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Masticatory Function Before and After Masticatory Muscle-Related Temporomandibular Disorder Treatment: An Observational Study

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TITLE: MASTICATORY FUNCTION BEFORE AND AFTER MASTICATORY MUSCLE-RELATED TEMPOROMANDIBULAR DISORDER TREATMENT: AN OBSERVATIONAL STUDY

RUNNING TITLE: MASTICATORY FUNCTION AND TMD

ABSTRACT

Background: Muscle-related temporomandibular disorders (TMD) may affect the masticatory function. Chewing function can be assessed objectively using bolus kneading tests, such as two-color chewing gum mixing ability test.

Objective: The aim was to compare the masticatory function with a two-color chewing gum test before and after treatment of the masticatory muscle-related temporomandibular disorder.

Methods: Twenty-one patients with masticatory muscle disorder according to Diagnostic Criteria for Temporomandibular Disorders (DC/TMD) were recruited as an experimental group, and further twenty-one participants without any TMD were included as controls. Pain intensity (scored on a visual analog scale)

and maximum mouth opening (MMO) were recorded. Jaw Functional Limitation Scale-8 (JFLS-8) was conducted on all patients. Before and after treatment, masticatory function was evaluated with a validated bolus-kneading test, using two-color chewing gum.

Results: There was no statistically significant difference in chewing function before and after treatment in the experimental group (p=0.715). When these values were compared with the control group, there were no statistically significant differences (p=0.489, p=0.890). There was no correlation between masticatory function and VAS, MMO, JFLS-8 before and after treatment in the experimental group.

Conclusion: The two-color chewing gum test is not sensitive when the masticatory performance is not severely impaired.

Keywords: bolus kneading test, colour-mixing ability, masticatory function, masticatory muscles, masticatory performance, temporomandibular disorders.

*ClinicalTrials.gov Identifier: NCT04379609

BACKGROUND

Temporomandibular disorders (TMD) are defined by pain in the temporomandibular joint (TMJ) and related tissues, limitations in the lower jaw movements, and/or TMJ noises.[1,2] TMD are classified into four groups as temporomandibular joint disorders, masticatory muscle disorders, headache attributed to TMD, and associated structures.[3,4]

Of these, masticatory muscle disorders are the most common TMD subtype seen in dental clinics.[5-7] In general, two major symptoms of masticatory muscle disorders are pain and dysfunction. Pain is the most common complaint in masticatory muscle disorders. Dysfunction is a common clinical symptom associated with masticatory muscle disorders. It is usually seen as a decrease in the range of mandibular movement.[8]

It is known that individuals with TMJ pain chew slower and the duration of the chewing cycle is longer when compared with healthy individuals.[9] Also, it has been reported that the maximum bite force decreased in patients with temporomandibular disorders.[10] These consequences directly affect patients' quality of life. Therefore, rehabilitation of limited masticatory functions is one of the important therapeutic goals for TMD patients.[11]

Masticatory function in TMD patients can be measured objectively by various methods. Jaw kinematics, jaw muscle activity and bite force are defined as indirect methods used to measure masticatory function. These tests can be used as indicators of masticatory muscle strength and functioning. In addition, masticatory performance methods can be used to analyze the Masticatory function directly.[12] In the literature, only a few studies have measured masticatory performance in TMD patients.[13-17] Only two of these studies investigated the effect of TMD treatment and used the sieve method to measure masticatory

performance.[16,17] Although the sieve method is considered the gold standard, the procedure is complex and time-consuming.[18,19]

To eliminate these disadvantages, masticatory performance measurement with two-color chewing gum tests, which are simple and do not require special equipment or training, can be used. The effect of many different conditions and treatments on masticatory performance was evaluated with this method.[20] However, there is no study in the literature evaluating TMD treatment with this method to our knowledge.

This study aimed to compare the masticatory performance with two-color chewing gum test before and after treatment of the masticatory muscle-related temporomandibular disorder. We hypothesized that masticatory function will be impaired due to masticatory muscle-related TMD which will be improved after the treatment.

METHODS

This study was performed at the Department of Prosthodontics in Ondokuz Mayıs University Faculty of Dentistry. The study was conducted with approval from the Local Ethics Committee (Clinical Research Ethics Committee of Ondokuz Mayıs University Experimental Medicine Research and Application Center; 2017/410). Written consent was obtained from all the participants before the study. All clinical procedures were performed in accordance with the Declaration of Helsinki. The reporting of this study conforms to the STROBE statement.[21] The study was registered at clinicaltrials.gov (ClinicalTrials.gov Identifier: NCT04379609).

