JKPT Vol. 35, No. 6, December 2023
J Kor Phys Ther 2023;35(6):185-189
pISSN 1229-0475 eISSN 2287-156X

Original Article

https://doi.org/10.18857/jkpt.2023.35.6.185

Immediate Effects of Asymmetric Chewing on Temporomandibular Joint Kinematics

Tae-Joon Um, Han-Seung Choi, Dong Yeop Lee, Jae Ho Yu, Jin Seop Kim, Seung Gil Kim, Jiheon Hong

Department of Physical Therapy, College of Health Sciences, Sun Moon University, Asan, Republic of Korea

Purpose: This study investigated the immediate biomechanical effects of unilateral mastication for 10 minutes on the temporomandibular joint (TMJ) with 21 healthy adult participants.
Methods: The gum group chewed gum on the right side for 10 minutes, and the control group rested for 10 minutes. Biomechanical data were obtained using a three-dimensional infrared camera before and after intervention. An independent t-test assessed the variation of kinematic data to identify differences between before and after intervention.
Results: Among biomechanical variables, the gum group's length of the left forehead middle region and the temporomandibular joint angle decreased compared to the control group ($p < 0.05$).
Conclusion: Caution with unilateral masticatory activity is recommended, as unilateral mastication causes biomechanical changes due to excessive load on the soft tissues of the contralateral TMJ.

Keywords: Temporomandibular joint, Masticatory movement, Unilateral mastication

INTRODUCTION

The temporomandibular joint (TMJ) is a complex and crucial component of the human craniofacial system, serving as a pivotal junction between the temporal bone and the mandible.[1] This anatomical structure facilitates essential functions such as speech, eating, and facial expressions, highlighting its significance for an overall healthy life. The intricate TMJ mechanics incorporate a harmonious interplay between muscles, ligaments, and the joint itself, making it vulnerable to various influences that can perturb its function. Most people have a unilateral chewing preference or a habitual mastication side.[2]

Asymmetrical mastication patterns are implicated in the etiology of temporomandibular disorders, encompassing various conditions affecting the TMJ and the surrounding structures.[3] Furthermore, asymmetrical chewing habits impact craniofacial growth and development, contributing to facial asymmetry.[4] The preference for chewing on one side causes the condylar path angle and the dental arch to change and become distorted. Masticatory laterality significantly influences maximum bite force and occlusal contact, and a unilateral chewing preference is correlated with better masticatory performance.[5,6] Human mastication, driven by an intricate neural network and coordinated muscle actions, is far from symmetrical. Exploring brain activity during asymmetrical chewing through functional MRI has revealed a connection between chewing-side preference and hemispheric dominance. In particular, the primary sensorimotor cortex orchestrates rhythmic chewing movements.[7]

A comprehensive exploration of asymmetrical mastication effects on TMJ dynamics is essential for gaining insights into potential pathophysiologic mechanisms and strategies for prevention and intervention. In recent years, considerable advancements have yielded sophisticated systems tailored for recording and analyzing these movements. These methods quantify parameters to support temporomandibular disorder clinical diagnosis and treatment.[8-10] However, most studies investigated patients with unstable TMJs or impairments, focusing on therapeutic approaches for temporomandibular disorder management.[1-7] Despite the significance of unilateral chewing preference, the exact kinematic alterations within the TMJ from such habits remain inadequately understood. Optical mo-

Received November 20, 2023 **Revised** December 26, 2023
Accepted December 28, 2023
Corresponding author Jiheon Hong
E-mail hgh1020@hanmail.net

tion capture systems have been effectively employed in researching TMJ motion and kinematics, demonstrating exceptional validity, reliability, and precision.[11,12]

By shedding light on the biomechanical consequences of unilateral chewing, researchers and clinicians can better address its potential impact on TMJ health and overall craniofacial harmony. Therefore, studying the biomechanical changes of the asymptomatic temporomandibular joint for unilateral chewing is crucial. This study utilized an optical motion capture system to examine immediate TMJ changes due to asymmetric mastication in normal adults.

METHODS

1. Subjects

The Institutional Review Board of Sunmoon University granted ethical approval for this study (Approval No. SM-202204-009-1). First, 21 healthy students (ten males and eleven females) aged 20-30 were recruited for this research. Inclusion criteria encompassed the absence of pain in the temple, face, TMJ, or jaw within the preceding week. Exclusion criteria comprised neurological disorders, ongoing dental treatment, neck or jaw trauma history, and torticollis. Participants received comprehensive explanations of the study's objectives and procedures and provided written informed consent before involvement.

Participants were randomly allocated into the "gum group" (five males and five females: mean age: 23.0 ± 1.4) or the "control group" (five males and six females; mean age: 24.9 ± 3.1). The gum group was instructed to chew a piece of gum solely on the right side in a comfortable sitting position and speed for 10 minutes, while the control group refrained from any masticatory activity and rested for the same duration. Three-dimensional kinematics data of TMJ were acquired before and after the 10-minute intervention to assess intervention impacts.

