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A CBCT Evaluation of the Proximity of Mandibular Molar Roots and Lingual Cortical Bone in Various Vertical Facial Patterns and Factors Related to Root-Cortical Bone Contact

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Abstract: The objective of this study was to assess the proximity of the mandibular molar roots and the lingual cortical bone in patients with various vertical facial patterns and determine factors related to root-cortical bone contact. A total of 145 patients (84 males, 61 females, mean age: 22.0 ± 1.76 years) were assigned to hypodivergent (36 patients), normovergent (80 patients) and hyperdivergent (29 patients) groups based on their facial height ratio. Cone-beam computed tomography (CBCT) images were used to measure the distance between the mandibular molar roots and the lingual cortical bone, and any instances of root-cortical bone contact were identified. The study investigated the correlation between the contact of the mandibular molar roots with the lingual cortical bone and several variables, including sex and cephalometric measurements. The distance between the mandibular molar roots and the lingual cortical bone was significantly shorter in the hyperdivergent group than in the hypodivergent group ($p < 0.05$). Of the total root-cortical bone contact, 87.6% was observed in the mandibular second molars, and the distal roots of the mandibular second molars had the highest contact rate at 43.1% in the hyperdivergent group ($p < 0.05$). Among the evaluated variables, only the distance between the distal root apex of the mandibular second molar and the mandibular plane was found to be associated with contact of the mandibular molar roots with the lingual cortical bone. An increase of 1 mm in this distance was associated with a 22% decrease in the likelihood of contact between the mandibular second molar roots and lingual cortical bone ($p < 0.001$). Given the proximity and high contact ratio between the mandibular molar roots and lingual cortical bone, it is recommended that these structures be evaluated using CBCT before planning molar distalization or intrusion in hyperdivergent patients.

Keywords: lingual cortical bone; cone beam computed tomography; vertical facial morphology

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1. Introduction

The development of skeletal anchorage has gradually expanded the scope of non-surgical orthodontic treatment. Biomechanics using skeletal anchorages can create various lines of action by adjusting the placement site of temporary anchorage devices and the application point of force. Doing this enables precise tooth movement while minimizing undesirable tooth movement. However, it is difficult to achieve teeth movement beyond the anatomical limits, and excessive teeth movement can increase the risk of side effects such as root resorption [1]. Therefore, it is still crucial to know the anatomical limits of tooth movement to achieve a treatment goal.

Unlike the U-shaped mandibular dental arch, the mandibular basal bone has a V-shape with its width increasing posteriorly. Therefore, the posterior mandibular roots become closer to the mandibular lingual cortical bone in the posterior region [2–4]. Despite the proximity of the posterior mandibular roots to the lingual cortical bone, the anatomical limit of posterior movement was thought to be the mandibular ramus [5,6]. This is because the interference between the roots and lingual cortical bone cannot be confirmed in a two-dimensional image. However, recent studies using three-dimensional computed tomography showed that posterior movement of mandibular teeth was limited by the lingual cortical bone, not the mandibular ramus [2].

The lingual cortical bone of the posterior mandible contains a mylohyoid line to which the mylohyoid is attached and a fossa for the submandibular gland in the posterior part. The shape of the alveolar bone, the mylohyoid line, and the submandibular fossa differ between individuals. Unfortunately, some may have insufficient space for tooth movement [7–10]. Additionally, the intrusion force applied on the buccal side can cause the mandibular molar roots to move lingually. When the mandibular molar roots and the lingual cortical bone are in contact, distal or intrusive movement of the mandibular posterior teeth may be even more difficult. Information on the buccolingual distance between the mandibular molar roots and lingual cortical bone is currently limited. Most previous studies on the relationship between the mandibular molar roots and lingual cortical bone focused on the limits of the posterior movement of the posterior teeth and measured the anteroposterior distance between the roots of the second mandibular molar and lingual cortical bone [2,11–13].

The shape of the jaw, thickness of the cortical bone, and buccolingual inclination of the teeth differ according to the vertical facial patterns [14–18]. As those with a hyperdivergent facial type have a narrow buccolingual width of the mandible and no differences in the buccolingual inclination of the posterior mandibular teeth, we hypothesized that the proximity of the mandibular molar roots and lingual cortical bone would differ according to the vertical facial pattern.

Therefore, we compared the distance and contact ratio between the mandibular molar roots and lingual cortical bone in young adults with various vertical facial patterns using cone-beam computed tomography (CBCT). Additionally, the relationship between variables and root-lingual cortical bone contact was evaluated.

2. Materials and Methods

Patients who had undergone CBCT imaging at Wonkwang University Dental Hospital in 2019 and satisfied the following conditions were selected: (1) Young adults between the age of 20 and 25, (2) permanent dentition without deciduous teeth or dental implants, (3) no history of root canal treatment in the mandibular molar region with healthy apical tissues, (4) no furcation involvement of mandibular molars, (5) no degenerative changes in the temporomandibular joints, (6) no facial asymmetry, and (7) no orthodontic braces or retainers.

CBCT images were acquired using Alphard VEGA (Asahi Roentgen, Kyoto, Japan). Images were taken with 17-s exposure times at a tube voltage of 80 kVp and a tube current of 7 mA. The size of the voxel was $0.39 \times 0.39 \times 0.39$ mm.

Original CBCT data of the 145 patients (84 men, 61 women, mean age: 22.0 ± 1.76 years) were stored in digital imaging and communications in medicine format and analyzed using Ondemand3D software (Version 1.0, Cybermed, Seoul, Republic of Korea). Two-dimensional lateral and frontal cephalograms were obtained from the reoriented CBCT images (Figure 1).

The following variables were measured on lateral and frontal cephalograms (Figure 2, Table 1): facial height ratio (FHR; S-Go/N-Me), distance from distal root apex of the second mandibular molar to the mandibular plane (D7MP), ANB angle, sella-nasion to mandibular plane angle (SNMP), palatal plane to mandibular plane angle (PPMP), and the maxilla and mandible width ratio (J-J/Ag-Ag ratio). D7MP was measured by dividing the left and right sides of the hemifacial CBCT-generated cephalograms.

