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Original Article

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Changes in Muscle Activity and Contraction Rate in Patients with Hallux Valgus Using Mulligan Taping

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| Abstract |

Purpose: Although foot muscle imbalance has been confirmed in patients with hallux valgus deformity, there is insufficient information on how corrective taping affects muscle activity and contraction rate of the foot muscles. The purpose of this study was to confirm the effectiveness of Mulligan taping as a treatment method for hallux valgus deformity by examining changes in muscle activity and contraction rate when Mulligan taping with inelastic tape was applied to these patients.
Methods: Thirty-two patients with hallux valgus deformity were randomly divided into two groups, experimental and control. In the experimental group, Mulligan taping with inelastic tape was applied to correct the hallux valgus angle of the big toe, and in the control group, placebo taping was performed in which inelastic tape was applied in a straight line without modifying the angle of the big toe. Muscle activity and muscle contraction rate were measured before and after the intervention, and changes were compared and analyzed.
Results: In the experimental group where Mulligan taping was applied, the muscle activity and muscle contraction rate of the abductor hallucis muscle significantly increased after the intervention ($P < 0.05$). On the other hand, the muscle activity and muscle contraction rate of the adductor hallucis muscle and tibialis posterior muscle significantly decreased ($P < 0.05$). There was no significant difference in muscle activity and muscle contraction rate in the control group, where placebo taping was applied ($P > 0.05$).
Conclusion: Mulligan taping significantly changed muscle activity and contraction rates compared to placebo taping. By correcting the position of the big toe, the activity and contraction rate of the abductor hallucis muscle increased, while the activity and contraction rate of the adductor hallucis muscle and tibialis posterior muscle decreased. Therefore, Mulligan taping is considered an intervention that can prevent symptom worsening and enhance foot function by improving muscle imbalance in patients with hallux valgus deformity.

Key Words: Hallux valgus deformity, Mulligan taping, Muscle activity, Muscle contraction rate

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Ⅰ. Introduction

Hallux valgus is one of the most common foot diseases; it causes pain and alters the biomechanics of the foot. Hallux valgus occurs due to a combination of a lateral deviation of the big toe and a medial deviation of the first metatarsal bone, along with malposition of the metatarsophalangeal joint. Problems in the metatarsophalangeal joints lead to pain and deformity, causing discomfort and psychological disorders in the patient's daily life activities (Albright et al., 2000). In addition, hallux valgus increases gait and balance disorders and the risk of falls in elderly patients (Menz et al., 2010). The causes of hallux valgus are divided into congenital and acquired factors, and wearing high-heeled shoes is a major external factor in the progress of hallux valgus deformity. Heredity is also a major factor, and 68% of hallux valgus patients have a family history. Other clinical factors include first toe ray mobility, ligament laxity, and tension in the triceps muscle of the calf (Myerson et al., 2000). The first toe ray consists of the first metatarsal bone and the medial cuneiform bone of the toe and intersects the transverse and medial longitudinal arches. Excessive adduction of the big toe and flat feet are also associated with hallux valgus (Golightly et al., 2014). Hallux valgus is classified into mild (15～20°), moderate (20～40°), and severe (more than 40°) cases, depending on the valgus angle of the big toe (Laura et al., 2015).

In hallux valgus, imbalances between the sole muscles and changes in muscle thickness appear, leading to restrictions in normal muscle contraction activities. In a comparative ultrasound study of the plantar muscles of normal people and patients with hallux valgus, Lobo et al. (2016) found decreases in the thicknesses of the abductor hallucis and flexor hallucis brevis muscles. In addition, hallux valgus shows decreases in the cross-sectional area and thickness of the abductor hallucis muscle, regardless of the degree of progress of the deformity. Based on the results of related studies, morphological changes in the abductor hallucis muscle occur early in the development of hallux valgus (Stewart et al., 2013). In patients with hallux valgus, the abduction activity of the abductor hallucis muscle is significantly reduced compared to its adduction activity. An imbalance between the abductor hallucis and adductor hallucis muscles is evident in hallux valgus deformity, and this imbalance is the cause or result of joint deformity (Arinci et al., 2003). Such joint deformities increase the load on the tibialis posterior muscle, thereby further increasing the likelihood of functional disorders (Incel et al., 2003). Arcella and Petitdant (2020) reported that the tibialis posterior muscle can affect the deformation of hallux valgus. The tibialis posterior muscle is a long, fusiform muscle located at the back of the calf and extending into the arch of the foot. The longitudinal tendon of this muscle extends in many branches. The main tendons of the muscle extend to the flexor pollicis brevis and the abductor hallucis muscles (Dufour, 2016).

