sciendo

DOI: 10.2478/aoj-2004-0011

Prediction and causes of open gingival embrasure spaces between the mandibular central incisors following orthodontic treatment

Tadataka Ikeda, Masaru Yamaguchi, Daijiro Meguro and Kazutaka Kasai
Department of Orthodontics, Nihon University School of Dentistry at Matsudo, Japan

Background: An open gingival embrasure space (OGES) between the mandibular incisors, also known as a "black triangle" (BT), can be an undesirable outcome of adult orthodontic treatment.
Objectives: The purpose of this study was to determine the parameters that contributed most to the occurrence of an OGES between the mandibular central incisors, the area with the highest incidence of BT in the lower arch following orthodontic treatment.
Methods: A stepwise regression model was used to identify the variables (age, crowding, treatment duration, alveolar bone height, and six variables describing crown morphology) related independently to OGES score. Intra-oral photographs taken before and after orthodontic treatment, study models and intra-oral radiographs of 60 patients were used. Embrasures between the mandibular central incisors were measured and classified into three types: papilla filling, pinpoint, and BT.
Results: Age at the first consultation, length of active treatment and maximum crown width were larger in the BT group than in the normal group. In contrast, incisal edge – centre of the contact point, upper contact point – lower contact point, mesial CEJ – distal CEJ, and mesial CEJ – distal CEJ / maximum crown width were smaller in the BT group than in the normal group. Variation in OGES score was explained by the independent contributions of age at the first consultation, duration of active treatment, maximum crown width, and mesial CEJ – distal CEJ width. The multiple regression coefficient was 0.98, and the regression coefficient square was 96 per cent.
Conclusion: We conclude that age at the first consultation, duration of active treatment, and crown morphology are involved in OGES manifestation. We suggest also that BT occurrence may be predictable prior to treatment.
(Aust Orthod J 2004; 20: 87–92)

Received for publication: February 2004
Accepted: June 2004

Introduction

An open gingival embrasure space (OGES), also known as a "black triangle" (BT), is occasionally found between the anterior teeth before and after orthodontic treatment (Figure 1). Patients often complain that the condition is aesthetically unfavorable and that food is retained in OGESs.[1–3] It has been reported that retraction of the interdental papilla, age changes in alveolar bone, and crown morphology contribute to OGES between the upper anterior teeth.[4] The characteristics of OGES in the mandible are largely undefined because there are generally fewer aesthetic concerns and, as a result, fewer reports of the occurrence of mandibular OGES. The aim of this study was, firstly, to determine the incidence of OGES between the mandibular central incisors in a group of adult orthodontic patients and, secondly, to obtain by a multiple regression analysis the parameters that contribute to OGES.

Materials and methods

Subjects

We studied retrospectively 60 patients with crowding, who had the four first premolars extracted followed by orthodontic treatment with a multi-bracket appliance. There were 16 men and 44 women between 14 and 31 years of age at the start of treatment (Mean age: 22 years). Informed consent was obtained from all subjects according to a protocol reviewed by the Board of Nihon University School of Dentistry at Matsudo.

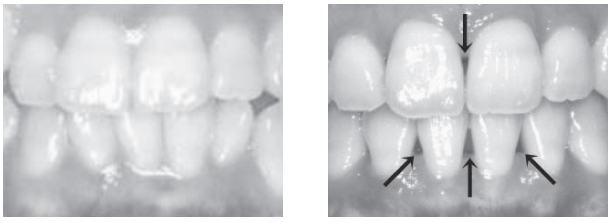


Figure 1. Open gingival embrasure space (OGES), pretreatment (left) and post-treatment (right).

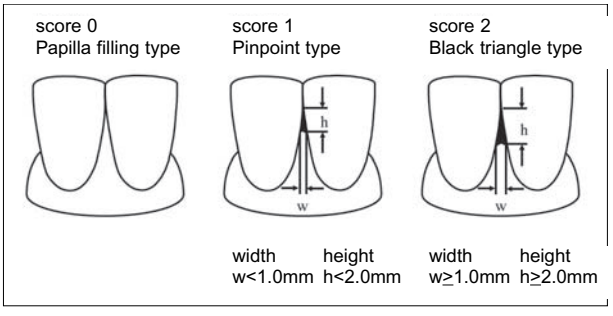


Figure 2. The classification of OGES.

