Acta Odontologica Scandinavica. 2014; 72: 428–431

informa
healthcare

ORIGINAL ARTICLE

Effect of water-soluble titanium microparticle-permeated tape on temporomandibular disorders-related pain: A preliminary study

AKIRA NISHIYAMA, KOJI KINO, KAORI TSUKAGOSHI, SHOKO TOBE & NATSUKO OTOMO

Section of Temporomandibular Joint and Oral Function, Department of Comprehensive Patient Care, Graduate School, Tokyo Medical and Dental University, Tokyo, Japan

Abstract

Objective. Recent research has focused on the applicability of titanium particle-impregnated materials in healthcare and medical products. This preliminary study was undertaken to investigate the effect of water-soluble titanium microparticle-permeated (WSTi) tape on temporomandibular disorder (TMD)-related pain. ***Materials and methods.*** The study included 32 patients (41.5 ± 14.4 years, 26 women) who had visited the Temporomandibular Joint Clinic, Tokyo Medical and Dental University, for treatment of TMD-related pain. The subjects were instructed to apply the WSTi tape (AquaTitan tape) on the most painful area before going to sleep and remove the tape on awakening daily for 2 weeks. Seven outcome variables were statistically analyzed: maximum mouth-opening ranges with and without pain, spontaneous pain intensity, mouth-opening pain intensity, chewing pain intensity, TMD-related limitation of daily functions (LDF-TMD) and subjective evaluation of any change in TMD-related pain. ***Results.*** The mean maximum mouth-opening ranges with ($p = 0.011$) and without ($p = 0.002$) pain were significantly greater and mean pain intensities on mouth opening ($p < 0.001$) and chewing ($p = 0.001$) were significantly lower at the 2-week follow-up than at the baseline. The mean LDF-TMDQ scores were also significantly lower at the 2-week follow-up ($p = 0.004$). After 2 weeks of using the WSTi tape, 53.1% and 12.5% of the subjects reported a slight improvement and an improvement, respectively, in TMD-related pain. ***Conclusion.*** WSTi tape seems to have beneficial effects on TMD-related pain and LDF.

Key Words: *analgesia, temporomandibular disorders, water-soluble titanium, visual analog pain scale*

Introduction

Temporomandibular disorders (TMD) are a variety of conditions affecting the masticatory muscles, temporomandibular joint (TMJ) and orofacial structures due to dysfunction of the stomatognathic system. The most common symptoms are jaw and facial pain. TMD have been identified as the main cause of non-dental pain in the orofacial region and are considered a sub-class of musculoskeletal disorders [1]. Reportedly, 5–12% of the general North-American population has TMD [2,3]. Since the 1970s, a multifactorial etiology for TMD has been proposed, in which pain and dysfunction result from biopsychosocial factors [4,5] including structural conditions, psychological morbidity and behavioral problems such as parafunctional habits [6–9].

Analgesia is an important part of TMD management, for which non-steroidal anti-inflammatory drugs or acetaminophen are typically used. However, the side-effects associated with long-term administration of analgesics necessitate an alternative form of pain relief. In recent years, the effects of titanium on living tissue have been widely studied. The reported health benefits include reduced muscle-tendon stiffness during recovery from exercise in male athletes wearing garments permeated with water-soluble titanium microparticles (WSTi) [10] and decreased physiological and psychological stress in emotionally stressed office workers sleeping in a room containing titanium [11]. Collectively, these observations suggest that the application of WSTi to various materials could be useful in both everyday and medical situations.

Correspondence: Akira Nishiyama, Section of Temporomandibular Joint and Oral Function, Department of Comprehensive Patient Care, Graduate School, Tokyo Medical and Dental University, 1-5-45, Yushima, Bunkyo-ku, Tokyo 113-8549, Japan. Tel: +81 3 5803 5713. Fax: +81 3 5803 5713. E-mail: anishi.tmj@tmd.ac.jp

(Received 23 April 2013; accepted 25 September 2013)

ISSN 0001-6357 print/ISSN 1502-3850 online
DOI: 10.3109/00016357.2013.850173

Table I. Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
Diagnosis of TMD based on the RDC/TMD	Pain from systemic bone or joint disease
Pain in the TMJ and/or masticatory muscles for 2 weeks or more	Regular use of medicines such as analgesics, anti-anxiety drugs, antidepressants and other psychotropic agents
Older than 19 years	Presence of inflammation (swelling, fever, flare and throbbing pain)
	Medical history of skin disease or skin inflammation due to tape adhesive

TMD, temporomandibular disorder; TMJ, temporomandibular joint; RDC/TMD, Research Diagnostic Criteria for Temporomandibular Disorders.