Patients with hallux valgus have deformed walking patterns due to foot pain, and the resulting incorrect walking habits lead to a vicious cycle that further worsens hallux valgus symptoms (Benvenuti et al., 1995). When severe, hallux valgus can cause pain, appearance problems in terms of beauty, and a reduction in quality of life in relation to health. When hallux valgus worsens and becomes severe, the only treatment method is surgery (Deenik et al., 2008). However, although more than 130 surgery techniques are described in the literature related to the treatment of hallux valgus, surgery techniques to eliminate a single cause are not perfect, and there is no surgery technique to address multiple causes (Robinson et al., 2005). Therefore, conservative treatment is necessary in the early stages of hallux valgus development to reduce pain and prevent further increases in the hallux valgus angle (Ferrari et al., 2004).

Currently, various assistive devices have been developed to correct hallux valgus, but their materials are hard and difficult to wear in daily life. As an alternative, taping techniques are widely used, and in particular, Mulligan taping has been noted as an effective method for correcting the hallux valgus angle. Mulligan taping has been proven to contribute to improving feedback on joint position and weight by enhancing neuromuscular sensation (Agrawal et al., 2015). One of the main features of Mulligan taping is that it focuses on improving joint movement and relieving pain through a functional approach. This method adjusts abnormal movements in joints to immediately improve movement and provide stability during functional movements. It also stimulates joint mechanoreceptors to strengthen muscle activities and promote neural reflexes in the ankle-stabilizing muscles (Akaras et al., 2020). In addition, Mulligan taping reestablishes joint alignment to provide immediate pain relief and increased range of motion, which helps perform limited movements without pain. These features of Mulligan taping help to alleviate foot dysfunction and pain associated with hallux valgus, and contribute to improving foot function and postural control.

The purpose of this study was to investigate whether Mulligan taping could improve muscle imbalance in patients with lateral hallux valgus by analyzing ultrasound examinations and quantitative electromyography signals of the plantar muscles related to hallux valgus and to establish a theoretical foundation for the possibility of improving the hallux valgus angle through taping. Through this, we evaluated the effectiveness of Mulligan taping in correcting muscle imbalance in hallux valgus and its potential effect on improving the angle, and we hope to contribute to more effective treatment strategies for this disease.

Ⅱ. Method

1. Study subjects

This study was conducted with patients who have mild hallux valgus, specifically those with a hallux valgus angle ranging from 15° to 20°. Participants who had undergone lower extremity surgery or had mental and psychological problems, rheumatoid arthritis, systemic diseases, hysteria and nervous system problems, skin lesions, or allergies were excluded from the study. All subjects heard explanations about the purpose and experimental method of the study and filled out a consent form to participate in the study. The subjects were randomly assigned to a Mulligan taping group and a placebo taping group consisting of 16 subjects each. All research procedures were conducted in compliance with the Declaration of Helsinki.

2. Intervention method

The subjects were randomly divided into two groups, and muscle activity and muscle contraction rate were measured before and immediately after attaching the inelastic tape. The experimental group used the Mulligan taping method to correct the hallux valgus angle to the normal position (Fig. 1), and the control group applied a straight taping to ensure that the hallux valgus angle had no effect (Fig. 2).

1) Mulligan taping

In the case of Mulligan taping, inelastic tape (Battlewin C-type, NICHIBAN, Japan) was used to completely wrap the big toe starting from the medial side of the big toe

Fig. 1. Mulligan taping.

Fig. 2. Placebo taping.

toward the lateral side when the subject was sitting comfortably in a neutral position with the big toe in the state of adduction and eversion, and the tape was moved to the medial side of the foot. From this point, the taping extended laterally from the underside of the foot, terminating at the lateral and upper portions of the foot (Mulligan, 1993)(Fig. 1).

2) Placebo taping

For placebo taping, the same inelastic tape used for the Mulligan taping was used. The tape was cut into a straight shape and attached to the medial part of the foot without stretching (Fig. 2).

