Original Article / Özgün Araştırma

# A Comparison of Chewing Movements of Individuals with Normal Occlusion by the Patients with Orthodontic Abnormalities During Treatment Progress

## *Normal Oklüzyonlu Bireylerle Ortodontik Anomali Tedavisi Gören Hastaların Çiğneme Hareketlerinin Kıyaslanması*

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**Abstract**

**Objective:** Comparison of chewing movements of individuals with normal occlusion and those with orthodontic anomalies under treatment.

**Materials and Methods:** This is a prospective clinical study carried out on a total of 63 individuals, including 43 patients with malocclusion and an average age of 16.79 years, whose growth and development were partially complete and 20 individuals with normal occlusion and an average age of 24.77 years. Subjects with normal occlusion have not any orthodontic treatment history.

**Results:** There were significant differences in chewing occlusion times ($p<0.05$) and opening and closing times ($p<0.01$). Furthermore, significant differences were also found in modification results of class 1 ($p<0.05$) and class 2 ($p<0.01$) malocclusions.

**Conclusion:** Repositioning of the teeth in chewing movements obtained at the onset of orthodontic treatments tends to change within the end of the 6-month period from the onset of the treatment in individuals with malocclusion.

**Keywords**
Masticatory movements, orthodontic treatment, dental occlusion

**Öz**

**Amaç:** Normal oklüzyonlu ve tedavi altındaki ortodontik anomalili bireylerin çiğneme hareketlerinin karşılaştırılması.

**Gereç ve Yöntemler:** Bu çalışma, maloklüzyonlu 43 hasta ve ortalama yaşları 16,79 yıl olmak üzere, büyüme ve gelişmesi kısmen tamamlanmış, 20'si normal oklüzyonlu ve yaş ortalaması 24,77 yıl olan toplam 63 birey üzerinde yapılan prospektif bir klinik çalışmadır.

**Bulgular:** Oklüzyon süresinde ($p<0,05$) ve açılma ve kapanma oranlarında anlamlı fark bulundu ($p<0,01$). Ayrıca, sınıf 1 ($p<0,05$) ve sınıf 2 ($p<0,01$) malokluzyonların modifikasyon sonuçlarında da anlamlı farklılıklar bulunmuştur.

**Sonuç:** Ortodontik tedavinin başlangıcında elde edilen çiğneme hareketlerinde dişlerin yeniden konumlandırılması, maloklüzyonlu bireylerde tedavinin başlangıcından itibaren altı aylık sürenin sonunda değişme eğilimindedir.

**Anahtar Kelimeler**
Çiğneme, ortodonti, oklüzyon

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## Introduction

Studies on mastication physiology and chewing patterns have a long history in dentistry. However, it has been observed that less studies were conducted on effect of chewing performance on malocclusion in the literature (1). Furthermore, there is no study found which compares the chewing patterns of young individuals with malocclusion who are about to complete normal occlusion development. Hypothetically, changes in chewing characteristics must be expected within the 6-month period from the onset of the treatment procedure because of changing of tooth movement. In this study chewing performance is measured and benchmarked before and after the study by using a jaw tracker device.

In the literature view, the following methods are commonly used in the studies investigating the chewing function (2): a-Analysis of chewing movements, b-Analysis of chewing muscle activity (Electromyography studies) (3-6) or c-Analysis of chewing process results (analysis of the status just after chewing and before swallowing a food particle) (1,7). Efficiency of restorations, the status before orthodontic studies, chewing analyses during and after the treatment process may provide important information about treatment process and outcomes (8). Thomas et al. (1) obtained the findings indicating that orthodontic treatment process may recover motor functions such as chewing in a pilot study conducted on 15 individuals.

No study has been found that focuses on the change of chewing patterns in the groups with orthodontic malocclusion on the individuals with class 1 occlusion and on the control group in the literature (9).

The chewing pattern is a periodical and functional movement style and aims to break down, mesh and prepare the food for digestion. All receptors in the system are enabled to create such function (3). A central pattern generator and associated motor neurons control strength, form, opening and closing durations and occlusion durations of biting forces and prevent damage of the organs in peripheral nervous system (10,11).

In a manuscript published by Hill (2), chewing cycle has three main components as follows; opening time (OT), closing time (CT) and occlusal time (OcT). Normal cycle duration varies between 600 and 900 miliseconds and each phase is roughly 1/3 of total chewing cycle. The OcT is slightly less than 1/3 of total chewing time. Record of chewing movements are observed at three planes as frontal, sagittal and horizontal. The most commonly used material used for chewing movements is the gum. Pattern of the chewing movement also depends on the food. Opening phase and closing phase were detected as 225±25 msec whereas occlual phase was 200±25 msec (10,12). The disoders during occlusal phase of teeth contacts of chewing phase would affect harmonization of the chewing system and cause pathological changes in the joints (13).

Analysis of temporomandibular joint (TMJ) under a load during functioning is important for operation for joint problems. Restructuring and recreation of TMJ with realistic anatomic and kinematic data is the only method providing an *in vivo*, three dimensional, dynamic and real time quantitative aspect to the relation between articulation surfaces of a joint (14).

