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Original article

Infrared Thermal Imaging in Patients with Medial Collateral Ligament Injury of the Knee - A Retrospective Study

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Key Words

digital infrared thermographic imaging, knee joint, medial collateral ligament, thermography

Abstract

Objectives: Digital infrared thermographic imaging (DITI) has been used widely for various inflammatory diseases, circulatory diseases, skin diseases, musculoskeletal diseases and cancers. In cases of ligament injury, obviously the temperature of the damaged area increases due to local inflammation; however, whether the temperature also increases due to DITI has not been determined. The purpose of the present study was to identify whether or not the changes of temperature in patient's with medial collateral ligament injury were really due to infrared thermography and to determine the applicability of DITI for assessing ligament injuries.

Methods: Twenty patient's who underwent DITI for a medial collateral ligament injury from September 2012 to June 2014 were included in the current study. The thermographic images from the patient's knees were divided to cover seven sub-areas: the middle of the patella, and the inferomedial, the inferolateral, the superomedial, the superolateral, the medial, and the lateral regions of patella. The temperatures of the seven regions were measured, and the temperature differences between affected and unaffected regions were analyzed by using the Wilcoxon signed rank test.

Results: The 20 patient's were composed of 14 women (70%) and 6 men (30%), with a mean age of 62.15 ± 15.71 (mean ± standard deviation (SD)) years. The temperature of the affected side, which included the middle of the patella, and the inferomedial, the superomedial, the superolateral, and the medial regions, showed a significant increase compared to that of the unaffected side ($P < 0.05$). The inferolateral and the lateral regions showed no significant changes.

Conclusion: Our study results suggest that DITI can show temperature changes if a patient has a ligament injury and that it can be applied in the evaluation of a medial collateral ligament injury.

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1. Introduction

The knee joint is one of the largest and most complex joints in the human body, and bio-mechanically, the joint between the femur and the tibia, which functions as the longest lever in the bone structure, can be easily damaged by various external forces [1]. A medial collateral ligament (MCL) injury of the knee, which is caused by valgus stress on the knee, is the most common form of knee ligament injury. Also, an injury of the tibial attachment is more common than one of the femoral attachment, and in the former, an oppressive pain is the signature symptom of the medial femoral region [2].

Digital infrared thermographic imaging (DITI) is an examination that screens any existing disorders and any improvements or deteriorations of symptoms in

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the body through computer imaging that detects traces of infrared light on the surface of the skin on the human body [3]. It is non-invasive, painless, and highly stable and avoids the risk of radiation exposure. Further, it is used as a supplemental means of diagnosis that effectively improves the understanding of the patient by displaying the results visually, and it enables an objective and quantitative evaluation of the physiological and functional states of pain [4, 5]. However, its baseline data as a diagnostic instrument are still lacking. For instance, diagnosing a symmetrical symptom or a subtle temperature difference on the surface of the body and understanding the normal body temperature are difficult due to insufficient standardized diagnostic criterion for the body's temperature [6].

Studies on DITI in patient's with osteoarthritis of the knee have been reported [7-9]; however, no research on infrared thermal imaging related to ligament injuries has been published. Thus, whether the temperature increase seen on DITI is due to the injury to the ligament or to the DITI process itself is difficult to determine. For that reason, we conducted an analysis of the temperature differences between the affected and the unaffected sides of a knee with a MCL injury by using thermography. The purpose of the present study was to determine the applicability of thermography in patient's with a MCL injury.

2. Materials and Methods

Twenty patient's with a MCL injury who underwent DITI at the Korean Medicine Hospital of Sangji University between September 2012 and June 2014 were included in this study. The patient's information was obtained from the hospital's medical records, and target records were selected by reviewing the medical records with the diagnostic code search terms "MCL". We requested the data anonymously, and we extracted and analyzed data such as gender, age, final diagnosis, date of onset, present illness, physical examination, and infrared thermal image from the selected chart records. This study was approved by the institutional review board of the Korean Medicine Hospital of Sangji University (SJ IRB-14-007). The patient's records were selected by using the following criteria: chief complaints of medial knee pain, tenderness at the MCL of the knee, positive results on the valgus stress test, and the existence of DITI data on the knee before the treatment. However, the records of some patient's were excluded based on the following criteria: pain in both knees, arthritis (degenerative arthritis, rheumatoid arthritis, etc.,) and referred pain caused by spine disorders.

