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# The effect of debridement performed before capsular plication on biomechanical properties of the knee joint capsule: an experimental study in rabbits

## *Plikasyondan önce debridman uygulamasının diz kapsülünün biyomekanik özelliklerine etkisi: Tavşanda deneysel çalışma*

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**Amaç:** Plikasyon uygulanan eklem kapsülünde ameliyat sonrası erken dönemde meydana gelen biyomekanik değişimler araştırıldı ve debridman ile kapsül iç yüzünde kanamalı bir yüzey oluşturulmasının iyileşme üzerine etkisi değerlendirildi.

**Çalışma planı:** Elli dört yetişkin Yeni Zelanda beyaz tavşanının 48'inin tek taraf diz medial eklem kapsülüne tek başına (n=24) ya da debridmanla kapsül iç yüzünde kanamalı bir yüzey oluşturulduktan sonra (n=24) plikasyon yapıldı. Altı tavşanın sağlam dizi kontrol grubunu oluşturdu. Ameliyat sonrasında tavşanların dizleri tespit edildi. Debridman uygulanan ve uygulanmayan gruplarda altışar tavşanın yaşamı sırasıyla ameliyattan hemen sonra, birinci ikinci ve üçüncü haftalarda sonlandırıldı. Her altgrupta beş tavşan mekanik testler için, bir tavşan ise histolojik değerlendirme için kullanıldı.

**Sonuçlar:** Deney gruplarında kopma kuvveti üçüncü haftaya kadar kontrol grubundan yüksek bulundu ($p<0.01$). Bu fark üçüncü haftada ortadan kalktı ($p>0.05$). Ayrıca, birinci haftadaki kopma kuvveti, ikinci ve üçüncü hafta sonuçlarından anlamlı derecede yüksekti ($p<0.01$). İkinci ve üçüncü hafta arasında anlamlı fark saptanmadı ($p>0.05$). Debridman uygulanmayan gruba göre, debridman uygulanan grubun birinci haftadaki kopma kuvveti belirgin olarak daha azdı ($p<0.01$). Bu fark ikinci ve üçüncü haftalarda gözlenmedi ($p>0.05$). Histolojik örneklerde deney gruplarında tüm haftalarda benzer bulgular elde edildi; birinci haftadan itibaren her iki grupta da artan fibrozisle birlikte iyileşme gözlendi.

**Çıkarımlar:** Plikasyondan sonra kapsül, sağlam kapsülden daha zayıf değildir. Debridmanla daha hızlı veya daha iyi iyileşme olduğu gösterilememiştir. Debridman kapsülün biyomekanik özelliklerini olumsuz etkileyebilir.

**Anahtar sözcükler:** Artroskopi; eklem kapsülü/cerrahi; eklem instabilitesi/cerrahi; tavşan; omuz eklemi/cerrahi; germe kuvveti; yara iyileşmesi.

**Objectives:** The purpose of this study was to evaluate early postoperative biomechanical changes in plicated joint capsules and to determine the effect of debridement to create a bleeding inner capsular surface on the healing process.

**Methods:** Fifty-four mature New Zealand white rabbits were used. Plication was performed in unilateral medial knee joint capsules of 48 rabbits either alone (n=24) or following debridement (n=24) to create a bleeding inner capsular surface. Six rabbits remained untreated for the control group. The operated knee joints were immobilized in flexion postoperatively. The rabbits from the two study groups were sacrificed in groups of six immediately after operation, in the first, second, and third weeks, of which five were evaluated in tensile tests and one was evaluated histologically.

**Results:** Compared to the controls, tensile strengths were significantly higher in both study groups until the third week ($p<0.01$), after which the difference became insignificant ($p>0.05$). The strength of the plicated capsules was significantly higher in the first week in both study groups than those measured in subsequent weeks ($p<0.01$), whereas similar tensile strengths were recorded in the second and third weeks ($p>0.05$). Compared to its absence, the use of debridement was associated with a significantly lower strength in the first week ($p<0.01$), but this difference was not observed afterwards ($p>0.05$). Histological findings were similar in the two study groups and were characterized by healing with increased fibrosis starting from the first week.

**Conclusion:** A plicated capsule would not be weaker than an intact one. Our findings do not favor debridement for a more rapid and better healing process. Rather, it might have adverse effects on the biomechanical properties of the capsule.

