

ORIGINAL ARTICLE



The effect of anterior repositioning splint therapy on maximum bite forces in patients with disc interference disorders

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ABSTRACT

Objective: To evaluate the effect of anterior repositioning splint (ARS) on maximum bite force (MBF) values in patients with disc interference disorders (DID).

Material and methods: Twenty-two patients with disc interference disorders and 22 healthy subjects participated in to study. The Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) Axis I have been used to diagnose DID patients. All patients received ARS therapy for 6 weeks. The MBF measurement was performed with Flexi-Force piezo-resistive sensors for both healthy subjects and patients before and after ARS therapy.

Results: A significant difference was recorded by the increase of the mean MBF values after the use of the ARS in the patient with disc derangements ($p < .05$).

Conclusions: APS therapy is efficient for eliminating pain and increasing MBF of the patients with DID. In addition, the use of FlexiForce sensors may be a practical solution to assess the bite force in the clinical setting.

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Introduction

Temporomandibular disorders (TMDs) are a collected term, embracing many clinical problems such as the masticatory muscles, the temporomandibular joints (TMJs), and the related structures [1–5]. The main goal of TMDs management is to reduce or eliminate the pain, and to improve the mandibular function as well as the quality of life [1]. A general approach in the treatment sequence is determining the aetiological and perpetuating factors leading to TMDs signs and symptoms at first, and then solving the pathological effects [1–6].

Many studies suggest that management of TMDs should be aimed to decrease pain and load on the muscles and joints and facilitate patients' restoration of function and quality of life [2,6]. Among many treatment options for managing TMDs, occlusal appliance therapy has of primary importance and is the most popular treatment. The occlusal splints cover the occlusal or incisal surfaces of the teeth in the maxillary or mandibular arch forming the proper occlusal contact and stable occlusal relationship [2,6–8]. Although many types of occlusal appliances have been suggested for the treatment of TMDs, depending on diagnosis the stabilisation appliance and anterior repositioning appliance have been used most frequently [2].

The anterior repositioning splint (ARS) is used to treat disc derangement disorders and to direct the mandible to a more anterior position than the intercuspal position. By altering the mandibular position, the anteriorly displaced discs could

return back to their normal position (recaptured), to the stabilised condyle-disc relationship [8]. While it is creating a better condyle-disc relationship in the fossae, the anterior positioned mandible leads to redistribution of the load of the masticatory system and decreases the overload on the retro-discal tissue. Therefore, the retro discal tissues can adapt or be repaired. Although after the removal of ARS the stability of adaptation could not be maintained in the majority of TMJ, the use of ARS has shown good short-term clinical outcomes [9]. The expected result from this treatment is to make possible the adaptation of retro-discal tissues [2,8,10,11]. As a result, the adapted tissues and the redistribution of loading of the masticatory system may change the maximum bite force often been studied as an indicator of the masticatory system. Nevertheless, the effect of ARS on bite force has not been stated before. The measurement of bite force has been widely used in dentistry to the determination of mastication mechanics, therapeutic effects of prosthetic devices, and also to ensure references in the studies of biomechanics of prosthetic devices. Maximum bite force (MBF) is generated by the masticatory muscles, which is a good parameter giving an idea about their activities [12–14]. Additionally, it may be a key factor in the diagnosis of masticatory disorders, and also presents reference values on biomechanics and efficiency of the prosthetic treatments [15–17]. The effect of bite force on the development of the masticatory complex has been interesting for a long time [17]. It has been stated that not only the potential bite force

and horizontal mandibular forces but also masticatory movements may be affected in patients with TMDs [4]. Indeed, the MBF might be dependent on numerous subjective factors such as age, gender, craniofacial morphology, dentition, the pain threshold of the subject during the test, and other influencing factors, such as recording technique used, and the area in which the measurement was made [4,6,13,18–20]. Therefore, a controversial point has arisen that whether the reduced bite force of patients with TMDs is related to the disorder, and it can also be recovered with treatment [4].

