Original Article

Assessment of Dental Pulp Volumes of Maxillary Permanent Teeth in Thai Patients with Complete Unilateral Cleft Lip and Palate Using Cone Beam Computed Tomography

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Abstract

Objective: To assess and compare the dental pulp volumes of the maxillary permanent teeth between the cleft and the non-cleft sides in Thai patients with complete unilateral cleft lip and palate (UCLP), using cone beam computed tomography.

Materials and Methods: Two hundred and eight CBCT images of maxillary permanent teeth of 20 Thai patients with complete UCLP (mean age 10.50±2.24 years) were used to construct three-dimensional dental pulp models. The dental pulp volume of each tooth was calculated automatically by Mimics Research 15.01 software. The mean dental pulp volume of each tooth type from both sides was compared, using the parametric paired sample t-test ($p < 0.05$).

Results: The maxillary first molar illustrated the greatest dental pulp volume (96.16±25.93 mm3 on the cleft side and 95.99±29.17 mm^3 on the non-cleft side), and the maxillary lateral incisor presented the least (17.50±9.76 mm^3 on the cleft side and 26.62±11.96 mm^3 on the non-cleft side). The comparisons of the dental pulp volumes of the maxillary permanent teeth on the cleft side and those of their counterparts on the non-cleft side revealed no significant differences.

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Conclusions: The dental pulp volume of maxillary permanent teeth in Thai patients with complete UCLP did not associate with the CLP anomaly. The maxillary first molar showed the greatest dental pulp volume while the maxillary lateral incisor showed the least.

Keywords: cleft lip and palate, cone beam computed tomography, dental pulp volumes, three-dimensional

Introduction

Orofacial clefts are a common congenital craniofacial malformation of the craniofacial region.[1,2] Cleft anomalies affect both craniofacial growth and the dentition. Some previous studies have reported a higher than normal prevalence of dental anomalies, such as anomalies in number, size, shape, stage of development, eruption, and root formation, in patients with cleft lip and/or palate.[3-6] Moreover, some studies have revealed that tooth development is delayed in patients with cleft lip and palate (CLP) in comparison with the general population.[7-9] Dental anomalies and dental root morphology have been widely investigated to assess root development in patients with CLP.[7,10,11] However, no study has focused on the effects of the CLP anomaly on dental pulp development in patients with CLP.

Dental pulp is a unique soft tissue of mesenchymal origin.[12] Knowledge of the morphology and dimensions of the dental pulp is an essential factor in periodontics, endodontics and orthodontics.[13-15] The assessment of dental pulp volume provides information for determining the effect of periodontal disease. Pulp volume decreases because of periodontitis.[13] In orthodontics, orthodontic force is associated with dental pulp response involving cell damage, inflammation, and wound healing. Some studies have stated that orthodontic forces produce a decrease in size of the dental pulp and may affect the vitality of teeth, particularly traumatized teeth.[14,15] Moreover, the dental pulp volume can also be used in age estimation of living individuals, which is vital in forensic science.[16-20] Therefore, the accurate assessment of dental pulp volume is critically important.

Many methods for measuring the volume of dental pulp have been introduced, e.g., celluloid molds of the pulp cavity, the molten metal injection technique, the Indian ink preparation technique and the radiopaque elastomer injection technique.[21-23] Nonetheless, those methods showed notable disadvantages; they were time-consuming, complex, expensive or inaccurate, and required tooth extraction.[21] Therefore, radiographic approaches have been used.[22] Three-dimensional (3-D) radiographs are more accurate than two-dimensional 2-D radiographs. Therefore, cone beam computed tomography (CBCT} has been suggested as an appropriate method for measuring the dental pulp volume of vital teeth in living individuals.[13,15,16,24,25]

Nowadays, CBCT has become widely used in dentistry because its applications allow customized settings and provides superior, accurate, 3-D images, resulting in decreased scanning time and reduced radiation dose compared to conventional radiographs.[26-28] Moreover, CBCT can be enhanced with other software to create 3-D mathematical models of teeth and can be used to calculate surface areas and volumes of the models conveniently, efficiently and accurately. Consequently, CBCT is useful to determine the dental pulp volume of vital teeth.[13,15,16,24,25]

Understanding the effects of the CLP anomaly on dental pulp development is important in the development of an appropriate orthodontic treatment plan and improvement of the prognosis of teeth. The objective of this investigation was to assess and compare the dental pulp volumes of the maxillary permanent teeth between the cleft and the non-cleft sides in patients with complete UCLP, using CBCT.

