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der Medizinischen Fakultät Charité – Universitätsmedizin Berlin

DISSERTATION

Prospective clinical evaluation of the LHB-Score

zur Erlangung des akademischen Grades
Doctor medicinae (Dr. med.)

vorgelegt der Medizinischen Fakultät
Charité – Universitätsmedizin Berlin

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Datum der Promotion: 05.06.2016

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List of abbreviations

ACJI	Acromioclavicular Joint Instability Score
ADL	Activities of Daily Living
ASES	American Shoulder and Elbow Score
CS	Constant Score
LHB	Long Head of Biceps Tendon
ROM	Range of Motion
SLAP	Superior Labrum Anterior Posterior
UCLA	University of California at Los Angeles
WOSI	Western Ontario Shoulder Instability Index

Kurzzusammenfassung (Abstrakt)

Prospektive klinische Evaluation des LHB-Scores

Einleitung:

Der LHB-Score (engl.: Long Head of Biceps Tendon) wurde als Evaluationswerkzeug zur Kontrolle von Verlauf und Behandlungsergebnissen bei Patienten, die eine Bizepstenodese und –tenotomie erhalten hatten, entwickelt. Er besteht aus den Unterpunkten Schmerz (30 P), Krämpfe (20 P), Kosmetik (30 P) und Kraft (20 P). Ziel der Studie war die Evaluation des LHB-Scores an einem prospektiven Patientenkollektiv, um mit Hilfe prä- und postoperativer Ergebnisse Behandlungsfortschritte validierbar zu machen.

Material/Methoden:

Siebenundfünfzig Patienten (29 w/ 28 m, Ø Alter 61,0 J.), bei denen präoperativ der Verdacht auf eine Begleitläsion der LBS (lange Bizepssehne) bei Rotatorenmanschettendefekten, Impingement und/oder AC-Gelenksarthrose vorlag, wurden eingeschlossen. Ausgeschlossen wurden Patienten mit Schultersteife, Arthritis im Glenohumeralgelenk oder vorheriger Operation der LBS auf der Gegenseite. Bestätigte sich intraoperativ eine relevante LBS-Läsion, wurde diese mittels Tenodese oder Tenotomie versorgt. Konnte keine relevante Läsion festgestellt werden, wurde die Bizepssehne nicht adressiert. Die Patienten wurden prä- sowie ein und zwei Jahre postoperativ mittels Erhebung des LHB-Scores sowie des Constant Scores evaluiert.

Ergebnisse:

Sechsundzwanzig Patienten erhielten eine Tenodese (Gruppe I: Ø Alter 61,2 w/m = 8/18), 17 eine Tenotomie (Gruppe II: Ø Alter 64,2, w/m = 12/5) und bei 14 Patienten wurde die LBS nicht operativ versorgt (Gruppe III: Ø Alter 56,8, w/m = 9/5). Präoperativ erzielten die Patienten in Gruppe I 74,3 (41-97) P, in Gruppe II 73,4 (57-97) P und in Gruppe III 71,1 (58-80) P im LHB-Score. Postoperativ stiegen alle drei Gruppen signifikant ($p<0,05$) auf durchschnittlich 94,2 (80-100) P in Gruppe I, 84,2 (49-100) P in Gruppe II und 90,8 (70-100) P in Gruppe III an. Im Vergleich der postoperativen

Ergebnisse zeigten Patienten der Gruppe II signifikant schlechtere Ergebnisse im LHB-Score sowie im Unterpunkt Kosmetik.

Schlussfolgerung:

Die Evaluation mittels LHB-Score wird bei Pathologien der LBS empfohlen, da die LBS-spezifischen Unterpunkte wie Krämpfe, „Popeye“-Deformität, Flexionskraft und Schmerz im Sulcus bicipitalis den LHB-Score ein hilfreiches Werkzeug zur Beurteilung des Behandlungsverlaufs werden lassen. Neben LBS-Pathologien beschreibt der Score auch den allgemeinen Zustand der Schulter.

Schlüsselwörter:

LHB-Score, Bizepssehne, Tenodese, Tenotomie, Schulter, Ergebnisevaluation

Abstract

Prospective clinical evaluation of the LHB-Score

Background:

The LHB-Score was especially designed to assess the progress of patients who underwent a biceps tenodesis or tenotomy. It consists of the items pain (30 P), cramps (20 P), the patient- and examiner-dependent grading of the cosmetic result (30 P) and elbow flexion strength (20 P). The aim of this study was to evaluate the LHB-Score with the aid of a prospective collective of patients.

Methods:

Fifty-seven patients (29 f/ 28 m, Ø age 61.0 yrs) were prospectively included. All had symptoms that made a pathologic LHB (Long Head of the Biceps Tendon) likely. Moreover, rotator cuff tears and/or impingement were diagnosed. Patients with a frozen shoulder, glenohumeral arthritis or with previous surgery of the LHB of the contralateral shoulder were excluded. The clinical evaluation contained the Constant Score as well as the LHB-Score. Within this prospective study, the patients were scored preoperatively as well as one and two years postoperatively.

Results:

Twenty-six patients underwent biceps tenodesis (group I; 8 f/ 18 m, Ø age 61.2 yrs.), 17 had a biceps tenotomy (group II; 12 f/ 5 m, Ø age 64.2 yrs.) and 14 had neither (group III; 9 f/ 5 m, Ø age 56.8 yrs.). Before surgery, patients in group I scored 74.3 (41-97) pts., in group II 73.4 (57-97) pts. and in group III 71.1 (58-80) pts. on average. Significant increases ($p<0.05$) in each group were recognized postoperatively (group I 94.2 (80-100) pts.; group II 84.2 (49-100) pts.; group III 90.8 (70-100) pts.). There were significantly better outcomes ($p<0.05$) in the general LHB-Score and in the subitem “cosmetics” for the tenodesis patients compared to the tenotomy patients.

Conclusion:

We recommend that LHB pathologies are evaluated using the LHB-Score, since it provides biceps specific items like “Popeye” deformity, cramps and strength of flexion,

and illustrates clinical progress. Moreover, the LHB-Score describes the overall state of the shoulder as well.

Key words:
LHB-Score, biceps tendon, tenodesis, tenotomy, shoulder outcome measurement

1 Introduction

1.1 The biceps tendon – a generator of pain

Pathologies of the long head of the biceps tendon (LHB) may generate pain within the anterosuperior shoulder.[1] They can affect the supraglenoid tubercle, the intraarticular pathway of the biceps tendon, the pulley system at the entrance to the intertubercular sulcus and cause lesions in the groove.[2] Pain usually arises from LHB instability at its origin, the so-called SLAP complex ("superior labrum anterior posterior"), or the pulley system.[3]

Causes of these pathologies can be degenerative as well as traumatic.[2] Younger patients, especially overhead athletes, are more often affected by traumas and recurrent micro traumas, degenerative lesions and instabilities are usually found in patients who are older than 50 years.[2]

According to Habermeyer et al., 89.9% of patients with an arthroscopically diagnosed pulley lesion also showed involvement of the long head of the biceps tendon such as synovitis, subluxation, dislocation and partial or complete tearing.[4] They found that lesions of the pulley system, especially with concomitant supraspinatus and subscapularis tendon tears, significantly contribute to the development of an anterior superior impingement.[4] The result of a progressive pulley lesion is an unstable long head of the biceps tendon which may subsequently lead to impingement due to increased passive anterior translation and upward migration of the humeral head.[4]

Isolated lesions of the proximal biceps tendon occur rarely.[2] A tendinitis, partial lesion or instability of the biceps tendon are often associated with partial or total rotator cuff tears.[2] Rotator cuff pathologies usually overlap symptoms due to the long head of the biceps tendon.[2] Therefore, a precise preoperative differentiation is often difficult.[2] Nevertheless, it is necessary for an adequate treatment and thus reduction of pain and dysfunction of the shoulder.

1.2 The biceps muscle

1.2.1 Anatomy of the biceps muscle

It is necessary to have a detailed knowledge of the anatomy of the shoulder in order to understand its pathologies and to develop a precise diagnosis.[1]

The biceps muscle, innervated by the musculocutaneous nerve, is said to have two major functions deriving from its anatomy. It has two heads whose points of origin are the supraglenoid tubercle in respect of the long head of the biceps tendon and the coracoid process in respect of the short head of the biceps tendon. The LHB runs along the intertubercular sulcus. Both heads unite in the proximal third of the upper arm to form one muscle belly, inserting at the radial tuberosity via the distal bicipital tendon[5] (Figure 1).

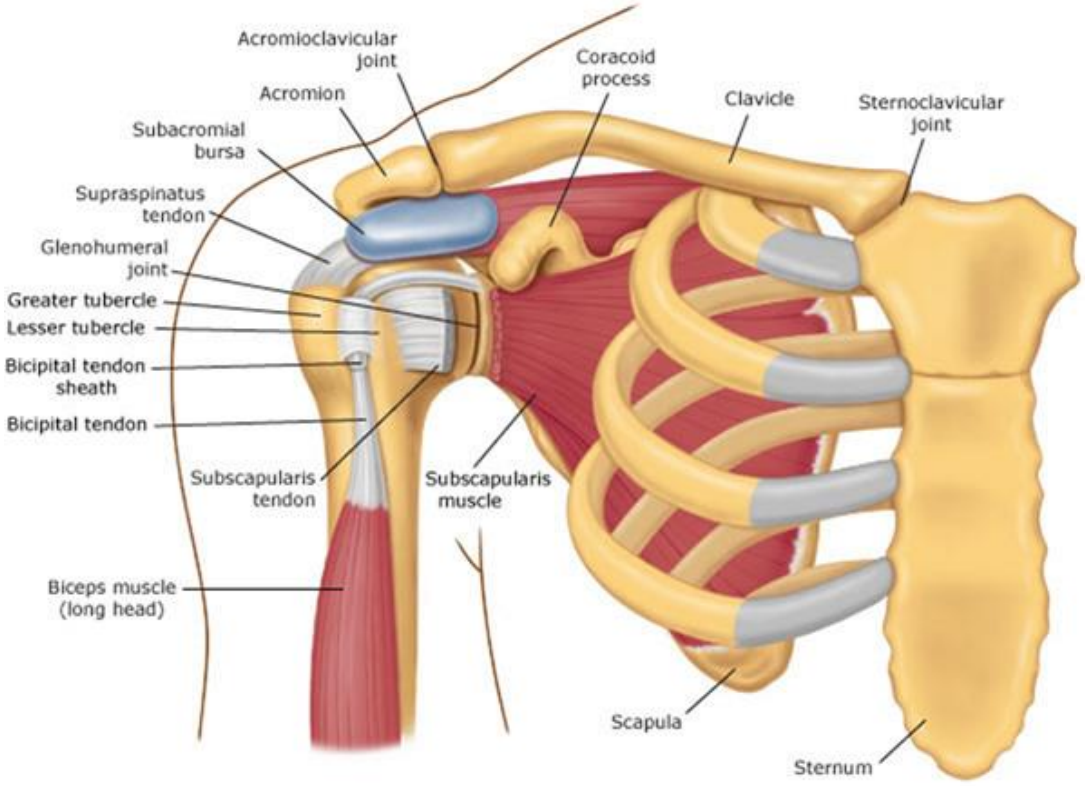

Figure 1[6]: Anatomy of the shoulder

1.2.2 Function of the biceps muscle

Due to its anatomy, the biceps muscle affects two joints. It anteverts, abducts, adducts and rotates inwardly in the glenohumeral joint.[5] The flexion of the forearm is supported by the brachialis muscle, the brachioradialis muscle, the extensor carpi radialis longus muscle and the pronator teres muscle (humeral head).[5] The biceps muscle, together with the supinator muscle, is most relevant for supination and for elbow flexion.[5] In elbow flexion it is the strongest supinator of the forearm.[5]
Since the biceps muscle is a big muscle, it contributes to the appearance of the arm. The relative impact on the outer shape depends on the extent of the biceps muscle and the amount of fat underneath the skin.[7]

