

# Effects of Repetitive Shortwave Diathermy for Reducing Synovitis in Patients With Knee Osteoarthritis: An Ultrasonographic Study

**Background and Purpose.** Shortwave (SW) diathermy can be used to improve vascular circulation and reduce inflammation and pain for patients with osteoarthritis. However, reduction in synovial inflammation has never been explored. The purpose of this study was to investigate whether repetitive SW diathermy, using ultrasonographic examination, could reduce synovitis in patients with knee osteoarthritis. **Subjects and Methods.** Thirty subjects with 44 osteoarthritic knees participated in this study. Eleven subjects received SW, and 10 subjects received SW and nonsteroidal anti-inflammatory drugs. Nine subjects received no treatment and served as a control group. Synovial sac thickness superior, medial, and lateral to the patella was measured using ultrasonography. The sum of these 3 measurements was taken as the total synovial sac thickness. Subjects in the treatment groups underwent ultrasonographic examination before and after 10, 20, and 30 treatments, whereas control subjects underwent ultrasonographic examination before the experiment and then once every 2 or 3 weeks for a total of 3 follow-up measurements. **Results.** After 10 SW diathermy treatments, the total synovial sac thickness in both treatment groups was significantly less than the initial thickness, and the synovial sac continued to become significantly thinner with 20 sessions of treatment. These observations were not made in the control subjects. **Discussion and Conclusion.** The results indicate that SW diathermy in patients with knee osteoarthritis can significantly reduce both synovial thickness and knee pain. Such reductions of synovial sac thickness and pain index continue over treatment sessions. [Jan MH, Chai HM, Wang CL, et al. Effects of repetitive shortwave diathermy for reducing synovitis in patients with knee osteoarthritis: an ultrasonographic study. *Phys Ther.* 2006;86:236–244.]

**Key Words:** *Knee osteoarthritis, Shortwave diathermy, Synovitis, Ultrasonography.*

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It is widely known that shortwave (SW) diathermy can be used to reduce pain and swelling, accelerate the inflammatory process, and promote healing in tissues with chronic inflammation.<sup>1-3</sup> Application of SW diathermy to the involved tissues may increase vascular circulation and change tissue temperature, which directly results in vascular dilatation, an increase in pain threshold, and a decrease in pain and swelling.<sup>4,5</sup> Such vascular improvement also accelerates the inflammatory process by increasing nutrition and oxygen supply and by removing metabolic and waste products.<sup>1-4</sup>

Knee osteoarthritis is often associated with synovitis, an inflammatory process of the surrounding synovium. There exist sophisticated neurovascular networks within the 3 layers of synovial tissues that provide a high density of blood supply.<sup>6</sup> In a chronic osteoarthritic joint, fragments of cartilage break off and irritate the synovium, causing synovial inflammation and, with time, chronic inflammation.<sup>7</sup> In chronic synovitis, the synovial villi become thickened and excrete more synovial fluid, leading to an increase in synovial sac thickness.<sup>7,8</sup> Synovitis has been associated with the degree of knee pain<sup>9</sup> and the predicted progression of cartilage loss.<sup>10</sup> Therefore, synovial sac thickness (as a total of the thicknesses of synovium and synovial fluid) may be regarded as an index of assessing the extent of the synovitis.<sup>7,8</sup>

The goals of treatment of knee osteoarthritis are to relieve pain, to improve function, and to alleviate joint destruction by changing the inflammatory process. Shortwave diathermy is a nonpharmacologic management approach<sup>11,12</sup> that involves the application of deep

heat, and this treatment has been reported to have a measurable effect for patients with knee osteoarthritis.<sup>13-15</sup> The effects of SW diathermy in increasing tissue temperature and circulation and reducing pain in patients with degenerative osteoarthritis have been well documented.<sup>11-15</sup> However, few studies have investigated its effect on reducing synovial sac thickness or its ability to change the inflammatory process.