It was revealed in a study conducted by Ngom P.I. et al. (15) where chewing efficiency was evaluated on 102 untreated individuals that recovery of chewing functions should be one of indication options as well as aesthetic and other indications for treatment. Yamashita et al. (16) reported in a review that a significant association exists between chewing efficiency and chewing pattern and hardness of the food was suggested to affect the chewing pattern and along with customization of the pattern, count may also be important.

Clark and Evans (17) have determined an ideal orthodontic occlusion frame where one of the basic rules was reported as demonstration of the function. However, Trawitzki et al. (14) could not detect any significant association between maximum isometric chewing strength and class 2 and class 3 dentofacial deformity in their study conducted on 125 volunteer patients. Furthermore, they reported that the values of both (class 2 and class 3) study groups were below the values of the control group. Effect of curve of spee on chewing efficiency was also investigated; it was concluded that the idea that a regular curve of Spee may create an efficient chewing is not true (17,18).

Therefore, the investigation of this topic is necessitated. The aim of the present study is to compare chewing patterns of the individuals with skeletally normal occlusion with those who have

abnormalities during an orthodontic treatment to offer an insight to further studies. In this comparison, differences of possible changes in chewing efficiency, opening and CT, OcT during chewing, vertical opening distance and the distance between opening and closing were analyzed.

## Materials and Methods

The study protocol was approved by the Ethics Committee at the İstanbul Aydın University, Faculty of Dentistry, and written informed consent was obtained from all subjects prior to the study.

The present prospective clinical study was carried out on 63 individuals referred to Department of Orthodontics, Faculty of Dentistry, İstanbul Aydın University for treatment purposes in 2016 including 43 patients with malocclusion and average age of 16.8 years whose growth and development terminated partially and 20 individuals with normal occlusion and average age of 24.8 years who never had any orthodontic treatment before. Healthy individuals who were at permanent dentition period and might tolerate the treatment were also included into the study. The present research was divided into three groups.

1. Group 1; 25 individuals (58%) class 1, (8 male + 17 female)

2. Group 2; 18 individuals (41.9%) class 2, (9 male + 9 Female)

3. Control group including 20 class 1 individuals with normal occlusion who were not treated before.

Data collection was performed with the parameters consisting of three main components at two intervals: T0, before the treatment; T1 6$^{th}$ month after the treatment. A fixed Edgewise Roth technique was applied to the patient for treatment purposes. During first 6-month period of the treatment, 0.22-inch Roth bracket and 0.014 Ni-Ti arch wires for alignment of lower and upper mandible at the beginning were used; 0.016, 0.018 and 0.016x0.022 Ni-Ti arch wires were used during the treatment. The following criteria were considered during material collection;

1. Being at the end of pubertal excretion period skeletally,

2. Individuals being at permanent dentition period and eruption of all teeth,

3. Being angle class 1 and class 2 in terms of skeletal and dental molar association clinically and not having premolar and molar tooth loss more than one,

4. For the control group, having skeletal and dental molar and canine teeth with normal occlusion and angle class I and minimum crowding on the anterior zone. The following points are used to exempt patients from the study,

5. Individuals with previously known syndrome, systemic disorder, craniofacial abnormality, cleft lip/palate,

6. Individuals who had any orthodontic treatment before with removable or fixed apparatus,

7. Individuals with complaint of any periodontal and TMJ disorder,

8. Congenital tooth deficiency except 3$^{rd}$ large grinders.

Approval of İstanbul Aydın University, Medicine and Health Sciences Research Board and Commitee of Ethics were obtained to carry out the research (B.30.2.AYD.0.00.00-480.2/0106, EK-1) (ANNEX-1) 9) All individuals participated into the present research voluntarily and informed consent forms were obtained from all patients and their parents.

The study group (n=43) had average age of 16.8 years and Standard deviation of ±5.55 whereas the control group (n=20) had average age of 24.8 and Standard deviation of ±4.04.

The study materials consisted of lateral cephalometric and panaromic radiographs taken before and during fixed orthodontic treatment with/without extraction, intraoral and extraoral digital photos, orthodontic cast models and chewing analysis records (Figure 1).

Lateral cephalometric films of all participants were taken in İstanbul Aydın University, Department of Orthodontics. The anatomic spots and measurements used in the present research were obtained through selection from Steiner analyses. Ten lateral films were selected randomly and radiographs of same patients were drawn subsequently with 1-month interval to minimize the errors of drawing. Method error of each measurement was calculated to detect repeatibility. Measurement recurrence coefficients range between 0.95 and 0.99.

For the cephalometric points, planes and angles used in the research; point S was marked as Cella; point N was marked as frontonasal suture; point A was marked as subspinal and point B was marked as supramental points. Angles SNA, SNB and ANB were created according to Steiner's analysis.