The inclusion criteria were: a diagnosis of Class I crowding with no skeletal structural problems, and no OGES pretreatment. Intra-oral photographs, before and after orthodontic treatment, study models and intra-oral radiographs were obtained for each subject. No subject had marked periodontal disease, congenital abnormalities, deformed teeth, prosthetic teeth, marked attrition or abrasion of the mandibular incisors.

Evaluation of OGES

Using Ko-Kimura's modification of Burke *et al.*'s classification[5,6] the embrasures between the mandibular central incisors were measured and classified into three types: papilla filling type (Score 0, normal group); pinpoint type (Score 1, normal group; width < 1.0 mm, height < 2.0 mm); and BT type (Score 2, BT group; width ≥ 1.0 mm, height ≥ 2.0 mm). For the pinpoint and BT types either the width and/or height criteria had to be met. The embrasure measurements were made with a digital caliper (Max-Cal, NSK Company, Japan) capable of measuring to 0.01 mm (Figure 2).

For each subject the following variables were recorded:

1. Age at initial consultation (years).

2. Amount of crowding (mm). This was the difference between available length (the distance from the mesial surface of right mandibular lateral incisor to the mesial surface of the contralateral incisor) and required length (the sum of the maximum widths of the crowns of the mandibular central incisors) on the pretreatment study models.

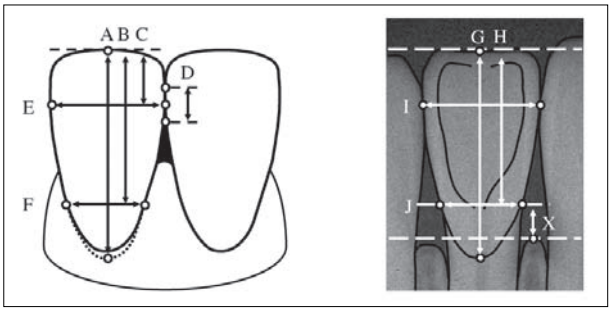


Figure 3. Crown and alveolar bone.
Crown length = A (G was expanded and was corrected, using the magnification ratio E/I).
Incisal edge – CEJ = B (H was expanded and corrected, using the magnification ratio E/I).
Incisal edge – centre contact point = C.
Upper contact point – lower contact point = D.
Maximum crown width = E.
Mesial CEJ – distal CEJ = F (J was expanded and corrected, using the magnification ratio E/I.).
Crest of the alveolar bone – CEJ = X.

3. Length of active treatment (months).

4. Distance from the alveolar bone to cemento-enamel junction before treatment (mm).

5. Crown morphology (crown length, incisal edge – CEJ, incisal edge – centre contact point, upper contact point – lower contact point, maximum crown width, mesial CEJ – distal CEJ width) (Figure 3).

Because gingival inflammation and crowding made it difficult to measure the crown variables directly, the study models and intra-oral radiographs were used. Crown morphology (six variables) and crowding were measured 10 times with the digital caliper used above. The standard deviations of the repeated measurements were: crowding (SD: 0.09 mm) and crown measurement (SD: 0.07 mm). From these findings we concluded that relatively small dimensions could be measured accurately with our method.

Statistical processing

The subjects were classified into two groups, the normal group (Score 0 and 1) and the BT group (Score 2), and the mean and standard deviation of age at the first consultation, amount of crowding, length of active treatment, crest of the alveolar bone – CEJ, and the six variables describing crown morphology (crown length, incisal edge – CEJ, incisal edge –

Table I. OGES between the mandibular central incisors.

Score	Type	Per cent
0	Papilla filling	20.0
1	Pinpoint	26.7
2	Black triangle	53.3

centre contact point, upper contact point – lower contact point, maximum crown width, mesial CEJ – distal CEJ) calculated. A stepwise regression model was then calculated[7] using age at the first consultation, amount of crowding, length of active treatment, crest of the alveolar bone – CEJ, and crown morphology (crown length, incisal edge – CEJ, incisal edge – centre contact point, upper contact point – lower contact point, maximum crown width, mesial CEJ – distal CEJ) as explanatory variables and OGES score (0, 1, 2) as the objective variable. The significance of the coefficient of the regression model was determined using a *t*-test. The estimated OGES score was obtained by substituting the explanatory variables in the regression model. The precision of the calculated regression model was determined using an F-test, on the basis of the regression coefficient square (R^2), which could be explained by the multiple regression coefficient (multiple R) that showed a correlation between the assessed value, the actual measurement results, and the regression model.