Ultrasonography is an inexpensive, simple-to-use, and noninvasive imaging technique that has advanced substantially over the past decade. It allows direct visualization of the structures of the soft tissues and joint compartments as well as repeated measurements without the risk of exposure to ionizing radiation. Its use as a quantitative method to measure synovitis of the knee has been validated against arthroscopic findings for osteoarthritis or rheumatoid arthritis<sup>16-18</sup> or magnetic resonance imaging.<sup>19</sup> These studies revealed that ultrasonography had high intrarater and interrater reliability for detecting synovitis in the knee joint. The purposes of this study were to investigate whether repetitive SW diathermy could reduce synovitis in patients with knee osteoarthritis and to examine the relationship between synovial sac thickness and pain index. The specific objectives were to examine the changes in synovial sac thickness using ultrasonography, to assess knee pain using a visual analog scale after repetitive SW diathermy therapy, to compare the differences of synovial thickness between the treatment and control groups, and to compare the differences in such changes with different treatment sessions.

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Mrs Jan and Mrs Tsai provided concept/idea/research design. Mrs Jan, Dr Chai, and Mrs Tsai provided writing. Mrs. Tsai provided data collection, and Dr Chai, Dr Lin, and Mrs Tsai provided data analysis. Mrs Jan and Dr Wang provided project management and facilities/equipment. Dr Lin provided subjects. Mrs Jan provided institutional liaisons. Dr Chai provided consultation (including review of manuscript before submission).

The protocol was approved by the Ethics Committee of National Taiwan University Hospital.

The results of this study were presented orally at the Annual Research Conference of the Physical Therapy Association of the Republic of China; September 15, 2003; Taipei, Taiwan.

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**Table.**  
Baseline Characteristics of All Participants<sup>a</sup>

	<b>SW Group (n=11, 14 Knees)</b>	<b>SW+NSAIDs Group (n=10, 14 Knees)</b>	<b>Control Group (n=9, 16 Knees)</b>
Age (y) ( $\bar{X}\pm SD$ )	62.7 $\pm$ 10.5	68.4 $\pm$ 9.2	66.0 $\pm$ 6.2
Sex ratio (M:F)	2:9	2:8	2:7
Height (cm) ( $\bar{X}\pm SD$ )	158.9 $\pm$ 4.9	155.6 $\pm$ 6.6	157.6 $\pm$ 8.9
Weight (kg) ( $\bar{X}\pm SD$ )	59.0 $\pm$ 10.1	65.4 $\pm$ 11.6	60.6 $\pm$ 13.0
Duration of knee osteoarthritis (y) ( $\bar{X}\pm SD$ )	4.8 $\pm$ 3.3	3.3 $\pm$ 3.3	3.7 $\pm$ 2.3
Initial TSST (cm) ( $\bar{X}\pm SD$ )	1.66 $\pm$ 0.55	2.11 $\pm$ 0.75	1.94 $\pm$ 0.65
Radiographic grade			
I	3	0	4
II	6	11	11
III	5	3	1
Initial pain index ( $\bar{X}\pm SD$ )	6.0 $\pm$ 1.9	7.4 $\pm$ 2.1	2.9 $\pm$ 1.1

<sup>a</sup> SW=shortwave diathermy, NSAIDs=nonsteroidal anti-inflammatory drugs, M=male, F=female, TSST=total synovial sac thickness.

## Method

### Subjects

All subjects were referred to the study from the outpatient department by orthopedic surgeons. Subjects had a degenerative osteoarthritic knee of grade 3 or less based on radiographic diagnosis in the Kellgren and Lawrence grading of osteoarthritis,<sup>20</sup> had no limitation of range of motion except for minimum tightness in the knee joint, did not engage in any high joint-loading exercises<sup>21,22</sup> such as hiking or tennis playing, and had not undergone any specific treatments 3 months before entering the study. Participants were excluded from the study after on-site evaluation if they presented other musculoskeletal problems associated with the knee joint, such as fracture, tendon or ligament tears, or meniscus injury; musculoskeletal problems associated with the hip or ankle/foot joints; or central or peripheral neuropathy.

