

ORIGINAL RESEARCH

Assessment of contact area variations in primary molars of children based on the OXIS classification

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(Derya Sarioğlu)**Abstract**

Background: The localization and depth of caries in primary teeth vary based on eruption timing, mouth position, and contact type with adjacent teeth upon occlusion. **Methods:** On plaster models of 153 children aged 3 to 10 years, obtained from Gaziantep University Faculty of Dentistry, 373 contact points created by caries-free primary molars were assessed. The OXIS criteria were used to evaluate the type of contact between primary molars. In addition to figures, prevalence was expressed as percentages. The association between contact areas, age, gender, and arches was examined using the chi-square test. **Results:** The most common contact type was Type I (50.94%), followed by Type S (29.75%), Type X (16.09%) and the least common, Type O (3.22%). Type S was most prevalent in the maxilla (46.63%) and Type I in the mandible (68.33%). After age 6, Types I and S contacts increase, while Type O is more common in children under 6. No gender differences were found. **Conclusions:** The OXIS classification can be regarded as a systematic approach to investigate the impact of contact areas on caries and the prevalence of contact areas in various ethnic groups.

Keywords

Contact area; OXIS classification; Primary molars; Proximal caries

1. Introduction

The location and depth of caries in primary teeth differ depending on the time of eruption, the position in the oral cavity, and the type of contact with adjacent teeth when the eruption ends. The possibility of interproximal caries varies depending on the contact type between the teeth. Therefore, comprehending the different types of contact in primary teeth is crucial for early disease recognition [1]. Primary teeth are compared to permanent teeth; the thinner enamel and dentin layers, lower mineralization, wider dentinal tubules, and broader contact areas that facilitate biofilm accumulation in primary teeth make them more susceptible to the formation and fast progression of interproximal caries. Therefore, early detection of proximal caries is essential [2].

Although the differences in the contact area of primary molars are of great importance for early diagnosis, there are very few studies on this theme in the literature. Warren *et al.* [3] conducted the first study examining the contact areas of primary teeth. In 2002, Warren and his colleagues categorized the spaces between primary teeth into four groups: gap over 1 mm, Gap under 1 mm, no gap, teeth touching, no gap, teeth touching and crowded [3]. Other studies have attempted to determine the contribution of contacts to caries and the rate of caries progression in the interproximal area by characterizing contacts as “open” and “closed”. Allison *et al.* [4] measured the open and closed groups according to the floss resistance of contact points. Later, Cortes *et al.* [5] categorized the contact

areas of teeth according to their surface angles and named them concave-concave, concave-convex, convex-concave and convex-convex. It was determined that those with concave contact areas were the most at-risk group in terms of caries [5].

The idea of classifying the contact areas of primary teeth to facilitate early diagnosis of caries was first proposed in 2018. This classification called the OXIS classification, represents the open contact type in primary molars indicated as “O”, the point contact type in primary molars indicated as “X”, the flat contact type in primary molars indicated as “I”, and the curved contact type in primary molars indicated as “S” (Table 1, Ref. [6]).

Considering this information, our study aims to identify the prevalence of contact variations in primary teeth. The OXIS classification was used to determine the contact type in the primary molars. The null hypothesis of the study is that no significant result can be reached in the contact diversity of primary teeth between age, gender and jaws.

2. Materials and methods

2.1 Research protocol

This thesis study was conducted between 01 August 2024 and 01 December 2024 at the Department of Pediatric Dentistry, Faculty of Dentistry, Gaziantep University. The Gaziantep University Clinical Research Ethics Committee approved the

TABLE 1. Diagrammatic representation of contact area variations according to the OXIS classification [6].

OXIS classification types	Features
	O—open contact When there is no contact between the primary molars.
	X—shaped contact When there is a point of contact (≤ 1.5 mm) between the primary molars.
	I—shaped contact When there is a straight contact (≥ 1.5 mm) between the primary molars.
	S—shaped contact When there is a straight contact (> 1.5 mm) between the primary molars.

study with decision number 2024/272 dated 31 July 2024. Detailed voluntary consent forms were obtained from parents, and child consent forms were obtained from literate children. According to the power analysis, the minimum number of contacts was 363. However, considering that parents or patients would withdraw from participating in the study at any stage, a sample of 400 contacts was considered.

