employed was RME with a Hyrax appliance soldered to the bands of the maxillary first permanent molar, with the Hyrax wire extending to the first premolars for anchorage. The data were collected from the same provider and subjected to a commonly used activation protocol of one turn per day (0.25 mm/turn) until the palatal cusps of the maxillary molars were in contact with the buccal cusps of the mandibular molars. The expander was retained for 3 months post-expansion, followed by fixed orthodontic treatment with an edge-wise appliance. All teeth in the study group received orthodontic forces during treatment before the completion of root apexification. Most teeth received direct force from the RME along with the fixed orthodontic appliances, whereas some of the second premolars received only force from the fixed orthodontic appliance. The same repository was searched for an untreated control group (pre-treatment patients) matched to the sex and post-treatment age of the experimental group, with the absence of restorations or root canal fillings, and the absence of any craniofacial anomaly or syndrome.

Patients in the experimental group (n=19) with a mean pre-treatment age of 10.9±1.3 years and post-treatment age of 13.66±1.29 years were matched with an untreated control group (n=15) with a mean age of 13.69±1.08 years. In the experimental group, roots of premolar teeth were incompletely formed with open apex at different stages of tooth development. We report the root formation stages as defined by Nolla.[20] The second premolars were in stages 7 and 8, and the first premolars were in stages 8 and 9 of tooth development at T1 in the experimental group, while the apices of the first molars were fully formed (Nolla stage 10). The apices of the roots were closed and fully formed in the control group (Table 1). In the experimental group, two CBCT scans were performed (T1 and T2) with a mean treatment duration of 2.7 years. All CBCT scans were taken using the same i-CAT machine (Imaging Sciences International, Hartfield, PA, USA) at 120 KVp and 0.5 mm nominal focal spot size, rendering a 17.0 cm x 23 cm field of view with a 0.3 mm voxel size image. DICOM images of both groups were imported and processed using

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Mimics software (version 21.0 Materialize, Leuven, Belgium). The maxillary first molar and first and second premolars on both right and left sides were segmented manually. A custom bone threshold was initially set (range: 226 to 3071), the masks were then cleaned manually for accurate tooth segmentation, and three-dimensional images were reconstructed with the edit and region grow functions for the measurements (Figure 1). The same threshold values were used for the segmentation of each patient's pre- and post-treatment records.[21]

The reconstructed images of each tooth were divided into crown and root sections by a plane passing through the cementoenamel junction (CEJ) perpendicular to the long axis of the tooth for root volume measurement. Since the CEJ is curved as it circles the tooth, an interactive multiplanar reconstruction function was used for image orientation, such that the planes were adjusted along the long axis of the tooth and in the axial view, sagittal and coronal planes were adjusted to intersect at the center of the tooth at the level of buccal and palatal CEJ. Subsequently, three points were marked on the buccal, mesial, and palatal surfaces to form the reference plane (Table 2).

Table 1. Characteristics of cases according to root formation stage

Characteristics	Experimental results at T2	Control	p-value
Root formation	Nolla Stage 10 Closed Apex	Nolla Stage 10 Closed Apex	
n	19	15	
Mean age in years (SD)	13.66 (1.29)	13.69 (1.08)	0.93
Males, n (%)	7 (36.8%)	4 (26.6%)	0.7
Females, n (%)	12 (63.15%)	11 (73.3%)	0.6

*Significance at $p<0.05$
SD, standard deviation.

Measurements

1. Root length: Root length was measured using the axial guided navigation method,[22] in which the axial cursor is moved in the sagittal and coronal multiplanar reconstruction to determine the cusp tip and root tip. The linear distance between the cusp tip and the root apex was measured. In developing roots, the distance from the cusp tip to the center of the most apical part of the root was measured. The lengths of all three molar roots were measured, and only the buccal roots of premolars were measured, as some of the premolars had fused buccal and palatal roots.

