Original

Assessment of Root and Root Canal Shapes of Supernumerary Teeth in Maxillary Incisor Region Using Cone-Beam Computed Tomography

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Abstract: Supernumerary teeth are most commonly located in the maxillary incisor region. Recently, their directions and crown shapes were observed in detail using cone-beam computed tomography (CBCT), and their sizes were measured. Here, the root shapes and courses of the root canal of supernumerary teeth in the maxillary incisor region were assessed using CBCT. A total of 126 supernumerary teeth were assessed. The root shape, root curvature, and root canal deformity were evaluated. Also, delayed eruption of the permanent incisor and a median diastema were evaluated as complications caused by supernumerary teeth. The bifurcated-root type was noted in only 4.0%. Root curvature was observed in 27.4%, and root canal deformity was observed in 12.4%. Significant differences in root lengths were noted in root curvature and root canal deformity. Delayed eruption was observed in 12.9%, and a median diastema was observed in 25.0%. In conclusion, the root shapes and courses of the root canal of supernumerary teeth in the maxillary incisor region could be observed in detail using CBCT. The bifurcated-root type was rare. Root curvature was frequent in the inverted and horizontal types. Root canal deformity was frequent in the inverted type.

Key words: Cone-beam computed tomography, Mesiodens, Root canal shape, Root shape, Supernumerary teeth,

Introduction

Supernumerary teeth are very common and can occur in any region of the mouth; many appear between the two maxillary centrals, when they are referred to as mesiodens. As a general rule, supernumerary teeth are smaller than teeth of the normal series and are misshaped¹⁾.

Recently, cone-beam computed tomography for dental use (CBCT) was applied for the diagnosis of supernumerary teeth, and their directions and crown shapes were observed and sizes were measured²⁻⁴⁾. However, the root shapes and courses of the root canal of supernumerary teeth have not been assessed in detail.

Here, the root shapes and courses of the root canal of supernumerary teeth in the maxillary incisor region were assessed using CBCT. Also, delayed eruption of the permanent incisor and a median diastema were evaluated as complications caused by supernumerary teeth, and relationships between root curvature and complications and between root canal deformity and complications were assessed.

Materials and Methods

Subjects

One hundred and one patients (36 females and 65 males, median age: 8.2 years) diagnosed with supernumerary teeth showing complete development based on CBCT images in the maxillary incisor region from January 2015 to December 2017 were enrolled, and a total of 3 patients showing a cleft of alveolar bone, a dentigerous cyst of a supernu-

merary tooth, and enamel hypoplasia of a supernumerary tooth were excluded. Thus, a total of 126 supernumerary teeth were assessed in the investigation. Unilaterally, 1 supernumerary tooth was found in 65 patients. Bilaterally, 2 supernumerary teeth whose development had completed were found in 24 patients. Bilaterally, 1 of 2 supernumerary teeth had completed in 10 patients, and unilaterally 1 of 2 supernumerary teeth had completed in 1 patient. Two of four supernumerary teeth had completed in 1 patient.

An investigation of supernumerary teeth in the maxillary incisor region, with permission from the Ethical Committee, School of Dentistry, Aichi Gakuin University (approval number: 531), was conducted.

Cone-beam computed tomography

A CBCT unit, Alphard VEGA (Asahi Roentgen Industry, Kyoto, Japan) was used. The exposure volume was set at 51 or 102 mm in diameter. The edge of each cubic voxel was 0.1 or 0.2 mm, respectively. The tube voltage and tube current for children were set at 80 kV and 5 mA in a 51-mm-diameter exposure volume and 80 kV and 3 mA in a 102-mm-diameter exposure volume, respectively, in accordance with the manufacturer's recommendations. For adults, the tube current was set at approximately twice that for children. Two-dimensional and 3-D CBCT images were reconstructed using 3-D visualization and measurement software (Aquarius Institution Edition ver. 4.4.13, TeraRecon Inc., Tokyo, Japan).