Evaluation of lateral cephalometric films;

Films with angle ANB between > 0° and -<4° with crowding at lower and upper mandibles were selected as angle class 1 malocclusion group,

1. Films with angle ANB > 4° was evaluated as skeletal angle class 2 div1 and selected as class 2 malocclusion group.

2. Films with angle ANB between >0° and -<4° and individuals with normal occlusion who do not need any treatment were selected as the control group.

The association of chewing movements with occlusion and characteristics of chewing pattern of the present study were obtained by a device called Bio-JT developed by Bioresearch Inc. (Milwaukee, USA) and a chewing analysis sfotware developed by Prof. Maruyama (13,14). For occlusion evaluation of chewing movements in the study, head of the patient was positioned to make the frankfort plane paralel to the ground. The head part was placed to the patient for chewing movement and both sides were made symmetrical and even through right and left screws. The lower horizontal bar was placed; then, a special magnet adhesive which was specifically developed for the device was placed on anterior surface of lower-anterior teeth through a wax (Ormco, No.757-0001) and fixed. A gum was given to the participant and the participant was instructed to chew it on the left side. Same chewing movement was instructed to all participants both inthe control and study group and uniformity of the study was provided. After a chewing movement for about 15 to 20 minutes, record was completed and the procedure was ended, the records were kept in the computer for statistical analysis.

Analyses of the present study was performed on 7 parameters obtained through three main components during chewing: 1. Opening phase, 2. Closing phase, 3. Occlusal phase.

The software "Mastication" which operates as integrated in Biopak program with Bio-JT device was used (14). Chewing velocity was assessed and maximum opening distance during chewing was examined. The following parameters were analyzed through chewing pattern analysis; (1) Chewing OT, (2) Chewing CT, (3) Chewing OcT (4) Cycle Time (cycleT) (mm/sec), (5) Terminal Chewing Position (TCP) Vertical (mm) (vertical TP), (6) Opening Velocity (mm/sec), (7) Closing Velocity (mm/sec).

**Statistical Analysis**

Evaluation of all following findings provide data of chewing efficiency of the individuals in the study group without any orthodontic abnormality and the individuals with malocclusion. The statistical analysis performed with chewing analysis findings: Power and sample size calculation (Version: 3. 1. 2, Copyright 2017, Informer Technologies, Inc., New York, USA) software was used for selection of the individuals and creation of the groups. Although working with equal sample sizes are highly desired, the present study was carried out on the groups with equal unit sample counts and different unit sample counts. The study was started with 90 individuals and this sample count was reduced to 63 by considering the inclusion criteria. The strength of the test was accepted as 80% and significance level as ($p<0.05$) for hypotheses to be established on at least 13 patients (13 and 43 patients each in both groups) through sample calculation program (19).

All statistical analyses performed on the data base were done through SPSS software (IBM SPSS Statistics Version 19-22, New York, USA). Averages and standard deviations of all samples were calculated by this software. In consideration of equal sample counts ($n=n_1=n_2$) and different sample counts, "paired sample t-test" and nonparametric Wilcoxon test were used to compare two dependent group averages, and Mann-Whitney U test was utilized for comparison of two independent group averages. The p values of ($p<0.05$) and ($p<0.01$) were accepted as significant, respectively for the hypotheses to compare the differences between averages of the variables in both groups (20).

## Results

In the present study, findings of the individuals who completed their development during the 6-month period of the treatment may be reviewed under three phases the first phase is the comparison of the statistical changes and the control of the importance to detect the differences between the control group and the group with initial malocclusion. Table 1 presents the comparison of the control group and malocclusion group under seven parameters, the values of the control group is lower than OcclT0 and CycleT0 changes and this was not statisically significant. The CT0 parameter was found higher, which

was not statistically significant. The measurement values of the other five parameters were found higher, and statistically significant changes are in question (p<0.01). The distribution of the variables of malocclusions according to the groups was provided in Figure 2.

Table 2 presents the association between initial values of the abnormality group and changes after the first 6-month treatment. Among such variables, OpenT0 (p<0.05) increased, and such increase is statistically significant. The increase at CT0, vertical TCP, Average opening velocity and Average closing velocity (p<0.01) levels is statistically significant. Furthermore, OcclT0 (p<0.05) decreased by treatment, and this was also found as statistically significant. Although the variable CycleT0 decreased by the treatment, such decrease was not statistically significant. Figure 3 provides the averages of the variables observed at the beginning and the end of the 6-month period.

Initial values of the individuals with class 1 and class 2 malocclusion were compared with the changes after 6-months through comparison of averages of two independent groups.

It was detected that class 1 and class 2 values of 6 variables increased by treatment and OcclT0 class 2 variable decreased; however, these were not found statistically significant.

