

Assessment of open and incomplete bite correction by incisor overlap and optical density of polyvinyl siloxane bite registration

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SUMMARY Open bite (OB) is a generalized term, which could incorporate subgroups that react differently to vertical correction. The objectives of the present study were to detect vertical treatment changes in incomplete bite (IB: inter-incisor overlap with no lower incisor contact with teeth or palate) and OB (no inter-incisor overlap) groups compared with a complete bite (CB: inter-incisor overlap with full lower incisor contact with teeth or palate) control group, to evaluate treatment response of the central and lateral incisors, and to study the vertico-sagittal interaction. Dental casts were taken at three time points, pre-treatment, post-treatment, and after one year of retention, from 54 Class II patients (22 males and 32 females with a mean age of 11 years 6 months) divided into three groups: CB ($n = 21$), IB ($n = 18$) and OB ($n = 15$). Measurements included incisor overlap (mm) and optical density (OD/mm²) of occlusal bite registration made of polyvinyl siloxane.

Both CB and IB groups demonstrated post-retention bite opening. However, bite opening in the CB group was three times greater than that in the IB group (e.g. lower lateral = -1.42 mm, 118 OD/mm² versus -0.40 mm, 107 OD/mm²). Conversely, the OB group showed a significant ($P < 0.001$) bite closure (e.g. lower lateral = 1.30 mm, -377 OD/mm²). Overjet changes affected OD measurements, causing diversity in OD and millimetric measurements of the lateral incisors in the IB group. In conclusion, the OB group demonstrated a significant stable vertical correction; a post-treatment non-contact inter-incisor relationship was determined by a vertico-sagittal relapse; and full compensation of an IB was not possible.

Introduction

An open bite (OB) is one of the most common malocclusions (Hoppenreijns and van der Linden, 1992; Chevitaresh *et al.*, 2002). Correction of an anterior OB is a difficult orthodontic objective because susceptibility to post-treatment relapse is high (Lopez-Gavito *et al.*, 1985; Beckmann and Segner, 2002; Shapiro, 2002; Janson *et al.*, 2003). Some relate this inherent side-effect to the underlying skeletal pattern (Nemeth and Isaacson, 1974; Ceylan and Eroz, 2001; Klocke *et al.*, 2002) with a genetic trait (Beane *et al.*, 2003; Lauc *et al.*, 2003). Others oppose this view (Stuani *et al.*, 2003) underscoring muscle imbalance as the major causative factor (Cayley *et al.*, 2000; Fujiki *et al.*, 2000; Yamaguchi *et al.*, 2000; Hotokezaka *et al.*, 2001; Matsumoto *et al.*, 2002). However, treatment success has been shown with diverse modalities, such as the multilooped archwire (Kim, 1987; Kim *et al.*, 2000), crib therapy (Huang *et al.*, 1990), or repelling magnets (Dellinger and Dellinger, 1996; Bazzucchi *et al.*, 1999). The correction mechanism comprises relative mandibular vertical growth, bodily incisor movement toward the occlusal plane, and lingual tipping of the lower incisors. Others relate success and stability of bite deepening to retrusion of the maxillary incisors and enlargement of the symphyseal height through a moderate increase in symphyseal volume (Beckmann and

Segner, 2002), or to change from infantile to mature tongue posture (Justus, 2001).

It has been suggested that an incomplete bite (IB) is a subgroup of an OB malocclusion (Denison *et al.*, 1989), which raises the question as to whether an OB and an IB react similarly in terms of correction and stability. Another problem when evaluating an OB is the interdependency between overbite and overjet (Figure 1). Katsaros and Berg (1993) defined post-treatment success when at least two incisors are in occlusal contact. This could suggest that the response to correction and/or relapse is not necessarily equal between all four incisors.

