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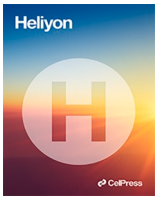

Research article

Sustained increase of pinch strength after traction treatment for symptomatic distal interphalangeal joint osteoarthritis

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ABSTRACT

Background: Symptomatic distal interphalangeal joint osteoarthritis is a common joint disease that causes hand disability and reduces quality of life. There are few conservative treatment options for this condition. The purpose of this study was to investigate the effect of traction treatment on symptomatic distal interphalangeal joint osteoarthritis.

Methods: This prospective, longitudinal study involved multiple time-series observations and within-subject controls. The most painful distal interphalangeal joints in patients with hand osteoarthritis were treated by daily, 15-min joint traction at home using a finger trap orthosis. The corresponding contralateral digits were used as within-subject controls. The primary outcome measure was two-point pinch strength, and the secondary outcome measures were radiographic findings and treatment adherence. Longitudinal and pairwise comparison analyses of the treated and control digits examined improvements in two-point pinch strength at months 1, 3, and 6 from baseline. The durability of treatment effects after treatment discontinuation was investigated at month 12.

Results: Eighteen treated digits and 18 corresponding control digits were eligible for analysis. There was a significant increase in two-point pinch strength after 1-month traction, and this increase was maintained until month 6 despite the absence of radiographic changes. Compared to controls, significant improvement in two-point pinch strength relative to baseline was seen at every observation time point, with a moderate to large effect size. There was no time–treatment interaction. Treatment adherence was high. At months 3 and 6, around 60–80 % of digits were voluntarily treated. Pinch strength was comparable between months 6 and 12, with greater improvement than in the control group.

Conclusion: Joint traction treatment can improve pinch strength in symptomatic distal interphalangeal joint osteoarthritis. Larger, randomized studies on traction treatment and the effect on hand function are warranted.

Hand osteoarthritis (OA) is one of the most common OA phenotypes. Recent large-scale epidemiological studies have revealed that more than half of middle-aged and elderly individuals suffer from hand OA [1,2]. Distal interphalangeal (DIP) joint OA accounts for more than half of hand OA cases, and social interest in this condition has increased over the past two decades due to its growing prevalence [3]. Approximately 5 % of patients with Heberden's nodes complain of temporary or continuous pain and swelling around the affected joints [4], indicating that 1–2% of the general population suffers from symptomatic DIP joint OA. Painful DIP joints are

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associated with impaired pincer and gripping functions [5]. Therefore, joint pain under load is one of the most important factors negatively affecting hand function in patients with DIP joint OA.

Over the past decade, joint distraction has emerged as a joint-preserving therapeutic option for end-stage OA, and has been used especially for OA of the knee and ankle joints. Joint distraction involves the continuous [6–8] or intermittent [9] application of an external fixation frame for 1–3 months to keep the joint separated. Clinical trials of joint distraction have demonstrated symptomatic and functional improvement [10] as well as cartilage repair at long-term follow-up [11,12]. Suggested mechanisms involve not only pain alleviation by mechanical unloading onto cartilage, but also enhanced tissue repair activity by hydromechanical effects secondary to cyclic loading and unloading [13]. Mechanical traction treatment has also been shown to improve pain and physical function in patients with knee osteoarthritis [14]. The efficacy of distraction or traction treatment for small and non–weight-bearing joints has not been well studied [15]. The purpose of this study was to investigate the effects of joint traction on symptomatic DIP joint OA.

1. Patients and methods

1.1. Ethics

Ethical approval was obtained from the Ethics Committee of Kyoto University, Graduate School and Faculty of Medicine on Jan 26, 2021 (approval number: R2774). This study was implemented in accordance with the Declaration of Helsinki. Written informed consent was obtained from all patients participating in this study.

