European Journal of Orthodontics 20 (1998) 65–72

The relationship between irregularity of the incisor teeth, plaque, and gingivitis: a study in a group of schoolchildren aged 11–14 years

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SUMMARY The relationship between irregularity of teeth and periodontal disease was investigated in 201 children aged 11–14 years. The upper and lower incisor teeth were assessed for spacing, labio-lingual displacement, and mesiodistal overlap at each of the six contact areas. Plaque and gingivitis were assessed at six sites on each of the four upper and four lower incisor teeth. There was evidence for a direct relationship between the number of contact areas with tooth displacement combined with overlap and the number of sites with gingival redness ($R = 0.25$, $P < 0.001$), bleeding ($R = 0.18$, $P < 0.01$), and profuse bleeding ($R = 0.25$, $P < 0.001$). There was no evidence for a relationship between labio-lingual displacement alone and gingivitis. One-hundred-and-twenty-eight subjects without tooth displacement combined with incisor overlap had, respectively, 34, 15, and 35 per cent fewer sites with redness ($P < 0.01$), bleeding ($P < 0.05$), or profuse bleeding ($P < 0.01$) than the 73 subjects with overlap. The statistical significance of these differences was unaffected by covariate adjustment to take account of the effect on gingivitis of variation in the number of sites with plaque. There was no evidence of a relationship between incisor overlap and amount of plaque in these subjects. The results indicate that overlapping of incisor teeth is directly related to gingivitis and this relationship cannot be explained simply by an effect on oral hygiene.

Introduction

One possible justification for orthodontic treatment is that irregular teeth are more difficult to clean and therefore predisposed to gingivitis. However, when considering the possible risks and benefits of orthodontic treatment, Shaw *et al.* (1991) drew attention to the contradiction in research findings concerning the relationship between dental irregularity and periodontal disease. They considered that this arose from the difficulty of distinguishing the effect of irregularity from that of other important factors such as social class, gender, motivation and even toothbrushing hand (Addy *et al.*, 1988). The main influence of these factors on gingivitis would be through differences in the effectiveness of oral hygiene procedures. This view finds general support in the literature, for example, Buckley (1981) found that individual tooth irregularity had a low, but statistically significant correlation with plaque and gingival inflammation in a group of 300 teenagers, although he considered that the likely sequence was that crowded and irregular teeth facilitated the accumulation of bacterial plaque and then indirectly contributed to gingival inflammation.

Ainamo (1972), in a study of 154 army recruits, noted that periodontal disease was worse when adjacent to malaligned teeth around the maxillary anterior teeth, but the relationship was less marked in the premolar areas. He considered that an association between malalignment of teeth and periodontal disease would be most evident

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in the presence of average rather than exceptionally good oral hygiene or no oral hygiene. Presuming that the degree of malalignment allowed 'exceptionally good oral hygiene', then clearly such a level of plaque control would be consistent with periodontal health. However, it is possible to envisage malalignment, specifically that resulting in approximated roots, which would render it extremely difficult if not impossible to attain such a high standard of plaque control.

In a study of 11–14-year-old children a relationship between both mouth-breathing and lip coverage of the upper incisor teeth and gingivitis has been demonstrated (Wagaiyu and Ashley, 1991). Data on incisor irregularity were also collected, but the initial analysis of these data was extremely limited. The aim of the present study was to carry out a more detailed analysis of the data relating to incisor irregularity and gingivitis, and to investigate the influence on this relationship of other factors such as plaque amount and both mouth-breathing and lip coverage of the upper incisor teeth.

Subjects and methods

The subjects were 201 schoolchildren from the first three years of an inner-city comprehensive school. Parental consent had been obtained for 213 subjects to be examined; five subjects were absent from school and seven were excluded because of the presence of orthodontic appliances. The group comprised 86 females and 115 males with a mean age of 12.7 years (SD = 0.9).