The aim of this preliminary study was to investigate the effect of WSTi tape on TMD-related pain.

Materials and methods

Subjects

The study included patients with TMD who had visited the Temporomandibular Joint Clinic at Tokyo Medical and Dental University for treatment between May and August 2012. TMD were diagnosed according to the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) [12]. Thirty-six subjects were selected according to the inclusion and exclusion criteria of this study (Table I). They were informed about the nature of their conditions on the basis of radiographic findings.

This study was approved by the ethics committee of Tokyo Medical and Dental University (No. 727). All the subjects gave their written consent after the purpose of the research was explained.

Procedures

AquaTitan-tape (Phiten Co., Ltd., Kyoto, Japan) was used as the WSTi tape in the study. The subjects were instructed to apply the WSTi tape on the most painful location before going to sleep and remove it on awakening daily for 2 weeks. No other analgesia was administered. AquaTitan results from the dispersion of microscopic titanium particles in water [13]. The material is utilized as a dye in the tape-manufacturing process, where the microscopic titanium particles are embedded into the fabric and become an integral component of the tape.

Outcome measures

Seven outcome variables were assessed: maximum mouth-opening ranges with and without pain, spontaneous pain intensity, mouth-opening pain intensity, chewing pain intensity, TMD-related limitation of daily functions (LDF-TMD) and subjective evaluation.

The maximum mouth-opening range was measured as the distance between the incisal edges of the maxillary and mandibular central incisors when the subjects reported both the presence and the absence of pain in the TMJ or masticatory muscles. Pain intensity was estimated by using a visual analog pain scale (VAS) consisting of a 100-mm line with 'no pain' on the extreme left and 'intolerable pain' on the extreme right. The subjects rated the severest TMD-related pain experienced at rest, during mouth opening and during chewing.

The LDF-TMD were assessed by using the LDF-TMD questionnaire [14]. The questionnaire consisted of the question:

How much does your present jaw problem prevent or limit you from the following daily activities?:

- Opening your mouth when you eat big pieces of food
- Grinding thin food.
- Clenching your teeth.
- Brushing your back teeth.
- Yawning.
- Talking for a long period.
- Using your jaw for a long period during meals.
- Performing activities at home, school and/or work.
- Falling asleep soon after going to bed.
- Sleeping continuously at night.

For each item, the subject chose any one of five levels on a numerical rating scale from 'no problem at all' (0) to 'extremely difficult' (4 points). The summary score of the 10 items, ranging from 0–40 points, was used for analysis.

The subjects were also asked to evaluate any change in TMD-related pain after 2 weeks of using the WSTi tape by choosing one of five options: aggravation, slight aggravation, no change, slight improvement or improvement.

Statistical analysis

The questionnaires of four respondents were excluded from the statistical analysis because of missing data. Therefore, data from 32 participants were analyzed.

All statistical analyses were performed by using SPSS version 12.0 software (IBM, Inc., Armonk, NY). The paired *t*-test was used to analyze the differences between the baseline and the 2-week follow-up data. The *t*-test

Table II. Comparison of the outcome variables between the baseline and the 2-week follow-up.

Variable	Baseline	2-week follow-up	p*
Maximum mouth-opening range without pain (mm)	32.2 (8.9)	36.7 (8.5)	0.002
Maximum mouth-opening range with pain (mm)	39.2 (8.7)	41.7 (8.4)	0.011
Spontaneous pain intensity, VAS (mm)	21.4 (20.5)	17.1 (22.4)	0.227
Mouth-opening pain intensity, VAS (mm)	58.0 (26.3)	39.9 (28.0)	< 0.001
Chewing pain intensity, VAS (mm)	52.9 (28.3)	35.2 (27.6)	0.001
LDF-TMDQ score	13.1 (4.0)	10.3 (5.4)	0.004

LDF-TMDQ, temporomandibular disorder-related limitation of daily functions questionnaire; VAS, visual analog pain scale.
*Paired *t*-test.
Data represent means (SD).

was used for analyzing the differences in subjective evaluation between the non-improvement (aggravation, slight aggravation and no change) and the improvement (slight improvement and improvement) groups. $p < 0.05$ was considered significant. Data are presented as means (SD).

Results

The mean age of the subjects was 41.5 (14.4) years and 26 subjects were women (81.8%). The mean pain duration at the baseline was 17.6 months (minimum, 1 month; maximum, 120 months). From the onset of TMDs to the time of enrollment in this study, three (9.4%), 21 (65.6%), and eight (25.0%) subjects reported their symptoms as being worse, unchanged, and better, respectively.

