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Muscle strength in rheumatoid elbow: quantitative measurement and comparison to Larsen's X-ray grade

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Abstract

Accurate assessment of elbow function is important to determine the total ability of the arm. The purpose of this study was to clarify the relationship between isometric muscle strength of the elbows of patients with rheumatoid arthritis (RA) and Larsen's X-ray evaluation. Fifty-six elbows of 45 RA patients aged 47 to 77 years (mean age, 63 years) were tested. Muscle strength was measured with an isometric torque-cell dynamometer. Test-retest reliability of the dynamometer was proven by measuring 12 elbows of 6 healthy young men. In RA patients, elbow flexion and extension strength decreased in proportion to increases in the severity of Larsen's grades from Grade 1 to 4. However, Grade 5 elbows had greater muscle strength than those in Grade 4. Forearm pronation and supination strength also decreased in proportion to increases in the severity of Larsen's grades from Grade 1 to 5. This quantitative study made it clear that the muscle strength of RA patients' elbows almost completely correlates to X-ray finding according to the grade of Larsen's evaluation based on X-rays. With regard to muscle strength of postoperative elbows, both flexion strength and supination strength after total elbow replacement (TER) were about two times greater than before TER, and after synovectomy it was as great as those in non-operative RA patients of Grade 2.

KEYWORDS: elbow, rheumatoid arthritis, muscle strength, Larsen's X-ray evaluation

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Muscle Strength in Rheumatoid Elbow: Quantitative Measurement and Comparison to Larsen's X-Ray Grade

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Accurate assessment of elbow function is important to determine the total ability of the arm. The purpose of this study was to clarify the relationship between isometric muscle strength of the elbows of patients with rheumatoid arthritis (RA) and Larsen's X-ray evaluation. Fifty-six elbows of 45 RA patients aged 47 to 77 years (mean age, 63 years) were tested. Muscle strength was measured with an isometric torque-cell dynamometer. Test-retest reliability of the dynamometer was proven by measuring 12 elbows of 6 healthy young men. In RA patients, elbow flexion and extension strength decreased in proportion to increases in the severity of Larsen's grades from Grade 1 to 4. However, Grade 5 elbows had greater muscle strength than those in Grade 4. Forearm pronation and supination strength also decreased in proportion to increases in the severity of Larsen's grades from Grade 1 to 5. This quantitative study made it clear that the muscle strength of RA patients' elbows almost completely correlates to X-ray finding according to the grade of Larsen's evaluation based on X-rays. With regard to muscle strength of postoperative elbows, both flexion strength and supination strength after total elbow replacement (TER) were about two times greater than before TER, and after synovectomy it was as great as those in non-operative RA patients of Grade 2.

Key words: elbow, rheumatoid arthritis, muscle strength, Larsen's X-ray evaluation

More than 50 % of the patients with rheumatoid arthritis (RA) have some elbow deterioration (1). The elbow joint plays an important role in the arm, and impediment of the elbow impairs total function of the arm. Furthermore, it is important to accurately measure elbow function in order to accurately assess the total ability of the arm in RA patients.

Measurement of muscle strength is particularly important for the assessment of the joint function. However, until now an accurate method for measurement of muscle strength in patients with RA has been lacking. This is due to subjective factors such as pain and instability of the elbow, as well as limited cooperation of patients. Earlier studies have shown that patients with RA, as compared with healthy subjects, have reduced muscle strength of the lower extremities (2-4), but few studies have been conducted for the upper extremities (5, 6) in this regard.

Isometric muscle strength measurement of the elbow is an easy, reliable (7) and inexpensive method that can provide a maximum strength profile similar to more elaborate methods. In a clinical setting where work-related disabilities and a wide range of pathological conditions are assessed, there appears to be a need for basic data concerning RA patients. The purpose of our study was to clarify the relationship between isometric muscle strength of the elbows in patients with RA and X-rays findings evaluated according to Larsen's criteria (8). Larsen's X-ray grade is used for the evaluation of chronic inflammatory joint conditions and consisits of 6 Grades. The first grade, Grade 0, represents the normal condition and subsequent grades reflect increasing degrees of bone destruction and cartilage reduction. Refining test-retest reliability of our original isometric torque-cell dynamometer with normal controls was also performed in this study.