1.2.3 Lesions of the long head of the biceps muscle

Some lesions of the biceps muscle can be diagnosed by simply inspecting the patient´s arm.[7] A so-called “Popeye” sign implies rupture or at least subluxation of the LHB.[7] Moreover, a distalization of the muscle belly can be due to an insufficient tenodesis.[7] If a biceps tenotomy has been performed, that can be another reason for a distal migration.[7] Some tenotomy patients do not show a “Popeye” sign because of auto-tenodesis.[7] An insufficient auto-tenodesis within the bicipital groove will cause a major “Popeye” sign, whereas a subluxation of the LHB out of the bicipital groove is not so apparent.[7]
Auto-tenodesis is a phenomenon which can occur after tenotomy due to the fact that the cut biceps tendon does not pass through the bicipital groove.[8] A hypertrophy of the intraarticular portion is called hourglass biceps and may cause pain in the anterior part of the shoulder and a restriction of final elevation.[9] If snapping, pain or loss of strength during rotation is experienced, this hints at an unstable LHB due to (sub)luxation.[7]

Rotator cuff tears are often accompanied by lesions of the long head of the biceps tendon.[10] Therefore, treatment of the LHB during surgery can be indicated as well. Rotator cuff tears can be caused by strain and heavy exertion. Consequently, the dominant arm is more likely to be involved in LHB pain.

1.3 History and clinical examination

LHB pathologies mostly start with unspecific symptoms and patients cannot name a specific occurance that caused it.[2] Patients describe pain in the area of the intertubercular sulcus.[11] The pain, spreading to the upper arm and cubital fossa, can be disruptive on exertion as well as at rest.[2]

Other than the history, a structured clinical examination is essential for a precise diagnosis.[12] Moreover, a good understanding of the examination maneuvers and their mechanisms will enable reliable findings.[12] Pain, loss of strength, decreased range of motion and instability are symptoms caused by different shoulder pathologies.[12]

Clinical examination should be done with the patient bare-chested.[2] Inspection of the skin and soft tissues can show muscle atrophy as well as distalization of the biceps muscle belly.[2]

Evaluation of active and passive movement for abduction, flexion/elevation, external rotation and internal rotation is carried out.[2] A combination of external rotation and abduction usually provokes pain.[2,13]

DePalma states that the most characteristic sign of a lesion of the long biceps tendon is tenderness on pressure along its course through the glenohumeral joint and within the sulcus[13] (Figure 2). Also, movements stretching the tendon produce pain.[13]

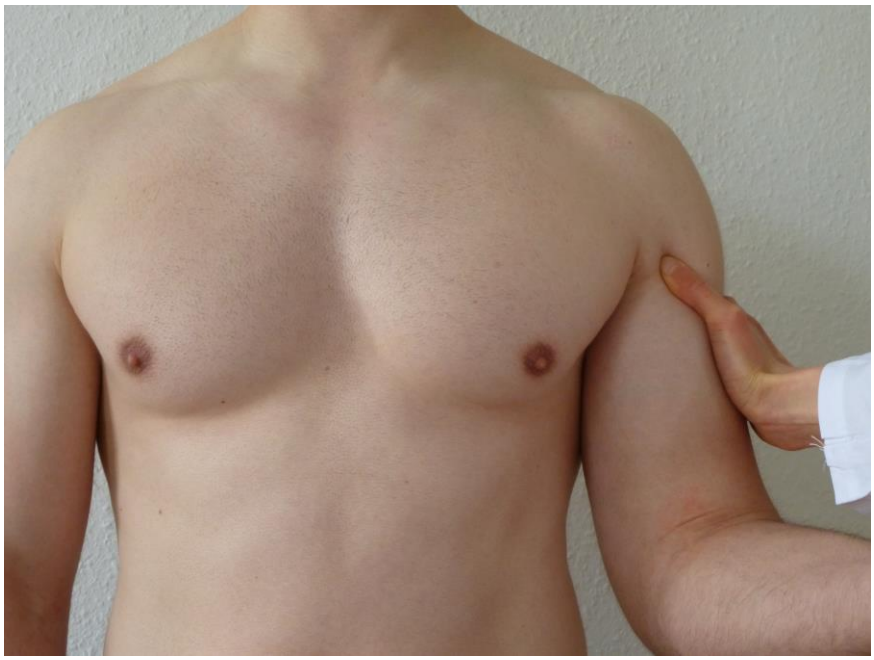

Figure 2: Tenderness over the bicipital groove

As mentioned by Ejnisman et al., a jumping biceps tendon can be palpated during movement if the instability of the biceps tendon is distinct.[11]
Pain during palpation of the biceps tendon within the bicipital groove is an unspecific sign of LHB pathologies.[7] The Speed´s test, which is usually also positive for lesions of the rotator cuff, is more meaningful.[7,14]

For the Speed´s test, the patient is asked to press the forearm with an extended elbow and the palm facing upwards against the examiner´s hands [15] (Figure 3). People suffering from LHB lesions complain about pain in the area around the bicipital groove during this procedure.[15] Bennett suggested not to rely on a positive Speed´s test to make a diagnosis, but to use it as an aid.[15,16]

Figure 3: Speed´s test[16]

The O´Brien test (Active Compression test) is a further well-established test. Even though it is an established test for diagnosing lesions of the glenoid labrum, it usually turns out to be positive in the case of pulley pathologies as well.[4]
The examiner stands behind the patient. The patient flexes the arm 90° with an extended elbow and adducts the arm 10° to 15° medial to the sagittal plane. Moreover, the thumb points downward, internally rotating the arm. The examiner pushes the arm downward against the patient´s resistance (Figure 4). This maneuver is repeated with a

supinated arm (Figure 5). If pain, elicited during the first maneuver, is reduced during the second maneuver, the test can be said to be positive.[17]

Since this test also provokes pain in the acromioclavicular joint, patient and examiner have to distinguish between superficial pain (in the area of the acromioclavicular joint) and pain deep inside the shoulder.[17]

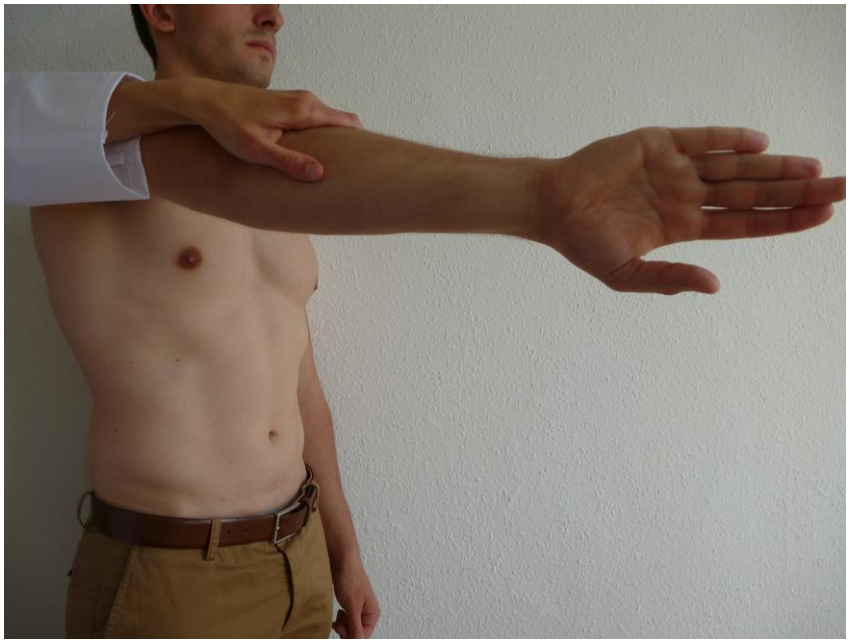

Figure 4: O´Brien test: First maneuver[17]

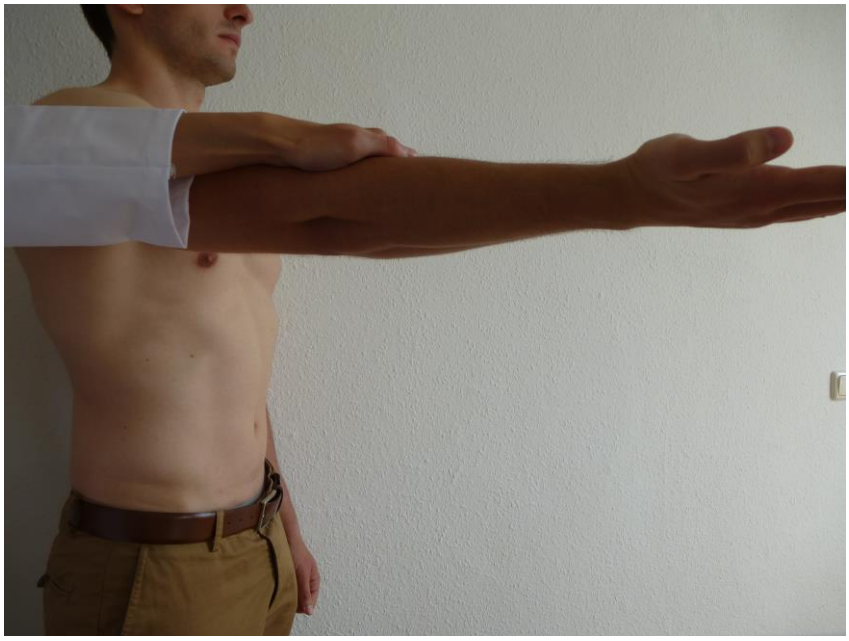

Figure 5: O´Brien test: Second maneuver[17]