Initially, 63 patients fulfilled the above criteria from January 2002 to January 2003. However, 15 patients were unwilling to participate in this study, and 12 patients were unable to be present for SW therapy regularly; therefore, a total of 36 patients participated in this study. All participants signed consent forms before the experiment.

After being instructed in the study protocol, the participants were divided into 3 study groups, as determined by the participants' own decision rather than random assignment. Fourteen participants received SW diathermy, 13 participants received SW diathermy and nonsteroidal anti-inflammatory drugs (NSAIDs), and 9 participants who did not receive any treatment but were willing to be present for follow-up served as a control group. Participants in the SW and control groups did not

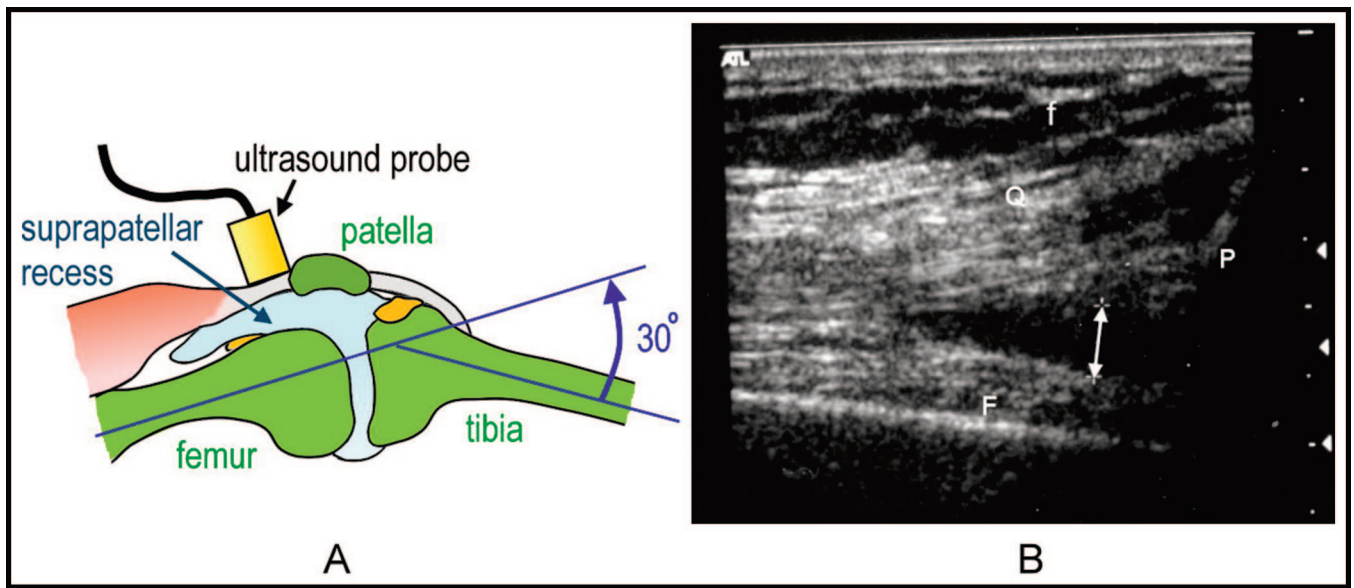
receive any medicine or treatment during the experiment period, but those in the SW+NSAIDs group, were allowed NSAIDs during the experiment period as needed. At the end of the experiment, 3 participants from each of the 2 treatment groups were unable to attend the last follow-up examination due to personal reasons not related to knee pain. Therefore, there were 30 participants for whom complete data were available, 14 of whom had bilateral osteoarthritis of the knee. Thus, a total of 44 knee joints of 30 subjects (6 men and 24 women) with knee osteoarthritis were investigated in this study. Baseline subject characteristics are listed in the Table.

