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Original article

Comparison of Anterior Maxillary Root Surface Areas in Patients with Normal Overjet and Large Overjet using Cone Beam Computed Tomography

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Abstract

Background: Root surface area is related to orthodontic force magnitude used to induce alveolar bone remodeling with minimize periodontal damage. These detriments are highly concerned especially in anterior teeth that often needed to be retracted. **Objective:** To compare root surface area of maxillary anterior teeth between patients with normal overjet and large overjet. **Materials and methods:** Twelve cone beam computed tomography (CBCT) images of each group were used. Three-dimensional construction of each tooth was created using Mimics software. The surface area apical to cemento-enamel junction was measured and calculated as root surface area using 3-Matic software. The data was analyzed with descriptive analysis. **Results:** Mean age of the patients was 19.75 ± 2.25 years. Mean root surface area of maxillary anterior teeth ranged from 181.32 to 282.16 mm^2. The mean root surface area of maxillary central incisor, lateral incisor, and canine in normal overjet patients were 199, 181 and 249 mm^2 respectively. While the mean root surfaces in large overjet patients were 210, 197, 282 mm^2 respectively. **Conclusion:** The root surface areas of maxillary lateral incisor and canine in large overjet patients were significantly greater than in normal overjet patients. However, there was no significant difference in maxillary central incisor. These findings presented that the difference overjet pattern might associated with the root surface area of maxillary lateral and canine.

Keywords: Cone beam computed tomography, Large overjet, Maxillary anterior teeth, Root surface area

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Introduction

Orthodontics is the dental science to move the teeth to their proper position. It allows a better masticatory distribution and improves cleansing ability in the oral cavity. Hence, it requires a mutual understanding of the treatment plan between the dentist and the patient. The main purpose of orthodontics is to achieve the desired tooth position with the least harm to the periodontal support as it could be accomplished by using a light force to conduct proper alveolar bone remodeling.[1] Therefore, knowing the root surface area needed to move will allow the operator to use a proper magnitude of the force to minimize side effects such as root resorption, decreased alveolar bone crest level, or gingival recession. It has been argued that the relative size of the root(s) may indicate a tooth's resistance to an orthodontic force or the anchorage value.[2-3] The anterior teeth are highly needed to be retracted for a better position or aesthetic concern, especially for patients with large overjet. As the previous study indicated patients with large overjet are at higher risk of root resorption. If the large overjet is diagnosed at an early age, interceptive orthodontic treatment may aid in improving the overjet and overbite at an early and hence enhance dental and periodontal health. We can prevent the sequel to occlusal hypofunction by early interception. Their study conveys that careful diagnosis and intervention of such type of malocclusion is required at an early age. Late intervention requires efficient treatment planning. Adequate diagnosis and lighter force application should hence be considered while planning the treatment of such cases.[4] And the experimental findings in rat molars have included external root resorption during tooth movement, in association with hypofunction.[3]

In a vertical dimension, Suteerapongpun and co-worker[5] reported that a smaller root surface area can be found more often in the anterior open bite group that lacks functional force or bite force in comparison with the normal overbite group, normal functional force. Self[6] reported a study that found a significant correlation between bite force or functional force and tooth formation presented by crown shape, crown size, root shape, and root length. A larger root surface area was observed in harder diets consumer bat species. The results from the study indicated that the tooth root and crown size varied in response to the magnitude of occlusal loads. Determining the relation between root size and bite force production supports the hypothesis that functional force production may have a strong role in inducing root development.

