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*ORIGINAL STUDY*

# Histological and biochemical evidence related to the collagen quality in torn rotator cuff tendons

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**This study investigates the histological background of torn rotator cuff tendons, evaluates the stability of newly synthesized collagen by measuring the hydroxyproline content and attempts to correlate these findings with the clinical outcome after reconstruction of the rotator cuff.**

**Sixty-one patients underwent reconstruction for a rotator cuff tear. They were evaluated preoperatively with the Constant-Murley score, MRI and ultrasound. Biopsy samples were taken from chronic rotator cuff tears and histological analysis was performed. Hydroxyprolin presence was evaluated in various tissues.**

**Mean follow-up was 46 months. Histological analysis revealed collagen fragmentation and thinning (90.2% of patients), myxoid degeneration (88%), hyaline degeneration (50.8%), chondroid metaplasia (44.3%), calcification (24.7%), fatty infiltration (20.4%) and vascular proliferation (62.3%). Hydroxyproline was under-represented in newly synthesized collagen in 57% of patients. In the majority of the patients with a low hydroxyproline/collagen ratio the histological findings were abnormal. None of the findings was related to the clinical outcome with a statistical significance.**

**Histological and biochemical findings reflected the poor quality of the tendon. The good clinical outcome did not depend on the histological or biochemical findings but rather on the meticulous surgical reconstruction and physical therapy.**

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**Keywords** : rotator cuff tear ; histological characteristics ; rotator cuff reconstruction ; Hydroxyproline ; Collagen ; Tendon healing ; hydroxyproline/collagen ratio.

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## INTRODUCTION

Rotator cuff tears are frequent shoulder injuries causing pain and disability and have been extensively studied in the literature (*4,20*). The basic cell biology of tendons remains not fully understood and the management of tendon injury poses a considerable challenge for clinicians. The healing potential of the tendon depends on the tendon quality, muscle contracture, stable reattachment of the tendon to bone and a careful and slow rehabilitation program ensuring protection from premature overloading that might risk attenuation of repair site (*6,10,14*).

There is no consensus on the pathogenesis and healing of rotator cuff tendons, but it is well known that pre-existing degenerative processes in association with microtrauma are responsible for rotator cuff tendon tears. The changes in staining qualities and tendon structure are age-related (*18*).

Recent studies in animal models have shown that over time, an improvement occurs in tissue properties of the tendon. This healing of the defects indicates that this mechanism of healing is active, but inadequate as a response to the defect occurred in the tendon (*3*). The wound healing response at the site of rotator cuff reattachment and its insertion is significantly different from the uninjured tendon site. Despite remodelling, the repair sites remained histologically unrecognised and biomechanically inferior in comparison to uninjured tendons (*10,17*).

The major component of the normal tendon is type I collagen, with increasing amounts of type III collagen in pathologic tissues. It is essential for the tissue repair to secure a tendinous edge with active local fibroblasts, and sufficient vascularity to provide an adequate synthesis of type I procollagen (*11,16*).

Hydroxylation of proline which is catalyzed by prolyl hydroxylase, represents a major post-translational modification of collagen. Moreover, the presence of hydroxyproline (Hyp), which is the result of this important modification, increases the stability of the collagen triple helix. Because of its restricted and unique distribution in connective tissue collagen and its regulation is studied by measuring the Hyp content in a number of clinical situations. In the present study we measured for the first time the Hyp content in tissue samples from the ruptured edges and its relationship to the newly synthesized collagen.

This study focuses on histological and biochemical findings in torn rotator cuff tendons taken at the time of repair. To our knowledge, it is the first approach in human tissue specimens that correlates the quality of tendon to the quality of the produced collagen. The study also focuses on correlating samples where hydroxyproline is under-represented in collagen with histological observations showing collagen fibre abnormalities (in the same patients) and could potentially provide a reliable prognostic marker for healing of the cuff repair.

