Introduction

Ruptures of traumatic finger tendons are common musculoskeletal soft tissue injuries that often occur in male adults [1]. Surgery is the primary choice for treatment of finger tendon rupture, but postoperative complications, such as peritendinous adhesions, continue to occur even in patients treated by experienced surgeons and therapists [2]. In most cases, diagnosis of finger tendon rupture or injuries can be made by history of trauma and clinical examination, but three-dimensional computed tomographic imaging can be useful when the diagnosis of flexor tendon rupture cannot be made by clinical examination [3, 4]. There has been limited information about the value of ultrasonography in the diagnosis of hand or finger tendon injuries. Ultrasound examination of other tendon injuries, such as distal biceps tendon rupture, provided additional diagnostic information to clinical findings [5]. With peroneal tendon tears, the diagnostic sensitivity and specificity of ultrasonography were more than 90% [6]. In a retrospective analysis of a variety of surgical conditions involving hands and wrists, ultrasonography was shown to be reliable in evaluating tendon ruptures [7]. However, in the presence of inflammation, sonographic diagnostic accuracy in tendon ruptures of hands was reduced in comparison with clinical examination [8]. In the present study, we sought to assess the value of high-frequency ultrasonography in the diagnosis and in guiding surgical repair of zone 2 flexor tendon injuries.
Subjects and Methods

Patient Selection
This study was approved by our Institutional Review Board. Written informed consent was obtained from all participants before the study. Between January and December 2009, patients who were admitted to the Department of Surgery for finger tendon injuries were approached to participate in this study. The main selection criteria were: ≥ 18 years old, and zone 2 flexor tendon injuries in one or more fingers following hand trauma that required surgical repair. Patients with concomitant hand or finger fractures, vascular injuries requiring arterial repair, or a crush injury with soft tissue loss were excluded. A total of 92 patients (185 digits) were recruited (49 males and 43 females, mean age 32.6 ± 11.2 years, range 18–69). All injuries were clean and primary injuries due to work accidents or self-inflicted. They were randomly divided into study (n = 46, 95 digits) and control groups (n = 46, 90 digits) by random drawing of numbers from a container.

Study Protocols and Surgical Techniques
In the study group, preoperative ultrasound was performed, and surgical repair of the ruptured tendons was performed under general anesthesia. The surgical incision on the injured fingers was based on the location of the tendon stumps identified by ultrasound scans. In the control group, diagnosis of tendon rupture was based on history of trauma and clinical examination. Surgical incision on the injured fingers was based on the results of clinical examination. All patients had surgery within 48 h after the injury occurred. Two surgeons (D.S. and X.M.) who had more than 10 years’ hand surgery experience used a standardized technique, in which two core sutures (four strands) of 3–0 polyester material, and a running epitendinous suture were used to repair flexor digitorum superficialis and flexor digitorum profundus tendons [9]. No repair of the tendon sheath was performed in order to minimize the risk of adhesion formation. The two slips of the flexor digitorum superficialis tendon were repaired using of simple su-

Ultrasound and Tendon Rupture

Ultrasound Examination
In the study group preoperative ultrasound examination (LOGIQ 9, GE Healthcare, probe frequency 10 MHz) was conducted by an experienced ultrasonographer (Z.G.) with more than 10 years’ experience of hand tendon examination. The ultrasonographer was not blinded to patient groupings because this was an open study. However, she was not informed of the clinical and surgical findings. The time interval between the injuries to preoperative ultrasound examination was 6.5 ± 2.2 h (1–18 h). In a sitting or supine position, the affected hand and fingers were fully exposed, and the probe was moved longitudinally and transversely along the affected tendon to perform multisectional scans. During the scan, patients were instructed to flex and extend the affected fingers to assess tendon and muscle movements. The unaffected hand and fingers were also examined in the same fashion as the affected fingers for comparison.

