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Original Article

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The Effectiveness of Air Insoles in Improving Temporomandibular Disorders

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| Abstract |

Objective: In patients with temporomandibular joint disorders, air insoles are used to investigate functionality and pain changes in the temporomandibular joint when walking in daily life.

Intervention: Sixty-five patients with temporomandibular joint disorder were recruited: 34 as a control group who walked more than 7,000 steps a day in daily life, and 31 as an experimental group who were instructed to take at least 7,000 steps every day while wearing their air insoles.

Measurements: To determine the effects of air insoles on temporomandibular joint pain, steady-state pain, maximum mouth opening, average pain, and the most severe pain were measured before and after the experiment. In addition, to evaluate functionality, the ability to open the mouth in a comfortable state, pain when opening the mouth, and the point of sound and maximum degree to which the mouth could be opened were evaluated before and after the experiment.

Results: Pain, mouth openness, and sound points showed significant differences from the control group after the experiment, and the maximum mouth opening range showed no significant difference.

Conclusion: When air insoles were used by patients with temporomandibular joint disorder, the functionality of the temporomandibular joint was improved and pain was decreased.

Key Words: Temporomandibular Joint, Air Insole, Walking, TMJ Disorder

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Ⅰ. Introduction

Temporomandibular disorders (TMDs) are major musculoskeletal conditions affecting the orofacial region and are among the most common causes of orofacial pain(Yang & Kim, 2009). The common pain regions associated with TMDs are the masticatory muscles, frontal ear, and temporomandibular joint (TMJ). Pain can be triggered or aggravated by talking, chewing, or lower jaw movements, in general, and is often accompanied by symptoms such as condylar jamming, TMJ noise (clicking sounds), limitation of mouth opening, and asymmetric facial motion (Schiffman et al., 1990).

Various causes of TMDs have been reported. They include impaired neuromuscular control, impaired TMJ development, malocclusion, incorrect restoration, incorrect oral exercise habits, stress, trauma, nutrition deficiencies, and hormonal and metabolic disorders (Jung & Kim, 2005). Despite their high prevalence, TMDs are often missed, and they may lead to chronic pain if they are not diagnosed early and fully treated. Chronic pain can have negative effects on the physical, mental, and social wellbeing and quality of life of individuals (Walczyńska-Dragon et al., 2014).

In addition to pain, TMDs can impair chewing ability, and a compromise of chewing ability can lead to a deterioration of quality of life. Various subjective and objective methods for assessing chewing ability have been introduced (Lee et al., 2010). General treatments for TMDs include occlusal devices, pain treatment, and psychological intervention; however, a standard treatment is yet to be established, and the risk factors associated with TMDs are not fully understood (Cairns, 2010).

Kwon et al. (2000) reported that conservative and invasive treatment approaches are effective; however, invasive options can exacerbate TMD symptoms, and conservative treatments should be considered as primary options. Several studies have assessed the association between TMJ motion and body posture, and other extensive clinical studies are ongoing (Kim et al., 2012).

A functional foot orthosis can correct deformities of body segments and enhance foot functions directly related to the sole when wearing shoes. It also helps maintain body balance and an upright posture by supporting weakened parts of the body (Hertel et al., 2005). Orthotic insoles, which can be used comfortably inside different types of footwear, protect the lower-limb joints by absorbing shock and weight and reduce fatigue by optimally distributing weight (Garner., 1988). Customized insoles positively affect joint angles and weight distribution and have excellent shock absorption properties (Moon, 2012).

Several previous studies have reported on the advantages of various insoles; however, little attention has been paid to their use to improve TMDs. This study was designed to investigate the pain severity, range of mouth opening, and functional level of patients with TMDs when walking at a constant pace with air insoles in their footwear. The results of this study are expected to provide evidence for the improvement of TMDs using insoles.

Ⅱ. Methods

1. Participants

The study population included adult men and women residing in D city, Republic of Korea. The participants were recruited from July to September 2022 through one-on-one interviews. The following two questions were asked: (1) Have you ever felt pain in the temple, face, front of the ear (TMJ), or jaw at least once in the past week? (2) Have you ever felt pain when opening your mouth or chewing food? Respondents who answered in

