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Prevalence and correlation of OXIS contacts using Cone Beam Computed Tomography (CBCT) images and photographs

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Abstract

Background: The contact areas in between primary teeth are broader, flatter, and located further cervically when compared with the contact areas of permanent molars.

Aim: We investigated the prevalence of interproximal contact area types of primary molars using CBCT images in children aged 3-10 years. Our second objective was to correlate OXIS contact areas when observed with CBCT images and clinical photographs.

Design: A retrospective cross-sectional study was performed with 367 CBCT images of children, aged 3-10 years, obtained from Children's Dental Centre, South Korea. The type of contacts in between primary molars was scored at various levels, specifically, occlusal, middle, and cervical thirds, according to OXIS criteria. Following this, the same patient's records were checked for the presence of clinical photographs and scored according to the same criteria. Prevalence was stated as percentages along with numbers. Chi-square test was applied to determine association of contact areas across genders and arches. The correlation between the two methods was done by Cohen's Kappa correlation test.

Results: The prevalence of the OXIS contacts obtained from CBCT images was as follows: I (79.7%), followed by X (10.0%), S (6.6%), and, finally, O (3.7%). The overall score of all the 1343 contact areas matched with the score observed at the occlusal third. All included contacts were of O (open) type at cervical third, and 1,231 contacts were of O (open) type at the middle third. Significant results were observed with respect to arches ($P < .001$). The correlation between the two methods was found to be 0.958.

Conclusions: The contact area observed at the occlusal level determined the overall type of contact based on OXIS criteria. Thus, reports in the literature concluded that contact areas are broad, flat, and extend further gingivally should be revised. The study also concluded almost perfect agreement between CBCT images and clinical photographs.

M. Kirthiga and M. S. Muthu have contributed equally to this research work.

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KEYWORDS
child, computed tomography, cross-sectional study, dental photography, primary teeth, proximal contact

1 | INTRODUCTION

A contact area denotes the height of contour of the proximal surfaces of two adjacent teeth in the same arch. According to existing literature, the contacts between primary molars are broader, flatter, and located further cervically than those of permanent molars.[1] Although the contact characteristics of permanent teeth have been well-documented, primary teeth remain relatively unexplored.[2,3] The shape and size of the contact area can predispose the tooth to proximal caries. Furthermore, broader proximal contact areas are likely to increase susceptibility to early childhood caries, because of the limited movement between teeth caused due to reduced self-cleansing action.[4,5]

For better understanding of tooth morphology, computer-based techniques have been used. Among these, cone beam computed tomography (CBCT) has been gaining popularity in recent years. Since risk associated with x-ray exposure is greater for children, it is important that CBCT be used, so that their relative exposure to radiation is far less than other 3-dimensional imaging techniques.[6] CBCT images facilitate the clinician to observe a particular area of interest in three different planes, namely the axial, sagittal, and coronal. It also acts as a practical tool for 3-dimensional (3D) and non-invasive reconstruction imaging of dental morphological structures and their analyses.[7,8] Although it has been well-documented in the literature that there is a significant association of closed contact types with proximal caries when compared with open contacts in posterior primary molars,[3,9,10] there is little information about the types of contacts in primary dentition. Recently, a retrospective cross-sectional investigation was conducted[11] to assess the variations in contacts between primary molars as seen from the axial view. This study was performed on 28 existing CBCT images and identified four types of contacts in between the primary molars, that is, open contact (O), point contact (X), straight contact (I), and curved contact (S), based on their shapes. The OXIS classification of contact areas was proposed following the patterns observed in the study. Following this classification, an epidemiological study was conducted in Puducherry, a union territory, where this was confirmed clinically.[12]

A comprehensive understanding of the anatomy of contact areas of primary molars is of utmost importance for a proper understanding of the epidemiology of early childhood caries, which will further aid in improved diagnosis and patient management. Although a few studies have been conducted on OXIS contacts by means of clinical or radiographic examination, none have correlated the two methods in the same population. Further, the previous CBCT study[11] was a pilot study to check the feasibility, and the sample size was small. Therefore, the primary objective of this study was to assess the prevalence of contact areas between primary molars in the maxilla and the mandible in a South Korean population by means of CBCT images in children aged 3-10 years. The secondary objective was to compare and correlate the contact types of caries-free primary molars when captured by CBCT images and clinical photographs.

