Introduction

Joint contracture, which can result from various complications that occur after a hand injury, remains a common orthopedic problem. After fracture, a hand therapist should avoid placing the hand in an incorrect position and having the joints fixated for longer than medically necessary, and they should be cautious about inappropriate rehabilitation such as the excessive use of strong force. Contractures in the metacarpophalangeal (MCP) joint can occur after a joint trauma or burn [1].

Continuous stretching is an effective treatment for contractures, and its efficacy can be improved with a dynamic orthosis [2], a well-accepted modality used to regain joint motion in an injured hand [3]. Dynamic orthotic positioning is expected to achieve greater clinical results in joints with less pretreatment stiffness and in those with a short window between injury and treatment. Here we studied the effect of dynamic orthotic positioning on the metacarpophalangeal (MCP) joint using computed tomography (CT).

Abstract: Background: Continuous stretching is an effective treatment for contractures, and its efficacy can be improved with a dynamic orthosis. Dynamic orthotic positioning is expected to achieve greater clinical results in joints with less pretreatment stiffness and in those with a short window between injury and treatment. Here we studied the effect of dynamic orthotic positioning on the metacarpophalangeal (MCP) joint using computed tomography (CT).

Methods: The MCP joints of 10 human index fingers were examined using CT in healthy subjects who wore flexion- or traction-type orthoses versus those who wore no orthoses.

Results: The palmar joint distance between the traction-type and no orthosis group was not significantly different; however, the distance was shorter with the flexion-type than the traction-type orthosis ($p < 0.05$). Compared to healthy subjects without orthoses, the palmar joint space decreased in patients with flexion-type orthoses ($p < 0.05$) and increased in healthy subjects with traction-type orthoses ($p < 0.05$).

Conclusions: The traction-type dynamic orthosis was designed to correct flexion while achieving joint traction to enhance MCP joint area spacing and minimize damage caused by articular surface collision. Our findings show that the traction-type dynamic orthosis causes joint space widening and may reduce the risk of articular surface collision compared with the flexion-type orthosis.

Keywords: tomography, orthotic devices, metacarpophalangeal joint, pilot projects, traction

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Corresponding to: Jun Nakayama, Department of Allied Health Sciences, Kansai University of Welfare Sciences, 3-11-1, Ashigakoka, Kashiharashi, Osaka 582-0026, Japan
E-mail: j-nakayama@tamateyama.ac.jp
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(Rapid Communications: Computed Tomography Investigation of the Effects of a Dynamic Orthosis on the Metacarpophalangeal Joint)

Jun Nakayama$^1$, Mituru Horiki$^2$, Kakuro Denno$^2$, Kazunori Ogawa$^3$, Hisao Oka$^4$, Kazuhisa Domen$^5$

$^1$ Department of Allied Health Sciences, Kansai University of Welfare Sciences
$^2$ Department of Orthopaedics Surgery, Kansai Rosai Hospital
$^3$ Daiya Gum Industry Co.
$^4$ Graduate School of Health Science, Okayama University
$^5$ Department of Physical Medicine and Rehabilitation, Hyogo College of Medicine
achieve range of motion improvements [5]. Decreased finger motion reduces one’s ability to perform activities using the hand and activities of daily living (ADLs) [7]. In contrast, traction reduces fracture fragments via ligamentotaxis and helps prevent periarticular joint ligament contracture. Conventional traction orthoses are often used in the treatment of joint fractures that require surgical invasion [8]. However, few reports state that a dynamic orthosis can increase flexion while achieving joint traction without increasing the risk of subsequent surgical intervention.

If a dynamic orthosis that provided traction while bending the MCP joint existed, patients’ conditions could improve smoothly without pain and patients may experience an early improvement in ADLs. However, since such a device does not exist, a flexion-type dynamic traction orthosis was developed [9] (hereafter, traction-type orthosis). The precedent study stated that activity difficulty was reduced by improving the range of motion of the MCP joint [1]. Therefore, we used a traction-type orthosis to extend the ligament. Computed tomography (CT) is useful in the anatomical evaluation of the MCP joint [10]. One study showed the usefulness of the orthosis-wearing effect using CT [11]. Therefore, the aim of this study was to evaluate the distance and area of the joint space using CT in healthy subjects fitted with a flexion-type, a traction-type, or no orthosis.