The objectives of the present study were to compare the correction potential and relapse tendency in complete OB malocclusion (negative overbite) versus an IB malocclusion (positive overbite with inter-incisor/palate clearance, i.e. non-contact) in relation to a control complete bite (CB) malocclusion (positive overbite with inter-incisor/palate contact), to determine if the central and lateral incisors show a similar reaction to vertical correction and relapse, and to study the vertico-sagittal interaction. The null hypothesis suggested no difference in vertical correction and relapse between the three groups, no diverse reaction between the incisors, and no vertico-sagittal interaction.

Subjects and methods

Sample groups

The study sample consisted of 54 patients (22 males, 32 females) with a Class II malocclusion, with a mean age of 11 years and 6 months. The sample was divided into three groups: OB ($n = 15$), IB ($n = 18$), and CB ($n = 21$, control).

Group selection was based on initial dental casts. The OB group was defined by no interjaw incisor overlap; the IB group by interjaw incisor overlap with no contact of the lower incisors with the hard tissues (upper incisors or palate); and the CB group by interjaw incisor overlap with full contact of the lower incisors with the hard tissues (upper incisors or palate). All groups were treated with straight wire edgewise appliances (Victory series brackets; 3M Unitek, Monrovia, California, USA). Dental casts were taken at three time points: T_1 – pre-treatment, T_2 – post-treatment, and T_3 – after one year of retention. Criteria for inclusion in the study were intact incisal edges of all eight upper and lower anterior teeth.

The diagnostic measurement on which this study was based was the anterior bite clearance. This distance was defined and measured, using the following two methods:

1. Incisor overlap: the extent of overlap or non-overlap of the lower incisors by the upper incisors was measured

from the dental casts in millimetres to the first decimal. Incisor overlap was measured at four sites, i.e. for each lower incisor. Overbite was assigned positive values, OB negative values, and an edge-to-edge incisal position 0 mm. The measurements were taken with a Digimatic Electronic calliper (Mitutoyo, Tokyo, Japan) accurate to 0.03 mm and with a resolution of 0.01 mm.

2. Optical density of occlusal bite registration: the change in thickness of the bite registration impression material was measured in optical density (OD) at the same four lower incisor sites. For each case, three bite registrations were made corresponding to the three treatment time points. Bite registration was taken with the silicone base polyvinyl siloxane, (Whaledent Inc., Mahwah, New Jersey, USA; Figure 2). Interocclusal registration for each time point was established according to the method of Owens *et al.* (2002). In contrast to wax, polyvinyl siloxane polymerization is temperature independent (Corso *et al.*, 1998) and its optical characteristics are stable after setting (Owens *et al.*, 2002). Polyvinyl siloxane, as an impression material, demonstrates superior mechanical properties, i.e. high strain tolerance (low modulus of elasticity). This allows its removal without distortion from dental undercuts (Chai *et al.*, 1998), which justifies its use as an interocclusal record material (Campos and Nathanson, 1999).

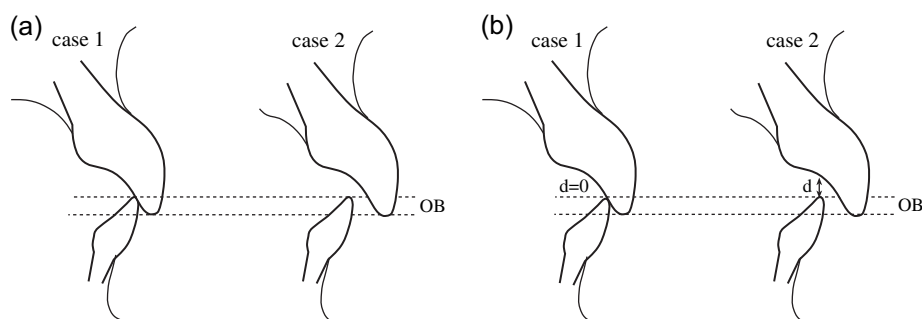


Figure 1 (a) In its classical definition, case 1 and 2 demonstrate the same amount of overbite. (b) However, when observing the dental casts in a postero-anterior direction, the lower incisor can be in contact with the upper counterparts (case 1) or not in contact (case 2) and the interocclusal distance (d) differs between the cases.