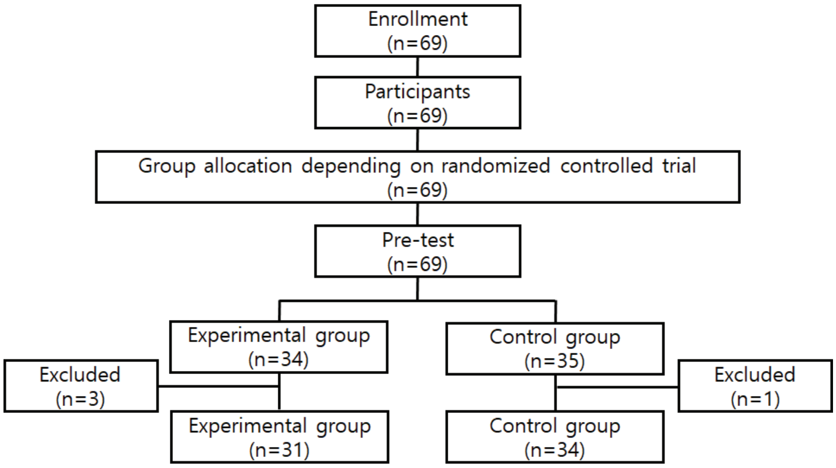

Fig. 1. Flow diagram for participants.

the affirmative to both questions were classified as patients with TMDs (Nilsson et al., 2006). Participants were excluded if they had neurological problems, were receiving orthodontic treatment, had a history of neck or jaw trauma, were receiving regular dental care, or were unable to take at least 7,000 steps/day. A total of 69 participants were recruited and randomly assigned to two groups: 34 in the experimental group and 35 in the control group. Three participants undergoing dental correction were excluded from the experimental group, while one participant receiving regular dental treatment was excluded from the control group. After excluding these individuals, a total of 31 participants in the experimental group and 34 in the control group were selected as the final sample.

2. Research Procedure

Fig. 1 shows the flow diagram of the study.

3. Assessment Tools and Techniques

1) Study procedure and intervention protocol

Before using air insoles for TMD patients, one-on-one interviews were repeated to assess the baseline (pre-experiment) conditions to determine participants eligible for the study. The following baseline items were assessed: severity of TMDs using the TMD assessment questionnaire, TMJ pain using the Numeric Pain Rating Scale (NPRS), and range of mouth opening. The subjects were randomly assigned to the experimental and control groups using a randomization table. Before the experiment, the experimental group was provided with two pairs of air insoles matching their shoe sizes (one for the experiment and one as a reserve) (Fig. 2). The experimental group was instructed to take at least 7000 steps every day while wearing their air insoles (Dr. AIR, Mantoo, Korea) and report their compliance or noncompliance with the plan and their health conditions. The air insole was made of a 3-mm-thick laminated thermoplastic polyurethane, which is an eco-friendly material with no environmental hormones to facilitate optimal elasticity. It emits far-infrared rays and negative ions and has excellent antibacterial properties. By adding graphene, thermoplastic polyurethane becomes more elastic with thermal conductivity without losing its electrical properties when stretched or bent and harmless to the human body. Thermoplastic polyurethane is optimized for maintaining a high elasticity and horizontal force. The post-intervention assessment was performed after 8 weeks of using the air insoles. All participants in the experimental group were provided with a pedometer bracelet (Mi Band5, Xiaomi, China) to monitor their compliance with 7000 steps throughout the day. There were no further restrictions on walking such as the walking pace. The control group was also provided with the pedometer bracelet to monitor their compliance with 7000 steps throughout the day just like the experimental group. The participants could monitor the number of steps taken with the pedometer on the bracelet in real-time. The participants reported their results of taking at least 7000 steps each week to the researchers every Monday. The reporting was conducted by sending a weekly report through the application. This study was conducted after obtaining approval from the Institutional Review Board of of Daegu Health College (DHCIRB-2022-06-0007).

Fig. 2. Air insoles.

2) Assessment items and measures

TMD questionnaire: The severity of TMD was assessed using a questionnaire (Williamson & Hoggart, 2005) covering the following (yes/no variables): Pain you feel in your current stable state, Pain currently felt during maximum mouth opening, Average pain felt over the past 4 weeks, The most severe pain in the past four weeks, Open mouth range without pain, The point of pain and sound when opening your mouth, Maximum range of mouth opening. NPRS (Numeric Pain Rating Scale) pain scale: The TMJ pain severity was assessed using the NPRS pain scale; the participants were asked to indicate their perceived pain severity on a Numeric Pain Rating Scale of 0 to 100 mm. The validity of the NPRS pain scale was high with a Cronbach's alpha of 0.92 and a test-retest validity of 0.85 (Williamson & Hoggart, 2005). Lower LPRS scores indicated milder pain while higher NPRS scores indicated severe pain.