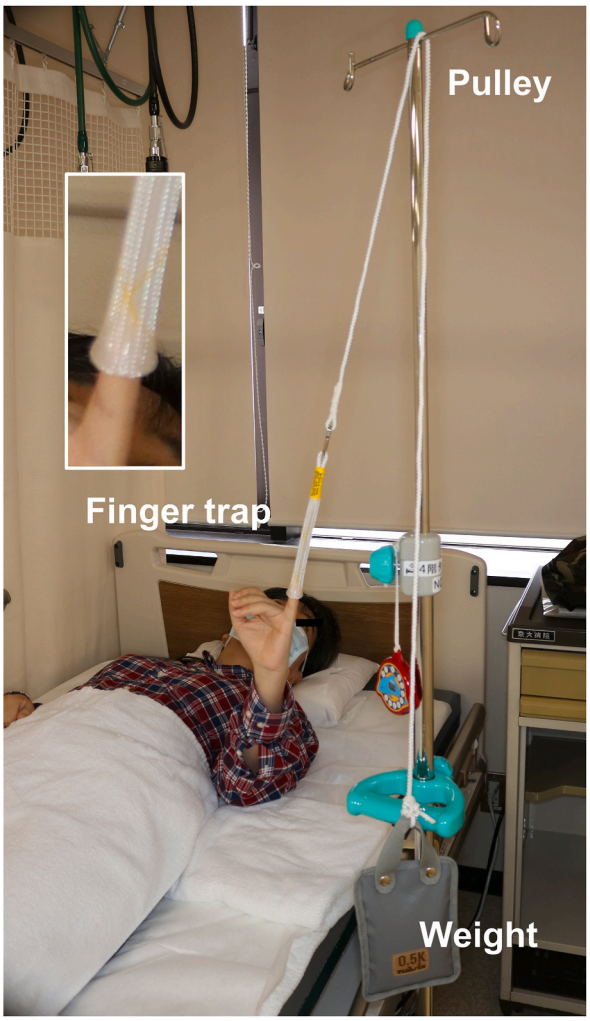

Fig. 1. Photograph showing a patient receiving instruction on traction treatment at the outpatient clinic. A finger trap orthosis is applied to reach the level of the distal interphalangeal crease (*inset*). The finger trap was pulled upward by a string attached to a weight.

1.2. Study design

We conducted a prospective longitudinal study with multiple time-series observations in patients with symptomatic DIP joint OA. Untreated contralateral digits were used as within-subject controls.

1.3. Participants

To be eligible, patients had to satisfy the following criteria: age 20 years or older; attend a hand surgery outpatient department at Kyoto University Hospital, Kyoto, Japan; have a diagnosis of hand OA according to American College of Rheumatology criteria [16]; and show evidence of radiographic OA, with at least one symptomatic DIP joint and with pain lasting for the preceding 6 weeks or longer. Patients with secondary hand OA, inflammatory arthritis, or other neurological or skeletal diseases contributing to hand pain were excluded. Patients with thumb OA, deformity or pain were also excluded because these conditions may affect pincer function, thus making it more difficult to assess the primary outcome measure, namely the effect of the treatment on two-point pinch strength. Patients who fulfilled the inclusion criteria underwent baseline functional evaluation. The most symptomatic joint was treated.

1.4. Joint traction procedure

A finger trap orthosis was used for intermittent joint distraction (Fig. 1). Instructions on how to perform joint traction were provided at the outpatient clinic, and subsequently each patient performed the traction at home. The patient was placed in a supine position on the bed, with the shoulder joint in the zero position, the elbow joint flexed at 90°, the forearm in the mid-pronation-supination position, and the wrist in the zero position. A piece of thick, double-sided adhesive tape was attached to the dorsum of the nail, and a finger trap orthosis (Daiya Industry, Okayama; Hill-Rom Holdings, Chicago, IL) was applied to the digit so that the proximal end of the orthosis reached the distal interphalangeal crease. The distal end of the finger trap was tied to a string and pulled upward. The string passed through a pulley and was then pulled downward by a weight attached to the end. The traction force was

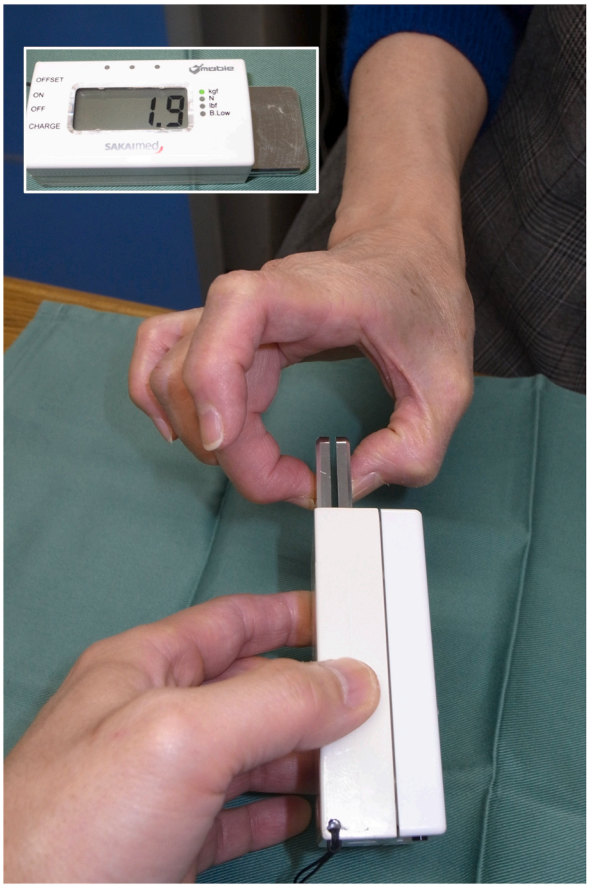

Fig. 2. Pinch strength measurement using a digital pinch dynamometer. The dynamometer has two plate-shaped sensors installed in parallel, and a digital monitor screen that displays the maximum value for each measurement (*inset*). The patient is asked to pinch the sensors at their center. During the measurement, neither the patient nor the examiner is able to see the monitor screen.

altered by adjusting the weight (approximately 500 g for women, 1 kg for men). Patients were instructed to perform traction for 15 min nearly daily for the first month. Patients were also instructed to discontinue traction until the next consultation if traction worsened their pain. After consultation at month 1, patients were permitted to decrease the frequency or discontinue the treatment.