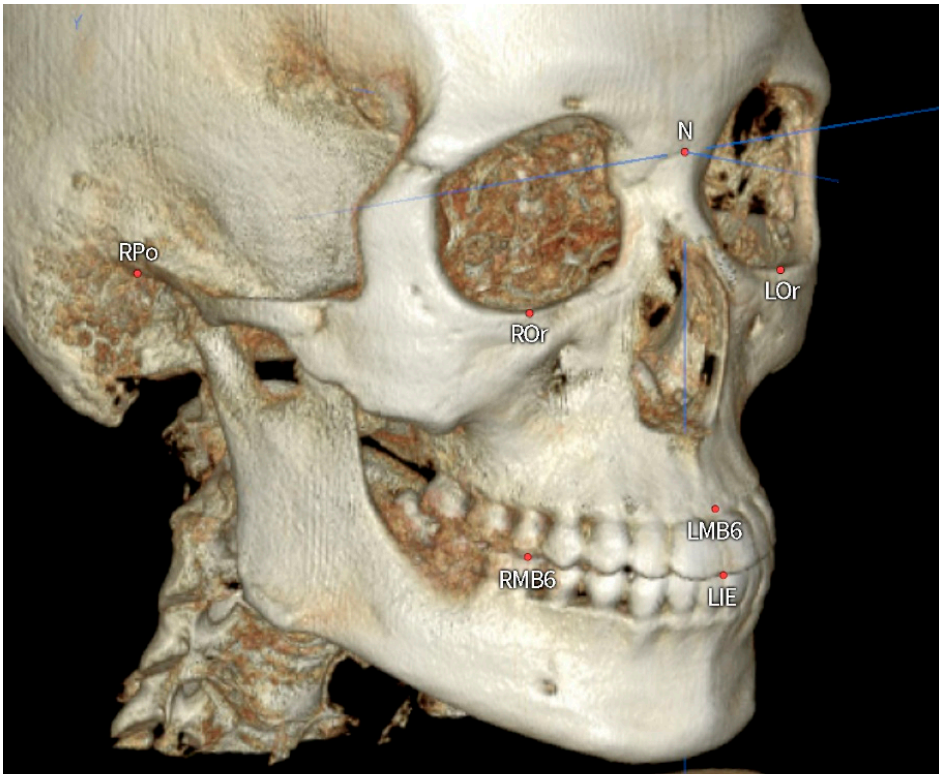

Figure 1. Reference planes and landmarks for reorientation of the CBCT images. Nasion, right and left orbitale and right porion were used for reorientation to generate two-dimensional cephalographs. The mandibular occlusal plane was formed by the lower incisor edge (LIE) and right and left mesiobuccal cusps of the mandibular first molars (RMB6, LMB6).

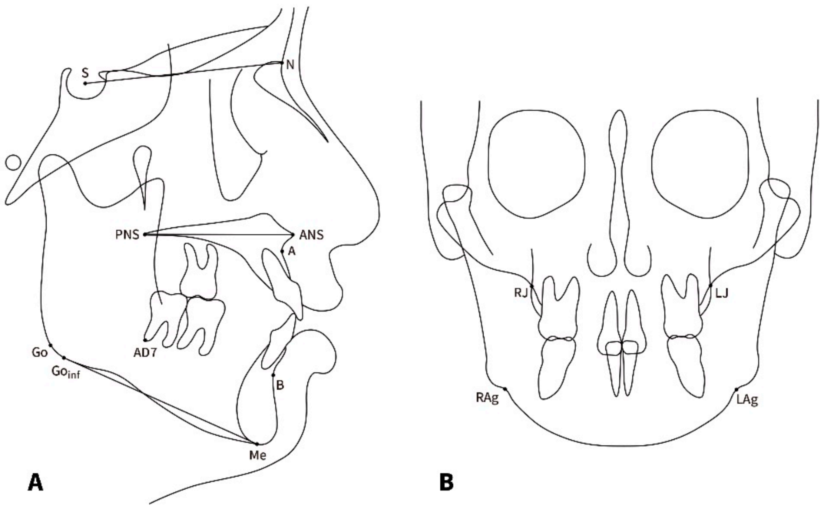

Figure 2. (**A**). Landmarks and planes on a lateral cephalogram. S, sella; N, nasion; ANS, anterior nasal spine; PNS, posterior nasal spine; A, point A; B, point B; Me, menton; Go, gonion; Go$_{inf}$, inferior gonion; AD7, apex of the distal root of the mandibular second molar; SN plane, line from S to N; palatal plane, line from ANS to PNS; mandibular plane, line from Me to Go$_{inf}$. (**B**). Landmarks on a posteroanterior cephalogram. RJ, right jugale; LJ, left jugale; RAg, right antegonion; LAg, left antegonion.

Table 1. Linear and angular measurements on lateral and frontal cephalograms.

Measurements	Description
Anterior facial height (AFH) (mm)	Distance from nasion to menton
Posterior facial height (PFH) (mm)	Distance from sella to gonion
Facial height ratio (FHR) (%)	Ratio of PFH to AFH (PFH/AFH)
D7MP (mm)	Distance from AD7 to mandibular plane
ANB (°)	Angle formed by point A, nasion, and point B
SNMP (°)	Angle between SN plane and mandibular plane
PPMP (°)	Angle between palatal plane and mandibular plane
J-J/Ag-Ag ratio (%)	Ratio of RJ-LJ to RAg-LAg

Patients were assigned to hypodivergent (FHR $\geq$ 69%, n = 36), normovergent (61% $\leq$ FHR < 69%, n = 80), and hyperdivergent (FHR < 61%, n = 29) groups according to FHR (Table 2). This study was approved by the Institutional Review Board (IRB) of Wonkwang University Dental College Hospital (WKDIRB202005-01).

Table 2. Patient characteristics (mean ± standard deviation or counts).

	Age, y	Facial Height Ratio, %	ANB, °	No. of Patients	
				Males	Females
Hypodivergent group (FHR $\geq$ 69%, n = 36)	22.1 ± 1.8	72.2 ± 2.5	2.4 ± 2.6	31	5
Normovergent group (61% $\leq$ FHR < 69%, n = 80)	22.3 ± 1.8	64.9 ± 2.2	2.9 ± 2.0	46	34
Hyperdivergent group (FHR < 61%, n = 29)	21.4 ± 1.7	58.2 ± 1.9	4.0 ± 2.0	7	22

FHR is the ratio of posterior facial height (S-Go) to anterior facial height (N-Me).

