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ORIGINAL RESEARCH

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Changes in Andrews' fifth key of occlusion (interproximal contacts) before and after orthodontic treatment

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Abstract

This study aimed to assess the changes in interproximal contacts before and after orthodontic treatment using the OXIS classification. OXIS refers to the types of contacts that is open (O), point contact (X), straight contact (I), and curved contact (S), and thus the acronym "OXIS". Interproximal contact data of 30 orthodontic patients were obtained at three time points: T0, at the beginning of treatment; T1, at the end of fixed appliance treatment; and T2, one-year post-treatment. For the maxillary second molar–first molar contact, the most common contact at T0, was the "S" pattern (41.6%) which increased to 61.6% at T1 and reduced to 48.3% at T2. For the maxillary first molar–second premolar contact, maxillary second premolar–first premolar contact, and maxillary first premolar–canine contact, the most common contact at T0 was the "I" pattern (58.3%, 46.5% and 43.3%, respectively), which increased to 88.3%, 93.3% and 73.3%, respectively at T1 and decreased to 80%, 88.3% and 71.6%, respectively at T2. For the maxillary canine–lateral incisor contact and lateral–central incisor contact, the most common contact at T0 was the "O" pattern (45% and 33.3%) while it was the "X" pattern at T1 (63.3% and 80%) and T2 (58.3% and 80%). A similar observation was made for the posterior mandibular and anterior teeth. There was statistical significance for most of the changes in the mandibular contacts ($p < 0.05$). Interproximal contacts change significantly from T0 to T1. Broader contacts were normal at T1 and T2 in the posterior segments. At T2, changes in the interproximal contacts were observed in the posterior segments, and substantial evidence was available, particularly for the mandibular arch.

Keywords

Andrews' fifth key; OXIS; Malocclusion; Inter proximal contacts

1. Introduction

While the main goal of orthodontic treatment is to obtain a normal relationship between the teeth and facial structures, the maintenance of dental alignment after orthodontic treatment continues to be a challenge for orthodontists. This is because achieving "ideal" occlusion and dental alignment does not prevent the tendency for relapse [1, 2]. In follow-up studies after orthodontic treatment, the instability of the occlusion is often described as relapse [3].

While Andrews' six keys to occlusion are the objectives of successful orthodontic treatment [4], there is minimal literature on the fifth key, that is, interproximal contacts. The importance of the interproximal contacts is proven. It plays a critical role in maintaining and stabilizing the dental arch [4, 5]. A well-located and steady contact are considered essential for periodontal health [6]. The location of the interproximal contact area, however, differs within the dentition. For the central incisors, it is located at the coronal incisal third, whereas for the lateral incisors, canines and premolars it is more apical from anterior to posterior teeth when viewed from the frontal [7]. In certain malocclusions like class II, the location of the tooth and therefore the contact might be altered since the maxillary alveolar processes and the teeth therein drift mesially, and therefore the contacts play an important role in the correction of malocclusion [8]. Further, the other keys of Andrews' six keys to occlusion [4] would affect the fifth key like rotations of the posterior teeth which would occupy more mesiodistal space. This rotation would not permit the tooth to fit in it's the designated area and bring undesirable points of interproximal

contact. These in turn would jeopardize the stability of arch form and affect oral hygiene and therefore the periodontal status.

Previous literature on primary dentition has described the contacts as open/closed [9] or as convex and concave [10], or as open, light or substantial [11]. Recently, Muthu *et al*. [12] have studied and classified interproximal contacts of the primary molars as being of four different types, namely, open (O), point contact (X), straight contact (I), and curved contact (S), and thus the acronym "OXIS". For the interproximal contacts of the primary anterior teeth, a modification of the OXIS classification has recently been reported [13]. The OXIS classification has also been used on permanent dentition [14].