The MBF could be measured directly by inserting a sensor between the opposing teeth, or indirectly by calculating the forces generated by physiological factors [18]. Various equipment and methods have been used to evaluate the bite force such as portable hydraulic pressure gauges, bite fork, force-sensing resistors, strain gauge transducers, pressured rubber tube, foil transducers, pressure-sensitive sheets, and gnathodynamometer. On the other hand, with electromyographic technique, the activity of the masticatory muscles could present data on the force generated [18,20–22]. The function of all the modern instruments used in this field is based on the electrical resistance of the strain gauge, and the forces may be measured repeatedly. However, due to the measurement of bite force is not yet used clinically, it is widely measured in studies by customised devices [13]. Indeed, there are a few commercial devices for the measurement of bite force and have been tested for their reliability. Recently, many investigators have proposed the use of the piezo-resistive force transducer FlexiForce to measure bite force in clinical settings as a much simpler and practical solution [14,23–25]. These are flexible sensors consisting of presentative active sheets within a thermoplastic layer. When a force is applied, a change of conductivity of the active sheets occurs proportionally, and this change is recorded as a force on software. These sensors may be a useful opportunity for measurement of bite force with their very low thickness and lower cost, however, up to the present, there have been only a few dental applications in studies.

The present study was aimed to determine the anterior repositioning splint therapy efficiency *via* maximum bite force measurements in patients with disc interference disorders. For this purpose, piezo-resistive force transducer FlexiForce sensors were used, and the maximum bite force values obtained from the healthy subjects and the patients were compared. After that, the baseline data (such as pain) were also compared after splint use for the patients.

Material and methods

Selection of patients

A total of 44 subjects participated in the present study. The research protocol was approved by the Human Research Ethics Committee (#24074710-6), following the principles of the Helsinki Declaration. A written and verbal information about the experimental study was given to all participants and a written consent form has been signed. The patients who were referred to the Dental School of Gazi University

Department of Prosthodontic clinics were subjected to a standard clinical examination for a functional evaluation of the masticatory system. According to the following inclusion and exclusion criteria, voluntary subjects aged between 18 and 48 years were assigned into two groups as asymptomatic or symptomatic. The exclusion criteria are the pregnancy and the presence of any psychiatric disorders, systemic conditions, tumours. The individuals who had a history of TMJ surgery or any TMD treatment, or who complained only of any muscle disorders were also excluded. The initial inclusion criteria were: Patients who had no reported systemic disease or apparent facial asymmetry, no craniofacial trauma or surgery, no use of any medication, and had full permanent dentition (not including third molars). A detailed questionnaire and clinical examination were made using the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) Axis I to the diagnosis of TMD patients. Then, the diagnosis of TMD was verified with the vibrational analysis of the Temporomandibular Joint (BioJVA) (Biopak, Bioresearch Associates, Inc. Milwaukee, WI, USA) which has been reported as a reliable tool in many studies [26,27] using MRI. BioJVA uses Piper's Classification for the diagnosis of TMD. According to Piper's classification, the analysed temporomandibular joints were divided into 5 groups, based on the registered vibrational energy and the range of opening motion. Piper 1 classification indicates that disc is normal, Piper 2 indicates that disc is in a normal position, but ligaments are stretched, Piper III indicates that disc is partially displaced, Piper IV indicates that disc is completely displaced, Piper V indicates that there is no longer any tissue between the condyle and eminence. A total of 22 TMD patients who were diagnosed as disc displacement or disc dislocation with reduction were included in the present study and assigned as an asymptomatic group (17 females; 5 males; mean age 24.64). The total integral (PaHz) values of participated subjects were listed in Table 1. The 22 number of patients has been determined according to G-Power analysis. The identical number of healthy voluntary subjects (22) with a similar gender to the patients participated in the study as an asymptomatic group with an average age of 21.82 years. The patients with TMD received anterior repositioning splint therapy; however, for the healthy subjects, nothing was made except for clinical examination and recording of the maximum bite force.