CBCT images were reoriented such that the mandibular occlusal plane passed through the midpoint of the mandibular central incisor edge and right and left mesiobuccal cusps of the mandibular first molar (Figure 1) [2]. The distances between the left and right mandibular molar roots and the inner and outer surfaces of lingual cortical bone were measured (Figure 3).

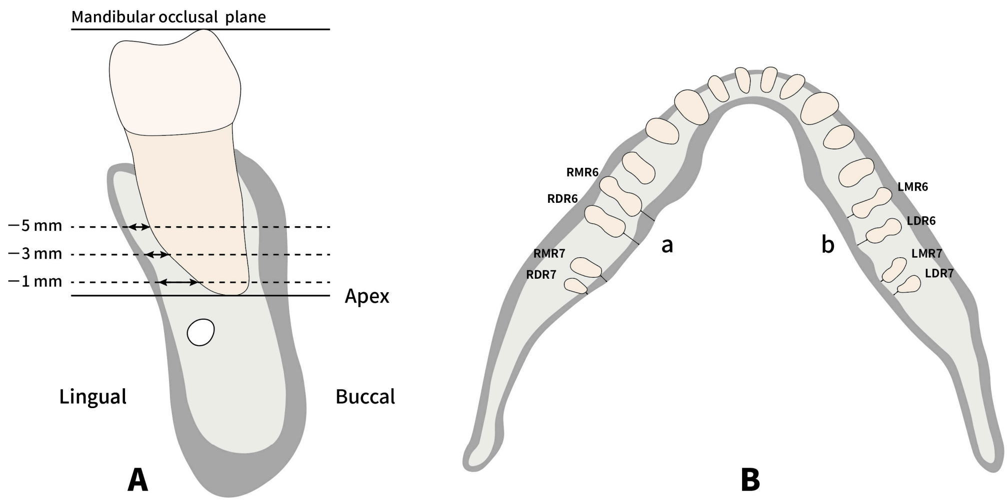

Figure 3. (**A**) The distance between the root and the lingual cortical bone was measured in a plane parallel to the mandibular occlusal plane and 1, 3, and 5 mm away from the apex. (**B**) Schematic diagram showing the distance measured between the root and lingual cortical bone on the axial plane. (a) distance between molar roots and outer lingual cortical bone, (b) distance between molar roots and inner lingual cortical bone.

Measurements were made 1, 3, and 5 mm above the individual apex of the mesial and distal roots of the mandibular molars. In molars having two distal roots, the distance was measured at the distolingual root. In the C-shaped roots, the distance from the most protruding point of the mesial and distal parts was recorded.

If the roots invaded the lingual cortical bone, the distance between the roots and medial cortical bone was recorded as 0, even though periodontal ligament space was observed between the roots and lingual cortical bone.

Additionally, contact between the first and second molar roots and lingual cortical bone was assessed. If contact between molar roots and lingual cortical bone in the horizontal plane was suspected, the contact was confirmed in multiplanar reconstruction images (Figure 4).

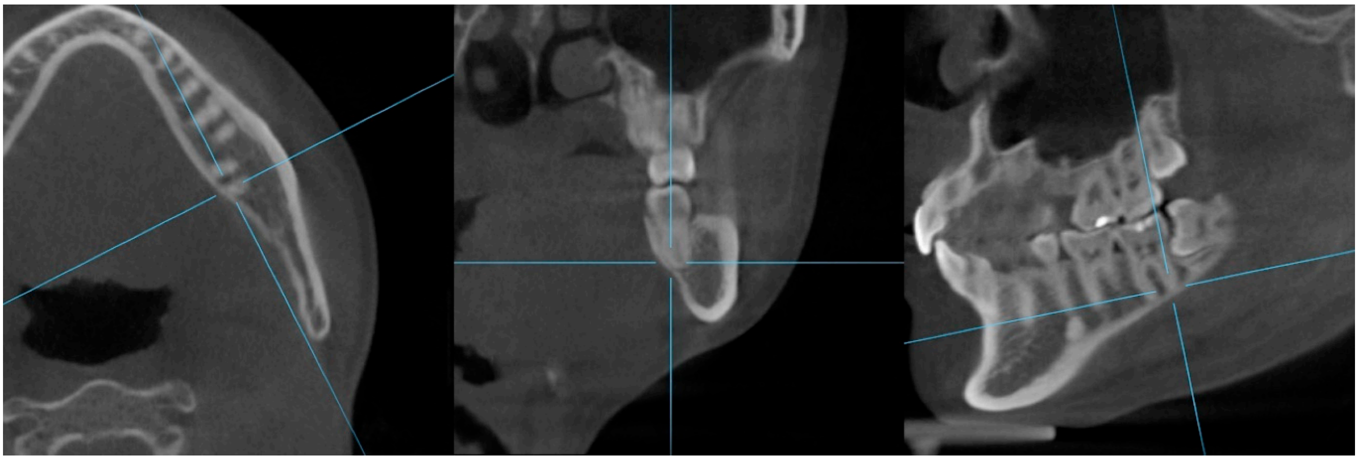

Figure 4. Confirmation of contact between mandibular molar roots and lingual cortical bone with multiplanar reconstruction images.

The minimum number of samples required for one-way analysis of variance (one-way ANOVA) was calculated using G*power (Dusseldorf, Germany). With an effect size of 0.25, α of 0.05, and power of 0.80, the minimum number of samples required was 53. Considering that the measurements were made on the left and right sides, the minimum number of patients required in each group was 27.

All measurements were made by a single orthodontist with 6 years of clinical experience (S-K, C.) at two-week intervals. Measurement error was calculated using the Dahlberg formula: Se = $\sqrt{(d^2/2n)}$, d and n indicated the difference between the two measurements and the number of pairs of measurements, respectively.

R software (version 4.0.3; R Foundation for Statistical Computing, Vienna, Austria) and SPSS software (version 12; SPSS Inc, Chicago, IL, USA) were used for statistical analysis. The normality of the distance between molar roots and lingual cortical bone was confirmed using the Kolmogorov Smirnov test. Thus, parametric methods were used for statistical analysis. A one-way ANOVA was conducted to compare the distance between the roots and lingual cortical bone of the three groups, and Scheffe analysis was conducted for multiple comparisons. A chi-square test was conducted to analyze differences in the ratio of the mandibular molar root-lingual cortical bone contact according to the variables, and simple logistic regression analysis was performed to evaluate the relationship of sex and cephalogram measurements on mandibular second molar-lingual cortical bone contact (L7-LCC). A p-value less than 0.05 was considered statistically significant.

