Accuracy of Tooth Development Stage, Tooth Size and Dental Arch width in Multi-Detector Row Computed Tomography of Human Skulls

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Abstract

In pediatric dentistry, examination of the development of crown or tooth root is essential to determine the physiological development age. Measurements of the tooth size and dental arch width are also required to predict normal occlusion and oral function, and to plan appropriate dental treatment. Some dental anomalies are keys to identify congenital malformation syndromes. In patients with behavioral disorders, it is quite difficult to take diagnostic dental models and pantomographs, since patient co-operation and stability in body movement for a few minutes is necessary while taking the dental impression and pantomographs. For patients with severe mental retardation and behavioral disorders, performing computed tomography under general anesthesia or deep sedation is easier than taking pantomographs while awake. The aim of the present study was to compare the tooth development stage on pantomographs and mesiodistal diameter measurements of tooth size and dental arch width of dry human skulls with the images of those on 128 multi-detector row computed tomography (MDCT). Based on the results, the measurements of tooth development stage, tooth size and dental arch width on MDCT images were clinically precise.

Introduction

In pediatric dentistry, examination of the tooth development is essential to determine the physiological development age (1, 2). Measurements of tooth size and dental arch width are also required to predict normal occlusion (3) and oral function, and to plan appropriate dental treatment. Some dental anomalies are keys to identify congenital malformation syndromes (4). For thorough examination, dental models and pantomographs are necessary. To evaluate the craniofacial growth in children, lateral cephalometry (5) and pantomography (6) have been utilized. Tooth size anomalies like macrodontia or microdontia, abnormalities in teeth numbers and dental arch width with narrowed arch or high arched palatal vault are important in the detection of some

syndromes. However, in some patients with behavioral disorders, taking diagnostic dental models and pantomographs is quite difficult, since the patient must co-operate and remain stable for a few minutes while taking the dental impression and pantomographs. In these patients, taking a dental impression involves the risk of apnea. For patients with severe mental retardation and severe behavioral disorder, performing computed tomography (CT) under general anesthesia or deep sedation is easier than taking pantomographs while awake.

A medical CT system known as multi-detector row computed tomography has recently been developed and is now being applied for the diagnosis of tumors (7), external injuries (8) and in the dental field for clarifying the relationship between the lower

third molar and inferior canal (9). In comparison with conventional CT systems, multi-detector row CT allows rapid imaging with a smaller burden on the patient, and yields higher image quality while requiring a small exposure dose (10, 11).

In recent years, up-to-date CT technology including cone beam CT with less radiation than conventional CT has been increasing in popularity. Recently, the 128 multi-detector row computed tomography (MDCT) used in the present study gained attention, because the CT provides detailed and accurate three-dimensional construction images with less radiation than conventional CT. The best method of assessing tumor response in most clinical situations is MDCT, as it can detect a large number of lesions with smaller diameters and measurement is more precise when compared with other methods (12). No study has compared the tooth development stage on conventional and MDCT pantomographs, and the tooth size and dental arch size on the skull and on the MDCT.

Hence, the aim of the study was to compare the tooth development stage of permanent teeth on pantomographs and mesiodistal diameter measurements of tooth size and dental arch width on the skull with MDCT images.

Materials and Methods

Six dry human skulls were obtained from the collection of the Department of Oral Anatomy and Physical Anthropology of Nihon University School of Dentistry at Matsudo. One skull (Phantom 1) with primary dentition, 2 skulls (Phantom 2 and Phantom 3) with mixed dentition and 3 skulls (Phantom 4, Phantom 5 and Phantom 6) with permanent dentition were used to estimate the tooth development of permanent teeth, and to measure the mesiodistal diameter of tooth size and dental arch width in primary, mixed and permanent dentitions. The mandibular position of phantoms was fixed with broad tape from the ipsilateral temporal bone around the horizontal ramus of the mandible to the contralateral temporal bone.

