Original Article

Centric Slide, Bite Force and Muscle Tenderness Changes Over 6 Months Following Fixed Orthodontic Treatment

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ABSTRACT

Objective: The postorthodontic change of the masticatory muscles was evaluated using three parameters: maximal voluntary bite force (MVBF), slide in centric (difference between maximal intercuspation and retruded contact position), and muscle sensitivity to palpation.

Materials and Methods: MVBF was measured with a custom-made rubber tube bite force device, centric slide with a digital caliper, and sensitivity to palpation of the masseter and temporalis muscles (scale 0–3) during application of standardized digital force (10 N). Data were collected at four time points: T0, before bracket removal; T1, immediately after bracket removal; T2, after 3 months of retention; and T3, after 6 months of retention. Patients ($n = 41$; 22 females, 19 males; mean age 17.4 ± 5.4 years) were examined from T0 to T1 and from T1 to T2. Of these, 28 (15 females, 13 males) were followed at T3.

Results: Immediately after bracket removal (T0 to T1), MVBF increased significantly by 15%. Another significant increase (15.5%) was found 3 months posttreatment (T1–T2), and almost no increase (2%) at 6 months (T2–T3). The slide in centric remained within normal values during the three time points. A decline in sensitivity to palpation from T1 to T3 was found for both masseter and temporalis muscles.

Conclusions: Neuromuscular adaptability begins within several minutes after bracket removal. A second stage of muscular adaptation occurs within 3 months of retention. These findings suggest that muscular adjustment occurs within a short period after orthodontic treatment.

KEY WORDS: Bite force; Slide in centric; Masticatory muscles; Muscle sensitivity; Muscular adaptation

INTRODUCTION

Several changes occur in the stomatognathic system when orthodontic treatment following bracket removal is completed. A new biological balance is obtained as a natural result of tooth, periodontal ligament, bone, and muscle adaptation. These posttreatment changes, also referred to as orthodontic relapse, have been extensively investigated,[1,2] but the role of the masticatory muscles post–orthodontic treatment remains unclear.

Three parameters are considered when addressing this issue: maximal voluntary bite force (MVBF), slide in centric, ie, difference between maximal intercuspation (ICP) and retruded contact position (RCP), and muscle tenderness to palpation.

After arch-wire change, pain develops, which reduces muscle activity during function.[3] Mastication of tough foods should be avoided during orthodontic treatment because of tooth sensitivity or for fear of bracket displacement.

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It can be hypothesized that changes in MVBF during and after bracket removal are an indicator of posttreatment muscle adaptation. The slide in centric (RCP-ICP difference) is related to the horizontal position of each or both dental arches or jaws.[4,5] Changes in posttreatment centric slide can provide information on masticatory muscle adaptation, because centric slide is partially determined by the masticatory muscles, and orthodontic correction involves tooth/jaw horizontal changes. A weak muscle function may be more susceptible to pain and more sensitive to palpation compared to untreated matched controls. In epidemiologic studies, muscle tenderness to palpation is the most accepted method to assess facial muscular pain,[6] and should be included when addressing posttreatment masticatory muscle adaptation.

Bite forces can be directly measured using a suitable transducer. This direct method appears well suited for submaximal forces only, because the possibility of dental fractures and pain caused by biting on the metal surfaces of the transducer prevent the maximal performance needed to record MVBF.[7] However, Braun et al[8] demonstrated that MVBF can be recorded when the bite force registration device is made of a cushioned material. An alternative method is to indirectly estimate bite forces by recording the electromyographic (EMG) activity of the superficial masticatory muscles. Ferrario et al[7,9] found that a linear relationship exists between recording submaximal bite forces and surface EMG potentials of mandibular elevators. Nevertheless, MVBF assessment is preferable to measuring the EMG activity of the masticatory muscles. The relationship between EMG activity and clenching force is linear, up to only 80% of the maximal clenching force, whereas the direct method provides a uniform bilateral biting force distribution.[10]

Because masticatory muscles could play a key role in the postorthodontic adaptation process, the objective of the present study was to evaluate orthodontic posttreatment muscle adaptability by examining three parameters: MVBF, slide in centric (RCP-ICP), and muscle tenderness to palpation. Three null hypotheses were postulated: slide in centric is not changed posttreatment; MVBF is not altered posttreatment; and no difference in superficial muscle tenderness is foreseen posttreatment.

MATERIALS AND METHODS

Patients (n = 41; 22 females, 19 males, mean age 17.4 ± 5.4 years) were consecutively selected from those completing their orthodontic treatment. All patients were treated with fixed edgewise appliances. Criteria for inclusion were a pretreatment orthodontic malocclusion (Class II or Class I), no symptoms indicating temporomandibular disorders (TMD), and good periodontal and dental health. All patients and their parents signed a written consent form. The Helsinki Accords Committee approved the study.