3. Results

3.1. Distance between Mandibular Molar Roots and Lingual Cortical Bone

The intraclass correlation coefficient between measurements taken at two-week intervals was 0.93. The paired t-test did not show significant differences in the distance between mandibular molar roots and lingual cortical bone measured at 2-week intervals. In this study, second measurements were used. The measurement error calculated using the Dahlberg formula was 0.26 mm.

The distances between the mandibular molar roots and lingual cortical bone are presented in Tables 3 and 4. In all groups, the distance between the mandibular molar roots and the inner and outer surfaces of the lingual cortical bone decreased from the mesial side to the distal side. Specifically, the distance between the distal roots of the mandibular second molar and lingual cortical bone was the shortest. The distance between the mandibular molar roots and lingual cortical bone was significantly shorter in the hyperdivergent group than in the hypodivergent group for all measurements ($p < 0.05$, Table 3).

Table 3. Mean distance (± standard deviation) between the mandibular molar roots and lingual cortical bone according to the vertical facial patterns.

	1 mm				3 mm				5 mm			
	Hypo	Normo	Hyper	*p* Value	Hypo	Normo	Hyper	*p* Value	Hypo	Normo	Hyper	*p* Value
Root-inner cortical bone distance												
M6	4.5 ± 1.4^{a}	4.1 ± 1.4^{a}	3.4 ± 1.0^{b}	0.000 ***	3.8 ± 1.2^{a}	3.3 ± 1.1^{b}	2.8 ± 0.9^{c}	0.000 ***	2.9 ± 1.1^{a}	2.5 ± 1.0^{ab}	2.2 ± 0.9^{b}	0.000 ***
D6	3.8 ± 2.0^{a}	3.4 ± 1.7^{ab}	2.9 ± 1.6^{b}	0.016 *	3.3 ± 1.7^{a}	2.9 ± 1.5^{ab}	2.5 ± 1.3^{b}	0.015 *	2.8 ± 1.4^{a}	2.5 ± 1.2^{ab}	2.1 ± 1.0^{b}	0.009 **
M7	2.3 ± 1.3^{a}	1.9 ± 1.3^{ab}	1.5 ± 1.3^{b}	0.000 ***	2.1 ± 1.0^{a}	1.8 ± 1.1^{ab}	1.6 ± 1.0^{b}	0.008 **	2.0 ± 0.8^{a}	1.7 ± 0.8^{ab}	1.5 ± 0.6^{b}	0.000 ***
D7	2.0 ± 1.3^{a}	1.5 ± 1.2^{b}	1.1 ± 1.0^{b}	0.000 ***	2.1 ± 1.1^{a}	1.5 ± 1.0^{b}	1.2 ± 0.9^{b}	0.000 ***	2.2 ± 1.0^{a}	1.7 ± 0.9^{b}	1.4 ± 0.7^{b}	0.000 ***
Root-outer cortical bone distance												
M6	7.1 ± 1.6^{a}	6.7 ± 1.4^{a}	5.8 ± 1.1^{b}	0.000 ***	6.3 ± 1.4^{a}	6.0 ± 1.2^{a}	5.3 ± 1.2^{b}	0.000 ***	5.4 ± 1.4^{a}	5.2 ± 1.1^{ab}	4.7 ± 1.3^{b}	0.007 **
D6	6.1 ± 2.0^{a}	5.6 ± 1.9^{ab}	5.1 ± 1.6^{b}	0.015 *	5.4 ± 1.9^{a}	5.2 ± 1.7^{ab}	4.6 ± 1.3^{b}	0.024 *	5.0 ± 1.7^{a}	4.7 ± 1.4^{ab}	4.2 ± 1.1^{b}	0.004 **
M7	4.4 ± 1.5^{a}	4.0 ± 1.6^{ab}	3.6 ± 1.5^{b}	0.016 *	4.1 ± 1.2^{a}	3.9 ± 1.3^{ab}	3.6 ± 1.2^{b}	0.023 *	3.9 ± 1.1^{a}	3.7 ± 1.0^{a}	3.2 ± 0.8^{b}	0.000 ***
D7	4.0 ± 1.6^{a}	3.4 ± 1.6^{ab}	2.8 ± 1.5^{b}	0.000 ***	4.1 ± 1.3^{a}	3.5 ± 1.4^{b}	3.0 ± 1.3^{b}	0.000 ***	4.0 ± 1.2^{a}	3.4 ± 1.1^{b}	3.1 ± 1.0^{b}	0.000 ***

M6, mesial root of mandibular first molar; D6, distal root of mandibular first molar; M7, mesial root of mandibular second molar; D7, distal root of mandibular second molar. The same lowercase letters are not significant. 1-way ANOVA and Scheffe post-hoc test: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

The distances between the mandibular first molar roots and the inner and outer surfaces of the lingual cortical bone increased as they approached the root apex in all groups. However, there was no significant difference in the distance between the mandibular second molar roots and lingual cortical bone based on the root level, except for one area (distance between the mesial root of the mandibular second molar and outer cortical bone in the normovergent group) (Table 4).

Table 4. Mean distance (± standard deviation) between the mandibular molar roots and the lingual cortical bone according to the root level.