Interproximal contacts contribute to proper occlusion, which is necessary to retain corrected malocclusion. The variation in the interproximal contacts before and after treatment could be the determining factor because the nature of the interproximal contacts would change during and following treatment [15]. Thus, there is a need for more information on the role of interproximal contacts in treated occlusion. With the OXIS classification [12–14, 16, 17] being a clinically useful method to describe interproximal contacts, this study aimed to use the OXIS classification to determine the change in interproximal contacts from pre-treatment to post-treatment and one year after orthodontic treatment.

2. Material and methods

2.1 Study design

Records were retrospectively taken at baseline (pretreatment, T0) and debonding (post-fixed appliance-T1). The patients were followed up prospectively for one year after treatment (T1).

2.2 Sample size

The required sample size was calculated based on a pilot study on the interproximal contacts of the 10 patients study cast (26 contacts each) which were evaluated at three time points: before orthodontic treatment (T0), after treatment (T1), and one year after treatment (T2). With a 14% prevalence of transition from T0 to T1 of "S" pattern to "I" pattern, relative precision of 20%, and desired confidence level of 95%, the sample size required was 777 contacts. As each cast provided data on 13 interproximal contacts, 30 patient casts (30 maxillary and 30 mandibular) were assessed to generate data for the required sample size of 777 contacts, which was rounded to 780. We are expecting a least prevalence of transition from X to O.

2.3 Inclusion and exclusion criteria

The inclusion criteria were casts of patients aged between 14 and 25 years with a full complement of permanent teeth. The exclusion criteria were the presence of caries, restorations or occlusal wear or any developmental anomalies affecting tooth morphology (peg laterals). Any patients who developed caries or underwent interproximal reduction during the orthodontic treatment were also excluded. From 122 patient records, 38 pre (T0) and post-treatment (T1) study casts of patients whose treatment involved non-extraction mechanics and a standardized retention protocol of upper and lower canine-canine fixed and upper removable Essix retainers were included as the study sample.

2.4 Baseline characteristics

The baseline malocclusion of the patients was 17 patients with class I malocclusion and spacing, 3 patients with class I and mild crowding, 5 patients with class II division 1 malocclusion, 2 patients with class II division 2 malocclusion and 3 with class III malocclusion. These patients were followed up for 1 year. Patients who reported a break/loss of retainers or those who did not report for follow-up were excluded from the study.

2.5 Assessment and evaluation

The examiner randomly measured a maximum of five patient casts per day. The casts were one-to-one replicates without any magnification. The assessment was performed based on the method suggested by Muthu *et al*. [12]. Briefly, the procedure was as follows: the casts were placed on a flat table for assessment, and the evaluation was performed from a standardized distance. Assessment of the maxillary and mandibular casts always started from the second molar–first molar interproximal contact in the right quadrant and proceeded across the midline to the left quadrant second molar–first molar interproximal contact. Third molars were excluded from this study.

2.5.1 Evaluation of posterior tooth contacts

The shape of the contact area between the maxillary and mandibular posterior teeth was examined by observing the occlusal surfaces. Four posterior teeth contacts were assessed per quadrant, from the contact between the mesial aspect of the second molar and distal aspect of the first molar to the contact between the mesial aspect of the second premolar and distal aspect of the first premolar. This was performed for the right and left sides and maxillary and mandibular casts. The contacts were classified based on the OXIS classification [12]. Briefly, this classification applied "O", that is, open contact if there was no contact between the adjacent teeth; "X", if there was a point contact of less than or equal to 1.5 mm; "I", if there was a straight contact of more than 1.5 mm; and "S", if there was a curved contact of greater than 1.5 mm between the adjacent teeth (Fig. 1). Whenever there was any doubt regarding the quantum of measurement with visual inspection, a Williams probe and a scale were used to measure the distance and the contact was graded accordingly.