Each subject was assessed by two examiners. The first examiner (EW) recorded gingivitis and irregularity, and the second (FPA) assessed plaque accumulation, as well as mouth-breathing and lip coverage of the upper incisor teeth. The mesio-buccal, mid-buccal, and disto-buccal sites together with the corresponding palatal sites on each of the eight upper and lower incisor teeth were assessed in each subject, yielding 48 sites per subject. The gingival assessment included the recording of the presence or absence of gingival redness and bleeding on probing (Sidi and Ashley, 1984). Plaque accumulation was assessed initially using modified Silness and Löe (1964) criteria where code 2 (plaque visible without probing) was the maximum score used. Subsequently, all the available plaque was collected from these sites and dry weight estimated (Ashley *et al*., 1984). Irregularity was assessed for the three contact areas of the incisor teeth in each jaw by recording the amount (mm) of spacing, mesiodistal overlap, and labio-lingual displacement for each of the contact areas using a metal ruler (Todd and Lader, 1988). Spacing, displacement, or overlap of less than 1 mm was not recorded. Upper lip coverage of the maxillary incisors was categorized using the criteria of Addy *et al*. (1987).

An assessment of whether the subjects were predominantly mouth-breathers was made on the basis of both observation, their response to questioning, and by the use of a mirror test (Wagaiyu and Ashley, 1991). The test was carried out by placing a double-sided mirror in a horizontal position between mouth and nose, and asking the subject to breathe normally whilst seated in a relaxed upright position.

In the statistical analysis clinical variables such as plaque and bleeding on probing, which had been recorded at two levels of severity, were collapsed to create dichotomous scores and the number of sites per subject which were affected was calculated.

The status of the six contact areas of the upper and lower incisor teeth was expressed as the number of contact areas with labio-lingual displacement with mesiodistal overlap, labio-lingual displacement without mesiodistal overlap, either type of configuration (a combination of the last two variables), and finally spacing.

Initially, the relationship between clinical variables was assessed using Spearman correlation coefficients, as it was difficult to achieve a normal distribution with variables representing irregularity of teeth. Subsequently, analysis of variance was performed comparing subjects with and without mesiodistal overlap for gingivitis using plaque, mouth-breathing, and lip coverage as covariates. Subjects were also split into three groups of approximately equal size according to their oral hygiene status in order to permit examination of the relationship between incisor irregularity and gingivitis in subjects with good, moderate, or poor oral hygiene. Finally, limited

Table 1 Mean scores for irregularity and spacing of incisor teeth: six contact areas assessed (201 subjects).

	Mean	Standard deviation
Contact areas with:		
Labio-lingual displacement with mesiodistal overlap	0.64	1.07
Labio-lingual displacement without mesiodistal overlap or spacing	0.30	0.66
Overlap and/or displacement without spacing	0.94	1.27
Spacing	0.80	1.23

Table 2 Mean scores for plaque and gingivitis around incisor teeth: 48 sites assessed (201 subjects).

	Mean	Standard deviation
Number of sites with:		
Plaque	20.14	11.71
Visible plaque	4.08	6.69
Plaque dry weight (mg)	1.63	1.61
Number of gingival sites with:		
Redness	10.32	10.52
Bleeding on probing	23.58	11.23
Profuse bleeding on probing	9.06	9.28

Table 3 Spearman correlation coefficients: number of contact areas with irregularity or spacing versus gingivitis scores (201 subjects).

	Number of gingival sites with		
	Redness	Bleeding	Profuse bleeding
Number of contact areas with:			
Labio-lingual displacement with mesiodistal overlap	0.25***	0.18**	0.25***
Labio-lingual displacement without mesiodistal overlap or spacing	0.04	–0.01	–0.06
Overlap and/or displacement without spacing	0.22**	0.15*	0.19**
Spacing	–0.10	–0.23***	–0.22**

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

analysis was carried out for the upper and lower incisor sites separately. Examiner reproducibility was assessed by repeating the examination of 16 randomly selected subjects after the completion of the main study.

Results

Seventy-three of the 201 subjects had one or more incisor teeth contact areas with labio-lingual displacement and mesiodistal overlap, 41 had displacement without overlap or spacing, 97 had overlap and/or displacement without spacing, and 77 had spacing. The mean values for irregularity and spacing are presented in Table 1, and for plaque and gingivitis in Table 2.