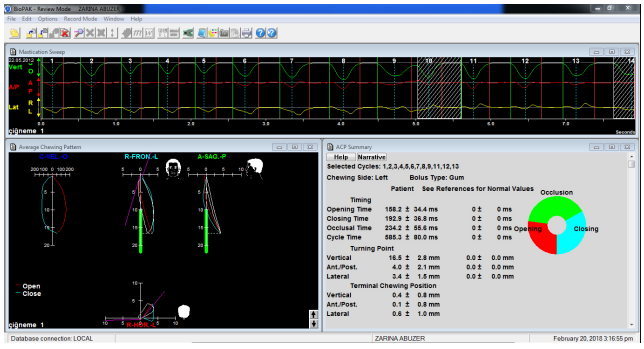

**Figure 1.** Evaluation of chewing patterns with JT

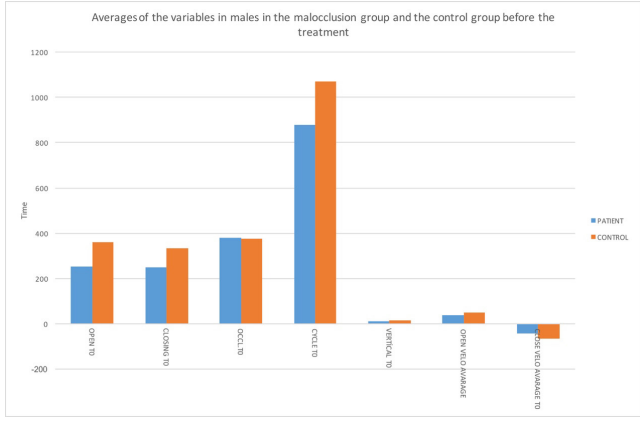


**Figure 2.** Averages of the variables of malocclusions before the treatment (T0: Control values) according to T0 group

**Table 1. Averages of malocclusions before the treatment according to time 0; comparison with the control group and control of importance**

| Parameters | Mean | n | SD | SE | p | |
|---|---|---|---|---|---|---|
| Open time 0 (initial) | 271.08 | 43 | 77.08 | 11.75 | 0.008 | ** |
| Open time 0 (control) | 338.19 | 20 | 78.93 | 21.89 | | |
| Closing time 0 (initial) | 258.66 | 43 | 50.08 | 7.67 | 0.006 | ** |
| Closing time 0 (control) | 315.42 | 20 | 94.20 | 26.13 | | |
| Occlusal time 0 (initial) | 384.07 | 43 | 173.11 | 26.40 | 0.786 | NS |
| Occlusal time 0 (control) | 370.13 | 20 | 112.24 | 31.24 | | |
| Cycle time 0 (initial) | 864.965 | 43 | 277.12 | 42.26 | 0.773 | NS |
| Cycle time 0 (control) | 837.04 | 20 | 383.12 | 106.26 | | |
| Vertical TCP T0 (initial) | 9.00 | 43 | 3.09 | 0.47 | 0 | ** |
| Vertical TCP T0 (control) | 15.71 | 20 | 4.4 | 1.22 | | |
| Avarage open velo time 0 (initial) | 34.54 | 43 | 14.64 | 2.23 | 0.001 | ** |
| Average open velo time 0 (control) | 51.45 | 20 | 13.72 | 3.80 | | |
| Avarage close velo time 0 (initial) | -37.84 | 43 | 16.39 | 2.50 | 0.000 | ** |
| Average close velo time 0 (control) | -60.85 | 20 | 14.35 | 3.98 | | |
| (p<0.05)*, (p<0.01)**, NS: Not significant, SD: Standard deviation, SE: Standard error, TCP: Terminal chewing position | | | | | | |

Table 3 compares the changes of class 1 and class 2 malocclusion during at the and of the 6-month treatment period. Analyses of the dependent in-group averages of abnormalities were performed with paired t-test and Wilcoxon test. CycleT0 class 1, class 2 parameters and OpenT0 class 1 were not found as statistically signifcant. The other parameters showed changes with the treatment and statistically significant changes appeared after the treatment, ($p<0.05$) and ($p<0.01$). Table 4 includes the cephaloetric measurements.

**Table 2. Changes of abnormalities and initial variables within 6-month treatment period and control of the associations**

| Parameters | Mean | n | SD | SE | p | |
|---|---|---|---|---|---|---|
| Open T0 (initial) | 271.08 | 43 | 77.08 | 11.75 | 0.024 | * |
| T1 (Treatment 6th Month) | 307.70 | 43 | 74.83 | 11.41 | | |
| Closing T0 (initial) | 258.66 | 43 | 50.08 | 7.64 | 0.002 | ** |
| T1 (Treatment 6th Month) | 302.58 | 43 | 78.54 | 11.98 | | |
| Occlusal T0 (initial) | 384.07 | 43 | 173.11 | 26.34 | 0.023 | * |
| T1 (Treatment 6th Month) | 312.44 | 43 | 91.27 | 13.92 | | |
| Cycle T0 (initial) | 864.96 | 43 | 277.12 | 42.26 | 0.626 | NS |
| T1 (Treatment 6th Month) | 844.06 | 43 | 246.99 | 37.67 | | |
| TCP vertical T0 (initial) | 9.00 | 43 | 3.10 | 0.47 | 0.000 | ** |
| T1 (Treatment 6th Month) | 14.56 | 43 | 4.18 | 0.64 | | |
| Avarage open velo (initial) | 34.58 | 43 | 14.64 | 2.23 | 0.000 | ** |
| T1 (Treatment 6th Month) | 54.13 | 43 | 16.11 | 2.46 | | |
| Avarage close velo (initial) | -37.4 | 43 | 16.39 | 2.50 | 0.000 | ** |
| T1 (Treatment 6th Month) | -59.79 | | 19.15 | 2.92 | | |