3. Measurement method

1) Measurement of muscle contraction rate

The thickness of each muscle was measured using ultrasound imaging equipment (MicrUs EXT-IH, Telemed, Lithuania). Ultrasound images were measured in B-mode using a 7.5 MHz linear probe. When measuring each muscle, the subject lay on their side with the ankle in a neutral position, and the measurement was performed with minimal pressure to minimize the effect on the muscle thickness while ensuring that the ultrasound transducer could be in optimal contact with the skin (Barotsis et al., 2020). The thickness of the abductor hallucis muscle was measured at the anterior edge of the medial malleolus, located in front of an imaginary line about 1–2 cm behind the navicular bone tuberosity. The thickness of the adductor hallucis muscle was measured at the most prominent part of the muscle belly, just proximal to the third metatarsophalangeal joint. The thickness of the tibialis posterior muscle was measured at the location of the muscle where the fifth finger is located when the thumb is placed parallel to the tibial tubercle.

Muscle thicknesses at rest and at maximum contraction were measured at the same location before and after attaching the tape. Using these two values, the muscle

$$MTF = \frac{\text{Thickness at maximum contraction} - \text{Thickness at rest}}{\text{Thickness at rest}} \times 100$$

Fig. 3. Abductor Hallucis MT measurement.

Fig. 4. Adductor Hallucis MT measurement.

Fig. 5. Tibialis posterior MT measurement.

thickness fraction (MTF) was obtained by subtracting the thickness at rest from the thickness at maximum contraction, dividing it by the thickness at rest, and then multiplying by 100.

2) Measurement of muscle activity

To measure muscle activity, a wireless electromyography system (DTS Probe Transmitter, Noraxon, USA) was used, and electrodes were attached with reference to surface electromyography guidelines (Kim et al., 2013). Maximal voluntary isometric contraction (MVIC) was used to standardize the action potential of each muscle. For MVIC measurement, the average value of signals for 3 seconds was used, excluding the first and last 1 second of the signals measured while the subject performed MVIC for 5 seconds. All measurements were performed three times each to reduce measurement errors, and the average of the three measurements was used for the data analysis. Electromyography (EMG) signals were recorded and processed using the Noraxon EMG program MR 3.16, and as for the unit of measurement, the measured values were recorded in ㎷. A notch filter of 60 Hz and a band-pass filter of 10–500 Hz were used, and the sampling rate was set to 1,000 Hz.

The electrodes were attached to the thickest part of the muscle belly, identified by ultrasound measurement. The electrode for the abductor pollicis muscle was attached to the anterior edge of the medial malleolus, located in front of an imaginary line approximately 1~2 cm posterior to the navicular bone tuberosity. The electrode for the adductor hallucis muscle was attached just proximal to the third metatarsophalangeal joint. The electrode for the tibialis posterior muscle was attached to the location of the tibialis posterior muscle where the fifth finger is located when the thumb was placed parallel to the tibial tubercle.

As for the measurement positions by muscle, in a supine position based on the manual muscle test position, in the case of the abductor hallucis muscle, resistance was provided to the center of the proximal phalanx of the big toe using the hand of the measurer while the big toe was in the maximum open position. In the case of the adductor hallucis muscle, the maximum voluntary isometric contraction force was measured when the big toe was maximally adducted. In the case of the tibialis posterior muscle, the maximum voluntary isometric contraction force was measured by medially rotating the foot with plantar flexion to provide resistance during maximum contraction.

To measure the activity of the experimental muscles before and after the intervention, electromyography signals from three muscles were collected for 5 seconds while the subject maintained a heel-lifting motion in a sitting position. Heel lifting can contract all muscles of the foot simultaneously and can be considered an important functional movement for improving posture control (Seo et al., 2021). To enable the patients to maintain the heel-lifting motion with constant force while sitting, a 45 cm-diameter gym ball was placed 30 cm in front of the patient's toes so that the patient's fingertips could touch it. The collected EMG signals were processed as root mean square values, and the signals collected while the patients were maintaining the heel-lifting motion in a sitting position were normalized to percentage maximal voluntary isometric contraction (%MVIC).

4. Data analysis

Data analysis in this study used the PASW 18.0 for Windows (IBM, USA) statistical program. An independent t-test was conducted to analyze the general characteristics of the experimental and control groups and the amount of change in measured values before and after intervention. And the difference in changes before and