This test is a pioneering tool in diagnosing SLAP lesions[7]. It can be associated with LHB pathologies[4] and might be an indication for surgical treatment of the biceps. However, Lafosse et al. report that the O´Brien test and the Speed´s test correlate only minimally with intraoperative findings.[18]
Shoulder pain originating from other structures might overlap with LHB specific symptoms. Injecting local anesthetics into the biceps tendon or its sheath can be helpful in differentiating these.[2,19]

1.4 Imaging modalities

Imaging modalities include standardized X-rays in at least two planes[2]. X-rays are usually normal when there are biceps pathologies only and therefore the primary aim of these standardized X-rays is to detect concomitant pathologies, particularly bone pathologies.[11]

Ultrasound is a cheap and readily available method allowing a dynamic examination of the LHB and the rotator cuff.[2] Armstrong et al. emphasized a specificity of 100% and a sensitivity of 96% concerning subluxation and dislocation of the LHB.[20] Moreover, ultrasound is an accurate method for the recognition of total ruptures of the biceps tendon.[21] However, it has low accuracy in respect of partial-thickness tears and non-tear abnormalities.[21]
MRI is a further method suitable for obtaining information about the biceps tendon with its SLAP complex and rotator cuff.[11] (Sub)luxation of the tendon from the intertubercular sulcus, ruptures, as well as severe tendinopathies can be seen.[2] Specific pathologies are more apparent if contrast medium is injected prior to scanning.[2] Even though it is difficult to detect tendinopathy or rupture of the biceps tendon with the aid of MRI, a correct diagnosis can be made by combining several MR criteria in two imaging planes.[22]

Arthroscopy is still the gold standard for diagnosing LHB pathologies.[11] As well as being able to precisely diagnose lesions, tendinopathies and instabilities of the LHB, it is also used to detect concomitant pathologies of the rotator cuff, of cartilages and the capsulolabral complex.[2] Moreover, the pathologies can be treated straight away.[2]

1.5 Options for treatment of pathologies associated with the LHB

1.5.1 Conservative treatment

The treatment depends on the existing pathology.[2] The treatment of symptoms arising from a sore LHB primarily includes adjustment of physical activities as well as the temporary use of NSAIDs and physiotherapy.[23,24]
Injections of local anesthetics and glucocorticoids can be administered either intraarticularly or into the tendon´s sheath.[2]
The duration of conservative treatment is adjusted depending on the existing pathology, the patient´s age, concomitant pathologies, profession, physical activity level and level of pain.[2]

1.5.2 Surgical treatment

If conservative treatment has failed and quality of life is reduced, surgical therapy is indicated.[2]
Whereas refixation of the SLAP complex and debridement is commonly accomplished arthroscopically, there are open, “mini open” and arthroscopic techniques for tenodesis of the LHB.[2] Keyhole tenodesis has been done successfully for decades.[25]

Arthroscopic suprapectoral tenodesis comprises cutting the LHB at its origin before affixing it to soft tissue or bone at the entrance to the intertubercular sulcus.[26] Scheibel et al. prefer the bony fixation because of significant advantages in the clinical and structural outcome.[26]
Both tenodesis and tenotomy have been proposed as treatments that have demonstrated good results in minimizing LHB associated pain.[27,28] Unlike tenodesis, tenotomy only comprises cutting the LHB.

Certain authors have dealt with the advantages and disadvantages of tenodesis and tenotomy to treat bicipital pain. According to Romeo et al., tenotomy is not only associated with deformities (“Popeye” sign) but also with spasms and a disadvantageous relationship between length and tension.[29] Nevertheless, both

tenotomy and tenodesis can successfully diminish LHB pain and reductions of function if a patient suffers from a biceps lesion due to an irreparable rotator cuff tear.[10] According to Boileau et al., there was no significant difference in the Constant Score or the patient´s level of satisfaction with regards to pain and the function of the shoulder regardless of whether a simple tenotomy or a tenodesis using an interference screw for intraosseous fixation was performed.[10] In 2005, Kelly et al. recommended the release of the LHB to patients with chronic, refractory biceps tendinitis, who mentioned fatigue as a further complaint.[30]
New arthroscopic techniques to treat shoulder pathologies are being published frequently.[31]

1.6 Scores

In order to document patients´ progress, a tool showing changes in health status is needed. A score is a point value for a patient´s condition ascertained by the examiner in a medical assessment.[32] Several diagnostic parameters are taken into account[32] allowing a subsumption of the patient´s condition and thus giving the physician a rough impression of the patient´s state. Nevertheless, a score cannot describe a patient well enough. Therefore, it does not replace a detailed physical examination.
Scores are used to classify injury severity, to evaluate therapies as well as follow-ups and to enable quality checks and quality assurance.[33] Based on measurements, they can be susceptible to disturbance variables but have to be practicable and reliable.[33]

Assessing and quantifying surgical results has always led to disputes.[34] Physicians can have different opinions about the method of examination. There are several existing tests for the LHB, for instance.[13,15,17] Each examiner might prefer different ones and would assess the importance of their outcomes as well as other symptoms a patient might complain about differently. Even patients themselves would not rate pain, function etc. the same way as another patient with the same complaints. Each person has an individual everyday life (occupation, spare time activities...) and different challenges to master. Interindividual differences have to be taken into account. However, these differences are accepted when talking about the usage and creation of scores, which offer many advantages.

Scores allow data to be more comparable. Comparisons of certain criteria between groups of patients, treatment in different hospitals etc. are much easier to make through the use of scores. Therefore, the need for standardized scores has been acknowledged and they are needed in clinics all around the world for better patient evaluation.[35-38] Examiners and physicians can more easily arrive at decisions about treatment. The importance of comparable data has already been acknowledged in the past.[32] In times of globalization, the importance of scores is increasing since comparisons improve the treatment of patients with the same, similar or even different symptoms.

Data about treatments and their results can be used for a certain patient collective with specific symptoms to choose the best treatment for other patients with similar characteristics. Scores are needed in many clinical fields and are used in different areas. Alongside diagnosis, prognosis and treatment, scores are also important for the collection of statistics.
In times of a growing flood of information, requests for the quantification of qualitative data have increased in efforts to improve information processing. That is why the number of scores has increased.[32]

Contemplating different kinds of information, the variables can be classified into demographic (age, gender and occupation), paraclinical (referring to laboratory tests, radiography and biopsies), therapeutic (treatments) and clinical (patient´s symptoms and concomitant diseases).[39] Feinstein described demographic, paraclinical and therapeutic data as “hard” and thus reliable and trustworthy, whereas clinical data is referred to as “soft”, not precise and it was therefore ignored in the early 1980s.[39]
The number and variety of clinical scores nowadays demonstrates that the impact of clinical data has clearly increased since then. The scores used in this study, namely LHB-Score and Constant Score, deal with clinical data in particular. Demographic data has been collected as well.
Feinstein claims that scientific studies have to deal with clinical data.[39] Indeed, he emphasizes that medicine is about the patient and his/her discomfort and thus about the fight against dehumanization.[39]
The use of scores is common among physicians, including for the evaluation of joints. Certain scores for the assessment of shoulders have been established. Constant Shoulder Score[35] and Oxford Shoulder Score[40] are commonly known. The Constant

Score[35], the Rowe Rating System[36], the UCLA Shoulder Rating System[37] and the ASES[38] belong to the most commonly used scores in literature.[31,41]
Apart from the overall function and condition of the shoulder, there are also scores dealing with specific details, for example the ACJI dealing with the acromioclavicular joint established by Scheibel et al.[42]

1.7 Long head of the biceps tendon (LHB)-Score

Several authors dealing with LHB pathologies use the Constant Score as well as other additional diagnostic criteria like the “Popeye” sign, tenderness over the bicipital groove and strength.[43,44] This demonstrates the need for a particular score describing function, pain, cosmesis and strength of the biceps tendon/muscle as a whole.
Many shoulder scores evaluate the overall shoulder state. Pain, strength and movement are often evaluated. But there is no commonly used score to describe the long head of the biceps tendon (LHB) in particular, other than the LHB-Score established by Scheibel et al. in 2011.[26]
The LHB-Score includes clinical criteria relevant for lesions of the LHB.[26]

1.8. Aim of the study

The purpose of this study was the evaluation of the LHB-Score. A prospective cohort study was set up, including patients with clinically suspected LHB pathologies. Those were intraoperatively divided into three groups, namely tenodesis patients, tenotomy patients and patients without biceps surgery.
Results of single subitems of the LHB-Score were investigated. Patients undergoing tenodesis and tenotomy were compared to each other and to patients who did not undergo any LHB-related surgery. Comparisons to the contralateral side and the score over time (preoperatively, one year and two years postoperatively) were evaluated as well as the results of the Constant Score.

2 Patients and methods

2.1 Patient demographics

Between November 2009 and January 2011, 57 patients (29 f/ 28 m, Ø age 61.0 yrs.) were prospectively evaluated using the LHB-Score. All patients had pathologies possibly demanding surgical LHB treatment (inclusion criterion) according to the clinical examination. Rotator cuff tears and/or impingement were diagnosed. Conservative therapy had failed in all cases. Patients with a frozen shoulder, glenohumeral osteoarthritis or who had already had a tenodesis or tenotomy of the contralateral shoulder were excluded (exclusion criteria). Charts were reviewed, data collected and patients interviewed to ensure that they met the inclusion and exclusion criteria.
Everyone included underwent clinical examination before surgery, as well as one year and two years afterwards. The LHB-Score and Constant Score were surveyed each time.

Patients with a strongly developed biceps muscle were more likely to have a tenodesis in order to avoid a “Popeye” sign. The surgeon decided in favor of a tenodesis in patients with high functional demand. Obese patients were more likely to get a tenotomy. If patients insisted on getting a tenodesis instead of a tenotomy, their request was considered.

2.2 Surgical procedures

Every patient was informed about risks and benefits of the operation. With their written consent, the patients underwent surgery under general anesthesia in a beach-chair position. The patients were treated according to the indication such as rotator cuff tears and subacromial impingement. The final decision whether a patient´s LHB needed treatment was made during surgery.
The procedure was standardized. The elbow was fixed in a hydraulic holding device (Spider, Tenet corp., Calgary, Canada). The bony landmarks were marked. A standard posterior portal was created for inserting an arthroscope into the glenohumeral joint in order to perform a diagnostic arthroscopy and evaluation of the LHB for any pathology.

An anteroinferior working portal was created. The portion of the LHB located within the bicipital groove can be examined by drawing the LHB into the joint. If treatment of the biceps tendon was necessary, a tenodesis or a tenotomy was performed before any other concomitant procedures. Further pathological changes in the glenohumeral joint were subsequently addressed.

