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Occlusal bite force changes during 6 months of orthodontic treatment with fixed appliances

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Background: Occlusal bite force (OBF) is reported to change during fixed appliance orthodontic treatment.
Aims: The aim of the present study was to determine bite force changes during the first 6 months of fixed appliance orthodontic treatment and to investigate the relationship between patients' subjective pain levels and recorded changes in OBF.
Methods: Forty-seven subjects (34 females, 13 males) were recruited from the Dental Teaching Centre at the Jordan University of Science and Technology. The subject's ages ranged between 18 and 26 years (average 19.0 ± 3.36 years). Bite force was measured using a portable OBF gauge at nine time intervals (T0 - T8). At each OBF recording, subjects were asked to describe their subjective pain level using a visual analogue scale (VAS). A repeated-measures analysis of variance and a Bonferroni post-hoc comparison test were applied to determine differences at the various time intervals.
Results: Bite force significantly reduced during the first month of orthodontic treatment and approximately 50% of pretreatment OBF was lost by the end of the first week. However, bite force recovered to pretreatment levels by the end of the sixth month. Visual analogue pain scores were higher during the first 2 weeks of treatment and were positively correlated with the OBF loss.
Conclusion: OBF reduced during the first month of orthodontic treatment but, with time, recovered to pretreatment levels.
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Introduction

While many indicators have been used to assess the functional state of an occlusion, occlusal bite force (OBF) has been a key predictor of masticatory performance.[1] The number and size of occlusal contacts are considered the primary determinants of masticatory function for individuals with a complete dentition.[2] The nature of occlusal contacts has been shown to determine 10% to 20% of the variation of maximum bite force in adults.[3]

A reduced maximum bite force has been associated with a malocclusion.[4-6] Children with a unilateral posterior crossbite have been shown to have reduced maximum bite force and a reduced number of occlusal contacts compared with children possessing normal occlusions.[4] Sonnesen and Bakke[11] confirmed that bite force reduced immediately after the commencement of unilateral crossbite treatment but increased after retention and approached bite force levels in children with a normal occlusion. It was postulated that the fluctuation in bite force during crossbite correction was due to transient changes in occlusal contact and support.[11] In addition, Yawaka et al.[9] examined changes in the average occlusal bite force of patients with an anterior crossbite in the primary dentition and noted that bite force was lowest as the crossbite was treated but then gradually increased. Furthermore, Winocur et al.[10] found that occlusal bite force increased after orthodontic treatment compared with that measured prior to appliance removal and Henrikson et al.[7] revealed that females with normal occlusions had better masticatory performance than their Class II counterparts.

Maximum OBF has been shown to decrease during orthodontic treatment.[8-11] Thomas et al.[8] indicated that bite force decreased in patients scheduled for orthognathic surgery. However, unlike routine orthodontic treatment, presurgical treatment often increased the severity of a malocclusion by the decompensation process and a likely reduction in the number of occlusal contacts. In addition, pain is considered to be a modifying factor which limits the force of maximum bite due to reflex mechanisms.[12,13] Goldreich et al.[14] reported that pain had an effect on muscle activity even when it did not originate in the associated muscle or a related joint. Pain and discomfort of the orthodontic appliances and the induced malocclusion produced a reduction in occlusal bite force during and after presurgical orthodontics.[8]

While bite force changes have been shown to occur during routine orthodontic treatment,[9] research in this area has been minimal and mostly performed on surgical cases. Therefore, the aims of this study were to determine OBF changes during the first 6 months of fixed appliance orthodontic treatment and to investigate the relationship between patients' subjective pain levels and observed changes in OBF.