2. Volume measurements: The volume of the rendered 3D root models was measured by the software after dividing the crown and root with the CEJ plane.

Statistical Analysis

The normality of the data distribution and the equality of variances were assessed using the Shapiro-Wilk, Kolmogorov-Smirnov, and Levene's tests. The data showed normal distribution and equal variances. Therefore, the experimental group's changes in root length and volume were compared between pre- and post-treatment using the paired t-test. The Independent Student's t-test was used to compare mean ages and changes in root values between groups.

The intraclass correlation coefficient was used to analyze intraobserver reliability. For this purpose, a random sample (10% of the overall sample) was re-segmented and re-measured by the same researcher T.D. 2 weeks apart. The reliability was

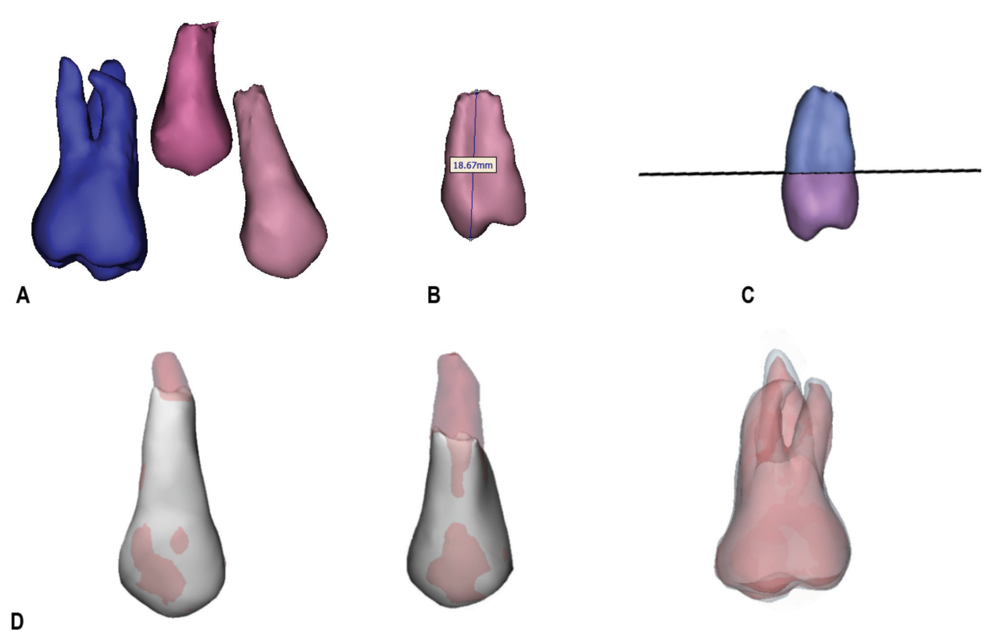

Figure 1. Three-dimensional reconstruction and measurement: **A)** Segmented and reconstructed images of maxillary first molar and premolars at T1; **B)** Root length measurement; **C)** CEJ plane dividing crown and root; **D)** Superimposition of T1 (White) and T2 (Red) images showing increase in root length of premolars and decrease in palatal and distobuccal root length of molars

further tested using a paired t-test, Bland-Altman level of agreement, and Dahlberg's method error.

All statistical analyses were performed using SAS Software Version 9.4 (SAS Institute Inc., Cary, NC, USA), with the significance level set at 0.05.

RESULTS

Overall, the measurements were found to have excellent reliability for all parameters studied, with interclass correlation values of >0.96, and method errors, as described in Supplementary Table 1.

The average pretreatment age of patients in the experimental group was 10.9±1.3. There was no significant difference between the post-treatment age of the experimental group (13.66±1.29) and the age of the control group (13.69±1.08) (p>0.05), with similar sex distributions (Table 1).