Where a tenotomy was performed, the LHB was cut as close as possible to its proximal insertion at the superior labrum. The LHB often remains at the entrance of the intertubercular sulcus. Adhering to the surrounding structures there, it is called auto-tenodesis.

If a tenodesis was indicated, an anterolateral portal through the rotator interval was established, and the LHB was secured using a clamp. Possible pathologic remnants of the LHB were dissected.
A tenotomy was then performed close to the tendon´s origin. Holding the LHB with the clamp, the tendon was retrieved via an anterolateral portal and fixed epiosseously by performing a Krackow stitch with a No. 2 FiberWire® suture.[45] At the proximal end of the bicipital groove, a bleeding bone bed was prepared with a bur, and the LHB was fixed using a 4.5mm bioabsorbable knotless Pushlock® anchor (Arthrex, Naples, Florida). Concomitant pathologies were addressed afterwards.

2.3 Postoperative care

Talvosilen forte, a combination of Paracetamol and Codein, was given three times on the day after surgery. Further medication was provided if necessary, according to an appropriate standardized scheme. Rest and cooling was indicated for everyone. Twenty-four hours after surgery the bandage was supposed to be changed.

The following scheme is proposed especially for the postoperative care of tenodesis patients.
Lymph drainage and cryotherapy were indicated during the first and the second weeks after surgery beginning on day one.

Moreover, the patients were advised to wear a simple arm sling (shoulder immobilizer, DJO, Carlsbad, California) for three weeks. Active mobilization of the hand, passive mobilization of the elbow and mobilization of the scapula were performed on the first postoperative day. In addition, patients had to practice proper posture. Passive, symptom-adapted and active assisted mobilization, including flexion and abduction until 90°, external rotation until 30° and internal rotation until 60° was allowed during the first and the second postoperative weeks, beginning on day two after surgery. The physiotherapist needs to consider isometric activities, focusing on active centralization of the humeral head. Forced flexion and supination were forbidden. Heat packs were indicated from week two on. Working on free active range of motion (ROM), training of the rotator cuff and deltoid muscle began in the third postoperative week. No training against resistance with a long lever arm was allowed.
Sports-specific training was no longer prohibited from week six on. However, the surgeon´s permission was needed before resuming normal training. Individual pain levels and physical status were monitored.

The rehabilitation protocol was adjusted in accordance with ancillary treatment, such as rotator cuff repair. Patients with rotator cuff repair were allowed to perform exercises up to a flexion and abduction of 60° in the first three weeks and up to 90° in the following three weeks. External rotation and active internal rotation were prohibited within the first six weeks. Free passive range of motion and increasing symptom-adapted mobilization was allowed from week seven on. Slight deviations for patients with further indications had to be monitored. The patients were to be reexamined by the surgeon six weeks, six months, twelve months and 24 months postoperatively.

2.4 Functional evaluation

The follow-ups, including evaluation of the shoulder outcome measurements, were implemented after twelve and 24 months.
Clinical evaluation comprised items of the LHB-Score and the Constant Score, such as pain, cramps, cosmetic outcome, strength, range of motion and activities of daily living.
All postoperative examinations were performed by the author.

LHB-Score

The LHB-Score was designed as a tool to assess the progress of patients who underwent a biceps tenodesis or tenotomy. Consisting of three subitems, the LHB-Score covers with pain and cramps, cosmetic outcome and elbow flexion strength.[26] One hundred points can be achieved in total. Not only the affected side, but also the opposite side is evaluated[26] (Figure 6).

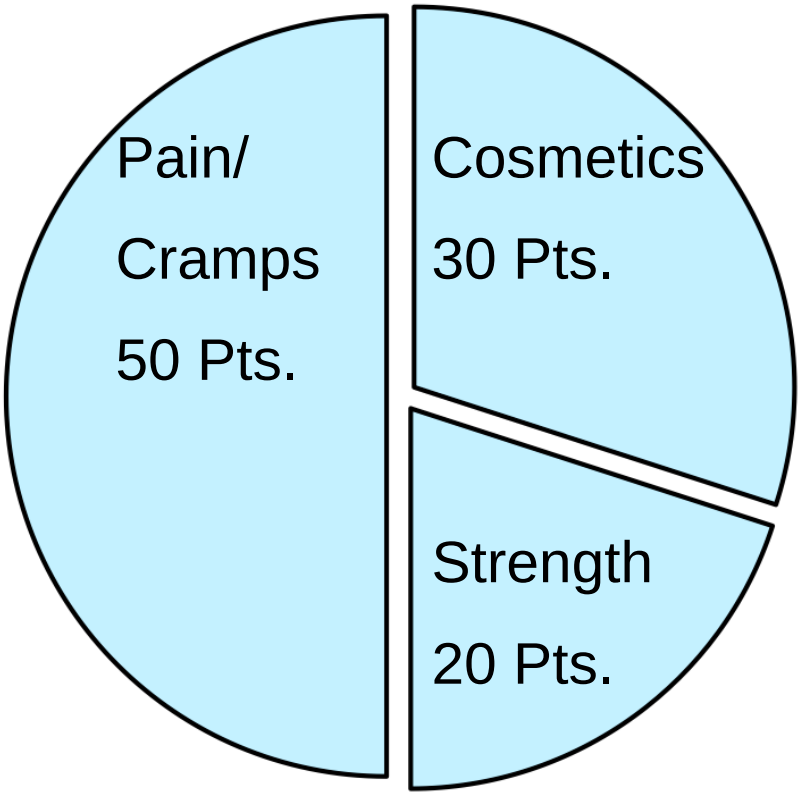

Figure 6: Distribution of points of the LHB-Score[26]

The biggest share of points pertains to pain and cramps.[26] Fifty points are recorded here only if patients have no complaints in this regard.[26] Ten points are allocated if there is no pain over the anterior shoulder.[26] A further ten points are given if there is no tenderness over the bicipital groove.[26] Another ten points are awarded for a painless Speed test.[26]

The Speed test is graded positive if the patient feels pain in the anterior part of the shoulder during elbow flexion against resistance.[16]

Evaluating pain on a scale from zero to ten, where zero means no pain and ten represents the strongest imaginable pain, the patient is given more points for less pain.[26] The final 20 points for pain are recorded if patients have no cramps in the biceps muscle.[26] Ten points are awarded if the patient has no cramps during exercise and ten points if they have no cramps even at rest.[26] Summarizing the first item, painlessness in all three categories is evaluated with 30 points and the absence of cramps is awarded 20 points.[26]

Whereas the pain and cramps item is subjectively evaluated by the patient, the second item concerning cosmetic effect is evaluated by the patient and the examiner.[26] Both of them can give equal points for the cosmetic appearance of the upper arm.[26] If no "Popeye" sign is seen, 15 points are given.[26] A mild deformity of the biceps muscle is assessed with ten points and a moderate distal migration of the biceps muscle only five points.[26] A severe "Popeye" deformity is rated with zero points.[26] It is important that both patient and examiner determine the amount of points independently so that a subjective and objective evaluation is possible.[26] For a standardized evaluation of the Popeye sign, the patients are supposed to hold the forearms at a 90° angle with the palms facing upwards. Furthermore, they are asked to tense their biceps muscles, since this position makes evaluation of a possible biceps deformity easier.[26]

The strength of the biceps muscle is rated with the same number of points as cramps. A maximum of 20 points can be given for elbow flexion strength.[26]
Wittstein et al. stated that there is no significant difference in peak torque and endurance for supination and elbow flexion strength, comparing the dominant and non-dominant arm.[46] The contralateral side can be used as a matched control when measuring biceps isokinetic strength.[46] Adjustments for handedness are not necessary.[46] Thus, the strength of the operated shoulder is rated with reference to the non-affected side in the LHB-Score.[26]
The shoulder undergoing no surgery is given a score of 20 points, whereas the affected side only scores 20°points if it achieves more than 90% of the contralateral strength. Sixteen points are recorded for between 80% and 90%, twelve points for between 70% and 80%, eight points for between 60% and 70% and four points for between 50% and 60% of the strength which is achieved by the healthy side.[26] If the strength of the

affected side power is 50% or less of that of the healthy side, zero points are given for that shoulder.[26]

This measurement is performed using a digital measurement device (Isobex® TM dynamometer, Medical Device Solutions AG, Burgdorf, Switzerland)[26] (Figure 7). The arm must not be pressed against the side of the body since this might falsify the measurement. It is also important to ensure that the elbow is kept at a 90°-angle. The maximum strength of each arm must be measured in order to use the data for comparison.[26] The examiner measures the strength of each side three times. Elbow flexion strength contributes another 20 points to the LHB-Score.[26]

Demographic information is noted as well.[26]

Figure 7: Flexion strength measurement

LHB-Score

Patient name: _____ Date of birth: _____

Date of examination: _____

Pain / Cramps (max. 50 points) right side left side

LHB-pain:

severe none

0 1 2 3 4 5 6 7 8 9 10

Tenderness over the bicipital grove:

severe none

0 1 2 3 4 5 6 7 8 9 10

Speed-Test:

severe none

0 1 2 3 4 5 6 7 8 9 10

Cramps:

0= at rest, 10= on exertion, 20= none

Cosmesis (max. 30 points)

Patient-dependent deformity

15= none, 10= mild, 5= moderate, 0= severe

Examiner-dependent deformity

15= none, 10= mild, 5= moderate, 0= severe

Elbow flexion strength (max. 20 points)

affected side	opposite side	%
_____ kg x 100	/ _____ kg =	_____

≤ 50 %	= 0
51-60 %	= 4
61-70 %	= 8
71-80 %	= 12
81-90 %	= 16
91-100 %	= 20

Total:

Constant Shoulder Score

Consisting of four categories, 100 points for each shoulder can be scored in the Constant Shoulder Score. This score was published by Constant et al. in 1987.[35] Evaluation of pain (max. 15 points), activities of daily living (max. 20 points), painless active movement (max. 40 points) and strength (max. 25 points) are recorded.[35]

For the first item, patients are asked about the most severe pain experienced during ordinary activities over a 24-hour period.[35] They are asked to rank it on a scale from zero points, representing no pain, to 15 points, standing for the strongest imaginable pain.[35]

“Activities of daily living” consist of four parts. Sleep, work, leisure and positioning are itemized.[35] Undisturbed sleep is given two points, disturbance every once in a while one point and sleep disturbed every night is given zero points.[35] Limitations at work due to one´s shoulder are classified from one point for severe reductions to four points for no impediments.[35] The same ranking system applies for leisure time activities.[35] All of the items previously explained are subjectively evaluated by the patient. Comfortably moving the arm only to one´s waist line achieves two points.[35] A further two points are recorded if the shoulder allows movement to the level of the xyphoid process.[35] An additional two points are scored for each of the following: moving the hand to one´s neck and to the head.[35] Ten points are given if the hand is comfortably used overhead.[35] All in all, four to 20 points are designed for activities of daily living.[35]