Normal occlusal loading and function are responsible for developing dental root, alveolar bone, and supporting tissue. It provides the required stimulus for adequate root and alveolar bone formation. Occlusal hypofunction decreases alveolar bone mass, accelerates bone resorption, causes deficient root development, and leads to atrophic changes in the periodontal ligament, such as narrowing of the periodontal space, vascular constriction, and deformation of the mechanoreceptors. According to experimental findings performed on rat molars, external apical root resorption was associated with hypofunction, and atrophic changes were seen in the periodontium.[7-11] Several previous studies have reported that individuals with anterior open bite had a tendency to develop short dental roots from the incisors to the premolars that could be associated with occlusal hypofunction or loss of occlusal contact.[4]

In a horizontal dimension, the amount of anterior overjet is associated with anterior functional force while chewing. In the case of patients with large overjet of more than 4 mm, no incisor contact, and less anterior function is observed in most patients. We presumed that they may have diminished occlusal force induced in anterior teeth in comparison with a patient with normal overjet. The difference in occlusal force level may result in a difference root surface area related to length and size of dental root formation apart of gender, race, age, etc.

In the past, the root surface area could be measured by manually indirect technique measurement from cadaver's teeth or extracted tooth such as membrane technique,[12] Sectional Lucite block with 3D computer plot.[13] The process of data collection was difficult, thorny, and more chance of error. Nowadays by importing cone beam computed tomography (CBCT) image into simulation software as Mimic and 3-Matic to convert the Digital Imaging and Communications in Medicine (DICOM) format to the Stereolithography (STL) format. The software were utilized to calculate root surface area without prior tooth extraction.[5,14-15]

Concerning about orthodontic force applied for orthodontic tooth movement, determined by the average of the root surface area of each tooth type, but had no report about same tooth type with difference functional condition. So the objective of this study is to compare the root surface area of maxillary anterior teeth between the patient with normal functional condition (normal overjet) and diminished functional condition (large overjet).

Materials and methods

This study was approved by the Ethics Review Board of Rangsit University (COA. No. RSUERB2019-016). All participants provided informed consent before participating in this study.

The sample size was calculated using G*Power program[16] to detect the mean difference between two independent groups with an effect size of 0.8 at a significance level of $\alpha = 0.05$, and the power of test $(1-\beta) = 0.8$. The calculation required at least 21 samples for each tooth type group. Each CBCT image contained right and left sides of three tooth type of upper anterior teeth. Therefore, this study utilized 24 tooth/each tooth type (central incisor, lateral incisor and canine) from the subjects with normal and large overjet.

The CBCT image was selected from data base taken in July 2012 until July 2017. Pre-treatment CBCT images of twelve Thai orthodontic patients with normal overjet (overjet between 2-4 mm) and twelve patients with large overjet (overjet > 4 mm) were enrolled in the study.

Each tooth had to fulfill the following conditions:

1) Patient's age ranges from 18 to 25 years.

2) The root must be completely developed.

3) The root should not deviate from the normal shape.

4) Non-occluded anterior teeth in large overjet patients group.

5) No history of orthodontic treatment.

6) No presence of severe craniofacial anomalies.

7) No presence of periapical or bone lesion in radiographic image.

8) No previous trauma in the upper anterior region.

Creating research tools

All CBCT images were produced using a ProMax 3D machine (Planmeca OY, Helsinki, Finland) at 84 kVp, 10 mA, on an 8×8 cm field of view, and a voxel size of 0.16 mm. All images were categorized by types of teeth as follows: maxillary central incisor, maxillary lateral incisor, and maxillary canine. Subjects were positioned in the cephalostat and horizontal occlusal plane.

Each CBCT image was converted from a DICOM format to an STL format by Mimics software (version 15.01, Materialise, Leuven, Belgium), which allowed the production of 3-dimensional photographs. All crowns and roots of the anterior maxillary teeth (central, lateral, canine) were subtracted from the rest of the skull by manually removing the pixels of supporting structures from sagittal, coronal, and axial planes (Figure 1). Once each tooth was subtracted intentional extension spine markings were added manually to identify the Cemento-enamel junction (CEJ) after 3-dimensional dental reconstruction.

Data Collection

Each 3-dimensional dental image was labeled on the CEJ, followed by intentional extension spine marking. All images were then exported to and measured, one by one, the surface area apical to the CEJ to define the root surface area by 3-Matic software (version 7.01, Materialise, Leuven, Belgium) (Figure 2). The root surface area of each selected tooth was measured twice to determine the value.