	Hypodivergent				Normovergent				Hyperdivergent			
	1 mm	3 mm	5 mm	*p* Value	1 mm	3 mm	5 mm	*p* Value	1 mm	3 mm	5 mm	*p* Value
Root-inner cortical bone distance												
M6	4.5 ± 1.4^{a}	3.8 ± 1.2^{b}	2.9 ± 1.1^{c}	0.000 ***	4.1 ± 1.4^{a}	3.3 ± 1.1^{b}	2.5 ± 1.0^{c}	0.000 ***	3.4 ± 1.0^{a}	2.8 ± 0.9^{b}	2.2 ± 0.9^{c}	0.000 ***
D6	3.8 ± 2.0^{a}	3.3 ± 1.7^{ab}	2.8 ± 1.4^{b}	0.002 **	3.4 ± 1.7^{a}	2.9 ± 1.5^{b}	2.5 ± 1.2^{c}	0.000 ***	2.9 ± 1.6^{a}	2.5 ± 1.3^{ab}	2.1 ± 1.0^{b}	0.006 **
M7	2.3 ± 1.3	2.1 ± 1.0	2.0 ± 0.8	0.294	1.9 ± 1.3	1.8 ± 1.1	1.7 ± 0.8	0.539	1.5 ± 1.3	1.6 ± 1.0	1.5 ± 0.6	0.821
D7	2.0 ± 1.3	2.1 ± 1.1	2.2 ± 1.0	0.639	1.5 ± 1.2	1.5 ± 1.0	1.4 ± 0.7	0.209	1.1 ± 1.0	1.2 ± 0.9	1.4 ± 0.7	0.148
Root-outer cortical bone distance												
M6	7.1 ± 1.6^{a}	6.3 ± 1.4^{b}	5.4 ± 1.4^{c}	0.000 ***	6.7 ± 1.4^{a}	6.0 ± 1.2^{b}	5.2 ± 1.1^{c}	0.000 ***	5.8 ± 1.1^{a}	5.3 ± 1.2^{a}	4.7 ± 1.3^{b}	0.000 ***
D6	6.1 ± 2.0^{a}	5.4 ± 1.9^{ab}	5.0 ± 1.7^{b}	0.001 **	5.6 ± 1.9^{a}	5.2 ± 1.7^{b}	4.7 ± 1.4^{c}	0.000 ***	5.1 ± 1.6^{a}	4.6 ± 1.3^{ab}	4.2 ± 1.1^{b}	0.001 **
M7	4.4 ± 1.5	4.1 ± 1.2	3.9 ± 1.1	0.102	4.0 ± 1.6^{a}	3.9 ± 1.3^{ab}	3.7 ± 1.0^{b}	0.025 *	3.6 ± 1.5	3.6 ± 1.2	3.2 ± 0.8	0.14
D7	4.0 ± 1.6	4.1 ± 1.3	4.0 ± 1.2	0.933	3.4 ± 1.6	3.5 ± 1.4	3.4 ± 1.1	0.91	2.8 ± 1.5	3.0 ± 1.3	3.1 ± 1.0	0.623

M6, mesial root of mandibular first molar; D6, distal root of mandibular first molar; M7, mesial root of mandibular second molar; D7, distal root of mandibular second molar. The same lowercase letters are not significant. One-way ANOVA and Scheffe post-hoc test: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

3.2. Contact Ratio between Mandibular Molar Roots and Lingual Cortical Bone

In all groups, the contact rate between the mandibular molar distal roots and lingual cortical bone increased from the mesial side to the distal side. Overall, a total of 87.6% of total mandibular molar root-lingual cortical bone contact was observed in the mandibular second molars. The contact rate was the greatest in the distal roots of the mandibular second molars ($p < 0.001$, Table 5). Significant differences in the contact rate between the mandibular molar roots and lingual cortical bone were observed only at the distal roots of the mandibular second molars in the three groups. A contact rate of 43.1% was observed between the distal roots of the mandibular second molars and lingual cortical bone in the hyperdivergent group, which was the greatest of all the contact rates ($p < 0.05$, Table 5).

Table 5. Comparison of the contact rate between the roots of the mandibular molars and the lingual cortical bone.

	M6	D6	M7	D7	p Value
Hypodivergent ($n = 72$)	0 (0%)	2 (2.8%)	9 (12.5%)	15 (20.8%)	0.000 ***
Normovergent ($n = 160$)	2 (1.3%)	11 (6.9%)	37 (23.1%)	53 (33.1%)	0.000 ***
Hyperdivergent ($n = 58$)	0 (0%)	7 (12.1%)	16 (27.6%)	25 (43.1%)	0.000 ***
p value	0.441	0.115	0.082	0.024 *	

M6, mesial root of mandibular first molar; D6, distal root of mandibular first molar; M7, mesial root of mandibular second molar; D7, distal root of mandibular second molar. Chi-square test: * $p < 0.05$, *** $p < 0.001$.

3.3. Factors Related to Contact between Mandibular Second Molar Roots and Lingual Cortical Bone

The ratio of L7-LCC was significantly different according to FHR and D7MP (Table 6). The contact rate was the greatest in the hyperdivergent group ($p < 0.05$) and the groups with small D7MP ($p < 0.001$).

Table 6. Comparison of contact rate between the mandibular second molars and lingual cortical bone according to the clinical variables.

Variable	Contact Rate (%)	Number of Teeth	p Value
Sex			
Male	32.1	168	0.381
Female	37.7	122	
FHR			
Hypodivergent (>69%)	23.6	72	0.05 *
Normovergent (≥61%, <69%)	36.3	160	
Hyperdivergent (<61%)	43.1	58	
D7MP			
Small (<12 mm)	51.0	96	0.000 ***
Average (≥12 mm, <15 mm)	31.7	104	
Large (≥15 mm)	20.0	90	
ANB			
Class I (≥0°, <4°)	32.9	170	0.653
Class II (≥4°)	38.0	100	
Class III (<0°)	46.2	20	
SNMP			
Hypodivergent (<27°)	28.3	46	0.528
Normovergent (≥27°, <37°)	37.0	154	
Hyperdivergent (≥37°)	33.3	90	
PPMP			
Hypodivergent (<19°)	30.0	50	0.671
Normovergent (≥19°, <29°)	36.4	176	
Hyperdivergent (≥29°)	32.8	64	
J-J/Ag-Ag ratio			
Low (<72%)	28.1	64	0.478
Average (≥72%, <78%)	36.8	144	
High (≥78%)	35.4	82	

Chi-square test: * $p < 0.05$, *** $p < 0.001$.

In a simple logistic regression, significant results were observed only at D7MP, and when D7MP increased by 1 mm, the probability of contact between the root and cortical bone decreased by 22% ($p < 0.001$, Table 7).

Table 7. Comparison of odds ratio according to the clinical variables.

	Unit	Odds Ratio	Lower 95% CI	Upper 95% CI	p Value
Sex	Male	Reference			
	Female	0.996	0.610	1.63	0.986
FHR	%	0.965	0.920	1.01	0.140
D7MP	mm	0.777	0.706	0.856	0.000 ***
SNMP	°	1.02	0.978	1.06	0.397
PPMP	°	1.0	0.966	1.05	0.813
ANB	°	1.050	0.938	1.17	0.403
J-J/Ag-Ag ratio	%	1.010	0.957	1.07	0.686

Simple logistic regression. *** $p < 0.001$.