Results

The occurrence rates of OGES between the mandibular central incisors are given in Table I. BT type (Score 2) was seen in 53.3 per cent of the subjects, while pinpoint type (Score 1) accounted for 26.7 per cent and papilla filling type (Score 0) 20.0 per cent. Black triangles were found between the central incisors in 50 per cent or more of the cases after orthodontic treatment.

The comparisons of the normal group and BT group are given in Table II. The subjects in BT group tended to be older at the first consultation, and they were treated for a longer period of time. No significant differences were observed in amount of crowding or the distance from the crest of the alveolar bone to the CEJ between the two groups. In comparison with the normal group, the BT group had smaller mandibular incisal edge – centre contact point distance, and upper contact point – lower contact point distance, which indicated that the contact point (at the maximum crown width) was positioned closer to the incisal edge, making the adjacent crown contact area smaller. Furthermore, maximum crown width tended to be slightly larger, whereas mesial CEJ – distal CEJ width and mesial CEJ – distal CEJ / maximum crown width were significantly smaller, which showed that the central incisors were more tapered in the BT group. Crown length, incisal edge – CEJ, and maximum crown width / crown length were similar in both groups.

The multiple regression of OGES and the regression model of OGES score are given in Tables III and IV. Variation in OGES score was explained by the independent contributions of age at the first consultation, duration of active treatment, maximum crown width, and mesial CEJ – distal CEJ. Thus, the OGES score increased as age, the duration of treatment and the maximum crown width increased and as the mesial CEJ – distal CEJ dimension reduced. The multiple regression coefficient was 0.98, and the regression coefficient square was 96 per cent (Table IV). F-test results revealed that the regression model was significant with a risk rate of 0.1 per cent.

Discussion

It has been reported that the occurrence of BT involves retraction of the interdental papilla, age changes in alveolar bone (the distance between contact point and alveolar bone increases), crown morphology (position and morphology of contact point, size, morphology, and position of the crown), and the distance between the roots of adjacent teeth.[8] In the present study, age at the first consultation, the length of treatment and the amount of crowding were investigated to determine their involvement in the occurrence of BT.

We found the occurrence of BT between the mandibular central incisors after orthodontic treatment was higher than that reported by Kawauchi *et al.*[9] The likely reasons for this difference are the different criteria used by both groups of researchers to identify subjects with BT and/or our subjects were treated over a longer period of time. We found there was a higher incidence of BT in older subjects, and when orthodontic treatment was protracted. These results agree with an earlier study that reported a higher incidence of BT in patients over 20 years of age.[5] It would appear that the periodontal tissues in

Table II. Comparison of the groups.

		Normal (N = 28)		BT (N = 32)		
		Mean	SD	Mean	SD	*p*
Age at the first consultation	(years)	19.3	3.8	23.1	3.5	*
Amount of crowding	(mm)	-0.5	0.62	-1.19	0.94	
Length of active treatment	(months)	34.7	7.4	41.3	4.6	*
Crest of the alveolar bone – CEJ	(mm)	0.94	0.32	1.12	0.15	
Crown length	(mm)	8.36	1.26	8.56	0.95	
Incisal edge – CEJ	(mm)	5.63	0.88	6.2	0.95	
Incisal edge – centre contact point	(mm)	2.03	0.61	1.48	0.35	*
Upper contact point – lower contact point	(mm)	2.32	0.86	1.18	0.39	*
Maximum crown width	(mm)	5.56	0.48	6.02	0.09	*
Mesial CEJ – distal CEJ	(mm)	5.32	0.42	4.87	0.28	**
Mesial CEJ – distal CEJ / maximum crown width		0.96	0.04	0.84	0.07	**
Maximum crown width / crown length		0.69	0.1	0.7	0.07	

*$p < 0.05$, **$p < 0.01$

Table III. The result of multiple regression of OGES.