## PATIENTS AND METHODS

Sixty-one consecutive patients with rotator cuff tear underwent open repair. Included in the study were patients with persistent pain and functional disability refractory to nonoperative treatment. The patients failed nonoperative treatment of at least six months (range from 1 to 96 months). At least two (two to five) subacromial injections of corticosteroids were performed in twenty (29%) shoulders preoperatively for pain relief during an acute clinical episode. There were twenty-eight men (46%) and thirty-three (54%) women with a mean age of 56 years (range 35-73 years). Twelve patients (20%) were younger than 50 years, twenty-nine (48%) were between 50 and 65 years old and twenty (32%) were older than 65 years. The dominant arm was involved in forty-one (66%) patients.

Preoperative evaluation consisted of a patient's questionnaire, physical examination and medical history. The results were evaluated by SF-36, Visual Analogue Scale (VAS) and Constant Murley Score (*5*). Imaging included anteroposterior and lateral x-rays of the shoulder, ultrasound and MRI (Phillips MR NT Intera 1.0 T, Germany). The ultrasound and MRI images were reviewed by two radiologists and two surgeons.

All patients were operated with an open approach under general anaesthesia combined with an interscalene block. The procedure was performed in a beach-chair position. Through a superolateral 4 to 5-cm-long incision, a mini-open approach was used. An anterio-inferior acromioplasty was performed in 49 patients where an impingement syndrome was apparent. Resection of the lateral aspect (7-10 mm) of the clavicle was performed in

17 patients with painful osteophytic changes in the acromioclavicular joint.

We performed a precise mapping of the torn tendons regarding type, size and location of the lesion by rotating the humeral head in order to visualize the margin of the tear. Once the rotator cuff was adequately mobilized, circumferential excision of 2-3 mm at the edges of the torn tendons was carried out in all 61 patients and these tissue specimens were sent for histological and biochemical analysis. Careful attention was paid to the orientation of the tendon's fibers pattern.

The cuff was repaired by side to side sutures in eleven patients (17%) and a single or double row fixation with suture anchors was performed in the remaining fifty patients (83%) (Mitek-Panalok Worldwide Westwide, MA, USA) placed just on the medial side of the greater tuberosity and when needed an inverted horizontal or oblique mattress tension, allowing a compression of the repaired tendon against the footprint without tension on the sutures with the patient's arm adducted. The mean number of suture anchors used per patient was 2.15 (range 1-4 anchors). One anchor was used in 21 cases, two anchors in 14 cases, three anchors in 8 cases and four anchors in 7 cases with larger or massive tears. At the end of the procedure we checked under direct visualization for the integrity of the rotator cuff by rotational movements of the humeral head and we found no failure of the sutures in any case. Then, the fascia of the deltoid muscle was reattached on the acromion.

Patients were discharged the second postoperative day. For large or massive tears, patient's arm was protected with an abduction pillow for 6 weeks after surgery. Patients with smaller tears used a sling. Rehabilitation was done under supervision of an experienced physiotherapist for 3 months. Patients were followed prospectively at one, three, six, 12 and 24 months by an independent observer using the Constant Murley Score.

## Operative findings

Thirty-seven (54%) patients had an isolated supraspinatus tear. Of these patients, 23 had a small tear (< 1 cm), 13 patients had a medium size tear (1-3 cm) and one patient had a large (3-5 cm) tear. There was not an isolated infraspinatus tear. Combined supraspinatus and infraspinatus tears were found in 24 (34%) patients. Of these five had a medium tear and 11 patients had a large tear. Finally, nine patients (14%) had a massive tear (supraspinatus, infraspinatus and subscapularis). They were treated by side to side repair and double row fixation using suture anchors (2 to 4 anchors).

The size of the tear was measured in length and width intraoperatively with an elastic ruler scaled to millimeters, holding the arm at the side in neutral position. In four patients there was a co-existing biceps tendon degeneration with hypertophic and inflamed tissue.

## Histological analysis

After specimen preparation, histological analysis was performed via tissue dehydration in formalin and embedding in paraffin blocks. Coronal sections were performed at 3 mm thickness staining with Hematoxylin-Eosin and microscopy. In addition, in the histochemical stains, Masson Trichrome and Alsian blue were performed.

## Biochemical analysis

### *Assay for the determination of Hyp content and salt soluble collagen fraction*

We examined the presence of hydroxyproline (Hyp) into newly synthesized collagen from the edges of the rotator cuff tendons according to Edwards and O'Brien (*7*) and Reddy and Enwemeka (*15*). These report describe a simplified method for accurate colorimetric determination of Hyp from various tissues. A duplicate standard curve was used in every assay for Hyp determination.