1.5. Assessment

Traction frequency was investigated at months 1, 3, and 6, and was classified into five categories: every day, every 2–3 days, every 4–7 days, not performed at all, and not performed because no pain was present. Patients were only included in longitudinal and pairwise analyses if their traction frequency was at least every 2–3 days for the first month, if their follow-up period was ≥3 months, and if they had a control digit.

1.6. Outcome measures

The primary outcome measure was two-point pinch strength at short-term (month 1), mid-term (month 3), and long-term (month 6) follow-up. Improvement in two-point pinch strength relative to baseline (before treatment) was compared to that observed in control digits. Secondary outcome measures were radiographic findings and the degree of adherence to joint traction. Baseline patient demographic data included age, sex, medical history, and use of medications, especially anti-inflammatory and analgesic medications. At each observation, patients were asked about their general health condition and their current medication regimen. Two-point pinch strength was measured using a digital pinch dynamometer (SAKAI Medical, Tokyo) in the standardized manner [17] (Fig. 2). The affected digits and corresponding control digits were measured alternately. During the measurements, both the patient and examiner were blinded to the values. Two-point pinch strength was measured twice at each observation, and the two values were averaged [18]. Two-point pinch strength data acquired before and after traction for non-intervention digits were used to evaluate measurement reproducibility. Anteroposterior and lateral radiographs of the digits were obtained at baseline and at month 6. The OA severity in involved joints was rated on the basis of the Kellgren and Lawrence scale [19,20] and the Verbruggen-Veys anatomical phase [21]. Joint angulation was defined as an angle ≥20° between the longitudinal axes of the distal and middle phalanges.

2. Statistics

Estimation of minimal sample size and statistical power was performed with G*Power 3.1.9.7 (https://www.psychologie.hhu.de/arbeitsgruppen/allgemeine-psychologie-und-arbeitspsychologie/gpower) using the MANOVA with within-subjects design mode. The calculation resulted in a sample size of 11 patients, with a 0.3 effect size, 0.05 α error probability, and 80 % power. Assuming a possible dropout rate of 50 %, we determined that 22 patients should be enrolled at baseline.

Assuming that the increase in two-point pinch strength would be multiplicative, we examined the homoscedasticity of time-series data. Data on pinch strength were subjected to logarithmic transformation after heteroscedasticity was confirmed. Longitudinal changes in pinch strength were assessed using one-way, within-subjects, repeated ANOVA. The difference-in-differences method was used to assess the response to treatment. The difference between each observation time and baseline was used to standardize the inter-group difference at baseline. Two-way repeated ANOVA with within-subjects design was performed on the differences. A post hoc test using Tukey's test, and effect size estimation using Cohen's *d* value, were performed to evaluate the effect of treatment at each observation time point. *P* values < 0.05 were considered statistically significant. The last-observation-carried-forward imputation method was used for missing data on two-point pinch strength due to patient absence or discontinued traction. This method was used only if there was improvement between a previous and later time point, or if there was improvement before the time point at which data were missing.

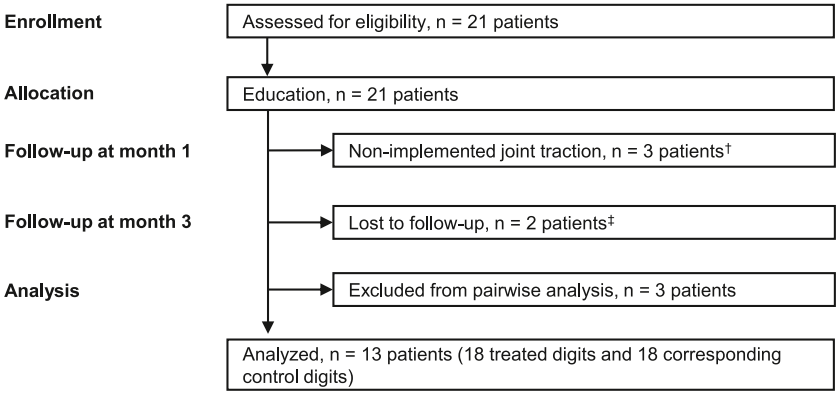

Fig. 3. Study flowchart. †At month 1, three patients were removed from the study because they had not performed traction: one was worried about exacerbation of comorbid arrhythmia, one had difficulty applying the finger trap to the digit, and one had spontaneous improvement of pain. ‡At month 3, two patients were lost to follow-up but both had improved two-point pinch strength at month 1.