Imaging protocol

Each phantom was positioned in the cephalostat (AUTO IIIN CM: Ashahi Roentogen) by fixing it between the ear rods. The ear rods were placed in the external acoustic meatus and the Frankfort horizontal plane was placed perpendicular to the floor. For all phantoms, pantomographs were taken with the following radiographic settings: 75 kV, 12 mA, 0.63 s. The same phantoms were placed in MDCT of SOMATOM Definition AS+ (SIEMENS) on a foam platform with the Frankfort horizontal plane perpendicular to the floor and the position of the center of SOMATOM was set using the midline light beam to coincide with the midsagittal plane. The following imaging conditions were maintained for all phantoms in the extended height mode: 120 kV; 120 mAS; resolution, 0.12~0.15 mm; FOV, 180 mm~200 mm; slice width, 38 mm; helical pitch (HP), 1.2 mm; exposure time, 4.18 s; window width, 1500; and window level, 450.

Tooth developmental stage

Based on the criteria of Nolla (1), the developmental stage of each permanent tooth was evaluated on conventional and MDCT pantomographs using a set of drawings illustrating the 10 stages of the teeth by a pedodontist who had over 5 years of clinical experience.

Tooth size and dental arch width

Crown mesiodistal diameter and dental arch width were directly measured on the six phantoms three times using a 1/20 mm caliper by the same observer. Dental arch width was expressed as Wc and We which means the distance between the most distal corners of the left-right primary canines and primary second molars, respectively, and W3 and W6 means the distance between the most distal corners of left-right permanent canines and permanent first molars, respectively.

On MDCT images, one dentist evaluated the most mesial and distal corners of each tooth, and Wc, We, W3 and W6 were measured three times. All data were calculated by Syngo fastview (standalone view-

ing tool for DICOM images) software in each phantom. In MDCT images, crown mesiodistal diameters and dental arch widths were measured from converted data based on the scale bar which was calculated and fixed as a true distance in each image.

Statistical analysis

From the conventional and MDCT pantomographs, one dentist evaluated the tooth developmental stage and measured crown diameter and dental arch width three times with a time interval of 1 day. The data of tooth development stage on conventional and MDCT pantomographs were statistically compared by Wilcoxon rank sum test, and tooth size and dental arch width were analyzed by paired t-test.

Results

Tooth development stage

Comparison of the tooth developmental stage of each permanent tooth on conventional and MDCT pantomographs of Phantom 1 is shown in Table 1 and Fig. 1. The difference of the average intraobserver errors of tooth development stage on conventional and MDCT pantomographs of Phantom 1 was 0.3. Data from Phantoms 2 and 3 are not shown,

Fig.1. Tooth development stage of permanent teeth by MDCT Pantomograph

because those phantoms were very similar to Phantom 1. The average tooth development stages of permanent teeth in maxilla on the MDCT pantomographs in Phantoms 1, 2 and 3 were significantly higher than those of conventional pantomographs ($P < 0.05$). No significant difference, however, was seen the average stages of the teeth in mandible between conventional and MDCT pantomographs in Table 2.

Tooth size and dental arch width

Mesiodistal diameters of each primary tooth and

Table 1. Tooth development stage in pantomograph and MDCT of Phantom 1 with primary dentition

	mean(RU)	SD	σ_i	mean(LU)	SD	σ_i	mean(RL)	SD	σ_i	mean(LL)	SD	σ_i
pantomograph												
1	5.0	0.0	0.0	5.0	0.0	0.0	6.0	0.0	0.0	6.0	0.0	0.0
2	4.7	0.5	0.6	4.7	0.5	0.6	5.7	0.5	0.6	5.7	0.5	0.6
3	4.3	0.5	0.6	4.3	0.5	0.6	4.3	0.5	0.6	4.3	0.5	0.6
4	2.0	0.8	1.0	2.0	0.8	1.0	3.5	0.0	0.0	3.5	0.0	0.0
5	2.0	0.0	0.0	2.0	0.0	0.0	2.0	0.0	0.0	2.0	0.0	0.0
6	4.7	0.5	0.6	5.0	0.0	0.0	5.7	0.5	0.6	5.3	0.5	0.6
7	0.0	0.0	0.0	0.3	0.5	0.6	1.0	0.0	0.0	2.0	0.0	0.0
CT												
1	5.7	0.5	0.6	5.7	0.5	0.6	7.2	0.0	0.0	7.2	0.0	0.0
2	5.7	0.5	0.6	5.7	0.5	0.6	7.2	0.0	0.0	7.2	0.0	0.0
3	4.7	0.5	0.6	4.7	0.5	0.6	6.0	0.0	0.0	6.0	0.0	0.0
4	4.0	0.0	0.0	4.0	0.0	0.0	4.3	0.5	0.6	4.3	0.5	0.6
5	2.7	0.5	0.6	2.7	0.5	0.6	2.7	0.5	0.6	2.7	0.5	0.6
6	6.0	0.0	0.0	6.0	0.0	0.0	6.0	0.0	0.0	6.0	0.0	0.0
7	1.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	3.0	0.0	0.0