### Assessments

**Ultrasonographic imaging examination.** Ultrasonography was performed on the osteoarthritic knees at the initial and 3 follow-up sessions using the HDI 5000 ultrasound system.\* A 12-5 MHz broadband linear-array transducer (L12-5 38 mm) was used, and all parameters were set at ranges suitable for assessment of the knee joint.<sup>23</sup>

The measurement technique used to assess synovial sac thickness of knee joints was similar to the method described by van Holsbeeck et al,<sup>24</sup> except that no pressure was added on the examined area during the testing process. Van Holsbeeck et al applied some pressure on the examined area in order to expel the joint fluid apart from the synovial sac. However, in our experience, the pressure the examiner applies may not be the same for each measurement or for each patient, which may influence in the accuracy of the measure-

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**Figure 1.** (A) Longitudinal view of the suprapatellar recess. The probe is positioned above the patella with the patient in a supine position and the knee in 30 degrees of flexion. (B) Sonographic view of knee joint synovitis in a patient with osteoarthritis of the knee. We measured the largest anteroposterior diameter of the suprapatellar recess between the arrows. No compression was allowed in this picture. P=patella, f=fatty tissue, Q=quadriceps tendon, F=femoral cortex.

ment. Therefore, we measured the synovial sac thickness without allowing any contact between the ultrasonic probe and the skin (ie, the measurement of synovial sac thickness included the thickness of both synovium and synovial fluid).

Participants were in a relaxed supine position during the whole measurement process. The tested leg was stabilized on a tripod with the knee joint at 30 degrees of flexion, which was confirmed with a universal goniometer (Fig. 1A). In such a position, overstretching of the synovial sac was avoided, and the patella did not overlie the suprapatellar recess and thus did not affect the measurement. Markers were made on bony prominences around the patella. The investigator (LYT) placed the water-soluble acoustic gel onto the examined area, and then gently placed the ultrasonic probe onto the gel without making contact with the patient's skin. The position of the ultrasonic probe varied with assessment sites. When the suprapatellar recess was examined, the ultrasonic probe was placed to get a longitudinal view. It was placed centrally and superiorly to the patella, with the tail end near the proximal top of the patella. When either the medial or lateral parapatellar recess was examined, the ultrasonic probe was placed with the tail end lying in the middle trisection of the patella in order to have a longitudinal view. Throughout the examination process, the ultrasonic probe remained perpendicular to the skin surface, and the thickest part of the synovium on the image was taken (Fig. 1B). These images then were saved immediately on the hard disk of a desktop computer.

**Pain index assessment.** A visual analog scale was used for the assessment of knee pain.<sup>25</sup> It is an ordinal scale, using a 10-cm line divided into 10 equal sections, with 0 representing "no pain" and 10 representing "unbearable pain." Each participant was asked to indicate on the scale the level of pain in his or her knee joint before and after treatment.

#### Intervention Protocol

The intervention protocol for 2 treatment groups consisted of 30 sessions of 20-minute induction-coil SW diathermy therapy.<sup>26</sup> The participants were positioned supine and comfortably on the treatment plinth with the affected knee extended. A towel was wrapped around the knee joint, and then the induction coil cable was applied circularly along the affected leg. All participants received treatments from the same SW diathermy machine.<sup>†</sup> The intensity of the current was set based on each participant's sensation of warmth (a mild but pleasant sensation of heat).<sup>27,28</sup> Each treatment session lasted for 20 minutes. In cases where bilateral knees were involved, SW diathermy was applied to each knee separately and the total treatment time for both knees was extended to 40 minutes.