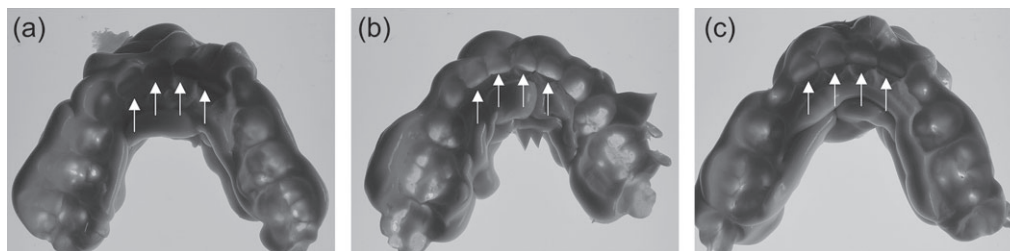


Figure 2 Bite registration was taken with a silicone base (polyvinyl siloxane) material. Optical density measurements were taken at four sites (arrows), corresponding to the mid incisal edge of the four lower incisors. (a) Pre-treatment: due to the open bite, no light is transmitted through the polyvinyl siloxane at the interincisor region. (b) Post-treatment: with a reduction in bite clearance, and consequently in polyvinyl siloxane thickness at the interincisor region, an increase in light transmission takes place. (c) Post-retention: due to relapse an increase in the interincisor distance and the polyvinyl siloxane thickness occurred causing a reduction in light transmission.

Prior to bite registration, the dental casts were lubricated with liquid paraffin along the occlusal tables and incisal edges of the posterior and anterior teeth to prevent incorporation of plaster particles in the polyvinyl siloxane registration material.

OD measurements of the interocclusal polyvinyl siloxane were taken at the mid-incisal point of all four lower incisors, using a computing transmission photodensitometer (Bio Imaging System 202D BIS, Rhenium, Jerusalem Israel). OD increased with an increase in thickness of the polyvinyl siloxane material, i.e. with increase in interocclusal clearance.

Statistical analysis

Descriptive statistics including mean OD values and standard deviations were calculated. Initial paired *t*-test examination demonstrated no right/left difference for both central and lateral incisors in each group. Based on these findings, right and left data were averaged for the central and lateral incisors per subject. For each measurement type (mm or OD), a one-way analysis of variance (ANOVA) was used to compare the three groups (CB, IB, OB) based on the differences between T_2 and T_1 (change during active treatment time) and T_3 and T_1 (total change after one year of retention). Tukey's *post-hoc* test was used when the ANOVA showed that the group means differed. Statistical significance was considered for $P < 0.05$.

Results

The reproducibility of the two measurement techniques (mm, OD) was examined by the ratio of the variance within subjects to the variance between subjects. This variance ratio was 1.25 per cent for the OD measurements and 0.25 per cent for the millimetric measurements, demonstrating that both measuring methods were reliable.

Incisor overlap (mm)

The incisor overlap for both incisors demonstrated a significant interaction ($P < 0.01$) between groups and time (Figure 3). As shown by one-way ANOVA and Tukey's test, the incisor overlap (central and lateral) of the OB group differed significantly ($P < 0.03$ – 0.001) from the CB and/or the IB groups at all time points (T_2 – T_1 and T_3 – T_1 ; Table 1). There was significant interaction over time between the groups due to the OB group ($P < 0.001$), and a significant ($P < 0.01$) diverse response between the central and lateral incisors.