Observation and measurements of supernumerary teeth

At first, the direction was visually classified into 3 types: vertical, inverted, and horizontal types, and the crown shapes were visually clas-

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Figure 1. CBCT images of root shape. A. 2D CBCT image of single-root type (Scale bar: 2.0 mm), B. 3D CBCT image of single-root type, C. 2D CBCT image of bifurcated-root type. The root bifurcated and bifurcations of the root canal were located in each root. (Scale bar: 2.0 mm), D. 3D CBCT image of bifurcated-root type

Figure 2. Measurement of angle for root curvature. The angle between the root long axis and axis in the root apex was measured and it was 53.7 degrees.

sified into 4 types: single-cusp, multi-cusp, incisor-like, and canine-like types⁴⁾. The root length measured between the root apex and middle of the cement-enamel junctions in the previous study⁴⁾ was used in the investigation.

The root shape was visually classified into 2 types: single-root and bifurcated-root types (Fig. 1).

Moreover, in the single-root type, the angle between the root long axis and axis in the root apex was measured referring to the measure-

Figure 3. Root canal deformity. The root canal of the supernumerary tooth was curved to the palatal side. The foramen of the root apex was located on the palatal side, and it was not consistent with the morphological root apex. Arrows indicate the foramen of the root apex. (Scale bar: 2.0 mm)

ment method for a curved root canal (Fig. 2)⁵⁾. When the angle was 25 degrees or more, it was defined as root curvature. When there was disagreement between the locations of the apical foramen and morphological root apex in the single-root type, it was defined as root canal deformity (Fig. 3).

Complications caused by 1 unilateral supernumerary tooth of single-root type

Delayed eruption of a permanent incisor and a median diastema were evaluated as complications caused by 1 unilateral supernumerary tooth of the single-root type using CBCT images. The vertical distance between the edges of the permanent incisor related to supernumerary teeth and the corresponding permanent incisor on the opposite side was measured using CBCT images. When the vertical distance was more than half of the crown length of the permanent incisor, and the permanent incisor related to supernumerary teeth was more superiorly located than the corresponding incisor on the opposite side, it was defined as delayed eruption (Fig. 4). Median diastema presence was evaluated in patients whose central and lateral incisors on both sides had erupted using CBCT. Further, the relationships between root curvature and complications and between root canal deformity and complications were assessed.

All observations and measurements were performed by a single author. Measurements were repeated 3 times and in the same way 4 weeks later, and they were averaged.

Statistical analysis

The differences of root shape types among crown shape types and direction, and the differences of root curvature and root canal deformity among directions were statistically evaluated using the Chi-squares test. Then, the differences in the frequency of delayed eruption and a median diastema between with and without root curvature, and between with and without root canal deformity were statistically evaluated using the

Figure 4. Delayed eruption of the permanent incisor. A. Measurement of crown length of permanent incisor related to supernumerary tooth, The crown length of the left central incisor was 12.4 mm. B. Measurement of vertical distance between the edges of a permanent incisor related to supernumerary teeth and corresponding permanent incisor on the opposite side, The vertical distance between the edges of the left and right central incisors was 7.7 mm, and being more than half of the crown length.

Figure 5. Root curvature. A. 2D CBCT image, The root of the inverted supernumerary tooth curved to the palatal side. (Scale bar: 2.0 mm), B. 2D CBCT image, The root of the inverted supernumerary tooth curved to the palatal side. The angle between the root long axis and axis in the root apex was 107 degrees. (Scale bar: 2.0 mm)

Chi-squares test.

Moreover, the root lengths between with and without root curvature, and between with and without root canal deformity were evaluated using the Mann-Whitney U-test. Differences were considered significant of $P < 0.05$.

Results

Direction of supernumerary teeth

The vertical type was noted in 14 teeth (11.1%), inverted type in 83 teeth (65.9%), and horizontal type in 29 teeth (23.0%).

Crown shape of supernumerary teeth

The single-cusp type was noted in 104 teeth (82.5%), multi-cusp

type in 6 teeth (4.8%), canine-like type in 14 teeth (11.1%), and incisor-like type in 2 teeth (1.6%).