Data Analysis

All data was tested for normality. The errors of the method and the reliability of the measurements were tested. Twenty-four CBCT images of maxillary jaws were randomly selected and re-measured by the same examiner in a four-week interval. There was excellent reliability between the first and the second root surface area measurements by the same examiner as calculated by the intraclass correlation coefficient more than 0.98. SPSS version 16.0 (SPSS Inc., Chicago, Illinois, USA) was used to analyze the data by descriptive analysis to define the mean and standard deviation of all measurements. The results were considered to be statistically significant at $P < 0.05$. A paired t-test was applied in the analysis to evaluate the difference between measurements on the right and the left sides. An independent t-test was also used to compare the mean values of all collected measurement from patients with normal overjet (2-4 mm) and large overjet (> 4 mm).

Results

The mean age of the patients was 19.75 ± 2.25 years. The t-test analysis between left and right sides of central incisor, lateral incisor and canine is $P = 0.022$, $P = 0.188$, and $P = 0.119$, respectively. It's show there have no difference between left and right lateral incisor and canine but they have significant difference between left and right central incisal. The mean and standard deviation of the root surface area of maxillary central incisor, lateral incisor, and canine in normal overjet patients were 199.06 ± 20.43, 181.32 ± 23.42, and 249.01 ± 46.01 mm^2 respectively along with 210.37 ± 31.89, 197.70 ± 28.63, 282.16 ± 54.51 mm^2 respectively in large overjet patients (Table 1).

The result showed the mean root surface area of maxillary anterior teeth ranged from 181.32 to 282.16 mm^2 The largest root surface area was observed in the canine of patients with large overjet (282.16 ± 54.51 mm^2) while the smallest root surface area was observed in the lateral incisors of normal overjet patients (181.32 ± 23.42 mm^2).

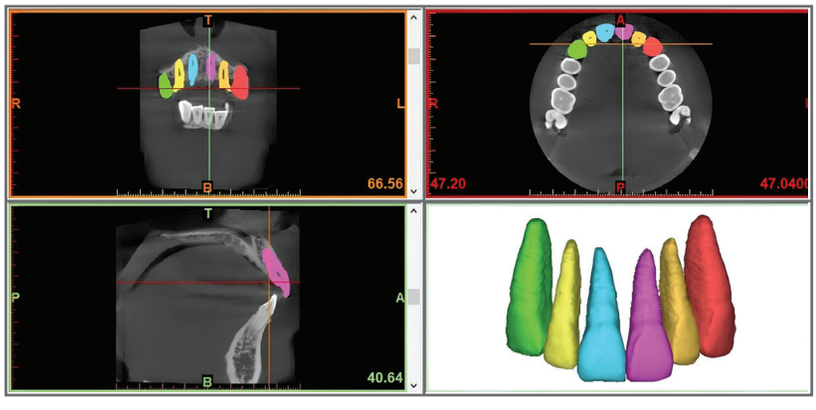

Figure 1 Digital imaging and Communication in Medicine (DICOM) dataset of the patients were imported into Mimics® Innovation Suite 15.01 and reconstructed into 3-dimensional images.

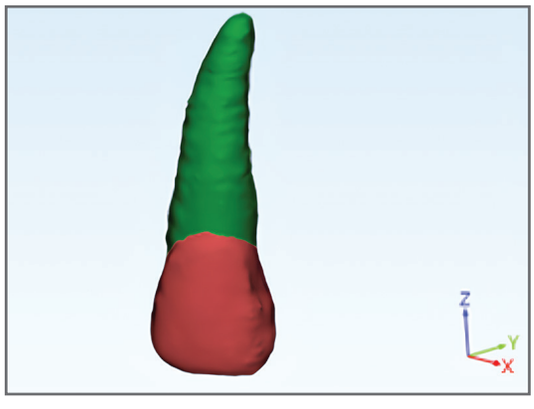

Figure 2 The root surface area of each tooth is calculated using the 3-Matic software (green area)