**Key words:** Arthroscopy; biomechanics; joint capsule/surgery; joint instability/surgery; rabbits; shoulder joint/surgery; tensile strength; wound healing.

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Capsular laxity has been proposed as the cause of multidirectional instability of the shoulder.[1] Primary management of this condition is usually a trial rehabilitation program. When nonoperative treatment fails, either open or arthroscopic stabilization with inferior capsular shift procedure has been recommended.[1,2] Capsular redundancy has also been implicated as a contributor to traumatic, unidirectional shoulder instability. Failure to address the capsular laxity in the treatment of anterior instability has been suggested as a cause of the high failure rates initially reported for arthroscopic Bankart procedures.[3,4] Arthroscopic capsular plication is one method of treating excessive capsular laxity.[2,5-8] To provide a better healing potential to the synovial inner surface of the capsule, before plication, debridement of this area until bleeding tissue is obtained, is recommended.[2,5,8-10] Cadaveric studies indicate that suture plication is effective in reducing glenohumeral intraarticular volume.[11,12] However, there is little information on the capsular healing after plication and effect of the debridement on the capsular healing process. Tensile properties of the plicated capsule are of utmost importance for the timing of postoperative rehabilitation protocols. Postoperatively, most current protocols include an early immobilization period of at least 3 weeks even for isolated capsular plications, assuming an acute decrease in the failure load of the capsule.[8,13,14] The biomechanical changes that occur with healing after capsular plication have not been questioned in experimental studies yet. The aim of this in vivo study is to evaluate time-dependent changes of biomechanical properties of the plicated capsule in early postoperative period and determine the effect of the debridement on the healing process. We hypothesized that the mechanical and histologic properties of capsule after plication were similar between debrided and non-debrided groups.

## Materials and method

The study group consisted of 54 adult New Zealand white rabbits. Capsular plication to the medial patellar retinacular area of the knee joint capsule in vertical plane was applied in unilateral knees of randomly selected rabbits. In 24 knees of 48 rabbits, synovial debridement was added before plication, while in the other 24 knees only plication was applied. Six intact knee specimens of 6 rabbits constituted the control group. After the surgery, operated knees were immobilized. The rabbits were divided into two groups. In one group abrasion was performed and not in the other. Both groups subsequently were randomly devided into three sub-groups (n=6 in each group) and were sacrificed immediately after surgery, in the first, second and third week. One animal in each group was taken for histological evaluation without a tensile test, and the remaining five animals were used for biomechanical tests. After the failure tests, histological evaluation was performed to all specimens.

### Surgical technique

Surgical procedures were performed in an animal surgical laboratory under sterile conditions. All animals were premedicated with an intramuscular dose of ketamine (50 mg/kg) and xylazine hydrochloride (5 mg/kg). Rabbits were anesthetized with halothane, oxygen, and nitrous oxide inhalation via a mask. One leg of the rabbits was shaved and disinfected with 10% iodine solution. One dose of cefazolin sodium (50mg/kg) was used for infection prophylaxis.

A 5 cm long anterior longitudinal incision was made. Subcutaneous tissues were dissected bluntly between muscle planes to minimize any soft tissue injury. The medial knee capsule was exposed. A stab incision was made in the upper part of the medial patellar retinacular area of the knee joint to the midpoint between medial collateral ligament (MCL) and quadriceps tendon. In the group in which the knee capsule was debrided, a meniscus repair rasp (Arthrex, Naples, FL) inserted from the stab incision and capsule was debrided until a bleeding tissue was obtained. Through the same incision a haemostatic forceps (pean/straight, Aesculap Inc. USA) was inserted without damaging the capsule. Two horizontal mattress sutures were applied in standard manner over the forceps in order to stitch the capsule (Figure 1a). For capsular plication, a #0 monofilament synthetic absorbable suture (PDS, Ethicon Inc, Somerville, NJ., USA) was used. The horizontal mattress sutures were applied one cm apart. After placement of the sutures, the forceps was pulled out and plication was applied in the middle of MCL and patellar bone (Figure 1b). This resulted in a capsular plication of approximately 0,5 cm. In the control group a haemostatic forceps (pean/straight, Aesculap Inc. USA) was only inserted from the stab incision and pulled-out. An additional surgical intervention was performed for immobilization of the operated knee joint as described previously (Figure 1c) [10] For this purpose a #5 braided non-