4. Discussion

In recent decades, the use of CBCT has increased dramatically in dentistry. CBCT images have less distortion than conventional two-dimensional radiographic diagnostic images and are not affected by overlapping structures. Although CBCT images provide more accurate information about dentoskeletal structures, clinicians should be aware that the effective dose of radiation with CBCT is much higher than that of panoramic radiographs or cephalograms. Thus, CBCT is only recommended for limited purposes, including assessment of tooth impaction, maxillofacial deformities, and facial asymmetry. The use of CBCT as a routine orthodontic diagnostic tool is still debated [19–21]. Most CBCT images used in this study were obtained for extraction of the mandibular third molar instead of orthodontic diagnosis. Those who wore braces or other orthodontic retainers were excluded from the study to exclude the effects of orthodontic treatment. It cannot be definitively stated that all the patients included in the study had never had orthodontic treatment. So, to completely eliminate any possibility of any effect due to prior orthodontic treatment, a study including information on the patients' complete dental history would be necessary.

This study was initiated with a question of whether there is any difference in the root-cortical bone distance based on facial divergency and whether it is possible to predict patients at high risk of root-cortical bone contact based on the 2D radiographs commonly used in daily practice. In this study, the relationship between measurement values related to facial divergency (FHR, SNMP, and PPMP) and skeletal transverse discrepancy (J-J/Ag-Ag ratio), and root-lingual cortical bone contact was confirmed.

Based on the findings of Kim et al. [2], which showed a decrease in the distance between mandibular molar roots and the posterior lingual cortical bone as it approaches the root apex, we hypothesized that the risk of contact between the mandibular molar roots and the lingual cortical bone is greater in the lower root area. To test this hypothesis, we included the most posteroinferior point of mandibular dentition (D7MP) in our measurement list. We considered that the area 1, 3, or 5 mm from the root apex would be the best spots to determine the relationship between the lower roots and the lingual cortical bone, assuming a root length of 12 mm for the mandibular molar.

We observed that the distance between the mandibular molar roots and the outer surface of the mandibular lingual cortical bone decreased from mesial to distal. This finding was consistent with the observations of Aljarbou et al. [3]. The distance between the mandibular first molar roots and the lingual cortical bone increased from the cervical to the apex. In contrast, there was no significant difference in the distance between the mandibular second molar roots and the lingual cortical bone relative to the root level. In addition, the lingual cortical bone of the distal part of the second molars shows an S-shaped curve, which is in contrast to the lingual cortical bone near the first molar that is parallel to the dental arch. (Figure 5). The morphology of the lingual cortical bone is thought to be related to the location of the mylohyoid line. Aoki et al. reported that the mylohyoid line is 16 mm away from the mandible lower edge in the distal root area of the mandibular second molars [8]. Considering the mean D7MP measured in our study was 13.44 mm, the distal roots of the mandibular second molars appear to be located close to the mylohyoid line. Overall, these findings suggest that second molars are more likely to be a problem than first molars during distalization or intrusion of the mandibular posterior teeth.

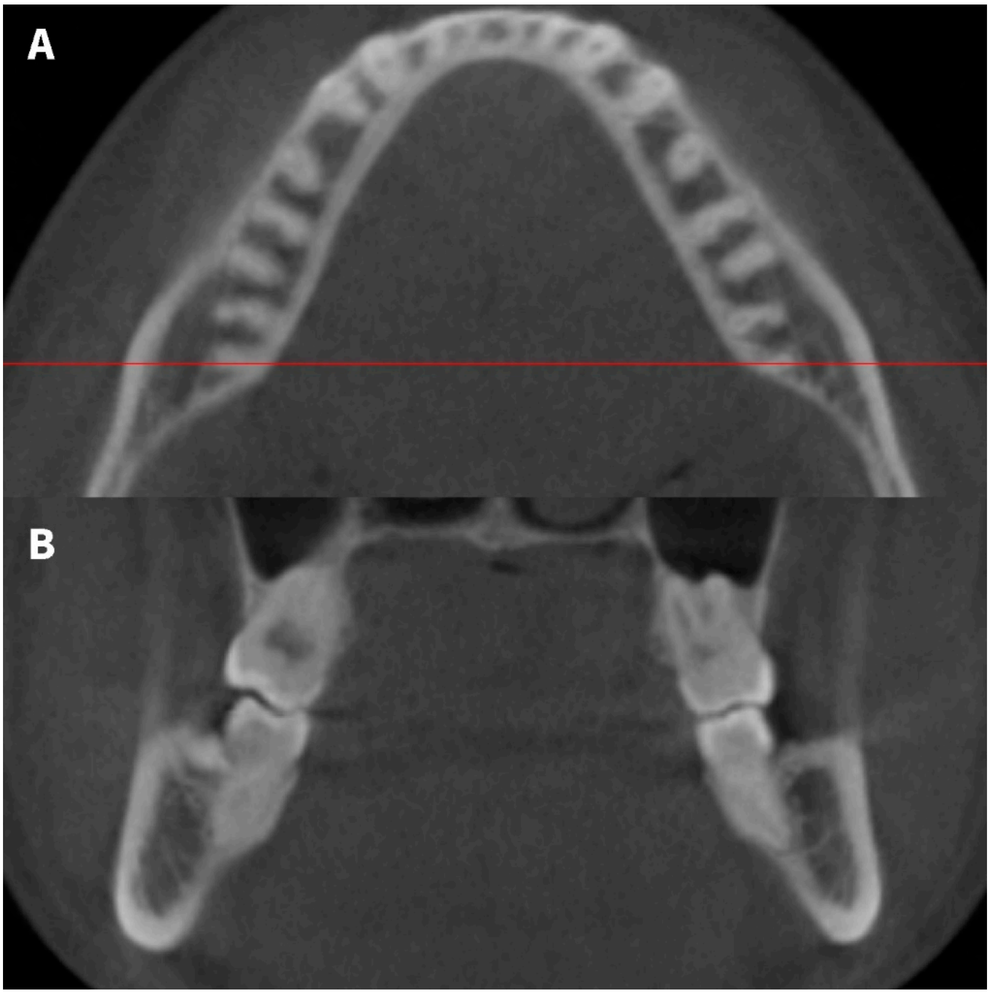

Figure 5. CBCT multiplanar reconstruction images showing contacts between distal roots of mandibular second molars and the lingual cortical bone. (**A**) axial view, (**B**) coronal view.