“Painless active movement” is categorized into flexion, abduction, internal rotation and external rotation.[35] If flexion of the arm does not go beyond 30°, no points are given.[35] Two points are given for each additional 30° achieved by the patient, resulting in a maximum of ten points for exceeding a flexion of a 150° angle.[35] Abduction is rated in the same way as flexion.[35] Two points are recorded if the patient is able to place the back of their hand onto their gluteal muscles.[35] Two more points are added for achieving each of the following levels: moving the dorsal hand to the lumbosacral junction zone, the waist line, the fifth vertebra and in between the scapulae, which is the highest level of internal rotation recorded in the Constant Shoulder Score.[35] If the

patient can place their hand on the back of their head with the elbow pointing forwards, two points are recorded for external rotation.[35] Further levels of external rotation in the Constant Score are the ability to put their hand on the back of their head with the elbow pointing downwards, on the crest of their head with the elbow pointing forwards and on the crest of the head with the elbow pointing downwards.[35] Each level is rewarded with two additional points, whereas total elevation with the hand on the crest of the head scores a total of ten points.[35] Optimal self-initiating movements without another person´s assistance in the absence of pain are represented by 40 points; ten points are given for each subitem.[35]

The fourth part of the Constant Shoulder Score deals with abduction strength.[35] For lifting less than one kilogram in an abduction position with the arm at an abduction angle of 90°, zero points are given.[35] A range of between one kilogram and two kilograms earns three points.[35] For every further kilogram two points are added.[35] This scale has been modified slightly compared to the original Constant Shoulder Score.[35] The measurement can be done using a digital measurement device (Isobex® TM dynamometer, Medical Device Solutions AG, Burgdorf, Switzerland).[35]
Contrary to the LHB-Score, which measures elbow flexion strength, the patient´s abduction strength is measured in the Constant Shoulder Score.[26,35]

2.5 Further information requested

Patients were also asked about their level of physical activity and their level of satisfaction with the surgery. Both items were evaluated subjectively by the patient and recorded in the form of points. No physical activity scored no points, moderate training scored one point and a lot of daily physical activity two points. If the patient was very satisfied, two points were assessed. One point was given for moderate satisfaction and no points for no satisfaction.

2.6 Statistical evaluation

Statistical evaluation was done using the Mann-Whitney U test to compare the groups and the Wilcoxon test to compare pre- and postoperative data within one group. The program SPSS (SPSS® Inc. Chicago) was used for the statistical analysis.
The level of significance was set at $p<0.05$.

3 Results

Twenty-six of 57 patients underwent biceps tenodesis (group I: 8 f/18 m, Ø age 61.2 years, range 44-76 years), 17 biceps tenotomy (group II: 12 f/5 m, Ø age 64.2 years, range 48-75 years) and 14 no surgical treatment of the LHB (group III: 9 f/5 m, Ø age 56.8 years, range 38-73 years). The first follow-up was after 12.3 months (range 11-14 months) on average. The data from 47 patients (26 f/21 m) could be evaluated after a mean follow-up of 24.2 months (range 23-26 months). Twenty-three patients in the tenodesis group (8 f/15 m, Ø age 61.3 years, Ø f/u 24.2 months), 16 patients in the tenotomy group (12 f/4 m, Ø age 63.6 years, Ø f/u 24.0 months) and 8 patients in the group without tenodesis/tenotomy (6f/2m, Ø age 58.5 years, Ø f/u 24.6 months) could be evaluated after two years. In the first group three patients, in the second group one patient and in the third group six patients were lost to follow-up due to denial or remote residence.

3.1 Dominant vs. non-dominant side

Approximately three out of four patients in the entire patient collective received surgery on their dominant shoulder (35 of 47 patients; 74.5%).
Eighteen of 23 (78.3%) tenodesis patients (group I) received surgery on their dominant arm, 12 of 16 (75.0%) tenotomy patients (group II) and 5 of 8 (62.5%) patients with neither tenodesis nor tenotomy (group III) were affected on their dominant arm.

3.2 Intraoperative findings and concomitant procedures

The most frequent pathology was a lesion of the supraspinatus tendon. It occurred in all patients, except in one from the third group. Other lesions of the rotator cuff were found as well. A lesion of the subscapularis tendon needing reconstruction was seen in 30.4% (7 out of 23) of tenodesis patients, in 31.3% (5 out of 16) of tenotomy patients and in 37.5% (3 out of 8) of patients who had neither tenodesis nor tenotomy. Lesions of the infraspinatus tendon occurred as well. They were reconstructed in 34.8% (8 out of 23)

of the first group, 12.5% (2 out of 16) of the second group and 25.0% (2 out of 8) of the third group. Moreover, 36 of 47 patients suffered from an impingement syndrome (73.9% of group I, 81.3% of group II and 75.0% of group III). A combination of several pathologies was often found.

Lesions associated more closely with the LHB such as tears of the LHB itself and pulley lesions were diagnosed intraoperatively. Partial or full-thickness tendon tears of the LHB were present in 17.4% (4 of 23) of tenodesis patients and in 31.3% (5 of 16) of tenotomy patients, whereas 69.6% (16 of 23) of tenodesis patients had biceps tendinitis and 50.0% (8 of 16) of tenotomy patients. Pulley lesions (30.4% (7 of 23) of tenodesis patients, 43.8% (7 of 16) of tenotomy patients) occurred more frequently than (sub)luxations of the LHB (30.4% (7 of 23) of group I, 12.5% (2 of 16) of group II).

3.3 Clinical results

3.3.1 LHB-Score

Preoperative results

Preoperatively, patients in group I scored 74.3 points (range 41-97 points), in group II 73.4 points (range 57-97 points) and in group III 71.1 points (range 58-80 points) on average, demonstrating similar starting conditions. These differences are not significant ($p>0.05$).

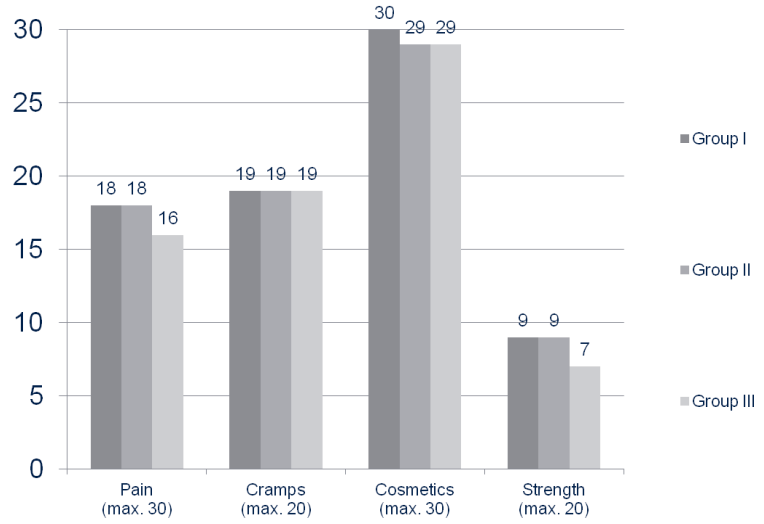

Figure 8: Subitems of the LHB-Score preoperatively

Comparing the three groups with each other, neither the total LHB-Score, nor the subitems differ significantly ($p>0.05$) (Figure 8). Most patients scored highly for the subitems “cramps” and “cosmetics”. There were only a few complaints about these. Less than half of the points available for “strength” were given and only a little more than half of the points available for “pain” were achieved on average. Thus, the main complaints were pain and loss of strength.

Postoperative results

The follow-up after one year showed significant increases ($p<0.05$) in each group. The first group had 90.1 points (range 48-100 points), the second 84.2 points (range 51-97 points) and the third 86.9 points (range 53-100 points) on average. Similar to the preoperative evaluation, these values do not significantly differ from each other ($p>0.05$).

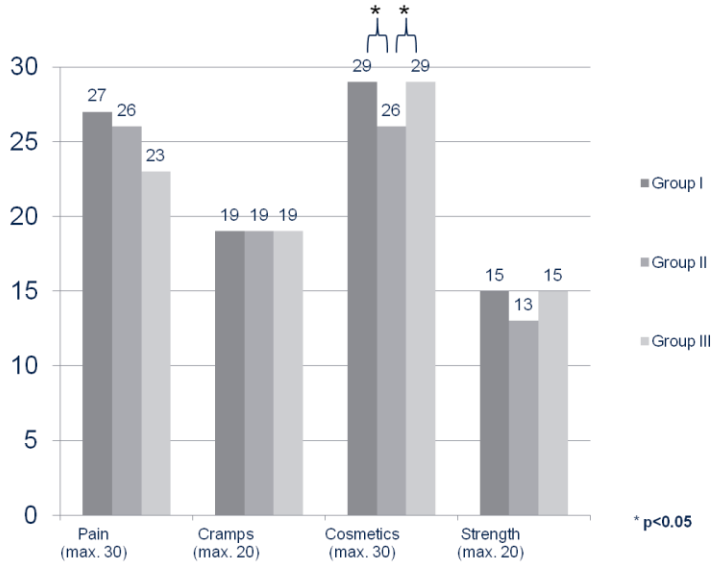

Figure 9: Subitems of the LHB-Score at the one-year follow-up

The results of each subitem are shown in figure 9. Patients in group II scored significantly less points for “cosmetics” compared to both of the other groups ($p<0.05$). The other differences are not significant ($p>0.05$).

At the follow-up after two years, group I achieved a significant increase again averaging 94.2 points (range 80-100 points) in the LHB-Score ($p<0.05$). For the subitems, an average of 29.4 points (range 25-30 points) was achieved for “pain”, 20.0 points for “cramps”, 28.9 points (range 20-30 points) for “cosmetics” and 15.8 points (range 0-20 points) for “strength”.

Group II showed an average LHB-Score of 84.2 points (range 49-100 points), which represents no significant increase compared to the one-year follow-up. Concerning the subcategories, an average of 27.8 points (range 15-30 points) was achieved for “pain”, 18.8 points (range 10-20 points) for “cramps”, 22.8 points (range 10-30 points) for “cosmetics” and 15.5 points (range 4-20 points) for “strength”.

Group III averaged 90.8 points (range 70-100 points) in the LHB-Score, which is a significant increase compared to the first follow-up ($p<0.05$). For the subitems, an average of 26.0 points (range 16-30 points) was achieved for “pain”, 20.0 points for “cramps”, 28.8 points (range 20-30 points) for “cosmetics” and 16.0 points (range 4-20 points) for “strength”.