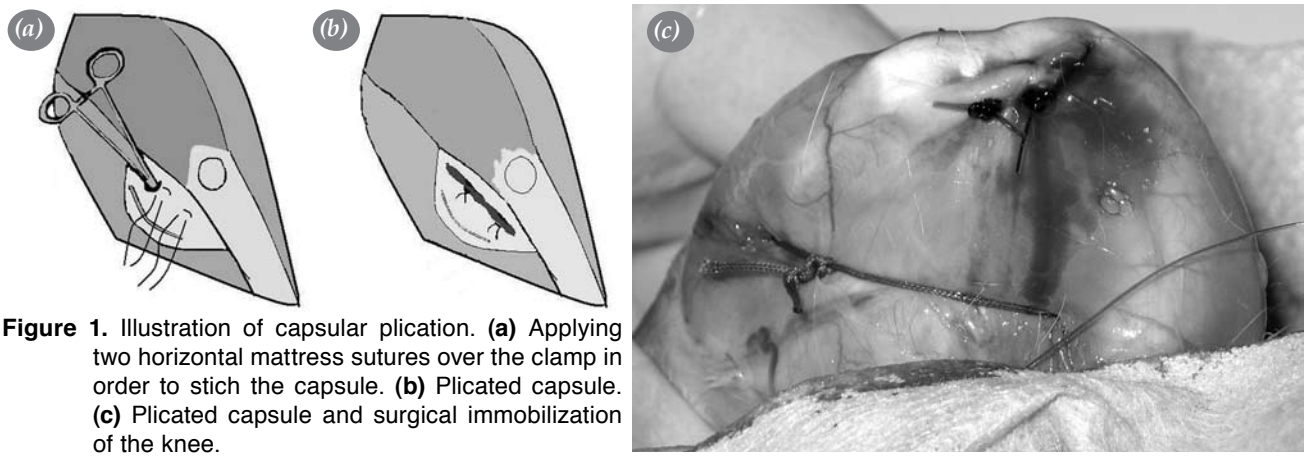


**Figure 1.** Illustration of capsular plication. **(a)** Applying two horizontal mattress sutures over the clamp in order to stich the capsule. **(b)** Plicated capsule. **(c)** Plicated capsule and surgical immobilization of the knee.

absorbable suture (Ethibond, Ethicon Inc, Somerville, NJ, USA) was passed anterior to the femur, beneath the rectus femoris muscle proximally and between the anterior tibia cortex and extensor muscle group distally. The suture was tightened while the joint was held in a maximally flexed position. The skin was closed using #3-0 monofilament non-absorbable sutures (Prolene, Ethicon, Somerville, NJ, USA). In the group in which the knee capsule was not debrided, the same procedure was applied except for the debridement before the plication. The rabbits were held in separate cages, fed a regular diet and observed daily for mortality and clinical signs of complications.

**Sample preparation**

Animals were sacrificed with an overdose of sodium pentobarbital. Hip joints were disarticulated on the operated side. All soft tissues except the medial joint capsule of the knee were dissected leaving only the medial joint capsule between the femur and tibia intact. MCL, quadriceps tendon, patellar bone and patellar tendon were cleaned off from the specimen and a capsular band of 1 cm width including the plicated area between MCL and patellar bone was prepared. Five of the obtained samples were evaluated for failure strength tests of the capsule and one sample was placed in 10% buffered formalin in preparation for histological evaluation in each group.

**Failure tests**

Failure tests were performed on the same day. The specimens were kept in a moist environment between killing and testing procedures using wet gauze soaked in saline solution.A universal testing machine was used for the failure tests (TecQuipment Ltd, Model/ Serial No: SM 100/J1007/4, Nottingham, England). The proximal femur and distal tibia were cleaned of all remaining soft tissues and crossing K-wires were inserted. Later the femur and tibia bones were embedded in plastic cylindrical frames using polyester resin. The plastic cylinders were mounted to the universal testing machine so that the bones formed a 60˚ angle in order to apply a longitudinal force on the plicated capsule. (Figure 2). The specimens had no preloading when installed. At a crosshead speed of 30 mm/min, tensile load was applied to the tibia and femur. The load values were collected via a load cell (Esit SPA 20 kg, SN: 836) at the data collecting system (ESAM, ESA Messtechnik GmbH, "Traveler Plus – Compu-