3. Results

3.1. Patients

Patients were enrolled between January 2021 and September 2022. The final study visit occurred in March 2023. A flowchart of sample inclusion is presented in Fig. 3. Twenty-one patients agreed to participate in the study. Eighteen patients who completed 1 month of joint traction were enrolled (Fig. 4). Excluding two patients who were lost at month 3 (both had improved two-point pinch strength at month 1), 16 patients completed 3-month follow-up. Of these, control data became unavailable for three patients; thus, they were excluded from the pairwise analysis: two patients performed traction bilaterally, and one patient underwent arthrodesis of the contralateral digit. All three of these patients showed continuously improved two-point pinch strength. Pairwise comparison analysis was performed for 18 digits of 13 patients (Table 1). The mean age was 64.9 years (range, 48–74), and most patients were women (85 %). More than 70 % of patients had pain for more than 1 year. No patients regularly took non-steroidal anti-inflammatory drugs or any other medications that would affect pain severity. Although joint traction was intended to target the most symptomatic digit, five patients intentionally performed traction on two digits that were equally symptomatic. About 90 % of the treated group had severe OA of grade 3 or higher on the Kellgren and Lawrence scale (Table 2). Treated digits were associated with significantly lower two-point pinch strength than control digits ($p < 0.001$).

3.2. Reproducibility of primary outcome measure

Two-point pinch strength for 25 untreated digits (six index, 11 middle, seven ring, and one little finger) was assessed before and after traction to evaluate the reproducibility of the measurements. These two measurements were performed approximately 30 min apart. The intraclass correlation coefficient was high (ICC [1,1], 0.912).

3.3. Effect of joint traction on two-point pinch strength

Fig. 5 shows longitudinal changes in two-point pinch strength for treated and contralateral untreated (control) digits, showing increased two-point pinch strength with heteroscedasticity in both groups. Fig. 6 shows longitudinal changes in two-point pinch strength after logarithmic transformation processing, addressing the heteroscedasticity.

Intragroup evaluation was performed for log two-point pinch strength in the treated and control digit groups (Table 3). For the treated digits, statistically greater log two-point pinch strength was observed at every time point relative to baseline; however, there was no significant difference between months 1 and 6. For the control digits, statistically greater log two-point pinch strength was observed at months 3 and 6 relative to baseline; however, there was no significant difference between baseline and month 1.

The increase in log two-point pinch strength in both the treated and control digits indicated that the longitudinal changes may have been associated with individual health conditions. There was a significant difference in the time factor ($F(2, 34) = 8.50$, $p = 0.001$, partial $\eta^2 = 0.33$) and the intervention factor ($F(1, 17) = 8.28$, $p = 0.010$, partial $\eta^2 = 0.33$), whereas there was no significant difference in the interaction between time and intervention factors ($F(2, 34) = 0.50$, $p = 0.608$, partial $\eta^2 = 0.03$). Post hoc pairwise

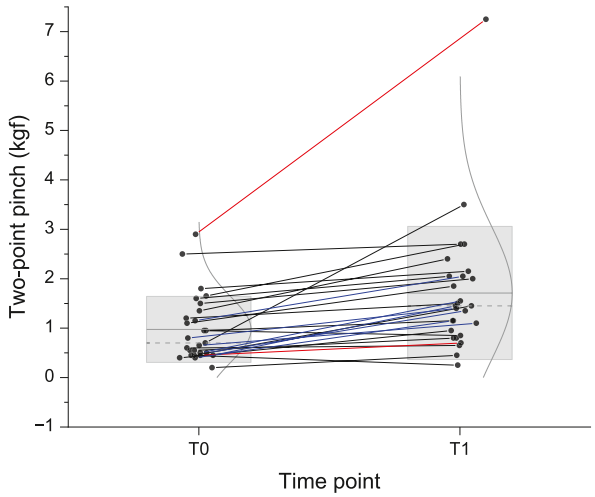

Fig. 4. Box-and-whisker plot with a normal distribution curve showing the change in two-point pinch strength from baseline (T0) to month 1 (T1) for 27 fingers (18 patients) subjected to 1-month joint traction. Red lines indicate patients who were lost to follow-up at month 3. Blue lines indicate patients whose data were excluded from the pairwise comparison analysis. Boxes indicate standard deviation. The gray solid lines and dotted lines in the boxes indicate the mean and median values, respectively. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Table 1
Patient demographics.

Characteristics	Patients (n = 13)
Age, mean (range)	64.9 (48–74)
Sex, n (%)	
Male	2 (15.4 %)
Female	11 (84.6 %)
Diabetes, n (%)	
Type 1	1 (7.7 %)
Type 2	1 (7.7 %)
Symptom duration, n (%)	
<1 year	3 (23.1 %)
1–3 years	9 (69.2 %)
>3 years	1 (7.7 %)
Treated digits per patient, n (%)	
One digit	8 (61.5 %)
Two digits	5 (38.5 %)

Table 2
Sample Characteristics at baseline.