Figure 1. A custom-made RTBF device.

Data were collected at four time points: T0, before bracket removal (for MVBF only); T1, immediately after removal of all orthodontic appliances; T2, during the retention period (3 months after T1); and T3, during the retention period (6 months after T1). Of the original patients, only 28 (15 females, 13 males, mean age 17.0 years) attended follow-up (T3). MVBF was recorded with a custom-made rubber tube bite force (RTBF) device modified, designed and constructed by Davidov after Braun.[8] A 20-cm-long, 9.5-mm-diameter, flexible rubber tube (Wingfoot 300, GoodYear, Akron, Ohio) was filled with water and sealed by a manometer (Armaturenbau GmbH, Wesel-Ginderich, Germany, 63′ RKG 300 psi) at one end. A thin, disposable nylon sheath covered the tube for hygienic purposes.

Patients were instructed to bite as hard as possible, once at the first molar region and once at the incisor region. The peak biting pressure was preserved by a special hand on the manometer dial, while three bite registrations were recorded at 1-minute intervals for each region at each time point (Figure 1). The pressure measurement was converted to force (N) after a calibration curve was defined. The calibration curve was obtained using a Materials Testing Machine (Instron, High Wycombe, England) by applying a known force to typodont teeth occluding on the RTBF device and by simultaneous registration of the developed pressure (Figure 2).

RCP-ICP were horizontally measured between the buccal surfaces of the maxillary and mandibular incisors using a digital caliper (Mitutoyo Digimatic Electronic Caliper, Aurora, Ill, 0.03-mm accuracy, 0.01-mm resolution). The caliper was pressed against the maxillary incisors exactly on the midline, with a rod extending until it touched the mandibular incisors (Figure 3). Overjet (in millimeters) was recorded first in ICP and then in RCP. Slide in centric (RCP-ICP difference) was calculated by subtracting the later from the former.

Prior to RCP recording, patients underwent deprogramming of the masticatory muscles by holding a piece of celluloid between the teeth for 5 minutes to allow condylar guidance into the so-called muscle-dic-

Figure 2. Calibration of the RTBF device in a Materials Testing Machine.

Figure 3. RCP-ICP measurement with a digital caliper.

tated centric relation.[11] RCP was measured using Dawson's mandibular bilateral manipulation method.[12] To achieve maximum accuracy, the caliper and rod were held horizontally with the rod parallel to the nose line. This distance measuring procedure was repeated in ICP with the same orientation of the caliper as in RCP.

Measurement reliability for intraexaminer error was evaluated by repeating the maximum bite-force readings and RCP-ICP measurements in 10 randomly selected subjects. For RCP-ICP and MVBF, the variance between repeated measurements within the 10 subjects was 0.003 and 2.04, respectively, and between the 10 subjects it was 0.085 and 59296, respectively. This suggests a strong reproducibility, because the ratio of within to between variance was 3.5% and 0.003% for RCP-ICP and MVBF, respectively.

Muscle sensitivity to palpation was evaluated on a scale of 0–3 (0 = no sensitivity, 1 = mild sensitivity, 2 = moderate sensitivity, and 3 = severe sensitivity), when force of approximately 10 N (according to the Research Diagnostic Criteria for TMD recommendations[6]) was applied by the examiner. The right and left superficial masseter (at the mandibular angle) and right and left anterior temporalis (at the anterior temporal fossa) were examined three times per session and mean muscle sensitivity calculated. Before the clinical examination, the clinician underwent calibration procedures to ensure his ability to exert 10 N by pressing on portable scales. The same examiner carried out all registrations.

Statistical Analysis

A repeated measures analysis of variance (ANOVA-RE-MEA) for temporalis and masseter sensitivity, RCP-ICP, and MVBF between T1, T2, and T3 was used to analyze the results. A paired *t*-test was used for anterior and posterior MVBF between T0 and T1. Level of significance was set at $P < .05$.

RESULTS

Maximal Voluntary Bite Force

Mean and standard deviation values for anterior and posterior MVBF were expressed in N for the four time points and are shown in Table 1. A significant change in MVBF over time (ANOVA-RE-MEA, $P < .001$) was found in each anterior and posterior dentition. Anterior and posterior MVBF significantly differed (ANOVA-RE-MEA, $P < .001$), with no interaction over time (ANOVA-RE-MEA, $P = .107$). MVBF significantly increased (paired *t*-test, $P < .001$) from T0 (before debonding) to T1 (after debonding on the same day). The mean increase in bite force with time for both anterior and posterior dentitions was 15% immediately after debonding, between T0 and T1, and 15.5% 3 months later, between T1 and T2; there was almost no increase (2%) between T2 and T3 (Table 1).