**Figure 2.**Specimens are mounted to the universal testing machine.

Table 1. The effect of debridement on biomechanical properties of the knee joint capsule, an experimental study in rabbits.

| | Debridement | Inflammatory infiltration | Vascularity | Fibrosis | Granuloma formationde | Mucinous generation | Fat necrosis |
|---|---|---|---|---|---|---|---|
| 0 Sample (Control) | | 0.16 | 0.16 | 0.16 | 0 | 0.33 | 0.50 |
| 1 Week | No | 1.20 | 1.00 | 0.80 | 0 | 0.60 | 0.60 |
| | Yes | 1.00 | 0.80 | 0.80 | 0 | 1.00 | 1.20 |
| 2 Week | No | 1.66 | 1.16 | 1.83 | 0 | 0.60 | 1.16 |
| | Yes | 1.16 | 1.66 | 2.16 | 0 | 1.00 | 1.33 |
| 3 Week | No | 2.16 | 2.00 | 2.00 | 0.16 | 0.50 | 1.16 |
| | Yes | 2.16 | 2.16 | 2.16 | 0.16 | 0.33 | 1.00 |

0: None; 1: Mild; 2: Moderate; 3: Severe.

ter Controlled Signal Condition Amplifier System") in real time at 100Hz and recorded in the computer. Testing was continued at constant speed until the point of failure of the specimen. The data collected in the computer was processed using ESAM 3 software. Maximum load to failure was recorded and a load – elongation curve was drawn for each specimen.

### Histological Evaluation

The samples used for the histological evaluation were obtained from the area between the two sutures. The same pathologist, who was blinded to the type of the procedure, performed the evaluation. Tissue samples were fixed in 10% formalin solution and paraffin-embedded. Three cross-sections of 4$\mu$m in thickness were produced and stained with haemotoxylin and eosin (H&E). Tissue sections were evaluated qualitatively by light microscopy in terms of inflammatory infiltration, vascularity, fibrosis, mucinous degeneration and fat necrosis (0: none, 1: mild, 2: moderate, 3: severe).[15]

### Statistical Evaluation

Mean values, standard deviations and standard errors were calculated for each of the three test groups, namely debrided group, non-debrided group and control group. Differences between the failure loads of groups were assessed using non-parametric tests, since there were relatively small numbers of samples in each group. Since more than two groups were compared, Kruscal-Wallis test was used to investigate significant differences between groups. Mann Whitney U test was used as a post hoc test. A P-value of 0,05 was set as the level of significance.

## Results

### Histological findings

In all weeks, histological findings were similar for both debrided and non-debrided samples (Figures 3). Both groups demonstrated mild inflammatory infiltration and vascularity in the first week. In the second week, there was mild inflammatory infiltration and increased vascularity in the debrided side while there was slightly increased inflammatory infiltration and mild vascularity in the non-debrided side. However these differences disappeared in the third week and moderate inflammatory infiltration and vascularity were observed in the both sides. When the samples were evaluated in terms of fibrosis, findings were also

**Table 2.** Results of tensile strength tests

| | | Week 1 | | Week 2 | | Week 3 | |
|---|---|---|---|---|---|---|---|
| | | Debridement | | Debridement | | Debridement | |
| Sample | Control | No | Yes | No | Yes | No | Yes |
| 1 | 26.7 | 124.4 | 52.6 | 49.0 | 48.0 | 25.0 | 23.0 |
| 2 | 26.6 | 130.5 | 38.2 | 54.0 | 63.0 | 49.0 | 34.6 |
| 3 | 20.3 | 82.8 | 39.8 | 59.0 | 49.0 | 37.0 | 35.7 |
| 4 | 34.3 | 115.8 | 67.7 | 82.0 | 26.0 | 59.0 | 37.0 |
| 5 | 31.6 | 91.9 | 63.6 | 38.0 | 46.0 | 53.0 | 35.6 |
| Ort±SS | 27.9±5.4 | 109.1±20.8 | 52.4±13.4 | 56.4±16.3 | 46.4±13.2 | 44.6±13.6 | 33.2±5.8 |