In the experimental group, there was a significant increase in the root lengths of the first and second premolars between T1 and T2. The greatest increase was observed in the roots of the right and left second premolars, with mean increases of 4.62±2 mm and 4.76±2.17 mm, respectively. A statistically significant decrease of 0.47 and 0.56 mm in the distobuccal and palatal root lengths of the right first molar, and 0.40 and 0.71 mm in the distobuccal and palatal root lengths of the left first molar were observed. No significant difference was observed in the mesiobuccal roots of the right and left molars (p-values of 0.83 and 0.7, respectively. There was a statistically significant increase in root volume of the right and left second and first premolars (p<0.05), however, the roots of the right and left first molars showed no significant change in volume post-treatment with a p-value of 0.64 and 0.38, respectively (Tables 3 and 4).

The comparison of post-treatment root length and root volume between the experimental and untreated control groups showed no statistically significant differences for all teeth (Tables 5 and 6).

DISCUSSION

As very few radiographic studies have looked into the effects of orthodontic treatment on developing roots, the objective of the present retrospective study was to determine the effects of RME and orthodontic treatment with fixed appliances on the length and volume of the developing roots by comparing them with an untreated control group.[14,15,23]

In the experimental group, the root length and volume of the maxillary premolars significantly increased after treatment (Tables 3 and 4). These results were consistent with a study on changes in the roots of developing teeth after orthodontic treatment, which showed an increase in the root length of immature incisors after treatment.[15] This implies that orthodontic treatment generally has little effect on teeth with immature roots. Another study compared the effects of rapid and slow maxillary expansion treatment on the developing roots of all the teeth.[16] The results of panoramic

Table 2. Reference points and the CEJ plane

Points and planes	Description
Buccal CEJ point	A point at the intersection of the coronal plane with the center of the buccal surface at the CEJ level.
Palatal CEJ point	A point at the intersection of the coronal plane with the center of the palatal surface at the CEJ level.
Mesial CEJ point	A point at the intersection of the sagittal plane with the center of the mesial surface at the CEJ level.
CEJ plane	At the level of the CEJ determined by the buccal, palatal, and mesial CEJ points.

CEJ, cementoenamel junction.

Table 3. Comparison of root length (mm) of right (R) and left (L) first molar and premolars between pre (T1) and post (T2) in Group 1 (experimental group)

Tooth	T1 (Mean±SD)	T2 (Mean±SD)	T2-T1 difference	p-value
First molar (R)				
MB	18.99±1.26	18.96±1.29	-0.02	0.834
DB	19.07±1.33	18.60±1.44	-0.47	0.004*
P	21.18±1.33	20.62±1.23	-0.56	0.002*
First molar (L)				
MB	19.25±1.37	19.21±1.60	-0.04	0.701
DB	19.08±1.24	18.68±1.56	-0.40	0.010*
P	21.17±1.37	20.46±1.51	-0.71	0.003*
Second premolar (R)	14.94±2.27	19.56±1.31	4.61	<0.001*
Second premolar (L)	14.88±2.55	19.64±1.39	4.76	<0.001*
First premolar (R)	16.91±2.48	19.79±1.66	2.87	<0.001*
First premolar (L)	16.82±2.49	19.98±1.33	3.16	<0.001*

*Significance at p<0.05
MB, mesiobuccal root; DB, distobuccal root; P, palatal root; SD, standard deviation.

Table 4. Comparison of root volume (mm^3) of right (R) and left (L) first molar and premolars between pre (T1) and post (T2) in Group 1 (experimental group)

Tooth	T1 (Mean±SD)	T2 (Mean±SD)	T2-T1 difference	p-value
First molar (R)	538.45±70.38	532.27±83.61	-6.18	0.647
First molar (L)	516.02±90.88	498.83±83.31	-17.19	0.383
Second premolar (R)	165.42±47.36	222.74±42.00	57.31	<0.001*
Second premolar (L)	159.83±44.57	203.83±37.86	43.99	<0.001*
First premolar (R)	193.80±60.39	227.21±42.83	33.41	0.001*
First premolar (L)	189.02±61.49	214.71±40.33	25.68	0.019*

*Significance at p<0.05
SD, standard deviation.