Slide in Centric (RCP-ICP Difference)

Table 1 presents the results of the ANOVA-RE-MEA of RCP-ICP difference for T1–T3. Time had a statistically significant effect ($P = .04$) only between T1 (0.61 ± 0.38 mm) and T2 (0.80 ± 0.36 mm) with an increase of 31%.

Muscle Sensitivity to Palpation

According to ANOVA-RE-MEA, no statistically significant difference was found between the left and right sides at each time point for the masseter ($P = .713$) or temporalis ($P = .212$). Therefore, a mean for the

TABLE 1. Mean and Standard Deviation Values for Anterior MVBF and Posterior MBVF at Four Time Points and for Centric Slide (RCP-ICP), Masseter Sensitivity, and Temporalis Sensitivity at Three Time Points. Percentage Change Between Time Points was Calculated[a]

	n[b]	T0	T1	T2	T3	P^c T1, T2	P^c T1, T2, T3	T0–T1 %	T1–T2 %	T2–T3 %
Anterior MVBF (N)	41	194.6 ± 66.4	221.8 ± 79.8			<.001		14%		
	28		236.5 ± 76.4	280.9 ± 92.7	299.1 ± 91.0		<.001		19%	6%
Posterior MVBF (N)	41	303.4 ± 131.2	352.1 ± 130.7			<.001		16%		
	28		373.3 ± 128.6	419.5 ± 137.2	412.6 ± 132.9		<.001		12%	−2%
RCP-ICP (mm)	28		0.61 ± 0.38	0.80 ± 0.36	0.72 ± 0.31		=.04		31%	−10%
Masseter sensitivity	28		1.07 ± 0.94	0.53 ± 0.69	0.41 ± 0.59		<.001		−50%	−23%
Temporalis sensitivity	28		1.19 ± 0.74	0.78 ± 0.68	0.26 ± 0.44		<.001		−34%	−67%

[a] MVBF indicates maximal voluntary bite force; RCP-ICP, difference between maximal intercuspation and retruded contact position.
[b] 41 patients were examined at T0, T1, and T2; of these, 28 patients were examined at T3.
[c] ANOVA with repeated measures; level of significance was set at $P < .05$.

left and right masseter was calculated. ANOVA-REMEA showed that time had a significant ($P = .001$) effect on the masseter muscle sensitivity to palpation. That is, a significant ($P < .001$) pattern of decline was found in sensitivity to palpation from T1 to T2 to T3 (Table 1). However, the decline occurred mostly (50%) from T1 to T2. Time also had a significant ($P < .001$) effect on sensitivity to palpation of the temporalis muscle. There was a pattern of decline that had statistical significance ($P < .001$) from T1 to T3, but the decline was greater from T2 to T3 (67%) than from T1 to T2 (34%) (Table 1).

Behavior over time of both masseter and temporalis muscles regarding sensitivity to palpation was parallel from T1 to T2, but from T2 to T3 the masseter almost reached a steady state, whereas the temporalis continued to decline.

DISCUSSION

Bite Force

The custom-made RTBF device modified, designed, and constructed by Davidov after Braun[8] is, in our opinion, safe, comfortable, and accurate, because the patient is asked to bite on a flexible rubber tube, which prevents the patient from avoiding maximal performance.

MVBF increases with age up to 12 years[13] and stabilizes after the age of 12–14 years.[13–15] Kamegai et al[15] found that MVBF reached its peak by the age of 12 and declined slightly (3.7%) by the age of 17. Similarly, Braun et al[14] found that after the age of 14, MVBF stabilized, with a minute change (2%) from 15 to 17 years. Because the mean age of the patients in the present study was 17 years, and because the examined period ranged from several minutes (T0–T1) to 3 months (T1–T2 and T2–T3), no attempt was made to examine a control group. The total study period was only 6 months. That is, the assumption of no change in untreated subjects at a mean age of 17 years during the examined short-term period (6 months) is evidence-based.[13–15]

The increase (Table 1) in MVBF in only a few hours from the time point with the brackets intraorally (T0) to the time point after bracket removal (T1) could indicate that MVBF was dependent on an adaptive neuromuscular feedback control mechanism. This response emanates from the teeth and other oral structures and governed by the central nervous system. The function of the masticatory system is controlled by several receptors located in the muscles, the temporomandibular joint, and the tooth-supporting structures, which are all part of the system that produces or absorbs the force.[16,17] Therefore, the low level of MVBF obtained at T0 relates to the signals transmitted by the teeth to the central nervous system because of premature bracket/tooth contacts, or the dental reaction imposed by the arch-wire. At T1, with removal of the orthodontic appliances and freedom from anxiety or physical discomfort, a prompt surge in MVBF occurred. Another possible explanation could be that, during treatment, patients were repeatedly required not to apply full masticatory forces, in order to prevent bracket debonding. This may have produced an adaptive muscular contraction[18] that unconsciously reduced the patient's ability to reach the maximal contraction capacity.