Why this paper is important to paediatric dentists

- This study showed 91.7% (1,231 contacts) of contacts were open at the middle third. All 1,343 contact areas exhibited the presence of O (open) type of contact at the cervical third. This warrants revision of the traditional information that contacts in between primary molars are broad, flat, and extend further cervically.
- The contact area observed at the occlusal level determined the type of contact based on OXIS criteria.
- The study found almost perfect agreement between CBCT images and clinical photographs for scoring OXIS contact areas, which implies that the latter is sufficient.

2 | MATERIALS AND METHODS

2.1 | Ethics approval

Ethical approval of the research protocol was obtained by the Research Ethics Committee of Children's Dental Centre (CDC), South Korea.

2.2 | Study population

The CBCT scans of children aged 3-10 years, for the present retrospective cross-sectional study, were obtained from a private paediatric dental centre, named the Children's Dental

Centre, Seoul, South Korea. All CBCT scans included in this study were taken during 01/01/2018 and 01/09/2019 for various diagnostic reasons, for instance location of supernumerary teeth, evaluation of endodontic and maxillofacial pathology, orthodontic treatment, and orthognathic surgery. There were no children who undertook CBCT scans for this study without an underlying clinical need. The sample consisted of 1459 CBCT images. All CBCT images except those of special children were included in the study.

2.3 | Selection criteria

Inclusion criteria were as follows:

1. CBCT images of good quality
2. Primary molars with no developmental malformations of tooth shapes
3. Primary molars with no congenital anomaly
4. Primary molars with intact contact areas
5. Primary molars with intact arches
6. Clinical photographs of good quality.

Exclusion criteria were as follows:

1. CBCT images of primary molars with restorations
2. CBCT images of primary molars with crowns
3. CBCT images of primary molars with caries
4. CBCT images of primary molars with deposits around teeth.

2.4 | Data collection

Data collection was performed by a paediatric dentist (KM) who was previously calibrated by a subject expert and was blinded to participants' information. The detailed process of calibration was explained in a previously published pilot study.[11] Before the investigation, 30 CBCT scans with 120 intact contacts (not included in this study) were screened by the examiner on two different occasions with an interval of two weeks. The intra-examiner reliability was calculated using Cohen's weighted kappa score and was observed to be 0.931 which denoted an almost perfect agreement.

2.5 | Assessment of CBCT Images

Based on the inclusion and exclusion criteria, 367 CBCT images (out of 1459 CBCT images) were deemed eligible for assessment. To ensure image standardization, all CBCT images were taken from the same machine and by the same trained personnel. The images were obtained from PaX-i3D TO-95LH by means of a standard field of view = 165 mm × 180 mm; voxel size of 0.30 mm; 9.0 mA and 120 kV; slice thickness of 0.4 mm;and exposure time of 9 s. They were exported as original and uncompressed DICOM file format and analysed with the help of a built-in EZ 3D-i digital imaging software, version 4.0 (Republic of Korea), on a 17.0-inch LGFLATRON L1742T LCD screen with an Intel® Core TM i7 3.0 GHz processor, and 8 GB of memory at a resolution of 1,280 × 1,024 pixels. All CBCT images were observed and evaluated by a previously calibrated examiner to provide a benchmark. Age and gender were noted for all included images. There were no time restrictions for the assessment of the CBCT images. The room for image observations had standardized conditions of low environmental lighting and noise. The presence of an illuminated desktop lamp enabled the observers to record their responses on a special sheet. The examiner was permitted to scroll through all the three planes (axial, coronal, and sagittal), to adjust brightness and contrast freely, and to evaluate the volume-rendered image. Using the measurement tool in the sagittal section, the total length of the crown of the primary second molar was determined. This extended from the tip of the mesiobuccal cusp up to the cemento-enamel junction. Based on this length, the crown was divided into three equal portions namely the occlusal, middle, and cervical thirds. Following this, the type of contact area in between the mesial surface of the second primary molar and distal surface of the first primary molar was scored at the three different levels (occlusal, middle, and cervical thirds) in the axial section according to the OXIS criteria mentioned in a previously published study.[11]