Materials and Methods

Subjects and image acquisition

This study was approved by the Human Experimentation Committee of the Faculty of Dentistry, Chiang Mai University, Thailand (No. 46/2018) with written informed consent from all patients and their parents before CBCT scanning. The samples consisted of 208 images of maxillary permanent teeth, categorized by tooth types: central incisor, lateral incisor, canine, first premolar, second premolar, and first molar from 20 Thai patients with complete UCLP (12 males and 8 females, age range eight - 15 years, mean age, 10.50±2.24 years). The maxillary second and third molars were excluded due to root variations. The CBCT images were produced using a Sirona XG 3-D CBCT unit (ORTHOPHOS® XG 3D, Bensheim, Germany) at 90 kV, 12 mA and 12.5x12.5-cm the field of view, and a voxel size of 0.1 mm. All patients required pretreatment CBCT images and met the following inclusion criteria: 1) Thai patients with complete ULCP aged from eight to 15 years who had a mixed or permanent dentition; 2) A history of previous lip repair and palatal cleft closure treatment; 3) No history of trauma or systemic disease; 4) No history of previous orthodontic and/or functional orthopedic treatment; and 5) No root restoration, caries, severe tooth wear or periapical root lesions.

Measurement of the dental pulp volume

CBCT data that was saved in digital imaging and communications in medicine (DICOM) files for all subjects were imported to Mimics Research 15.01 software (Materialise, Leuven, Belgium) on 17.3-inch UHD IPS monitor (Palo Alto, United States) and converted to the stereolithography (STL) format. The grayscale threshold values were predefined to be reconstructed as the areas of interest and described as a new mask (Figure 1). The mask was cropped in all

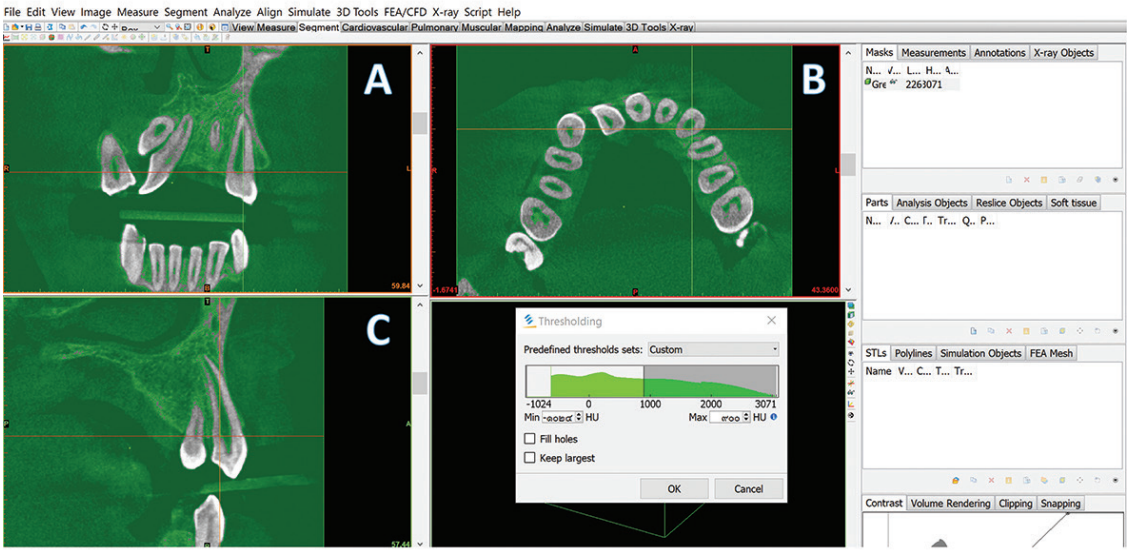

Figure 1 *Predefining the grayscale threshold values and a new mask creation in (A) Coronal view; (B) Axial view, and (C) Sagittal view.*