2.2 Clinical and radiographic patient selection

179 patients who applied to our clinic were included in the study. 26 of these patients were excluded from the study due to fear of the dentist, distortion of the impression and the parent’s reluctance to participate. For this reason, 153 patients participated in the study. 373 caries-free contacts were obtained from the measurements taken from 153 patients (Table 2). For this reason, the sample size was determined as 373.

- Inclusion criteria:
 - Children aged 3–10 years
 - Presence of at least one quadrant of primary molars without caries
- Cooperative patients
- Presence of written parental consent
- Exclusion criteria:
 - Presence of special healthcare needs
 - Developmental abnormalities in tooth morphology
 - Presence of dental plaque covering the contact area
 - Presence of a severe gag reflex
 - Presence of carious or crowned restorations in primary molars

2.3 Researcher calibration

Before the study, a 10-year specialist pediatric dentist gave a single dentist the necessary theoretical information and calibrated the dentist. Calibration was performed in three stages. In the first stage, the pediatric dentist was asked to follow the instructions on the official OXIS website, and the specialist trained the dentist in a presentation. Then, the dentist per-

TABLE 2. Gender of the patients and distribution of jaw quadrants to be evaluated.

Variables	Maxilla right	Maxilla left	Mandible right	Mandible left
Male	53	45	51	41
Female	49	46	43	45
Total	102	91	94	86

formed clinical observation with the pediatric specialist for 3 months. The specialist and the dentist evaluated plaster models taken from 50 patients separately. After two weeks, the dentist re-evaluated the plaster models separately, and the three evaluations were compared. The specialist and the dentist independently evaluated plaster models taken from 50 patients. After two weeks, the dentist re-evaluated the plaster models separately, and the three evaluations were compared. The kappa value was 0.95. There was excellent consistency in the assessments.

Initial radiographs of the patients were obtained from a digital panoramic X-ray device (Gendex Dental Systems, Lake Zurich, IL, USA). Two calibrated, experienced observers performed clinical examinations and radiographic evaluations of all patients. Primary molars found to be clinically and radiologically free of caries were included in the study.

2.4 Clinical procedures

The procedures were explained in detail to the patient’s guardian and themselves. A detailed voluntary consent form was obtained from the parents, and a child consent form was obtained from the literate children. Two calibrated, experienced observers performed clinical and radiological examinations of the patients who came for routine examination. Patients were examined using traditional methods with the help of panoramic films (Dentopix model, Gendex-700, Gendex Dent Systems, IL, USA). Primary molars confirmed to have no interdental caries were noted in the patient’s record book.

2.4.1 Taking impressions from patients

After determining that the primary molars were free of caries, appropriate impression trays (Disposable Impression Trays, 2165 Earlywood Drive Franklin, IN 46131 USA) were determined. Impressions were taken from the patients with alginate (Lot: 0000420342, Zhermack Spa, Badia Polesine (RO), Italy). To prevent the patients' vomiting and nausea reflex, alginate was placed only in the area where the relevant teeth were located. It was kept for 2 minutes on average for each patient.

2.4.2 Obtaining the plaster model

From the measurements taken, a model was created using Type IV plaster (Gypstone 3000 + Die Stone, IMICRYL, Konya, Turkiye). The plaster models were recorded together with the patient form.

2.4.3 Evaluation of the models

Once low-quality models were removed, the final number was deemed appropriate for assessment. LED-illuminated dental loupes (binocular dental loupe, Keeler Ltd, Windsor, England) were used to examine the models in order to expand the field of vision and enhance visualization of the contact area between the teeth of interest. On a white background, models were positioned. A separate file was created for each patient in the study, including the registration form, consent form, clinical and radiographic evaluations at the initial and follow-up appointments and measurements. Two observers evaluated the measurements taken from the patients according to the OXIS classification and recorded them on the registration

form. All the procedures are illustrated in Fig. 1 and example models of the OXIS classification are shown in Fig. 2.