2. Experimental procedures

1) Data acquisition

Mandibular movements were tracked using three motion analysis infrared cameras (Oqus100™, QUALISYS, Gothenburg, Sweden) placed 156 cm high and tilted down 15°.[11] One central camera (to see all markers) and one on each side (left and right) were placed around the participant. The left and right cameras were placed approximately 1m from the participant, forming a 120° angle, and the central camera was placed 1.3m away from the subject. A configuration comprising nine reflective markers facilitated the analysis of mandibular movement. These tracking markers were affixed using adhesive tape to specific facial regions, as follows: (1) forehead, (2) above the upper lip, (3) chin, (4) external TMJ surfaces on the left and right, (5) mandible angle regions on the left and right sides, and (6) within the middle region between the chin and the mandible angle on the left and right sides (Figure 1).[11]

The participant was comfortably seated in a chair with a marker attached to their face. The kinematic TMJ function analysis examined two distinct postures: the closed-mouth position where the teeth were in contact and the maximal mouth opening position. The gum group was provided chewing gum for only right-side mastication for 10 minutes while

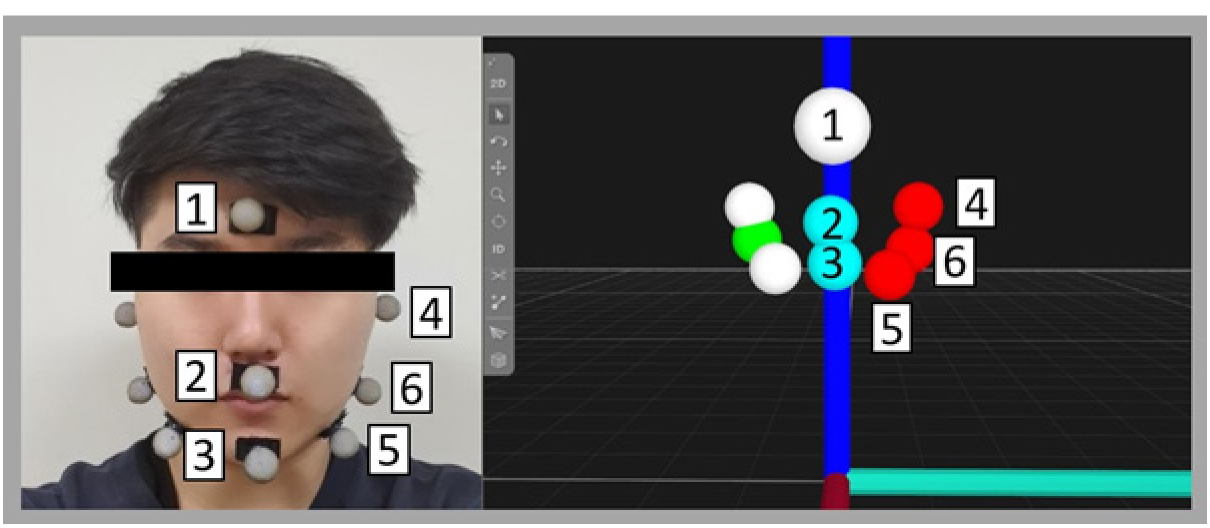

Figure 1. Reflective marker placements to examine mandibular movement: (1) forehead, (2) above the upper lip, (3) chin, (4) TMJ external surfaces, (5) mandible angle region, and (6) middle region between the chin and the mandible angle.

https://doi.org/10.18857/jkpt.2023.35.6.185

the control group rested. After this 10-minute interval, the two postures were once again evaluated.

2) Data analysis

Trajectory labeling was conducted using Qualisys Tracker Manager (QTM 2.8.1065, Qualisys, Sweden) to assess alterations in kinematic data on the mandible before and after the intervention. QTM utilizes a coordinate plane system (X, Y, Z) to calculate marker positions within a 3D space. The distance between two markers, denoted as points A (a, b, c) and B (d, e, f) in the 3D coordinate space, was determined using the Pythagorean theorem:

$$Distance\ AB = \sqrt{(a-d)^2 - (b-e)^2 - (c-f)^2}$$

The distance-related kinematic data included three distance values: forehead-to-chin (FC), forehead-right middle (RtFM), and forehead-left middle regions (LtFM). FC distance was calculated by adding the distance from the forehead to the upper lip marker and from the upper lip to the chin marker. FM distance was obtained by adding the distance from the forehead to the TMJ marker and from the TMJ to the middle region marker. The angle-related kinematic data included the forehead-to-chin angle (FCA) and both side TMJ angles. The FCA was the angle between the line connecting the forehead and the upper lip marker and the line connecting the upper lip and the chin marker. The TMJ angle was the angle between the line connecting the forehead and the TMJ marker and the line connecting the TMJ and the mandible angle regions marker.

