Appropriate Distraction Strength For Metatarsophalangeal Joint Arthroscopy

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Abstract

This study is to investigate the natural metatarsophalangeal joint (MTP) distance, the appropriate degree of distraction and the associated factors including age, gender, body mass index(BMI). Regarding natural MTP joint space size, the MTP-2 joint had the largest joint size (2.39 ± 0.37 mm). The MTP-5 joint had the smallest joint size (1.59 ± 0.34 mm). In MTP joint arthroscopy, traction power of 10 lbs is sufficient for appropriate distraction for all MTP joints while traction power of 5 lbs is an appropriate power for distraction of the MTP-2 joint. Manual traction is generally not appropriate for distraction because it is not consistent or sufficient. Less distraction power is required for males than for females, especially for MTP-1, MTP-3, and MTP-4 joints.

Introduction

Metatarsophalangeal (MTP) joint arthroscopy has recently been used more broadly than ever before due to the development of high-definition small joint arthroscopes and instruments. Diagnostic indications for MTP joint arthroscopy include swelling due to gout or rheumatoid arthritis, locking, and persistent joint pain. Therapeutic indications include arthrofibrosis, chondromalacia, degenerative joint disease, osteochondral lesion, osteophyte, sesamoid pathology, and synovitis¹. Since MTP joints have small sizes, appropriate distraction for metatarsophalangeal joint arthroscopy is paramount to increase visualization and decrease iatrogenic complications.

Several different skeletal and soft tissue traction techniques have been introduced, including distraction methods using manual distraction², mini external fixator³ and Kirshner wire⁴. Other methods using finger trap and positioning arm have also been devised⁵. However, few studies have studied the proper distraction strength, joint spacing, and factors affecting the distraction regardless of the distraction method. Thus, the purpose of this study was to investigate appropriate degree and strength of distraction for MTP joints arthroscopy as well as associate factors such as gender, age, and body-mass index (BMI).

Results

1. Natural MTP joint space size and appropriate distraction for a safe MTP joint arthroscopy

Regarding natural MTP joint space size, the MTP-2 joint had the largest joint size (2.39 ± 0.37 mm). However, only 9 (45.0%). of 20 patients had sufficient joint sizes to perform MTP arthroscopy. The MTP-5 joint had the smallest joint size (1.59 ± 0.34 mm, Table 1).

Table 1
The natural joint space and possible rate by traction

	MTP-1 joint t space(mm)	MTP-2 joint space(mm)	MTP-3 joint space(mm)	MTP-4 joint space(mm)	MTP-5 joint space(mm)
No traction	2.03± 0.37	2.39± 0.37	2.01± 0.47	1.76± 0.33	1.59± 0.34
Manual traction	2.89± 0.65	3.13± 0.50	2.70± 0.48	2.49± 0.48	2.43± 0.51
5lb traction	2.73± 0.68	3.32± 0.60	2.89± 0.50	2.67± 0.44	2.97± 0.49
10lb traction	3.09± 0.03	3.76± 0.72	3.56± 0.58	3.07± 0.47	3.52± 0.47
15lb traction	3.43± 0.63	4.07± 0.79	3.73± 0.56	3.64± 0.64	4.04± 0.62

Traction of 10 lb was an appropriate distraction force for all MTP joints. Traction of 5lb was an appropriate distraction force for MTP-2 (3.32 ± 0.60 mm), MTP-3 (2.89 ± 0.50 mm), and MTP-5 (2.97 ± 0.49 mm) joints based on the average joint space. Manual traction was appropriate for MTP-1 joint (2.89 ± 0.65 mm) and MTP-2 joint (3.13 ± 0.50 mm) based on the average joint space. (Table 1)

2. Mean MTP joint space size and distraction according to gender difference

For MTP-1 and MTP-4 joints, males had significantly greater joint space size than females for no traction, manual traction, and traction of 5 lbs, 10 lbs, and 15 lb (Table 2). In MTP-3 joint, males had significantly greater than females for no traction ($p = 0.028$) and traction of 5 lbs ($p = 0.008$). There was no significant gender difference in MTP-2 or MTP-5 joint space size (Table 2).