($p<0.05$)*, ($p<0.01$)**, NS: Not significiant, SD: Standard deviation, SE: Standard error, TCP: Terminal chewing position

**Table 3. Comparison of dependent in-group averages of the abnormalities**

| Parameters | n | Mean | SD | SE | p | |
|---|---|---|---|---|---|---|
| Open T0-T1 | 25 | 280.52 | 76.67 | 15.34 | 0.242 | NS |
| Open T0-T1 | 18 | 257.96 | 77.86 | 18.35 | 0.046 | * |
| Closing T0-T1 | 25 | 303.84 | 69.93 | 13.99 | 0.006 | ** |
| Closing T0-T1 | 18 | 313.06 | 82.92 | 19.54 | .0.050 | * |
| Occlusal T0-T1 | 25 | 253.94 | 50.38 | 10.07 | 0.021 | * |
| Occlusal T0-T1 | 18 | 265.22 | 50.34 | 11.86 | 0.270 | NS |
| Cycle T0-T1 | 25 | 287.63 | 54.20 | 10.84 | 0.307 | NS |
| Cycle T0-T1 | 18 | 323.35 | 101.53 | 23.93 | 0.778 | NS |
| TCP Vertical T0-T1 | 25 | 370.57 | 155.08 | 31.01 | 0.000 | ** |
| TCP Vertical T0-T1 | 18 | 402.81 | 198.61 | 46.81 | 0.000 | ** |
| Open velo T0-T1 | 25 | 53.35 | 12.85 | 2.57 | 0.000 | ** |
| Open velo T0-T1 | 18 | 55.22 | 20.15 | 4.75 | 0.002 | ** |
| Close velo T0-T1 | 25 | -37.01 | 13.26 | 2.65 | 0.000 | ** |
| Close velo T0-T1 | 18 | -38.98 | 20.33 | 4.79 | 0.004 | ** |

T0: Initial, T1: the end of the 6-month period of the treatment, ($p<0.05$)*, $p<0.01$)**, NS: Not significant, SD: Standard deviation, SE: Standard error, TCP: Terminal chewing position, (25=class I, 18=class 2), paired t-test and wilcoxon test

Intergroup tests were conducted among the anomalies of the variables during the treatment period. Statistically significant changes did not occur.

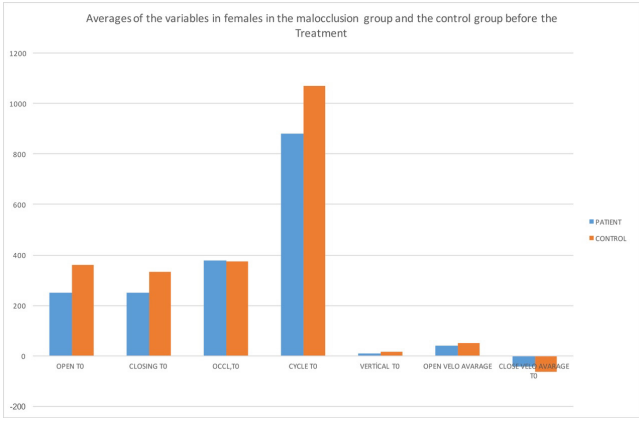


**Figure 3.** Averages of the variables at the beginning and the end of the 6-month period

Figure 4 demonstrates the average differences between initial and 6-months treatment values of class 1 and class 2.