Comparing the second follow-up values of the total LHB-Score for all three groups to each other, the outcome for the tenodesis patients was significantly better than for the tenotomy group (group I: 94.2 points (range 80-100 points) vs. group II: 84.2 points (range 49-100 points); ($p<0.05$). This significance was not seen at the one-year follow-up.

The comparison of the other groups at the two-year follow-up does not show significant differences, not even between the tenotomy patients (group II) and the patients without LHB surgery (group III) ($p>0.05$). The patients whose long biceps tendon showed no need for surgery (group III) do not demonstrate a better result than the tenodesis patients (group I). That is the case for postoperative values after one year as well as for those after two years (Figure 10).

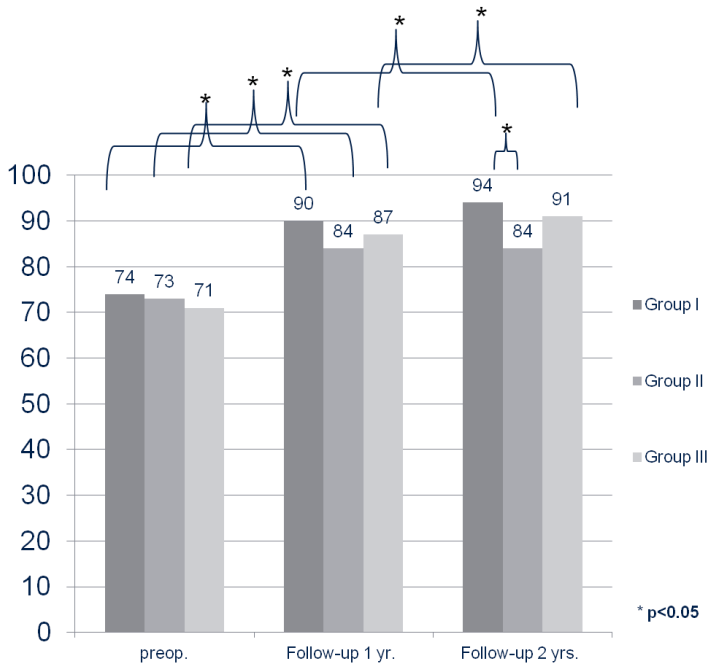

Figure 10: Total point values for the LHB-Score

The significant increases between preoperative values and the values of the two-year follow-up are not shown in figure 10 for visual display reasons.

Pain

The overall pain as well as the pain subcategories (“LHB-pain”, “tenderness over the bicipital groove” and “Speed test”) differ significantly ($p<0.05$) pre- and postoperatively at the one-year follow-up and pre- and postoperatively at the two-year follow-up for all three groups, except for the item “tenderness over the bicipital groove” for patients without LHB surgery ($p>0.05$). Table 1 shows the point values for group I (tenodesis), group II (tenotomy) and group III (without tenodeses/tenotomies).

		Group I	Group II	Group III
LHB pain (pts.)	Preoperative	5.9 (0-10)	6.2 (1-10)	4.1 (0-7)
	Follow-up 1 yr.	9.2 (5-10)	9.1 (5-10)	7.8 (1-10)
	Follow-up 2 yrs.	9.9 (8-10)	9.4 (5-10)	9.0 (7-10)
Tenderness over the bicipital groove (pts.)	Preoperative	6.2 (0-10)	6.3 (1-10)	5.8 (0-10)
	Follow-up 1 yr.	8.7 (2-10)	7.9 (2-10)	7.5 (0-10)
	Follow-up 2 yrs.	9.5 (5-10)	8.7 (2-10)	7.8 (3-10)
Speed test (pts.)	Preoperative	5.7 (0-10)	5.2 (0-10)	5.8 (2-10)
	Follow-up 1 yr.	9.6 (4-10)	9.1 (4-10)	8.1 (2-10)
	Follow-up 2 yrs.	10.0	9.7 (5-10)	9.3 (4-10)

Table 1: Pain subcategories for the LHB-Score

Cramps

For all patients included, all items of LHB- and Constant Scores showed a significant improvement in a comparison of pre- and both postoperative results, except for the subitem “cramps” in the LHB-Score (preop.: 19.1 points (range 10-20 points) vs. one-year follow-up: 19.1 points (range 0-20 points) vs. two-year follow-up.: 19.6 points (range 10-20 points)) ($p>0.05$).

No significant differences could be found looking at the pre- and postoperative results for group II (preop.: 18.8 points (range 10-20 points) vs. follow-up after one year: 18.8 points (range 10-20 points) vs. follow-up after two years: 18.8 points (range 10-20 points)) ($p>0.05$). One patient suffered from mild cramping during exercises before and

after surgery, another one had cramps only preoperatively and a third one only postoperatively.
The point value for group III was 19.3 points (range 10-20 points) preoperatively as well as at the follow-up after one year and 20.0 points at the follow-up after two years. This represented no significant change ($p>0.05$).
Group I improved significantly from 19.2 points (range 10-20 points) preoperatively to 20.0 points at the follow-up after two years ($p<0.05$).
At the second follow-up, there was neither a tenodesis patient (group I) nor a patient without biceps treatment (group III) complaining about cramps. Only two out of 16 tenotomy patients had cramps during strain (12.5%).

Cosmetics

Concerning the overall cosmetic results, group II demonstrated a significantly worse outcome compared to the other two groups at the second follow-up (group I: 28.9 points (range 20-30 points) vs. group II: 22.8 points (range 10-30 points) vs. group III: 28.8 points (range 20-30 points)) ($p<0.05$).

Four out of 23 patients (17.4%) treated with a tenodesis (group I) had a “Popeye” sign according to the examiner after two years. Three of them were mild (13.0%) and one was moderate (4.3%). Only one patient with a mild “Popeye” sign noticed it. Significant differences between the pre- and both postoperative values of group I are apparent (preop.: 30.0 points vs. 1 year postop.: 28.7 points (range 20-30 points) vs. 2 years postop.: 28.9 points (range 20-30 points)) ($p<0.05$).

Eleven out of 16 patients (68.8%) who underwent a tenotomy (group II) showed a “Popeye” sign (five mild (31.3%), six moderate (37.5%)). The results of group II differ significantly between pre -and both postoperative values as well (preop.: 29.1 points (range 20-30 points) vs. 1 year postop.: 25.9 points (range 20-30 points) vs. 2 years postop.: 22.8 points (range 10-30 points)) ($p<0.05$). Even the postoperative value of the two-year follow-up is significantly lower than the postoperative value of the one-year follow-up ($p<0.05$).
Three (18.8%) of 16 tenotomy patients (group II) who were evaluated at the second follow-up noticed a mild “Popeye” sign, whereas a moderate “Popeye” sign was obvious

to two of them (12.5%). Six patients (37.5%) had a “Popeye” sign, according to the examiner, without noticing it themselves. All in all, 68.8% of the tenotomy patients showed a “Popeye” sign at the two-year follow-up.

There are no significant differences between pre- and postoperative results for patients with neither tenodesis nor tenotomy (group III) ($p>0.05$). Nevertheless, two years postoperatively, one (12.5%) showed a moderate “Popeye” sign. It was not noticed by the patient herself.

Figures 11-14 show different cosmetic outcomes.

Figure 11: No “Popeye” sign

Figure 12: Mild “Popeye” sign at the right side

Figure 13: Moderate “Popeye” sign at the left side

Figure 14: Severe “Popeye” sign at the right side

At the second follow-up, a significant difference was apparent when group I and group II were compared. Both patient- and examiner-dependent results differ significantly ($p<0.05$). Group I scored 14.8 points (range 10-15 points) for patient-dependent and 13.9 points (range 5-15 points) for examiner-dependent cosmetic results, whereas group II averaged 12.8 points (range 5-15 points) for patient-dependent and 9.7 points (range 5-15 points) for examiner-dependent cosmetic results.
Only the examiner-dependent values of group II (9.7 points (range 5-15 points)) and group III (13.8 points (range 5-15 points)) differ significantly at the second follow-up ($p<0.05$). There are no significant differences between group I and group III when comparing patient-dependent and examiner-dependent evaluation of the cosmetic result pre- or postoperatively ($p>0.05$).

Strength

Elbow flexion strength significantly improved from pre- to postoperative in all three groups after one year (group I: preop. 8.8 points (range 0-20 points) vs. postop. 1 y. 14.8 points (range 0-20 points); group II: preop. 8.9 points (range 0-20 points) vs. postop. 1 y. 13.4 points (range 0-20 points); group III: preop. 6.9 points (range 0-20 points) vs. postop. 1 y. 15.1 points (range 0-20 points)) ($p>0.05$).

No significant improvement in strength could be found at the second follow-up compared to the first follow-up (p>0.05).
There was no significant difference in the elbow flexion strength of one group over another at the same time (preoperatively, first follow-up, second follow-up) (p>0.05).

3.3.2 Constant Score

Preoperative results

The Constant Score showed the following preoperative results: 41.7 points (range 20-70 points) in group I, 42.2 points (range 18-66 points) in group II and 45.7 points (range 22-77 points) in group III. The values of the subitems are shown in figure 15.

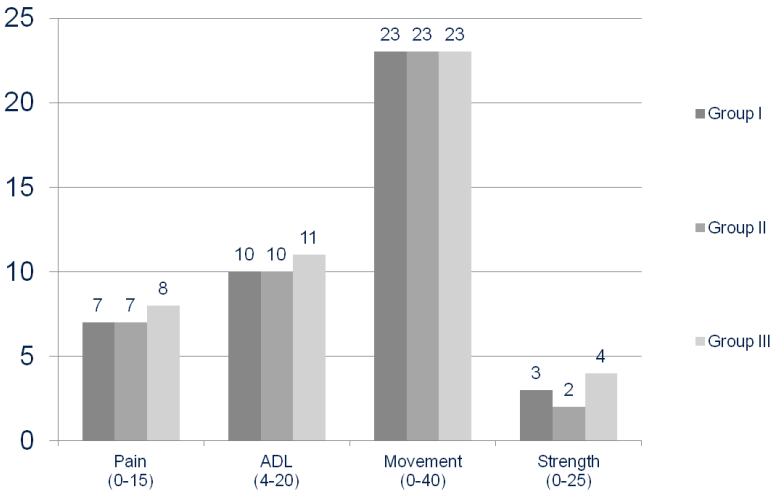

Figure 15: Subitems of the Constant Score preoperatively

Just like the preoperative values of the LHB-Score, the subitems for each group do not differ significantly from each other (p>0.05). The same applies to the total preoperative results for the Constant Score (p>0.05).
Most points were lost in the item “strength”. Only 16% of the maximum value (25 points) was achieved by patients without intraoperative biceps treatment on average, whereas both of the other groups scored even less than that. About half of the maximum points for the subitems “pain” and “activities of daily living” and a little more than half of the maximum was scored for “painless active movement” by all groups on average (Figure 15).