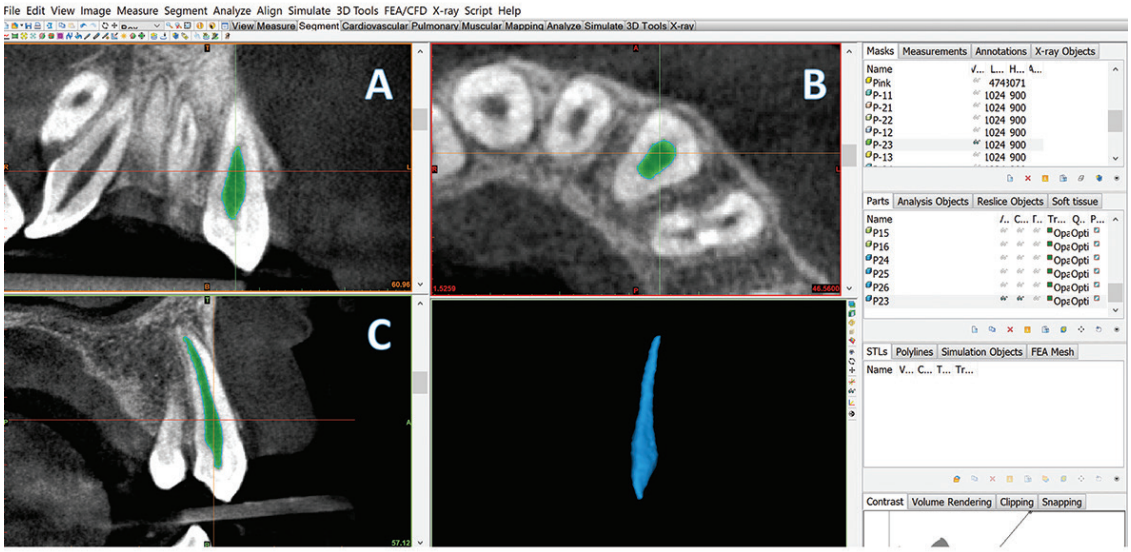

Figure 2 *Identification of dental pulp morphology in 3-D images of each slice orientation using Mimics Research 15.0. (A) Coronal view; (B) Axial view, and (C) Sagittal view*

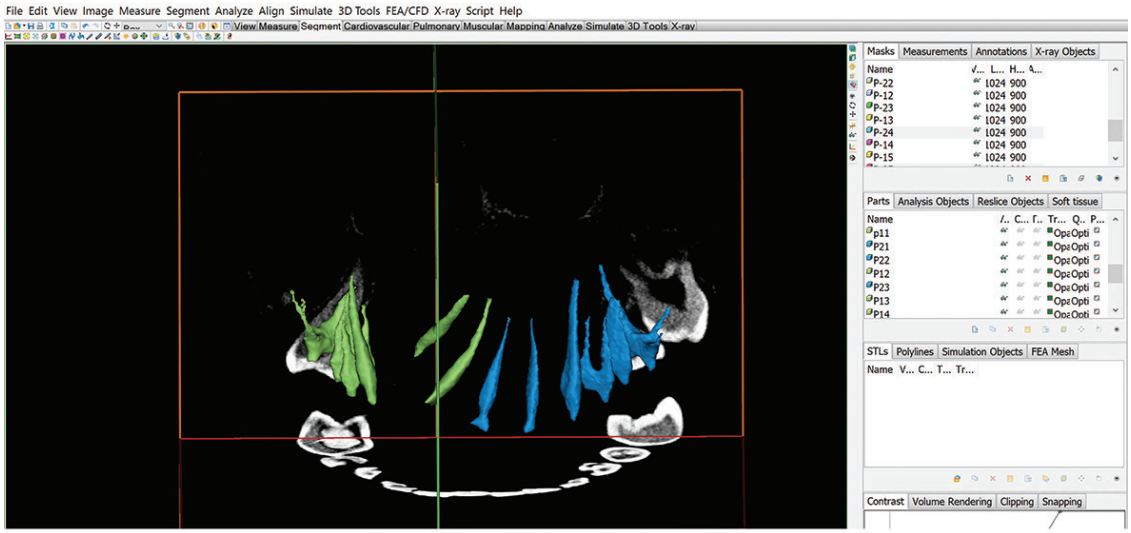

Figure 3 *Construction of a 3-D dental pulp models.*

three planes and was manually defined by identifying the outer boundaries of the dental pulp morphology on images of slices in each orientation for separation of the pulp cavity from the surrounding structures (Figure 2). The 3-D model of the dental pulp was created when the "Calculate 3-D" software function was selected (Figure 3). The 3-D dental pulp volume was then calculated automatically using this software (Figure 4).

Method reliability was tested by randomly selecting CBCT images of six maxillary permanent teeth of each tooth type (except second and third molars) and re-measuring by the same environment and examiner with four-year experience for assess CBCT after a four-week interval.