2.5 Statistical analysis

Descriptive statistics of the data obtained from the study are given, along with frequency and percentage analysis for categorical variables. Differences between categorical variables were tested with Chi-square analysis. Analyses were performed with the help of SPSS 22.0 (IBM Corp. Version 21.0. Armonk, NY, USA) program. It was selected $p < 0.05$ significance level.

3. Results

This study included 373 contacts belonging to 153 patients with at least one caries-free contact area on their primary molars (Fig. 3).

Regarding the ages of the participants, 22.22% ($n = 34$) of the participants were under 6 years of age, 77.78% ($n = 119$) were 6 years of age and over. In addition, 49.02% of the participants were female and 50.98% were male (Table 3).

When the primary tooth contact area classification is evaluated in Table 4, it is determined that 50.94% are in the I classification group, 29.76% in the S classification group, 16.09% in the X classification group, and 3.22% in the O classification group. The appearance of primary tooth contact areas in quadrants is determined as 27.35% as maxilla right, 25.2% as mandible right, 24.4% as maxilla left and 23.05% as mandible left.

In the maxilla, 46.63% S classification, 34.72% I classifi-

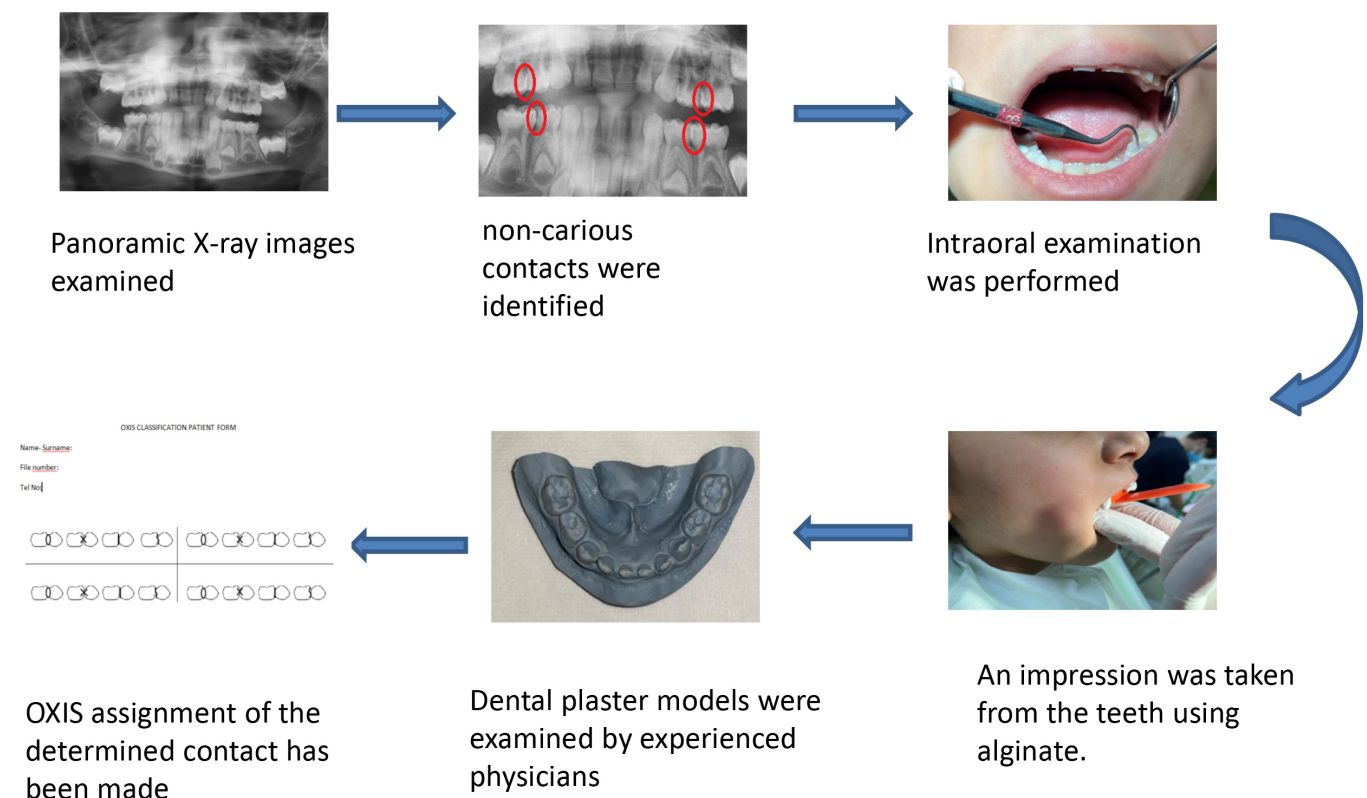


FIGURE 1. Schematic illustration of the methodology of our study.