In the CB group (control) the bite opened during the active treatment phase (T_2 – T_1) for both central (-1.6 ± 0.2 mm) and lateral (-1.5 ± 0.2 mm) incisors (Figure 4). There was almost no change during the retention phase, and consequently in the overall change (T_3 – T_1) bite opening

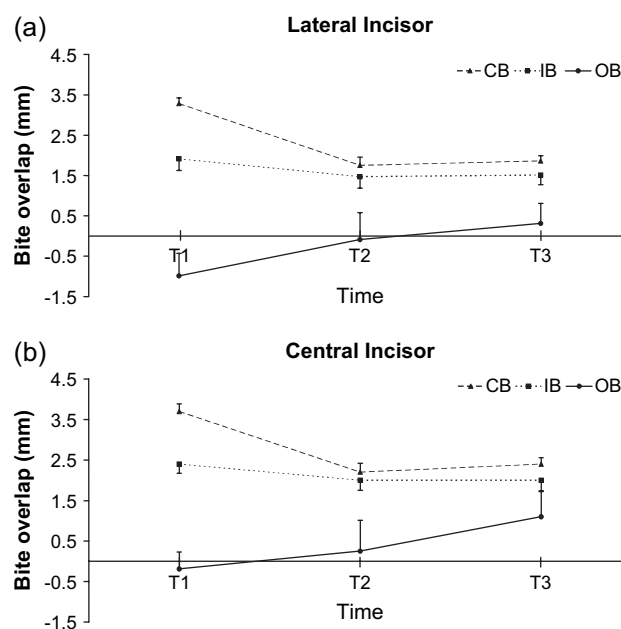


Figure 3 Change in bite overlap over time (T_1 = pre-treatment, T_2 = end of treatment, T_3 = one year of retention) for the three groups for the lateral (a) and central incisor. (b) CB, complete bite; IB, incomplete bite; OB open bite.

was maintained (central incisor = -1.4 ± 0.2 mm, lateral incisor = -1.4 ± 0.2 mm; Figure 4).

For the IB group, the bite opened slightly during the active treatment phase (central incisor = -0.4 ± 0.2 mm, lateral incisor = -0.4 ± 0.3 mm; Figure 5). It did not change during the retention phase, reaching an overall slight bite opening for both central (-0.3 ± 0.3 mm) and lateral (-0.4 ± 0.3 mm) incisors (Figure 5).

The OB group showed a significant converse reaction (Table 1) with an increase in overlap position during the active treatment phase (central incisor = 0.4 ± 0.7 mm, lateral incisor = 0.8 ± 0.7 mm; Figure 6), that continued during the retention phase reaching a significant overall decrease in bite opening for both central (1.3 ± 0.7 mm, $P = 0.003$) and lateral (1.3 ± 0.6 mm) incisors (Figure 6).

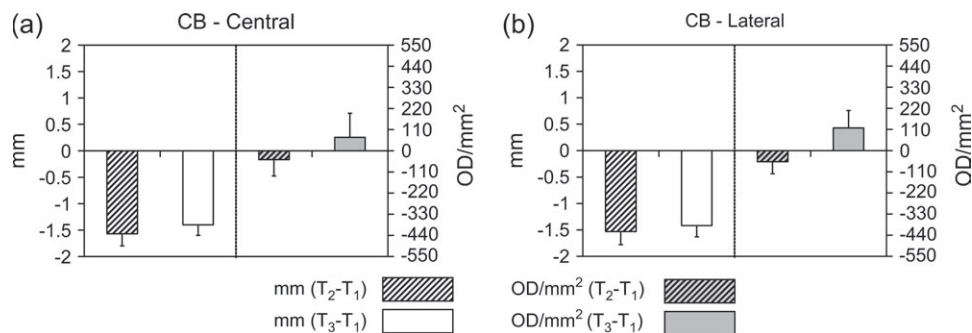
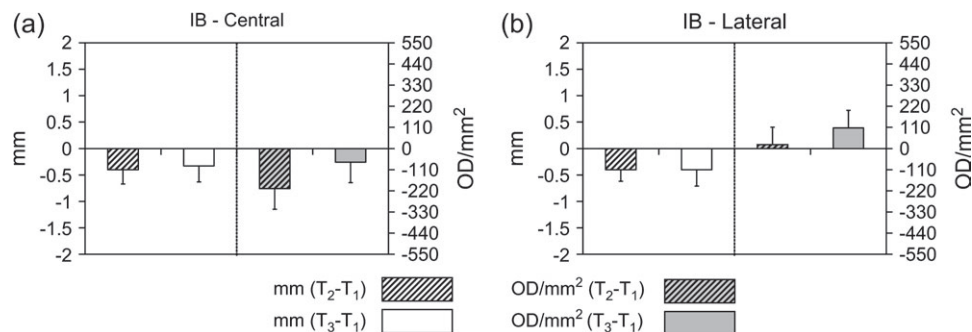
Optical density of occlusal bite registration (OD/mm²)