Table 5. Comparison of post-treatment root length (mm) between the experimental group (Group 1) and the untreated control group (Group 2)

Tooth	Group 1 T2 (Mean±SD)	Group 2 T1 (Mean±SD)	Group 1 and Group 2 (Mean±SD)	p-value
First Molar (R)				
MB	18.9±1.3	18.7±1.4	0.2±1.33	0.635
DB	18.6±1.4	18.6±1.6	-0.05±1.5	0.923
P	20.6±1.2	20.2±1.6	0.3±1.44	0.462
First Molar (L)				
MB	19.2±1.6	18.8±1.3	0.3±1.51	0.472
DB	18.6±1.5	18.7±1.5	-0.03±1.54	0.940
P	20.4±1.5	20.6±1.7	-0.1±1.62	0.723
Second Premolar (R)	19.5±1.1	19.8±1.9	-0.3±1.62	0.576
Second Premolar (L)	19.6±1.4	19.9±1.8	-0.2±1.63	0.621
First Premolar (R)	19.7±1.7	20.1±1.7	-0.3±1.7	0.544
First Premolar (L)	19.9±1.3	20.1±1.7	-0.1±1.55	0.766

*Significance at p<0.05
Group 1: experimental; Group 2: control
Group 1-Group 2: difference between two groups, SD: standard deviation
MB, mesiobuccal root; DB, distobuccal root; P, palatal root; R, right; L, left

Table 6. Comparison of post-treatment root volume (mm^3) between the experimental and control groups

Tooth	Group 1 T2 (Mean±SD)	Group 2 T1 (Mean±SD)	Group 1 and Group 2 (Mean±SD)	p-value
First Molar (R)	532.2±83.6	533.8±105.8	-1.5±93.99	0.961
First Molar (L)	498.8±83.3	513.4±99.3	-14.6±90.66	0.644
Second Premolar (R)	222.7±42.0	229.1±59.4	-6.4±52.46	0.713
Second Premolar (L)	203.8±37.8	218.8±49.5	-15.0±43.35	0.322
First Premolar (R)	227.2±42.8	236.9±48.8	-9.7±45.54	0.541
First Premolar (L)	214.7±40.3	230.8±47.4	-16.1±43.58	0.291

*Significance at p<0.05
Group 1: experimental; Group 2: control
Group 1-Group 2: difference between two groups, SD: standard deviation
R, right; L, left

radiographs revealed a significant increase in root length only in the second premolars of the maxillary arch after RME and reverse headgear treatment. The authors concluded that root development was disrupted in all other maxillary teeth. These contrasting results may be due to the use of headgear with RME and different treatment durations, as the root changes in that study were measured after expansion and protraction treatment (mean duration 8.15±2.4 months). However, in the present investigation, changes in the roots were evaluated after the completion of fixed orthodontic treatment, which encompasses the entire period of root development. In addition, the difference in results could be attributed to the use of panoramic radiographs in the previous study, as it has limitations due to the use of a focal trough. This feature makes root assessment challenging and may lead to an overestimation of root resorption. Da Silva Filho et al.[14] also studied the effect of leveling with a 2x4 appliance on the developing roots of incisors and found no disruption in root development. This assessment was conducted using periapical radiographs after 7 months of treatment.[14]

Additionally, in the present study, a reduction in the lengths of the distobuccal and palatal roots of molars was observed, with the palatal root of the left first molar being mostly affected (0.71 mm of length reduction). However, these values are clinically insignificant.[24] In addition, no significant changes in mesiobuccal root length and overall molar root volume was noted after treatment (Tables 3 and 4). The discrepancy between molars and premolars could be attributed to the different root formation stages, as the molar roots were fully formed compared with the premolar roots, which were still developing before treatment. This indicates that immature teeth are generally not affected by orthodontic treatment. The differences observed in teeth could also be the result of variations in anchorage, as during the RME phase, the Hyrax appliance was soldered to the bands on the molars while the premolars were anchored with the Hyrax wires. However, previous studies have shown no significant difference in root changes between banded and non-banded anchor teeth following RME.[9]