Table 2
MTP joint size according to different distraction methods with gender

	MTP-1 joint			MTP-2 joint			MTP-3 joint			MTP-4 joint			MTP-5 joint	
	Male (30)	Female (37)	p-value	Male (29)	Female(38)	p-value	Male (30)	Female(37)	p-value	Male (31)	Female(36)	p-value	Male (29)	Female(38)
No traction	2.14 ± 0.40	1.88 ± 0.28	0.039	2.45 ± 0.40	2.30 ± 0.31	0.218	2.14 ± 0.53	1.82 ± 0.33	0.028	1.84 ± 0.32	1.65 ± 0.31	0.063	1.71 ± 0.33	1.44 ± 0.2
Manual traction	3.16 ± 0.68	2.53 ± 0.40	0.002	3.21 ± 0.58	3.28 ± 0.37	0.257	2.79 ± 0.50	2.56 ± 0.45	0.146	2.64 ± 0.53	2.27 ± 0.34	0.015	2.44 ± 0.49	2.41 ± 0.5
5lb traction	2.99 ± 0.78	2.36 ± 0.26	0.004	3.46 ± 0.65	3.12 ± 0.49	0.074	3.08 ± 0.52	2.62 ± 0.32	0.008	2.82 ± 0.46	2.48 ± 0.32	0.014	3.00 ± 0.50	2.94 ± 0.5
10lb traction	3.31 ± 0.75	2.78 ± 0.22	0.013	3.91 ± 0.80	3.56 ± 0.58	0.136	3.57 ± 0.57	3.31 ± 0.58	0.156	3.23 ± 0.50	2.85 ± 0.32	0.010	3.59 ± 0.48	3.41 ± 0.4
15lb traction	3.64 ± 0.76	3.16 ± 0.28	0.024	4.20 ± 0.88	3.90 ± 0.66	0.242	3.86 ± 0.58	3.55 ± 0.52	0.096	3.80 ± 0.69	3.36 ± 0.48	0.018	4.18 ± 0.66	3.85 ± 0.5

3. Mean MTP joints space size and distraction according to age and BMI difference

There was no statistically significant difference in joint space size according to age or BMI for all MTP joints (Table 3,4).

Table 3
MTP joint size according to different distraction methods with age

	MTP-1 joint				MTP-2 joint				MTP-3 joint				MTP-4 joint	
	<30 (22)	30~60(21)	>60 (24)	p-value	<30 (20)	30~60 (25)	>60 (22)	p-value	<30 (21)	30~60 (23)	>60 (23)	p-value	<30 (24)	30~60 (25)
No traction	1.92±0.44	1.99 ± 0.32	2.18 ± 0.37	0.196	2.32± 0.34	2.35 ± 0.35	2.49 ± 0.45	0.322	1.96±0.38	1.96±0.46	2.10±0.57	0.740	1.80±0.30	1.71 ± 0.33
Manual traction	2.84 ± 0.523	2.91 ± 0.70	2.92 ± 0.76	0.956	3.28 ± 0.37	2.90 ± 0.50	3.26 ± 0.55	0.097	2.72 ± 0.47	2.65 ± 0.50	2.72 ± 0.50	0.918	2.50 ± 0.44	2.41 ± 0.5
5lb traction	2.59 ± 0.56	2.70 ± 0.72	2.87 ± 0.79	0.891	3.22 ± 0.65	3.25 ± 0.55	3.49 ± 0.63	0.408	2.73 ± 0.50	2.89 ± 0.41	3.01 ± 0.58	0.383	2.57 ± 0.45	2.94 ± 0.5
10lb traction	3.00 ± 0.42	3.09 ± 0.66	3.16 ± 0.79	0.714	3.80 ± 0.85	3.72 ± 0.52	3.78 ± 0.86	0.990	3.43 ± 0.63	3.45 ± 0.55	3.50 ± 0.62	0.957	3.05 ± 0.59	3.41 ± 0.4
15lb traction	3.22 ± 0.54	3.51 ± 0.60	3.54 ± 0.77	0.140	4.12 ± 0.97	4.02 ± 0.58	4.08 ± 0.90	0.980	3.74 ± 0.63	3.67 ± 0.46	3.79 ± 0.64	0.941	3.51 ± 0.73	3.85 ± 0.5

Table 4
MTP joint size according to different distraction methods with BMI

	MTP-1 joint				MTP-2 joint				MTP-3 joint				MTP-4 joint	
	<23 (19)	23~25(27)	>25 (21)	p-value	<23 (21)	23~25 (25)	>25 (21)	p-value	<23 (22)	23~25 (26)	>25 (19)	p-value	<23 (23)	23~25 (23)
No traction	1.89 ± 0.39	2.09 ± 0.32	2.09 ± 0.40	0.314	2.34 ± 0.29	2.34 ± 0.32	2.43 ± 0.44	0.749	1.88±0.41	2.02±0.29	2.07±0.57	0.553	1.72±0.32	1.65±0.3
Manual traction	2.95 ± 0.62	2.74 ± 0.49	2.93 ± 0.75	0.737	3.10 ± 0.43	3.16 ± 0.65	3.15 ± 0.49	0.954	2.72 ± 0.49	2.58 ± 0.50	2.73 ± 0.50	0.723	2.45 ± 0.50	2.34 ± 0.57
5lb traction	2.52 ± 0.49	2.70 ± 0.58	2.86 ± 0.83	0.759	3.07 ± 0.48	3.60 ± 0.62	3.34 ± 0.63	0.102	2.72 ± 0.37	2.99 ± 0.50	2.93 ± 0.57	0.416	2.59 ± 0.28	2.79 ± 0.56
10lb traction	2.94 ± 0.39	3.15 ± 0.43	3.15 ± 0.82	0.312	3.58 ± 0.56	4.11 ± 0.73	3.72 ± 0.80	0.221	3.41 ± 0.51	3.55 ± 0.48	3.45 ± 0.69	0.924	3.01 ± 0.40	3.25 ± 0.49
15lb traction	3.28 ± 0.45	3.61 ± 0.48	3.45 ± 0.80	0.279	3.91 ± 0.70	4.46 ± 0.79	3.99 ± 0.84	0.208	3.67 ± 0.52	3.98 ± 0.52	3.65 ± 0.60	0.202	3.57 ± 0.51	3.87 ± 0.10