Tendon ruptures were classified into complete and partial ruptures. A partial rupture was defined as a tendon with a partial loss (≥ 50%) of the fibrillar pattern, or with one or more areas of discontinuous echogenicity at the site of the injury (fig. 1). These patients also had some difficulties in finger gliding as a result of the rupture. Complete rupture was defined as a complete loss of the fibrillar pattern, and the gap between the two ends of the tendon could be filled with fluid. With complete rupture, the distance between the two ends or stumps of the ruptured tendons was measured.

Statistical Analysis
SPSS v13.0 was used for the statistical analysis. Quantitative variables are expressed as mean ± SD. Comparison of numerical data between groups was performed by Student’s t test; χ² test was used for comparison of categorical data between the two groups; p value <0.05 was considered statistically significant.

Results

General Findings
There was no statistically significant difference in the mean age (32.2 ± 9.6 vs. 32.7 ± 12.2 years, p = 0.461) or gender (male, 52.2 vs. 56.5%, p = 0.642) between the study group (52.2%) and the control group (56.5%). In all digits, ruptures involved both flexor digitorum superficialis and flexor digitorum profundus tendons. Single digit injury in the study and control groups was found in 5/46 (10.9%) and 4/46 (8.7%), respectively (p = 0.726). The mean distance between the proximal and distal ends of the complete ruptures was 9.2 ± 3.6 mm. Seven patients (10 dig-
its) in the study group (15.2%) and 6 patients (8 digits) in the control group (13.0%) had concomitant digital nerve injuries (p = 0.765). All patients underwent successful repair of the ruptured tendons, with no major perioperative complications such as infection or bleeding. All patients participated in postoperative rehabilitation programs at our clinics and completed follow-up studies.

**Concordance Rate between Clinical/Ultrasound Diagnosis and Surgical Findings**

The types of ruptures confirmed by surgical findings are listed in table 1. There was no statistically significant difference in complete ruptures between the study and the control groups, but the proportion of partial ruptures in the control group was slightly higher than in the study group (p = 0.04).

In the study group, the location of tendon ruptures, the distance between two ruptured ends and the type of rupture (complete or partial) identified by ultrasound examination were identical to surgical findings in all patients (table 1). In the control group, there was no statistically significant difference in the rate of complete or partial rupture between clinical and surgical diagnosis (p > 0.05, table 1). However, the concordance rate in the types of rupture and the distance between two ruptured ends in the control group was lower than in the study group (p = 0.02).

Among the 31 patients in the control group where clinical diagnosis did not match surgical findings, 11 (35.5%) surgically diagnosed partial ruptures were misdiagnosed as complete ruptures by preoperative clinical examination, and 7 (22.6%) surgically diagnosed complete ruptures were misdiagnosed as partial ruptures by clinical examination. In the remaining 13 patients, the location of the distal end of the ruptured tendon diagnosed preoperatively by clinical examination did not match surgical findings.

**Discussion**

In the present study, the study and the control groups were comparable in terms of concomitant nerve injuries and number of digits affected. The rate of scar connections in the study group was lower than in the control group. The reason for the lower scar connection rate in the study group is unclear. Whether it was due to reduced postoperative peritendinous adhesion as a result of ultrasound-guided tendon repair requires further investigation.

### Table 1. Comparison of diagnostic accuracy between study and control groups

<table>
<thead>
<tr>
<th></th>
<th>Study (n = 95 digits)</th>
<th>Control (n = 90 digits)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultrasound/clinical exam</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complete rupture</td>
<td>79 (83.2%)</td>
<td>67 (74.4%)</td>
<td>0.31</td>
</tr>
<tr>
<td>Partial rupture</td>
<td>16 (16.8%)</td>
<td>23 (25.6%)</td>
<td>0.12</td>
</tr>
<tr>
<td>Surgical verification</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complete rupture</td>
<td>79 (83.2%)</td>
<td>63 (70%)</td>
<td>0.22</td>
</tr>
<tr>
<td>Partial rupture</td>
<td>16 (16.8%)</td>
<td>27 (30%)</td>
<td>0.04</td>
</tr>
<tr>
<td>Concordance*</td>
<td>100 (100%)</td>
<td>31 (34.4%)</td>
<td>0.001</td>
</tr>
</tbody>
</table>

* Concordance between preoperative and surgical findings in terms of types of ruptures and distance between ruptured ends.