The distance between the mandibular molar roots and lingual cortical bone was shorter in all areas in the hyperdivergent group than in the hypodivergent group in this study. This finding may be due to (1) differences in mandibular morphology according to the vertical facial pattern and (2) reduced molar eruption because of insufficient mandibular forward rotation. Swasty et al. reported that the mandibular buccal width in the upper third of the mandibular molar was thinner in hyperdivergent patients [16]. It is thought that the thin mandibular buccal width in patients with a hyperdivergent facial shape affected the contact between the mandibular molar roots and lingual cortical bone. Furthermore, differences in the eruption of posterior teeth according to the mandibular rotation pattern also seem to be related to the proximity between roots and lingual cortical bone. Patients with a hyperdivergent facial pattern show reduced forward rotation of the mandible according to growth and rather backward rotation compared to those with a hypodivergent facial pattern [22]. This limits the eruption of the posterior teeth, which may lead to relative proximity between the mandibular molar roots and lingual cortical bone.

In general, given the same conditions, hyperdivergent patients have relatively retracted chins which leads to an increased protrusion of their lips. In these patients, distalization and intrusion of the entire dentition are required to improve the unesthetic facial profile, and these types of movements may be restricted by the root-cortical bone relationship. Therefore, it is necessary to check whether there is sufficient space between the mandibular molar roots and lingual cortical bone through CT when treating hyperdivergent patients. If the space is insufficient, extraction may be necessary.

The distance between the mandibular molar roots and lingual cortical bone was closest in mandibular second molars, and similarly, contact between the mandibular molar roots and lingual cortical bone was observed mostly in mandibular second molars (Table 5). Kim et al. reported that 35.3% of mandibular second molar roots were in contact with the lingual cortical bone in a study of skeletal Class I patients with normovergent facial patterns [2]. In our study, in agreement with these findings we also observed that 34.5% (100 out of 290) of the mandibular second molar roots were in contact with the lingual cortical bone. The mandibular second molar roots were in contact with the lingual cortical bone in 23.6% (17 out of 72), 36.3% (58 out of 160), and 43.1% (25 out of 58) of hypodivergent, normovergent, and hyperdivergent groups, respectively.

Some studies reported the rate of patients with mandibular second molar root-lingual cortical bone contact [12,13]. Chen et al. showed that contact between mandibular second molar roots and lingual cortical bone was observed in 49.3% of adults [12]. Zhao et al. reported that contact between the mandibular second molar and lingual cortical bone was observed in 12.2%, 26.8%, and 65.9% of hypodivergent, normovergent, and hyperdivergent patients, respectively [13]. In our study, mandibular second molar roots were in contact with the lingual cortical bone in 30.6% (11 out of 36), 42.5% (34 out of 80), and 51.7% (15 out of 29) of young adults with hypodivergent, normovergent, and hyperdivergent facial patterns, respectively.

The contact between the posterior mandibular teeth and the lingual cortical bone can also be inferred from previous clinical studies. Sugawara et al. reported on the movement patterns of mandibular first molars after the mandibular teeth were moved posteriorly using ramal plates [23]. The crown area moved 1.9 times more than the root region, and distal inclination was observed in approximately 31% of the posteriorly moved mandibular first molars. These findings suggest that the proximity of the posterior mandibular roots to the lingual cortical bone may have resisted posterior movement.

In the simple logistic regression analysis, only D7MP was found to be a significant predictor of L7-LCC. However, when a receiver operating characteristic (ROC) curve was plotted using D7MP as a predictor, the area under the curve (AUC) was only 0.68, suggesting that D7MP may not be a reliable diagnostic tool for confirming the presence of L7-LCC. L7-LCC is likely influenced by various other factors, such as the buccal inclination of teeth, the shape of the lingual cortical bone, the location of the mandibular mylohyoid line, and the presence of submandibular glands, which have been previously reported in the literature. Therefore, although D7MP can be used as a preliminary assessment tool, additional three-dimensional diagnostic imaging may be necessary to establish an accurate treatment plan.

In this study, D7MP was measured using the left and right hemifacial CBCT images, allowing for more accurate measurement without overlap due to teeth on the opposite side and the mandible. However, when using conventional two-dimensional lateral cephalograms, overlapping opposite structures can make it difficult to measure D7MP accurately. Therefore, further studies using lateral cephalograms should be conducted to confirm the effectiveness of D7MP in predicting L7-LCC.

There are several limitations to this study. First, it was conducted using only young adults, so it may not apply to growing patients. Second, the sample groups were determined solely based on FHR, and other factors were not taken into account. The hyperdivergent group had a high mean ANB value and a higher proportion of females, which may have influenced the observed differences between the groups. Therefore, further studies are needed to investigate the relationship between the mandibular molar roots and lingual cortical bone based on age, sex, and the anteroposterior relationship between the maxilla and mandible.

5. Conclusions

This study assessed the distance and contact rate between the mandibular molar roots and lingual cortical bone and factors that could predict contact. The following conclusions can be drawn based on the results of this study:

- Patients with a hyperdivergent facial pattern have a short distance and high chance of contact between mandibular molars and lingual cortical bone.
- The probability of contact between mandibular second molars and lingual cortical bone increases as the root apex of the mandibular second molars is closer to the mandibular plane.
- A CBCT evaluation is recommended if molar distalization or intrusion is planned in hyperdivergent patients.