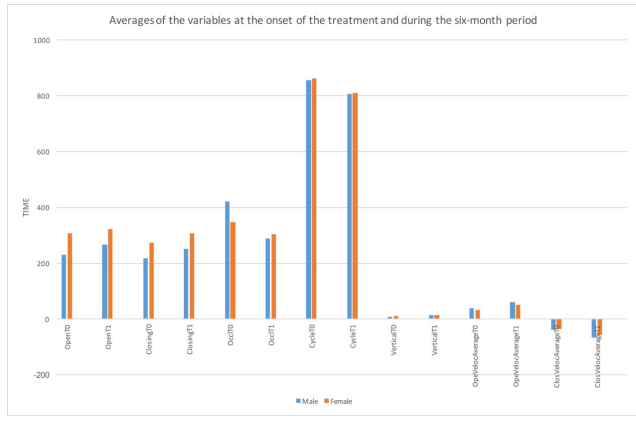


**Figure 4.** The average of the differences between groups of variables

**Table 4. Cephalometric measurements**

| | n | Range | Minimum | Maximum | Mean | | Standard deviation | Variance |
|---|---|---|---|---|---|---|---|---|
| | Statistic | Statistic | Statistic | Statistic | Statistic | Statistic | Statistic | Statistic |
| SNADERT0 | 43 | 10.3 | 73.00 | 83.3 | 798023.00 | 0.36 | 2.42 | 5.88 |
| SNADERT1 | 43 | 10.70 | 72.9 | 83.6 | 79.75 | 0.38 | 2.52 | 6.35 |
| SNADERT0 | 43 | 12.00 | 70.00 | 82.00 | 76.38 | 0.44 | 2.92 | 8.54 |
| SNADERT1 | 43 | 12.00 | 67.00 | 82.00 | 76.73 | 0.45 | 2.98 | 8.92 |
| SNADERT0 | 43 | 12.00 | 67.00 | 79.00 | 74.21 | 0.41 | 2.7 | 7.3 |
| SNADERT1 | 43 | 12,00 | 67.00 | 79.00 | 74.47 | 0.43 | 2.83 | 8.04 |
| ANDERT0 | 43 | 7.5 | 0.00 | 7.5 | 3.39 | 0.31 | 2.08 | 4.35 |
| ANDERT1 | 43 | 7.7 | 0.00 | 7.7 | 3.03 | 0.3 | 1.97 | 3.92 |
| PROGNBT0mm | 43 | 6,00 | -1.00 | 5.00 | 1.96 | 0.19 | 1.3 | 1.69 |
| PROGNBT1mm | 43 | 26.00 | -1.00 | 25.00 | 2.6 | 0.57 | 3.73 | 13.98 |
| GOGNSNT0der | 43 | 24.00 | 20.00 | 44.00 | 33.33 | 0.76 | 5.03 | 25.35 |
| GOGNSNT1der | 43 | 22.4 | 21.6 | 44.00 | 33.49 | 0.8 | 5.24 | 27.53 |
| COAT0mm | 43 | 17.00 | 72.00 | 89.00 | 80.41 | 0.56 | 3.69 | 13.63 |
| COAT1mm | 43 | 17.00 | 72.00 | 89.00 | 80.82 | 0.59 | 3.91 | 15.36 |
| ANPERPT0mm | 43 | 12.00 | -7.00 | 5.00 | -0.61 | 0.35 | 2.32 | 5.42 |
| ANPERPT1mm | 43 | 12.00 | -7.00 | 5.00 | -0.36 | 0.3 | 2.00 | 4.01 |
| ANSMET0mm | 43 | 25.00 | 51.00 | 76.00 | 61.95 | 0.89 | 5.86 | 34.37 |
| ANSMET1mm | 43 | 24.00 | 52.00 | 76.00 | 62.62 | 0.84 | 5.52 | 30.51 |
| BANPTMT0der | 43 | 15.00 | 79.00 | 94.00 | 86.76 | 0.63 | 4.13 | 17.13 |
| BANPTMT1der | 43 | 13.00 | 80.00 | 93.00 | 86.75 | 0.57 | 3.79 | 14.37 |
| SPpgoMeT0der | 43 | 22.00 | 14.00 | 36.00 | 24.2 | 0.72 | 4.77 | 22.78 |