RU ; Right upper, LU : Left upper, RL : Right lower, LL : Left lower

SD ; standard deviation, σ_i ; intraobserver errors

Table 2. Tooth development stages of upper and lower central incisor to second premolar in phantom and CT findings

	pantomograph			CT	
	mean	SD		mean	SD
Upper(1-5)	5.42	2.19	*	6.33	1.84
Lower(1-5)	6.06	2.01	NS	6.81	1.88

* ; P<0.05
NS; not significant

Table 3. Tooth size in the skull and MDCT of Phantom 1 with primary dentition

	teeth	Skull			CT		
		mean	SD	σ_i	mean	SD	σ_i
Right Upper	A	6.3	0.0	0.0	6.2	0.0	0.1
	B	5.0	0.1	0.1	5.0	0.1	0.1
	C	6.3	0.2	0.2	6.3	0.0	0.1
	D	6.5	0.1	0.1	6.3	0.3	0.4
	E	8.4	0.1	0.1	8.3	0.1	0.2
Right Lower	A	3.7	0.0	0.0	3.8	0.3	0.4
	B	4.2	0.1	0.1	4.4	0.2	0.3
	C	5.6	0.0	0.0	5.6	0.0	0.1
	D	8.0	0.0	0.0	7.9	0.2	0.3
	E	9.5	0.5	0.6	9.5	0.2	0.2

SD; standard deviation, σ_i ; intraobserver errors

Table 4. Tooth size in the skull and MDCT of Phantom 6 with permanent dentition

	teeth	Skull			CT		
		mean	SD	σ_i	mean	SD	σ_i
Right Upper	1	9.0	0.1	0.1	8.8	0.1	0.1
	2	7.3	0.0	0.0	7.2	0.2	0.2
	3	7.8	0.0	0.0	7.8	0.1	0.1
	4	6.3	0.1	0.1	6.2	0.2	0.2
	5	5.8	0.1	0.1	5.7	0.0	0.1
	6	10.2	0.2	0.2	10.0	0.4	0.6
	7	9.3	0.1	0.2	8.7	0.1	0.2
Right Lower	1	5.7	0.0	0.0	5.5	0.1	0.2
	2	6.6	0.0	0.0	6.6	0.1	0.2
	3	6.9	0.1	0.1	6.9	0.2	0.2
	4	6.4	0.1	0.1	6.3	0.2	0.3
	5	6.6	0.0	0.0	6.5	0.4	0.5
	6	10.6	0.1	0.2	10.7	0.2	0.2
	7	9.9	0.0	0.0	10.4	0.1	0.2

SD; standard deviation, σ_i ; intraobserver errors

permanent tooth on Phantom 1 and Phantom 6 on their MDCT images are shown in Table 3 and Table 4, respectively. Phantoms 2, 3, 4 and 5 are not shown. The intraobserver errors of tooth size on phantoms and MDCT images of Phantom 1 and Phantom 6 were limited within 0.6 mm, and dental arch widths of Wc, We, W3 W6 were within 0.4 mm, 0.3, 0.3 and 0.2, respectively. The tooth size and dental arch

