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Functional occlusion after fixed appliance orthodontic treatment: a UK three-centre study

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SUMMARY This study aimed to assess the prevalence of functional occlusal contacts in cases treated to a Class I incisor relationship by upper and lower fixed appliance therapy. Helkimo's dysfunction indices were used by one examiner to assess mandibular mobility, clinical dysfunction and occlusal status. One-hundred-and-eighty-eight subjects participated in three UK orthodontic centres; Cardiff, Newport and Liverpool.

The results show that RCP (CR)–ICP (CO) discrepancies occurred in 33 (18 per cent) cases, non-working side contacts were present in 31 per cent and posterior contacts on protrusion occurred in 44 (23 per cent) subjects. These interferences were significantly more frequent in cases treated by postgraduate students compared with those treated by staff clinicians ($P < 0.05$). An overbite greater than 2.4 mm resulted in a highly significant reduction in the occurrence of non-working side contacts and posterior protrusive contacts ($P < 0.001$). The prevalence of functional occlusal discrepancies in this UK sample of orthodontic cases is similar to that reported in the American literature.

Introduction

The relationship between orthodontic treatment and temporomandibular (TM) joint disorders or occlusal dysfunction has been assessed by several researchers, mainly in the USA and Scandinavia (Sadowsky and BeGole, 1980; Janson and Hasund, 1981; Rinchuse and Sassouni, 1983; Mohlin and Thilander, 1984; Sadowsky and Polson, 1984; Olsson and Lindqvist, 1992; Sadowsky, 1992). The results suggest that the prevalence and development of TM disorders is no greater in orthodontically-treated patients than in untreated control subjects. The aetiological influence of dynamic or functional occlusal interferences on TM disorders is controversial, and even the 'ideal' or desirable occlusal features themselves are not universally agreed upon. Bilateral canine guidance was reported to predominate in 1200 subjects (Scaife and Holt, 1969), whereas Ingervall *et al.* (1991) reported that group function was more frequent on the working side in dental students. Contact on both working and non-working sides in a lateral excursion of the mandible was deemed normal and desirable, whereas a non-working side contact preventing contact on the working side was regarded as an interference (Carlsson and Ingervall, 1988). However, the optimum occlusion was described as one requiring a minimum of adaptation by the patient (Shillingburg *et al.*, 1981). The criteria for such an occlusion included the need for disclusion of teeth on the non-working side in lateral excursions and disclusion of posterior teeth on mandibular protrusion (Dawson, 1989). Overlapped anterior teeth bear all the occlusal load on excursions, but are slightly out of contact in the Intercuspal Position (ICP), when the posterior teeth are in contact and axially loaded. This is termed the Mutually Protected Occlusion (MPO). Consequently, the anterior teeth protect the posterior teeth in all mandibular excursions and the posterior teeth protect the anterior teeth in ICP (Shillingburg *et al.*, 1981). An MPO was a recommended orthodontic treatment goal within the limits of treatment and chairside time (Roth, 1981). Furthermore, the development of canine guidance has been

reported to be associated with an FMPA of 24 degrees or less, whilst group function occurred in all subjects with a greater FMPA (DiPietro, 1977).

Temporomandibular status and functional occlusion have received some attention from UK-based orthodontists (Pilley *et al.*, 1992). The introduction of two occlusal indices, the Index of Treatment Need (IOTN; Brook and Shaw, 1989) and the Index of Orthodontic Treatment Standards (Peer Assessment Rating or PAR Index; Richmond *et al.*, 1992) include aspects of static occlusal assessment, but are not designed for functional occlusal analysis (Shaw *et al.*, 1991). Many of the studies cited in the relevant literature use the clinical dysfunction and occlusal state indices described by Helkimo (1974). These established indices were used in the present study, the aim of which was to assess functional occlusion in orthodontic cases treated to a Class I incisor relationship by fixed appliance therapy in two university orthodontic departments and a district general hospital within the UK.