The salt soluble fraction represents the most recent collagen secreted by the cell. In order to measure the newly-synthesized collagen, the Sircol collagen assay (Biocolor Ltd., Newtownabbey, Northern Ireland) was used according to the manufacturer's instructions. This method of extraction represents the simplest procedure for recovering the recently synthesized collagen pool from tissues. Samples for analysis were collected under aseptic conditions, weighed prior to freezing and stored at -80° C for collagen determination. To optimize collagen extraction tissue was homogenized in ten volumes of solvent to weight tissue. Newly synthesized collagen was extracted by the use of salt soluble collagen solvent (0.05 M Tris-HCl, pH 7.5, containing 1.0 M sodium chloride, in the presence of protease inhibitors. The sample was stirred overnight at 0° to 5°C, centrifuged in the morning for 60 min at 14000 rpm and finally a transparent solution was obtained – containing salt soluble collagen. The Sircol is a colorimetric assay and it is essential that test samples are transparent. 50 µl of the supernatant was added to 1 ml of the Sircol dye. After

incubation with shaking for 35 min the tubes were centrifuged for 15 min at 13000 rpm. Unbound dye solution was drained by turning the tubes upside down on a tissue, removing any remaining droplets from the top half of the tube with a cotton swab. After Alkali reagent addition (1 ml), the bound dye was released into the solution by vortexing. 1 ml of the solution was transferred in a cuvette and the optical density was measured at 540 nm wavelength. Collagen content was calculated using a standard curve and expressed either as a hydroxyproline to collagen ratio or as μg/sample. The supernatant was used for the Sircol collagen assay and compared with a standard curve prepared from rat tail collagen by using the Sircoll collagen dye binding assay (BioColor Ltd., Newtownabbey, U.K.) according to the manufacturer's directions. Dilute acetic acid (0.5 M, pH 3.0) was used to solubilise non-cross linked, and some cross linked forms of acid soluble collagens. The solvent to tissue ratio and extraction times were similar to salt extraction. In all the control tissue samples that we measured, the normal Hyp content varied between 10-15% which is in agreement with previous studies reporting that Hyp is 12.5% of collagen (*8*).

## RESULTS

### Functional results

This study reports functional and subjective results comparable to those previously published by Fuchs *et al* (*9*) 2006 for open repair and by Bishop *et al* (*1*), Boileau *et al* (*2*) and Thomazeau *et al* (*19*), with arthroscopic techniques.

All patients were followed clinically and radiographically for an average of 46 months (range from 30 to 52 months). The pain was recorded using a VAS scale of 0 to 10 points. The average score was improved from 7.2 points preoperatively to 2.2 points postoperatively, with 42 patients (70%) reporting minimum or no pain (0-2 on VAS). There was a significant improvement in the average and gender-adjusted Constant score, from 57.4 (range, 35 to 92) preoperatively to 84.8 (range 41 to 94) postoperatively. There was also a significant improvement in the average score for daily activities from 10.9 points preoperatively to 18.2 points postoperatively. Increased shoulder mobility (flexion, abduction, internal and external rotation) was measured as well without a significant improvement of external rotation. The result was rated as excellent in 45 shoulders (74%), good in 11 (17%) and fair in five shoulders (9%).

Patients with a massive tear were more possible to have a less satisfactory outcome (Constant Score less than 65) with $p < 0.05$. Patients with massive tears and fatty infiltration were also more possible to have a less satisfactory outcome ($p < 0.05$). Regarding patient's satisfaction, 51 patients (85%) were very satisfied with pain relief. Two patients were disappointed because of persistent pain.

### Histological findings

Histopathologic examination revealed characteristic features of the stump of the torn tendons, and these were classified as collagen fragmentation, myxoid change, hyaline degeneration, fibrocartilage (chondroid metaplasia), calcification (calcified deposits), vascular proliferation, fatty infiltration and fibrin (Fig. 1, Table I). Thinning and disorientation of collagen fibres was observed in 55 patients.