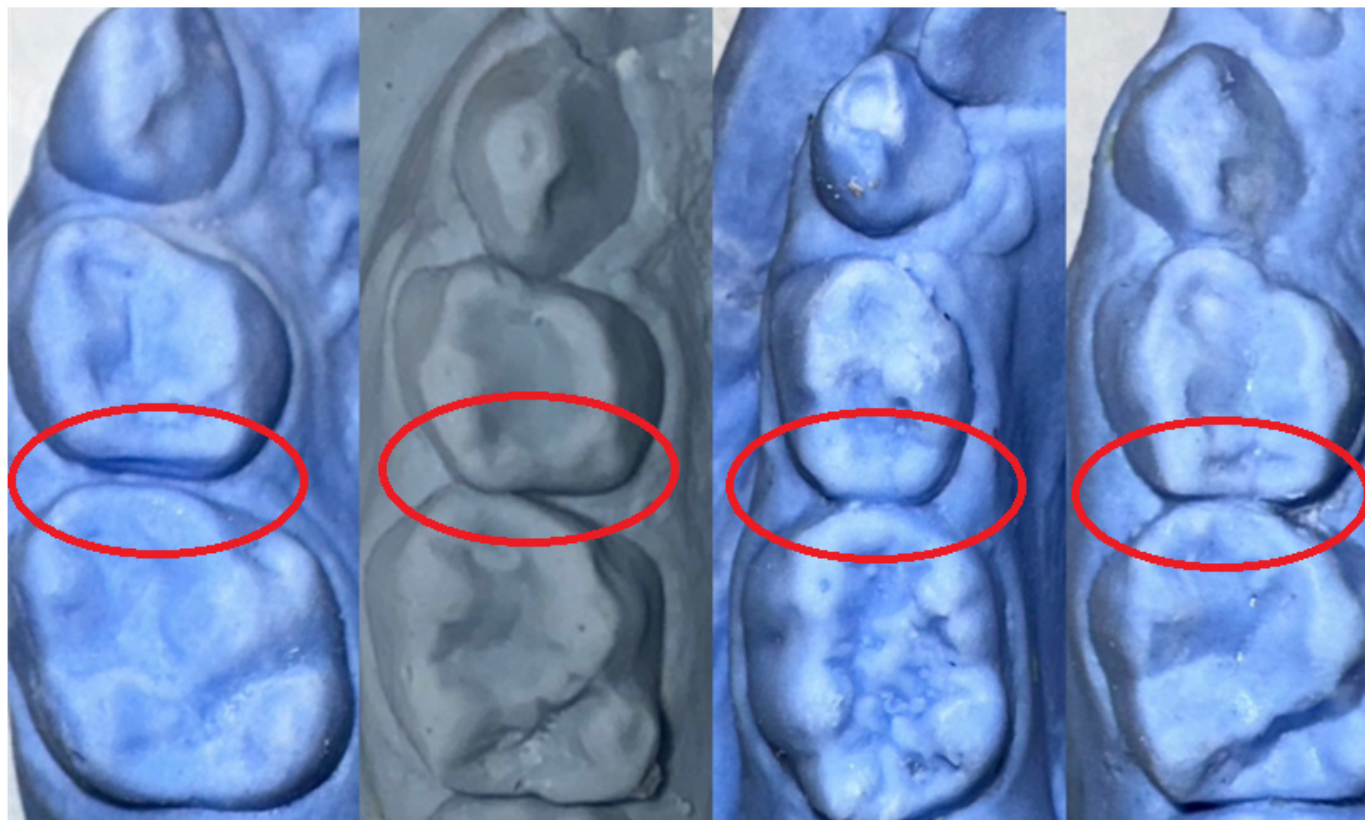


FIGURE 2. Contact areas of the plaster models (from left to right; “O” represents open type contact, “X” represents point contact, “I” represents flat contact type, and “S” represents curved contact type).

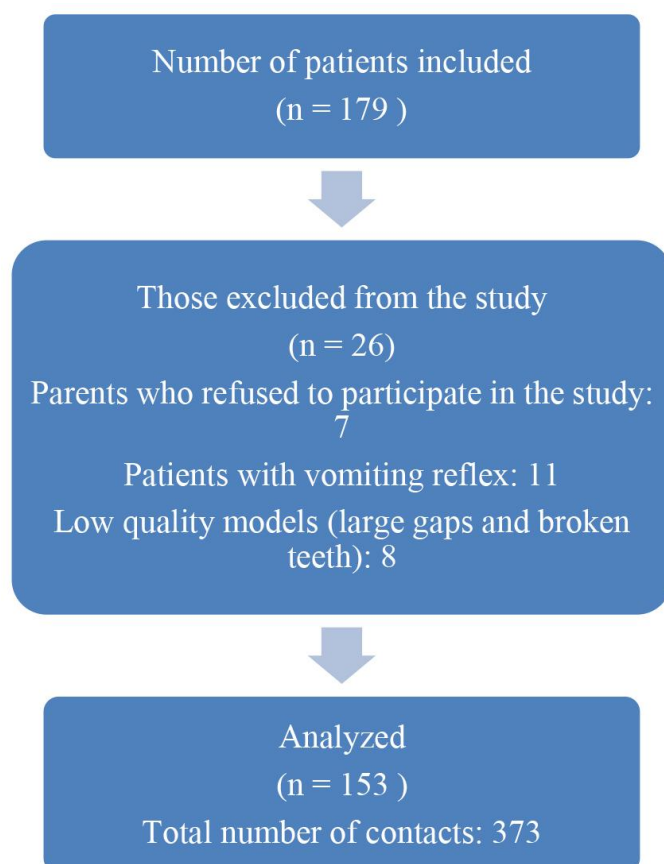


FIGURE 3. Flow chart of patients participating in the study.

TABLE 3. Demographic characteristics of the participants.

Variables	n (%)
Age	
<6 yr	34 (22.22)
≥6 yr	119 (77.78)
Gender	
Female	75 (49.02)
Male	78 (50.98)

TABLE 4. Prevalence of quadrants and OXIS classification.

Variables	n (%)
Quadrants	
Maxilla right	102 (27.35)
Maxilla left	91 (24.40)
Mandible right	94 (25.20)
Mandible left	86 (23.05)
Classification	
O	12 (3.22)
X	60 (16.09)
I	190 (50.94)
S	111 (29.75)

cation, 16.06% X classification, and 2.59% O classification are seen. In the mandible, 68.33% I classification, 16.11% X classification, 11.67% S classification and 3.89% O classification are observed. It was determined that there was a statistically significant difference between the classification of primary tooth contact areas and quadrants ($p < 0.05$). Accordingly, while S classification is more common in the maxilla, I classification is more common in the mandible (Table 5).

TABLE 5. OXIS classification prevalence according to quadrants.

Classification	Maxilla n (%)	Mandible n (%)	<i>p</i>
O	5 (2.59)	7 (3.89)	0.001*
X	31 (16.06)	29 (16.11)	
I	67 (34.72)	123 (68.33)	
S	90 (46.63)	21 (11.67)	

* χ^2 : chi-square value; $p < 0.05$: significant.