Characteristics	Treated digits, n = 18	Control digits, n = 18 (the corresponding digits of the contralateral hands)
Digital ray, n (%)		
Index	5 (27.8 %)	
Middle	8 (44.4 %)	
Ring	4 (22.2 %)	
Little	1 (5.6 %)	
Radiographic findings		
Osteoarthritis scale[a], n (%)		
2	2 (11.1 %)	4 (22.2 %)
3	1 (5.5 %)	2 (11.1 %)
4	15 (83.3 %)	8 (44.4 %)
Others	0 (0 %)	4 (22.2 %)[c]
Osteoarthritis phase[b], n (%)		
S phase	2 (11.1 %)	4 (22.2 %)
J phase	14 (77.8 %)	8 (44.4 %)
E phase	2 (11.1 %)	2 (11.1 %)
R phase	0 (0 %)	0 (0 %)
Others		4 (22.2 %)[c]
Joint alignment, n (%)		
Angulation ≥20°	5 (27.7 %)	2 (11.1 %)
Straight	13 (72.2 %)	16 (88.9 %)
Two-point pinch (kgf)		
Mean (SD)	1.03 (0.61)	1.54 (0.72)
Median	0.95	1.6
Range	0.2–2.5	0.45–2.7

[a] Kellgren and Lawrence scale.
[b] Verbruggen-Veys anatomical phase.
[c] Joint fusion at baseline: three joints were surgically fused and one was spontaneously fused. SD, standard deviation.

comparison showed that there was no significant difference in the time factor in either group. For the intervention factor, significant differences were observed at every time point ($p = 0.008$, 0.004, and 0.002 for months 1, 3, and 6, respectively).

3.4. Adherence to joint traction

During the first month, joint traction was performed daily for 17 of 18 digits (94.4 %), and once every 2–3 days for the remaining digit (Table 4). High adherence was maintained even at months 3 and 6, when 60–80 % of digits were still treated daily or once every 2–3 days. Two patients discontinued traction due to the absence of pain.

3.5. Radiographic changes

There was no change in the Kellgren and Lawrence score between baseline and month 6. The Verbruggen-Veys anatomical phase remained unchanged in all joints except in one patient, whose treated joint and the corresponding contralateral joint showed phase

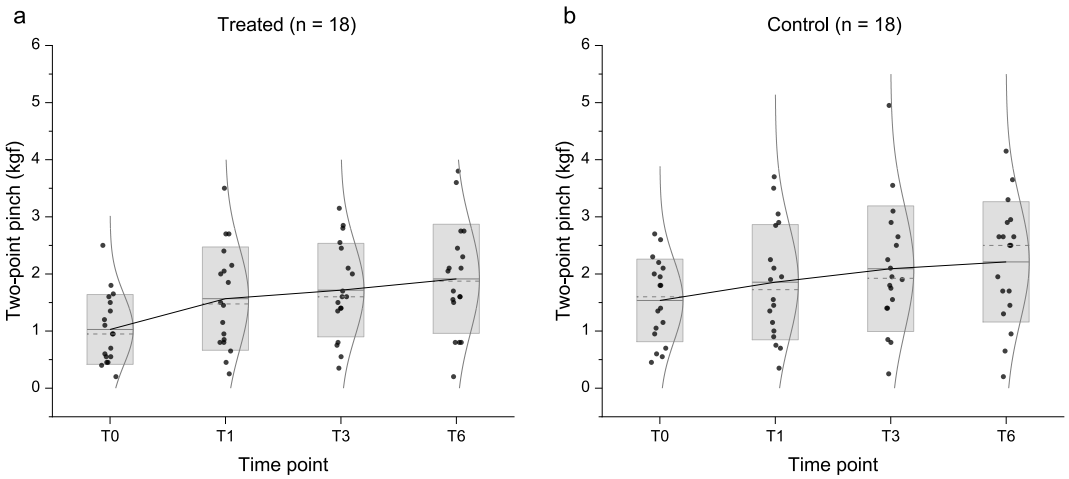

Fig. 5. Box-and-whisker plots with normal distribution curves showing differences in two-point pinch strength over time for 18 fingers (13 patients) for which pairwise comparison analysis was applied. (**a**) treatment group; (**b**) control group. T0, T1, T3, and T6 indicate baseline and months 1, 3, and 6, respectively. Boxes indicate standard deviation. The gray solid lines and dotted lines in the boxes indicate the mean and median values, respectively.