Assessment of the range of mouth opening: The range of mouth opening was assessed using a tape measure with the patient in the sitting position; the midline distance between the upper and lower teeth was measured with the mouth maximally open without pain. The maximum range of mouth opening was measured in triplicate, and the mean value was obtained. The normal range of mouth opening was 40-60 mm.

4. Data analysis

Data analysis was performed using the SPSS 22.0 version software (SPSS Inc, USA) on Windows. The general characteristics of the participants were summarized as means and standard deviations. The Kolmogorov-Smirnov test was used to determine the normality of the data distributions. An independent t-test was used to compare the pre- and post-experiment scores

Table 1. General characteristic of subjects (n=65)

Variables	Experimental group (n_1=31)	Control group (n_2=34)	F	*p*
Gender (M / F)	16 / 15	16 / 18		
Experience in treatment (Y / N)	12 / 19	14 / 20		
Age (year)	45.09 ± 8.75	45.10 ± 4.43	2.93	0.99
Wight (kg)	63.64 ± 12.01	68.20 ± 10.44	0.16	0.37
Height (cm)	167.09 ± 9.91	170.09 ± 7.74	0.20	0.33
Foot size (cm)	246.36 ± 17.19	257.50 ± 19.04	1.26	0.18

for the experimental and control groups. The threshold for statistical significance was set to p = 0.05.

Ⅲ. Results

1. General characteristics of the participants

34 and 31 participants were allocated to the experimental and control groups, respectively. No intergroup differences were observed in gender, age, height, weight, and foot size (Table 1).

2. Pre- and post-experiment scores of the experimental and control groups

The pre- and post-experiment scores of the experimental and control groups are provided in Table 2. Significant differences were found between the experimental and control groups for all the assessment items, except the maximum range of mouth opening.

Table 2. Air-insole Experiment Results Control group versus experimental group (n=65)

	Experimental (n=31)	Control (n=34)	F	t	*p*
1. Pain you feel in your current stable state					
Before	1.40 ± 0.97	1.54 ± 1.13	0.41	0.32	0.76
After	1.30 ± 0.82	0.55 ± 0.82	0.00	2.10	0.04*
2. Pain currently felt during maximum mouth opening					
Before	4.50 ± 0.85	4.27 ± 1.74	2.56	0.37	0.71
After	4.30 ± 0.67	1.45 ± 1.51	3.23	5.48	0.00**
3. Average pain felt over the past 4 weeks					
Before	2.90 ± 0.57	2.82 ± 0.75	1.64	0.28	0.78
After	2.80 ± 0.63	1.45 ± 0.93	2.59	3.82	0.00**
4. The most severe pain in the past four weeks					
Before	5.20 ± 0.63	5.00 ± 1.61	6.60	0.37	0.72
After	4.90 ± 0.88	2.55 ± 1.51	4.80	4.32	0.00**
5. Open mouth range without pain					
Before	2.52 ± 0.75	3.04 ± 0.90	0.67	1.43	0.17
After	2.51 ± 0.69	3.62 ± 0.63	0.02	3.86	0.00**

	Experimental (n=31)	Control (n=34)	F	t	*p*
6. The point of pain and sound when opening your mouth					
Before	3.06 ± 0.64	3.81 ± 0.83	1.05	2.41	0.07
After	3.06 ± 0.64	4.20 ± 0.59	0.11	4.24	0.00**
7. Maximum range of mouth opening					
Before	4.69 ± 0.71	4.43 ± 0.64	0.01	0.45	0.66
After	4.30 ± 0.65	4.69 ± 0.71	0.04	1.31	0.21

IV. Disscussion

According to a research finding, conservative treatment options are more effective than surgical interventions during the initial stages of TMDs (Ro et al., 2013). Conservative treatment options for TMDs include physiotherapy such as massage (Kim et al., 2016), orthotic devices such as occlusal splint to increase or maintain the range of mouth opening (de Paula Gomes et al., 2014), and methods to control the excessive use of masticatory muscles such as thermal therapy, cold therapy, passive muscle stretching exercise, and exercise therapy (Song et al., 2005). TMJ pain or TMJ motion limitation can be controlled relatively easily with adequate conservative and behavioral therapy (Shim, 2020). Unlike previous studies that directly applied conservative treatments to the TMJ, this study aimed to examine the effects of gait quality on TMJ using air insoles.