The changes in molar roots, nonetheless, are consistent with the findings of previous research. Cardinal et al.[17] evaluated the three-dimensional effect of RME on the developing roots of molars in patients with cleft molars, with a mean age of 10.7 years. The authors compared the effect of different types of rapid maxillary expanders on developing roots and found no difference in the root length of molars with both open and closed apices when evaluated three months after expansion. Other research on root resorption after RME showed maximum changes in the palatal and mesiobuccal roots of the molar.[8,11] In contrast, another study measuring apical root resorption on CBCT scans after non-extraction fixed orthodontic treatment found maximum effects on the distobuccal roots of maxillary molars.[22] However, our results indicated that the distobuccal and palatal roots were affected. The discrepancies may be due to the differences in treatment duration or the effect of fixed orthodontic treatment after RME. A recent study compared the extent of root resorption in patients treated with tooth-borne and bone-borne RME and found significant reductions in volume and length in both groups, with a greater reduction in the tooth-borne group.[25] This result can be attributed to the absence of direct forces on the teeth. We did not observe any effect on root maturation. However, the use of a bone-borne RME could potentially reduce changes in root length and volume.

In addition, no significant effect was observed on the root volume of the molars after treatment. This finding could be attributed to either the small volumetric changes or the use of CBCT images with voxel sizes of 0.3 mm (300 µm). However, there is no consensus on the optimal voxel size for assessing radicular volume. A previous study showed that CBCT images with a 0.3-mm voxel size were effective in detecting external root resorption.[26] Conversely, another study found that CBCT with 300 µm underestimated volumetric measurements compared to smaller voxel sizes.[27] More recent research reported no significant differences in sensitivity and specificity between 120, 200, 250, and 300 µm voxel sizes.[28]

In comparison with the control group with untreated normal roots, the post-treatment root dimensions of the experimental group showed no significant difference, which implies attainment of normal root dimensions (Tables 5 and 6). Similarly, Rosenberg[29] reported that incompletely formed premolars and canines reached normal root length after Begg orthodontic treatment. In addition, other authors reported that immature teeth reached a normal root length after treatment compared with fully formed roots, which is in agreement with our findings.[23] These studies were assessed radiographically without a control group, whereas in the present study, changes in developing roots were evaluated three-dimensionally and compared with normal roots. Our results also corroborate those of a recent histological investigation, which showed the attainment of normal root length and less root resorption in immature teeth after treatment compared with completely formed roots.[30]

In this study, the control group was selected randomly from a large CBCT repository and matched to the posttreatment age and sex of the experimental group to ensure a valid comparison. During the selection process, the criteria were the completion of root development, age and sex matching, absence of restorations or root canal fillings, and absence of any craniofacial problems or syndromes. Therefore, the possibility of having short roots or small teeth in the control group can be considered a random error that should not cause any bias in the results. The exclusion of a second time point in the control group was due to the method of comparing root length and volume, not the amount of root formation, during the same period of time. The final root length comparison was thought to be more clinically relevant since the final root length and surface area had the greatest impact on actual tooth movement. Therefore, adding a longitudinal dataset would diverge from our hypothesis.