2.5.2 Evaluation of anterior tooth contacts

The shape of the contact area between the maxillary and mandibular anterior teeth was examined by observing the incisal surfaces. The contact between the mesial aspect of the first premolar and distal aspect of the canine, starting from the right side to the corresponding tooth contact on the left side, was assessed. The anterior tooth contacts were classified based on a modification of the OXIS classification [13], where the S type alone was modified as S1 and S2. When the tooth was rotated and only one of its surfaces (either proximal or labial/lingual) was in contact with the adjacent tooth, the

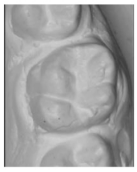
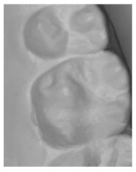
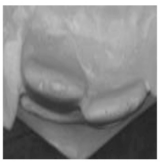
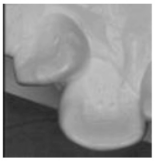
S No	Representative image	Criteria	Type of contact	Score
Posterior teeth				
1		When there is no contact between adjacent teeth	Open contact	0
2		When there is point contact (≤ 1.5mm between adjacent teeth) was in contact with the adjacent tooth	X shaped contact	1
3		When there is point contact (>1.5mm between adjacent teeth)	I shaped contact	2
4		When there is a curved contact (>1.5mm between adjacent teeth)	S shaped contact	3
Anterior teeth				
5		When the tooth is rotated and only one of its surfaces (either proximal or labial/lingual) was in contact with the adjacent tooth	S1	4
6		When the tooth is rotated and two surfaces - proximal (mesial/distal) and labial or lingual - in contact with the adjacent tooth	S2	5

FIGURE 1. Pictorial representation of the OXIS classification.

contact was classified as S Type I (S1). When the tooth was rotated and had two surfaces–proximal (mesial/distal) and labial or lingual, in contact with the adjacent tooth, the contact was classified as S Type II (S2).

2.5.3 Scoring

The interproximal contact data of 30 patients were collected at three time points: T0, at the beginning of treatment; T1, at the end of fixed appliance treatment; and T2 at one-year post-treatment. For posterior contacts, open (O) contacts were scored as 0, X as 1, I as 2 and S as 3. For anterior tooth contacts, the O, X and I contacts were scored as 0, 1 and 2, respectively; S1 was scored as 3, and S2 was scored as 4.

2.6 Statistical analysis

Descriptive statistics were obtained for all independent variables. A total of 2340 contacts, that is, 780 at each time point were collated. The prevalence of the types of contacts were assessed using Analysis of Variance (ANOVA).

3. Results

3.1 Posterior teeth contacts

At T0, for the maxillary and mandibular posterior teeth, the most common contact was "I" pattern (42.2% and 58.9% respectively). At T1, for the maxillary and mandibular posterior teeth, the most common contact was "I" pattern (81.7% and 80% respectively). At T2, for the maxillary and mandibular posterior teeth, the most common contact was "I" pattern (75% and 71.1% respectively).

3.2 Anterior teeth contacts

At T0, for the maxillary anterior teeth, the most common contact was "O" pattern (31.9%) while it was the "X" pattern (38.1%) for the mandibular teeth. At T1, for the maxillary and mandibular anterior teeth, the most common contact was "X" pattern (63.8% and 73.3% respectively). Similar findings were observed at T2, with the most common contact being "X" pattern (59.5% and 74.3% respectively) Tables 1,2,3,4,5).

3.3 Statistical evaluation

Statistical evaluation of the posterior and anterior contacts at the three time points revealed that there was no statistical significance for most of the contacts in the maxillary arch ($p > 0.05$) while it was statistically significant in the majority of the mandibular contacts. Statistical significance was observed for the posterior contacts only for the right second molar–first molar contact at T0–T1 when the "I" contact changed to "S" ($p = 0.003$) and at T0–T2 ($p = 0.01$). Statistical significance was observed for anterior contacts at the left canine–lateral incisor contact at T0–T2 when the "O" contact changed to "X" ($p = 0.005$) and at T1–T2 when "S2" contact changed to "X" ($p < 0.001$) and "S2" contact changed to "I" ($p = 0.002$) and for the right lateral incisor–central incisor contact at T0–T1 when the "O" contact changed to "X" ($p = 0.01$), "S1" contact changed to "X" ($p = 0.002$) and at T0–T2 when the "O" contact changed to "X" ($p = 0.01$). Statistical significance was also observed for the left lateral incisor–central incisor at T0–T1 when the "O" contact changed to "X" ($p = 0.002$) (**Supplementary material**). Figs. 2,3,4,5 are representative cast images and their equivalent clinical photographs of the interproximal contacts of maxillary and mandibular posterior regions at pre-treatment, post treatment and one-ear post treatment.