Subjects and methods

All subjects treated with upper and lower fixed orthodontic appliances and completed to a Class I incisor relationship were invited to participate in this study, which was carried out at three orthodontic departments within the UK. These departments were at Liverpool University Dental Hospital, University of Wales College of Medicine Dental School, Cardiff and the Royal Gwent Hospital, Newport, Wales. For the purpose of this study, an end of treatment Class I incisor relationship included those cases where the lower incisor edge was situated below the palatal aspect of the upper incisor. The overjet ranged between 1 and 5 mm and the overbite between 0 and 5 mm. Other inclusion criteria for the study were that the active phase of treatment had been completed and all subjects were in retention, and had not received orthognathic surgery. There was no residual space remaining from first molar to first molar (or second molar if present) in either arch and there was a good interdigitating buccal occlusion with either a Class I or Class II molar relationship.

The orthodontic assessment was carried out by one operator (RHAS). The original incisor malocclusion, the extraction pattern, if any, the type of fixed orthodontic appliance and whether or not the upper or lower second molars were banded were all noted. The overjet at the end of treatment was recorded by one operator (AM) with a ruler from the labial surface of the lower right incisor to the labial of the upper right incisor. The overbite was measured from the incisor edge of the upper right central to the incisor edge of the lower right central incisor. Lateral cephalographs taken at the beginning of treatment and upon completion of the active orthodontic phase enabled start and finish MMPAs to be measured. The operators carrying out the treatment were categorized into either postgraduate students or departmental staff members. The postgraduate students (n = 12), all registrars, were those individuals on a recognized course in preparation for the M.Orth diploma. Staff (n = 4) were those individuals who had already obtained their postgraduate orthodontic qualification, i.e. senior registrars and consultants. Neither the staff nor the students were aware of the orthodontic and occlusal parameters to be assessed.

The subjects were examined in the supine position by one operator (AM) who was calibrated on six subjects, examined on two occasions at least 3 weeks apart. The functional status of the stomatognathic system was assessed with the aid of the Helkimo indices of clinical dysfunction, mandibular mobility and occlusal status. Clinical dysfunction was based upon the responses to palpation of the temporomandibular joints and jaw opening muscles. Maximum mandibular opening was measured by dividers and a metal ruler (Rabone, England). Maximum mandibular protrusion from the upper right central incisor edge to the lower right central incisor edge was measured with the ruler, as well as maximum left and right excursive mandibular movements between the respective upper and lower canine tips. The occlusal index included a count of the total number of teeth present in the mouth as well as the number of teeth in contact in the Intercuspal Position (ICP)/Centric Occlusion (CO). In order to determine the relationship and examine for possible interferences/deviations

between Retruded Contact Position (RCP)/ Centric Relation (CR) and Intercuspal Position, the subjects were instructed to bite on a wooden tongue spatula for 5 minutes. This acted as a 'de-programmer', by discluding all teeth, which aided the subsequent bilateral mandibular manipulation into RCP. Following closure into RCP, the subjects were instructed to move the mandible into their most natural or comfortable position. The amount and direction of movement was assessed visually by one examiner (AM) for all cases. If RCP and ICP were coincident or a straight sagittal slide of up to 1 mm occurred then a score of 0 was given; a slide anteriorly of more than 1 mm, but less than 2 mm anteriorly and/or less than 0.5 mm laterally was scored 1; a slide anteriorly of more than 2 mm and/or more than 0.5 mm laterally was scored 2.

These criteria are expressed as no interferences between RCP and ICP, mild interferences or severe interferences. A modification to Helkimo's occlusal index was made in order to determine the guiding contacts on the working (rotating) and non-working (orbiting) sides in either right or left lateral mandibular excursions, and also on protrusion. Working side contacts were designated as none, canine-guided, group function, molar or incisor only. Non-working contacts were designated as either absent or present and when present were confirmed by dental floss, passed around the interfering cusp to see that the floss was not pulled through. Contact in protrusion was either anterior guided with incisor group function (all incisors in contact) and posterior disclusion, or was anterior guided without incisor group function (not all incisors in contact), but still with posterior disclusion, or there was no anterior (incisor) guidance, but posterior contact was present. These functional occlusion criteria are compatible with an MPO. The time between debond and analysis was calculated.