Materials and methods

Ethical approval for the present study was obtained from the Research Board of Jordan University of Science and Technology (JUST). All patients attending the orthodontic clinic at the Dental Teaching Centre during the period between October 2008 and June 2009 were screened. Of the 253 orthodontic patients, 47 (34 females, 13 males) patients who fulfilled the following criteria were included in this study:

1. No prior orthodontic treatment.
2. Adult Caucasian (>18 years).
3. Class I skeletal pattern (2° ≤ ANB ≤ 4°).
4. Average maxillomandibular plane angle (27 ± 5°).
5. No or mild crowding (0-4 mm).
6. No congenitally absent or missing permanent teeth.
7. No posterior crossbite.
8. No signs or symptoms of temporomandibular joint dysfunction.
9. No craniomandibular anomalies or systemic muscle or joint disorders.
10. No large carious lesions or restorations on upper or lower first permanent molars, and small carious lesions elsewhere restored prior to orthodontic treatment.
11. No periodontal disease.

The age of the subjects ranged between 18 and 26 years with a mean age of 19.0 ± 3.36 years. The average ANB angle for the sample was 3.60 ± 0.73 degrees, while the average maxillomandibular plane angle was 28.31 ± 2.85 degrees. Overjet was slightly increased and averaged 4.57 ± 0.29 millimeters. The average crowding was 2.39 ± 1.40 millimeters.

A control group comprising 47 dental students (34 females, 13 males) who possessed normal occlusions was selected and examined in order to provide comparative OBF levels over a period of six months. Occlusal bite force was recorded in these subjects on six separate occasions with an interval of one month between measurements. The OBF registration procedure was explained and written consent obtained from all subjects prior to the commencement of the study.

Orthodontic treatment involved the insertion of a preadjusted edgewise orthodontic appliance (Omni 0.022 inch Roth prescription, GAC International Inc., NY, USA) to the upper and lower arches. Upper and lower first and second permanent molars were banded in all treatment patients (GAC International Inc., NY, USA). Neither extra-oral appliances nor maxillary expansion devices were used for any patient. All patients were treated by the same consultant (EA) utilising a non-extraction treatment protocol. The archwire (3M Ltd, Unitek, Monrovia, CA, USA) sequence used during orthodontic treatment was the same for all patients (Table I). Occlusal bite force was recorded using a battery-operated portable type of OBF gauge (GM10, Nagano Keiki, Tokyo, Japan). The bite force gauge consisted of a hydraulic pressure gauge and a biting element made of a vinyl material encased in a polyethylene tube (disposable cap). The measured OBF force was calculated in Newtons (N) and displayed digitally.

OBF was bilaterally measured in the first permanent molar region. Before recording, each subject was instructed to sit upright, looking forward without head support and with the Frankfort plane parallel to the floor. Each subject was instructed to bite as hard as possible without moving their head. Three OBF measurements were recorded on each side with a 15 second rest between each bite. The maximum OBF measurement achieved on each side was recorded. The averaged maximum OBF was considered as the occlusal bite force (OBF) for that patient and included in the analysis. All measurements were carried out by the same investigator (SA) and OBF was recorded at the following time intervals:

Table I. Archwires sequence used during orthodontic treatment.

Recall visit	Archwire (Nickel-Titanium (Ni-Ti)), stainless steel (SS)
Bond-up visit	Upper and lower 0.014 Ni-Ti archwires
First month	Upper and lower 0.016 Ni-Ti archwires
Second month	Upper and lower 0.018 Ni-Ti archwires
Third month	Upper and lower 0.016 x 0.022 Ni-Ti archwires
Fourth month	Upper and lower 0.016 x 0.022 SS archwires
Fifth month	Upper and lower 0.017 x 0.025 SS archwires

1. Just prior to orthodontic elastic separator insertion (T0).
2. One week after the placement of orthodontic appliances (T1).
3. Two weeks after the placement of orthodontic appliances (T2).
4. One month and up to six months (T3-T8) after placement of orthodontic appliances and before the scheduled arch wire change for that visit.