4. Discussion

This study aimed to assess variations in interproximal contacts before (T0), after (T1), and one-year post treatment (T2). At T0, the patients presented with malocclusion, including individual malpositioning of the teeth, such as crowding, spacing and rotations. The data were representative of these malpositions and were in accordance with the results reported by Kailasam *et al.* [14].

At T1, immediately after the fixed appliance treatment, correction of the malpositions resulted in a change in interproximal contacts. For the maxillary and mandibular posterior teeth, the "O" and "X" patterns were corrected to "I" and "S" patterns indicating that broader contacts were the norm at T1. For the maxillary and mandibular anterior teeth contacts, the "O", "S1" and "S2" patterns were corrected to "X" and "I" patterns. The mandibular interproximal contacts had a greater prevalence of "X" patterns than that of the maxillary contacts. This could have been owing to the smaller size of the mandibular teeth, which led to a smaller interproximal contact.

Although the contacts in both the posterior and anterior regions were similar at T1 and T2, minor changes were observed in the mandibular interproximal contacts which were primarily an alteration between "I" and "S" patterns. The changes in the contacts at T1 and T2 could be owing to an improvement in occlusion during the settling period [18, 19]. We could not compare our results at T1 and T2, as there were no similar studies, and ours was the first study to assess the variations in interproximal contacts after orthodontic treatment.

These changes could also have been due to relapse. More changes were observed in the posterior mandibular interproximal contacts possibly owing to the retention protocol. We advised maxillary Essix retainers with full-time wear and canine-to-canine fixed retainers. This protocol could have contributed to the changes in the mandibular posterior interproximal contacts. The changes were evaluated 1 year after treatment as Reitan reported that the first 8-month post-treatment period appears to be critical [20].

Interproximal contacts play an important role in all aspects of dentistry. Improper location of contact point also affects periodontal health. Establishing contact too occlusally will create a smaller occlusal embrasure enabling food accumulation. Establishing it too gingivally will induce an inflammatory response leading to bone loss [21]. While an open contact in the deciduous dentition is physiological, it has been reported that an open contact must not be considered a causal factor for periodontal diseases, but a modifier of the periodontal condition in the permanent dentition [22]. Proximal contact loss is also an emerging frequent complication [23]. In implant dentistry, Interproximal contact loss appears to increase over time [24], Open contacts further increase the risk for peri-implant disease [25]. A recent systematic review [26] has reported that the thickness of the proximal enamel is greater on the distal aspect and could be related to the contact loss at the mesial aspect of the implant restorations being higher [27]. Adequate contacts are also related to healthy bone levels and marginal ridge relationships [28].

The strengths of our study are that this was the first to assess the variations in contacts after orthodontic treatment and that the mechanics were standardized to a non-extraction treatment plan. The limitations were that the effect of the third molars was not considered, the initial malocclusion (T0) was not standardized and the actual wear time/cooperation of the patient with the full time wear protocol of the Essix retainer. Muthu *et al.* [12] have reported that the "S" and "I" types of contacts in primary molars had higher odds for caries development. Hence future research should be directed towards evaluating the caries risk assessment of the various patterns of the interproximal contact in the permanent dentition and in orthodontic patients and the effect of various retention protocols on the interproximal contacts during the follow up periods.

TABLE 1. Prevalence and percentages of maxillary teeth contacts (right side).