The mean maximum mouth-opening ranges with and without pain were significantly greater and mean pain intensities on mouth opening and chewing were significantly lower at the 2-week follow-up than at the baseline (Table II). The mean LDF-TMDQ score at the 2-week follow-up was also significantly lower than that at the baseline. After 2 weeks of using the WSTi tape, 53.1% and 12.5% of the subjects reported a slight improvement and an improvement, respectively. The only significant difference between the non-improvement and the improvement groups was a higher mean LDF-TMDQ score in the improvement group (Table III).

Discussion

The mean maximal mouth-opening range of healthy individuals is reportedly 50.9–57.7 mm [15,16]. Therefore, the mean mouth-opening ranges with and without pain at the baseline in the present study are 55.8–63.3% and 67.9–77.0%, respectively, of the healthy ranges. After 2 weeks of using the WSTi tape, the mean mouth-opening ranges with and without pain increased to 63.6–72.1% and 72.3–81.9%, respectively, of the healthy values.

According to Collins et al. [17], a patient with a baseline VAS score exceeding 30 mm would be experiencing at least moderate pain and a baseline VAS score more than 54 mm would indicate severe pain. The initial mean VAS score of the present subjects for pain intensity due to mandibular movements was 52.9–58.0 mm. Therefore, they would have been experiencing severe TMD-related pain at the baseline.

In the Emshoff et al. [18] study, the mean VAS score for pain intensity in patients with TMD at the first clinical examination was 50.1 (22.2) mm and the clinically significant change in the VAS score for pain

Table III. Comparison of the improvement and non-improvement groups.

Variable	Non-improvement group (n = 11)	Improvement group (n = 21)	p*
Pain duration at the baseline (months)	26.3 (46.8)	13.0 (28.8)	0.325
Maximum mouth-opening range without pain (mm)	31.5 (10.2)	32.6 (8.3)	0.731
Maximum mouth-opening range with pain (mm)	40.8 (8.0)	38.5 (9.2)	0.480
Spontaneous pain intensity, VAS (mm)	21.6 (17.1)	21.2 (22.5)	0.959
Mouth-opening pain intensity, VAS (mm)	51.9 (24.4)	61.1 (27.3)	0.354
Chewing pain intensity, VAS (mm)	45.1 (29.3)	54.9 (28.5)	0.367
LDF-TMDQ score	11.2 (4.0)	14.1 (3.7)	0.046

LDF-TMDQ, temporomandibular disorder-related limitation of daily functions questionnaire; VAS, visual analog pain scale.
*Paired *t*-test.
Data represent means (SD).

intensity at 12 week was −19.5 mm (−37.9%). In the present study, the changes in the VAS scores for mouth-opening and chewing pain intensities at 2 weeks were −18.1 mm (−37.9%) and −17.7 mm (−33.5%), respectively. Despite these changes being slightly smaller than the reported values, they are clinically important given the shorter treatment time. The decrease in the LDF-TMDQ score demonstrates a significant improvement in daily function after 2 weeks of using the WSTi tape.

Noteworthily, 24 of the subjects (75%) had reported that their TMD-related pain was unchanged or worse since the diagnosis, but 21 subjects (65.6%) reported an improvement in the pain status after using the WSTi tape for 2 weeks. No significant differences in the mouth-opening ranges with and without pain, pain intensity, and pain duration at the baseline were seen between the improvement and the non-improvement groups. Given the homogeneity of the groups at the baseline, the reason for the lack of pain relief with the WSTi tape in the non-improvement group is not clear.

Parafunctional habits such as sleep bruxism and tooth contacting habit [19,20] are contributing factors to TMD-related symptoms. Psychosocial factors such as stress, anxiety and depressive mood increase such habitual behaviors. Pingitore et al. [21] found that the total score of life stress events was significantly and positively correlated with bruxism in 125 dental patients. Moreover, Kanehira et al. [22] reported that stress was significantly correlated with parafunctional habits such as sleep bruxism and daytime clenching. Daytime clenching also appears to be associated with psychosocial factors [23]. Given the link between stress and habitual behaviors and TMD-related symptoms, and the finding that titanium can decrease physiological and psychological stress [11], the WSTi tape used in the present study may have improved TMD-related pain by a favorable effect on masticatory muscle and TMJ stiffness due to parafunctional habits.

In conclusion, the WSTi tape seems to have beneficial effects on TMD-related pain and LDFs. Although our report supports previous findings of the analgesic properties of WSTi, the underlying mechanism remains unknown. The effect of the WSTi tape on TMD-related pain should be investigated in a double-blind, placebo-controlled trial.