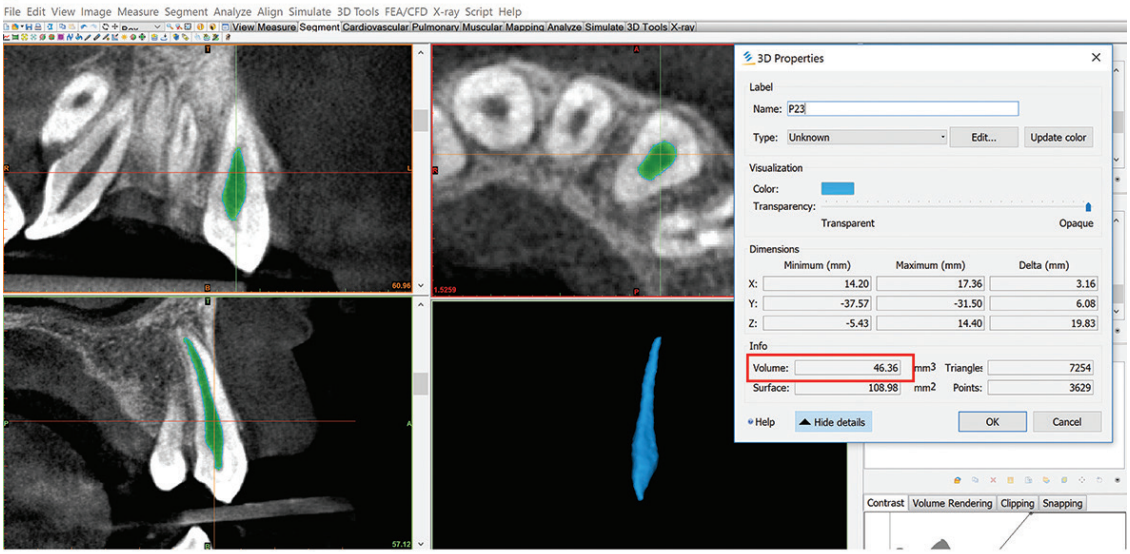

Figure 4 *Calculation of the dental pulp volume of each tooth.*

Statistical analysis

The Statistical Package for Social Sciences (SPSS) version 22.0 for Windows (SPSS Inc., Chicago, Illinois, USA) was used to calculate the results. The Shapiro-Wilk test was used to test normality of data. The mean differences in the dental pulp volumes of maxillary permanent teeth (except second and third molars) between the cleft side and the non-cleft side in Thai patients with complete UCLP were compared using the paired samples T-test. The results were considered statistically significant at $p<0.05$. The intra-examiner reliability was assessed using the intra-class correlation coefficient (ICC)

Results

A high intra-examiner correlation (r = 0.964) was revealed, indicating a high level of reproducibility of the dental pulp volume measurements.

The prevalence of congenital absence, bilateral congenital absence, and unilateral congenital absence of the maxillary lateral incisor was 80.0%, 40.0%, and 40.0%, respectively. Means and standard deviations of the dental pulp volumes of the teeth

Table 1 *The number, means, standard deviations and comparisons of the dental pulp volumes of the maxillary permanent teeth on the cleft side and those of its counterpart on the non-cleft side in Thai patients with complete UCLP.*

Group	Cleft side		Non-cleft side		*p* value [a]
	Number (N)	Mean (SD)	Number (N)	Mean (SD)	
Central incisor	20	38.50 (15.19)	20	42.41 (17.36)	0.206
Lateral incisor	4	17.50 (9.76)	4	26.62 (11.96)	0.223
Canine	20	55.14 (22.79)	20	53.12 (24.28)	0.521
First premolar	20	48.30 (15.95)	20	48.58 (16.82)	0.915
Second premolar	20	48.89 (16.90)	20	48.42 (15.96)	0.872
First molar	20	96.16 (25.93)	20	95.99 (29.17)	0.954