Research on various applications of insoles, such as for injury prevention while walking (Nagano et al., 2018), orthotics for flat feet (Herchenröder et al., 2021), and the induction of left-right symmetrical gait for hemiplegic stroke patients, has been ongoing (Kim et al., 2021; Ma et al., 2018). However, studies on the effects of insoles on TMDs are limited.

The turtle neck posture is among the main causes of TMDs (Cortese et al., 2017). This posture induces excessive tension of the sternocleidomastoid muscle, which can cause TMD symptoms such as a limited range of mouth opening (Lee & Chon, 2020). Varus or valgus knee alignment and excessive lordosis can also lead to TMDs (Cortese et al., 2017). Storm (2007) reported association between TMD and posture, for TMD patients present greater shifts in the gravity center of their body, with their head thrust forward, which could lead to the shortening of some muscles. An anterior position of the head would presumably influence the gravity center of the head, thereby indicating the relationship between body posture and TMD. Likewise, postural alterations of the cervical region could cause TMD, modify the orientation of the head, and thus the position of the jaw. A previous study reported using insoles to correct body alignment and improve balance (Park et al., 2021). This study found that the use of insoles led to the improvement of TMD symptoms. The use of insoles resulted in improved balance and alignment, which is believed to have contributed to the improvement of TMD symptoms. However, limited research has been conducted on the effects of insoles in improving TMDs. This study demonstrated the positive effects of air insoles on TMJ function. Air insoles may stimulate righting and equilibrium reactions, which are closely associated with body alignment, leading to enhanced stability of postural muscles, improved body alignment, and subsequent improvement of TMD symptoms. This is supported by the findings of a previous study that wearing insoles increased core muscle activities (Kim & Yi, 2015), improved posture, and increased the joint range of motion. The post-experiment scores showed improvements for all the assessed items, except the maximum range of mouth opening, suggesting that insoles can help improve TMDs. Considering that the joint range of motion varies from person to person, the maximum range of mouth opening did not show a significant difference in the post-experiment score because the measurements were made within the individual range of each participant.

This study has several limitations. First, the long-term effects of wearing insoles and maintenance of the improvements in TMDs could not be assessed, given the relatively short intervention period. Second, the difficulty of taking 7000 steps per day (e.g., comfortable or brisk pace) was not controlled. Third, the steps taken beyond the compulsory 7000 per day were not controlled because the number of steps represents the steps assumed to be taken in the course of daily living. Follow-up research is required to further evaluate the effects of wearing air insoles by addressing the limitations of this study.

Taking 7,000 steps or more per day while wearing air insoles had significant positive effects on patients with TMDs in this study. TMJ function in patients with TMDs can be improved by taking 7,000 steps or more per day while wearing comfortable and easy-to-use air insoles tested in this study. In this study, did not measure the changes in posture that occur after using insoles. Further research will be needed to investigate the additional effects on posture.

V. Conclusion

When air insole was applied to patients with Temporomandibular joint disorder, it was confirmed that the function of the Temporomandibular joint and the positive effect on pain were confirmed.

References

Cairns BE. Pathophysiology of TMD pain-basic mechanisms and their medications for pharmacotherapy. *Journal of Oral Rehabilitation.* 2010;37(6):391-410.

Cortese S, Mondello A, Galarza R, et al. Postural alterations as a risk factor for temporomandibular disorders. *Acta Odontologica Latinoamericana.* 2017;30(2):57-61.

de Paula Gomes CAF, Politti F, Andrade DV. et al. Effects of massage therapy and occlusal splint therapy on mandibular range of motion in individuals with temporomandibular disorder: a randomized clinical trial. *Journal of Mnipulative and Physiolofical Therapeutics.* 2014;37(3):164-169.

Garner LI, Dziados JE, Jones BH, et al. Prevention of lower extremity stress fracture: A controlled trial of a shock absorbent insole. *American Journal of Public Health.* 1988;78(12):1563-1567.

Herchenröder M, Wilfling D, Steinhäuser J. Evidence for foot orthoses for adults with flatfoot: a systematic review. *Journal of Foot and Ankle Research.* 2021;14(1):1-11.

Hertel J, Sloss BR, Earl JE. Effect of foot orthotics on quadriceps and gluteus medius electromyographic activity during selected exercises. *Archives of Physical Medicine and Rehabilitation.* 2005;86(1):26-30.

Jung H, Kim YK. The Systemic Clinical Treatment of TMJ Disorder. *Narae Publishing*. 2005.