Myxoid degeneration was seen in 51 patients along with the thin and disoriented collagen fibres as tissue stained with alcian blue. Hyaline degeneration was noted in 31 patients and fibrocartilage (chondroid) metaplasia in 27 cases. Calcification was seen in 15 of the samples and vascular proliferation with granulation tissue formation was seen in 38 of the tendons. Fatty infiltration was noted between the collagen fibres in 12 samples and fibrin deposition in 11. Finally, the outcome index hydroxyproline / collagen (Hyp/Col) was outside the normal range (10-15%) in 35 of the 61 patients (57%).

Logistic regression was carried out in order to determine the following correlations : Hyp/Col and the eight histological factors, hydroxyproline / collagen and the factors related to the lesion's nature, Hyp/Col and the age categories and the gender ; correlations between the eight histological factors, correlations with the characteristics of the lesion (time – is equal to the duration of the symptoms, severity – small, middle, large or massive lesion) and age, gender and their interaction. Logistic and multinomial logistic regression is carried out and the method used is Forward LR entry.

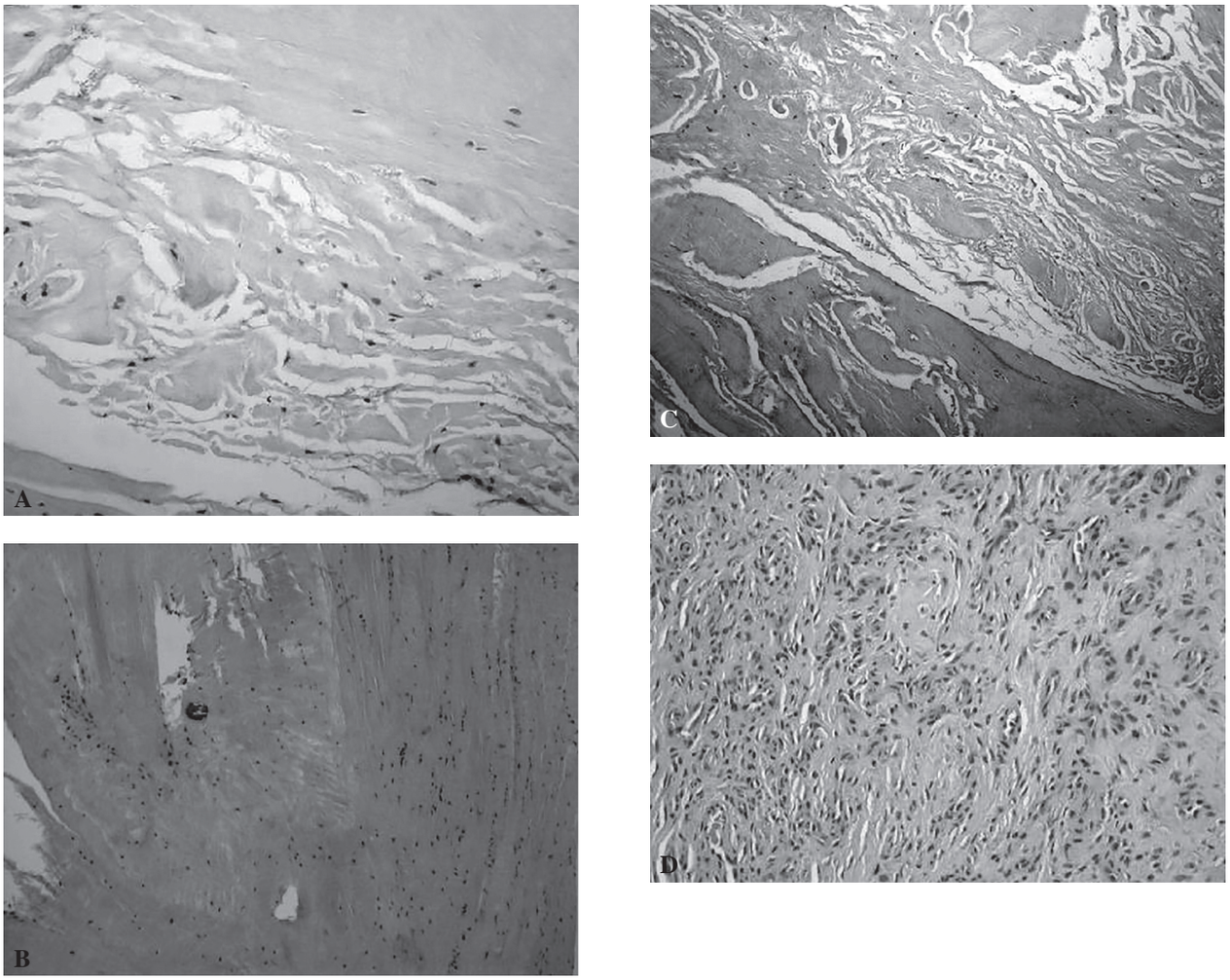



***Fig. 1.* —** Figures of histological characteristics in cuff tissues taken at the time of repair : **A.** collagen fragmentation ; **B.** hyaline degeneration ; **C.** myxoid degeneration ; **D.** vascural proliferation.

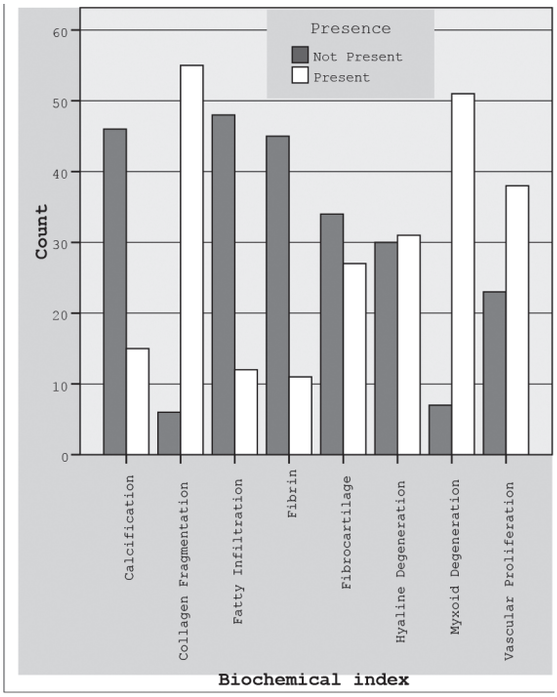
## Statistical analysis

Chi square tests were carried out to examine correlations between Hyp/Col and gender, age group and their interaction. The correlation test between the outcome measure and the gender and the age showed no statistically significant results.