**Table 4. contiuned**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| SPpgoMeT1der | 43 | 23.00 | 13.00 | 36.00 | 24.72 | 0.72 | 4.72 | 22.3 |
| PNPOGT0mm | 43 | 21.00 | -17.00 | 4.00 | -5.74 | 0.59 | 3.88 | 15.1 |
| PNPOGT1mm | 43 | 20.00 | -16.00 | 4.00 | -5.24 | 0.54 | 3.57 | 12.8 |
| WittsT0mm | 43 | 12.00 | -3.00 | 9.00 | 1.23 | 0.41 | 2.72 | 7.42 |
| WittsT1mm | 43 | 11.00 | -3.00 | 8.00 | 0.87 | 0.4 | 2.63 | 6.95 |
| NA1T0mm | 43 | 17.00 | 0.00 | 17.00 | 5.08 | 0.45 | 2.95 | 8.76 |
| NA1T1mm | 43 | 17.00 | 0.00 | 17.00 | 5.11 | 0.41 | 2.74 | 7.52 |
| NA1T0DRCE | 43 | 33.00 | 6.00 | 39.00 | 22.63 | 1.16 | 7.66 | 58.69 |
| NA1T1DRCE | 43 | 26.00 | 13.00 | 39.00 | 23.52 | 0.79 | 5.21 | 27.14 |
| NB1T0mm | 43 | 9.00 | 0.00 | 9.00 | 4.43 | 0.31 | 2.02 | 4.1 |
| NB1T1mm | 43 | 9.00 | 0.00 | 9.00 | 4.86 | 0.28 | 1.87 | 3.49 |
| NB1T0DRCE | 43 | 23.5 | 11.5 | 35.00 | 24.74 | 0.84 | 5.5 | 3.02 |
| NB1T1DRCE | 43 | 17.3 | 15.7 | 33.00 | 25.69 | 0.66 | 4.29 | 18.46 |
| T011DRCE | 43 | 53.5 | 106.5 | 160.00 | 130.88 | 1.83 | 11.99 | 143.85 |
| T111DRCE | 43 | 52.5 | 107.5 | 160.00 | 129.35 | 1.32 | 8.64 | 74.58 |
| ALT1APGT0mm | 43 | 11.00 | -3.00 | 8.00 | 1.69 | 0.3 | 1.98 | 3.93 |
| ALT1APGT1mm | 43 | 10.00 | -2.00 | 8.00 | 2.04 | 0.29 | 1.91 | 3.66 |
| U1AVERTT0mm | 43 | 17.00 | -5.00 | 12.00 | 3.62 | 0.53 | 3.51 | 12.38 |
| U1AVERTT1mm | 43 | 14.5 | -3.00 | 11.5 | 3.91 | 0.44 | 2.88 | 8.33 |
| OCCLSNT0 | 43 | 13.00 | 11.00 | 24.00 | 16.96 | 0.44 | 2.94 | 8.69 |
| OCCLSNT1 | 43 | 23.00 | 2.5 | 25.8 | 16.53 | 0.57 | 3.75 | 14.07 |
| IMPAT0DRCE | 43 | 35.00 | 74.00 | 109.00 | 92.32 | 1.11 | 7.29 | 53.27 |
| IMPAT1DRCE | 43 | 36.5 | 74.5 | 111.00 | 93.2 | 1,00 | 6.6 | 43.58 |
| HldawayfarkT0 | 43 | 10.00 | -2.00 | 8.00 | 2.75 | 0.36 | 2.38 | 5.67 |
| HldawayfarkT1 | 43 | 9.00 | -1.00 | 8.00 | 3.02 | 0.35 | 2.33 | 5.46 |
| S-LT0 | 43 | 21.00 | 34.00 | 55.00 | 45.46 | 0.67 | 4.43 | 19.68 |
| S-LT1 | 43 | 22.00 | 34.00 | 56.00 | 45.83 | 0.73 | 4.81 | 23.17 |
| S-ET0 | 43 | 8.00 | 15.00 | 23.00 | 19.32 | 0.3 | 1.98 | 3.93 |
| S-ET1 | 43 | 7.5 | 15.00 | 22.5 | 19.31 | 0.27 | 1.82 | 3.34 |
| OVERJETT0 | 43 | 9.00 | 1.00 | 10.00 | 4.01 | 0.32 | 2.12 | 4.5 |
| OVERJETT1 | 43 | 6.6 | 0.4 | 7.00 | 3.38 | 0.26 | 1.73 | 2.99 |
| OVERBITET0 | 43 | 10.5 | -2.5 | 8.00 | 2.68 | 0.34 | 2.28 | 5.21 |
| OVERBITET1 | 43 | 9.9 | -2.9 | 7.00 | 2.45 | 0.28 | 1.89 | 3.6 |
| 6U6LOCPT0 | 43 | 8.00 | -3.00 | 5.00 | -0.43 | 0.24 | 1.57 | 2.47 |
| 6U6LOCPT1 | 43 | 8.6 | -3.6 | 5.00 | -0.34 | 0.26 | 1.71 | 2.94 |
| 3U3LOCPT0 | 43 | 8.6 | -3.6 | 5.00 | 0.2 | 0.25 | 1.68 | 2.83 |
| 3U3LOCPT1 | 43 | 8.2 | -3.2 | 5.00 | 0.59 | 0.27 | 1.79 | 3.23 |
| ALT1-OCPT0 | 43 | 6.1 | -0.4 | 5.7 | 2,00 | 0.21 | 1.42 | 2.02 |
| ALT1-OCPT1 | 42 | 5.00 | 0.00 | 5.00 | 1.71 | 0.2 | 1.32 | 1.75 |
| Valid N (listwise) | 42 | | | | | | | |

## Discussion

The chewing material used in the present study was the chewing gum. The quantity of the gum is equal at each chewing time and the hard gum is softened after 3 to 5 chewing cycles. All participants' chewing movements were recorded when the gum was hard and softened. The chewing patterns obtained in the control group of the present study was found consistent with those obtained by Kuwahara et al. (12,18). Furthermore, such data are quite similar when compared with the findings obtained by both Hill and Piancino et al. (2,21). Since the first 2 or 3 cycles of chewing were not recorded in the present study, this allowed the participants to adopt the equipment used. The results obtained by Papa Ibrahima Ngom et al. (15) are similar with the present study and harmonization of all organs in the chewing system was achieved.

A study conducted by Winocur et al. (22) evaluated the changes in the muscles after orthodontic treatments through the parameters of maximum biting strength, maximum sliding from intercuspal position and muscle sensitivity by palpation; and it was reported that neuromuscular modification just starts in orthodontic treatments and muscle adoptation is observed to be settled within 3-months after the treatment. Similarly, harmonization of opening and closing movements within first 6-months of the treatment is detected.