One-way ANOVA showed the change in OD between the groups during active treatment time (T_2 – T_1) was significant for the central ($P < 0.05$) and lateral incisors ($P < 0.001$). Tukey's *post-hoc* test demonstrated that during the active treatment time (T_2 – T_1), the central incisor in the OB group reacted significantly differently to that in the CB group (Table 1). For the lateral incisor, the OB group differed significantly from the IB group (Table 1). In the overall change (T_3 – T_1), only the lateral incisor of the OB group differed significantly ($P = 0.003$) from the IB group.

In the CB group OD decreased for both incisors (central = -46.5 ± 85.6 OD/mm², lateral = -57.8 ± 62.9 OD/mm²)

Table 1 Change during active treatment time (T_2-T_1) and during total change after one year of retention (T_3-T_1) for the central and lateral incisors in optical density (OD/mm²) and vertical overlap (mm) for the three groups.

Time	Tooth	Units	Complete bite	Incomplete bite	Open bite	Tukey	P
T_2-T_1	1	OD/mm ²	-46.5 ± 85.6	-209.7 ± 107.3	-401.7 ± 104.8	CB ≠ OB	<0.05
		mm	-1.6 ± 0.2	-0.4 ± 0.2	0.4 ± 0.7	CB ≠ OB	<0.001
	2	OD/mm ²	-57.8 ± 62.9	19.7 ± 91.1	-439.7 ± 102.2	IB ≠ OB	<0.001
		mm	-1.5 ± 0.2	-0.4 ± 0.3	0.8 ± 0.7	CB ≠ OB	0.03
T_3-T_1	1	OD/mm ²	69.8 ± 125.5	-71.1 ± 107.5	-141.1 ± 158.8	CB,IB ≠ OB	0.52
		mm	-1.4 ± 0.2	-0.3 ± 0.3	1.3 ± 0.7	CB,IB ≠ OB	<0.001
	2	OD/mm ²	118.1 ± 91.2	107.2 ± 92.7	-377.0 ± 143.6	IB ≠ OB	0.003
		mm	-1.4 ± 0.2	-0.4 ± 0.3	1.3 ± 0.6	CB,IB ≠ OB	<0.001

**Figure 4** Complete bite (CB) group: change in incisor overlap (mm) and optical density (OD/mm²) of occlusal bite registration from pre- to post-treatment (T_2-T_1) and from pre- to one year of retention (T_3-T_1) for (a) the lower central and (b) lateral incisor.**Figure 5** Incomplete bite (IB) group: change in incisor overlap (mm) and optical density (OD/mm²) of occlusal bite registration from pre- to post-treatment (T_2-T_1) and from pre- to one year of retention (T_3-T_1) for (a) the lower central and (b) lateral incisor.

during the active treatment time (T_2-T_1) implying a decrease in bite clearance (Figure 4). The OD consequently reverted to an overall increase at the end of T_3 (central incisor = 69.8 ± 125.5 OD/mm², lateral incisor = 118.1 ± 91.2 OD/mm²) indicating an increase in bite clearance (Figure 4).

Different responses were found in the IB group for the central and lateral incisors. OD decreased in the central incisor ($T_2-T_1 = -209.7 \pm 107.3$ OD/mm², $T_3-T_1 = -71.1 \pm 107.5$ OD/mm²) and increased in the lateral incisor ($T_2-T_1 =$

19.7 ± 91.1 OD/mm², $T_3-T_1 = 107.2 \pm 92.7$ OD/mm²; Figure 5).