The pattern of correlation observed between irregularity and gingivitis (Table 3) indicated a consistent, statistically significant, direct relationship between the number of sites with labio-lingual displacement combined with mesiodistal overlap and gingivitis, but there was no evidence for a relationship between labio-lingual displacement and gingivitis if mesiodistal overlap was absent. There was still evidence of a statistically significant direct relationship between the number of sites with irregularity of any kind and gingivitis, but the level of statistical significance was reduced in comparison with consideration of sites with labio-lingual displacement combined with mesiodistal overlap. There was a statistically significant inverse relationship between the number of sites with spacing and the number of sites with bleeding ($0.01 > P > 0.001$), but not with the number of sites with gingival redness.

As expected, the three measures of plaque showed statistically significant positive correlations with gingivitis (Table 4), but there was no

Table 4 Spearman correlation coefficients for all incisor sites: plaque versus gingivitis and plaque versus crowding or spacing (201 subjects).

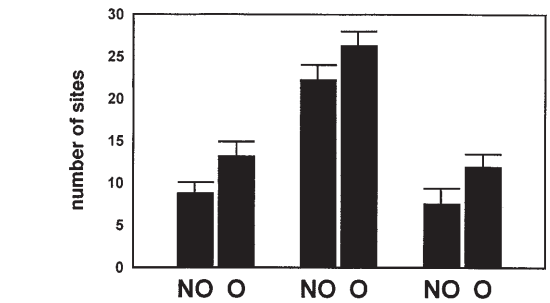
	Number of sites with		Plaque dry weight
	Plaque	Visible plaque	
Number of gingival sites with:			
Redness	0.58***	0.52***	0.52***
Bleeding on probing	0.39***	0.32***	0.34***
Profuse bleeding on probing	0.41***	0.38***	0.37***
Number of contact areas with:			
Labio-lingual displacement with mesiodistal overlap	0.08	0.03	0.07
Labio-lingual displacement without mesiodistal overlap or spacing	–0.08	–0.10	–0.08
Overlap and/or displacement without spacing	0.05	–0.01	–0.03
Spacing	–0.02	0.13	0.05

***$P < 0.001$.

evidence in these subjects of any relationship between irregularity and plaque. Notwithstanding, it was considered important to determine whether variations in gingivitis due to plaque were contributing to the relationship observed between labio-lingual displacement combined with mesiodistal overlap and gingivitis.

The 128 subjects without displacement combined with overlap of incisor teeth had respectively, 34, 15, and 35 per cent fewer sites with redness, bleeding, or profuse bleeding than the 73 subjects with both displacement and overlap of one or more incisor teeth (Figure 1). The statistical significance of these differences was unaffected by covariate adjustment to take account of any influence of variation in the number of sites with plaque or gingivitis. Further covariate adjustment to take account of additional variation due to mouth-breathing and lip coverage was also carried out resulting in F values of 5.41 ($P = 0.02$) for sites with redness, 2.19 ($P = 0.14$) for sites with bleeding, and 4.53 ($P = 0.04$) for sites with profuse bleeding.

The subjects were then split into three groups of approximately equal size according to their oral hygiene status (Table 5). A trend to an increase in the number of sites with displacement combined with overlap was noted as the groups' plaque scores increased, but there were no statistically significant differences between these



	redness	bleeding	profuse bleeding
ANOVA	8.95**	5.56*	9.60**
COVA adjusted for plaque	8.73**	4.58*	8.79**
COVA adjusted for plaque, lip coverage and mouthbreathing	5.41*	2.19	4.53*

* p<0.05 ** p<0.01

Figure 1 Bar diagram showing mean number of sites with redness, bleeding, or profuse bleeding for 128 subjects without labio-lingual displacement combined with mesiodistal overlap (no incisor overlap, NO) and 73 subjects with this condition (incisor overlap, O) at one or more incisor contacts. Bars represent standard errors of the mean. Table shows variance ratios (F values) for the differences between groups by analysis of variance (ANOVA) and analysis with covariate adjustment (COVA).