In women, the I classification is seen in 46.99%, the S classification in 31.69%, the X classification in 18.58% and the O classification in 2.74%. In men, the I classification is seen in 54.74%, the S classification in 27.89%, the X classification in 13.68% and the O classification in 3.69%. It was determined that there was no statistically significant difference between gender and deciduous tooth contact area classification ($p > 0.05$) (Table 6).

TABLE 6. OXIS classification prevalence by gender.

Classification	Female n (%)	Male n (%)	<i>p</i>
O	5 (2.74)	7 (3.69)	0.362
X	34 (18.58)	26 (13.68)	
I	86 (46.99)	104 (54.74)	
S	58 (31.69)	53 (27.89)	

In those under the age of 6, 48.42% had I classification, 24.21% had S classification, 16.84% had X classification and 10.53% had O classification. In those 6 years and older, 51.8% had I classification, 31.65% had S classification, 15.83% had X classification and 0.72% had O classification. It was determined that there was a statistically significant difference between the OXIS classification and age groups ($p < 0.05$). Accordingly, while O classification was more common in those under 6, X, I and S classifications were more common in the 6-year-old and older group (Table 7).

TABLE 7. OXIS classification prevalence according to age group.

Classification	<6 yr (n (%))	≥6 yr (n (%))	<i>p</i>
O	10 (10.53)	2 (0.72)	0.001*
X	16 (16.84)	44 (15.83)	
I	46 (48.42)	144 (51.80)	
S	23 (24.21)	88 (31.65)	

* χ^2 : chi-square value; $p < 0.05$: significant.

In the maxilla right, 44.12% S classification, 35.29% I classification, 17.65% X classification and 2.94% O classification are seen. In the maxilla left, 49.45% S classification, 34.07% I classification, 14.29% X classification, and 2.2% O classification are seen. In the mandible, right, 69.15% I classification, 15.96% X classification, 11.7% S classification, and 3.19% O classification are seen. In the mandible left, 67.44% I classification, 16.28% X classification, 11.63% S classification and 4.65% O classification are seen. It was determined that there was a statistically significant difference between the deciduous tooth contact area classification and the quadrant ($p < 0.05$). Accordingly, while S classification is more common in the maxilla right and maxilla left quadrants, I classification is more common in the mandible right and mandible left quadrants (Table 8).

4. Discussion

In the first studies using OXIS classification, sample size varied. The first OXIS study conducted by Kirthiga *et al.* [6] included 74 contacts between the ages of 3 and 14 were included in the study. The sample size was increased in the subsequent study and they investigated 1231 contacts [7]. In another study by Muthu *et al.* [8], the sample size was 4476. Walia *et al.* [9] examined 400 contact areas in a study conducted in two separate centers. In another study, Muthu *et al.* [10] retrospectively checked the decay rates of 1102

TABLE 8. OXIS classification prevalence according to quadrants.

Classification	Maxilla right n (%)	Maxilla left n (%)	Mandible right n (%)	Mandible left n (%)	<i>p</i>
O	3 (2.94)	2 (2.20)	3 (3.19)	4 (4.65)	0.001*
X	18 (17.65)	13 (14.29)	15 (15.96)	14 (16.28)	
I	36 (35.29)	31 (34.07)	65 (69.15)	58 (67.44)	
S	45 (44.12)	45 (49.45)	11 (11.70)	10 (11.63)	

* χ^2 : chi-square value; *p* < 0.05: significant.

contacts. In the study conducted by Debnath *et al.* [11], the sample size was 124. Kailasam *et al.* [12] examined 520 contact areas of permanent teeth in patients between the ages of 14 and 25. In their study, Gupta *et al.* [13] included a sample of 65 contacts from patients between the ages of 3 and 9. Kumari *et al.* [14] examined 300 contacts in patients between 3 and 5. Based on these studies, the minimum number of contacts required was determined to be 363, according to the power analysis performed in our study. Three hundred seventy-four contacts were included in the study.