#### Experimental Procedure

Before the experiment, the ultrasonographic images of all 30 participants (44 osteoarthritic knees) were examined for synovial sac thickness, and a pain index assess-

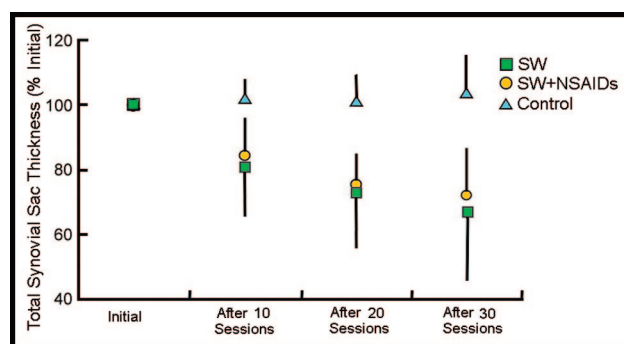
<sup>†</sup> Enraf, Curapuls 419, the Netherlands.

ment also was undertaken. After this initial examination, 21 participants (28 osteoarthritic knees) in the 2 treatment groups received SW diathermy 3 to 5 times a week for a total of 30 treatment sessions within 8 weeks. Follow-up evaluations were performed on the day after the 10th, 20th, and 30th treatment sessions. For the control group, the same series of evaluations were performed every 2 to 3 weeks after the initial evaluation.

### Data Analysis

Although synovial sac thickness was measured at 3 different areas around the patella, the total synovial sac thickness was calculated as the sum of the thickness of the synovial sac located superiorly, medially, and laterally to the patella. For each outcome variable, including both total synovial sac thickness and pain index, each patient underwent measurements before the experiment and the day after the 10th, 20th, and 30th treatments, respectively. To control individual variance at the time of initial status assessment, the total synovial sac thickness for each measurement was normalized by that of the initial status and expressed as the percentage of the initial status (% initial). In addition, the difference in pain index for each measurement from the initial status was calculated and used for comparison of improvement in knee pain.

SPSS 10.0 statistical software<sup>†</sup> was used for all statistical analyses. One-way analysis-of-variance (ANOVA) tests were performed for participants' age, sex, height, weight, duration of knee osteoarthritis, initial total sac thickness, and pain index to examine the differences among the 3 study groups. A 3 (group) × 4 (measurement) ANOVA for repeated measures was used to analyze the main effect of different study groups and measurements as well as their interactions in total synovial sac thickness. A *P* value of .05 or below was considered significant for all statistical analyses. If the interaction effect of study group and measurement was significant, an ANOVA for repeated measures was performed separately for each study group, and multiple comparisons using a Bonferroni adjustment were applied to examine the differences between measurements (*P* < .0083). If any statistical significance was noted in the main effect of study group, Bonferroni *post hoc* multiple comparisons were performed to compare the differences in the changes of those outcome variables among the 3 study groups (*P* < .017). The Friedman test was used to test for pretreatment-posttreatment differences in pain scale ratings for all 3 groups. The Kruskal-Wallis rank test was used to compare the pain scale difference between the initial (baseline) and follow-up assessments to determine whether any significance existed. In addition, the relationship between the total



**Figure 2.**

Changes in total synovial sac thickness (% initial) at different sessions of treatment. The error bars represent standard deviations for each group. SW=shortwave diathermy, NSAIDs=nonsteroidal anti-inflammatory drugs.

synovial sac thickness and pain index was examined by Spearman correlation coefficient.

### Results

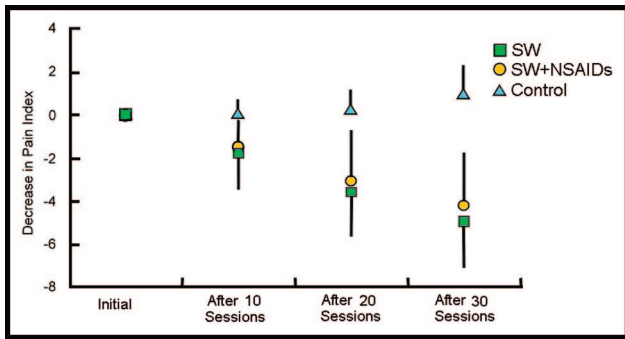
Thirty patients (44 osteoarthritic knees) completed the entire series of experiments. Basic information regarding the 3 study groups is presented in the Table. There were no significant differences in age, sex, body height, and body weight among 3 study groups (*P* > .05). The initial total synovial sac thickness and duration of knee osteoarthritis in the 3 study groups also were not statistically different (*P* > .05), indicating that the initial synovium status of all participants in this study was homogeneous before the experiment. The pain index, however, was lower in the control group than in both treatment groups ( $F_{1,28}=73.01$  and  $F_{1,28}=54.33$ , respectively; both *P* < .0005).