At each OBF was recording, subjects were asked to describe their subjective pain level experienced at the time of their previous arch wire change using a 'Visual Analogue Scale' (VAS). The scale used a horizontal 10 cm baseline with two extremes representing 'no pain' extending to 'pain as bad as it could possibly be'. The patient was asked to indicate their subjective pain level relative to the two extremes and the distance from the low end of the scale to the patient's mark was measured to the nearest millimetre to represent the index of pain intensity. All measurements were made by the same investigator (SA) using the same stainless steel ruler. Subjective pain levels were then classified into three categories according to the VAS scores; mild pain if the VAS scores were between 0.1 cm and 3 cm, moderate pain if the VAS scores were between 3.1 cm and 6 cm and severe pain if the VAS scores were greater than 6 cm. OBF measurements for the control group were taken in a similar manner to the treatment group.

Statistical analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences computer software (SPSS 17.0, SPSS Inc., IL, USA). Shapiro-Wilks w-test revealed that OBF data were normally distributed. Descriptive statistics for OBF and VAS scores at the different time intervals were program calculated. The independent-sample student *t*-test was used to detect gender differences in OBF and VAS scores. A repeated measures analysis of variance (within-subjects ANOVA) test and a Bonferroni post-hoc comparison test were conducted to examine and define the differences between the OBF and VAS scores at the different time intervals before and during orthodontic treatment. Spearman correlation coefficients were calculated for OBF changes in relation to VAS pain scores. Statistical significance was predetermined at the $p \leq 0.05$ level.

Method error

The Dahlberg formula[15] was used to calculate the standard error of the method $S = \sqrt{\sum d2/2n}$. Houston's coefficient of reliability[16] was also calculated. Dahlberg error was 2.74 N and the coefficient of reliability was 89 per cent.

Results

The mean OBF, standard deviation and percentages of OBF loss and recovery during orthodontic treatment at the different time intervals for females, males and the total treatment group are shown in Table II. The patterns of OBF change during orthodontic treatment at different time intervals (T0 - T8) for females, males and the total treatment group are shown in Figures 1 and 2 respectively. Gender differences in OBF were not detected.

The mean OBF in the control group was 662.60 ± 246.37 N and 467.38 ± 173.99 N in the treatment

Table II. Mean OBF, SD and percentages of OBF loss and recovery at different time intervals.

Time interval	Control (N = 47)	Females (N = 34)			Males (N = 13)			Total treatment group (N = 47)		
	OBF (Mean ± SD)	OBF (Mean ± SD)	OBF loss %	OBF recovery %	OBF (Mean ± SD)	OBF loss %	OBF recovery %	OBF (Mean ± SD)	OBF loss %	OBF recovery %
Before Bond-up (T0)	-	418.91 ± 135.81	-	-	594.15 ± 203.13	-	-	467.38 ± 173.99	-	-
1st week (T1)	-	152.76 ± 109.45	63.53*	-	398.54 ± 201.28	32.92*	-	220.74 ± 177.52	52.71*	-
2nd week (T2)	-	212.82 ± 114.31	49.20*	22.57	442.54 ± 196.93	25.51*	22.49	276.36 ± 174.01	40.82*	22.55
1st month (T3)	662.60 ± 246.37	310.68 ± 142.06	25.84*	59.33	499.62 ± 186.66	15.91	51.68	362.94 ± 175.68	22.32*	57.65
2nd month (T4)	648.38 ± 245.99	359.94 ± 135.55	14.08	77.84	547.54 ± 192.34	7.85	76.71	411.83 ± 173.28	11.87	77.48
3rd month (T5)	647.32 ± 243.04	391.21 ± 129.32	6.61	89.59	611.62 ± 202.78	0	108.93	452.17 ± 180.71	3.25	93.83
4th month (T6)	644.08 ± 233.66	383.09 ± 135.52	8.55	86.54	587.69 ± 155.80	1.09	96.69	439.68 ± 167.53	5.91	88.77
5th month (T7)	640.52 ± 237.72	397.82 ± 126.78	5.03	92.08	617.15 ± 198.09	0	111.76	458.49 ± 177.77	1.90	96.39
6th month (T8)	640.52 ± 254.07	408.50 ± 123.83	2.49	96.09	623.31 ± 217.66	0	114.90	467.91 ± 181.09	-0.001	100.21

Minus sign donates that there is an increase rather than a decrease
* significant at the 0.05 level

Table III. Mean VAS scores and distribution of patients according to the severity of pain at different time intervals.