Logistic regression (Forward LR entry) was carried out to examine the effect of the eight histological factors (collagen fragmentation, myxoid degeneration, hyaline degeneration, fibrocartilage, calcification, vascular proliferation, fatty infiltration, fibrin) and physical characteristics of the lesion (lesion time : mean time of the shoulder trauma episode was 9 months, lesion severity : small medium large or massive tear) on the Hyp/Col ratio. There were many patients with normal or abnormal Hyp/Col ratio that presented with the following degenerative characteristics : collagen fragmentation ($p = 0.700$), myxoid degeneration ($p = 0.366$), fibrocartilage (myxoid metaplasia, $p = 0.069$), calcification ($p = 0.813$), vascular proliferation ($p = 0.241$), fatty infiltration ($p = 0.896$) and fibrin ($p = 0.547$) leading to the conclusion that there is no significant correlation between these factors and the value of Hyp/Col ratio.

Table I. — Presentation of percentages of histological characteristics

| | | Count | Percent |
|---|---|---|---|
| Collagen Fragmentation | Not Present | 6 | 9,8% |
| | Present | 55 | 90,2% |
| Myxoid Degeneration | Not Present | 7 | 12,1% |
| | Present | 51 | 87,9% |
| Hyaline Degeneration | Not Present | 30 | 49,2% |
| | Present | 31 | 50,8% |
| Fibrocartilage | Not Present | 34 | 55,7% |
| | Present | 27 | 44,3% |
| Calcification | Not Present | 46 | 75,4% |
| | Present | 15 | 24,6% |
| Vascular Proliferation | Not Present | 23 | 37,7% |
| | Present | 38 | 62,3% |
| Fatty Infiltration | Not Present | 48 | 80,0% |
| | Present | 12 | 20,0% |
| Fibrin | Not Present | 45 | 80,4% |
| | Present | 11 | 19,6% |