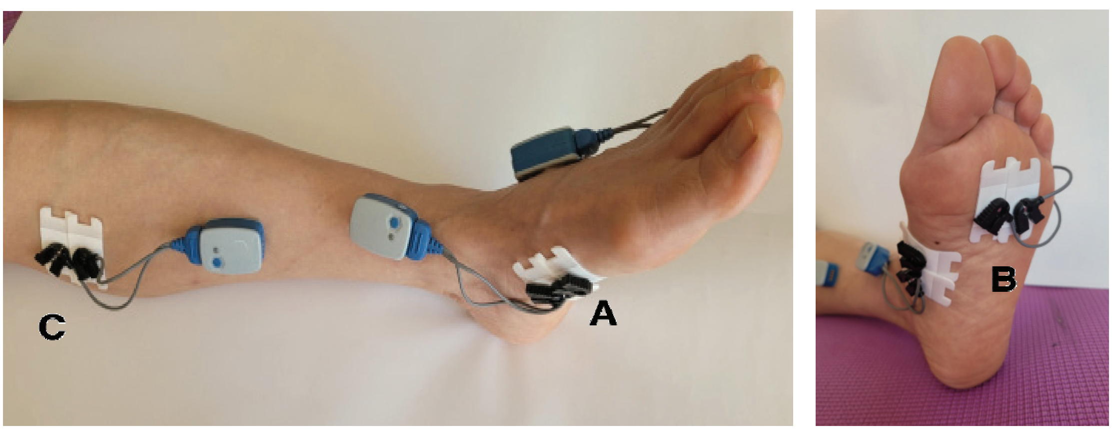

Fig. 6. Electrode placement of the foot muscles. A : Abductor halluces, B : Adductor halluces, C : Tibialis posterior.

after intervention within each group was analyzed using paired samples t-test. Since the data followed a normal distribution, a parametric test was performed, and the statistical significance level (α) was set to 0.05.

Ⅲ. Results

1. General characteristics of subjects

In this study, 32 adults (14 men, 18 women) with mild hallux valgus were randomly and equally assigned to the experimental and control groups (16 participants, 7 men and 9 women in each group). The average ages of the experimental and control groups were 43.21 and 44.06 years, respectively. The average height of the experimental and control groups was 164.63 cm and 163.75 cm, respectively. The average body weight was 60.38 kg and 63.00 kg in the experimental and control groups, respectively. Additionally, body mass index was found to be 22.69 kg/m^2 and 23.99 kg/m^2 in the experimental and control groups, respectively. No significant differences were observed between the two groups in age, height, weight, and body mass index ($p>0.05$) (Table 1).

2. The change in the foot muscles activity

1) Intragroup comparison in the foot muscles activity pre- and post- intervention

In the experimental group, muscle activity of the abductor hallucis significantly increased ($p<0.05$). Muscle

Table 1. General characteristics of subjects (N=32)

Variables	Experimental group	Control group	t	p
Age (years)	43.21±7.41	44.06±9.53	-0.25	0.81
Height (cm)	164.63±9.16	163.75±8.84	0.28	0.79
Body weight (kg)	60.38±8.12	63.00±9.78	-0.74	0.46
BM I (kg/m^2)	22.69±1.75	23.99±2.91	-0.43	0.67

BMI; body mass index
Mean±SD

Table 2. Comparison of the %MVIC between pre- and post-test (N=32)

Group	Muscle	Pre-test	Post-test	t	p
Experimental group	AbH	50.50±16.61	60.93±11.51	-7.80	0.00*
	AdH	61.64±19.73	50.28±19.58	6.46	0.00*
	TP	51.25±13.84	43.01±11.81	4.37	0.00*
Control group	AbH	48.22±18.43	48.88±17.90	-0.58	0.57
	AdH	56.49±14.03	55.81±13.34	0.73	0.47
	TP	51.28±14.79	50.28±15.21	1.79	0.09

Mean±SD
AbH; abductor hallucis
AdH; adductor hallucis
TP; tibialis posterior
MVIC; maximal voluntary isometric contraction
Unit; %MVIC

activity of the adductor hallucis and tibialis posterior was significantly decreased ($p<0.05$). In the control group, there was no significant difference in all muscles ($p>0.05$) (Table 2).

2) Between the groups comparison of changes in the foot muscles activity pre- and post-intervention

The experimental group had significantly greater pre- and post-intervention the foot muscles activity changes than the control group ($p<0.05$) (Table 3).

3. The change in the foot muscles contraction rate

1) Intragroup comparison in the foot muscles contraction rates pre- and post- intervention

In the experimental group, the muscle contraction rate of the abductor hallucis significantly increased ($p<0.05$). The muscle contraction rate of the adductor hallucis and tibialis posterior was significantly decreased ($p<0.05$). In the control group, there was no significant difference in all muscles ($p>0.05$) (Table 4).