[a] *Significance levels: * p<0.05*

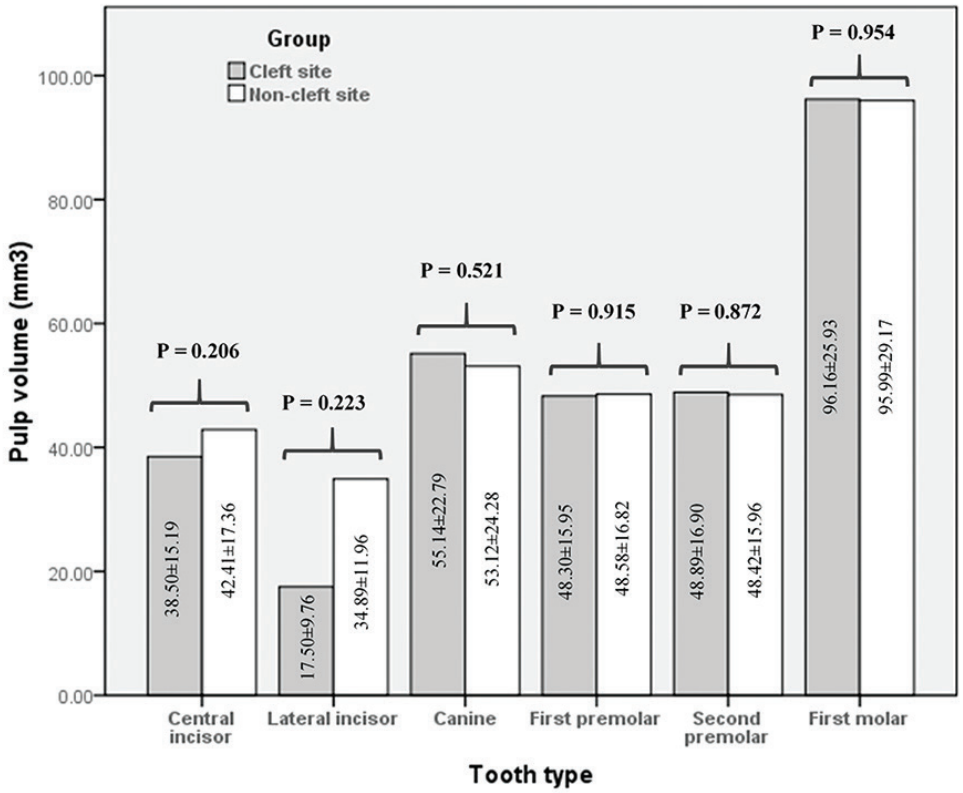

Figure 5 *Bar graph demonstrating means and standard deviations and comparisons of the dental pulp volumes of the maxillary permanent teeth on the cleft side and on the non-cleft side in Thai subjects with complete UCLP.*

sequentially from the maxillary central incisor to the maxillary first molar on the cleft side and the non-cleft side, as shown in table 1. In both groups, the maxillary molar showed the greatest value while the lateral incisor showed the least.

The comparisons of the dental pulp volumes of the maxillary permanent teeth on the cleft side and on the non-cleft side revealed no significant differences, as shown in Figure 5.

Discussion

The lack of statistically significant difference in dental pulp volumes of maxillary permanent teeth of each tooth type on the cleft side compared to the non-cleft side indicates a similar pattern of dental pulp development on both sides, and that the CLP anomaly does not affect the dental pulp volume in patients with UCLP. This finding disagrees with the findings of previous studies, which suggested that the CLP anomaly affects tooth development.[7-9] The tooth development, indicated by the measurement of root length, or by root volume, is delayed in patients with CLP in comparison with the general population, and is delayed on the cleft side in comparison with the non-cleft side. Therefore, this finding implies that the CLP anomaly may not affect the dental pulp volume, whereas it may affect other features of the tooth, such as the length and volume of the tooth and root in patients with CLP. However, because the prevalence of congenitally absent maxillary lateral incisors in this study was 80.0%, it may not be concluded the CLP anomaly affects the dental pulp volume of this tooth. Further investigations with more sample are essential.

The assessment of the dental pulp volume is important not only for the study of tooth development in patients with CLP but also for other knowledge of dentistry, such as forensic dentistry and orthodontics. Recently-developed dental age estimation methods are also based on the development of the dental pulp volume.[16-20] Orthodontic treatment plays a vital role in the interdisciplinary treatment of patients with CLP. It has been reported that orthodontic force leads to a minor risk of pulpal damage and a decrease in the size of the dental pulp volume.[15] Thus, the calculation of the dental pulp volume may lead to manipulation of orthodontic treatment plans and improvement of the prognosis of teeth in patients with CLP.

Conclusions

The dental pulp volume of maxillary permanent teeth in Thai patients with complete UCLP did not associate with the CLP anomaly. The maxillary first molar presented the greatest dental pulp volume, whereas the maxillary lateral incisor presented the least.

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