3) Statistical analysis

This study analyzed the kinematic data variations between the gum and control groups to verify the effect of 10-minute unilateral gum chewing. We calculated kinematic data changes by subtracting the post-intervention data from the pre-intervention data. The Shapiro-Wilk test confirmed that all kinematic data variations met the normality assumption. An independent t-test compared the differences in distance and angle shifts between groups. All analyses used SPSS (IBM SPSS Statistics for Windows, Version 28.0. Armonk, NY) and an $\alpha = 0.05$ statistical significance.

RESULTS

Table 1 provides the mean distance and angle variations between pre-intervention and post-intervention obtained from the closed-mouth and the maximal mouth opening positions. Independent t-test results indicated that the gum group had a significant decrease in LtFM length and the left TMJ angle at the maximal mouth opening position compared to the control group ($p < 0.05$). There were no significant differences in other kinematic data in the maximal mouth opening position and all lengths and angles in the closed-mouth position ($p > 0.05$).

DISCUSSION

This study investigated the immediate effects of unilateral gum chewing on jaw kinematics and TMJ movements in healthy subjects. We measured jaw kinematics with a motion analysis system 10 minutes before and after right unilateral gum chewing. The changes between the chewing and con-

Table 1. Distance and angle variation before and after intervention

			Gum	Control	p
Closed mouth	Distance (mm)	FC	-0.75±1.32	0.17±1.02	0.584
		RtFM	-0.32±0.69	-0.50±0.63	0.854
		LtFM	-0.90±0.92	1.52±1.26	0.072
	Angle (°)	FCA	0.10±0.90	-0.33±1.07	0.765
		Rt. TMJ	0.31±0.64	0.99±0.40	0.375
		Lt. TMJ	0.11±0.64	-0.26±0.58	0.671
Maximal mouth opening	Distance (mm)	FC	0.34±2.00	-3.53±2.07	0.196
		RtFM	-0.71±0.61	0.16±0.49	0.274
		LtFM	-1.27±0.92	1.66±0.79	0.027*
	Angle (°)	FCA	-0.39±1.43	1.69±1.28	0.146
		Rt. TMJ	0.97±0.83	-0.05±0.53	0.310
		Lt. TMJ	-6.52±1.02	-0.90±0.56	0.001*

Mean±standard deviation. FC: forehead to chin, RtFM: forehead to right middle region, LtFM: forehead to left middle region, FCA: forehead-to-chin angle, TMJ: temporomandibular joint. *$p < 0.05$.

trol groups at the mouth-closed position were not significantly different before and after treatment. However, the chewing group's LtFM length and left TMJ angle at the maximal mouth opening position decreased compared to the control group. FA length reflected the mandible position. The left side length decreased due to unilateral gum chewing, but the right side did not change, indicating that the lower jaw did not move to one side. Additionally, the opening length in the fully opened mouth position did not change, but the left TMJ angle decreased. These two changes are due to a decrease in left temporomandibular joint space. To our knowledge, this study is the first to determine that unilateral gum chewing can cause asymmetric loading on the TMJ and alter jaw kinematics during mouth opening.

Previous studies have indicated that unilateral chewing preference is governed by neurological control and have aimed to enhance masticatory function efficiency.[5-7] Nevertheless, chewing side preference may have a deleterious effect on the TMJ of the corresponding side and is associated with lateral facial asymmetry.[13] A previous electromyographic study demonstrated that the right masseter muscle exhibited 38% muscle activity compared to maximum voluntary contraction during 10 minutes of chewing gum on the right side.[14] Conversely, the left masseter muscle indicated 19% activity. Most participants (75%) in that investigation experienced muscle fatigue but did not report pain. As such, the authors found no evidence supporting the theoretical foundation of myofascial pain/dysfunction syndrome following 10 minutes of unilateral gum chewing. In this study, 10 minutes of unilateral gum chewing may cause masseter muscle fatigue but does not directly affect jaw movement.