Study Limitations

A potential limitation of this study is the small sample size, which is typical for a pilot study. The comparison between the control and experimental groups did not show statistical significance, possibly because of the small sample size. To assess the required number of subjects, a post-hoc analysis was performed using G*Power 3.1.9.7 (Franz Faul, Universität Kiel, Germany) with an effect size of 0.37. The results indicated that a sample size of 119 per group was required to achieve 80% power with a type I error of 0.05. However, ethical considerations regarding radiation exposure limited the number of cases in the untreated control group. Also, future research using surface-based deviation 3D analysis would be beneficial to assess the exact areas of surface changes.[25,31]

From a clinical perspective, the results of this study can help dentists better understand root changes in immature teeth after orthodontic treatment. Early treatment does not appear to have a negative impact on root formation. However, to obtain a definite inference, further long-term studies with appropriate sample sizes are necessary.

CONCLUSION

This pilot study suggests that RME and orthodontic treatment with fixed appliances do not interrupt normal dental root formation, which supports early orthodontic and orthopedic treatment. Larger-scale studies are needed to confirm these findings.

Ethics

Ethics Committee Approval: Ethical permission was granted by the Institutional Review Board of Boston University (approval no.: H-32515, date: 10.12.2018).

Informed Consent: Retrospective pilot study.

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Footnotes

Author Contributions: Concept - M.M.; Design - L.A.W., M.M.; Data Collection and/or Processing - T.D.; Analysis and/or Interpretation - T.D., A.A.A., M.S., M.M.; Literature Search - T.D., M.S.; Writing - T.D., A.A.A., L.A.W., M.S., M.M.

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Supplementary Table 1. Intra-rater reliability using paired t-tests, Bland and Altman limits of agreement, and Intraclass correlation and Dahlberg method error

Variable	Paired t-test	Bland and Altman limits of agreement				Intraclass correlation (ICC)			Dahlberg method error
	MD (M1-M2)	SD	p-value	Lower 95% CI	Upper 95% CI	ICC	Lower 95% CI	Upper 95% CI	
UR_1M_PRL	-0.04	0.14	0.495	-0.20	0.11	0.99	0.98	1	0.055
UL_1M_PRL	-0.01	0.09	0.798	-0.10	0.08	0.99	0.99	1	0.025
UR_1M_MBRL	-0.25	0.38	0.165	-0.65	0.14	0.98	0.89	0.99	0.047
UL_1M_MBRL	0.03	0.13	0.537	-0.10	0.18	0.99	0.99	1	0.035
UR_1M_DBRL	0.33	0.52	0.179	-0.21	0.88	0.96	0.75	0.99	0.173
UL_1M_DBRL	-0.01	0.18	0.899	-0.20	0.18	0.99	0.98	1	0.037
UR_2PM_BRL	0.17	0.18	0.1	-0.02	0.36	0.99	0.98	1	0.021
UL_2PM_BRL	-0.005	0.08	0.899	-0.09	0.08	1	0.99	1	0.013
UR_1PM_BRL	0.09	0.15	0.217	-0.07	0.25	0.999	0.99	1	0.022
UL_1PM_BRL	-0.05	0.14	0.39	-0.21	0.09	0.99	0.99	1	0.019
UR_1M_RV	-3.24	23.20	0.746	-27.59	21.11	0.99	0.93	0.99	0.098
UL_1M_RV	1.99	30.41	0.879	-29.92	33.90	0.98	0.90	0.99	0.129
UR_2PM_RV	2.71	5.69	0.296	-3.26	8.68	0.99	0.98	1	0.05
UL_2PM_RV	0.22	6.49	0.937	-6.58	7.03	0.99	0.96	0.99	0.037
UR_1PM_RV	2.64	10.13	0.552	-8.00	13.28	0.99	0.96	0.99	0.076
UL_1PM_RV	-1.82	4.50	0.367	-6.55	2.90	0.99	0.99	1	0.019

*Significance at $p<0.05$
M1, one measurement; M2, two measurement; CI, confidence interval; MD, mean difference; SD, standard deviation; UR, upper right; UL, upper left; 1M, first molar; PRL, palatal root length; MBRL, mesiobuccal root length; DBRL, distobuccal root length; 2PM, second premolar; 1PM, first premolar; BRL, buccal root length; RV, root volume.