2) Between the groups comparison of changes in the

Table 3. Comparison of the %MVIC variation between two groups (N=32)

Muscle	Experimental group	Control group	t	p
AbH	10.43±6.26	0.66±4.30	5.97	0.00*
AdH	-11.37±7.04	-0.78±2.85	-5.13	0.00*
PT	-8.24±7.54	-1.01±2.24	-3.68	0.00*

Mean±SD
AbH; abductor hallucis
AdH; adductor hallucis
TP; tibialis posterior
MVIC; maximal voluntary isometric contraction
Unit; %MVIC

Table 4. Comparison of the MTF between pre- and post-tests (N=32)

Group	Muscle	Pre-test	Post-test	t	p
Experimental group	AbH	37.98±13.64	47.19±14.58	-9.09	0.00*
	AdH	55.19±12.56	44.94±16.63	5.59	0.00*
	PT	47.64±10.41	35.76±12.87	7.69	0.00*
Control group	AbH	33.84±11.96	35.40±11.91	-1.86	0.08
	AdH	54.19±16.75	50.49±15.58	1.82	0.09
	PT	53.68±11.25	53.48±11.43	2.51	0.70

Mean±SD
AbH; abductor hallucis
AdH; adductor hallucis
TP; tibialis posterior
MTF; Muscle thickness fraction
Unit; %

Table 5. Comparison of the MTF variation between two groups (N=32)

Muscle	Experimental group	Control group	t	p
AbH	9.20±4.05	1.56±3.36	5.81	0.00*
AdH	-10.25±7.33	-3.69±8.11	-2.39	0.02*
PT	-11.87±6.17	-0.19±1.98	-7.21	0.00*

Mean±SD
AbH; abductor hallucis
AdH; adductor hallucis
TP; tibialis posterior
MTF; Muscle thickness fraction
Unit; %

foot muscles contraction rate pre- and post-intervention

The experimental group had significantly greater pre- and post-intervention the foot muscles contraction rate changes than the control group ($p<0.05$) (Table 5).

Ⅳ. Discussion

Patients with hallux valgus show an imbalance between the abductor hallucis and adductor hallucis muscles, and the degrees of foot bending and abduction movements during walking are very small in general compared to normal people (Hwang, 2005). This is because the patient is inclined to walk on the outside of the foot to avoid stimulation of the affected area, since the affected area is located on the first metatarsal bone. For this reason, a vicious cycle occurs in which hallux valgus becomes more severe. Mulligan taping brings about improvement of functions and enhancement of stability through immediate realignment of the joints. It also improves the positional sense of the joints and activates muscles by stimulating mechanoreceptors in the skin where the taping is attached (Shadegani et al., 2023). Mulligan taping is a method that can simultaneously promote muscle activation and functional recovery, and can have a synergistic effect when used in conjunction with other intervention methods. Unlike acupuncture or surgical intervention, it is non-invasive and has few side effects.

This study was conducted to determine the effect of Mulligan taping on the muscle activity and contraction rate of the foot muscles in 32 patients with hallux valgus. The subjects were divided into two groups, and Mulligan taping and placebo taping were applied. To confirm the improvement in foot muscle imbalance in patients with hallux valgus deformity when Mulligan taping was applied, ultrasound and electromyography measurements were performed on the abductor hallucis, adductor hallucis, and tibialis posterior muscles. Mulligan taping significantly increased the muscle activity and contraction rate of the abductor hallucis muscle and significantly decreased the muscle activity and contraction rate of the adductor hallucis and tibialis posterior muscles immediately after the intervention. Since it is difficult to measure endogenous foot muscle strength alone, the functional capacity of the muscle was checked by proxy measurement of muscle strength through the muscles' morphological characteristics (thicknesses at rest and contraction) and EMG activity (Kurihara et al., 2014).

Measuring muscle activity is a good way to check muscle function because it is evaluated by quantifying muscle movements and functions. In this study, the muscle activity of the foot muscles was measured before and after taping to determine the effect of Mulligan taping. The muscle activity of the abductor hallucis was found to increase in the experimental group during heel-lifting motion in a sitting position. According to the literature, extension weakening due to abnormal alignment of the first metatarsophalangeal joint reduces abduction and flexion strength in subjects with hallux valgus (Glasoe et al., 2016); that is, based on the length–tension relationship, when the endogenous muscle is stretched beyond its resting length, the muscle is unable to generate optimal tension on its own (Jung et al., 2011). When there is a hallux valgus deformity, the abductor hallucis muscle is stretched and becomes hypertonic, preventing normal muscle activity. As a result of this study, it could be seen that the muscle activation of the abductor hallucis muscle improved when Mulligan taping was applied. In addition, insufficient strength or inappropriate coordination of endogenous foot muscles is the cause of many foot-related diseases (Brantingham et al., 2012). The basic principle of taping is to protect and support the injured area while allowing optimal functional movement. Mulligan taping corrects excessive adduction and valgus deformity of the big toe in patients with hallux valgus and improves muscle imbalance caused by the deformity. The results of the measurement of foot muscle activity in this study confirm that the muscle imbalance appearing in hallux valgus patients was improved.