Table 5. Average of tooth size in the Skull and MDCT of 6 phantoms

tooth	Skulls		CT		t-test	Skulls		CT		t-test
	mean(RU)	SD	mean(RU)	SD		mean(RL)	SD	mean(RL)	SD	
1	8.6	0.3	8.6	0.3	0.9	5.1	0.3	5.2	0.3	0.7
2	6.5	0.5	6.6	0.5	0.7	5.6	0.7	5.6	0.7	0.9
3	7.4	0.4	7.4	0.3	1.0	6.4	0.4	6.5	0.4	0.8
4	6.1	0.2	6.3	0.2	0.3	6.4	0.2	6.5	0.1	0.5
5	5.9	0.6	5.9	0.6	0.9	6.4	0.4	6.4	0.3	0.8
6	10.1	0.4	10.3	0.3	0.1	10.6	0.2	10.7	0.2	0.4
7	9.7	0.6	9.6	0.6	0.7	10.0	0.5	9.7	0.5	0.2
8	8.7	0.6	8.7	0.6	0.9	10.0	0.4	10.1	0.4	0.9
A	6.2	0.0	6.2	0.2	0.4	3.9	0.3	3.9	0.2	0.8
B	5.0	0.1	4.9	0.1	0.5	4.5	0.2	4.4	0.2	0.3
C	6.6	0.4	6.7	0.4	0.9	5.8	0.2	5.9	0.2	0.7
D	6.4	0.4	6.3	0.5	0.5	7.9	0.2	7.9	0.1	0.3
E	8.7	0.7	9.0	0.5	0.4	9.8	0.5	9.8	0.6	0.7

RU; Right upper, RL; Right lower

p<0.05 SD; standard deviation

Table 6. Dental arch width in Skull and MDCT of Phantom 1 with primary dentition

		Skull			CT		
		mean	SD	σ_i	mean	SD	σ_i
Upper	Wc	31.1	0.2	0.2	31.0	0.1	0.2
	WE	42.3	0.2	0.3	42.8	0.1	0.2
Lower	Wc	25.2	0.1	0.1	24.9	0.3	0.4
	WE	41.0	0.2	0.2	41.6	0.2	0.3

SD; standard deviation, σ_i ; intraobserver errors

Table 8. Average of dental arch width in Skulls and MDCTs of primary and mixed dentition

		Skulls		CT		<i>t</i> -test
		mean	SD	mean	SD	
Upper	Wc	33.9	3.7	34.3	4.0	0.9
	WE	49.3	5.8	49.6	5.9	1.0
Lower	Wc	27.4	2.6	27.7	3.0	0.9
	WE	48.4	5.5	48.8	5.4	0.9

p<0.05 SD; standard deviation

width in phantoms and MDCT images were very similar. Table 5 shows the average mesiodistal diameter measurements of primary teeth and permanent teeth of the six phantoms. The differences of the mean mesiodistal diameter in upper and lower primary and permanent teeth between phantoms and MDCT images were less than 0.3 mm. Comparison of dental arch width on skull and MDCT images of Phantom 1 are shown in Table 6. Table 7 shows the mean dental arch width on phantom and MDCT images of Phantom 6. The average differences of the measurement of Wc and WE in primary and mixed dentitions were within 0.4 mm (Table 8), and W3 and W6 on the six phantoms and MDCT images were less than 0.2 mm (Table 9). No significant differences were noted between them.

Discussion

In pediatric dentistry, determination of the physiological age and dental characteristics of child patients is essential to predict adult occlusion and proper dental treatment. Minor anomalies mostly occur in the craniofacial and oral regions. CT images are employed for diagnosis of some syndromes with

Table 7. Dental arch width in Skull and MDCT of Phantom 6 with permanent dentition

		Skull			CT		
		mean	SD	σ_i	mean	SD	σ_i
Upper	W3	40.3	0.0	0.1	40.3	0.1	0.2
	W6	57.9	0.1	0.1	57.7	0.1	0.2
Lower	W3	31.7	0.1	0.1	31.5	0.3	0.3
	W6	54.6	0.0	0.1	54.3	0.1	0.2

SD; standard deviation, σ_i ; intraobserver errors

Table 9. Average of dental arch width in Skulls and MDCTs of permanent dentition

		Skulls		CT		<i>t</i> -test
		mean	SD	mean	SD	
Upper	W3	39.3	1.5	39.4	1.3	0.9
	W6	58.0	0.1	58.2	0.4	0.4
Lower	W3	30.3	1.0	30.1	1.0	0.9
	W6	52.9	1.6	53.0	1.6	1.0

p<0.05 SD; standard deviation

mental retardation. Craniosynostosis is seen frequently in Apert, Crouzon and carpenter syndromes, delayed closure of fontanels is frequently seen in cleidocranial dysostosis and Down, Hallermann-Strief and Russell-Silver syndromes, maxillary hypoplasia with narrow and high arched palate are seen frequently in Crouzon, Marfan and Sotos syndromes, prognathism is seen frequently in Angelman, Gorlin and Sotos syndromes, micrognathia is seen frequently in Pierre Robin sequence and de Lange and Treacher-Collins syndromes, anodontia is seen frequently in ectodermal dysplasia and Ectrodactyly-ectodermal dysplasia-clefting syndrome (EEC), late eruption of teeth is seen frequently in cleidocranial dysostosis, de Lange syndromes and X-linked hypophosphatemic rickets, and microdontia is seen frequently in Down syndrome and ectodermal dysplasia. CT images are able to reveal the above anomalies in some syndromes with mental retardation (4).