Table 1 The root surface area of each type of maxillary anterior teeth

Tooth type	Overjet	N	Min (mm^2)	Max (mm^2)	Mean (mm^2)	Standard deviation
Central incisor	Normal	24	160.49	230.68	199.06	20.43
	Large	24	168.91	277.17	210.37	31.89
Lateral incisor	Normal	24	142.55	219.62	181.32	23.42
	Large	24	155.73	262.42	197.70	28.63
Canine	Normal	24	163.25	322.29	249.01	46.01
	Large	24	201.52	389.02	282.16	54.51

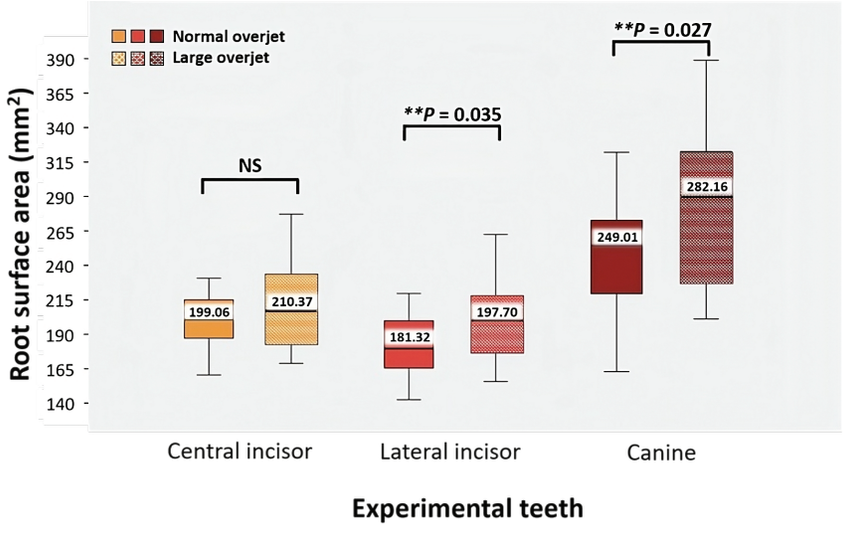

Figure 3 Box plot showed root surface area of maxillary anterior teeth in normal and large overjet patients.

The root surface area of maxillary anterior teeth in a patient with large overjet was significantly greater than those in normal overjet in those of lateral incisor and canine ($P = 0.035$ and $P = 0.027$ respectively, Figure 3). But they had no significant difference in central incisor.

Discussion

Our CBCT-based investigation indicated that the maxillary canine acquired both groups' largest root surface area and the smallest root surface area observed in the maxillary lateral incisor as same as the previous studies.[2,4-5] However, when compared between the normal and large overjet groups, the mean root surface area of anterior teeth in the large overjet group is greater than the normal one. This finding was in contrast with the study on vertical problems by Suteerapongpun,[5] as we presumed that due to less occlusal contact, the anterior function in the large overjet group should be diminished as in open bite patients. Suteerapongpun's study has concluded that the root surface area of anterior teeth in the open bite patients is smaller than the normal bite group. Their study pointed out our weakness in the clinical data insufficiency from failing to follow up on the patient's functional masticatory records. Additional factors, including those that affect

mastication or a force-induced root formation,[6,17] such as patients' dental habits that encourage anterior protrusion causing large overjet, should also be considered.