Root length of supernumerary teeth

The root lengths obtained in a previous study⁴⁾ ranged from 2.8 to 13.9 mm with a mean of 6.9 mm (s.d.: 1.9 mm).

Root shape of supernumerary teeth

Single-root type was noted in 121 teeth (96.0%), and bifurcated-root type in 5 teeth (4.0%).

The directions in the single-root type were: vertical type in 14 teeth (11.6%), inverted type in 79 teeth (65.3%), and horizontal type in 28 teeth (23.1%). The directions in the bifurcated-root type were: inverted

Table 1. Number and percentage of supernumerary teeth with and without root curvature in direction types

Direction types	Vertical	Inverted	Horizontal	Total
Root curvature	1 (3.0)	24 (72.7)	8 (24.2)	33 (100)
No root curvature	13 (14.7)	55 (62.5)	20 (23.9)	88 (100)
Statistical analysis				P=0.1951

Values shown are number (%).

Table 2. Number and percentage of of supernumerary teeth with and without root canal deformity in direction types

Direction types	Vertical	Inverted	Horizontal	Total
Root canal deformity	1 (6.7)	14 (93.3)	0 (0.0)	15 (100)
No root canal deformity	13 (12.3)	65 (61.3)	28 (26.4)	106 (100)
Statistical analysis				P<0.05

Values shown are number (%).

Table 3. Number and percentage of relationship between root curvature and delayed eruption

	Delayed eruption	No delayed eruption	Total
Root curvature	4 (22.2)	14 (77.8)	18 (100)
No root curvature	4 (9.1)	40 (90.9)	44 (100)
Statistical analysis			P=0.3258

Values shown are number (%).

Table 4. Number and percentage of relationship between root canal deformity and delayed eruption

	Delayed eruption	No delayed eruption	Total
Root canal deformity	0 (0.0)	8 (100.0)	8 (100)
No root canal deformity	10 (18.5)	44 (80.8)	54 (100)
Statistical analysis			P=0.4156

Values shown are number (%).

type in 4 teeth (80.0%), and horizontal type in 1 tooth (20.0%). There were no significant differences among the directions in root shape types.

Also, crown shapes in the single-root type were: single-cusp type in 100 teeth (82.6%), multi-cusp type in 6 teeth (5.0%), canine-like type in 13 teeth (10.7%), and incisor-like type in 2 teeth (1.7%). And, crown shapes in bifurcated-root type were: single-cusp type in 4 teeth (80.0%), and canine-like type in 1 tooth (20.0%). There were no significant differences between single and bifurcated root shape types in crown shape types.

Root curvature of supernumerary teeth

Root curvature was evaluated in 121 supernumerary teeth with the single-root type, and it was observed in 33 teeth (27.3%) (Fig. 5A). The measurements ranged from 26.4 to 109.1 degrees with a mean of 42.8 degrees (s.d.: 18.3 degrees). The angle in 2 teeth was more than 90 degrees (Fig. 5B).

The rate of supernumerary teeth with root curvature in each direction was 7.1% in the vertical type, 30.4% in the inverted type, and 28.6% in the horizontal type. The rate of supernumerary teeth with root curvature in the inverted and horizontal types was frequent in comparison with the vertical type. The directions of supernumerary teeth with root curvature were: vertical type in 1 tooth (3.0%), inverted type in 24 teeth (72.7%), and horizontal type in 8 teeth (24.2%) (Table 1). There were no significant differences between with and without root curvature in the directions. The root length of supernumerary teeth with root curvature ranged from 4.7 to 13.9 mm with a mean of 7.8 mm (s.d.: 1.8 mm). The root length without root curvature ranged from 2.8 to 13.4

mm with a mean of 6.6 mm (s.d.: 1.9 mm). The root lengths of supernumerary teeth with root curvature were significantly longer than those of supernumerary teeth without root curvature ($P<0.01$).