Time interval	Females						Males						Total treatment group					
	Mean (SD)	No Pain	Pain scores 0.1-3 cm	Pain scores 3.1-6 cm	Pain scores 6.1-10 cm	Pain total	Mean (SD)	No Pain	Pain scores 0.1-3 cm	Pain scores 3.1-6 cm	Pain scores 6.1-10 cm	Pain total	Mean (SD)	No Pain	Pain scores 0.1-3 cm	Pain scores 3.1-6 cm	Pain scores 6.1-10 cm	Pain total
T1	4.46 (2.67)	4 (12%)	7 (21%)	12 (35%)	11 (32%)	88%	2.66 (3.02)	4 (31%)	5 (39%)	2 (15%)	2 (15%)	69%	3.96 (2.86)	8 (17%)	12 (25.5%)	14 (29.8%)	13 (27.7%)	83%
T2	3.07 (2.46)	8 (24%)	11 (32%)	9 (26%)	6 (18%)	76%	0.79 (0.95)	6 (46%)	7 (54%)	0 (0%)	0 (0%)	54%	2.44 (2.37)	14 (29.8%)	18 (38.3%)	9 (19.2%)	6 (12.7%)	70.2%
T3	1.43 (1.91)	17 (50%)	12 (35%)	4 (12%)	1 (3%)	50%	0.97 (1.43)	8 (62%)	4 (31%)	1 (7%)	0 (0%)	38%	1.30 (1.79)	25 (53.2%)	16 (34%)	4 (8.5%)	2 (4.3%)	46.8%
T4	0.98 (1.60)	23 (68%)	5 (14%)	6 (18%)	0 (0%)	32%	1.51 (1.92)	7 (54%)	4 (31%)	2 (15%)	0 (0%)	36%	1.13 (1.69)	30 (63.8%)	9 (19.1%)	8 (17.1%)	0 (0%)	36.2%
T5	0.29 (1.12)	31 (91%)	2 (6%)	1 (3%)	0 (0%)	9%	0.54 (1.45)	11 (86%)	1 (7%)	1 (7%)	0 (0%)	14%	0.36 (1.21)	42 (89.4%)	3 (6.4%)	2 (4.2%)	0 (0%)	10.6%
T6	0.50 (1.24)	28 (82%)	4 (12%)	2 (6%)	0 (0%)	18%	0.77 (1.36)	9 (69%)	3 (24%)	1 (7%)	0 (0%)	31%	0.57 (1.26)	38 (80.9%)	6 (12.7%)	3 (6.4%)	0 (0%)	19.1%
T7	0.15 (0.70)	31 (91%)	2 (6%)	1 (3%)	0 (0%)	9%	0 (0.00)	13 (100%)	0 (0%)	0 (0%)	0 (0%)	0%	0.11 (0.60)	44 (93.6%)	2 (4.3%)	1 (2.1%)	0 (0%)	6.4%
T8	0.24 (0.82)	31 (91%)	2 (6%)	1 (3%)	0 (0%)	9%	0.31 (1.11)	12 (93%)	0 (0%)	1 (7%)	0 (0%)	7%	0.26 (0.90)	43 (91.5%)	4 (8.5%)	0 (0%)	0 (0%)	8.5%

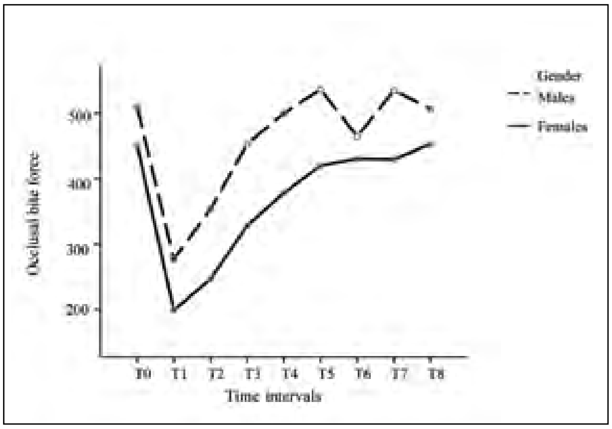

Figure 1. Pattern of maximum bite force change during fixed orthodontic treatment for females and males at different time intervals (T0 - T8).