The prevalence of OXIS has been investigated using various diagnostic methods. These methods are visual examination, plaster models created by taking intraoral measurements, intraoral photographic records, photographic records of plaster models, and Cone Beam Computed Tomography (CBCT) records. In the first study where OXIS was used, CBCT images were scanned [6]. The first study divided the crown length into three equal parts. The necessary OXIS assignment was made for each part. According to the results, it was understood that the primary determinant of the classification was the middle third. For this reason, the crown length was excluded from the calculation in other studies. Apart from this study, other studies are using CBCT images [7, 13]. Muthu *et al.* [8] used the traditional examination method in their research. Clinical photographs and plaster models were used in different studies [9, 11, 12, 14]. Kirthiga *et al.* [15] have a study investigating the accuracy of OXIS diagnostic methods. This study shows that clinical photography and plaster models yield more accurate results than traditional examinations.

CBCT is not used in routine examinations. Especially in children and adolescents, high radiation exposure may lead to cytostatic effects. Therefore, the use of CBCT should be based on diagnostic necessity. Based on this result, it is possible that OXIS assessment does not require CBCT [6]. In our study, although traditional examination provides time-saving, it is reliable, but it is low, and although clinical photography has high reliability, it has insufficient calibration, so the plaster modeling technique was preferred [15]. These plaster models were kept to examine the risk of caries and to prepare the ground for a new study. In a study conducted by Muthu *et al.* [8] in 2020, an equal number of children from five different regions were analyzed. The sample size consisted of 4476 contact areas in 1119 children. The dentist evaluated the children with a traditional examination and plaster models were taken from them. This study is the first epidemiological study using the OXIS classification. However, the study has some limitations. One of them is that the OXIS classification cannot

be generalized across racial and ethnic groups [8]. Walia *et al.* [9] they investigated 200 contacts in two different regions, Ajman and Puducherry, in the same year and compared the prevalences. Our study is the first OXIS study in our region. Although the OXIS classification was made for primary teeth, some studies show that it can also be used in permanent teeth. Kailasam *et al.* [12] evaluated 520 contact areas of permanent teeth in patients between the ages of 14 and 25. Both anterior and posterior teeth were evaluated in the study. Contact areas were classified as second molar-first molar, first molar-second premolar, and second premolar-first premolar.

In the first study by Kirthiga *et al.* [6] in 2018, 66.2% I contact type, 21.6% X contact type, 9.4% O contact type and 2.7% S contact type were seen. In another study, the most common type was I contact type with a rate of 75.5%, while the least common type was O contact type [7]. In a study by Walia *et al.* [9], research was conducted in 2 different centers. The most common type of contact was I contact, with a rate of 53% and 75.5% in the centers, respectively, followed by X, S and O. In the study conducted by Debnath *et al.* [11] on Bengali children, the most common type of contact was I contact, with a rate of 78.2%, while the least common type was O contact, with a rate of 6.4%. Kumari *et al.* [14] found the most common type of contact as I, with a rate of 44%, while the least common type was S contact, with a rate of 9%. Kailasam *et al.* [12] examined 520 contact areas in permanent teeth. In total, the most common contact type between permanent second molar and permanent first molar is I contact type with 46.5%, the most common contact type between permanent first molar and permanent second premolar is I contact type with 46.65%, and the most common contact type between permanent second premolar and permanent first premolar is X contact type with 59.62% [12]. Our statistical analysis showed that the most common contact type is I classification (50.94%), followed by S classification (29%) and X classification (16.09%). The least common type is O classification (3.22%). Our study consists of Turkish pediatric patients from the Gaziantep province of Türkiye. This situation proves that the most and least common contact variations according to OXIS classification may vary in different ethnicities.