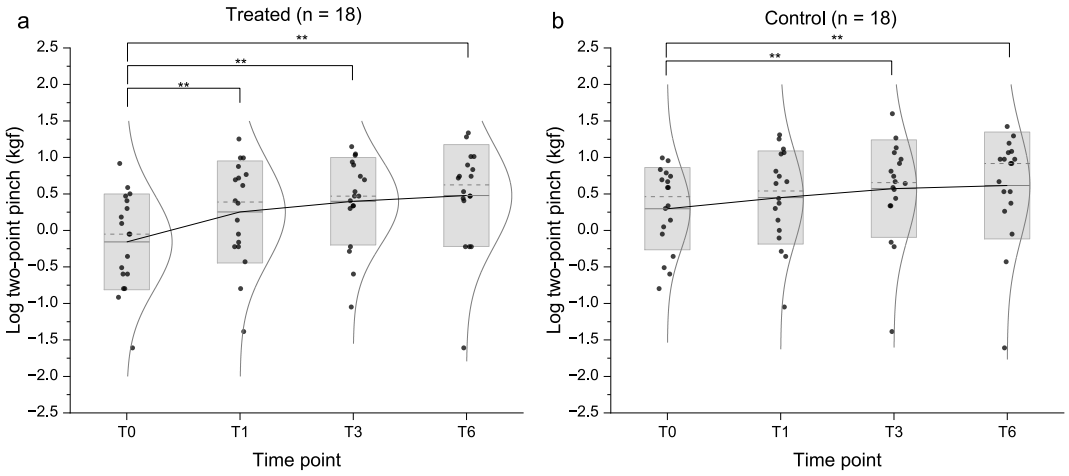

Fig. 6. Box-and-whisker plots with normal distribution curves showing longitudinal changes in two-point pinch strength after logarithmic transformation processing for 18 fingers (13 patients) subjected to pairwise comparison analysis. (**a**) treatment group; (**b**) control group. $^{**}p < 0.01$. T0, T1, T3, and T6 indicate baseline and months 1, 3, and 6, respectively. Boxes indicate standard deviation. The gray solid lines and dotted lines in the boxes indicate the mean and median values, respectively.

progression from J to E. No joints showed increased angulation.

3.6. Durability of improved pinch strength after treatment cessation

Because patients showed high adherence to the treatment even at month 6, the durability of improved pinch strength after treatment cessation was investigated at month 12 (Fig. 7). One patient discontinued the study due to thrombocytopenic purpura; this patient had two digits that were previously analyzed. Arthrodesis was performed on one digit of a patient with multiple symptomatic digits. At month 12, patients were no longer performing traction on 10 of 15 (66.7 %) digits overall (pain was completely absent in half of these digits). Data on pinch strength were available for 14 digits and were comparable between months 6 and 12, with greater improvement than in the control group at month 12. The radiographic condition of these digits remained unchanged.

4. Discussion

In this study, the effect of joint traction on symptomatic joints in patients with DIP joint OA was assessed over time with inter-subject controls. A significant increase in two-point pinch strength was observed after 1 month of joint traction, and this increase

Table 3
Between-group comparison analysis of improvement in two-point pinch strength.

	Time				Repeated measures ANOVA		Effect size		
	T0	**T1**	**T3**[a]	**T6**[b]	*F*	*p*	Partial η^2	f^{b}	Effect size
Two-point pinch, kgf (SD)									
Treated (n = 18)	1.03 (0.61)	1.57 (0.91)	1.72 (0.82)	1.91 (0.96)					
Control (n = 18)	1.54 (0.72)	1.86 (1.01)	2.09 (1.10)	2.21 (1.05)					
Log two-point pinch, kgf (SD)									
Treated (n = 18)	−0.16 (0.66)	0.25 (0.70)[a]	0.40 (0.60)[a]	0.48 (0.70)[a]	Time: F (3, 51) = 17.91	6.37E-5		1.03	Large
Control (n = 18)	0.29 (0.56)	0.45 (0.64)	0.57 (0.67)[a]	0.62 (0.73)[a]	Time: F (3, 51) = 6.37	0.008		0.61	Large
Difference of log two-point pinch from T0, kgf (SD)		**T1-T0**	**T3-T0**	**T6-T0**					
Treated (n = 18)		0.41 (0.44)	0.56 (0.45)	0.65 (0.59)	Time: F (2, 34) = 8.50	0.001	0.33	0.71	Large
Control (n = 18)		0.15 (0.31)	0.27 (0.46)	0.31 (0.45)	Intervention: F (1, 17) = 8.28	0.010	0.33	0.70	Large
Pairwise comparison treated vs untreated					T × I: F (2, 34) = 0.50	0.608	0.03	0.17	Small /Medium
Mean difference, kg (SE)		0.26 (0.09)	0.28 (0.09)	0.32 (0.09)					
p		0.008	0.004	0.002					
95 % CI		[0.07, 0.44]	[0.09, 0.47]	[0.13, 0.50]					
Cohen's *d*[c]		0.65	0.64	0.62					

[a] Statistically significant difference compared to T0.
[b] The effect size for ANOVA was evaluated based on the following criteria: large = 0.4, medium = 0.25, small = 0.1.
[c] The effect size for Cohen's *d* was evaluated according to the Cohen's criteria (large = 0.8, medium = 0.50, small = 0.20). SD, standard deviation; SE, standard error. T0, T1, T3, and T6 indicate baseline and months 1, 3, and 6, respectively.

Table 4
Adherence to joint traction.