	Co	SE-Co	*t*	*p*
Age at the first consultation	0.053	0.019	2.711	*
Amount of crowding	-0.059	0.09	-0.659	
Length of active treatment	0.02	0.009	2.342	*
Crest of the alveolar bone – CEJ	0.125	0.447	0.28	
Crown length	0.272	0.322	1.838	
Incisal edge – CEJ	-0.361	0.154	-2.082	
Incisal edge – centre contact point	0.049	0.267	0.186	
Upper contact point – lower contact point	-0.146	0.161	-0.909	
Maximum crown width	1.233	0.282	4.366	**
Mesial CEJ – distal CEJ	-1.78	0.152	-11.684	***
Multi.R		0.98		
R square		0.961		

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$
Co : regression coefficient
SE-Co : standard error of regression coefficient
t : t value

Table IV. Regression model of OGES score.

OGES score = 0.05 a + 0.02 b + 1.23 c - 1.78 d + 1.30 ***
a: age at the first consultation (years),
b: length of active treatment (months),
c: maximum crown width (mm),
d: mesial CEJ – distal CEJ (mm)
Multiple.R = 0.98
R square = 0.96
F value = 53.1

***$p < 0.001$

younger patients are more active and, hence, are more likely to recover from appliance-induced stress. In our earlier study[5] we reported there was no difference between patients treated for more than 3 years and those who were treated in less than 3 years. Our present results suggest otherwise: long-term persistent orthodontic force has a harmful effect on the periodontal tissues leading to OGES. This disagreement may be due to treatment differences between the two studies.

We also found that pretreatment crowding was not an important determinant: BT was just as likely to occur in cases without crowding as in crowded cases, which agrees with the report by Kawauchi *et al.*[9] Others[10] have reported that plaque and gingival indices were significantly higher in patients with 4 mm or more mandibular incisor crowding than in patients without crowding. Diedrich *et al.*[11] also noted that patients with lower anterior crowding were more likely to have gingival inflammation, which if aggravated by periodontal disease resulted in an increase in the prevalence of BT. But the disagreement between our study and the report by Kawauchi *et al.*[9] may be due to the oral hygiene measures employed. In the present study, patients were reminded frequently of the importance of good oral hygiene throughout treatment. This simple measure may have been sufficient to lower the incidence of BT.

Tarnow *et al.*[12] reported that the prevalence of BT increased as the distance from maximum crown diameter to alveolar bone increased: the prevalence was about 0 per cent when this distance was 5 mm or less, and 73 per cent when it was 7 mm or more. In a study of resorption of alveolar bone during orthodontic treatment Hamp *et al.*[13] reported that, on average, 0.29 mm of alveolar bone was lost in the treatment group. Furthermore, Artun *et al.*[14] reported that 2.24 per cent of the alveolar bone support in the anterior region in adults was lost during orthodontic treatment. Thus, it appears resorption of the alveolar crest may occur during treatment and it may predispose to BT in adult patients. In the present study, because we were looking for predictors of OGES we measured the distance from the crest of the alveolar bone to the CEJ before treatment, and investigated its relationship with the prevalence of BT following treatment. The *t*-test results showed no significant difference, although the amount of alveolar bone was slightly lower in the BT group after treatment. Therefore, we concluded that the distance from the bone crest – CEJ was weakly associated with the prevalence of BT after treatment (Table II).

As for crown morphology, the incisal edge – centre contact point, upper contact point – lower contact point, mesial CEJ – distal CEJ, and mesial CEJ – distal CEJ / maximum crown width were smaller and maximum crown width larger in the BT group as compared with the normal group. We concluded that these factors, which are reflected in increases in the base length and height of a BT and result in less gingival tissue filling the interdental space, may contribute to the occurrence of BT (Table II). This agrees with Kokich *et al.'s*[15] hypothesis that the morphology of the central incisor crowns may be a significant factor in OGES. However, our results disagree with to those reported by Kawauchi *et al.*[9] who found no significant differences in crown morphology.