***Declaration of Interest*:** The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

References

[1] Okeson JP. Bell's orofacial pains: the clinical management of orofacial pain. 6th ed. Chicago, IL: Quintessence Publishing; 2005.

[2] Rugh JD, Solberg WK. Oral health status in the United States: temporomandibular disorders. J Dent Educ 1985;49:398–406.

[3] Dworkin SF, Huggins KH, LeResche L, Von Korff M, Howard J, Truelove E, et al. Epidemiology of signs and symptoms in temporomandibular disorders: clinical signs in cases and controls. J Am Dent Assoc 1990;120:273–81.

[4] Weinberg LA. Temporomandibular dysfunctional profile: a patient-oriented approach. J Prosthet Dent 1974;32:312–25.

[5] Oral K, Bal Küçük B, Ebeoğlu B, Dinçer S. Etiology of temporomandibular disorder pain. Agri 2009;21:89–94.

[6] Moss RA, Garrett JC. Temporomandibular joint dysfunction syndrome and myofascial pain dysfunction syndrome: a critical review. J Oral Rehabil 1984;11:3–28.

[7] Schiffman EL, Fricton JR, Haley D. The relationship of occlusion, parafunctional habits and recent life events to mandibular dysfunction in a non-patient population. J Oral Rehabil 1992;19:201–23.

[8] Laskin DM. Etiology of the pain-dysfunction syndrome. J Am Dent Assoc 1969;79:147–53.

[9] Yap AU, Dworkin SF, Chua EK, List T, Tan KB, Tan HH. Prevalence of temporomandibular disorder subtypes, psychologic distress, and psychosocial dysfunction in Asian patients. J Orofac Pain 2003;17:21–8.

[10] Wadsworth DP, Walmsley A, Rowlands DS. Aquatitan garments extend joint range of motion without effect on run performance. Med Sci Sports Exerc 2010;42:2273–81.

[11] Aoi W, Kamata T, Ishiura Y, Tomaru M, Satoh Y, Hitomi Y, et al. Titanium-treated surroundings attenuate psychological stress associated with autonomic nerve regulation in office workers with daily emotional stress. Physiol Behav 2012;108:13–18.

[12] Dworkin SF, LeResche L. Research diagnostic criteria for temporomandibular disorders: review, criteria, examinations and specifications, critique. J Craniomandib Disord 1992;6: 301–55.

[13] Hirata Y, Ueda Y, Takase H, Suzuki K. High functional water containing titanium and method and apparatus for producing the same. NZ 522431; 2004.

[14] Sugisaki M, Kino K, Yoshida N, Ishikawa T, Amagasa T, Haketa T. Development of a new questionnaire to assess pain-related limitations of daily functions in Japanese patients with temporomandibular disorders. Community Dent Oral Epidemiol 2005;33:384–95.

[15] Pullinger AG, Liu S-P, Low G, Tay D. Differences between sexes in maximum jaw opening when corrected to body size. J Oral Rehabil 1987;14:291–9.

[16] Mezitis M, Rallis G, Zachariades N. The normal range of mouth opening. J Oral Maxillofac Surg 1989;47:1028–9.

[17] Collins SL, Moore RA, McQuay HJ. The visual analogue pain intensity scale: what is moderate pain in millimetres? Pain 1997;72:95–7.

[18] Emshoff R, Emshoff I, Bertram S. Estimation of clinically important change for visual analog scales measuring chronic temporomandibular disorder pain. J Orofac Pain 2010;24: 262–9.

[19] Nishiyama A, Kino K, Sugisaki M, Tsukagoshi K. Influence of psychosocial factors and habitual behavior in temporomandibular disorder-related symptoms in a working population in Japan. Open Dent J 2012;6:240–7.

[20] Sato F, Kino K, Sugisaki M, Haketa T, Amemori Y, Ishikawa T, et al. Teeth contacting habit as a contributing factor to chronic pain in patients with temporomandibular disorders. J Med Dent Sci 2006;53:103–9.

[21] Pingitore G, Chrobak V, Petrie J. The social and psychologic factors of bruxism. J Prosthet Dent 1991;65:443–6.

[22] Kanehira H, Agariguchi A, Kato H, Yoshimine S, Inoue H. Association between stress and temporomandibular disorder. Nihon Hotetsu Shika Gakkai Zasshi 2008;52:375–80.

[23] Manfredini D, Lobbezoo F. Role of psychosocial factors in the etiology of bruxism. J Orofac Pain 2009;23:153–66.