The OD in the OB group significantly decreased in both incisors during the active treatment phase (T_2-T_1) (central = -401.7 ± 104.8 OD/mm², lateral = -439.7 ± 102.2 OD/mm²; Figure 6). The overall response (T_3-T_1) was a decrease in OB in both incisors (central = -141.1 ± 158.8 OD/mm², lateral = -377 ± 143.6 OD/mm²; Figure 6). However, some correction was lost as a result of relapse of the central incisor, but not of the lateral incisor during the retention phase.

Discussion

Complete bite (CB)

The thickness of the polyvinyl siloxane bite registration impression material is determined by vertical and sagittal changes of the lower incisors in relation to the upper incisors or the hard palate. During treatment from T_1 to T_2 , the millimetric and OD measurements decreased. This means that in addition to correction of the OB, the Class II malocclusion was corrected by overjet reduction, which resulted in tighter inter-incisor contact (Figure 7a,b). However, the millimetric measurements did not change during the retention period (Figure 4), but the OD measurements increased to positive values (Figure 7b,c). This is explained by maintenance of the overbite combined with relapse (increase) in overjet. The rebound in overjet is associated with the patient's initial Class II malocclusion, causing increased thickness of the bite registration material and an increase in OD measurement. Zuroff (1990) also found this combination between overjet and overbite. In two studies using the same sample, relapse (35 per cent)

was found when overbite and overjet were considered (Lopez-Gavito *et al.*, 1985), and no relapse when the lower incisor position to the nasion-menton line was studied from cephalometric records (Zuroff, 1990). That is, in the first study (Lopez-Gavito *et al.*, 1985) when the post-treatment Class I occlusion rebounded to Class II, the distance from the lower incisor tip increased as it was measured to the hard palate. In the second study (Zuroff, 1990) as long as the post-treatment inter-incisor vertical relationship did not change, the treatment results were considered stable.

Incomplete bite (IB)

The IB group showed a similar bite opening reaction as the CB group for both the central and lateral incisors. However, this reaction was mild, approximately one-third the magnitude of that in the CB group. That is, relative to the CB group there was an improvement in bite closure, although statistically non-significant (Table 1). The reaction of the occlusal bite registration is perplexing. The two incisors reacted in an opposite direction. OD measurements

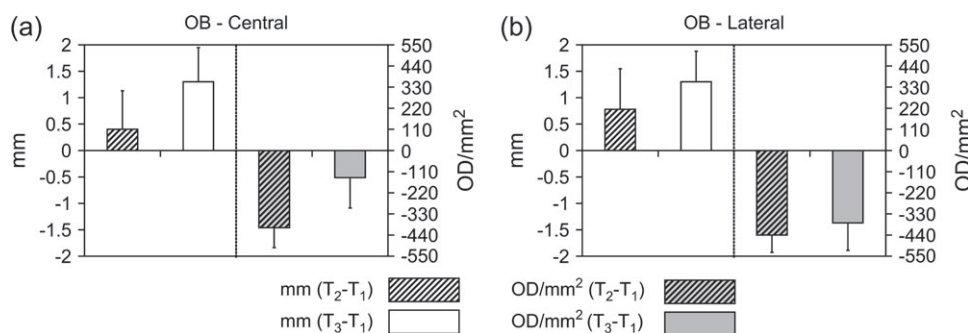


Figure 6 Open bite (OB) group: change in incisor overlap (mm) and optical density (OD/mm²) of occlusal bite registration from pre- to post-treatment (T_2-T_1) and from pre- to one year of retention (T_3-T_1) for (a) the lower central and (b) lateral incisor.