The increase in MVBF from T1 to T3 (Table 1) was statistically significant only between T1 and T2. The T3 bite force values showed stabilization of the system with values similar to T2 (increase of 6% in the anterior region, and decrease of 2% in the posterior). This means that the major changes in MVBF occurred during T1–T2 and not T2–T3. This is in accordance with present knowledge of temporary muscle restraint, in which reduced muscle activity leads to loss of muscle cell diameter, loss of number of muscle fibers, and atrophy. Loss of muscle strength is the most evident response to atrophy, but after 10 weeks of physical therapy and training, all alterations are reverted.[19,20] It is noteworthy that the same muscular recovery duration occurred in the present study (T1–T2 = 12 weeks). Most likely the absence of bands and wires in the T1–T3 period had its contribution to the muscle's ability to rebuild itself and strengthen during normal function, reversing the typical avoidance of tough foods that prevailed during active treatment time.

Furthermore, as in the study of Bakke et al,[21] bite force correlated with the number of occlusal contacts in which postdebonding reached a peak of settling in by the third month. Any temporary reduction in MVBF disappeared in less than 6 months.[22] The influence of added masticatory function is not limited to an increase in muscular force only.[23] Teeth used in mastication may also increase their force tolerance, which may be indicative of improved tooth adaptation and supporting structures.

Thus, the null hypothesis of no alteration in MVBF posttreatment was rejected.

Slide in Centric

In the present study, slide in centric at T1 (0.61 ± 0.36 mm) was of the same magnitude as reported for a normal nonorthodontic population (1.25 ± 1.0 mm).[5,24–26] A long centric of about 2–4 mm might develop when Class II is corrected to Class I during orthodontic treatment, and then relapses back (eg, to edge-to-edge molar relations). This was not the case in the current study (RCP-ICP changed from 0.6 ± 0.3 mm [T1] to 0.8 ± 0.3 mm [T2] to 0.7 ± 0.3 mm [T3]). Therefore, the range of change from T1 to T2 (0.2 mm) and then from T2 to T3 of −0.1 mm demonstrated a stable occlusion after 6 months, which could be because most of the patients were treated with edgewise and not functional mechanics.

No attempt was made to correct the occlusion by altering the fossa/condyle position. As to the question that relapse was examined in the short term (6 months) and not the long term (several years), and that this could be the reason for no deterioration in fossa/condyle relationship, the answer was provided by the present finding that clinically negligible relapse (0.2 mm) was shown in the first 3 months, whereas during the next 3 months, there was improvement (−0.1 mm). It can be stated that, from the clinical point of view, the null hypothesis that no difference in RCP-ICP posttreatment is present can be fully accepted. The accusations that are sometimes made that orthodontists ignore small centric slides, or even make them larger, have no basis according to the current study, which agrees with Cohen[27] and Johnston et al.[28] Thus, the allegation that Class II elastic wear is a predisposition for long centric was rejected in this study and is in agreement with Major et al.[29]

Muscle Sensitivity

The sharp decline in masseter muscle sensitivity from T1 to T2 (50%) and weak decline from T2 to T3 (23%) was probably related to the increase in posterior MVBF (11%) from T1 to T2 and no increase from T2 to T3 (−2%), which agrees with Sheikholeslam et al[30] and Moss et al.[31] The decline in temporalis sensitivity was greater from T2 to T3 than from T1 to T2. However, statistically the two muscles showed a similar pattern of reduced muscle sensitivity from T1 to T3. The increase in muscle force and decrease in sensitivity after bracket removal is also supported by the findings of Vandenborne et al[19] and Kasper et al[20] of an increase in muscle mass because of occlusal stability and comfort. Thus, the null hypothesis of no posttreatment change in superficial muscle tenderness was rejected.

CONCLUSIONS

- Neuromuscular adaptability possibly starts within several minutes after bracket removal.
- A second stage of muscular adaptation occurs within the first 3 months of retention, with a substantial reduction in muscular changes within the next 3 months.
- These findings suggest that muscular adjustment occurs within a short-term period after orthodontic treatment.
- Clinically, these findings emphasize the major merit of full-time wear of a retention appliance immediately post–active orthodontic treatment.

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