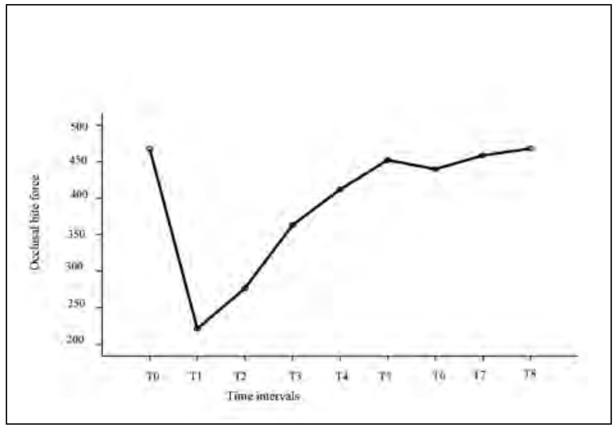

Figure 2. Pattern of occlusal bite force change during fixed orthodontic treatment at different time intervals (T0 - T8) for total treatment group.

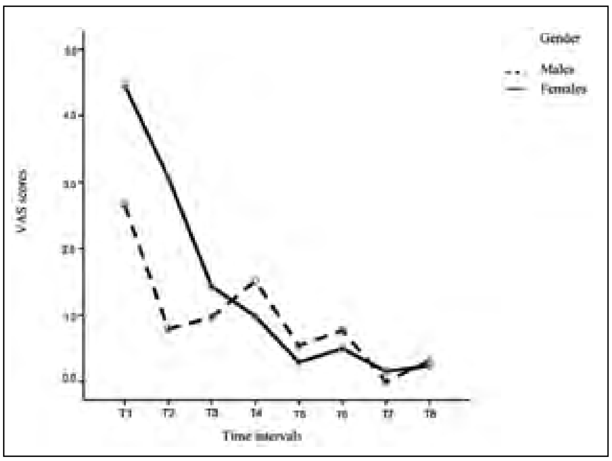

Figure 3. Pattern of VAS pain scores change during fixed orthodontic treatment for females and males at different time intervals (T1 - T8).

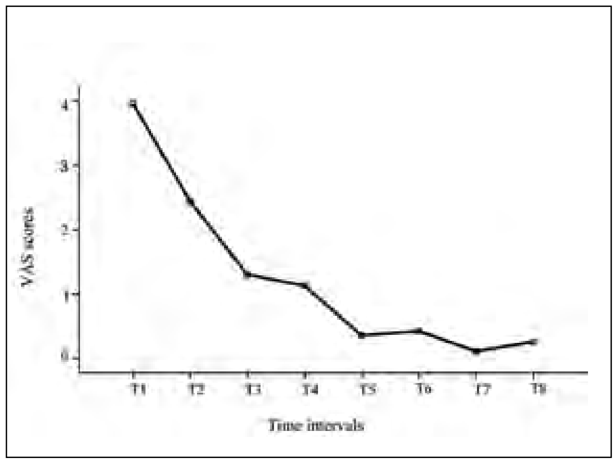

Figure 4. Pattern of VAS pain scores change during fixed orthodontic treatment at different time intervals (T1 - T8).

group ($p < 0.001$). No significant differences in OBF magnitude were found over the six month period in the control group ($p > 0.05$).

The mean VAS scores and the distribution of patients according to the severity of pain at different time intervals for females, males and the total treatment group are shown in Table III. Figures 3 and 4 represent the pattern of VAS score change during treatment at the different time intervals (T1 - T8) for females, males and the total treatment group respectively. Gender differences in VAS scores were not detected.