All data were analysed using the SPSS program on the University of Liverpool Unix system (Statistical Package for the Social Sciences, SPSS Inc., Chicago, IL, USA). Categorical data were analysed by chi-square tests and continuous data by the appropriate parametric comparison.

Results

A total of 188 subjects participated in this study, of whom 124 (66 per cent) were female and 64 (34 per cent) male, with an overall mean age of 17 years. The mean age for females, at 17.2 years (SD = 5.2 years) was not statistically different to the mean age of 16.6 years (SD = 3.0 years) for males (Student's *t*-test = 0.85). Inter-examiner reproducibility for the three Helkimo Indices was good with an overall unweighted Kappa value of 0.83.

The prevalences of the original incisor malocclusions are shown in Table 1, with over half the cases being Class II division 1. Most of the treatment was carried out with the use of a pre-adjusted straight wire appliance (Roth prescription; Table 2) with no significant differences of functional occlusion outcome between the various appliances. The means and standard deviations of several measures are shown in Table 3 with a mean time between debond and date of analysis of 6.9 months. The lower second molars were banded in 83 cases (44 per cent) compared with only 47 (25 per cent) banded upper second molars.

The prevalence of RCP–ICP discrepancies and excursive 'non-ideal' contacts is shown in Table 4, and Figure 1 presents the prevalences of the grades of severity of the Helkimo Indices.

Table 1 Original incisor malocclusion.

Class I	45 (24%)
Class II division 1	104 (55%)
Class II division 2	13 (7%)
Class III	26 (14%)
Total	188

Table 2 Type of fixed appliances.

Appliance	Number	Percentage
Andrews SWA	54	28
Bioprogressive	4	2
Begg	3	2
Edgewise	18	10
Roth SWA	109	58
Total	188	100

Table 3 Means with standard deviations of orthodontic and mandibular mobility variables. Mean time between debond and date of analysis also presented.

OJ (mm)	OB (mm)	Start MMPA	Finish MMPA	Maximum mandibular opening (mm)	Maximum excursion to right (mm)	Maximum excursion to left (mm)
2.4 (1.1)	2.4 (1.1)	27.9 (5.8)	27.4 (6.3)	45.7 (5.2)	5.6 (1.8)	5.5 (1.7)

Maximum protrusion (mm)	Total number of teeth	Total number of occluding teeth	Time between debond and date of analysis (months)
6.2 (2.0)	24 (1.5)	18 (5.0)	6.9 (5.5)

Table 4 The number of subjects with RCP–ICP discrepancies and excursive 'non-ideal' contacts.

	Absent	Present
RCP–ICP discrepancies	155 (82%)	33 (18%)
Right lateral non-working contacts	132 (70%)	56 (30%)
Left lateral non-working contacts	127 (68%)	61 (32%)
Protrusive interferences	144 (56%)	44 (23%)

The frequency of 'non-ideal' functional occlusal contacts was significantly greater in subjects treated by postgraduate students compared with subjects treated by orthodontic staff. Tables 5 and 6 show the contingency tables for left lateral non-working side contacts and protrusive relationships, respectively, with the result of the right lateral non-working side contacts being similar to the left lateral.