Postoperative results

Patients achieved significant increases in the Constant Score at the first follow-up, averaging 76.3 points (range 29-88 points) in group I, 71.4 points (range 52-84 points) in group II and 71.9 points (range 43-88 points) in group III (p<0,05). However, just like the overall values of the LHB-Score at the first follow-up, these values do not differ significantly compared to each other (p>0.05). Figure 16 shows the subitems for the first follow-up.

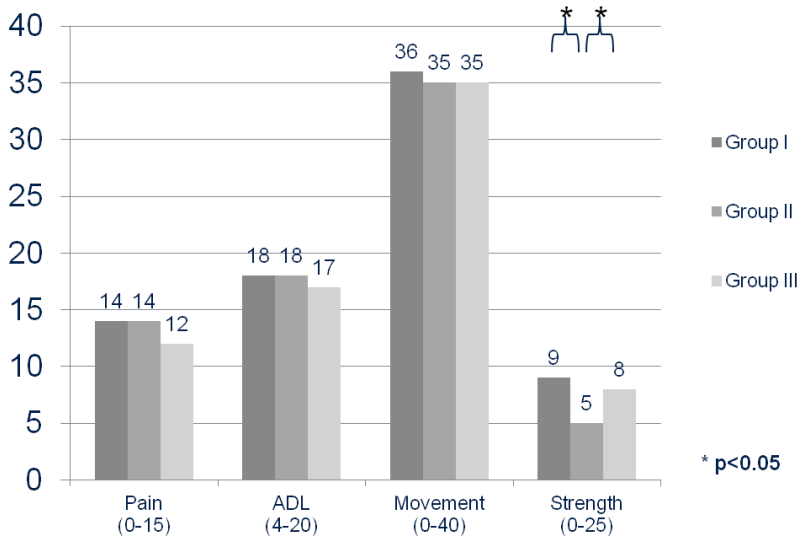

Figure 16: Subitems for the Constant Score at the one-year follow-up

Significant improvements for each group and subitem were found between pre- and postoperative results (p<0.05). At the second follow-up, group I (81.3 points (range 62-100 points)) showed a significantly better outcome compared to the first follow-up (p<0.05). However, this was not the case with groups II and III (p>0.05).

For the subcategories of group I, an average of 14.6 points (range 8-15 points) was achieved for “pain”, 19.2 points (range 13-20 points) for “activities of daily living”, 37.6 points (range 30-40 points) for “range of motion” and 10.2 points (range 3-25 points) for “strength” at the second follow-up.

Group II achieved a mean value of 75.3 points (range 41-84 points) and averaged 13.9 points (range 7-15 points) for “pain”, 17.7 points (range 12-20 points) for “activities of daily living”, 36.9 points (range 22-40 points) for “range of motion” and 6.8 points (range 0-9 points) for “strength” at the second follow-up.

The mean value of group III was 72.9 points (range 48-85 points) at the second follow-up. For the subcategories, they averaged 12.4 points (range 7-15 points) for “pain”, 17.0 points (range 12-20 points) for “activities of daily living”, 35.5 points (range 36-40 points) for “range of motion” and 8.0 points (range 3-15 points) for “strength”.

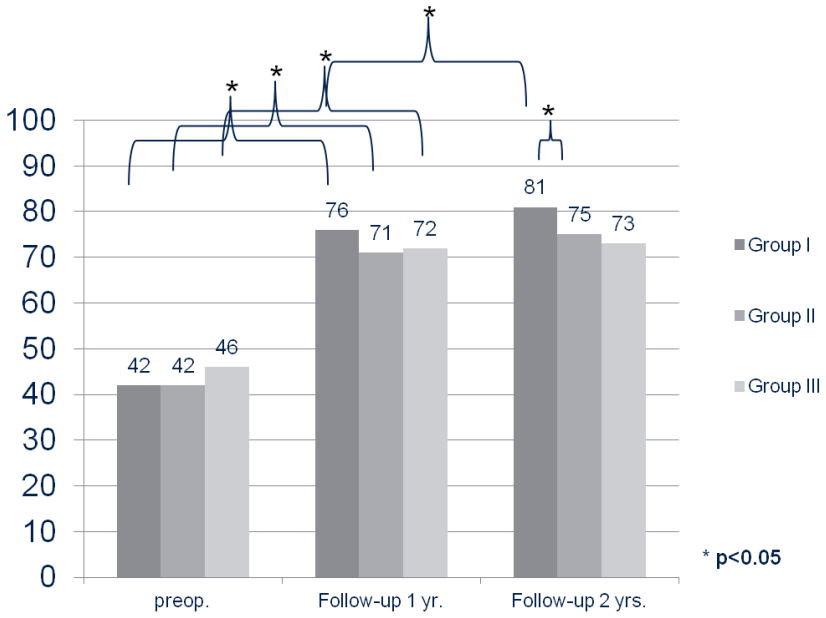

Figure 17: Total point values for the Constant Score

The significant increases between the preoperative values and the values of the two-year follow-up are not shown in figure 17 for visual display reasons.

Pain

Significant improvements in pain were noted between pre- and both postoperative results for each patient group ($p<0.05$). The point value of the tenodesis group (group I) improved from 6.6 points (range 0-15 points) preoperatively to 13.8 points (range 3-15 points) at the one-year follow-up to 14.6 points (range 8-15 points) at the two-year follow-up. Group II achieved 7.3 points (range 0-13 points) preoperatively, 13.9 points (range 8-15 points) at the first follow-up and 13.9 points again (range 7-15 points) at the two-year follow-up, whereas patients in group III scored 8.1 points (range 3-14 points) at first, improved to 11.8 points (range 2-15 points) at the one-year follow-up and to 12.4 points (range 7-15 points) at the two-year follow-up.

A significant decrease in pain between the follow-up after one year and the follow-up after two years was apparent for group I (13.8 points (range 3-15 points) at the one-year follow-up to 14.6 points (range 8-15 points) at the two-year follow-up) ($p<0.05$).
Comparing the groups to each other, patients in group III (11.8 points (range 2-15 points)) complained significantly more about pain than tenodesis patients in group I (13.8 points (range 3-15 points)) at the one-year follow-up ($p<0.05$). This was still apparent in the Constant Score at the two-year follow-up (group III: 12.4 points (range 7-15 points) vs. group I: 14.6 points (range 8-15 points)) ($p<0.05$).

ADL (Activities of daily living)

Both postoperative values for “activities of daily living” show a significantly better result compared to the preoperative Constant Score (group I: preop. 9.6 points (range 4-19 points) vs. 1 year postop. 18.1 points (range 9-20 points) vs. 2 years postop. 19.2 points (range 13-20 points); group II: preop. 10.1 points (range 6-15 points) vs. 1 year postop. 17.5 points (range 13-20 points) vs. 2 years postop. 17.7 points (range 12-20 points); group III: preop. 10.6 points (range 6-18 points) vs. 1 year postop. 16.9 points (range 7-20 points) vs. 2 years postop. 17.0 points (range 12-20 points))($p<0.05$).

Range of motion

The postoperative results showed a significant improvement in “range of motion” compared to the preoperative scores in all three groups (group I: preop. 22.7 points (range 12-40 points) vs. 1 year postop. 35.5 points (range 10-40 points) vs. 2 years postop. 37.6 points (range 30-40 points); group II: preop. 22.6 points (range 8-40 points) vs. 1 year postop. 34.9 points (range 24-40 points) vs. 2 years postop. 36.9 points (range 22-40 points); group III: preop. 22.6 points (range 4-40 points) vs. 1 year postop. 34.9 points (range 22-40 points) vs. 2 years postop. 35.5 points (range 36-40 points)) ($p<0.05$).
Furthermore, the tenodesis group demonstrated a significantly increased range of motion over time comparing the one-year and the two-year follow-up ($p<0.05$).
However, the comparisons between the groups showed that no group achieved a significantly better score than another at any given time ($p>0.05$).

Strength

Significant improvements between pre- and both postoperative results were found for tenodesis patients (group I: preop.: 3.4 points (range 0-13 points) vs.1 year postop.: 8.8 points (range 0-15 points) vs. 2 years postop.: 10.2 points (range 3-25 points)), tenotomy patients (group II: preop.: 2.2 points (range 0-7 points) vs.1 year postop.: 5.1 points (range 0-9 points) vs. 2 years postop.: 6.8 points (range 0-9 points)) and patients without surgical biceps treatment (group III: preop.: 4.4 points (range 0-13 points) vs.1 year postop.: 8.4 points (range 3-15 points) vs. 2 years postop.: 8.0 points (range 3-15 points)) ($p<0.05$).

Even the postoperative result of the two-year follow-up was significantly higher than that of the one-year follow-up for group I (one-year follow-up: 8.8 points (range 0-15 points) vs. two-year follow-up: 10.2 points (range 3-25 points)) and group II (one-year follow-up: 5.1 points (range 0-9 points) vs. two-year follow-up: 6.8 points (range 0-9 points)) ($p<0.05$).
This was not the case for patients in group III ($p>0.05$).
Similar to the results of the LHB-Score, there was no significant difference in strength between the groups preoperatively ($p>0.05$).
However, it changed in the one-year follow-up. Group II had significantly less strength of abduction and therefore scored less points in the item “strength” for the Constant Score (group I: 8.8 points (range 0-15 points) vs. group II: 5.1 points (range 0-9 points) vs. group III: 8.4 points (range 3-15 points)) ($p<0.05$). Nevertheless, the general point value for the Constant Score was not significantly different ($p>0.05$).
This lack of abduction strength for group II was not found at the two-year follow-up ($p>0.05$).

3.3.3 Contralateral shoulder

Preoperatively, the LHB-Score of the contralateral shoulder was significantly higher than that of the affected side ($p<0.05$) (Figure 18).