There was a significant difference in pain scores associated with the different time intervals ($p < 0.001$). The highest reported pain was at T1 and lowest was at T7. However, pain scores were only considered significant at T1, T2, T3 and T4 time intervals ($p < 0.001$). A significant positive correlation (at the 0.01 level) was observed between OBF loss and VAS scores at T1, T2 for the total treatment group; at T1 for females and at T2 for males.

Discussion

Few studies have addressed the issue of occlusal bite force changes during fixed appliance orthodontic treatment.[8-11] Previous reports have measured OBF before and after treatment but have not reported OBF during treatment.[8,9,11] In the present study, a control group was used to record OBF changes on a monthly basis in subjects with normal occlusion. As no significant changes in OBF values were found over six months, the changes in OBF measured during this study were considered a result of orthodontic treatment.

The present study employed a hydraulic pressure gauge with a biting element encased in plastic covering whose accuracy and reliability had been previously reported.[17] The visual analogue scale (VAS) to measure subjective pain was used due to its common acceptance as a pain measurement tool.[18] It was found superior to other pain scales in relation to reproducibility and ease of measurement.[19] However, the VAS scale did not allow subjects to differentiate between tooth or soft tissue sources of discomfort.[20]

All patients were selected to possess average anteroposterior and vertical skeletal relationships as occlusal bite force has been shown to vary in patients with different craniofacial morphological characteristics.[11,21,22] Subjects aged 18 years and above were recruited as previous evidence suggested that OBF increases with age to stabilise after the age of 14 years.[23] Varga et al.[24] found that there was minimal increase in bite force following the cessation of the pubertal growth spurt.

Malocclusions are often associated with reduced OBF.[4,5] In the present study, the OBF in the treatment group, each of which possessed a Class I malocclusion, exhibited lower OBF values prior to treatment, compared with a control group with normal Class I occlusions. This supports previous findings which reported that masticatory performance is highest in subjects with Class I occlusions followed by Class I, Class II and Class III malocclusions in descending order.[5,7]

Expectedly, a large reduction in OBF (50%) occurred at the end of the first week following the placement of fixed appliances. Bite force remained significantly reduced during the second week and in the first month. The results of the present study confirmed those of Thomas et al.[8] who reported a reduction in OBF during treatment. In addition, the present results were supported by Goldreich et al.[14] who suggested that orthodontic adjustments tended to reduce functional muscle activity. Sonnesen and Bakke[11] found that significant reductions in OBF occurred on the crossbite side rather than on the contralateral non-crossbite side immediately after treatment of a unilateral crossbite. This was explained by transient changes in occlusal support, periodontal mechanoreceptor effects and jaw elevator muscle reflexes.[25] The reduction in OBF observed in the present study may be due to changes in occlusal contacts which occurred during treatment, as it was previously reported that occlusal contacts determine 10% to 20% of the variation of maximum bite force in adults.[3]

A significant correlation was found between the amount of OBF loss and the subjective orthodontic pain experienced by the patient. This was in accord with Michelotti et al.[26] who indicated that the short-term occurrence of orthodontic pain was associated with motor and sensory changes of the masticatory muscles and represented by a decrease of the motor output and pressure pain thresholds of the jaw-closing muscles. Furthermore, pain is considered as an important modifying factor which tends to limit the maximum bite force due to reflex mechanisms.[12-13]

Contrary to some studies,[27,28] the current investigation determined no significant differences in the levels of perceived pain for males and females according to the VAS. Previous studies have also indicated that gender appears not to affect perceived pain during orthodontic treatment.[18,29] However, this finding may be affected by an unequal gender distribution in the present study.

Conclusions

1. 50% of pretreatment OBF was lost by the end of the first week.
2. OBF showed a tendency to return to pretreatment levels after the second month of orthodontic treatment.
3. VAS scores were high during the first 2 weeks of appliance treatment.
4. VAS scores positively correlated with the reduction of OBF.

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