Posterior Teeth																*p* value
Contact	O			X			I			S						
	T0	T1	T2	T0	T1	T2	T0	T1	T2	T0	T1	T2				
Second molar–first molar	4 (13.3%)	0 (0%)	0 (0%)	4 (13.3%)	0 (0%)	0 (0%)	4 (13.3%)	22 (73.3%)	17 (56.6%)	18 (60.0%)	8 (26.7%)	13 (43.3%)				0.450
First molar–second premolar	0 (0%)	0 (0%)	0 (0%)	5 (16.7%)	1 (3.3%)	2 (6.6%)	21 (70.0%)	27 (90.0%)	25 (83.3%)	4 (13.3%)	2 (6.7%)	3 (10.0%)				0.720
Second premolar–first premolar	0 (0%)	0 (0%)	0 (0%)	12 (40.0%)	0 (0%)	0 (0%)	16 (53.3%)	28 (93.3%)	27 (90.0%)	2 (6.7%)	2 (6.7%)	3 (10.0%)				<0.001
Anterior teeth																*p* value
Contact	O			X			I			S1			S2			
	T0	T1	T2	T0	T1	T2	T0	T1	T2	T0	T1	T2	T0	T1	T2	
First premolar–Canine	6 (20.0%)	0 (0%)	0 (0%)	6 (20.0%)	8 (26.7%)	8 (26.7%)	10 (33.3%)	22 (73.3%)	22 (73.3%)	4 (13.3%)	0 (0%)	0 (0%)	4 (13.3%)	0 (0%)	0 (0%)	0.910
Canine–Lateral Incisor	9 (30.0%)	0 (0%)	0 (0%)	2 (6.7%)	18 (60.0%)	16 (53.3%)	3 (10.0%)	12 (40.0%)	14 (46.6%)	10 (13.3%)	0 (0%)	0 (0%)	6 (20.0%)	0 (0%)	0 (0%)	0.290
Lateral incisor–Central incisor	8 (26.7%)	0 (0%)	0 (0%)	4 (13.3%)	23 (76.7%)	25 (83.3%)	1 (3.3%)	7 (6.7%)	5 (16.7%)	11 (36.7%)	0 (0%)	0 (0%)	6 (20.0%)	0 (0%)	0 (0%)	0.160

O: open; X: point contact; I: straight contact; S: curved contact.

TABLE 2. Prevalence and percentages of maxillary teeth contacts (left side).

Posterior Teeth																*p* value
Contact	O			X			I			S						
	T0	T1	T2	T0	T1	T2	T0	T1	T2	T0	T1	T2				
Second molar–first molar	1 (3.3%)	0 0%)	0 (0%)	3 (10.0%)	0 (0%)	0 (0%)	9 (30.0%)	16 (53.3%)	11 (36.7%)	17 (56.7%)	14 (46.7%)	19 (63.3%)				0.370
First molar–second premolar	1 (3.3%)	0 (0%)	0 (0%)	12 (40.0%)	0 (0%)	0 (0%)	14 (46.7%)	26 (86.7%)	20 (66.7%)	3 (10.0%)	4 (13.3%)	10 (33.3%)				<0.001
Second premolar–first premolar	0 (0%)	0 (0%)	0 (0%)	10 (33.3%)	0 (0%)	0 (0%)	12 (40.0%)	28 (93.3%)	26 (86.6%)	8 (26.7%)	2 (6.7%)	4 (13.3%)				0.210
Anterior teeth																*p* value
Contact	O			X			I			S1			S2			
	T0	T1	T2	T0	T1	T2	T0	T1	T2	T0	T1	T2	T0	T1	T2	
First premolar–Canine	4 (13.3%)	0 (0%)	0 (0%)	6 (20.0%)	12 (40.0%)	7 (23.3%)	12 (40.0%)	18 (60.0%)	23 (76.7%)	4 (13.3%)	0 (0%)	0 (0%)	4 (13.3%)	0 (0%)	0 (0%)	0.620
Canine–Lateral Incisor	18 (60.0%)	0 (0%)	0 (0%)	4 (13.3%)	20 (66.7%)	19 (63.3%)	2 (6.7%)	10 (33.3%)	11 (36.6%)	2 (6.7%)	0 (0%)	0 (0%)	4 (13.3%)	0 (0%)	0 (0%)	<0.001
Lateral incisor–Central incisor	12 (40.0%)	0 (0%)	0 (0%)	6 (20.0%)	25 (83.3%)	23 (76.7%)	1 (3.3%)	5 (16.7%)	7 (23.3%)	7 (23.3%)	0 (0%)	0 (0%)	4 (13.3%)	0 (0%)	0 (0%)	0.670

O: open; X: point contact; I: straight contact; S: curved contact.