DITI was generally done before performing a physical examination and a treatment at the first visit, and a medical thermal imaging system (T-1000, Mesh Co., Wonju, Korea) was used for DITI. DITI was performed in an examination room under controlled conditions with no light and heat other than that from a fluorescent lamp and with consistent indoor air flow with no windows. During the DITI procedure, no personal were allowed to enter, leave, or move around. According to the heights of the patient's, the measurement distances were in the range of 110 – 120 cm. The patient's stood in comfortable positions, with their legs spread to shoulder width, and thermographic images were taken on one image around the patella. Thermography was conducted by using the routine thermography protocol of the Korean Medicine Hospital of Sangji University. The knees on the patient's thermographic images were divided to cover 7 sub-areas: the middle of the patella (R1), and the inferomedial region (R2; Naeseuran, LE201), the inferolateral region (R3; Dokbi, ST35), the superomedial region (R4; Seulsang 2, LE108), the superolateral region (R5; Seulsang 2, LE108), the medial region (R6; Naeseulbang, LE110), and the lateral region (R7; Oeseulbang, LE110) of the patella (Fig. 1).

We extracted the temperature of every region from the thermographic images of the patient's with a MCL injury to the knee and conducted an analysis of the temperature differences between the affected and the unaffected sides by using the Wilcoxon signed rank test. Significance was set at a level of 0.05, which was associated with the 95%

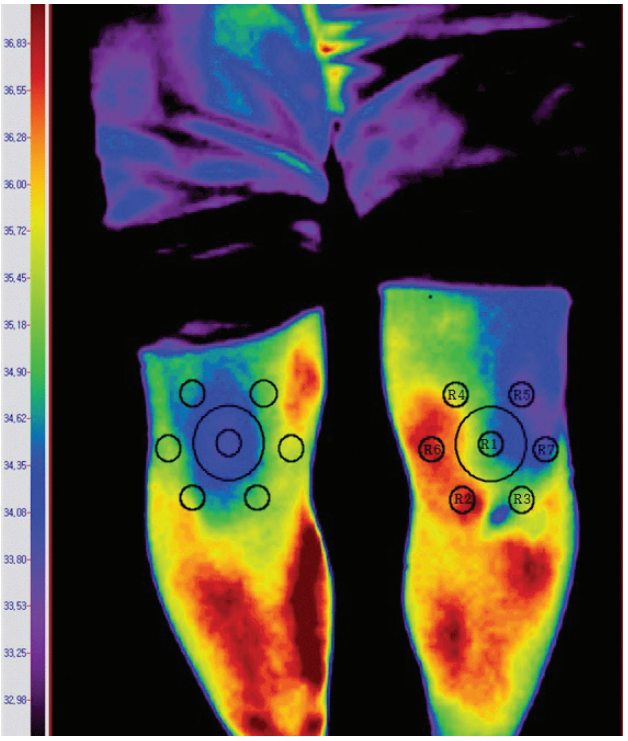

Figure 1 Thermal measurement in patient's with a medial collateral ligament injury of the knee. The thermographic image from the patient's knee was divided into 7 areas: the middle of the patella (R1), and the inferomedial region (R2; Naeseuran), the inferolateral region (R3; Dokbi), the superomedial region (R4; Seulsang2), the superolateral region (R5; Seulsang2), the medial region (R6; Naeseulbang), and the lateral region (R7; Oeseulbang) of patella. The temperatures of all regions were measured. The right knee of the patient shows a normal thermograph, but the left knee shows an abnormal one. Thermography on a normal knee joint shows that thermal symmetry exists over the knees, the knees are colder than the adjacent areas, and a narrow temperature isotherm produces a well-shaped oval central pre-patellar zone. The regions from R2 to R7 were equidistant from R1.