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References

1. Nakada, T.; Motoyoshi, M.; Horinuki, E.; Shimizu, N. Cone-beam computed tomography evaluation of the association of cortical plate proximity and apical root resorption after orthodontic treatment. *J. Oral Sci.* **2016**, *58*, 231–236. [CrossRef] [PubMed]
2. Kim, S.-J.; Choi, T.-H.; Baik, H.-S.; Park, Y.-C.; Lee, K.-J. Mandibular posterior anatomic limit for molar distalization. *Am. J. Orthod. Dentofac. Orthop.* **2014**, *146*, 190–197. [CrossRef]
3. Aljarbou, F.A.; Aldosimani, M.A.; Althumairy, R.I.; Alhezam, A.A.; Aldawsari, A.I. An analysis of the first and second mandibular molar roots proximity to the inferior alveolar canal and cortical plates using cone beam computed tomography among the Saudi population. *Saudi Med. J.* **2019**, *40*, 189–194. [CrossRef] [PubMed]
4. Porto, O.C.L.; Silva, B.S.F.; Silva, J.A.; Estrela, C.R.A.; Alencar, A.H.G.; Bueno, M.D.R.; Estrela, C. CBCT assessment of bone thickness in maxillary and mandibular teeth: An anatomic study. *J. Appl. Oral Sci.* **2020**, *28*, e20190148. [CrossRef]
5. Abu Alhaija, E.S.J.; AlBhairan, H.M.; AlKhateeb, S.N. Mandibular third molar space in different antero-posterior skeletal patterns. *Eur. J. Orthod.* **2011**, *33*, 570–576. [CrossRef]
6. Ghougassian, S.S.; Ghafari, J.G. Association between mandibular third molar formation and retromolar space. *Angle Orthod.* **2014**, *84*, 946–950. [CrossRef] [PubMed]
7. Ferreira, M.C.; Freitas, K.M.S.; Herrera-Sanches, F.S.; Santos, P.B.D.; Garib, D.; Janson, G.; Freitas, M.R. Evaluation of mandibular First Molars' Axial Inclination and Alveolar Morphology in Different Facial Patterns: A CBCT Study. *Eur. J. Dent.* **2020**, *14*, 250–259. [CrossRef]
8. Aoki, C.; Nara, T.; Kageyama, I. Relative position of the mylohyoid line on dentulous and edentulous mandibles. *Okajimas Folia Anat. Jpn.* **2011**, *87*, 171–176. [CrossRef]
9. Salemi, F.; Shokri, A.; Foroozandeh, M.; Karami, M.; Khalili, Z. Mandibular lingual concavity: A cross-sectional analysis using cone beam computed tomography. *J. Clin. Diagn. Res.* **2018**, *12*, ZC37–ZC41. [CrossRef]
10. Herranz-Aparicio, J.; Marques, J.; Almendros-Marqués, N.; Gay-Escoda, C. Retrospective study of the bone morphology in the posterior mandibular region. Evaluation of the prevalence and the degree of lingual concavity and their possible complications. *Med. Oral Patol. Oral Cir. Bucal.* **2016**, *21*, e731–e736. [CrossRef]
11. Choi, Y.-T.; Kim, Y.-J.; Yang, K.-S.; Lee, D.-Y. Bone availability for mandibular molar distalization in adults with mandibular prognathism. *Angle Orthod.* **2018**, *88*, 52–57. [CrossRef] [PubMed]
12. Chen, C.L.; Chen, C.H.; Pan, C.Y.; Chang, H.P.; Chen, P.H.; Tseng, Y.C. Cone beam computed tomographic analysis of the spatial limitation during mandibular arch distalization. *BMC Med. Imaging* **2020**, *20*, 39. [CrossRef] [PubMed]

13. Zhao, Z.; Wang, Q.; Yi, P.; Huang, F.; Zhou, X.; Gao, Q.; Tsay, T.P.; Liu, C. Quantitative evaluation of retromolar space in adults with different vertical facial types: Cone-beam computed tomography study. *Angle Orthod.* **2020**, *90*, 857–865. [CrossRef] [PubMed]
14. Hwang, S.-S.; Jeong, S.-J.; Choi, Y.-J.; Chung, J.C.-R.; Lee, H.-S.; Kim, K.-H. Three-dimensional evaluation of dentofacial transverse widths of adults with various vertical facial patterns. *Am. J. Orthod. Dentofac. Orthop.* **2018**, *153*, 692–700. [CrossRef] [PubMed]
15. Klinge, A.; Becktor, K.; Lindh, C.; Becktor, J.P. Craniofacial height in relation to cross sectional maxillary and mandibular morphology. *Prog. Orthod.* **2017**, *18*, 32. [CrossRef]
16. Swasty, D.; Lee, J.; Huang, J.C.; Maki, K.; Gansky, S.A.; Hatcher, D.; Miller, A.J. Cross-sectional human mandibular morphology as assessed in vivo by cone-beam computed tomography in patients with different vertical facial dimensions. *Am. J. Orthod. Dentofac. Orthop.* **2011**, *139*, e377–e389. [CrossRef]
17. Janson, G.; Bombonatti, R.; Cruz, K.S.; Hassunuma, C.Y.; Del Santo, M., Jr. Buccolingual inclinations of posterior teeth in subjects with different facial patterns. *Am. J. Orthod. Dentofac. Orthop.* **2004**, *125*, 316–322. [CrossRef]
18. Ozdemir, F.; Tozlu, M.; Germec-Cakana, D. Cortical bone thickness of the alveolar process measured with cone-beam computed tomography in patients with different facial types. *Am. J. Orthod. Dentofac. Orthop.* **2013**, *143*, 190–196. [CrossRef]
19. American Academy of Oral and Maxillofacial Radiology. Clinical recommendations regarding use of cone beam computed tomography in orthodontics. Position statement by the American Academy of Oral and Maxillofacial Radiology. *Oral Surg. Oral Med. Oral Pathol. Oral Radiol.* **2013**, *116*, 238–257. [CrossRef]
20. Garib, D.G.; Calil, L.R.; Leal, C.R.; Janson, G. Is there a consensus for CBCT use in Orthodontics? *Dent. Press J. Orthod.* **2014**, *19*, 136–149. [CrossRef]
21. De Grauwe, A.; Ayaz, I.; Shujaat, S.; Dimitrov, S.; Gbadegbegnon, L.; Vande Vannet, B.; Jacobs, R. CBCT in orthodontics: A systematic review on justification of CBCT in a paediatric population prior to orthodontic treatment. *Eur. J. Orthod.* **2019**, *41*, 381–389. [CrossRef] [PubMed]
22. Bjork, A.; Skieller, V. Facial development and tooth eruption. *Am. J. Orthod.* **1972**, *62*, 339–383. [CrossRef] [PubMed]
23. Sugawara, J.; Daimaruya, T.; Umemori, M.; Nagasaka, H.; Takahashi, I.; Kawamura, H.; Mitani, H. Distal movement of mandibular molars in adult patients with the skeletal anchorage system. *Am. J. Orthod. Dentofac. Orthop.* **2004**, *125*, 130–138. [CrossRef] [PubMed]