Adherence, n (%)	T1 (n = 18)	T3 (n = 17[a])	T6 (n = 15[b])	T12 (n = 15[c])
Every day	17 (94.4 %)	10 (58.8 %)	9 (60.0 %)	3 (20.0 %)
Every 2–3 days	1 (5.6 %)	4 (23.5 %)	0 (0 %)	1 (6.7 %)
Every 4–7 days	0 (0 %)	1 (5.9 %)	1 (6.7 %)	1 (6.7 %)
Not performed at all	0 (0 %)	0 (0 %)	2 (13.3 %)	5 (33.3 %)
Not performed because no pain was present	0 (0 %)	2 (11.8 %)	2 (13.3 %)	5 (33.3 %)

[a] Data for one digit were lost because the patient could not be examined.
[b] Data for one digit were lost because the patient could not be examined; data for two fingers of a patient with thrombocytopenia were lost because of discontinued follow-up at month 3.
[c] Data for two digits of a patient with thrombocytopenia were lost; data for one digit were lost because the digit underwent arthrodesis. T1, T3, T6, and T12 indicate months 1, 3, 6, and 12, respectively.

was maintained for 6 months. At every time point, the treated digits showed significantly greater improvement in two-point pinch strength from baseline compared to control digits, with a moderate to large effect size. There was high adherence to the treatment. At month 6, around 80 % of patients voluntarily continued joint traction.

Currently, there is no cure for hand OA. The efficacy of systemic corticosteroids as analgesics for hand OA is unclear [22]. Intra-articular glucocorticoid injection has not been reported to be more effective than placebo [23]. A recommendation by the European League Against Rheumatism (EULAR) stated that intra-articular steroid injections may be considered in patients with painful DIP joints [24]. A randomized controlled study in patients with interphalangeal joint OA demonstrated that intra-articular injection of triamcinolone hexacetonide with lidocaine had a superior pain-relieving effect than lidocaine only [25], but the two groups showed no difference in either grip strength or pinch strength. Inaccurate needle placement may be an issue during intra-articular injection of DIP joint OA [26]. Among non-pharmacologic treatments, only splint therapy has shown efficacy at relieving pain due to hand OA [27]. A prospective controlled trial conducted by Watt et al. [28] demonstrated that 3-month overnight application of a custom thermoplastic splint to DIP joints reduced pain at both 3 and 6 months compared to baseline (median reductions of 1.5 and 2.0, respectively, on a 10-point pain scale), although there was no significant difference in pain reduction or pinch strength between the intervention and control groups at 3 months. Interestingly, around 60 % of patients preferred to wear the splint beyond the study period. This implies that sustainable and minimally invasive treatments are preferred by patients with hand OA even though their pain-relieving effects are

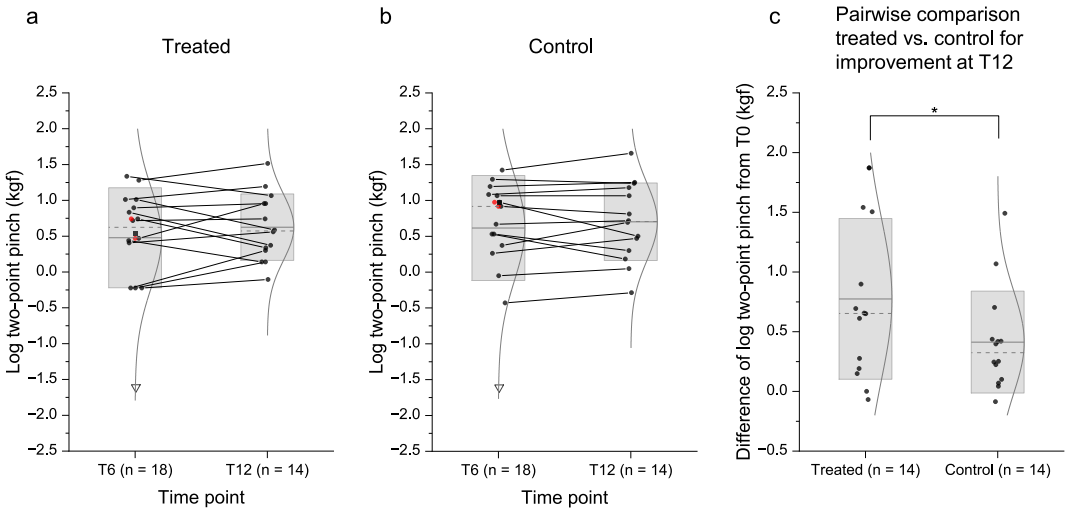

Fig. 7. Box-and-whisker plots with normal distribution curves showing changes in two-point pinch strength after logarithmic transformation processing between months 6 and 12 for the treatment (**a**) and control (**b**) groups, and pairwise comparison of improvement in two-point pinch strength at month 12 relative to baseline between the treated and control groups (**c**). Red dots indicate the digits of the patient with thrombocytopenic purpura who discontinued the study. Triangles indicate the patient with multiple symptomatic digits who underwent arthrodesis. $*p < 0.05$. T6 and T12 indicate months 6 and 12, respectively. Boxes indicate standard deviation. The gray solid and dotted lines in the boxes indicate the mean and median values, respectively. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

modest.