In large overjet patients, the protruded lateral incisor and canine position may induce a longer root length than in normal overjet patients. Longer root length could lead to a larger root surface area, as observed in this study. Further investigation the root length measurement is recommended to confirm these hypotheses. In contrast, several studies[4,11] reported that patients with anterior open bite tended to develop short anterior dental roots and it was related to small root surface area supported Suteerapongpun's study therefore, disclose the case our hypothesis based on the reported result of open bite patients was not achieved and the result was coming out in the opposite way. Many studies reported that important confounding factors such as gender, race, and patient age (regarding root development) can affect the root surface area. For instance, gender-related differences in the root surface area of maxillary canines are larger in males than in females.[18-19] Therefore, we hypothesize that root variations may influence the value of RSA. This was further potentiated by the meta-analysis performed by Hujoel in which significant heterogeneity was noted in various samples under investigation.[20] So, we designed to collect the sample between two groups with similar age, number in gender, and racial backgrounds to reduce these confounding factors. All anterior teeth from central to canine of all subjects were used to reduce selection bias. The measurement technique we used was proved by Tasanapanont[15] and the high-reliability score reported shows less measurement bias in our method.

From our study, the root surface area of the central Incisor shows a non-significant difference between normal and large overjet groups. From our point of view, we can discuss it in two ways. Focus on form and function theory; the central incisor usually has incisor contact while cutting and tearing food or some purposes, even in patients with normal or large overjet because the forward movement of the mandible is allowed. With similar function and force stimulation in both groups, the root forming and elongating should not be different, so we cannot find the difference in root surface area in this tooth type. But in another way, from statistical analysis, showed some differences between the samples on the left and right sides representing central Incisor. Therefore, the results of this tooth type have decreased in reliability. So we suggested that the sample size should be increased to reduce the standard deviation and increase the reliability of the study, and should possibly recruited from the population in every region of Thailand to represent the entire country's population.

Greater root surface areas of the lateral incisor and canine in the large overjet group are contrary to the study reported about the occlusal function related to dental root length and surface area due to the loss of functional contact in patients with the anterior open bite group. They concluded that normal occlusal loading induced normal development of periodontal tissue and root structure, especially in root length and root shape, and said that individuals with anterior open bite had a tendency to develop short dental roots.[4,11] But our study is the early paper found that the root surface area of maxillary lateral and canine in patients with large overjet are greater than in the normal overjet group.

Several previous studies have reported that individuals with anterior open bite had a tendency to develop short dental roots from the incisors to the premolars that could be associated with occlusal hypofunction or loss of occlusal contact.[4,11]

Hence, hypothesized that the stimulus of normal occlusal function is responsible for normal root development. The findings of this study indicate that patients with large overjet may have some differences in root surface area. If a final large overjet is diagnosed early, interceptive orthodontic treatment may aid in improving the overjet and overbite early,

enhancing dental and periodontal health and habit.[4] Late intervention requires efficient treatment planning; patients with large overjet or Class II division 1 malocclusion may have larger dental root surface area in lateral incisors and canines. Adequate diagnosis and orthodontic force application should be considered while planning the treatment of such cases.

In case of Larger root surface area, heavier orthodontic force required for tooth movement. Root resorption can be due to heavy loading forces, excessively proclined teeth due to inefficient distribution of forces along the root, and trauma from occlusion. This states that altered biomechanics will be required for treatment planning in such cases. Proper force magnitude is used to bring about tooth movement, and the bracket is positioned more gingival to maintain the normal biomechanical application of forces. Careful application of forces to avoid further root resorption is necessary. Excessive uncontrolled contraction forces are to be avoided.[11]

The root surface area of upper anterior teeth reported in this study can benefit further studies and clinical decisions. The dentist and researcher can use this result to select the amount of orthodontic force for patients with different overjet patterns to avoid unwanted side effects during orthodontic treatment such as root resorption and pulpitis.

Conclusion

The root surface area measured in CBCT images in the large overjet patients was significantly greater than in normal overjet patients in the maxillary lateral incisor and canine, aside from the central incisor with no significant difference between the two groups.

Author contributions

SL: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data Curation, Writing-Original Draft, Writing-Review & Editing, Visualization, Supervision and Project administration; KK: Supervision and Project administration; CH, RI and AV: Funding acquisition

Ethical statement

The research protocol was approved by the Ethics Committee of the Ethics Review Board of Rangsit University (COA. No. RSUERB2019-016).

Disclosure statement

No conflict of interest in the study

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