FIGURE 1 Scoring of the maxillary right molar contact area at 3 levels on the CBCT image. A, Score 3 at the occlusal third (S type); B, score 1 at the middle third (X type); C, and score 0 at the cervical third (O type), respectively

TABLE 1 Prevalence and percentages of the types of contacts between primary molars in accordance with arch, side, and gender

	Maxilla (n = 666)						Mandible (n = 677)						Overall	
	Right side (n = 340)		Left side (n = 326)				Right side (n = 335)		Left side (n = 342)					
Type of contact	M	F	M	F	Total	%	M	F	M	F	Total	%	Total (1343)	%
O	2	7	4	8	21	3.2	6	8	6	9	29	4.3	50	3.7
X	10	8	14	12	44	6.6	23	20	26	21	90	13.3	134	10.0
I	148	123	145	109	525	78.8	148	123	148	126	545	80.5	1070	79.7
S	22	20	16	18	76	11.4	2	5	2	4	13	1.9	89	6.6

Note: Maxilla vs mandible (right side): $\chi^2 = 41.44$; $P = <.001$. Maxilla vs mandible (left side): $\chi^2 = 21.02$; $P = <.001$.
Gender vs right maxilla: $\chi^2 = 3.726$; $P = .293$. Gender vs left maxilla: $\chi^2 = 3.601$; $P = .308$.
Gender vs right mandible: $\chi^2 = 0.877$; $P = .831$. Gender vs left mandible: $\chi^2 = 2.159$; $P = .540$.

The scoring of the types of contact areas was performed separately for the maxilla and mandible. The highest score among the three levels (occlusal, middle, and cervical) was chosen as the overall score for a particular tooth. For instance, in the right maxillary quadrant, if the contact between the two molars was 3 at occlusal (S shape), 1 at middle (X shape) and 0 at cervical thirds (O shape), then the overall score for this particular tooth would be 3. (Figure 1).

Data were extracted by means of a customized data extraction sheet.

2.6 | Assessment of clinical photographs

Following the screening and the final inclusion of the CBCT images, the same patient's records were checked for the presence of clinical photographs on the same date. The intraoral photographic series included a maxillary occlusal view, a mandibular occlusal view, and a frontal view. Photographs were acquired by means of an Olympus Corporation digital camera (model NO.E-M10 II) set at a fixed distance of 36 inches between the lens and the subject. All photographs were taken by two trained dental hygienists. Based on the inclusion criteria, the types of contact areas from the clinical photographs were scored according to the OXIS criteria from the occlusal view.

2.7 | Statistical analysis

Data were entered and analysed using Microsoft Excel Version 15 (2013). Descriptive statistics were used for data presentation and summarization. Prevalence of different types of contact areas was stated as percentages and numbers for CBCT images and clinical photographs separately. The chi-square test was applied to determine the association of contact areas in each quadrant across genders and interarch variability. The correlation between the radiographic and the clinical photographic methods was performed by Cohen's Kappa correlation test.