**Methods**

**Study design and ethics**

The study design was approved by the hospital’s ethics committee on human research, and written informed consent was obtained from each subject.

**Subjects**

The MCP joints in 10 healthy human index fingers from six men and four women (mean age, 29.4 years; range, 24–34 years) were evaluated. The average body mass index was 21.89 kg/m$^2$; average height was 166.6 cm; and average weight was 66.8 kg. All of the subjects were right-handed.

**Measurements**

This pilot study investigated the joint space distance and area in the MCP joint as a function of three alternative orthotic positioning methods. CT images of the subjects who wore a flexion-type, a traction-type, or no orthosis were obtained, and the sagittal sections of the MCP joint were measured. The images were obtained with patients in the prone position with the shoulder joint at 180° flexion, elbow joint extended, wrist joint at 30° of extension, and MCP joint at 40° of flexion. For those not wearing an orthosis device, the hand was passively positioned by the radiologist. The distance between the central, most dorsal, and most palmar parts of the joints and the area of the joint space in the palmar and dorsal parts of the joint were measured using digital photography analysis as described below. The wearing time for the orthosis was approximately 10 min, and the images were captured thrice.

**Orthotic devices**

The flexion-type orthosis was manufactured of thermoplastic Orfit (1835-7, 3 mm, no hole; OG Giken Ltd., Okayama, Japan), and a Velcro strap and elastic band were used. The traction-type orthosis was also manufactured from thermoplastic Orfit (3 mm, no hole; OG Giken Ltd.), aquaplast (1.6 mm, hole; OG Giken Ltd.), and a Velcro strap and elastic band were used (Fig. 1). These orthoses applied a 200-g force [12] on the proximal phalanx bone of the index finger. No subject experienced pain while wearing either orthosis.

**CT equipment**

The scan conditions for CT were as follows: number of rearrangement functions, Fc30; lines, 0.5 mm × 64; helical pace, 53; tube voltage, 120 kV; tube electric current, 100 mA; and turnover rate, 0.5 s. The CT equipment used was Aquilion One (Toshiba Inc., Tokyo, Japan). Regarding the CT device, 160 lines of volume helical scanning are possible. In addition, the CT device allows three-dimensional image construction. The images were taken in the sagittal plane at a 0.1-mm slice interval and analyzed using Vitrea software (Toshiba Inc.). The images were evaluated in a blinded fashion by a radiologist.

**Measurement of joint space distance in the MCP joint**

The level of the sagittal plane was measured at the middle point between the medial and lateral joint aspects. The most palmar points were identified on the proximal phalanx base and metacarpal head (Fig. 2(i)a). The most dorsal points were also obtained for the proximal phalanx base and metacarpal head (Fig. 2(i)b). The central points were defined as the points halfway between the most palmar and the most dorsal points for the proximal phalanx base and metacarpal head (Fig. 2(i)c). The central points were defined as the points halfway between the most palmar and the most dorsal points for the proximal phalanx base and metacarpal head (Fig. 2(i)c). The mean joint space distance was the average distance among three points on the proximal phalanx and the metacarpal head, namely the most proximal points, most distal points, and central point (Fig. 2(i)d–f).

**Measurement of joint space area in the MCP joint**

The level of the sagittal plane was measured at the middle point between the medial and lateral joint aspects.
aspects. The palmar area of the joint space was defined as the area between the central and most palmar parts of the joint. The dorsal area of the joint was defined as the area between the central and most dorsal parts of the joint (Fig. 2(ii)). A total of 20 points were marked on the proximal phalanx base and metacarpal head. These points were 0.1 mm apart based on the bone curvature. The ratio of cancellous bone and the articular cavity was maintained at 1:1.

Statistical methods

We used Friedman’s test to confirm whether there was a difference among the flexion-type, traction-type, and no orthosis groups. A significant difference was observed, so we performed the Steel-Dwass test for multiple comparisons to confirm whether there was a significant difference among groups. We then calculated the P value. Statistical analyses were performed using the SPSS Base 11.0J software package (SPSS Japan Inc., Tokyo, Japan). P values < 0.05 were considered statistically significant.