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Materials and Methods

Twelve elbows of 6 young adults aged 25 to 27 years (mean age, 26 years) were test-retested 5 times during 4 weeks (once a week). All were healthy men without a history of injury or disease of the arm.

Fifty-six elbows of 45 RA women aged 47 to 77 years (mean age, 63.3 years) with no history of elbow surgery were also examined. Mean duration of the disease was 15 years (range, 2 to 38 years). X-ray findings showed Larsen's Grade 1 in 7 elbows; Grade 2 in 15; Grade 3 in 11; Grade 4 in 12; and Grade 5 in 11 (Figs. 1, 2). The functional severity of rheumatoid disease (9) was class 2 in all.

Twenty-six elbows of 20 RA women aged 46 to 77 years (mean age at follow-up, 61.7 years) after total elbow replacement (TER) were examined (Fig. 3). Follow-up duration was from 1 to 113 months (mean duration, 43 months). X-ray findings before TER showed Larsen's Grade 4 in 14 elbows and Grade 5 in 12. Prosthesis of Kyocera Type 1 with stem (10) was used for all patients. Preoperative and postoperative muscle strength was measured and compared in 7 out of 26 elbows.

Eleven elbows of nine RA women aged 53 to 74 years (mean age at follow-up, 63.7 years) after elbow synovectomy were also examined (Fig. 4). Follow-up duration was from 61 to 166 months (mean duration, 139 months). X-ray findings at follow-up showed Grade 3 in one elbow, Grade 4 in three elbows and Grade 5 in seven elbows. Radial head resection was performed in all cases.

Muscle strength of elbow flexion and extension and forearm pronation and supination were measured with an isometric torque-cell dynamometer (OG Giken, Inc.,

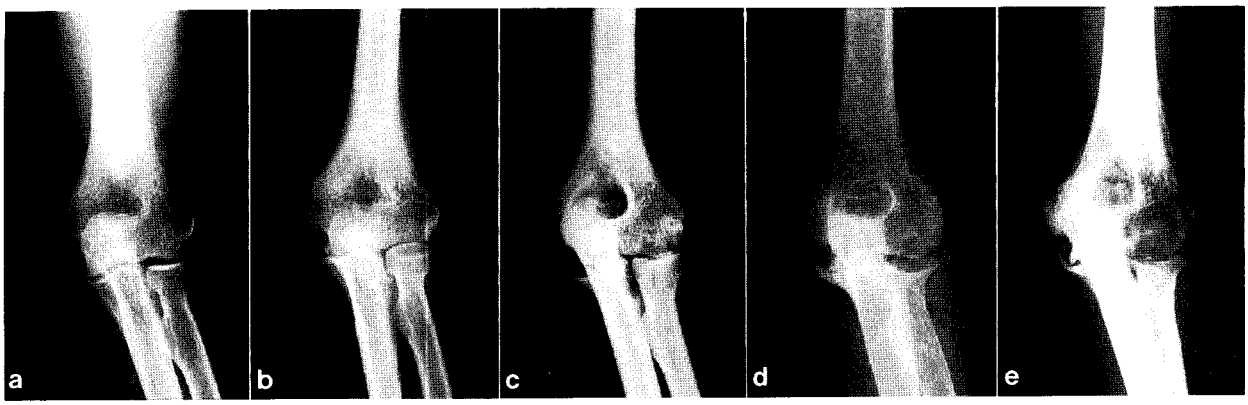

Fig. 1 Antero-posterior X-rays of rheumatoid elbows used as standards for Larsen's X-ray evaluation.
a: Grade 1; **b**: Grade 2; **c**: Grade 3; **d**: Grade 4; **e**: Grade 5.