#### Changes in Total Synovial Sac Thickness

Changes in total synovial sac thickness for the 3 study groups for the 4 measurements are presented in Figure 2. After 10 sessions of SW diathermy, the synovial sac thickness in both treatment groups decreased to approximately 81% to 84% of the initial thickness; after 30 treatment sessions, it was approximately 67% to 72% of the initial thickness. The synovial sac thickness in the control group, however, did not change during the follow-up period.

The 3 × 4 ANOVA for repeated measures revealed a significant interaction effect of study group and treatment session ( $F_{6,123}=14.55$ , *P* < .0001). Therefore, reduction in total synovial sac thickness in different treatment sessions was observed among the 3 study groups, which supports the stated hypotheses. Furthermore, analysis of the data revealed that both treatment groups showed a significant decrease in total synovial sac thickness with more sessions of SW diathermy compared with the control group ( $F_{1,28}=36.12$  and  $F_{1,28}=54.16$ , respectively; both *P* < .0001). Such a difference, however, did

<sup>†</sup> SPSS Inc, 233 S Wacker Dr, Chicago, IL 60606.



**Figure 3.** Changes in pain index at different stages after shortwave treatment. The error bars represent standard deviations for each group. SW=shortwave diathermy, NSAIDs=nonsteroidal anti-inflammatory drugs.

not appear between the treatment groups ( $F_{1,26}=.031$ ,  $P>.05$ , power=.059), suggesting that SW diathermy decreases synovial sac thickness regardless of whether NSAIDs are used.

Further analysis of the data showed that the decrease in synovial sac thickness in both treatment groups was significantly greater after 10 sessions of SW diathermy ( $F_{1,13}=21.24$  and  $F_{1,13}=24.97$ , respectively; both  $P<.0005$ ). Such changes continued to take place after 20 and 30 treatment sessions (all  $P<.0001$ ). Although total synovial sac thickness for both treatment groups continued to decrease till the end of 30 treatment sessions, the difference in total synovium sac thickness between 20 and 30 treatment sessions was not statistically significant ( $P>.0083$ ).

#### Decrease in Pain Index

Decreases in pain index for 3 study groups for the 4 measurements are presented in Figure 3. After 10 sessions of SW diathermy, the pain index in the SW group and the SW+NSAIDs group decreased approximately  $1.8 \pm 1.7$  and  $1.5 \pm 1.3$ , respectively. The pain index continued to decrease after 20 or 30 sessions of treatment. At the end of 30 sessions of SW diathermy, the decrease in pain index was approximately  $5.0 \pm 2.0$  and  $4.1 \pm 2.4$  from the initial status, respectively. The pain index in the control group remained the same for each follow-up session.

Similarly, the Friedman test revealed a significant interaction effect of study group and treatment session on pain index ( $P<.0005$ ). This finding indicates that reduction in pain index with different sessions of SW diathermy differed among the 3 study groups. Both treatment groups showed greater reduction in pain index than the control group ( $P<.005$ ), but there was no significant difference in pain reduction between the treatment groups at each follow-up examination ( $P>.05$ ). The pain index in both treatment groups was decreased significantly after 10, 20, and 30 treatment sessions (all  $P<.005$ ). Pain improved significantly

between each 2 examinations ( $P<.0083$ ), except between the 10th and 20th treatment session follow-ups and the 20th and 30th treatment session follow-ups. However, participants in the control group did not experience any changes in their pain index (all  $P>.0083$ ).