3 | RESULTS

3.1 | Assessment of CBCT Images

In total, 1459 CBCT scans were evaluated, of which 1092 were excluded based on the quality of the image, the presence of caries, restorations, crowns, or deposits around teeth. Finally, 367 scans (196 males and 171 females) involving 1,343 contacts were deemed eligible for analysis. The mean age of the sampled children was 7.41 years. The prevalence and percentages of the types of contacts in between primary molars according to the arch, side, and gender are shown in Table 1. The prevalence of the contacts observed in the descending order are as follows: I (79.7%), followed by X (10.0%), S (6.6%), and, finally, O (3.7%). The most and the least common contacts in the maxilla were I (78.8%) and O (3.2%), respectively. The most prevalent contact in the mandible was the I (80.5%) type, and the least prevalent was S (1.9%) type. The score of the contact observed at the occlusal third was similar to that of the overall score for all 1,343 contact areas. In this study, all 1,343 contacts were of O (open) type at the cervical third, whereas 91.7% (1231 contacts) of the contacts were of O (open) type at the middle third. The remaining 112 samples showed contacts at both middle and occlusal thirds. Of these, 49 had similar contacts at the middle and occlusal thirds. Among all the contacts, 96.3% were of the closed type (S, I, and X type of contact). When interarch comparison was performed, significant results were observed ($P < .001$). No significant

TABLE 2 Comparative prevalence and percentages of OXIS contacts between CBCT images and clinical photographs in accordance with arch and side

	Maxilla (n = 611)						Mandible (n = 624)						Overall			
	Right side (n = 311)		Left side (n = 300)		Total		Right side (n = 312)		Left side (n = 312)		Total		Total (1235)		%	
Type of contact	CBCT	Photo	CBCT	Photo	CBCT	Photo	CBCT	Photo	CBCT	Photo	CBCT	Photo	CBCT	Photo	CBCT	Photo
O	10	10	14	12	24	22	16	15	15	15	31	30	55	52	4.5	4.2
X	22	21	27	28	49	49	42	40	41	40	83	80	132	129	10.7	10.5
I	242	244	227	228	469	472	246	248	251	252	497	500	966	972	78.2	78.7
S	37	36	32	32	69	68	8	9	5	5	13	14	83	82	6.6	6.6

results, however, were found when gender was compared with individual quadrants (Table 1).

3.2 | Assessment of clinical photographs

Among the 1,343 contacts included, good-quality clinical photographs were present only for 1,235. The prevalence of the contacts observed in the descending order is as follows: I (78.8%), followed by X (10.4%), S (6.6%), and, finally, O (4.2%). In the maxilla, the most common contact type was I (77.2%) and the least common contact type was O (3.6%), respectively. In the mandible, the most common type was I (80%) and least common contact type was S (2.2%) correspondingly.

3.3 | Correlation of CBCT Images with clinical photographs

Table 2 shows the comparative percentages and prevalence of the OXIS contacts between CBCT images and clinical photographs according to arch and side. The overall correlation between the radiographic and the clinical photographic methods was found to be 0.958. Figure 2 shows the correlation of the CBCT images and clinical photographs of the O (open), X (point), I (straight), and S (curved) contacts, respectively.

4 | DISCUSSION

This cross-sectional study was performed with existing CBCT images of children and hence did not represent a random sample of the South Korean population. Therefore, extrapolation of these findings to the general population should be performed with caution. No CBCT scans were taken exclusively for this study. All the scans used were made for various other clinical reasons.

The most and least common contact areas in this study observed were I (79.7%) and O (3.7%), respectively. The highest and the least prevalent contact in the mandible, however, was the I (80.5%) type and S (1.9%) type, respectively. Compared with previous studies,[11,12] the results of our study were in perfect agreement with respect to the most common contact but were contradictory with respect to the least common contact which was different in all the three different studies. Overall, the order from the most to the least common contact areas in this study was I (79.7%), X (10.0%), S (6.6%), and O (3.7%), respectively, which was not consistent with the results of previous studies, which reported an order of I > X > O > S[11] and I > S > O > X.[12] These differences in findings could be attributed to the significant difference in the sample size, which consisted of 1,343 contacts in this study compared with 74