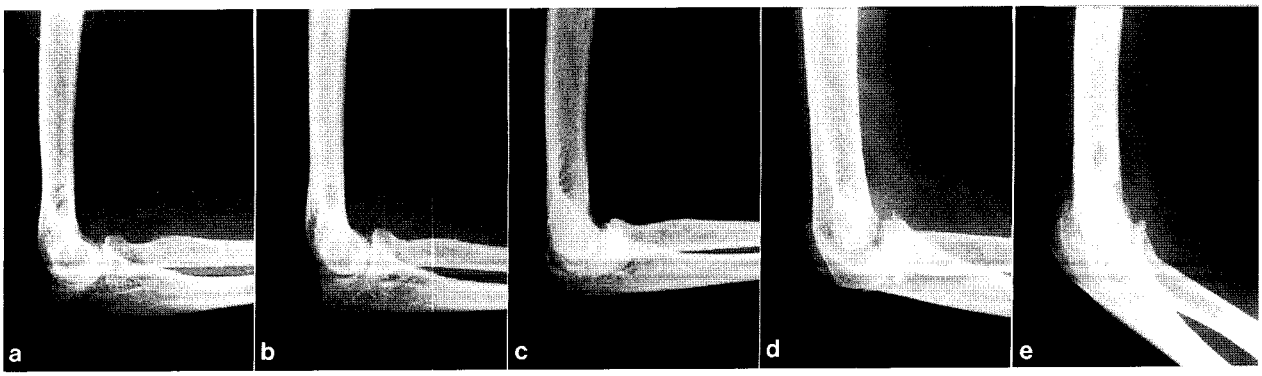

Fig. 2 Lateral X-rays of rheumatoid elbows used as standards for Larsen's X-ray evaluation.
a: Grade 1; **b**: Grade 2; **c**: Grade 3; **d**: Grade 4; **e**: Grade 5.

Okayama, Japan) (Fig. 5). Strength measurements were performed with the subjects seated on a rigid stool. Elbow flexion and extension strengths were measured with elbows flexed to 90 degrees and forearms in as full a supination position as possible. Forearm pronation and supination strengths were measured in a 90-degree flexion position of the elbow and in a neutral position of the forearm (Fig. 5). The subjects were asked to produce a maximum isometric voluntary contraction sustained for about three seconds in three separate trials, with a 30-sec.

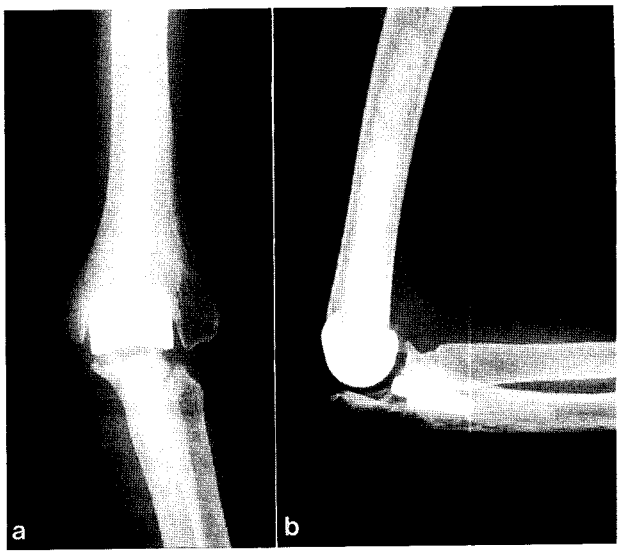

Fig. 3 X-ray 6 years after total elbow replacement (TER).
a: Antero-posterior view; **b**: Lateral view.