Table 1 Distribution of sex and age

Age	Female	Male	No	%
20 – 29	1	0	1	5
30 – 39	0	0	0	0
40 – 49	1	2	3	15
50 – 59	4	0	4	20
60 – 69	2	2	4	20
70 – 79	5	2	7	35
80 – 89	1	0	1	5
Total	14	6	20	100

Table 2 Temperature differences, means ± standard deviations, between the affected side and the unaffected side in patient's with medial a collateral ligament injury

Area	Affected Side	Unaffected Side	*P*-value
R1	34.59 ± 1.46	33.88 ± 1.29	0.005*
R2	35.29 ± 1.27	34.60 ± 1.18	0.011*
R3	34.69 ± 1.25	34.36 ± 1.16	0.055
R4	35.22 ± 1.29	34.78 ± 1.24	0.001*
R5	34.15 ± 1.13	33.78 ± 1.37	0.004*
R6	35.17 ± 1.27	34.53 ± 1.09	0.006*
R7	34.12 ± 1.11	33.72 ± 1.06	0.082

*P-value < 0.05 by using Wilcoxon signed rank test. R1, middle of the patella; R2, Naeseuran; R3, Dokbi; R4, Seulsang2; R5, Seulsang2; R6, Naeseulbang; R7, Oeseulbang.

confidence intervals. The SPSS software package (version 19.0; SPSS, Inc, an IBM Company, Chicago, Illinois) was used for the statistical analysis.

3. Results

The 20 patient's included in the current study were composed of 14 women (70%) and 6 men (30%), with a mean age of 62.15 ± 15.71 years (mean ± standard deviation (SD)) (Table 1). The temperature of the affected side, which included R1, R2, R4, R5 and R6, showed a significant increase compared to that of the unaffected side ($P < 0.05$). R3 and R7 showed no significant differences (Table 2).

4. Discussion

Knee joint injuries occur in many circumstances, such as trauma, traffic accidents, industrial disasters or accidents. The inside of the knee joint consists of three layers: Ⅰ, Ⅱ, Ⅲ). Layer Ⅰ is a superficial layer with the sartorius and its fascia. Layer Ⅱ is the MCL, and Layer Ⅲ is the articular capsule. Among these, the MCL is located from the medial side of the femoral medial epicondyle to the edge of the tibia, and it supports the medial side of the articular capsule; however, it is vulnerable to valgus stress and can be injured together with the cruciate ligament [10, 11]. When an acute injury of the MCL occurs, it is accompanied by swelling, rigidity, and pain on the medial or the lateral side. Because the medial collateral ligament is deeply involved in the stabilization of the knee joint, any disconnection of the MCL results in instability of the joint, unlike with the lateral collateral ligament [12]. Because recurrence and chronic pain are possible, precise assessment is needed when an injury occurs with hemarthrosis, severe exudation, or instability [13].

Assessment methods for a MCL injury are local tenderness, palpation of the tissue dent, the valgus stress test, magnetic resonance imaging (MRI), stress view X-rays, ultrasonography, etc. [5, 14]. Kim *et al* [15] suggested that ultrasonography was superior in safety and accuracy to MRI which only shows stationary images at high expense and was more effective than stress view X-rays which can damage the ligament with over force due to bias caused by the radiating angle and the loading position. However, ultrasonography requires a skilled tester, and without precise knowledge of the anatomical structure, diagnosing a disease by using ultrasonography is difficult.

DITI is an easy method that measures the temperature of the affected area and examines the degrees of hot and cold that occur with morbidity. Contrary to other diagnostic techniques, DITI makes it possible to objectify the state of the incipient disease by visualizing the temperature of the affected part. As a result, DITI has been used in various areas in the past [3-5, 16]. In Western medicine, DITI has been used to evaluate the physiological state of pain quantitatively by objectively visualizing the muscular condition and to check the progress of or the prognosis for a patient with a disease by identifying the acupoints of a body in Korean medicine [17].

Park *et al* [4] reported that a clinical application of thermography in Korean medicine was subject to two suppositions. One is the supposition of the exterior and interior, which states that some problems in the body cause problems at a neighboring or surrounding surface of the body. A problem in an organ can cause a problem on the surface of the body or the surrounding the organ, but cold or heat in the exterior and the interior could turn otherwise [3]. The other is the supposition of the meridian theory that stimulation of an organ in the body or of a specific region of the body causes a response of an acupoint according to meridian theory or a response of a distal region of a meridian passage. While the supposition of meridian theory is based on concrete Korean medicine theory, there is no reason that a change in skin temperature should occur in the same position as a meridian response.