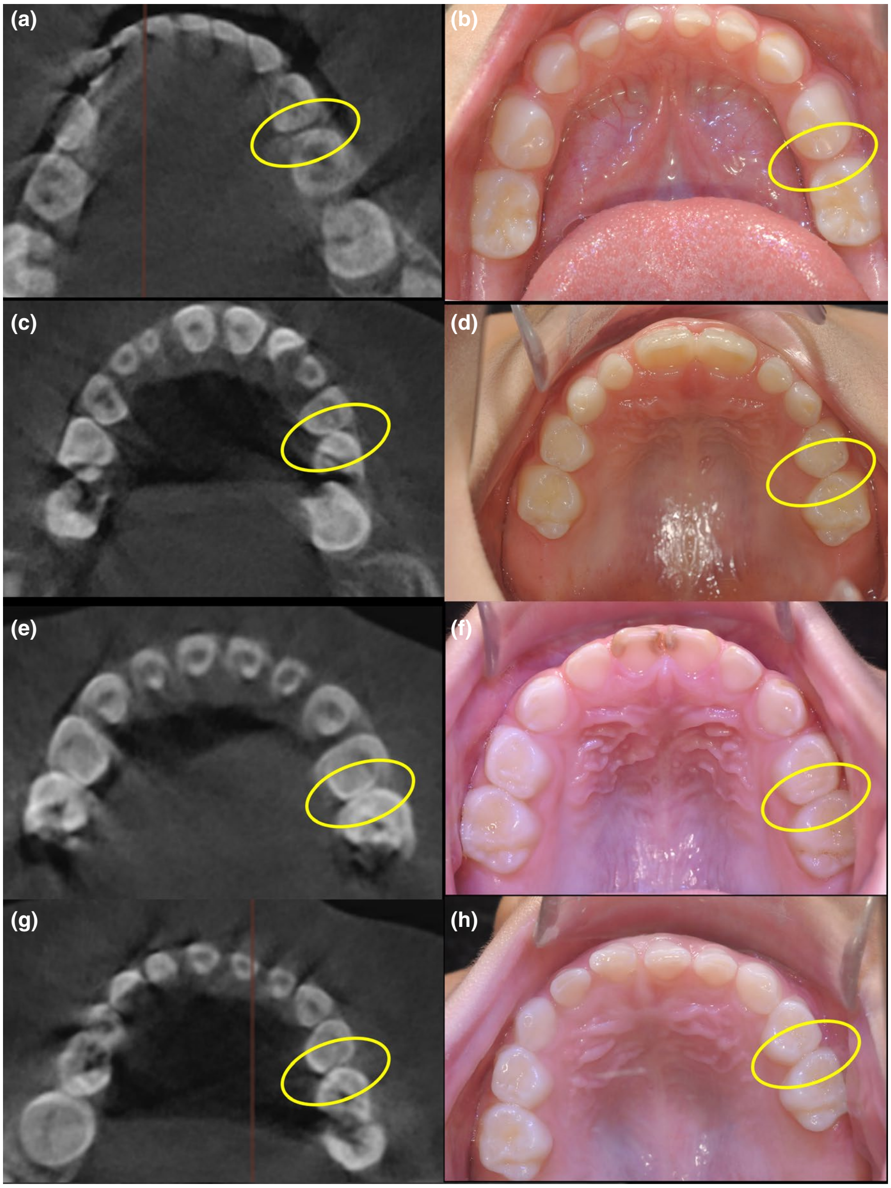

FIGURE 2 Correlation of the CBCT images and clinical photographs. A, B, depicting O or open type of contact; C, D, depicting X or point type of contact; E, F, depicting I or straight type of contact; G, H, depicting S or curved type of contact, respectively

contacts performed with CBCT images and 4,476 contacts in the clinical study. Also, the difference could be attributed to the ethnicity of the three different regions studied, namely, South Korea, South India, and Puducherry.