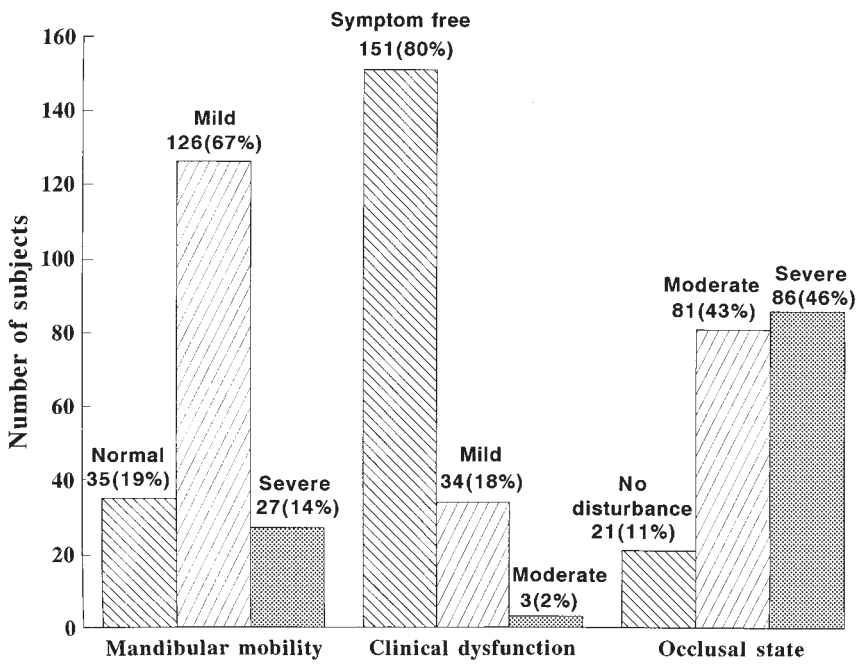

Figure 1 Prevalences of the Helkimo Indices.

Table 5 Occurrence of left lateral non-working side contacts according to operator.

	Postgraduate student	Staff orthodontist	Total
Non-working contact absent	83 (62%)	44 (80%)	127 (68%)
Non-working contact present	50 (38%)	11 (20%)	61 (32%)
Total	133 (71%)	55 (29%)	188 (100%)

$\chi^2 = 5.5$, df = 1, $P < 0.05$.

Table 6 Protrusive guidance according to operator.

	Postgraduate student	Staff orthodontist	Total
Anterior group function	15 (11%)	5 (9%)	20 (10%)
Anterior guidance without group function	80 (60%)	44 (80%)	124 (66%)
Posterior contact	38 (29%)	6 (11%)	44 (24%)
Total	133 (71%)	55 (29%)	188 (100%)

$\chi^2 = 8.0$, df = 3, $P < 0.05$.

Table 7 Frequency of functional non-working side and protrusive posterior contacts with a 2.4-mm overbite threshold.

	Overbite	No contact	Contact present	Total	*P* value
Right lateral non-working contacts	≤2.4 mm	44	38	82	
	>2.4 mm	88	18	106	
			$\chi^2 = 17.68$	df = 1	<0.001
Left lateral non-working contacts	≤2.4 mm	40	42	82	
	>2.4 mm	87	19	106	
			$\chi^2 = 21.89$	df = 1	<0.001
		Anterior guidance	Posterior contact		
Protrusive excursion	≤2.4 mm	47	35	116	
	>2.4 mm	97	9	72	
			$\chi^2 = 28.28$	df = 1	<0.001

The frequency of left and right canine guidance was not significantly greater in subjects with a pre-treatment MMPA of 24 degrees or less.

A moderate but significant association was found between the end of treatment overbite and dynamic excursive movements (Spearman's rho ranged between –0.4 and –0.3, $P < 0.01$). By setting a cut-off at the mean of 2.4 mm for overbite, the frequency of functional interferences with an overbite of less than, but equal to 2.4 mm compared with an overbite of more than 2.4 mm was highly significant and especially so with respect to protrusive posterior contacts (Table 7).

Discussion

The majority of subjects (80 per cent) in this study were in the clinically symptom-free category of the clinical dysfunction index (Figure 1) with only 20 per cent having symptoms, none of whom were in the severe category. This is similar to the results reported by Mohlin and Thilander (1984), but contrary to the high proportion of orthodontically-treated cases with mild through to severe symptoms found by Olsson and Lindqvist (1992). Janson and Hasund (1981) reported mild or moderate dysfunction symptoms

in the majority of their orthodontic subjects, but few were in the severe category. In the Illinois and Eastman studies (Sadowsky and Polson, 1984), the prevalence of TM clicks was found in a third of orthodontic subjects, which was not significantly different to the untreated control group.

Over 80 per cent of the subjects in the present study had moderate or severe disturbances of the occlusal status index (Figure 1). This can be accounted for by the high threshold set for the total number of teeth (28) and for those that occlude (24) in the 'no disturbance category'. Many of the subjects did not have a full complement of teeth because of orthodontic extractions and fell into the moderate/severe category. Therefore, the Helkimo Indices may not be appropriate for occlusal analysis in orthodontically-treated subjects with extractions. The frequencies of various functional occlusal relationships are thus presented and analysed as are the means of several variables in Table 3, rather than comparison of studies previously reported using the Helkimo Indices.