Root canal deformity of supernumerary teeth

Root canal deformity was evaluated in 121 supernumerary teeth with the single-root type. It was observed in 15 teeth (12.4%). The rate of supernumerary teeth with root canal deformity in each direction was 7.1% in the vertical type, and 17.7% in the inverted type. The rate of supernumerary teeth with root canal deformity in the inverted type was frequent in comparison with the vertical and horizontal types. Directions of supernumerary teeth with root canal deformity were: vertical type in 1 tooth (6.7%), and inverted type in 14 teeth (93.3%) (Table 2). There were significant differences between with and without root canal deformity in the directions ($P<0.05$). The root lengths of supernumerary teeth with root canal deformity ranged from 2.8 to 7.1 mm, with a mean of 4.7 mm (s.d.: 1.2 mm). The root length without root canal deformity ranged from 3.3 to 13.9 mm, with a mean of 7.3 mm (s.d.: 1.8 mm). The root lengths of supernumerary teeth with root canal deformity were significantly shorter than those of supernumerary teeth without root canal deformity ($P<0.01$).

Delayed eruption and median diastema

Delayed eruption of permanent incisors was evaluated in 62 permanent incisor teeth, and delayed eruption was observed in 8 incisors (12.9%, 7 central and 1 lateral incisor). Four of 18 (22.2%) supernumerary teeth with root curvature were related to delayed eruption (Table 3),

Table 5. Number and percentage of relationship between root curvature and median diastema

	Median diastema	No median diastema	Total
Root curvature	4 (50.0)	4 (50.0)	8 (100)
No root curvature	3 (15.0)	17 (85.0)	20 (100)
Statistical analysis	P=0.143		

Values shown are number (%).

Table 6. Number and percentage of relationship between root canal deformity and median diastema

	Median diastema	No median diastema	Total
Root canal deformity	1 (20.0)	4 (80.0)	5 (100)
No root canal deformity	6 (26.1)	17 (73.9)	23 (100)
Statistical analysis	P=1.0000		

Values shown are number (%).

and supernumerary teeth with root canal deformity was not related to delayed eruption (Table 4). There were no significant differences between with and without root curvature or between with and without root canal deformity in delayed eruption.

Median diastema presence was evaluated in 28 patients, and it was found in 7 patients (25.0%). Four of 8 (50.0%) supernumerary teeth with root curvature were related to a median diastema (Table 5), and 1 of 5 (20.0%) supernumerary teeth with root canal deformity was related to a median diastema (Table 6). There were no significant differences between with and without root curvature or between with and without root canal deformity in the presence of a median diastema.

Discussion

The primary dentition including deciduous teeth and molars arises from the dental lamina. The secondary dentition also arises from the dental lamina on the lingual aspect of the deciduous tooth germ. The teeth of the primary and secondary dentitions form in essentially the same manner, although at different times. Aberrations in this pattern of development result in missing teeth or the formation of extra teeth⁶.

The direction and crown shape of supernumerary teeth in the maxillary incisor region were observed in detail using CBCT images, and inverted and single-cusp types were reported to be frequent^{2,4}.

In the investigation, the characteristic root shapes and course of the root canal of supernumerary teeth in the maxillary incisor region were evaluated using CBCT. The root shape should be carefully observed on the extraction of supernumerary teeth. The resolution of CBCT is higher than that of multislice CT, and fine anatomical structures could be clearly observed in CBCT images⁷⁻⁹. Clinical guidelines for CBCT were published by A Committee on Clinical Practice Guidelines of the Japanese Society for Oral and Maxillofacial Radiology, and it was reported that CBCT provided information about the positional relationships to facilitate safe and reliable supernumerary tooth extraction¹⁰.

The process of tooth development is under strict genetic control¹¹. Clusters of blood vessels are found ramifying around the tooth germ in the dental follicle and entering the dental papilla during the cap stage. Their number in the papilla increases, reaching a maximum during the bell stage when matrix deposition begins. The vessels entering the papilla are clustered into groups that coincide with the position where the roots will form. Also, in root formation, Hertwig's epithelial root sheath of epithelial cells extends around the dental pulp between the dental papilla and dental follicle until it encloses all but the basal portion of the pulp. The rim of the root sheath, the epithelial diaphragm, encloses the

primary apical foramen⁶.