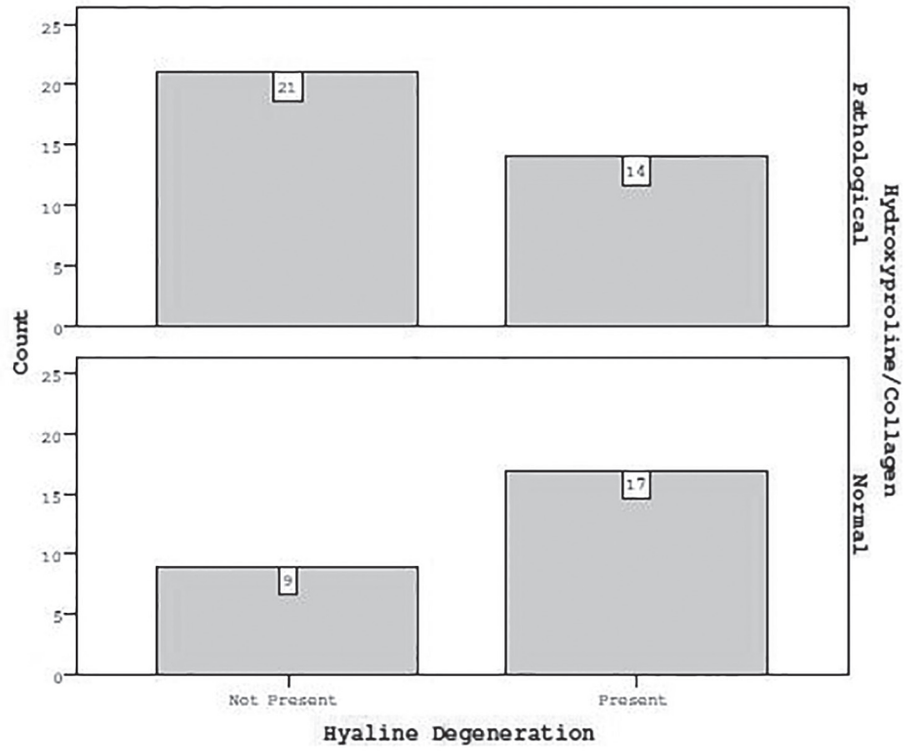

Regarding hyaline degeneration, it is presented more frequently in patients with normal Hyp/Col ratio than in patients with abnormal Hyp/Col ratio (Fig. 2). This correlation proves to be statistically significant ($p = 0.048$).

We examined the impact of factors related to the nature of the lesion (duration of the symptoms, severity) on the outcome measure, taking into consideration the gender and the age group. We can see that there are many pathological and non pathological cases, regardless of the time of the lesion ($p = 0.237$), the severity of the lesion ($p = 0.499$), leading to the conclusion that there is no significant correlation between these factors and the outcome measure of Hyp/Col.

Logistic regression (Forward L.R. entry) was also carried out to examine the effect of sex, age class, their interaction and the physical characteristics of the lesion on the eight histological factors. Tests were carried out for differences in the presence of the histological factors depending on the age, sex and their interaction. Logistic and multinomial logistic regression was carried out. Neither of the two factors, age and sex, affects the presence of all eight histological findings. Additionally, age, sex and their interaction do not affect the nature of the symptom's duration, and the lesion's severity.

Apart from sex and age, there is interest in examining the correlations between the eight biochemical factors and the five factors related to the nature of the lesion. Logistic regression was carried out. There are no significant correlations between collagen fragmentation (p-value $> 0.196$), myxoid degeneration (p-value $> 0.083$), hyaline degeneration (p-value $> 0.092$), fibrocartilage (p-value $> 0.070$), calcification (p-value $> 0.080$), fatty infiltration (p-value $> 0.080$) and fibrin (p-value $> 0.104$) and the factors of the nature of the lesion.