This necessary event for harmonization of neuromuscular mechanism was performed in a similar environment mentioned in Schindler's study (8). Comparison of opening and closing velocities between the occlusion group and the control group was used as an indicator for evaluation of chewing efficiency. The closing velocity of the present research was considered as the most important indicator of chewing technique as specified in the study of Radke. Radke reported in his study through use of JT that the velocity ratio in chewing velocity test is an important factor for evaluation of chewing efficiency (23).

Findings of the first phase in the present study are values of the control group as well as initial values of the treatment group. The significant difference between opening and CT fort the control group presented in table 1 is expected; the opening value of the individuals with malocclusion was 271.08 msec and this was very high in the control group as 338.19 msec. The difference between OpenT0 and OpenT1 was found significant in both groups ($p<0.01$). The difference between CT0 and CT1 was 56.763 msec which is significant ($p<0.01$). Opening period of the control group is 67 msec longer than OT of the malocclusion group. This significant difference is not an unexpected case for pre-treatment period. Higher value and significance of the difference are similar with findings of Lepley et al. (24) and Owens et al. (25). In a comparative study on chewing efficiency conducted by Lepley et al. (24), an artifical Cuttersil chewing material was chown by 30 individuals with class 1 occlusion and chewing performances were compared; they found the OT of the individuals without malocclusion as 274±22. When they evaluated with chewing efficiency, such time was detected to increase up to 325±27 msec in the individuals with malocclusion included into the poor chewing group and detected this difference as significant. The initial opening durations (338.20 msec) obtained in the present study are closely similar to durations of the individuals with malocclusion obtained in the study of J. Lepley (24). This indicated that chewing efficiency of the malocclusion group is lower and they have a less efficient chewing performance because of higher values than the control group. However, the difference between occlusion duration parameters in both groups was not significant; this result was considered that the malocclusion group acted faster and had a near-normal chewing pattern during closure. Total cycle time which was not significant at initial values is considered as a poor chewing pattern with a lower chewing performance. The most important parameters showing the chewing efficiency directly are Opening and Closing strength values and confirm this idea. Such results indicate that malocclusion group has a less chewing efficiency when compared with the control group. Values of the chewing efficiency increased due to some causes such as onset of the treatment for malocclusion, accurate movement of the teeth and resolvement of the crowding; in other words, malocclusion group showed a poor chewing efficiency. These findings may be seen in the values at months 6 of orthodontic treatment in Table 2. Since the occlusion started to improve, chewing opening and CT increased 34.54 msec than initial times and the difference was significant ($p<0.05$). Another important

effect of the treatment appeared on occlusion times; the initial value of Occlusion Contact Time was 384.07 msec and reduced to 312.44 msec ($p<0.05$). The most significant change at months 6 from onset of the treatment was increase of chewing efficiency (Initial value of Op-Velocity) which was 34.54 at the beginning to 54.13 (months 6 value of Op-Velocity) ($p<0.01$). This reveals the realistic change effect of the treatment on chewing efficiency.

Along with the increase in chewing efficiency in treated individuals, decrease in occlusal contact time indicates that a less time than before may be sufficient even occlusal contact zones were not changes. Occlusion time decreased and the OcclT0 value which has an initial value of 384.07 msec reduced to 312.44 msec ($p<0.05$). Functional occlusal zone was reported to have a more efficient chewing performance than the occlusal surface or plane surface. These findings comply with the outcomes of the studies conducted by Yawaka et al. (26), Owens et al. (25) and Okiyama et al. (27). The evaluation of the chewing movements of the individuals with class 1 and class 2 malocclusions whose growth and development were about to end at 6$^{th}$ month of the treatment suggested a statistically significant imporvement in the values obtained in both groups from onset of the treatment. Open-Velo T0-T1 values demonstrates the changes in initial and 6-months treatment values for class 2 are significant ($p<0.01$). However, the change rate in the group with class 2 malocclusion is more than the change rate of 25 individuals with class 1 malocclusion. Although such values are concrete, relative values obtained during comparison between them should not be evaluated as unexpected.

## Conclusion

We observed the changes on chewing movements of the individuals with malocclusion whose growth and development are completed within such a short period of 6-months from onset of the treatment when compared with initial values as well as the individuals with normal closing. Such changes are dependent to the treatment. Although this rapid effect of the treatment is considered to appear by recovery of the occlusion, it may also appear due to disruption of routine chewing pattern with malocclusion which was settled into the memory. This should not be ignored at treatment phases. It is also important for undesired temporomandibular disorders after the treatment. Because, it should be considered that the changing occlusion relation may have a positive effect on TMJ. To monitor these studies at the end of the treatment and during retention period after the treatment would be useful.

**Ethics**

**Ethics Committee Approval:** The study protocol was approved by the Ethics Committee at the İstanbul Aydın University, Faculty of Dentistry.

**Informed Consent:** Written informed consent was obtained from all subjects prior to the study.

**Peer-review:** Externally peer-reviewed.

**Conflict of Interest:** There is no conflict of interest of this study.

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