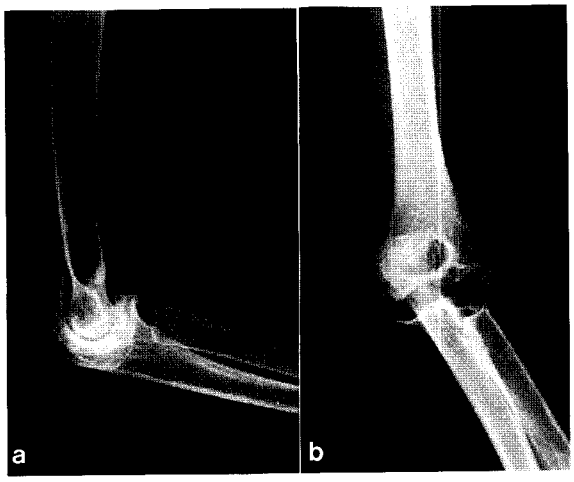

Fig. 4 X-ray 5 years after synovectomy.
a: Antero-posterior view; **b**: Lateral view.

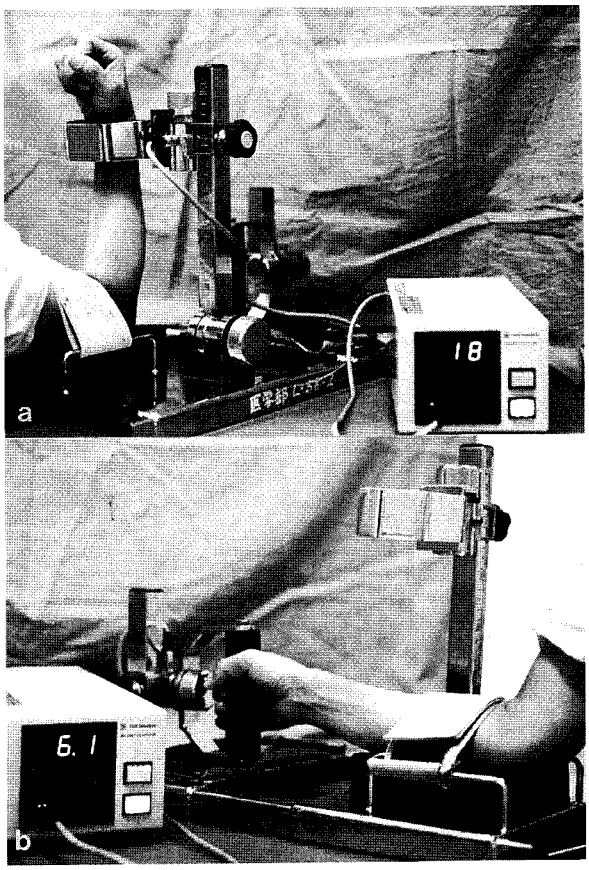

Fig. 5 Measurement of muscle strength of elbow.
a: Elbow flexion and extension; **b**: Forearm pronation and supination.

resting period between each trial. The highest value of the three trials was taken to represent RA patient's strength value. For a control value, the mean value of three trials of normal individuals' arms were used. The strength value of each RA elbow was compared to Larsen's X-ray evaluation (8).

Differences among Larsen's grades were analysed by one-way analysis of variance and Scheffe's method. A level of $P < 0.05$ was considered to be statistically significant. The coefficient of variance was calculated for the controls.

Results

The mean of elbow flexion strength in normal controls was 421.1 kg-cm and extension strength was 262.4 kg-cm. Forearm pronation strength was 47.9 kg-cm and supination strength was 68.8 kg-cm. Mean of the coefficient of

Table 1 Control study of muscle strength of elbows in 6 normal subjects

	Muscle strength (kg-cm)	CV (%)
Flexion	421.1 ± 83.7	8.17
Extension	262.4 ± 50.2	10.87
Pronation	47.9 ± 9.1	10.77
Supination	68.8 ± 11.2	7.58

CV: Coefficient of variance. Muscle strengths are expressed as mean ± SD. CV are expressed as mean CV of each healthy man's CV.

variance was 8.17 % in flexion, 10.87 % in extension, 10.77 % in pronation, and 7.58 % in supination (Table 1).