Table 5 Mean scores (SD) for displacement with overlap and gingivitis in subjects categorized according to plaque amount: group 1: 0–12 sites with plaque (n = 64); group 2: 13–26 sites (n = 69); group 3: >26 sites (n = 68).

	Group 1	Group 2	Group 3	P value*
Number of contact areas with displacement combined with overlap	0.48 (0.98)	0.67 (1.01)	0.75 (1.21)	0.35
Number of gingival sites with:				
Redness	3.77 (6.71)	9.48 (8.67)	17.35 (10.94)	<0.001
Bleeding on probing	19.03 (9.76)	23.04 (10.68)	28.41 (11.29)	<0.001
Profuse bleeding on probing	5.25 (5.64)	7.93 (8.65)	13.78 (10.67)	<0.001

*P-value related to overall analysis of variance between groups.

Table 6 Spearman correlation coefficients: irregularity versus gingivitis according to oral hygiene group: group 1: 0–12 sites with plaque (n = 64); group 2: 13–26 sites (n = 69); group 3: >26 sites (n = 68).

	Group 1 Good OH	Group 2 Moderate OH	Group 3 Poor OH
Number of contact areas with displacement combined with overlap versus number of gingival sites with:			
Redness	0.18	0.26*	0.26*
Bleeding on probing	0.06	0.12	0.31**
Profuse bleeding on probing	0.15	0.25*	0.31**

*$P < 0.05$; **$P < 0.01$.

Table 7 Spearman correlation coefficients: upper and lower incisors sites with displacement combined with overlap versus gingivitis scores (201 subjects).

Labio-lingual displacement with mesiodistal overlap:	Redness	Bleeding	Profuse bleeding
Upper incisors	0.17*	0.20**	0.21**
Lower incisors	0.19*	0.09	0.22**

*$P < 0.05$; **$P < 0.01$.

groups. Not surprisingly there were large, statistically significant differences in gingivitis between these groups.

A statistically significant relationship was observed between the number of sites with displacement combined with overlap and gingivitis in the moderate and poor oral hygiene groups, especially the latter (Table 6).

There was no evidence of a relationship in the subjects categorized as having good oral hygiene.

Finally, the data for the upper and lower incisor teeth were analysed separately (Table 7). The pattern of correlation observed was similar to that seen for upper and lower incisors combined (Table 3).

Reproducibility assessment based on the re-examination of 16 subjects approximately 3 months later indicated good agreement for both the number of sites with displacement and overlap, and sites with displacement alone, Cohen's Kappa being 0.7 (Bulman and Osborn, 1989). Reproducibility data for the other measurements have been published (Wagaiyu and Ashley, 1991).

Discussion

The results of the present study support the concept that there is an association between the presence of irregular incisor teeth and gingivitis. This relationship was more evident for incisor irregularity manifested by labio-lingual displacement with overlap rather than labio-lingual displacement without overlap. It is likely that the combination of displacement and overlap would have a more adverse effect on the ability to clean the approximal tooth surfaces than labio-lingual displacement alone and this might explain this finding. Such an explanation would also be consistent with the finding that spacing was associated with better gingival health in these 11–14-year-old schoolchildren. It is interesting to note that there is no evidence of a similar relationship in adults (Jernberg *et al*., 1983; Årtun and Osterberg, 1987)

Association does not infer causation and it might be argued that the presence of irregular teeth in 11–14-year-old subjects when orthodontic care is available could be indicative of a low level of dental awareness, which in turn might be accompanied by a less enthusiastic approach to oral hygiene. This did not appear to be the case in the present study as no relationship was found between irregularity and either the number of sites with plaque or the dry weight of the plaque which was collected from the incisor teeth. This finding contrasts with that of some earlier studies (for example, Alexander and Tipnis, 1970; Buckley, 1981; Griffiths and Addy, 1981), where statistically significant correlations were noted between crowding and amounts of plaque.