The TMJ is a synovial joint with a unique structure and convex articulating surfaces.[1] The joint is separated into upper and lower segments by a thin disk. The upper segment forms a plane gliding structure, while the lower segments act as a hinge joint. When the mouth opens, the mandibular condyle faces downward and is simultaneously pulled anteriorly. This action causes the condyle and the articular disc to glide forward from the mandibular fossa onto the downward projecting articular tubercle. These movements are largely produced by pterygoid muscles. The exterior oblique band becomes taut during condyle protraction, which accompanies the jaw opening, limiting the condyle's inferior distraction during forward gliding and rotational movements. The inner horizontal band tightens when the mandible head retracts, limiting posterior condyle movement.[15]

In other words, the disc repetitively moves back and forth during mastication due to the lateral pterygoid muscles, and the disc returns to its original position through connective tissue tension (outer oblique and inner horizontal band). Therefore, 10 minutes of unilateral gum chewing loosens the connective tissue and displaces the disc. Interestingly, this study observed biomechanical confusion for the TMJ on the opposite side of unilateral chewing. Jaw muscle activity and kinematics changed in response to food hardness.[16] For example, a traction force is applied to the TMJ's articular surface if food is present during chewing. Conversely, the load on the TMJ surface on the opposite side of unilateral chewing increases. Therefore, it seems that less articular movement occurs in the TMJ on the unilateral masticatory side compared to the contralateral side, augmenting stress on the contralateral side's connective tissue.

This study has several limitations. First, caution is needed when generalizing to all age groups since the sample group was relatively small, with only 21 healthy men and women in their 20s. Second, this study aimed to confirm immediate changes in masticatory movement; thus, it is difficult to determine the long-term effect. Third, there is limitation in generalizing the physical properties of the gum products used in this study. Fourth, since this study could not accurately examine the temporomandibular joint's muscular fatigue, further study is needed to support additional claims.

CONCLUSION

In conclusion, unilateral mastication results in biomechanical changes due to excessive load on the contralateral TMJ's soft tissue. The reason for biomechanical confusion regarding the temporomandibular joint is a change in disc position. Changes in the joint's soft tissue can alter muscular force points, leading to progressive diseases. Therefore, attention must focus on unilateral masticatory activity.

ACKNOWLEDGEMENTS

본 연구는 한국 정부가 지원하는 한국연구재단의 연구비 지원을 받은 연구임(RS-2023-00253175).

REFERENCES

1. Christensen LV, Radue JT. Lateral preference in mastication: a feasibility study. J Oral Rehabil. 1985;12(5):421-7.
2. Oh J, Kim SY, Kyung MS et al. Reliability of quantifying maximal mouth opening and lateral mandibular shift in individuals with and without temporomandibular disorder using three-dimensional ultrasound-

based motion analysis. Phys Ther Korea. 2019;26(3):99-105.
3. Lujan-Climent M, Martinez-Gomis J, Palau S et al. Influence of static and dynamic occlusal characteristics and muscle force on masticatory performance in dentate adults. Eur J Oral Sci. 2008;116(3):229-36.
4. Okeson JP. Management of temporomandibular disorders and occlusion-E-book. Edinburg, London, Elsevier Health Sciences, 2019:85.
5. Alomar X, Medrano J, Cabratosa J et al. Anatomy of the temporomandibular joint. Edinburg, London, Elsevier, 2007:170-83.
6. Rovira Lastra B, Flores Orozco EI, Salsench J et al. Is the side with the best masticatory performance selected for chewing? Arch Oral Biol. 2014;59(12):1316-20.
7. Jeon HM, Ahn YW, Jeong SH et al. Pattern analysis of patients with temporomandibular disorders resulting from unilateral mastication due to chronic periodontitis. J Periodontal Implant Sci. 2017;47(4):211-8.
8. Almotairy N, Kumar A, Grigoriadis A. Effect of food hardness on chewing behavior in children. Clin Oral Investig. 2021;25:1203-16.
9. Tiwari S, Nambiar S, Unnikrishnan B. Chewing side preference-Impact on facial symmetry, dentition and temporomandibular joint and its correlation with handedness. J Orofac Sci. 2017;9(1):22-7.
10. Jiang H, Liu H, Liu G et al. Analysis of brain activity involved in chewing-side preference during chewing: an fMRI study. J Oral Rehabil. 2015;42(1):27-33.
11. Naeije M. Local kinematic and anthropometric factors related to the maximum mouth opening in healthy individuals. J Oral Rehabil. 2002;29(6):534-9.
12. Kalaykova S, Naeije M, Huddleston Slater J et al. Is condylar position a predictor for functional signs of TMJ hypermobility? J Oral Rehabil. 2006;33(5):349-55.
13. McMinn R. Last anatomy regional and applied In: head and neck and spine. Edinburg, London Churchill Livingstone, 1994:523.
14. Furtado DA, Pereira AA, Andrade A de O et al. A specialized motion capture system for real-time analysis of mandibular movements using infrared cameras. Biomed Eng Online. 2013;12(1):1-16.
15. Christensen LV, Tran KT, Mohamed SE. Gum chewing and jaw muscle fatigue and pains. J Oral Rehabil. 1996;23(6):424-37.
16. Fukui TM, Tsuruta K, Murata K et al. Correlation between facial morphology, mouth opening ability, and condylar movement during opening–closing jaw movements in female adults with normal occlusion. Eur J Orthod. 2002;24(4):327-36.