The mean muscle strengths of the elbows in patients with RA, according to Larsen's grades, are shown in Table 2. Flexion strength in Grade 4 was greater than in Grade 1 (Scheffe's method, $P = 0.00153$) and that in Grade 5 was greater than in Grade 1 (Scheffe's method, $P = 0.00870$) (Fig. 6). Extension strength in Grade 4 was greater than in Grade 1 (Scheffe's method, $P = 0.00668$) and that in Grade 5 was greater than in Grade

Table 2 Mean elbow strength of RA patients

Group		Muscle strength (kg-cm)			
		Flexion	Extension	Pronation	Supination
Non-operative	Grade 1 (n = 7)	127.4 ± 74.0	78.2 ± 39.0	17.0 ± 7.6	19.9 ± 10.6
	Grade 2 (n = 15)	75.4 ± 46.3	51.9 ± 28.6	11.7 ± 5.2	16.0 ± 7.4
	Grade 3 (n = 11)	64.5 ± 38.1	50.7 ± 24.9	11.5 ± 6.5	11.1 ± 3.1
	Grade 4 (n = 12)	36.4 ± 23.7	30.3 ± 13.3	9.7 ± 3.7	9.7 ± 3.2
	Grade 5 (n = 11)	47.5 ± 28.0	32.1 ± 18.6	7.4 ± 3.5	8.3 ± 3.2
TER	(n = 26)	58.2 ± 39.3	33.9 ± 17.3	9.3 ± 3.9	9.5 ± 3.6
Synovectomy	(n = 11)	104.2 ± 55.8	65.2 ± 38.2	16.9 ± 7.3	19.4 ± 6.5

RA: Rheumatoid arthritis; TER: Total elbow replacement. Muscle strengths are expressed as mean ± SD.

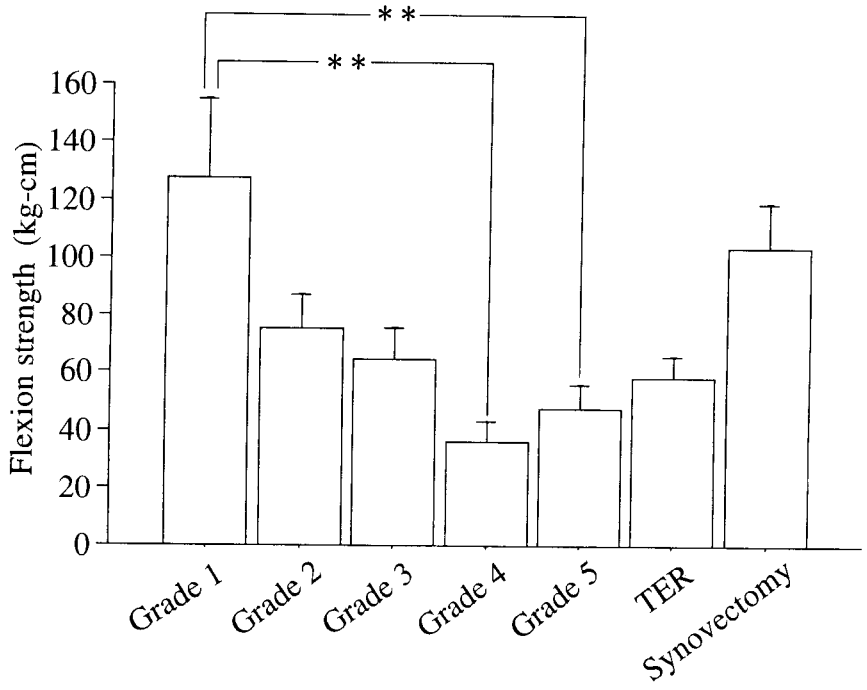

Fig. 6 Flexion strength of the elbow. Non-operative cases, cases after total elbow replacement (TER), and synovectomized cases were measured. Grade is Larsen's X-ray evaluation grade. Columns indicate the mean and bars indicate one SD. ** indicates a significant difference of $P < 0.01$.