Kim DK, Lim HD, Lee YM. Evaluation of quality of life according to temporomandibular disorder symptoms in dental hospital worker. *Journal of Oral Medicine and Pain*. 2012;37(1):61-72.

Kim J, Jung S, Song C. The Effects of Auditory Feedback Gait Training Using Smart Insole on Stroke Patients. *Brain Sciences.* 2021;11(11):1377.

Kim JS, Kim DE, Jung DH, et al. A review of recent studies for treatment of TMD using CNKI database. *Journal of Korean Medicine Rehabilitation.* 2016;26(2):

61-74.

Kim NH and Yi KO. The Effects of Corrective Hip Joint Exercises and Foot Orthotics on RCSP, Ankle's Range of Motion, and Core Muscle Strength for Middle School Students with Pes Planus. *Korean Journal of Sport Biomechanics.* 2015;25(4):401-412.

Kwon YD, Lim YE, Song YS. Relationship between temporomandibular joint (TMJ) disorder and Meridian. *Journal of Oriental Rehabilitation Medicine.* 2000;10(1):1-10.

Lee KH and Chon SC. Comparison and Correlation on Muscle Thickness and Muscle Tone of Masseter Muscle and Sternocleidomastoid Muscle, Maximum Jaw Opening in Subjects With and Without Temporomandibular Joint Disorder. *Journal of the Korean Society of Integrative Medicine*. 2020;8(3):93-101.

Lee YS, Byun YS, Choi JH, et al. Evaluation of masticatory efficiency and oral health related quality of life in temporomandibular disorder patients. *Journal of Oral Medicine and Pain*. 2010;35(2):135-147.

Iunes DH, Carvalho LCF, Oliveira AS, et al. Craniocervical posture analysis in patients with temporomandibular disorder. *Brazilian Journal of Physical Therapy*, 2009;*13*:89-95.

Ma CC, Rao N, Muthukrishnan S, et al. A textured insole improves gait symmetry in individuals with stroke. *Disability and Rehabilitation.* 2018;40(23):2798-2802.

Moon GS. The effect of gait ability for elderly women with the functional insole. *Korean Journal of Sport Science.* 2012;21(3):1443-1453.

Nagano, Hanatsu, Rezaul KB. Shoe-insole technology for injury prevention in walking. *Sensors.* 2018;18(5):1468.

Nakahara H. Nakasato N, Kanno A. et al. Somatosensory-evoked fields for gingiva, lip, and tongue. *Journal of dental research.* 2004;83(4):307-311.

Nilsson IM, List T, Drangsholt M. The reliability and validity of self-reported temporomandibular disorder pain in adolescents. *Journal of Oral and Facial Pain and Headache*. 2006;20(2).

Oh DW, Kim KS, Lee GW. Physical therapy on temporomandibular joint dysfunction. *Physical Therapy Korea.* 2000;7(1):101-120.

Park JH, Jeon HS, Kim JH. et al. Immediate effect of insoles on balance in older adults. *The Foot*. 2021;47:101768.

Ro HR, Kim MY, Park SH, et al. A review of recent clinical studies for manual therapy on temporomandibular joint disorder. *Journal of Korean Medicine Rehabilitation*. 2013;23(4):129-141.

Schiffman EL, Fricton JR, Haley DP, et al. The prevalence and treatment needs of subjects with temporomandibular disorders. *Journal of American Dental Assocication*. 1990;120(3):295-303.

Shim YJ. Diagnosis and treatment of Acute temporomandibular disorders. *Journal of the Korea Dental Association*. 2020;58(6):354-363.

Song MS, Heo YK, Choi KW, et al. Clinical comparison study on 40 cases of temporomandibulr disorder patients with idiopathic scoliosis treated by Chuna & general oriental method. *Journal of Acupuncture Research.* 2005;22(5):133-140.

Storm C, Wanman A. A two-year follow-up study of temporomandibular disorders in a female Sami population: validation of cases and controls as predicted by questionnaire. *Acta Odontologica Scandinavica.* 2007;65(6):341-7.

Walczyńska-Dragon K, Baron S, Nitecka-Buchta A, et al. Correlation between TMD and cervical spine pain and mobility: is the whole body balance TMJ related?. *Biomed Research International*. 2014.

Williamson A, Hoggart B. Pain: A review of three commonly used pain rating scales. *Journal of Clinical Nursing.* 2005;14(7):798-804.

Yang HY, Kim ME. Prevalence and treatment pattern of Korean patients with temporo- mandibular disorder. *Journal of Oral Medicine and Pain*. 2009;34(1):63-79.