Study Design

This clinical study was designed to evaluate masticatory performance before and after the treatment of the masticatory muscle-related temporomandibular disorder. 21 patients (17 women and 4 men, aged 18-53 yearswith an average of 24.81±9.74 years), who were referred to the Ondokuz Mayıs University Faculty of Dentistry Department of Prosthodontics with a complaint of pain in the chewing muscles were enrolled in this study. The control group (11 women and 10 men, aged 20-51 years with an average of 23.62±2.92 years.) comprised employees and students in the faculty of dentistry without any temporomandibular disorder (TMD), representative of the general population. A power analysis was conducted to determine sample size (d=49, σ=14,8 ve power=99,9).[15] All patients were examined according to Diagnostic Criteria of Temporomandibular Disorders (DC/TMD) by the same clinician.[4] Patients younger than 18 years, patients with missing teeth (except 3rd molars) or crown-bridge restorations, and patients with intra-articular temporomandibular disorder were excluded from the study.

Treatment Protocol

Patients were informed about the muscle-related TMD and their self-awareness was increased. Moist heat application and soft diet were recommended during the treatment. Non-steroidal anti-inflammatory drugs were prescribed, as needed. The patients were given a hard acrylic, maxillary stabilization splint. All splints were made and adjusted by the same clinician (R.B.C). Patients were instructed to wear the splint all night for 6 weeks.

All patients were evaluated with the visual analog scale (VAS) to assess their pain (from score 0: no pain to score 10: worst pain ever experienced). Maximum mouth opening (MMO) was measured as a distance between the incisal edge of the upper and lower right incisors with a ruler. Also, the Jaw Functional Limitation Scale-8 (JFLS-8), consisting of eight questions, was conducted as mentioned in the literature before.[22] All these measurements were recorded at baseline and six weeks after the treatment beginning. No treatment was administered to the control group. Masticatory performance values of the control group were used only to compare with the masticatory performance values of the experimental group.

Evaluation of Masticatory Performance

Two-color chewing gum mixing ability test was used to measure masticatory performance in the control group, before and after treatment in the experimental group.[23] Commercial two-color chewing gum was used (Vividen Fruit-Swing Watermelon & Asai Grape Flavors, Perfetti van Melle, Turkey). The gum was in the form of a strip and whole strip was used. It was placed on the patient's tongue and the patient was then asked to chew normally 20 times.

After chewing, the gum was placed in a transparent plastic bag and then squeezed into 1 mm thick using a specially produced mold with a 3D printer (Moment, Seoul, Korea). Both sides of the sample were scanned at 300 dpi resolution using a desktop scanner (HP Deskjet, California, USA) in the same day to prevent the colors from deteriorating due to saliva. For all patients, both sides of the scanned images were processed using ViewGum software (version 1.4, Dhal Software, Kifissia, Greece, www.dhal.com) as described previously.[24] The value of VOH (variance of hue) was taken as the value of masticatory performance. A high VOH value indicates low masticatory performance.

Statistical Analysis

Statistical analyses of the data were performed using SPSS 23.0 (IBM Corp, Armonk, NY). The Shapiro-Wilk test was used to evaluate the normality of the data distribution. Independent sample t-test and paired sample t-test were used to compare normally distributed data. Mann-Whitney U-test and Wilcoxon test were used to compare the non-normally distributed data. Relationships between variables were evaluated using a multiple linear regression model. The significance level was taken $p < 0.05$.

RESULTS

There was a significant decrease in VAS and JFLS-8 values before and after treatment (both $p<0.001$). There was no significant difference between MMO values before and after treatment ($p=0.073$). No statistically significant difference was found in terms of masticatory performance values before and after treatment ($p=0.715$) (Table 1). When these values were compared with the control group, there were no statistically significant differences ($p=0.489$, $p=0.890$) (Table 2).

According to the multiple linear regression model, no correlation was found between pre-treatment values of masticatory performance and VAS, MMO, JFLS-8 (Table 3). There was also no correlation between post-treatment values of masticatory performance and VAS, MMO, JFLS-8 (Table 4).

When the most common responses to JFLS-8 questions before treatment were examined with descriptive statistics, 90% of patients had difficulty eating hard food, 85% had difficulty yawning, and 75% had difficulty chewing. When the responses after treatment were analyzed, 64.7% of the patients had difficulty eating hard food, 64.7% had difficulty yawning, and 23.5% had difficulty chewing.