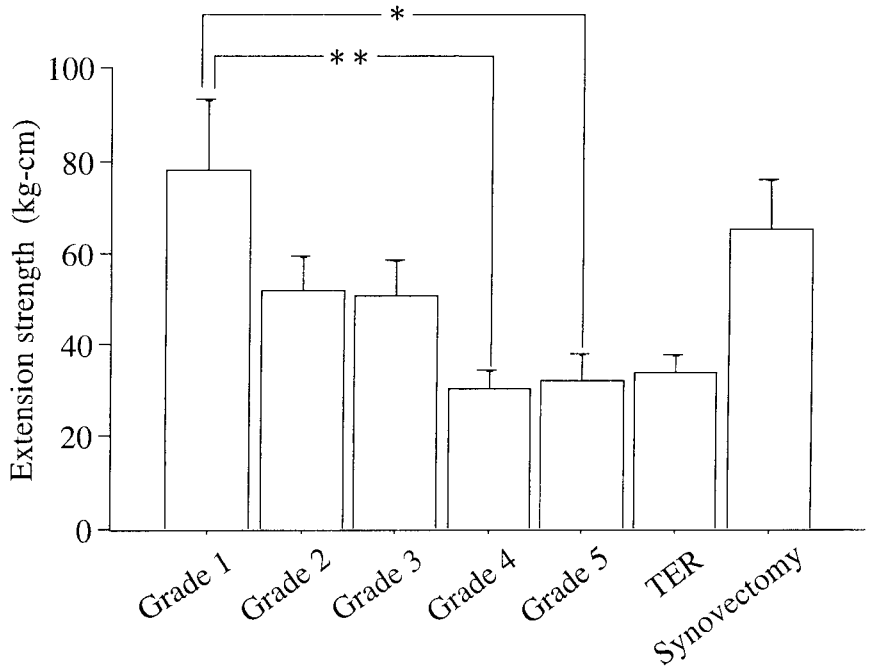

Fig. 7 Extension strength of the elbow. Non-operative cases, cases after total elbow replacement (TER), and synovectomized cases were measured. Grade is Larsen's X-ray evaluation grade. Columns indicate mean and bars indicate one SD. * and ** indicate a significant difference. * $P < 0.05$, ** $P < 0.01$.

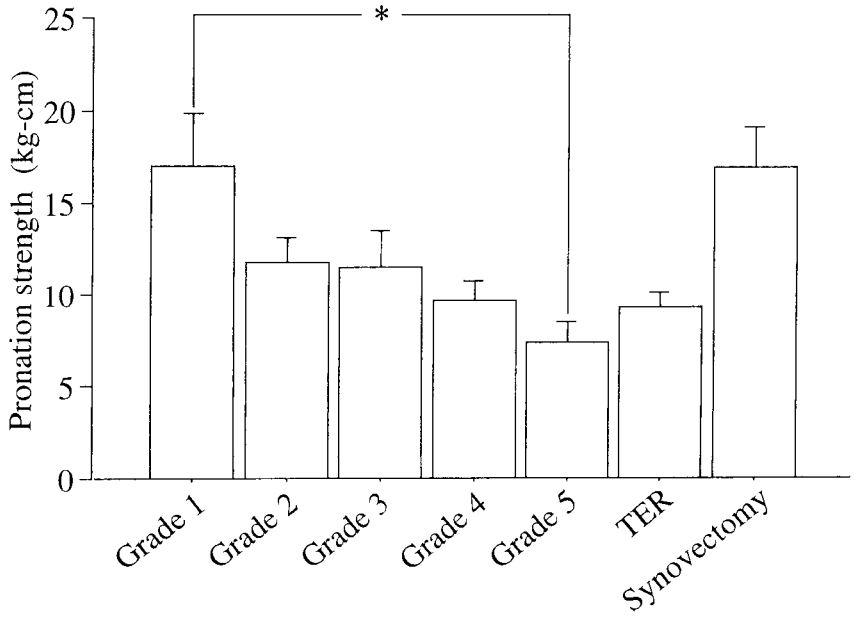

Fig. 8 Pronation strength of the elbow. Non-operative cases, cases after total elbow replacement (TER), and synovectomized cases were measured. Grade is Larsen's X-ray evaluation grade. Columns indicate mean and bars indicate one SD. * indicates a significant difference of $P < 0.05$.