Discussion

In general, traction of five pounds is an appropriate traction power. However, this study showed that traction of 5 pounds would be appropriate only for MTP-2, -3, and -5 joints. Moreover, based on 70% possible rate, such traction power was only enough for the MTP-2 joint. Rather, a traction of 10 pounds is thought to be an effective traction power for all MTP joints based on average joint space.

Because of the small size of the MTP joint, appropriate distraction is essential. Davies et al. ² have reported that the hallux can be suspended using a large Chinese finger trap with traction of approximately 2.7 kg over a pulley attached to the opposite side of the operating table. However, toes are shorter than fingers, making it difficult for a finger trap to effectively perform traction. Derner et al. ³ have reported that a traction can be applied to the great toe either with an assistant or a mini external fixator if necessary. Siclari ⁴ et al. have also reported that the hallux can be suspended using a Kirschner wire in the second phalange from an articulated arm on the operating table. However, a mini external fixator and a Kirschner wire have the disadvantage of being invasive. Hull et al. ⁶ have reported that an axial skin traction of 22 N (5 lbs) can be applied via skin traction through the hallux proximal phalanx/interphalangeal joint. Hunt et al. ⁷ have also reported that a 4 x 8 gauze can be used in a finger trap fashion for manual distraction. However, a manual traction has the disadvantage that the traction strength of an assistant is inaccurate and inconsistent.

In this study, traction was performed for toes by sling. It was conducted by directly using a distraction tower without a weight. Unlike the previous report ²⁻⁴, the novel machine devised by the authors has the advantage of being able to visually check the strength of traction and to be freely adjustable depending on the situation. Another advantage was that the traction strength could be kept constant. These advantages are expected to help prevent complications such as digital nerve traction injury and intraarticular cartilage damage.

Few studies have been conducted on the size of the MTP joint. The joint space without traction measured in this study is meaningful as it is the first study on real patients. Also, the MTP-2 joint space without traction is smaller than the standard 2.8 mm. It provides strong scientific evidence for why appropriate traction is needed for MTP joint arthroscopy.

MTP-1, MTP-3, MTP-4 joints of males were statistically greater joint space size than females. However, there was no statistically significant difference in joint space size according to age or BMI for all MTP joints. Therefore, in the case of men, regardless of age and BMI, it is possible to perform traction with less strength. In particular, in the case of men, because the size of the joint without traction was large, enough joint space could be secured with just 5 pounds of traction. Mass et al. ⁸ have reported plantar plate anatomy related to MTP joint stability of lesser toes with the importance of plantar plate anatomy and integrity for MTP joint stability. The joint space in traction situation depends on the strength and width of the plantar plate. Generally, males have thicker ligament tissues (including plantar plate) than females. Thus, males are expected to require more traction power than females. However, sufficient joint space was secured with less distraction power for males, especially for the MTP-1 joint.

In general, it is expected that younger people will need more traction power because they have stronger ligament structures including plantar plate. In this study, there was no significant difference in traction power needed according to age for all MTP joints. There is a little possibility that age can have influences during small joint arthroscopy. More studies are needed on the relationship between age and traction power. One of our hypotheses is that the higher the weight or BMI of a patient, the more traction power is needed. However, results showed no significant correlation between weight and traction power. Few studies have reported the correlation between weight and elasticity of ligament. Thus, more studies are needed in the future.

This study has some limitations. First, a small number of patients were enrolled. Another weak point would be that age and BMI were arbitrarily classified into three groups. However, it is meaningful in that this is the first study that investigates appropriate distraction powers for MTP joints and measures sizes of MTP joints. Further studies are needed to improve shortcomings of this study in the future.