It has also been reported that BT is difficult to predict because of the low discrimination rate,[9] although prediction formulae for BT incidence have been proposed. Our regression model, which used age at the first consultation, length of active treatment, maximum crown width, and mesial CEJ – distal CEJ as the coefficients, was more satisfactory than previous models. The multiple regression coefficient of the regression model was 0.98, the regression coefficient square was 96 per cent. Furthermore, OGES score increased as age at the first consultation, length of active treatment, and maximum crown

width increased, and as the mesial CEJ – distal CEJ width reduced. This implies that OGES scores will increase with age, long-term chronic orthodontic force, and if the crowns of the central incisors are tapered. However, factors such as the skeletal pattern, tooth extraction, variation in incisor inclination and periodontal disease still need to be investigated.

Conclusions

Incisal edge – centre contact point, upper contact point – lower contact point, mesial CEJ – distal CEJ, and mesial CEJ – distal CEJ / maximum crown width were smaller, and age at the first consultation, length of active treatment and maximum crown width larger in the BT group as compared with the normal group.

A regression equation using age at the first consultation, length of active treatment, maximum crown width, and mesial CEJ – distal CEJ width was obtained, and these factors were considered useful for predicting OGES. However, further investigations are necessary to establish if other factors, such as the skeletal pattern, tooth extraction, variation in incisor inclination and periodontal disease may play a part in the occurrence of OGES.

Acknowledgment

This research was supported in part by a Grant-in-Aid for Scientific Research from the Japan Society for the Promotion of Science (C:14571970).

Corresponding author

Dr Masaru Yamaguchi
Department of Orthodontics
Nihon University School of Dentistry at Matsudo
2-870-1 Sakaecho-Nishi
Matsudo City
Chiba 271-8587
Japan
Tel: (+81) 47 360 9412
Fax: (+81) 47 360 9413
Email: dai@mascat.nihon-u.ac.jp

References

1. Morris ML. Artificial crown contours and gingival health. J Prosthet Dent 1962; 12: 1146–56.
2. Hirshberg SM. The relationship of oral hygiene to embrasure and pontic design – a preliminary study. J Prosthet Dent 1972; 27: 26–38.
3. Ferencz JL. Maintaining and enhancing gingival architecture in fixed prosthodontics. J Prosthet Dent 1991; 65: 650–7.
4. Kamijo Y. Illustrated Oral Anatomy Vol. 1. Osteology. 2nd edition, Tokyo, Ishiyaku Shuppan, 1997; 27–36.
5. Ko-Kimura N, Kimura-Hayasi M, Yamaguchi M, *et al.* Some factors associated with open gingival embrasures following orthodontic treatment. Aust Orthod J 2003; 19: 19–24.
6. Burke S, Burch JG, Tetz JA. Incidence and size of pretreatment overlap and posttreatment gingival embrasure space between maxillary central incisors. Am J Orthod Dentofacial Orthop 1994; 105: 506–11.
7. Furukawa T, Tango T. Statistics for Medicine, Tokyo, Asakura Shoten, 1993; 271–8.
8. Sjølien T, Zachrisson BU. Periodontal bone support and tooth length orthodontically treated and untreated persons. Am J Orthod 1973; 64: 28–37.
9. Kawauchi M, Mitsuya H. The changes of interdental papilla following orthodontic treatment. Tohoku Orthod J 2001; 9: 12–19.
10. El-Mangoury NH, Gaafar SM, Mostafa YA. Mandibular anterior crowding and periodontal disease. Angle Orthod 1987; 57: 33–8.
11. Diedrich PR. Orthodontic procedures improving periodontal prognosis. Dent Clin North Am 1996; 40: 875–87.
12. Tarnow DP, Magner AW, Fletcher P. The effect of the distance from the contact point to the crest of bone on the presence or absence of the interproximal dental papilla. J Periodontol 1992; 63: 995–6.
13. Hamp S, Lundstrom F, Nyman S. Periodontal conditions in adolescents subjected to multiband orthodontic treatment with controlled oral hygiene. Eur J Orthod 1982; 4: 77–86.
14. Artun J, Urbye, KS. The effect of orthodontic treatment on periodontal bone support in patients with advanced loss of marginal periodontium. Am J Orthod Dentofacial Orthop 1988; 93: 143–8.
15. Kokich VG. Esthetics: The orthodontic – periodontic restorative connection. Semin Orthod 1996; 2: 21–30.