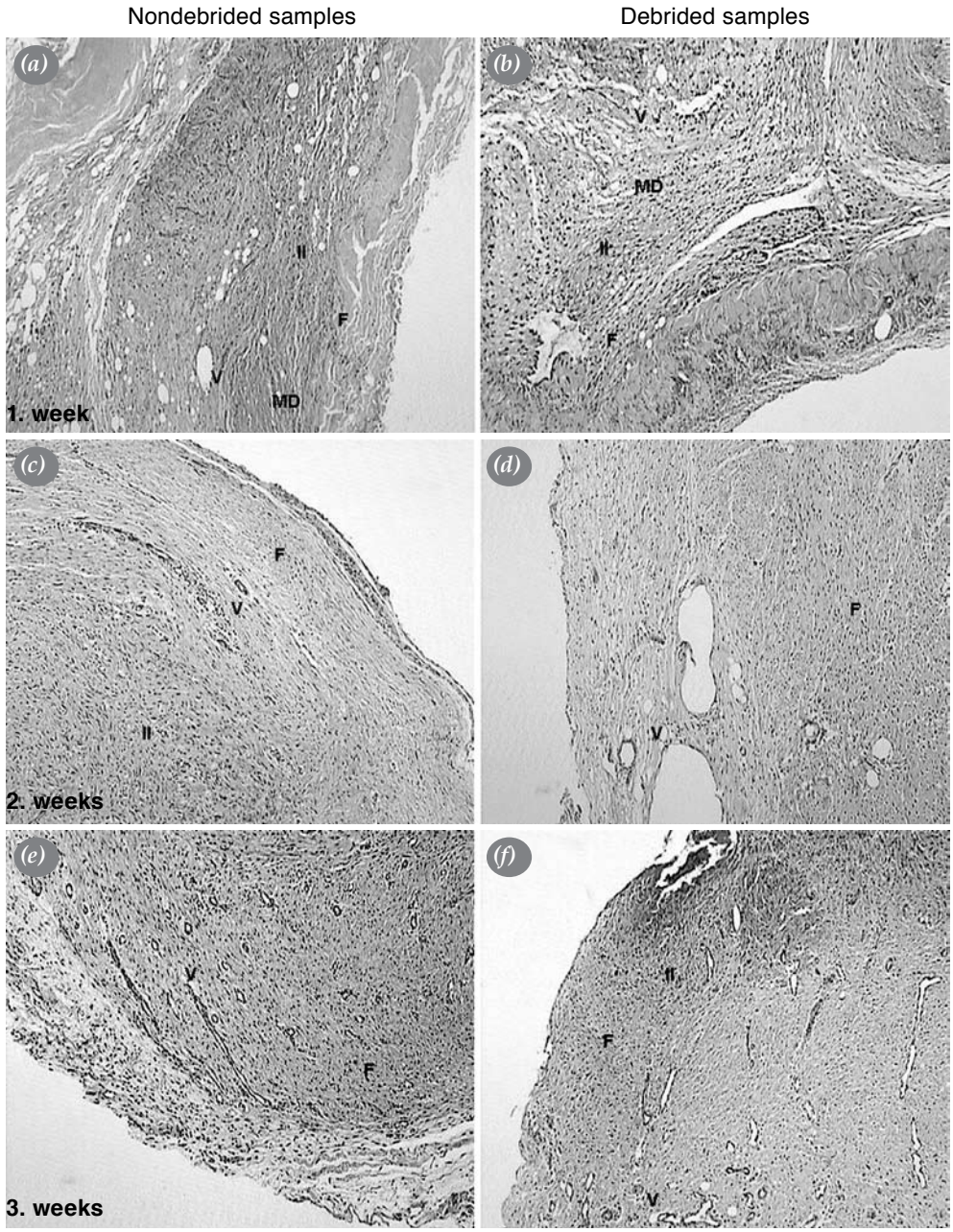


**Figure 3.** Histologic sections. **(a-b)** Mild inflammatory infiltrate (II), vascularity (V). and fibrosis (F), moderate mucinous degeneration (MD) present in both samples.**(c-d)** Mild inflammatory infiltrate in both samples, vascularity mild in left and moderate in right. Fibroblast-collagen severe in left and moderate in right. **(e-f)** moderate inflammatory infiltration and vascularity and severe fibroblast-collagen in both samples.

similar in both groups. From the first week onwards, healing was paralleled by fibrosis. Numerical results of qualitative evaluation of histological sections are given in Table 1.