1 (Scheffe's method, $P = 0.01187$) (Fig. 7). Pronation strength in Grade 5 was greater than in Grade 1 (Scheffe's method, $P = 0.01252$) (Fig. 8). Supination strength in Grade 4 was greater than in Grade 1 (Scheffe's method,

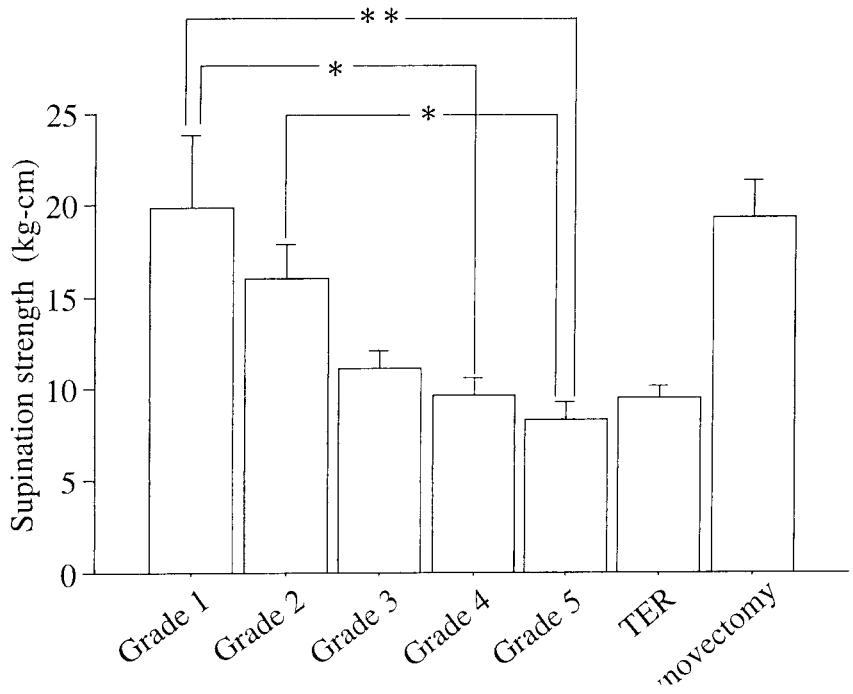

Fig. 9 Supination strength of the elbow. Non-operative cases, cases after total elbow replacement (TER), and synovectomy were measured. Grade is Larsen's X-ray evaluation grade. Columns indicate mean and bars indicate one SD.
** indicate a significant difference. * $P < 0.05$, ** $P < 0.01$.

$P = 0.01616$), that in Grade 5 was greater than in Grade 1 (Scheffe's method, $P = 0.00511$), that in Grade 5 was greater than in Grade 2 (Scheffe's method, $P = 0.03662$) (Fig. 9).

Elbow flexion and extension strength decreased in proportion to the increased severity of grades from 1 to 4, but elbows in Grade 5 had greater muscle strength than those in Grade 4. Forearm pronation and supination strength also decreased in proportion to the increased severity from Grades 1 to 5. Decrease of muscle strength in elbow flexion and extension was the largest between Grades 3 and 4.

Flexion strength after TER was 58.2 kg-cm, extension strength was 33.9 kg-cm, pronation strength was 9.3 kg-cm, and supination strength was 9.5 kg-cm. Both flexion strength and supination strength after TER were about two times greater than before TER, and both extension strength and pronation strength were about one and half times greater than before TER.

Flexion strength after synovectomy was 104.2 kg-cm, extension strength was 65.2 kg-cm, pronation strength was 16.9 kg-cm, and supination strength was 19.4 kg-cm. Muscle strength after synovectomy was as great as that in non-operative RA patients of Grade 2, showing good strength.