In this study, the physiological age based on the development of permanent teeth was defined by the stages of Nolla (1), who discussed the development of permanent teeth at each physical age using a set of

drawings illustrating the 10 stages of the teeth as observed radiographically. In addition, Nolla noted that in order to obtain an appraisal of the development of a particular tooth, the radiograph was matched as closely as possible with the comparative figure. When the radiographic reading lay between two grades, this appraisal was indicated with a value of 0.5. For example, if between one-third and two-third of the tooth formation was completed, the reading of the radiograph was given a value of 7.5. When the radiographic value was slightly greater than the illustrated grade, but not as much as half way between that stage and the next, the value 0.2 was added. For example, if slightly more than two-thirds of the crown were completed it would become 4.2, or if somewhat more than one-third of the tooth were completed the grade would become 7.2. In the present study, the authors used Nolla's criteria and the development stages of each permanent tooth in only maxilla on MDCT pantomographs were scored slightly higher than the conventional pantomographs. MDCT pantomographs were clearer at the apical part of permanent teeth than conventional pantomographs, because MDCT pantomographs can confirm the tooth apex by the image in each slice. With regards the difference between maxilla and mandible, the authors considered that the permanent germs in maxilla were complexly located within thick bone, the positions of those germs, however, in mandible were located within thin bone.

Mesiodistal diameter of the crown in each primary and permanent tooth, and upper and lower dental arch widths in MDCT images were close to the corresponding values on the phantom. As the reliabilities of the tooth size and dental arch width measurements on MDCT and on phantom were both high, there were no significant differences in the mean and standard deviation of tooth size and dental arch width between MDCT images and the six phantoms. The measurements of tooth size and dental arch width on MDCT were sufficiently precise for dental structure analyses.

However, helical CT places a high economic and biological burden on the patient because of its high

cost and high radiation exposure. As radiation has a cumulative effect on the human body, any reduction in exposure to radiation is considered beneficial. A newly developed type of CT reduces exposure time and simultaneously the absorbed radiation to the patient (13, 14), and MDCT exhibits more reduction of exposure.

Accurate landmarks should be put on images for mesiodistal diameter measurement. In some cases, it was quite difficult to identify the position of the landmark; however, the mean value was similar to the tooth size on the phantom. The diagnosis of microdontia, macrodontia and abnormality of tooth morphology was reliable in the MDCT images. It was found that the measurements of tooth size and dental arch width on MDCT image were not significantly different from phantom measurements. A slight difference between MDCT data and phantom data does not translate into clinical relevance. The significant differences in this study were similar in magnitude to those of Cavalcanti *et al.* (15), who used cone beam CT. In the present study, most data regarding tooth development stage in each permanent tooth on MDCT pantomographs were significantly larger than those of conventional pantomographs. This finding suggested that the CT pantomograph was clearer and it showed more detail than conventional pantomographs. When MDCT pantomograph is used to evaluate tooth development age in clinics, clinicians have to consider the disagreement from Nolla criteria which based on conventional pantomograph. From this study, it was found that the tooth development stage on MDCT pantomographs was significantly earlier than that on conventional pantomographs, and tooth size and dental arch width on MDCT were similar to those of direct measurement on phantoms using a 1/20 mm caliper.

Conclusion

In this study, the average intraobserver error of tooth development stages in 56 permanent teeth was 0.3, and that of tooth size and dental arch widths on phantoms and MDCT was within 0.6 mm. The tooth

development stages in all permanent teeth were evaluated using conventional and MDCT pantomographs of dry human skulls, and the data of MDCT panoramagraphs were slightly higher than that of conventional pantomographs in only maxilla. The average differences in the mesiodistal diameters of all teeth and dental arch widths between phantoms and MDCT images were less than 0.3 mm, which was not significant.

From this study, the tooth development stage, tooth mesiodistal diameter and dental arch width analyses on MDCT image were found to be clinically precise.

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