As to diseases of the knee joint, studies have been done on the correlation of osteoarthritis to DITI. Seo *et al* [7] reported that thermographs of the medial and the lateral aspects of the knee, the patella region, and the region 5 cm above the patella did not correlate with the Lequesne Functional Severity Index (LFI), the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), the Korean Health Assessment Questionnaire (KHAQ), and the visual analog scale (VAS), but that the thermal difference be-

tween the affected and the unaffected sides of the medial aspect of the knee did correlate with that of the lateral aspect of the knee ($P < 0.001$), and the thermal difference of the anterior thigh did correlate with that of the medial and the lateral aspects of the knee and the patella ($P < 0.001$). However, Kim *et al* [8] reported that the thermal difference between both patellae did correlate with the VAS, the LFI, and the WOMAC ($P < 0.05$), but that the thermal differences between regions such as the anterior region of the thigh, the knee, the tibialis anterior, the posterior region of the thigh, the popliteal region, and the gastrocnemius, did not correlate with age, duration, body mass index (BMI), and gender. With increasing degree of cartilage destruction, the arterial pattern on the patella became more irregular with formation of anastomoses. Thus, thermographs for chondromalacia patella or osteoarthrosis show an asymmetric temperature change in the knee [18]. Furthermore, the surface temperature of the skin on the knee joint correlates with the severity of knee osteoarthritis [19], so Kim *et al* [9] found that the more severe the symptoms of degenerative arthritis are, the more the lowest temperature of the patella increases.

Hwang *et al* [20] reported that subjects of research on thermography were not various and that studies on thermography had been decreasing recently, even though DITI is useful for the diagnosis of a disease. In this study, DITI was used to identify whether a temperature change occurred when a patient injured his or her ligament and to determine the diagnosis applicability of DITI for a ligament injury by measuring the temperatures in seven regions of both knees, including R1 – R7 and by measuring the temperature difference between the affected and the unaffected sides in each region. Thermography on a normal knee joint shows that a thermal symmetry exists over the knees, that the knees are colder than adjacent areas with the patella as the center, and that a narrow temperature isotherm produces a well-shaped oval central pre-patellar zone [21]. The regions from R2 to R7 were equidistant from the center of the patella. R2 is 'Naeseuran' (LE201), R3 is 'Dokbi' (ST35), R4 and R5 are 'Seulsang 2' (LE108), and R6 and R7 are 'Naeoeseulbang' (LE110) in meridian theory. Anatomically, R2 and R3 are on the medial and the lateral sides of the patellar ligament and are areas of arthroscopic injection in Western medicine. R4 and R5 are the medial and the lateral sides of insertion of the rectus femoris tendon, and R6 and R7 are the medial and the lateral epicondyle of the femur. As a result, the temperatures of R1, R2, R4, R5 and R6 showed significant increases compared to that of the unaffected side ($P < 0.05$).

When the valgus stress is applied to the MCL, stimulation with tissue damage triggers inflammation, and the blood vessels are extended by chemical mediators such as prostaglandin, followed by increased extensions of arterioles and capillaries due to the congestion of blood flow. As a result, local heat and redness may occur.

In this study, higher superficial temperatures of R2, R4 and R6 of the affected knee adjacent to the MCL and articular capsule were observed. Furthermore, by comparison of the superficial temperatures, the extent of the injury could be visually assessed. Thus, DITI can be used as a supportive tool for the diagnosis of a MCL injury to the knee. In addition, the superficial temperatures of R1, R4 and R5 of the affected knee showed significant increases compared to that of the unaffected side ($P < 0.05$). Thus, we can infer that the heat had spread to a region above the patella, given the fact that the exudation due to inflammation or the hemarthrosis due to an external force caused the supra-patellar bursa to extend as a result of swelling [22].

The limitation of the study is that it was a retrospective study based on medical records, so the medical histories of the patient's were erratic. Also, thermal images were taken during the first medical examination, so images of the knee after the pain had been alleviated were missing. Thus, we were not able to assess the changes in the thermal images after the symptoms had been alleviated correlation; neither were we able to find a correlation between the DITI and the state of the patient. Consequently, a further study should be conducted with more materials and accurately-controlled clinical parameters.

5. Conclusion

We reviewed and analyzed the records of 20 patient's with a MCL injury of the knee who underwent DITI at the Korean Medicine Hospital of Sangji University between September 2012 and June 2014. The temperature on the affected side, which included the middle of the patella and the inferomedial region, the superomedial region, the superolateral region, and the medial region showed a significant increase compared to that on the unaffected side ($P < 0.05$). This result supports the thesis that DITI can be used as a supportive diagnosis instrument for a MCL injury of the knee because the temperature increase is actually due to the ligament injury.

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Conflict of interest

The authors declare that there are no conflict of interest.

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