Next, to check muscle activity, muscle contraction rates were measured through ultrasound measurement. Ultrasound images are used to measure muscle thickness in exercise system conditions that affect physical therapy evaluation (Potter et al., 2013). The ultrasound measurement as such shows excellent intraclass correlation coefficients (ICC) ranging from 0.91 to 0.98 (Crofts et al., 2014). The ratio between muscle thickness during contraction and muscle thickness at rest indicates the degree of muscle activation and can evaluate the degree of muscle contraction. A higher ratio indicates greater muscle activity, and because the contraction rate of the foot muscles reflects the strength and function of the muscles, measuring the contraction rate is a good way to evaluate muscle functions. In a previous study, histological findings of muscular atrophy of the abductor hallucis muscle and ultrasound findings of reduced cross-sectional area were found in hallux valgus (Lobo et al., 2016). Through such studies, it can be seen that in hallux valgus deformity, muscle atrophy appears due to continuous stretching of the abductor hallucis muscle, and the rate of muscle contraction decreases because optimal tension cannot be generated. In this study, when Mulligan taping was applied, the muscle contraction rate of the abductor hallucis muscle improved by 9.20%. This appears to be the result of normalization of the change in position of the abductor hallucis muscle due to deformation of the big toe and restoration of the muscle's length, which enables optimal tension to be generated. In multiple studies, balance strength increased when Mulligan taping was applied to patients with lateral bowing of the big toe (Akaras et al., 2020; Gur at al., 2017). In addition, physical function improved when inelastic tape was applied to a female patient with hallux valgus deformity, with the speed of climbing 10 steps increasing by 0.5 seconds (Demirdel et al., 2022). An increase in the muscle contraction rate indicates improved foot muscle control, and foot muscles play an important role in performing precise and controlled movements. An increase in the muscle contraction rate of the foot muscles increases the efficiency of the muscle control system and can improve fine motor control and coordination of the muscles. Therefore, it can be said that the results of this study are consistent with the results of previous studies. Mulligan taping also helps improve the alignment of joints and muscles, which can help patients remember and maintain proper posture and movement patterns after the taping is removed. Among the effects of Mulligan taping, the improvement of neuromuscular function has a positive effect on how muscles are activated, which can lead to improved muscle function in the long term. Mulligan taping can help patients participate in rehabilitation exercises more effectively by reducing muscle fatigue and temporarily improving exercise capacity, which can contribute to improved function in the long term.

In summary, it can be said that the application of Mulligan inelastic tape to hallux valgus patients improves foot function by improving the imbalance of foot muscles. Since foot muscle imbalance is a major factor that worsens hallux valgus, it is believed that normal coordination of the foot muscles can improve the hallux valgus angle in the long term.

Hallux valgus is the most common and representative disease among deformities occurring in the foot (Thomas et al., 2003). There have been many studies on the improvement of angle and balance when applying taping in relation to hallux valgus (Gur et al., 2017; Choi et al., 2017; Yoo et al., 2020) but few studies have directly measured muscle activity and contraction rate. Therefore, this study has clinical significance in that it identified changes in the function of foot muscles thanks to the application of Mulligan taping by measuring muscle activity and contraction rate, and it could indirectly identify that the hallux valgus angle would be improved in the long term. However, this study did not identify the long-term effects of applying Mulligan taping, and although the minimum sample size required for the study was met, generalization of the results is difficult due to the relatively small sample size. Future studies should secure a larger sample size and should check the effectiveness of Mulligan taping as a therapeutic intervention for hallux valgus through comparative studies with other intervention methods. In addition, it is necessary to apply a longer treatment period to track long-term effects.

Ⅴ. Conclusion

The results of this study showed that Mulligan taping improved muscle imbalance by changing the muscle activity and contraction rate of foot muscles in adult patients with hallux valgus. This suggests that Mulligan taping is a useful method for treating patients with hallux valgus in clinical practice. Additionally, Mulligan taping can improve the foot function of patients with hallux valgus by improving the hallux valgus angle in the long term, which can improve the quality of life of patients.

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