**Biomechanical evaluation**

During the study period, failure load results of all operated groups remained higher than the knee capsules in control group. The results of tensile strength tests can be seen in Table 2 and Figure 4.

When the non-debrided knee joint capsule tensile strength was compared to the capsule in the control group, the non-debrided knee tensile strength was significantly higher than the control immediately after surgery ($p<0.01$), in the first ($p<0.01$) and second

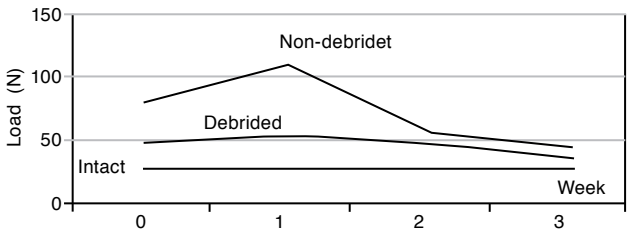


**Figure 4.** Graphic representation of tensile test results.

weeks ($p<0.01$) but this difference disappeared in the third week ($p>0.05$).

When the non-debrided knee joint capsules were evaluated, there was no significant difference between tensile strength immediately after surgery and the other three weeks ($p>0.05$). However, the tensile strength of the first week was significantly higher than the results of the second ($p<0.01$) and third weeks ($p<0.01$). There was no significant difference between week 2 and week 3.

When the debrided and the non-debrided knee joint capsules were compared, there was no significant difference between both groups immediately after operation. However, tensile strength of the debrided side was significantly weaker than the non-debrided side in the first week ($p<0.01$). This difference was not observed in the 2nd and 3rd weeks.

When the debrided knee tensile strength was compared to the capsule in the control group, the debrided knee tensile strength was significantly higher in week 1 ($p<0.05$). This difference disappeared in the second and third weeks.

When the debrided knee joint capsules were evaluated, there were no significant differences in tensile strength between week 0 and the other three weeks. A significant difference was also not found between week 1 and week 2 results, and week 2 and week 3. However, the tensile strength in the first week was significantly higher than third week results ($p<0,01$).

## Discussion

Results of this experimental study have shown that the tensile properties of the plicated capsule are not decreased, but increased within the first postoperative 3 weeks. This difference was statistically significant beginning from early postoperative period for both the debrided and non-debrided groups. The increase in the failure load was most prominent in the first week and was decreasing in the following weeks. This difference is likely related to the suture plication itself, but not to the healing of the tissues.

There was no significant difference in failure tests immediately after operation (Week 0) between debrided and non-debrided sides. However, failure tests in the first week showed that debridement of the capsule before suture plication can result weakened the capsule significantly. The debrided capsule remained weaker for the next two weeks. Negative effects can be expected on the biomechanical properties of the capsule after debridement.

In our study, healing by fibrosis was observed in all groups. Debrided group showed increased vascularity in the second week, while all other histological parameters were similar. Kelly reported healing by fibrosis previously in his in vivo animal study [16], comparing open shift and arthroscopic plication techniques. Although his study was not designed to investigate the effects of debridement, the authors recommended including capsular abrasion in the surgical technique, conclusively. According to our findings, we cannot support the hypothesis that debridement is mandatory for capsular healing in capsular plication. Even suturing the capsule itself can probably be enough to launch healing response. The capsular thickness, plication technique and postoperative immobilization protocols are specific to this study, thus numerical results may not be directly transferred to clinical practice. However quantitative relations of failure load results can be projected to clinical applications.

The traditional postoperative protocols recommend a protective approach with some degree of immobilization .[8,13,14] The results of this study have suggested that the period for postoperative immobilization after capsular plication might be questioned. Future research in this area should address functional and biomechanical considerations to further delineate the role of immobilization after capsular plication.

According to the finding of this in vivo experimental study, the following conclusions can be drawn:

1. Plicated capsule, with or without debridement, is not weaker than the intact capsule.

2. Debridement of the synovial inner surface of the capsule is found to have negative effects on the biomechanical properties of the capsule in the first week.

3. Histological findings of healing were similar in both groups for all three weeks.

4. Debridement might not be alleviating a better or faster healing.

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