#### Correlation Between Total Synovial Sac Thickness and Pain Index

A total of 176 measurements were carried out on 44 osteoarthritic knees to examine the probable correlation between the total synovial sac thickness and the pain index. A small but significant correlation was found between these 2 variables (Spearman  $\rho=.174$ ,  $P<.05$ ). The Spearman correlation test also was performed to analyze the relationship between the total decreased pain index and the total decreased synovial sac thickness from the baseline measurements. We found that the greater the reduction in synovial sac thickness, the greater the decrease in pain index (Spearman  $\rho=.600$ ,  $P<.0001$ ).

#### Discussion

This is the first controlled study to examine ultrasonographically detected changes in the synovial sac thickness in people with knee osteoarthritis after repetitive SW diathermy. Although SW diathermy has been documented to improve vascular circulation, changes in the synovial sac thickness—a sign indicating reduced synovitis—in response to this thermal effect have not been investigated. The results of this study suggest that a decrease in synovial sac thickness and knee pain is induced with use of a series of SW diathermy treatments in patients with knee osteoarthritis. Such treatment effects created by different treatment sessions also were found in this study. The results demonstrated that, with more treatment sessions, there was a further reduction in synovial sac thickness and knee pain.

#### Shortwave Diathermy Promoting Synovial Inflammatory Process

Compared with the control group, synovial sac thickness was reduced in both treatment groups after more than 10 sessions of SW diathermy. The results of this study demonstrated that SW diathermy therapy successfully decreases synovial sac thickness and suggest that SW diathermy can control synovial inflammation. The possible physiological mechanisms underlying such significant changes may be associated with improvement in circulation of vascular network in synovial membrane.<sup>29</sup> It has been found that synovial vascular density is lower in patients with chronic synovitis, adversely affecting the flow of blood and lymph fluid.<sup>29–32</sup> It also has been documented that SW diathermy may result in vascular dilation and increased blood flow.<sup>3,11,14</sup> Consequently, through the application of SW diathermy, the inflamma-

tory response in the synovium of the knee joint is reduced and both synovial thickness and pain are decreased.

In this study, participants in the SW+NSAIDs group did not show better results than those in the SW group. Whether this finding was due to the participants' non-adherence to medication use or to other causes was not possible to assess in this study. No attempt was made to follow up on their medication adherence, for either dosage or frequency that the medication was used. Further research is needed to determine the reasons for the lack of a difference between the treatment groups, but patients' agreement to use medicine should be considered.

In the present study, total synovial sac thickness, including the thickness of both synovium and synovial fluid, was examined instead of synovium thickness only, which is different from the van Holsbeeck et al method.<sup>24</sup> Karim et al<sup>18</sup> observed that increased synovial fluid could be detected using ultrasonography in patients with osteoarthritis and confirmed by arthroscopic findings with increased vigilance for synovitis. It is reasonable not to neglect the effect of thickness of synovial fluid for synovitis.

#### *More Treatment Sessions Resulting in Better Improvement*

This study demonstrated a decrease in synovitis with increased treatment sessions in patients with knee osteoarthritis. As treatments were repeated, the synovial sac became thinner and the amount of pain experienced by patients became lower, although the synovial thickness did not significantly change between 20 and 30 treatments. We do not think that the effect of treatment plateaued. However, we believe that the small sample size influenced the statistical results. The positive finding of SW diathermy is consistent with the results of previous studies that examined the therapeutic effects of SW diathermy.<sup>11,13,15</sup> This improvement in symptoms may be due to increased circulation around the knee joint and reduced retention of synovial fluid, which became more evident after a series of SW diathermy treatments. The results of this study represent direct evidence of the effect of SW diathermy on synovial sac thickness.