Only 33 (18 per cent) subjects exhibited an RCP–ICP discrepancy (Table 4), which was less than the Illinois orthodontic group (62 per cent), but similar to the Eastman orthodontic group (15 per cent; Sadowsky and Polson, 1984). A similar trend is found with the prevalence of protrusive contacts, 50 per cent of Illinois subjects and 21 per cent of Eastman subjects, compared with 23 per cent of the British subjects in this study. The most frequent functional occlusion potential interference was non-working side contacts occurring in 30 per cent of cases, which was less than the 85 per cent prevalence in the Illinois study or the 41 per cent prevalence in the Eastman study.

The significantly greater frequency of such potential interferences in cases treated by postgraduate students (Tables 5 and 6) may be accounted for by inexperience in correctly positioning brackets and bands. However, the presence of such functional occlusal contacts cannot necessarily be attributed to treatment since such contacts could have been present before treatment was commenced. Although, at the start of orthodontic treatment, canines are often malpositioned, and cannot contact the opposing arch or provide canine guidance during function, twice the number of subjects treated by postgraduate students had these contacts post-treatment; consequently, supervising staff are recommended to check the functional occlusion prior to debond in student cases.

The treatment outcome with respect to functional occlusion was not dependent upon the type of appliance, albeit most of the treatment was carried out with the Roth appliance (109 cases). Neither did the extraction pattern have any influence on the functional occlusion. Twenty subjects did not have any extractions, 126 subjects (67 per cent) had all four premolars removed, whilst the remaining 42 subjects underwent a variety of extraction combinations. The importance of an overbite greater than 2.4 mm to reduce the risk of resultant functional occlusal interferences has not been previously reported. The deeper overbite provides longer incisor and canine guidance on protrusion and lateral excursion respectively, which in turn discludes the remaining dentition. The presence of 'non-ideal' functional contacts does not necessarily imply that they are interferences or that TM problems will follow or that the tooth with the non-working contact will develop increased mobility consequent to septal bone loss (Yuodelis and Mann, 1965). There is good adaptation within the stomatognathic system in young healthy individuals. However, any change in occlusal stability or tooth position long-term coupled with a reduced adaptive capacity, could predispose the 'non-ideal' contact to become an interference and so, for instance, trigger bruxism. It would seem that an overbite of not less than 2 mm is a desirable feature in order to reduce potentially interfering contacts and should be considered an orthodontic treatment goal.

It is not surprising that an association was not found between canine guidance and an MMPA of 24 degrees, since compensatory mechanisms occur during the development of the stomatognathic system. DiPietro (1977) examined 112 subjects who had not undergone orthodontic treatment, whereas all the current subjects had, but it is unlikely that an extensive change in the relationship between MMPA and canine guidance would have occurred in the present study.

Other studies have compared functional occlusion in a control group to an orthodontic group, but no attempt was made to do this, since the prevalence of occlusal interferences after orthodontic treatment was the subject of this investigation. Furthermore, many subjects had an impacted or buccally displaced canine at the beginning of treatment, which prevented a meaningful evaluation of functional occlusion. It may be preferable, where feasible, for the functional occlusion to be assessed prior to the commencement of orthodontic treatment, during the retention phase and then at a later time, once the occlusion has settled. This would determine whether functional occlusion has or can be changed by fixed appliance orthodontic treatment and whether it remains so over a period of time.

Conclusions

The prevalence of functional occlusal interferences after fixed appliance orthodontic treatment in 188 British subjects was similar to previous American reports. However, significantly more protrusive and non-working side contacts occurred in subjects treated by postgraduate students compared with those treated by staff. Whether these contacts were present pre-treatment is not known, but supervising staff are recommended to closely monitor functional relationship in cases treated by students. An overbite greater than 2.4 mm resulted in significantly fewer protrusive posterior and non-working side contacts.

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