When interarch comparisons were performed, significant findings were obtained ($P < .001$) that correlated with those from the previous clinical study.[12] An interesting finding in the recent study was the even distribution of all types of contacts on the right and left sides in both the maxilla and mandible. No significant findings, however, were observed with respect to gender. Again, this finding was similar to that reported in the previous clinical study.[12]

The correlation between the types of contact areas by CBCT and clinical photographs has not been performed previously (Table 2). This study revealed a correlation of 0.958, indicative of an almost perfect agreement between the two methods. This indicates that a clinical photograph is sufficient to score the types of OXIS contact areas, and no further studies with CBCT images may be required. With respect to the individual contacts, maximum variation was present with respect to the I type, where a prevalence of 78.0% and 78.8% was observed in CBCT and clinical photographs, respectively, possibly because the I contact was more distinct in the clinical photographs when compared with CBCT images, especially in the mandible. Therefore, this type could have been scored differently, which led to the variations between the contacts. The other contacts, namely O, X, and S, showed minor variations, each of which could be attributed to subjective errors.

A noteworthy observation in this study was that the score of the contact area observed at the occlusal third was similar to the overall final score for all 1343 contact areas. Further, 91.7% (1231 contacts) of the contact areas were of O (open) type in the middle third. Both of these findings were consistent with those from the previous study conducted in this area.[11] In addition, all contacts showed the presence of O (open) type at the cervical third, which was in agreement with the previous study.[11] This further strengthens the evidence contradictory to the traditional information provided in textbooks, that is, contacts in between primary molars are broad, flat, and present further cervically..

The strengths of the study were as follows. First, the large sample size came from the CBCT database at the Children's Dental Centre, South Korea. Second, the collection of the samples was from a particular centre, hence ensuring standardization of all CBCT images. Additionally, the type of contact area was assessed at occlusal, middle, and cervical levels in all the three different sections. The only limitation of the study was that the results could not be generalized to other ethnic groups/populations.

This study hypothesized that I- and S-type contact areas might lead to greater plaque accumulation than O and X types, based on the morphology of the variations in contacts types. The clinical implications of a contact area require further discussion. The three-dimensional information of a contact area might facilitate this factor to be considered as a possible risk factor during caries risk assessment. Also, the OXIS contact areas may influence tooth preparation in class II cavities and stainless steel crown insertions. Further, the contact between a stainless steel crown and a sound tooth might alter the caries risk of the sound tooth, depending on the type of contact created following crown insertion. Such risks must be evaluated in future studies. Forthcoming studies should be carried out in different ethnic populations to confirm OXIS contact areas. Long-term cohort studies should evaluate the association between the variations of contacts in primary molars and the occurrence of early childhood caries.

In this study, 91.7% (1,231 contacts) of contacts were open in the middle third. All 1,343 contacts were of the O (open) type at the cervical third. Thus, the existing literature about contacts between primary molars being broad, flat, and cervically situated should be revised. The results of this study indicate that the contacts of primary molars can be classified as O (open contact), X (point contact), I (straight contact), and S (curved contact) types. This study also found almost perfect agreement between CBCT images and clinical photographs for scoring OXIS contact areas.

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CONFLICT OF INTEREST

The authors declare no potential conflicts of interest with respect to the authorship or publication of this article.

AUTHOR CONTRIBUTIONS

Dr M K and Dr M S M contributed to conception and design, data acquisition, analysis and interpretation, and drafted and critically revised the manuscript. Dr J C L contributed to conception, data acquisition, analysis and interpretation, and drafted and critically revised the manuscript. Dr G K and Dr V P M contributed to data analysis and interpretation, and drafted and critically revised the manuscript. Dr J S S and Dr K S contributed to data acquisition, and drafted and critically revised the manuscript. Dr R P contributed to data interpretation, and drafted and critically revised the manuscript. 'All authors gave final approval and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved'.

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