The occurrence of supernumerary teeth with root bifurcation is rare (4.0%). The rate was reported to be similar to that of the multi-cusp type in the crown shape of the maxillary incisor region⁴. It is embryologically and anatomically interesting that the supernumerary teeth with root bifurcation were observed in the maxillary incisor region.

Various methods were devised to measure the degree of root canal curvature¹². The measurement method used in the investigation was simple, and the obtained angle was classified into 3 grades: straight (5 degrees or less), moderate (10 to 20 degrees), and severe (25 to 70 degrees)⁵. So, when the angle was 25 degrees or more, it was defined as root curvature in the investigation. The occurrence of root curvature in the inverted and horizontal types was more frequent in comparison with the vertical type; however, there were no significant differences between with and without root curvature in the directions. Also, there were significant differences between with and without root canal deformity in the directions, and the rate of supernumerary teeth with root canal deformity was high in the inverted type.

Delayed eruption of the permanent incisor and a median diastema as complications caused by supernumerary teeth were evaluated using CBCT. The relationships between them and root curvature and between them and root canal deformity were assessed. In the investigation, patients simultaneously showing delayed eruption and a median diastema were not present. The frequency of delayed eruption was reported by Lee *et al.* (15.6%)³, Kim *et al.* (20%)¹³, and Gunduz *et al.* (38.8%)¹⁴. The frequency of median diastema presence was reported by Kim *et al.* (4%)¹³, Gunduz *et al.* (17.6%)¹⁴, and Lee *et al.* (24.9%)³. The present results of delayed eruption and a median diastema were similar to those reported by Lee *et al.*³ There were no significant differences between with and without root curvature or between with and without root canal deformity in terms of delayed eruption and a median diastema.

Root curvature might be caused by adjacent teeth and anatomical structures neighboring supernumerary teeth, such as the nasal floor, incisive canal, and palatal cortical bone. Also, root curvature and root canal deformity might be caused by the following factor. Liebgott¹⁵ reported that the maxillary artery parallels the course of the maxillary nerve through the pterygopalatine fossa and exits the fossa with the nerve through the infraorbital groove. At the point, it becomes the infraorbital artery. The infraorbital artery passes anteriorly in the infraorbital groove and canal. Within the canal, it branches into the anterior superior alveolar artery. The anterior superior artery supplies the pulp of the maxillary incisors and canines and mucosa of the anterior wall of the

maxilla. Supernumerary teeth in the maxillary incisor region would also be supplied by blood from the anterior superior alveolar artery. When the direction of a supernumerary tooth is the vertical type, an anterior superior alveolar artery running from a superior site would be able to readily enter the foramen of the root apex. However, in inverted supernumerary teeth, the anterior superior alveolar artery needs to be reversed to enter the foramen of the root apex. To be consistent with these results, it was considered that root curvature and root canal deformity would be observed. The root and root canal might readily adapt to various changes in the surrounding environment. These findings would be of interest when root formation and construction of the neurovascular system are discussed. Also, significant differences in the root length were noted between with and without root curvature, and between with and without root canal deformity, and they might be anatomically interesting.

The root shapes and courses of the root canal of supernumerary teeth in the maxillary incisor region could be observed in detail using CBCT. The occurrence of supernumerary teeth with root bifurcation was 4.0%. Root curvature was frequent in the inverted and horizontal types, and root canal deformity was frequent in the inverted type. Significant differences in root lengths were noted between supernumerary teeth with and without root curvature, and between supernumerary teeth with and without root canal deformity. Furthermore, there were no significant differences between with and without root curvature or between with and without root canal deformity in terms of delayed eruption and a median diastema.

Conflict of Interest

The authors have declared that no COI exists.

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