It is not surprising that single-session SW diathermy is not able to reduce synovitis in people with knee osteoarthritis immediately. In a preliminary study, we assessed the synovial sac thickness of 3 patients with knee osteoarthritis immediately, 30 minutes, and 60 minutes after single-session SW diathermy. The results showed that the synovial sac thickness around the patella remained unchanged in all 3 patients, indicating that single-session SW diathermy has no immediate effect on synovial sac thickness. In contrast, Jan and coworkers found increased cutaneous tissue temperature measured by infrared thermography<sup>33</sup> and increased blood flow using Doppler ultra-

sonic imaging<sup>14</sup> after a single session of SW diathermy. Therefore, the mechanism of therapeutic effect between single- and multi-session SW diathermy may be different. We hypothesized that the immediate effect of SW diathermy in patients with knee osteoarthritis may arise from improved circulation after treatment, whereas the long-term effect may be associated with the reduction in synovial inflammation. Thus, a single SW diathermy session cannot detect an immediate change in synovial sac thickness. Further study is needed to determine whether a reduction in synovial thickness might be noted after a longer period has elapsed after a single session of treatment.

Following 30 sessions of SW diathermy, although the reduction of the synovial sac thickness was significant, some participants still experienced some knee pain. We hypothesized that SW diathermy can reduce the synovial sac thickness, but that it might be not relieve patients' pain completely.

#### *Ultrasonography Is a Useful Tool to Detect Changes in Synovial Sac Thickness*

The results of this study show that ultrasonography is a useful tool to quantitatively detect changes in synovial thickness in the knee joint following SW diathermy therapy. The validity and reliability of data obtained with the ultrasonographic imaging technique in determining the synovial sac thickness in patients with inflammation of the knee joint has been established in previous studies. In the studies by Karim et al<sup>18</sup> and van Holsbeeck et al,<sup>24</sup> ultrasonographic imaging techniques were shown to yield valid and reliable data as well as more accurate data than clinical examination only, although only examination of thickness of the synovium, rather than the whole synovial sac, was performed. Tsai et al,<sup>34</sup> using the same measurement protocol used in our study, also demonstrated high interrater and intrarater reliability of measurements of synovial sac thickness obtained with ultrasonography in patients with knee osteoarthritis. In the present study, a series of examinations was applied to the same patient in order to evaluate the effect of the SW diathermy and successfully demonstrated the changes in synovial sac thickness. It may be concluded that ultrasonographic imaging is a valuable tool in the evaluation of the severity and progression of synovitis.

In addition, the measured suprapatellar synovial sac thickness in patients with degenerative osteoarthritis in this study was  $5.3 \pm 1.6$  mm ( $\bar{X} \pm SD$ ), which is slightly less than that measured by Rubaltelli and colleagues<sup>17</sup> in patients with rheumatoid arthritis ( $6.9 \pm 1.9$  mm). This finding was consistent with the results of a histological study<sup>35</sup>; that is, thickening of the synovial sac is less pronounced in degenerative osteoarthritis than in rheumatoid arthritis. These findings are consistent with clinical presentation of synovitis and further validate the use

of ultrasonographic imaging in the measurement of synovial sac thickness.

### Limitations of the Study

There are some limitations of this study including the lack of random assignment of participants to study groups, no monitoring of pain medication usage, and the fact that the control group had significantly less pain than those in the treatment groups. Perhaps the major concern of the first limitation is that the assignment of participants to study groups was dependent on the patients' own decision rather than being randomly assigned. In addition, patients with severe knee pain would hardly choose to get into the control group, which received no SW diathermy. We agree that the motivation of patients to receive SW diathermy treatment might have been a confounding factor in this study. This factor warrants more attention in future research.

This study highlights the need to explore the relationship between ultrasonographic image and histological finding of synovitis. Future studies are needed to examine the cost-effectiveness of using ultrasonography for assessing the disease progress compared with other assessment techniques, such as magnetic resonance imaging, and the treatment effect of SW therapy combined with other interventions on control of synovitis.

### Conclusion

This study attempted to quantify the thickness of synovial sac and pain index before and after application of SW diathermy for patients with knee osteoarthritis. The results of this study showed that the application of SW diathermy in patients with knee osteoarthritis can significantly reduce both synovial thickness and knee pain. Such reductions of synovial sac thickness and pain index continue with increases in treatment sessions. However, participants in the control group did not demonstrate any changes in synovial thickness or pain index.

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