DISCUSSION

Temporomandibular disorders were commonly seen in the population, with a strong predilection for females.[6] It is consistent with the distribution of the experimental group. However, to maintain a representative sample of the general population, we composed the control group equal by gender distribution. It can be thought that as a limitation of this study. At least 50% of TMD are masticatory muscle disorders.[5-7,25] Pain and dysfunction due to masticatory muscle disorders can restrict daily activities associated with the masticatory system. This situation also affects the patients' psychosocial functions and quality of life. It is important to record mandibular dysfunction both to understand the nature of TMD and monitor the course of treatment.[26] Masticatory function assessment tests can be used to evaluate the level of mandibular dysfunction.[11]

Several objective and subjective methods have been proposed to assess masticatory function. Masticatory performance is one of the ways to assess the masticatory function objectively. Masticatory performance tests are based on measuring the ability of individuals to grind a test food that is chewed with a predetermined number of chewing strokes or to the swallowing threshold.[12,27] Subjective assessment of masticatory function described as chewing ability. For this assessment responses to questionnaries about oral function are used.[12,28] When the studies evaluating masticatory function with objective methods are examined, it has been observed that the sieve method has been used in various patient groups for many years. In the sieve method, the distribution of the dry weights of the fragmented samples passed through sieves of various mesh widths is used. This method is considered the gold standard for measuring masticatory function.[18,19,29,30] By this method, the crushing ability of the masticatory system is measured.[31]

Due to the complex sieving procedure and difficulties in practice, researchers have tried to develop more practical and rapid assessment methods.[15,32-36]

In recent years, a new method that aims to measure masticatory performance with the mixing ability by using chewing gum containing two different colors has been described. A color scale or specially developed software can be used for this method.[23,37] Also, a color-changeable chewing gum and special visual color scale were developed by a Japanese research group. However, it is not possible to find this chewing gum outside Japan.[20]

When all tests for evaluating masticatory performance were reviewed, it was reported that the two-color chewing gum test is an easy method to apply and analyze.[20] Two-color chewing gum tests measure mixing ability, and sieve methods measure the crushing ability of the masticatory system. A study comparing these two methods found that mixing ability tests performed better than crushing ability tests in measuring masticatory performance in patients using full dentures.[38] Kaya et al. (2017) evaluated masticatory performance with the two-color chewing-gum test in children with mixed dentition. They reported that the crushing ability test reflected wider range values, but mixing ability was also appropriate to be used specifically in the evaluation of individuals who had difficulty in chewing.[39] Despite changes in value ranges, results of 20 cycles with mixing ability tests are correlated with the sieve method, which measures the crushing ability.[38]

There are few studies that measured masticatory performance in patients with TMD. In all of these studies, masticatory performance was evaluated by crushing ability tests or other chewing tests.[13-17] The two-color chewing gum test described by Schimmel et al. (2007) has been applied in many different patients and treatment groups.[23] Although there were many studies using this method about implant overdentures, children in mixed dentition, complete dentures, fixed implant prosthesis, etc., no studies about TMD patients were found in the literature.[39-42] In our knowledge, this is the first study to measure masticatory performance through mixing ability in TMD patients.

In the present study, when the JFLS-8 and VAS scores were evaluated, the improvement before and after treatment indicating that the treatment applied in the experimental group was successful.[4] There were no significant differences between the masticatory performance of the control group and both pre-treatment and post-treatment masticatory performance values. In previous studies evaluating masticatory performance in TMD patients with the sieve method, pretreatment masticatory performance was lower than the control group.[14,16] Perreria et al. (2009) also reported no significant difference between control groups and post-treatment masticatory performance.[16] Kümbüloğlu et al. (2013) reported that when 3.15 mm sieves were used to measure masticatory performance, there was no significant difference in post-treatment masticatory performance compared to the control group, but a significant difference was found when 0.5 mm sieves

were used.[17] In our study, there was no difference between the masticatory performance before and after treatment. Pereira et al. (2009) reported that masticatory performance did not change after treatment, in line with our results.[16] However, Kümbüloğlu et al. (2013) reported that masticatory performance increased after treatment in patients with TMD.[17]

Peroz and Tai (2002) reported that pain intensity and masticatory performance in patients with disc displacement without reduction were not correlated.[14] Kumbuloglu et al. (2013) also support this result in their study in patients with muscle-related TMD. The authors associated this result with the possibility of careful chewing activity in patients with higher pain intensity.[17] Likewise, no significant relationship was found between VAS and masticatory performance in our study.

Similarly, experimental pain researches show that pain has no severe effects on jaw muscle activities.[43,44] These results seem compatible with the Integrated Pain Adaptation Model (IPAM). IPAM reveals the relationship between muscle activity and pain. Therefore, it can be considered a combination of the Vicious Cycle Theory and the Pain Adaptation Model. This theory emphasizes pain is experienced as biopsychosocial and suggests that the individual's motor response to pain will also be variable.[45] Consistent with this model, Sae-Lee et al. (2008) reported that non-painful muscles might be used to perform defined tasks.[46] These findings may be a possible explanation for the average masticatory performance of patients with muscle pain.