Results

Joint space distance of the MCP joint

There was no significant difference in the most dorsal joint space distance between the flexion-type and traction-type orthoses (Fig. 3). When no orthosis was used, significant narrowing occurred compared to that of the flexion-type and traction-type orthoses ($p = 0.03$).

The central joint space increased significantly by the traction-type orthosis compared to that with the flexion-type orthosis ($p = 0.04$) or no orthosis ($p = 0.03$). In contrast, the palmar joint space decreased significantly with the flexion-type orthosis compared to the traction-type orthosis ($p = 0.02$) or no orthosis ($p = 0.04$).

Joint space area of the MCP joint

The dorsal joint space area significantly increased by the traction-type orthosis compared to that when no orthosis was used ($p = 0.02$). In contrast, the dorsal joint space area was not significantly different between the
FLEXION-TYPE ORTHOSIS VS TRACTION-TYPE ORTHOSIS

Fig. 3. Comparison of the joint space distance in the metacarpophalangeal joint
We examined 10 index fingers of healthy volunteers. (a) is the most dorsal part; and (b) and (c) are the central and the most palmar part. n.s; not significance, *; p < 0.05.
flexion-type orthosis and no orthosis (Fig. 4).

The palmar joint space area was significantly increased by the traction-type orthosis compared to the flexion-type orthosis ($p = 0.04$). In contrast, the palmar joint space area decreased insignificantly by the flexion-type orthosis compared with no orthosis ($p = 0.12$). Finally, the palmar joint space area of the traction-type orthosis was significantly greater than that of the flexion-type orthosis.

Discussion

CT is useful in the anatomical evaluation of the MCP joint; [10] hence, we used it to measure the effect of the dynamic (traction-type) orthosis on the MCP joint distance and area spacing. The traction-type orthosis can add traction to the MCP joint in a variety of flexed positions because it uses a rotary pipe. Compared to the flexion-type orthosis, the traction-type orthosis induced joint space widening and, therefore, can reduce the risk of articular surface collision, which can cause injury. However, compared to wearing no orthosis, wearing the traction-type orthosis did not significantly increase the joint space area in the most palmar part of the MCP. According to previous studies, the bony origin of the index collateral ligament of the MCP joint lies along the dorsolateral tubercle of the metacarpal, while its insertion is along the proximal phalanx near the volar plate [13]. Generally, the collateral ligaments of the MCP joint relax in the extended position and are tense in the coiled position. Furthermore, when the MCP joint is flexed to 40°, the radial collateral ligament and the ulnar collateral ligament are extended by 2−3 mm [13]. Therefore, in the 40° coiled position, approximately 70% of the collateral ligament is in a rigid state. The traction-type orthosis creates traction from the stiff angle, which suggests why it was ineffective at increasing the joint distance in the most palmar part.

MCP joint contracture is a common clinical condition [8]. The most common cause of extension contracture of the MCP joint is shortening of the collateral ligament [8]. It is important to maintain the maximum possible range of joint motion during the early treatment of contractures. Treatment is difficult and requires more time once the contracture is fully formed. Here, a traction-type dynamic orthosis was designed to correct flexion while achieving joint traction to enhance the MCP joint area spacing and minimize damage caused by articular surface collision [5, 9].

Based on the results of our study and previous studies, a therapist considers the power of traction and manufactures orthoses according to patients’ symptoms. Therefore, sharp pain caused by traction-type orthosis does not differ significantly from that caused by flexion-type orthosis [14]. However, our results show that the articular surface was pulled using a traction-type orthosis rather than a flexion-type orthosis. This shows that both ligament and joint capsules were pulled using the traction-type orthosis. Furthermore, another study reported that a significant improvement in ROM occurred with the traction-type orthosis compared with the flexion-type orthosis after 6 weeks [9]. In addition, the traction-type orthosis is effective for treating contractures of the MCP joint [15].