Prior to our study, ultrasonography has not been widely used to diagnose tendon ruptures in hands. The use of ultrasound technology in the diagnosis of tendon ruptures has been limited to large tendons, such as biceps, quadriceps or Achilles tendon, where ultrasound imaging is believed to provide additional information to clinical examination, or for confirmation of clinical diagnosis [5, 10–12]. In the diagnosis of clinically suspected Achilles tendon rupture, the nature of the rupture (complete or partial) and the size of the rupture measured before surgery by ultrasound have shown a high correlation with those directly measured during surgery [11]. The application of high frequency ultrasonography in the evaluation of ruptured finger tendons has not been previously reported. The reasons for underuse of ultrasound technology in the investigation of hand tendon ruptures are not clear, but diagnostic difficulties of ultrasonography in the presence of inflammation or infection [8], and the perceived accuracy of clinical diagnosis based on trauma history and physical examination of the injured tendons may be the main reasons. In an earlier case report on 3 patients with ruptured flexor digitorum profundus tendons, ultrasound was found to be accurate in diagnosing the rupture and in localizing the ruptured ends [12]. Ultrasound was also found accurate in diagnosing the integrity of flexor tendons in 3 patients who underwent surgery for tenolysis, scar release, or arthrodesis [12]. In a more recent study in a cadaver model of flexor hand tendon ruptures, surgeon-performed ultrasound correctly diagnosed 78 of 81 (92.6%) injured tendons [13]. Correct localization of the proximal tendon stump was made in 39 of 50 (78%) lacerated tendons [13]. This study also found that small finger injuries were most difficult to as-
In the present study on 46 patients and 95 digits, we found that the location of the tendon rupture, the distance between two ruptured ends and the type of rupture (complete or partial) identified by preoperative ultrasound examination were identical to surgical findings in all patients. We also found that the concordance rate between the clinical and surgical diagnosis on the types of the rupture and the distance between two ruptured ends was lower than in ultrasound-based diagnosis. These results suggest that ultrasound scans are more accurate than clinical examination in confirming the nature of a flexor tendon rupture, and in identifying the ruptured tendon stumps.

The use of ultrasound technology in the management of tendon ruptures has mainly been in the area of assessing postoperative tendon integrity [15]. However, real-time intraoperative ultrasound examination has been used to accurately position the foot and to help with the surgical repair of ruptured Achilles tendons [16]. High frequency ultrasonography may be valuable in guiding surgical repair of ruptured hand tendons. In our control group patients who had no preoperative ultrasonographic confirmation of the precise location of the ruptured tendon stumps, a surgical incision was made on the site where tendon rupture was clinically suspected. However, due to the retraction of some ruptured tendons, the distal stump of the ruptured tendon was not always underneath the skin incision. As a result, attempts were often made to extend the skin incisions to find the distal stump of the tendon, resulting in more skin and subcutaneous tissue damage, which may have subsequently increased the risk of postoperative adhesion. These problems can be largely avoided by the use of preoperative ultrasonography, as shown in the patients of the study group, as the distal stump of a ruptured tendon can be located in almost all cases.

A potential limitation of this study is that ultrasound examination was performed with a linear 10.2 MHz probe. Whether a higher frequency probe, such as 12–18 MHz, would yield better diagnostic and evaluation precision is yet to be investigated.

**Conclusion**

This study showed that high frequency ultrasound can be used to provide additional information for diagnosing finger tendon ruptures. The location and types of ruptures were accurately identified by preoperative ultrasound examination. Ultrasound-guided surgical repair of ruptured tendons may be associated with a reduced rate of postoperative peritendinous adhesion.

**References**