On the other hand, different masticatory performance assessment methods have been applied in the literature. These tests evaluate the partial features of chewing such as crushing, mixing, or shear ability. Therefore they are affected by the functions that constitute chewing at different rates. The relationship of mixing ability with maximum bite force is weaker than crushing ability.[31,38] It is possible that the decreased maximum bite force in TMD and the increase achieved at the end of treatment can not be adequately represented when mixing methods are used. Mixing tests may not be an appropriate method to determine the differences between healthy, young individuals with full dentition. Because chewing a gum can be very easy for individuals whose mandibular function is not severely affected.[47]

CONCLUSION

Evaluation of the masticatory performance with two-color mixing ability test may not be an appropriate method when the masticatory function is not severely impaired. Further clinical trials with long-term follow-up are needed to determine the masticatory function in TMD. Also, two-color mixing ability tests should be compared with sieve method in TMD patients.

Conflict of Interest:

The authors declare that they have no conflict of interest related to this study.

Informed Consent:

Consent was obtained from all individual participants included in the study.

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TABLES

Table 1. Comparison of VAS, MMO, JFLS-8, Masticatory Performance scores before and after treatment. Wilcoxon test for VAS, JFLS-8 and Masticatory Performance. Paired sample t-test for MMO.

	Before Treatment	**After Treatment**	**p**
VAS [MED (min-max)]	5 (3-8)	1 (0-5)	<0.001*
MMO (Mean±SD)	43.71±7.21	45.67±4.67	0.073
JFLS-8 [MED (min-max)]	3 (0-5)	1(0-4)	<0.001*
Masticatory Performance [MED (min-max)]	0.324 (0.215 - 0.558)	0.304 (0.236 - 0.400)	0.715

***:** p<0.05; Abbreviation(s): **VAS**, visual analog scale; **MMO,** maximum mouth opening; **JFLS-8**, Jaw Functional Limitation Scale- 8; **MED,** median; **min,** minimum; **max,** maximum; **SD,** standart deviation

Table 2. Comparison of masticatory performance values [MED (min-max)]. Independent sample t-test.

	Masticatory Performance	**p**
Control Group	0.314 (0.245 - 0.369)	0.489
Before Treatment	0.324 (0.215 - 0.558)	
Control Group	0.314 (0.245 - 0.369)	0.890
After Treatment	0.304 (0.236 - 0.400)	

Abbreviation(s): **MED,** median; **min,** minimum; **max,** maximum

Table 3. Comparison of the relationship between JFLS-8, VAS, MMO and masticatory performance before treatment. Multiple linear regression.

	B (%95CI)	Standard Error	Beta	t	p	Zero-Order	Partial
Constant	0.341 (-0.06-0.742)	0.190		1.796	0.090		
VAS	-0.01 (-0.034-0.014)	0.012	-0.201	-0.869	0.397	-0.081	-0.206
MMO	-0.001 (-0.007-0.006)	0.003	-0.060	-0.220	0.828	-0.229	-0.053
JFLS-8	0.024 (-0.011-0.058)	0.016	0.395	1.459	0.163	0.378	0.334

Adj. R^2=0.035; F=1.239; p=0.327

Abbreviation(s): **VAS,** visual analog scale; **MMO,** maximum mouth opening; **JFLS-8,** Jaw Functional Limitation Scale- 8; **CI,** confidental interval; **Adj. R^2,** adjusted coefficient of determination

Table 4. Comparison of the relationship between JFLS-8, VAS, MMO and masticatory performance after treatment. Multiple linear regression.

Variable	B (%95CI)	Standard Error	Beta	t	p	Zero-Order	Partial
Constant	0.454 (0.161-0.746)	0.139		3.276	0.004		
VAS	0.005 (-0.016-0.025)	0.010	0.125	0.485	0.634	0.173	0.117
MMO	-0.003 (-0.009-0.003)	0.003	-0.271	-1.099	0.287	-0.285	-0.258
JFLS-8	-0.003 (-0.031-0.025)	0.013	-0.066	-0.254	0.803	0.070	-0.061

Adj. R^2=0.094; F=0.590; p=0.630

Abbreviation(s): **VAS,** visual analog scale; **MMO,** maximum mouth opening; **JFLS-8,** Jaw Functional Limitation Scale- 8; **CI,** confidental interval; **Adj. R^2,** adjusted coefficient of determination