The joint distraction method was first introduced clinically in the 1990s for weight-bearing joints of the lower extremity [29,30], and more recently in small joints such as the thumb basal joint [15]. In addition to pain reduction, beneficial effects on articular cartilage thickness have been reported [10,31]. Most clinical trials have used sustained distraction (4 weeks–3 months) [6,8]. Some studies used an external fixator that allows passive joint motion [7]. Despite the observed clinical and structural benefits of joint distraction, the molecular mechanisms remain speculative. An external frame holds the articular cartilage planes apart when the extremity is unloaded, while the elastic frame prevents complete mechanical unloading during standing or walking [32]. Therefore, temporary removal of mechanical stress and also promotion of synovial fluid circulation during repeated loading and unloading have been considered beneficial for joint repair.

In the present study, a finger trap with a traction force of 500–1000 g per digit was employed for temporal distraction of the DIP joint. A cadaver study using magnetic resonance imaging showed that two finger traps, each with a traction force of 1000 g, resulted in widening of metacarpophalangeal joints [33]. Despite the absence of radiographic evidence showing joint cartilage repair in the present study, significant improvement of two-point pinch strength was observed. One patient exhibited radiographic progression from the J to E stage, but this was considered to be due to systemic factors, as the contralateral digit in this patient showed the same change.

One of the highlights of this study was the use of two-point pinch strength as a parameter to quantitatively demonstrate the effect of joint traction and its change over time. Except for those with erosive OA, most patients with hand OA do not have persistent pain [1], suggesting the need for highly reproducible methods rating momentary pain during movement or under load in patients with DIP joint OA. We used two-point pinch strength not to evaluate overall hand function, but to assess pain in specific DIP joints on the basis of the hypothesis that DIP joint pain is associated with decreased two-point pinch strength. The finding that there was a significant difference in this strength between the treated and corresponding contralateral non-treated digits at baseline supported our hypothesis.

Designing studies to discriminate the effect of an intervention from the placebo effect is very challenging in hand OA. For example, even intra-articular placebo injection resulted in effective 4-week pain relief in thumb basal joint OA [34]. In the present study, corresponding contralateral non-treated digits were used as study controls because two-point pinch strength varies by digit, and this approach therefore avoided the potential impact of finger differences on pinch strength and its improvement over time. The increase in log-transformed two-point pinch strength from baseline (which is mathematically equivalent to the log-transformed value of the ratio of improvement of two-point pinch strength relative to baseline) was significantly higher in treated digits than in control digits at all observation points. No time–group interaction was observed, indicating that this improvement was due to the treatment. A concern was that improvement ratio may have a small denominator (weak pinch strength at baseline), but in all cases, there was no statistical correlation between the improvement ratio at any time point and the baseline two-point pinch strength value. Another concern is that patients who dropped out may have had an unfavorable course. Two patients who were lost to follow-up at month 3 showed 1.6-fold and 2.5-fold increases in two-point pinch strength at month 1, respectively. Seven digits of three patients excluded from pairwise analysis had a 1.8-fold increase in two-point pinch strength at month 1, which was maintained till month 6. Therefore, data from these excluded samples do not negate the results of the controlled analyses.

This study has several limitations. First, we did not employ a large, randomized controlled design. The limited number of patients from a single institution might compromise the generalization of the results. There are potential biases associated with individual differences between patients with hand OA. We also did not evaluate the relationship between OA severity (especially erosive OA) and the effect of treatment. Second, we did not attempt to determine how great an increase in two-point pinch strength was required to improve overall hand function. Third, 1-year follow-up is insufficient to evaluate osteoarthritis progression. Moreover, we did not evaluate cartilage regeneration using imaging modalities such as magnetic resonance imaging and ultrasonography. Therefore, we could not provide data on the mechanisms underlying the improved pinch strength that was observed. Further large, randomized controlled studies with multiple primary outcome measures, including hand function tests and diagnostic imaging modalities, are needed to elucidate the efficacy of joint traction for improving hand function in patients with symptomatic DIP joint OA.

In conclusion, temporary joint traction for DIP joint OA provided a sustained improvement in two-point pinch strength over 6 months compared to control. Patients showed good adherence to the treatment. Joint traction is minimally invasive, sustainable, and does not limit the patient's social activities. Larger, randomized studies with diverse methods of assessing traction treatment and its effects on hand function are warranted.

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Data availability statement

The datasets generated and analyzed in this study are available from the corresponding author upon reasonable request.

CRediT authorship contribution statement

Susumu Saito: Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Aiko Makino:** Writing – original draft, Investigation, Formal analysis. **Naoki Morimoto:** Writing – original draft, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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