When intermaxillary OXIS was evaluated in the study conducted by Kirthiga *et al.* [6] on 74 contact points, the most common contact variation in the maxilla and mandible was I, with a rate of 67.4% and 64.5%, respectively. In the study conducted by Kumari *et al.* [14], the most common contact type in the maxilla and mandible was I, with a rate of 41% and 47%, respectively. In the study conducted by Gupta *et*

al. [13] on 65 CBCT images, the mandible and maxilla were evaluated separately, and the most common contact type in the maxilla was I, while the most common contact type in the mandible was O. In our study, as in the study of Kirthiga and Kumari, the most common contact type in the mandible was variant I, while, unlike other studies, the most common contact type in the maxilla was S. 78 males and 75 females were included in our study, and no statistically significant difference was found in the classification of the contact area between the genders. Similar results were found in other studies [6–14]. In the first OXIS studies, patient age groups were evaluated as a single group of 3–4 years or 3–6 years. In the study conducted by Walia *et al.* [9], patients were divided into groups of 3–4, 4.1–5 and 5.1–6. While I classification was the most common in the first two groups, O classification was more common in the 5.1–6 age group. Walia *et al.* [9] stated that the reason for this difference was due to jaw expansion in the 5.1–6 age group. In other studies, I classification was the most common classification in every age group. In our study, the effect of age on OXIS was examined. The age of eruption of the first molar tooth, 6 years, was taken as the basis because the spaces in the primary teeth were closed with the eruption of the first molar tooth [16]. Our aim was to reveal the effect of permanent first molar teeth on contact. Accordingly, patients were divided into two groups under 6 years and over 6 years. According to the study results, 48.42% I, 24.21% S, 16.84% X and 10.53% O were seen in children under 6 years of age, while 51.8% I, 31.65% S, 15.83% X and 0.72% O were seen in children 6 years of age and older, respectively. A statistically significant difference was found in the contact area classification between ages ($p < 0.05$). Accordingly, the O classification was more common under 6 years of age, while the X, I and S classifications were more common in the 6 years of age and older age group. Our study is the only study that performed statistical analysis based on the first molar tooth. Our study is important because it is the first study to examine contact assessment before and after the age of 6 and the first OXIS study conducted in the pediatric population in our region.

According to the results obtained, in while no significant difference was found in the contact diversity of primary teeth between genders, a significant difference was found between ages and jaws. The null hypothesis was partially rejected. In addition, our study has some limitations. Although this study is the first study conducted in the field of OXIS in our region, being a single-center study is among the limitations of the study. Therefore, the study should be supported with a multi-center sample size. At the same time, the difficulty of obtaining measurements from patients with nausea reflexes and patients younger than 6 years of age made it difficult to extend the study to the general population. Especially in children younger than 6 years of age, larger sample sizes will emphasize the necessity of OXIS classification. In light of this information, understanding the differences in OXIS contact area variations is important for preventive treatments. Therefore, our study will lead to future studies, and OXIS classification will bring a new breath to the literature.

5. Conclusions

In our study, the most common contact type was the I type, 50.94%, while the least common type was the O type, 3.22%. The most common type in the maxilla was the S type, 46.63%, while the most common type in the mandible was the I type, 68.33%.

While I and S type contact types increase after the age of 6, the O type contact type is more common in children before the age of 6. There is no difference between the genders. Therefore, the null hypothesis is partially rejected.

Understanding the variations in the contact area of teeth is essential in predicting the risk of tooth decay and re-evaluating the contact area characteristics in restorative procedures. The OXIS classification can be considered a standardized method to examine the prevalence of contact areas in different ethnic groups and the effect of contact areas on caries.

AVAILABILITY OF DATA AND MATERIALS

The data supporting the findings of this study are available from the corresponding author upon reasonable request. This manuscript is derived from Derya SARIOĞLU's specialty thesis in pediatric dentistry.

AUTHOR CONTRIBUTIONS

ZG—designed the research study. DS—performed the research; analyzed the data. ZG and DS—wrote the manuscript; revised and edited the manuscript. Both authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This thesis study was conducted between 01 August 2024 and 01 December 2024 at the Department of Pediatric Dentistry, Faculty of Dentistry, Gaziantep University. The Gaziantep University Clinical Research Ethics Committee approved the study with decision number 2024/272 dated 31 July 2024. Informed consent forms were obtained from all patients and their parents participating in the study.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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