Discussion

Accurate assessment of elbow function is important to determine the total ability of the arm. There are several systems for evaluating elbow function including those put forth by Dee (11), by Morrey (12) and by The Japanese Orthopaedic Association (13). Most of them do not emphasize muscle strength but instead emphasize pain, instability, limited range of motion, deformity and disability in daily living. Muscle strength of the elbow is influenced by pain, stability and limited range of motion of the joint, and is therefore a good indicator of total strength and elbow function. Furthermore, quantitative assessment of the elbow function becomes necessary to accurately assess the total ability of the arm. The method described herein seems to hold promise in this regard.

Some other evaluating systems for total ability of RA patients (8, 9) have also been used. Larsen's X-ray grade (8) is one of such system used to evaluate X-rays of joints of RA patients indicating the degree of joint destruction caused by synovitis. Our study showed that X-ray findings graded according to Larsen's criteria correlated statistically well with muscle strength. Increasing severity in grade reflects more pain and joint destruction as well as stability. Accordingly, muscle strength also decreases. X-ray findings evaluated according to Larsen's criteria not only show joint destruction but also indicate the level of muscle strength, thus representing the total joint function.

Manual muscle testing (14) is practical and useful for muscle strength measurement. However, it is not suitable for precisely and quantitatively comparing muscle strength before and after surgery, or among patients treated by different techniques. Quantitative analysis is necessary to assess muscle strength for evaluation of treatment benefit. Furthermore, it is difficult to measure muscle strength of RA patients, because each joint of RA patients is destroyed to a varying extent. Therefore, comparison of muscle strength to X-ray findings evaluated according to Larsen's criteria is necessary for accurate clinical assessment of RA patients' muscle strength.

Elbow strength, that is, flexion and extension, was measured with a strain-gauge dynamometer for the first time by Darcus (15), and Provins and Salter later proved its reliability (16). These instruments are simple and widely used by researchers. However, forearm strength, that is pronation and supination strength, cannot be measured with these instruments. Destruction of the elbow tends to start first in the ulno-humeral joint and progress to the radio-humeral joint (17). Forearm strength measurement is also necessary for assessment of total elbow function. The isometric torque-cell dynamometer is suitable for measurement of isometric muscle strength of the elbow in RA patients because of portability and simplicity.

Test-retest reliability of our dynamometer was confirmed before examination for RA patients. The muscle strength of the elbow measured by our dynamometer was reliable in normal individuals.

The correlation between Larsen's grade indicating bone destruction and functional ability including muscle strength has not been reported in previous papers. A lessening of pain seemed to increase flexion and extension strength from Grades 4 to 5. On the contrary, a lessening of pain decreased pronation and supination strength from Grades 4 to 5, because radio-humeral joint destruction is still progressing. In surgical treatment, this muscle strength loss is very important. As stated above, muscle strength is a good indicator of total elbow function. An aggressive treatment of the ulno-humeral joint from Grades 3 to 4 is effective to maintain elbow strength function.

Muscle strength of the elbow after TER was greater than that in non-operative elbows of Grades 4 and 5. Such surgery seemed to restore a good deal of strength to RA elbows which had suffered, prior to surgery, from significant losses in range of motion, stability and muscle strength. It can also help relieve pain and improve range of motion and elbow joint stability. Overall, TER gives RA patients much more muscle strength than before surgery (18), as indicated in this study. Muscle strengthening exercise must be encouraged after TER for achieving better joint function.

Vahvanen (19) measured flexion and extension strength of the elbow after synovectomy, and reported that flexion and extension strength was greater than half of the strength value of healthy age-matched controls. Patients' elbow strength after synovectomy was greater than in non-operative patients' elbows of the same grade. Range of motion might be also improved after synovectomy (20, 21). Synovectomy cannot inhibit the development of synovitis which destroys bone and joint (22). However, after several years, the operative elbow is better than non-operative elbows because a painless elbow promotes frequent use of the joint.

In the future, better understanding of the relationships between muscle strength, pain, joint stability and range of motion may lead more accurate measurement of total elbow function. It is our hope that studies like this one will help promote accurate measurement of the total function of the arm.

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