Conclusion

For natural joint space without traction, the MTP-2 joint had the largest joint size while the MTP-5 joint had the smallest joint size. In MTP joint arthroscopy, traction power of 10 lbs is sufficient for appropriate distraction for all MTP joints while traction power of 5 lbs is an appropriate power for distraction of the MTP-2 joint. Manual traction is generally not appropriate for distraction because it is not consistent or sufficient. Less distraction power is required for males than for females, especially for MTP-1, MTP-3, and MTP-4 joints.

Materials And Methods

Materials

Sixty-seven patients (each 20 MTP joints per toe, total 100 MTP joints,) who underwent MTP joint arthroscopy from April 2013 to June 2020 were enrolled.. Inclusion criteria was patients undertook MTP joint arthroscopy due to 20 (43 MTP joints) rheumatoid arthritis, 16 (18 MTP joints) gouty arthritis, 12 (15 MTP joints) unknown arthritis, 14 (19 MTP joints) osteochondral lesion, 4 (4 MTP joints) pyogenic arthritis, 1 (1 MTP joint) loose body. Exclusion criteria was patients undertook MTP joint arthroscopy due to joint contracture by trauma or burn, diabetic foot joint infection. Autoclavable 1.9 mm 30° high-definition arthroscopes (ConMed Linvatec, Largo, FL, USA) were used in this study. Small-joint shaver with 2.4 mm full-radius blades (Two-Button Ergo™ Shaver, ConMed Linvatec, Largo, FL, USA) was used. Instruments ranging in size from 1.6 to 2.8 mm in diameter included a probe, a basket, a grasper, and a curette. The minimum joint distance for MTP arthroscopy was defined at 2.8 mm which was the sheath size of a 1.9 mm 30° high definition arthroscope. In order to avoid iatrogenic injury during surgery, the joint space should be larger than the outer diameter of the instrument.

Methods

First, the patient was placed in a supine position and general spinal anesthesia was provided. A bump was created on the ipsilateral hip using a towel. Each toe was distracted using a string. The string was attached to the novel distraction machine originally developed by us (Figure 1). The novel distraction machine was approved by the Institutional Review Board of Chonbuk National University Hospital (CUH 2021-02-014-001). There are two joints that can adjust the angle. There is a device for measuring the strength of distraction. Therefore, the authors were able to check the strength of distraction in real time. Anterior-posterior foot plain radiographs were taken using a mini-fluoroscanner (InSight-FD, Hologic Inc. 35 Crosby Drive Bedford, MA, USA, Figure 2) in case of different traction powers such as no traction, manual traction, and traction of 5 pounds, 10 pounds, and 15 pounds. Plain radiographs were computerized and used to measure MTP joint space with a Maro-view 5.4 Picture Archiving Communication System (PACS) (Health Tech Solutions, Inc., Tarpon Springs, FL, USA) (Figure 2). To amend the discrepancy between the real joint space and the joint space in plain radiograph image, the foot plain radiograph was taken using a 1 cm Kirshner wire and then corrected by measuring the length in a PACS system. Age, gender, and body mass index were compared as associated factors. Age was divided into groups of under 30 years, 30~60 years, and over 60 years old. BMI was divided into under 23 years, 23~25 years, and over 25 years. To reduce measurement errors, measurements were taken twice and average values were calculated. We were able to achieve intra-observer and inter-observer reliabilities of 0.94 and 0.95, respectively. This study was approved by the Institutional Review Board of Chonbuk National University Hospital (CUH 2021-02-014-001) and all participants signed informed consent. The study was conducted in accordance with the Declaration of Helsinki principles.

Statistical analysis

In statistical analysis, Student T-test were used to compare gender. One way ANOVA test were used to compare age and body mass index. All statistical analyses were performed using SPSS ver. 17 (SPSS Inc., Chicago, IL, USA). Statistical significance was considered at $p < 0.05$.

Declarations

Author contributions

All authors made substantial contribution to design, collection and analysis of data. K.B.L. designed the study and collected the data. J.K.K analyzed the raw data and the statistics. J.K.K and D.Y.K. drafted and revised the manuscript and all authors reviewed the manuscript for important content.

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Figures

Figure 1

Pictures showing a novel traction machine. (A) A novel distraction machine: There are two joints that can adjust the angle and traction power (black arrow). (B) For effective traction, the new device for fixing legs to the bed was developed and straps (narrow black arrow) were used to fix legs. (C) A device for measuring the strength of distraction. Thus, the authors were able to check the strength of distraction in real time.

Figure 2

Anterior-posterior foot plain radiographs taken using a mini-fluoroscanner with manual traction (A), 5 lbs (B), 10 lbs (C), and 15 lbs (D) of traction. These plain radiographs were computerized and used to measure MTP joint space with a PACS system. Lines in these plain radiographs were wire lines representing distraction pound.