This study has a few limitations. First only healthy subjects, not those with MCP joint contractures, were evaluated; therefore, the data may not be extrapolated to other patients. Second, in clinical practice, an orthosis is often worn for long periods, but this study evaluated only the immediate effects of its application. The traction-type orthosis will most likely require several improvements. In addition, because of the risk of irradiation, studies need to be performed on patients with MCP joint contractures. However, the results of this study provide useful information on the immediate effects of traction-type orthosis on MCP joint area spacing.

![Fig. 4. Comparison of the joint space area in the metacarpophalangeal joint](image-url)

We dissected 10 fingers of healthy volunteers. (a) the most dorsal part; and (b) the most palmar part. n,s; not significance, *: $p < 0.05$. 
ation to the patient when using CT, it may be necessary in future studies to devise an alternative means of evaluating the usefulness of the dynamic orthosis. To validate the results of the current study, further long-term studies are needed in a larger patient population. In this study, we made our evaluations using surrogate scales without a functional standard. Furthermore, in the future, we wish to evaluate the dynamic orthosis using functional standards such as range of motion or sharp pain.

References

[1] Choi JS, Mun JH, Lee JY, Jeon JH, Jung YJ, Seo CH, et al. Effects of modified dynamic metacarpophalangeal joint flexion orthoses after hand burn. Ann Rehabil Med. 2011; 35: 880–6.

[2] Flowers KR, LaStayo P. Effect of total end range time on improving passive range of motion. J Hand Ther. 1994; 7: 150–7.

[3] Judith A. Rehabilitation of the hand. St. Louis: The C. V. Mosby Company; 1978. p. 322–9.

[4] Celeste G. Dynamic splinting for the stiff hand after trauma: predictors of contracture resolution. J Hand Ther. 2011; 24: 195–205.

[5] Nakayama J, Kurokawa K, Konishi A, Hamanami K, Oka H. A trial of a revolving-type dynamic traction splint for extension contracture of the metacarpophalangeal joint. Occupational Therapy. 2008; 27: 168–73. (in Japanese)

[6] Ueba Y, Kurata H, Ono I. Basic biomechanics for orthotic therapy of the hand. Bull Jap Soc Prosth Orthot. 1999; 15: 119–24. (in Japanese)

[7] Anzarut A, Chen M, Shankowsky H, Tredget EE. Quality-of-life and outcome predictors following massive burn injury. Plastic Reconst Surg. 2005; 116: 791–7.

[8] Jack RH. Management of a metacarpophalangeal joint fracture using a dynamic traction splint and early motion. J Hand Ther. 1999; 12: 219–27.

[9] Nakayama J. Effect of rehabilitation of a revolving type dynamic traction splint for extension contracture of the metacarpophalangeal joint. J Phys Med. 2009; 20: 351–7. (in Japanese)

[10] Vanderperren K, Ghaye B, Snaps FR, Saunders JH. Evaluation of computed tomographic anatomy of the equine metacarpophalangeal joint. Am J Vet Res. 2008; 69: 631–8.

[11] Nakayama J, Horiki M, Ogawa K, Oka H, Domen. Development of a new dynamic traction and flexion splint for MCP joint extension contractures. Tokyo Keio-gyuku: Soc Biomech Jap; 2014. p. 249–58.

[12] Shibata K, Ikuta M, Nomura T. Relation between traction force and cuff shape of splint on the peripheral blood flow of the digits. Occl Ther. 1986; 7: 485–6. (in Japanese)

[13] Kataoka T, Morimoto H, Miyake J, Murase T, Yoshikawa H, Sugamoto K. Change in shape and length of the collateral and accessory collateral ligaments of the metacarpophalangeal joint during flexion. J Bone Joint Surg Am. 2011; 93: 1318–25.

[14] Nakayama J, Horiki M, Denno K, Ogawa K, Oka H, Domen. Development of a new dynamic splint for MP joint extension contracture using a curved pneumatic artificial rubber muscle. 16th International Congress of the World Federation of Occupational Therapists 2014: PRE 18–26, 215.

[15] Nakayama J, Horiki M, Denno K, Ogawa K, Oka H, Domen. Pneumatic-type dynamic traction and flexion splint for treating patients with extension contracture of the metacarpophalangeal joint. Prosthet Orthot Intl. 2016; 40: 142–6.