According to Hashimoto *et al* (*12*), the tendon lesion is correlated to the following histological factors : collagen fragmentation, myxoid degeneration, calcification, fatty infiltration and fibrin. Instead, tendon healing is correlated more with fibrocartilage, vascular proliferation and hyaline degeneration factors. At the end of our study, we correlated the lesion severity (size of the tear) to the factors of tendon lesion and healing. From Fisher's exact test (Table II), it appears that there is not any statistical




**Model if Term Removed**

| Variable | | Model Log Likelihood | Change in -2 Log Likelihood | df | Sig. of the Change |
|---|---|---|---|---|---|
| Step 1 | Hyaline degeneration | -41,616 | 3,895 | 1 | ,048 |

***Fig. 2.* —** Hyaline degeneration is more frequent in patients with normal Hyp/Col ratio than in patients with abnormal Hyp/Col ratio. This correlation is statistically significant (p = 0.048).

significance between the size of the tendon's tear and the factors of tendon lesion (p = 0.541) and tendon healing (p = 0.975).

Finally, statistical analysis did not show any correlation between laboratory findings (histological and biochemical) and the clinical outcome.

## DISCUSSION

Histopathological characteristics were classified as thinning and disorientation of the collagen fibers (collagen fragmentation), myxoid and hyaline degeneration, vascular proliferation, fatty infiltration, fibrocartilage (chondroid metaplasia) and calcification into the three layers (superficial, middle and deeper) of the cuff tendons. The first six features are early degenerative, while the last two may be chronic pathological changes. Disorientation and thinning of the collagen fibres are the main findings and are more frequent in the deeper layers of the tendons, where they are present as longitudinally splinted (*12*).

Table II. — Correlation of the size of tendon tear and histological factors. There is no statistical significance between the size of the tendon tear and factors of tendon lesion (p = 0.541) or factors of tendon healing (p = 0.975)

| | | Tear | | | | |
|---|---|---|---|---|---|---|
| | | Small | Medium | Large | Massive | Total |
| Lesion (Histological factors) | Collagen Fragmenation | 29.6% | 31.5% | 18.5% | 20.4% | 90.2% |
| | Myxoid degeneration | 30.6% | 34.7% | 14.3% | 20.4% | 87.9% |
| | Fibrin | 30% | 10% | 30% | 30% | 19.6% |
| | Calcification | 53.8% | 15.4% | 0% | 30.8% | 24.6% |
| | Fatty infiltration | 30% | 20% | 10% | 40% | 20% |
| Healing (Histological factors) | Fibrocartilage (Chondroid-like) | 26.9% | 42.3% | 11.5% | 19.2% | 44.3% |
| | Vascular proliferation | 30.6% | 30.6% | 13.9% | 25% | 62.3% |
| | Hyaline degeneration | 30% | 40% | 10% | 20% | 50.8% |
| Biochemical outcome | Hyp/Collagen (normal) | 34.8% | 34.8% | 13% | 17.4% | 42.6% |
| | Hyp/Collagen (pathologic) | 30.3% | 27.3% | 21.2% | 21.2% | 57.4% |

**Lession Severity * biochemical factor Crosstabulation**

Count

| | | biochemical factor | | | Total |
|---|---|---|---|---|---|
| | | hyaline degeneration | fibrocartiladge | vascular proliferation | |
| Lession Severity | Small | 9 | 7 | 11 | 27 |
| | Middle | 12 | 11 | 11 | 34 |
| | Big | 3 | 3 | 5 | 11 |
| | Massive | 6 | 5 | 9 | 20 |
| Total | | 30 | 26 | 36 | 92 |

**Chi-Square Tests**

| | Value | df | Asymp. Sig. (2-sided) | Monte Carlo Sig. (2-sided) | | |
|---|---|---|---|---|---|---|
| | | | | Sig. | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
| Pearson Chi-Square | 1,255[a] | 6 | ,974 | ,973[b] | ,970 | ,976 |
| Likelihood Ratio | 1,267 | 6 | ,973 | ,972[b] | ,969 | ,975 |
| Fisher's Exact Test | 1,412 | | | ,975[b] | ,972 | ,978 |
| Linear-by-Linear Association | ,261[c] | 1 | ,609 | ,615[b] | ,605 | ,624 |
| N of Valid Cases | 92 | | | | | |

a. 3 cells (25,0%) have expected count less than 5. The minimum expected count is 3,11.

b. Based on 10000 sampled tables with starting seed 1042130385.

c. The standardized statistic is ,511.