Table 1. Bio JVA data of Healthy subjects and TMD patients before treatment.

Groups	Mean total integral value (PaHz)
Open (Left)	
TMDs patients	83,10
Healthy subjects	5,29
Open (Right)	
TMDs patients	94,72
Healthy subjects	5,98
Close (Left)	
TMDs patients	25,19
Healthy subjects	7,45
Close (Right)	
TMDs patients	37,53
Healthy subjects	9,20

Anterior repositioning splint construction

After taking the impression of the maxillary arch with an elastomeric material (Zeta plus, Zhermack, Rovigo, Italy), the cast was conventionally obtained. A 1.5 mm thick polyvinylchloride sheet (Proform, Keystone Industries, Myerstown, USA) was adapted to the cast with a pressure adapter (The Machine IV, Keystone Industries, Myerstown, USA). The appliance was fitted to the maxillary teeth. Because the key for successful anterior repositioning of splint fabrication is to find the most suitable position eliminating the patient's symptom, the anterior stop was used to locate it. A small amount of clear auto-curing acrylic resin (0-80 Orthodontic Acrylic, Imicryl Dental AS, Konya, Turkey) was added to the occlusal surface of the anterior portion of the appliances to provide the anterior stop. The surface of the stop was adjusted, so it was flat and perpendicular to the long axes of the mandibular incisors. Care was taken for that position to be the shortest distance from centric relation that eliminated the symptoms. Then, the joint symptoms were evaluated; if no signs and symptoms were noted, this position was verified as the correct anterior position for the splint. The auto-curing resin was then added to the other occluding area of the appliance; the mandible was closed on the anterior stop, and once the acrylic has set, the impressions of each mandibular buccal cusp tip are marked with a pencil. By the development of flat, even, and simultaneous occlusal contacts in the determined forward position, a well-adjusted splint was obtained. The anterior guidance ramp was developed into a smooth sliding surface so as not to promote catching or locking of the teeth in any position. The splint was smoothly polished and compatible with adjacent soft tissue structures. To prevent the harmful effect of the long-term use of ARS on dental occlusion, the patients were instructed to wear the splint only at night for 6 weeks. During the treatment period, all participants in the study were warned not to use any pharmacological agent.

Measurement of maximum bite force

The bite force measurement was made with a FlexiForce piezo-resistive sensor (Tekscan Inc., Boston, MA, USA), with a 9.53 mm diameter and 0.2 mm thickness (Figure 1). The sensors consist of two layers of the substrate like a polyester film. A conductive material (silver) is applied to each layer, followed by a pressure-sensitive ink layer. Then, the two layers of the substrate are laminated together with adhesive to form the sensor. The "active sensing area" is defined by the silver circle on top of the pressure-sensitive ink. The silver extends from the sensing area to the connectors at the other end of the sensor, forming the conductive leads. The sensor acts as a variable resistor in an electrical circuit. When the sensor is unloaded, its resistance is very high, when a force is applied to the sensor, the resistance decreases. The sensor's tab is positioned into the sensor handle. The handle gathers data from the sensor, processes it, and sends it to a computer through a USB connection. FlexiForce sensors can be used to measure both static and dynamic forces up to

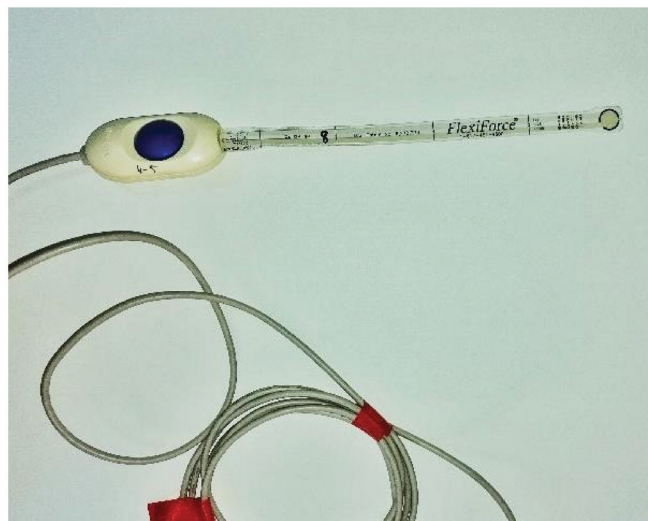


Figure 1. FlexiForce sensors.