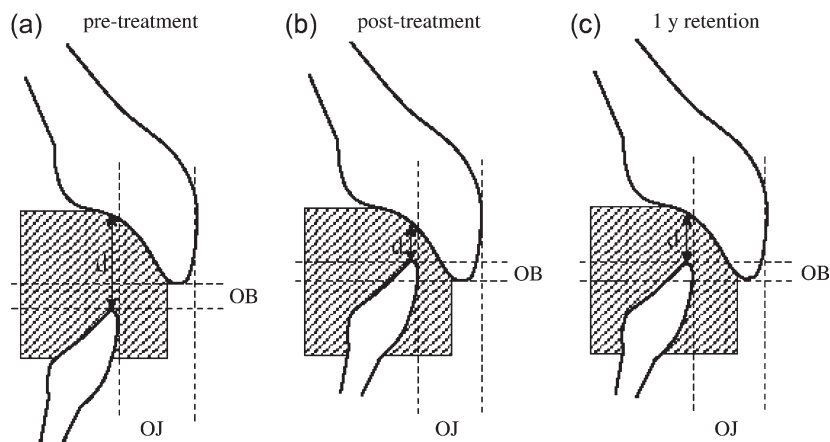


Figure 7 Schematic illustration of the interrelated effect of an open bite (OB) and overjet (OJ) on the optical density (OD) measurements. From (a) to (b) OB and OJ decreased, leading to a decrease in the bite registration material and in OD. From (b) to (c) OB was maintained, while OJ increased (relapse towards Class II), leading to an increase in the bite registration material and consequently in OD.

of the lower lateral incisor increased at both T_2-T_1 and T_3-T_1 , while those of the lower central incisor decreased, which indicates an increase in bite registration material in the former and a decrease in the latter (Figure 5). These findings suggest that with an IB the lateral incisor is prone to terminate in a non-contact inter-arch relationship, partially due to lingual displacement, especially during the post-treatment stage. In contrast, the lower central incisor, in spite of the mild decrease in overbite, acquired an improved inter-arch relationship with the upper central incisor. The fragile inter-arch relationship of the lower lateral incisor is probably related to its three teeth contact arrangement (upper central and lateral incisor with the lower lateral incisor) compared with the more stable inter-arch relationship of the lower central incisor formed by two teeth contact arrangement (lower and upper central incisors). The disconnection tendency of the lower incisor from its maxillary counterparts accentuates the need to retain its vertical and sagittal correction with a fixed measure in one or both dental arches. In general, the high standard deviation of the OD measurements was related to the two-dimensional influence of the vertical and sagittal dimensions on the thickness of the registration bite.

Open bite (OB)

The OB group showed the most substantial and significant vertical correction (Table 1). In contrast to the bite opening found in both the CB and IB groups, this group demonstrated at T_3 , bite closure of the same magnitude as the opening in the CB group but in the opposite direction (about 1.5 mm). That is, a positive change of almost 3 mm compared with the CB (control) group. Moreover, the vertical correction of this type of malocclusion was stable as bite closure continued to improve during the retention period (Figure 3). Expression in OD of the bite registration matched the millimetric changes in incisor overlap for both the central and lateral incisor. However, some deterioration in OD during the retention period was probably related to relapse in the sagittal plane.

The greater stability of the OB group compared with the IB group in the present study is supported by Zuroff (1990), who found that 20 per cent of OB patients relapsed back to an IB, 28 per cent of initial IB patients relapsed again to an IB, and in CB patients, only 4 per cent relapsed to an IB. This same pattern of relapse was also found in orthognathic patients who underwent LeFort I osteotomies (Denison *et al.*, 1989).

Conclusions

1. The OB group showed the greatest and statistically significant vertical correction and stability (1.5 mm) compared with the IB and CB groups.
2. The IB group showed the same bite opening tendency as the CB (control) group, although to a lesser extent

(one-third), which suggests that correction of an IB is feasible, but not completely.

3. Vertical bite clearance is determined by interrelated reaction between overjet and overbite as detected by OD measurements.
4. The lateral and central incisors demonstrated a similar response during and after treatment in the CB and OB groups in contrast to the IB group.
5. The lateral incisor in the IB group was prone to relapse.

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