TABLE 3. Prevalence and percentages of mandibular teeth contacts (right side).

Posterior Teeth													*p* value
Contact	O			X			I			S			
	T0	T1	T2	T0	T1	T2	T0	T1	T2	T0	T1	T2	
Second molar–first molar	0 (0%)	0 (0%)	0 (0%)	9 (30.0%)	0 (0%)	0 (0%)	15 (50.0%)	23 (76.7%)	18 (60.0%)	6 (20.0%)	7 (23.3%)	12 (40.0%)	<0.001
First molar–second premolar	0 (0%)	0 (0%)	0 (0%)	6 (20.0%)	0 (0%)	0 (0%)	14 (46.7%)	26 (86.7%)	21 (70.0%)	10 (33.3%)	4 (13.3%)	9 (30.0%)	0.290
Second premolar–first premolar	0 (0%)	0 (0%)	0 (0%)	2 (6.7%)	0 (0%)	0 (0%)	26 (86.7%)	29 (96.7%)	27 (90.0%)	2 (6.7%)	1 (3.3%)	3 (10.0%)	0.250

Anterior teeth																*p* value
Contact	O			X			I			S1			S2			
	T0	T1	T2	T0	T1	T2	T0	T1	T2	T0	T1	T2	T0	T1	T2	
First premolar–Canine	4 (13.3%)	0 (0%)	0 (0%)	8 (26.6%)	9 (30.0%)	9 (30.0%)	12 (40.0%)	21 (70.0%)	21 (70.0%)	4 (13.3%)	0 (0%)	0 (0%)	2 (6.7%)	0 (0%)	0 (0%)	0.980
Canine–Lateral Incisor	4 (13.3%)	0 (0%)	0 (0%)	8 (26.7%)	28 (93.3%)	29 (96.7%)	1 (3.3%)	2 (6.7%)	1 (3.3%)	8 (26.7%)	0 (0%)	0 (0%)	9 (30.0%)	0 (0%)	0 (0%)	<0.001
Lateral incisor–Central incisor	2 (6.6%)	0 (0%)	0 (0%)	18 (60.0%)	28 (93.3%)	28 (93.3%)	0 (0%)	2 (6.7%)	2 (6.7%)	6 (20.0%)	0 (0%)	0 (0%)	4 (13.3%)	0 (0%)	0 (0%)	0.010

O: open; X: point contact; I: straight contact; S: curved contact.

TABLE 4. Prevalence and percentages of mandibular teeth contacts (left side).

Posterior Teeth													*p* value
Contact	O			X			I			S			
	T0	T1	T2	T0	T1	T2	T0	T1	T2	T0	T1	T2	
Second molar–first molar	2 (6.7%)	0 (0%)	0 (0%)	7 (23.3%)	0 (0%)	0 (0%)	12 (40.0%)	20 (66.7%)	14 (46.7%)	9 (30.0%)	10 (23.3%)	16 (53.3)	<0.001
First molar–second premolar	1 (3.3%)	0 (0%)	0 (0%)	6 (20.0%)	0 (0%)	1 (3.3%)	15 (50.0%)	20 (66.7%)	22 (73.3%)	8 (26.7%)	10 (33.3%)	7 (23.3%)	0.070
Second premolar–first premolar	0 (0%)	0 (0%)	0 (0%)	4 (13.3%)	0 (0%)	0 (0%)	24 (80.0%)	26 (86.7%)	27 (90.0%)	2 (6.7%)	4 (13.3%)	3 (10.0%)	0.170