Figure 2. View of recording bite force from the participants.

4400 N and are thin enough to enable non-intrusive measurements [14,23–25,28]. The FlexiForce sensors have $\pm 2.5\%$ repeatability and $\pm 3\%$ linearity error.

Before testing, the sensors were calibrated by applying a force of 1200 N and also conditioned applying this force 5 times. Polyvinylchloride (PVC) film which had a thickness of 1.5 mm and a diameter of 1 cm (Proform, Keystone Industries, Myerstown, USA) fixed to both the bottom and top of the sensor with adhesive tape. During the measurements, the participants were seated on a dental chair in a natural posture looking straight with the Frankfort horizontal plane parallel to the floor. Then, the participants were asked to clench their teeth as forcefully as possible three times on the discs for 3 s with a 2 min interval between the measurements. Then, sensors were positioned onto the occlusal surface of the right or left mandibular first molar in turn during the measurement of the maximum bite force (Figure 2). The highest value of each clenching was determined as Newton

Table 2. Comparison of MBF value between patients with TMDs and healthy subjects.

Maximum bite force (N)	Mean	Min	Max	<i>p</i> value
Left				
TMDs patients	261.67	147.66	588.26	.526
Healthy subjects	274.36	139.10	550.90	
Right				
TMDs patients	241.01	107.20	492.60	.324
Healthy subjects	264.71	141.96	553.23	

* $p < .05$ ($n = 22$), (Mann-Whitney U test).

MBF: Maximum Bite Force; TMDs: Temporomandibular Disorders.

(N). The mean value of the three highest clenchedings was considered as the subject's maximum bite force. The measurements were realised for both groups including healthy subjects and patients before and after splint therapy.

Statistical analysis

The data were analysed by SPSS 22.0 program (IBM Statistics, Chicago, USA). G Power 3.1. A power analysis program (G*Power 3.1., Universitat Dusseldorf, Dusseldorf, Germany) was used to determine the number of participating subjects. A Shapiro Wilk test was applied to determine the normality of the variables ($p < .05$ at significance). The data were then analysed and MBF values of healthy subjects and the TMD patients were compared using Mann-Whitney U tests. Also, the Wilcoxon test was used to assess the difference between the MBF value of patients in each splint group before and after splint therapy. Nominal variables were evaluated Ki Kare test. Statistical significance was set on an alpha level of 0.05.

Results

The clinical examination, RDC/TMD screening, and BioJVA analysis showed that 14 patients had disc displacement and the other 8 patients had disc dislocation with reduction. The comparison of the maximum bite force values between TMD patients and healthy subjects is presented in Table 2. The asymptomatic group presented higher bite force values than those of the symptomatic group, but there were no significant differences between them ($p > .05$). However, within the symptomatic group before and after splint therapy, a significant difference was recorded ($p < .05$) (Table 3).

Discussion

The bite force measurement is very hard within the oral cavity because the thickness of the sensors may affect the physiological posture and also correct the applicability of biting [29]. An increase in occlusal vertical dimension may cause some changes in orofacial components. It has been stated that the length of elevator muscles and position of condyles in the articular fossae might be changed by increasing of occlusal vertical dimension, which in turn affected masticatory function and also biting force [18,30]. Therefore, force transducers between the teeth should not be equivalent to the subject's bite force due to a moderate increase in

Table 3. MBF values of patients with TMD before and after APS treatment.

Maximum bite force (N)	Mean	Min	Max	<i>P</i> value
Left				
Before treatment	261.67	147.66	588.26	.001*
After treatment	327.43	156.43	853.23	
Right				
Before treatment	241.01	107.20	492.60	.001*
After treatment	301.38	136.20	559.90	

* $p < .05$ ($n = 22$) (Wilcoxon Test).