**Lession Severity * biochemical factor Crosstabulation**

Count

| | | biochemical factor | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | collagen fragmentation | myxoid degeneration | calcification | fatty infiltration | fibrin | |
| Lession Severity | Small | 16 | 15 | 7 | 3 | 3 | 44 |
| | Middle | 17 | 17 | 2 | 2 | 1 | 39 |
| | Big | 10 | 7 | 0 | 1 | 3 | 21 |
| | Massive | 11 | 10 | 4 | 4 | 3 | 32 |
| Total | | 54 | 49 | 13 | 10 | 10 | 136 |

**Chi-Square Tests**

| | Value | df | Asymp. Sig. (2-sided) | Monte Carlo Sig. (2-sided) | | |
|---|---|---|---|---|---|---|
| | | | | Sig. | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
| Pearson Chi-Square | 11,105[a] | 12 | ,520 | ,536[b] | ,526 | ,546 |
| Likelihood Ratio | 12,856 | 12 | ,380 | ,491[b] | ,481 | ,500 |
| Fisher's Exact Test | 10,731 | | | ,541[b] | ,531 | ,551 |
| Linear-by-Linear Association | ,621[c] | 1 | ,431 | ,441[b] | ,431 | ,450 |
| N of Valid Cases | 136 | | | | | |

a. 12 cells (60,0%) have expected count less than 5. The minimum expected count is 1,54.

b. Based on 10000 sampled tables with starting seed 1509375996.

c. The standardized statistic is ,788.

These features were common changes in all cases, suggesting their possible role in the degeneration of rotator cuff tendons before tearing. Similar results have been shown by Hashimoto *et al* (*12*). In addition, the other collagen features of hyaline degeneration, chondroid metaplasia, dystrophic calcified deposition and vascular proliferation and granulation have been reported in previous studies (*12,13*). Histological findings like collagen degeneration and fibrocartilage-like changes may explain the quality of the tendon.

In this study, the main finding was thinning and disorientation of the collagen fibers with myxoid degeneration. The presence of collagen fragmentation and myxoid degeneration is rather intense, approaching 90%, as is that of calcification, at 75%. The absence of fatty infiltration and fibrin was observed in about 80% of the samples. Hyaline degeneration and fibrocartilage were present in 50% of the samples.

The outcome index Hydroxyproline/Collagen is idepended from sex and age of patients and is not related to the presence of collagen fragmentation, myxoid degeneration, fibrocartilage, calcification, vascular proliferation, fatty infiltration and fibrin. Instead, the presence of hyaline degeneration is more correlated to normal values of the Hyp/Col ratio in comparison to values that show abnormal Hyp/Col ratio.

Normal or abnormal Hyp/Col ratio is not correlated with any of the lesion's types : duration of the patient's symptoms and size of the tendon tear. Sex and age are not correlated with the size of the tendon tear.

Independently from the histologic findings healing could occur and no histologic finding is correlated with the size of the tear. Finally, there is no correlation between the value of Hyp/Col ratio and the size of the tear (Table II).

Because Hyproxyproline represents an important post-translational modification in collagen and in addition, it has an important role in collagen stability, we examined the Hyp/Col ratio in 61 patients with rotator cuff tears. Interestingly, the Hyp content was found lower than the normal range (average 12.5%) in 57% of patients with rotator cuff tear. This result may indicate that hydroxyproline modification process may be down-regulated in those patients. Although many explanations can be given in biochemical level for this observation, it is evident that Hyp content might represent an important index in repair and healing, based on the fact that stable and qualitative collagen is important for post-surgical projection.

## CONCLUSION

The clinical outcome of the patients in this study was not related to histological or biochemical findings of their torn rotator cuff. We believe that the satisfactory clinical outcome that was obtained was the result of the meticulous surgical reconstruction and careful postoperative rehabilitation.

The extensive statistical analysis of this study, showed no significant correlation between the abnormal Hyproxyproline content and all of the other histological parameters that was examined except hyaline degeneration which was under-represented in patients with abnormal Hyproxyproline content. There was no significant correlation between the Hyproxyproline content and the age or the sex of the patients. Finally there was no significant correlation between the histological-biochemical findings and the clinical outcome. However, all these statistical conclusions could be attributed to the limited number of patients that were included in the present study. New studies including a larger number of patients could reveal significant variations within patients with different levels of tissue damage.

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