This discrepancy may relate to the different methods used in the present study to assess irregularity and plaque, and to the fact that the investigation was limited to the incisor teeth. Nevertheless, both irregularity and plaque correlated separately with gingivitis. The only evidence in the present study for an effect of irregularity on plaque accumulation came from the categorization of subjects into three groups according to oral hygiene status (Table 5) when a trend for incisor overlap to be least prevalent in subjects with the lowest plaque scores was noted.

If the relationship between irregularity and gingivitis is not secondary to a relationship between irregularity and plaque another explanation is required. One possibility is that incisor overlap has an effect on the shape and size of the gingival tissues, in particular their thickness. Waerhaeg (1979) put forward the concept of a limited zone of destruction in the gingival connective tissue in relation to adjacent plaque deposits. It is possible that when overlapped teeth result in a very 'thin' gingival tissue, especially interdentally, plaque deposits on one tooth surface may result in gingival inflammation at more of the adjacent sites than would have been the case if no overlapping was present and the gingival tissues were 'thicker'. It should also be remembered that such irregularity may result in an increase in the area of plaque on the approximal surfaces which would not only be inaccessible to tooth brushing, but also to assessment, using the methods employed in the present study. In addition, variations in the composition of plaque rather than the amount of plaque may also have contributed to the present findings.

The results do not suggest that incisor overlap is associated with gingivitis in the absence of plaque as there was no evidence of statistically significant relationships between irregularity and gingivitis in the subjects who were categorized as having good oral hygiene. However, there was a relationship between irregularity and gingivitis not only, as expected, in subjects with moderate oral hygiene, but also in subjects with poor oral hygiene (Table 6). This appears to contradict Ainamo's (1972) suggestion that when oral hygiene was poor or non-existent, an association between malalignment and gingivitis would be less likely to be revealed. However, in the poor oral hygiene group (Table 5, Group 3) there was considerable variation in the number of sites with gingivitis, whereas Ainamo found that in his

subjects the plaque and gingivitis scores approached maximum values around the posterior teeth in all subjects, reducing the possibility of finding differences associated with malalignment. It is interesting to note that Behlfelt *et al*. (1981) who compared normal and malaligned teeth within the same subjects found that plaque and gingivitis were more widespread around malaligned upper lateral incisors and lower second premolars than around contralateral teeth well positioned within the dental arches. They considered that their subjects were of 'average' oral hygiene.

Mouth-breathing and lip coverage of the upper incisor teeth are two factors which have been shown to be associated with gingivitis in the present subjects, in particular at sites around the incisor teeth (Wagaiyu and Ashley, 1991). Analysis of the data using these factors as covariates reduced, but did not eliminate, the statistical significance of the mean differences seen in gingivitis between subjects with and without overlap of incisor teeth. It is recognized that assessment of mouth-breathing is difficult. However, the examiner in the present study had routinely assessed mouth-breathing clinically for over 30 years.

The reduction in statistical significance seen as a result of using mouth-breathing and lip coverage as covariates is consistent with the earlier finding of Jacobson and Linder-Aronson (1972) who reported that there was a correlation between crowding and gingivitis in 55 children who were mouth-breathers which was not apparent in 40 children who were nose breathers.

It should be stressed that the present study was not concerned with periodontitis and in view of the known variation in susceptibility to periodontitis in subjects with gingivitis (Löe *et al*., 1986) it would be difficult to establish whether the relationship observed between incisor irregularity and gingivitis would be translated to a relationship with periodontitis in adult life. The question arises: is it reasonable to use the present results to support the case for orthodontic treatment to improve periodontal health in the absence of such information? Incisor irregularity was not associated with significant gingival inflammation in the subjects with good oral hygiene, but for many subjects it is difficult to achieve consistently good oral hygiene in the long-term for a variety of reasons. These results suggest that most patients would have less gingival inflammation if they did not have overlapped incisors. In addition, the fact that part of the relationship between incisor crowding and gingivitis appeared to be independent of variations attributable to our assessment of plaque, mouth-breathing, or lip coverage, suggests that further work on the exact mechanisms underlying the relationship of crowding and gingivitis is required.

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