MBF: Maximum Bite Force; TMDs: Temporomandibular Disorder; APS: Anterior Positioning Splint.

the vertical dimension of occlusion [31]. Fernandes et al. [16] have compared the maximum bite force measurements using strain gauge bite forks and FlexiForce piezoresistive sensors, and have not found any significant difference between in the range of force 50–300 N of two different sensors. Piezo-resistive sensors have been highly reliable at a 93% for the recording of the repeatable amount of the forces applying at two different loading periods. In our study, FlexiForce piezo-resistive sensors were preferred, because of easy application, thickness, and lower cost [14]. They are made of a flexible and biocompatible material, and the total thickness of them was about 3.2 mm with the PVC discs. When the sensors were inserted between the first molars, and the patient clenched, the mouth opening was not above 2, 3 mm at the interincisal region. It means that the condyles are almost centred in the articular fossae where the most common jaw activities occur. The inter-incisal space created a useful passage of handle for the accurate position of the device.

There are conflicting results related to comparisons between TMD patients and asymptomatic individuals because of the great variations of used devices and methods in bite force records [30,32–34]. Many investigators emphasised that the patients with TMD had lower biting force compared to healthy subjects due to muscle pain or inflammation in tissues surrounding TMJ [4,19,31]. However, Pereira-Cenci et al. [5] have stated that there was not any difference between healthy subjects and female patients with bruxism and myofascial pain. Goiato et al. [12] have not also determined any interaction between myofascial pain and biting force and they pointed out that biting force increased depending on pain decrease after splint therapy. Although, they differ about the diagnostic procedures and methodologies, in the present study, no significant difference has been found between the maximum bite forces of asymptomatic and symptomatic groups ($p > .05$) in agreement with previous findings [5]. Based on this, it may be said that the presence of TMD did not influence the muscle strength of the studied sample. However, for the subjects with TMD, bite force tends to significantly increase when compared to baseline values, when the pain is eliminated ($p < .05$). Indeed, the pain was eliminated in most of the patients (12 patients; bilaterally and 6 patients; unilaterally), and in the others, it decreased after splint therapy. In this respect, splint therapy might be considered as successful at 95.45% and 81.1% for the right side and left side, respectively. This result suggests that such a therapy is effective for eliminating pain, and thus, improving mandibular function.

The limited bite force in the symptomatic group could be related to pain in the TMJ that articular pain may lead to a protective activity and control the contraction of the elevator muscles [34]. In the masticatory system, the force of the jaw elevator muscles (in turn, determined by the Central Nervous System (CNS) and feedback from muscle spindles, mechanoreceptors, and nociceptors) modified by the craniomandibular biomechanics [35]. In the presence of pain, the stimulation of nociceptors leads to inhibition in muscle activities. Therefore, if the pain is felt, the mandibular movement immediately is interrupted by nociceptive reflex [2]. As the decreased masticatory muscle activities would seem to be an essential and a common characteristic of patients with TMD, the evaluation of these properties could be a useful tool in the diagnosis and treatment of TMD patients [4].

As mentioned before, the maximum bite force may be affected by numerous factors based on the individuals' craniofacial morphology, body/mass index, gender, age and also recording instrumentation and technique employed. Therefore, comprehensive investigations are needed to determine bite force values by considering these factors in patients with any temporomandibular disorders.

Conclusion

In conclusion, the present investigation has demonstrated that: (1) maximum bite force values were not different between asymptomatic and symptomatic groups; and (2) anterior repositioning splint therapy is efficient for eliminating pain and increasing bite forces of the patients with TMD. Additionally, the use of FlexiForce piezoresistive sensors may be a practical solution to assess the bite force in the clinical setting; the limited thickness and easy repositioning of the device in the mouth and its low cost may overcome the most common problems encountered in such studies.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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