Anterior teeth																*p* value
Contact	O			X			I			S1			S2			
	T0	T1	T2	T0	T1	T2	T0	T1	T2	T0	T1	T2	T0	T1	T2	
First premolar–Canine	1 (3.3%)	0 (0%)	0 (0%)	7 (23.3%)	7 (23.3%)	10 (33.3%)	13 (43.3%)	23 (76.7%)	20 (66.7%)	4 (13.3%)	0 (0%)	0 (0%)	5 (16.7%)	0 (0%)	0 (0%)	0.280
Canine–Lateral Incisor	2 (6.7%)	0 (0%)	0 (0%)	8 (26.7%)	27 (90.0%)	23 (76.7%)	1 (3.3%)	3 (10.0%)	7 (23.3%)	11 (36.7%)	0 (0%)	0 (0%)	8 (26.7%)	0 (0%)	0 (0%)	<0.001
Lateral incisor–Central incisor	2 (6.6%)	0 (0%)	0 (0%)	9 (30.0%)	26 (86.7%)	27 (90.0%)	3 (10.0%)	4 (13.3%)	3 (10.0%)	10 (33.3%)	0 (0%)	0 (0%)	6 (20.0%)	0 (0%)	0 (0%)	<0.001

O: open; X: point contact; I: straight contact; S: curved contact.

TABLE 5. Prevalence and percentages of midline contacts.

Contact	Midline															*p* value
	O			X			I			S1			S2			
	T0	T1	T2	T0	T1	T2	T0	T1	T2	T0	T1	T2	T0	T1	T2	
Maxilla	10 (33.3%)	0 (0%)	0 (0%)	12 (40.0%)	29 (96.7%)	26 (86.7%)	2 (6.7%)	1 (3.3%)	4 (13.3%)	4 (13.3%)	0 (0%)	0 (0%)	2 (6.7%)	0 (0%)	0 (0%)	0.75
Mandible	1 (3.3%)	0 (0%)	0 (0%)	22 (73.3%)	29 (96.7%)	29 (96.6%)	1 (3.3%)	1 (3.3%)	1 (3.3%)	2 (6.7%)	0 (0%)	0 (0%)	4 (13.3%)	0 (0%)	0 (0%)	0.03

O: open; X: point contact; I: straight contact; S: curved contact.

FIGURE 2. Representative cast images and their equivalent clinical photographs of the interproximal contacts at pre-treatment, post treatment and one-ear post treatment of the maxillary posterior region.

FIGURE 3. Representative cast images and their equivalent clinical photographs of the interproximal contacts at pre-treatment, post treatment and one-year post treatment of the mandibular posterior region.

FIGURE 4. Representative cast images and their equivalent clinical photographs of the interproximal contacts at pre-treatment, post treatment and one-year post treatment of the maxillary anterior region.

FIGURE 5. Representative cast images and their equivalent clinical photographs of the interproximal contacts at pre-treatment, post treatment and one-year post treatment of the mandibular anterior region.

The variations in individual tooth morphology and the ethnicity which could in turn impact the type of contact also need assessment. The effects of extractions and interproximal reduction on the contacts would also be the areas of future research.

5. Conclusions

Interproximal contact changes from T0 to T1. Point (X) and open (O) contacts were observed at T0. At T1 and T2, broader contacts (patterns I and S) were observed in the posterior segments. While most of the contact patterns were maintained at T2, changes in the interproximal contact patterns between "I" and "S" were observed. These changes are more frequently observed in the mandibular arch.

AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available on reasonable request from the corresponding author.

AUTHOR CONTRIBUTIONS

VK and SMM—designed the research study, wrote the manuscript. VK—performed research work. VK, SMM, GUR and CK—analyzed the data. GUR, CK, MK, JA and AW—provided help and advice on treatment design. All authors contributed to the editorial changes in manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was approved by the Sri Ramachandra Institute of Higher Education and Research Institutional Ethics Committee (REF: IEC-NI/19/JUL/70/50). The patients' parents or guardians have signed a written informed consent to use their data including photos and images.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found, in the online version, at https://oss.jocpd.com/files/article/1808366876463382528/attachment/Supplementary%20material.docx.

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