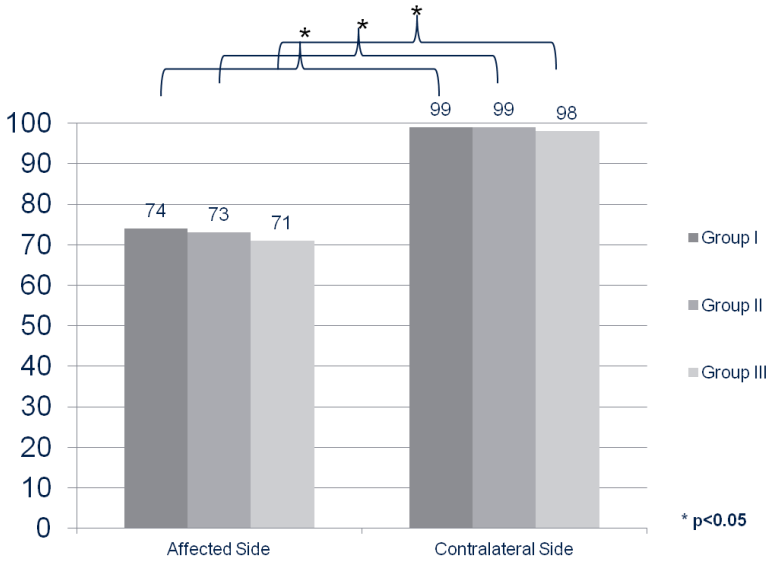

Figure 18: Preoperative values of the LHB-Score of affected and contralateral shoulders

In contrast to the treated shoulder, the LHB-Score of the contralateral side did not differ significantly regarding pre- and postoperative results for any group of patients ($p>0.05$) (Figure 19).

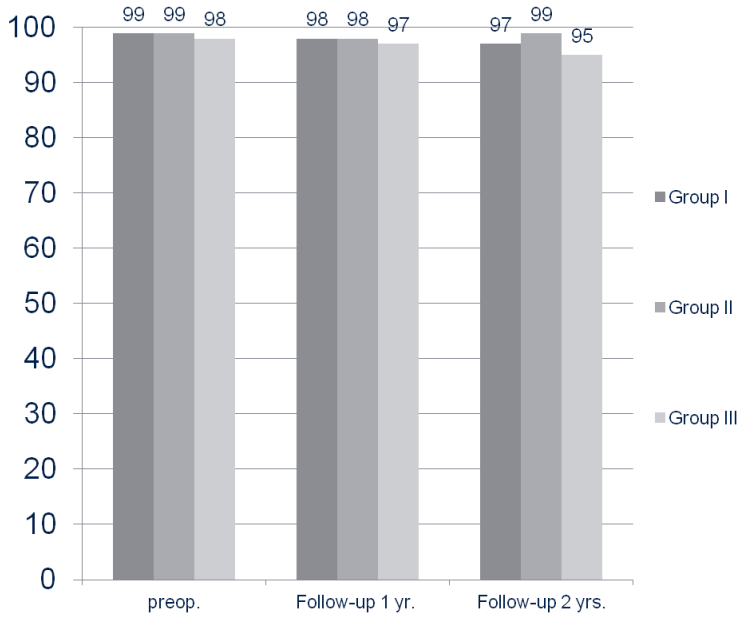

Figure 19: LHB-Score for the contralateral side

The Constant Score for the contralateral side for tenodesis patients (group I) averaged 86.5 points (range 69-100 points) before surgery. Compared to 81.3 points (range 60-98 points) at the one-year follow-up and 80.6 points (range 53-94 points) at the two-year follow-up; the postoperative score values show a significant deterioration ($p<0.05$).
The same applies to the results for “activities of daily living”. Group I scored significantly less points postoperatively (preop.: 20.0 points (range 19-20 points) vs. 1 year postop.: 18.9 points (range 12-20 points) vs. 2 years postop.: 18.3 points (range 12-20 points)) and the subitem “pain” (preop.: 14.5 points (range 10-15 points) vs. 2 years postop.: 12.6 points (range 0-15 points) ($p<0.05$).
Not only the tenodesis group (group I) but also the patients without tenodesis/tenotomy (group III) scored significantly less points in the subitem “pain” of the CS with their contralateral side at the two-year follow-up (preop.: 14.6 points (range 10-15 points) vs. 2 years postop.: 11.8 points (range 5-15 points) ($p<0.05$).
Group II did not show significant differences for the contralateral side in the subitem “pain” of CS ($p>0.05$).

3.4 Patient´s physical activity and satisfaction

Two years postoperatively, patients of group I received approximately 1.2 points (range 0-2 points) for physical activities, whereas tenotomy patients scored 1.1 points (range 0-2 points) on average and patients without surgical biceps treatment 0.9 points (range 0-2 points). These differences are not significant ($p>0.05$).

Every patient claimed to be satisfied with the result of the operation two years postoperatively. No patient scored zero points for satisfaction.
Tenodesis patients (group I) and tenotomy patients (group II) averaged 1.8 points (range 1-2 points), which means that 18 of 23 tenodesis patients (78.3%) and twelve of 16 tenotomy patients (75.0%) were very satisfied. However, the patients not treated with tenodesis or with tenotomy (group III) received 1.5 points (range 1-2 points). Four of eight patients were very satisfied (50.0%). These differences are not significant ($p>0.05$).

4 Discussion

4.1 Development of the LHB-Score

The development included collecting issues specific to LHB pathologies and treatments (biceps tenotomy or biceps tenodesis) by reviewing orthopedic publications and interviewing patients about their problems related to the LHB.

A certain methodological framework is needed for the development of measurement tools.[47] A part of this is the generation of items.[31] According to Kirkley et al., this is "arguably" the most important step.[31] It has to be comprehensive to ensure that the score meets the requirements.[31] Kirkley et al. stated that the most important indicator of successful treatment is the patient´s perception.[31] Even a strongly apparent "Popeye" sign might not be important to patients at all, whereas pain as a subjectively evaluated item can have a totally different significance for patients.
In contrast to the last-mentioned items, strength is the most objectively measured item. Patients usually do not know to what extent it has changed over the last period of time.
The patient´s perception is important to describe the current condition. Of course, the LHB-Score is an instrument measuring the "disease"-specific quality of life and is personally influenced by patients. Nevertheless, objective measurements and the opinion of an experienced examiner, for example to recognize changes in shape, are necessary as well, especially to compare patients to each other and thus kinds of treatment.
It takes the know-how of experienced surgeons and other health caregivers to assemble appropriate items in such a way that the score reflects what it is supposed to measure. In particular, experts who are familiar with pathologies of the LHB were imperative to design the LHB-Score. The feasibility of measuring score items should be considered as well.

Item reduction is another step in the process of obtaining a score.[31] We considered measuring the supination strength of the forearm as well as elbow flexion strength, given that the LHB is relevant to supination as well.[5]

Forearm supination can also provide information about the function of a biceps muscle but it is more difficult to test compared to the measurement of flexion strength. Many authors have not considered it.[10,43,48] Supination strength was measured by Sentürk et al.[44] No statistically significant differences in elbow flexion strength or forearm supination strength were observed in the tenotomy or in the tenodesis group.[44] As measuring forearm supination is not as common as the measurement of elbow flexion strength, the latter is more appropriate for scoring. A good method of measuring supination strength, which can easily be used by every examiner, is needed. Comparable data can be achieved using a standardized method. Special devices are needed to measure elbow supination strength exactly, as stated by Scheibel et al.[26]

A scale of fine graduation for each item is needed when a score is to be used as a discriminative tool (differentiating between several patients simultaneously) as well as an evaluative tool (detecting changes in patients over time).[31,49]
A visual analogue scale, extending over a ten-cm line with the extremes of the item at each end of it, is adequate.[31] The other major option is a Likert scale, including several adjectives describing the item, such as excellent, very good, good, moderate, poor, very poor, extremely poor.[31] In the opinion of Guyatt et al., the visual analogue scale is a little more sensitive to change.[50] It has more response options but is more variable and thus not as reliable.[31] Whereas Guyatt et al. have found that it is more difficult for patients to understand a visual analogue scale,[50] Kirkley et al. have not come to the same conclusion, but it was more difficult for the investigators around Kirkley to come up with consistent, meaningful and evenly spaced Likert scale-type responses.[31]

In contrast to the Western Ontario Shoulder Instability Index (WOSI),[31] the LHB-Score is filled out by the examiner and not by the patient. This is more practicable, since the examiner is more familiar with the measurement, and the examiner can also obtain objective items, for example cosmetics.

The examiner of the LHB-Score asks the patient to describe pain for the three “pain” items on a numeric scale. We found that patients are used to this procedure. Other examiners also use a numeric scale to rate pain. This is compared to the scale for the item “pain” in the Constant Score,[35] where patients found it confusing to express pain on a scale from zero to 15 points. If any patient has difficulty in understanding what s/he

is supposed to do, the examiner can provide further information by explaining the extremes with “no pain at all” and “strongest imaginable pain” and by showing the numeric scale printed on the LHB-Score. That makes the score more accessible to patients who are not used to such scales or who have difficulty understanding them, and thus, more accurate data is gained. Patients must not just mark anything. The point value must represent the patient´s state as precisely as possible.

Furthermore, asking the patients about the given items does not take as much time as allowing the patients fill out the score sheet on their own. Reading, understanding and figuring out how to interpret such a score usually takes more time than just answering. Time is an important factor in clinical daily routine.
If the examiner fills out the score sheet, examiner bias must be considered. It can be reduced if only one independent examiner is involved.

Whereas the item “cramps” only comprises three categories, the item “cosmetics” has four categories. We believe that the number of categories must be appropriate to the item. For “cramps”, it is more important to know whether a patient suffers from cramps only during exercise, even at rest or never, rather than creating a scale that tries to describe the exact intensity of the cramps. Moreover, we believe that a four-category scale to express the shape of the patient's arm is appropriate, since more categories would require examiners to be able to differentiate between very fine distinctions. It sometimes does not make sense to differentiate more precisely because there would be no clinical relevance.

The weighting of the several items can be complicated. We wanted to rate every item and describe the symptoms adequately by representing each item and subitem with an appropriate point value.
Weighting each item equally does not correspond to its importance. Since pain reduces the quality of life tremendously, we decided that “pain/cramps” should be represented by half of all available points. One hundred points can be achieved. The maximum number of points for other scores such as the Constant Score is 100 as well[35]. We decided to choose this limit, for it is a generally accepted mark and investigators are simply used to it.

Finding a specific collective of patients is also necessary for the process of establishing a clinical health status tool[47] like the LHB-Score, since pretesting is that part of the development in which a score can still be modified depending on the problems that arise. Modification can be important, for some essential items might not have been reflected, or may have not been sufficiently taken into account. For instance, it must be clear to examiners what to ask, how to examine the tenderness over the bicipital groove, how to perform the Speed test[15] and how to use the device to measure the patient´s strength. For pain, it is necessary to ask about pain in the anterior shoulder, otherwise some patients might talk about general shoulder pain or even neck pain.

All in all, a score should not contain too many tests, especially not those that measure the same issues. Because a score needs to be simple and time-efficient to accomplish, testing tenderness over the bicipital groove[13] and the Speed test[16] are included. The O´Brien test[17] is more complicated to conduct compared to the Speed test.[16]

The LHB-Score has already been successfully used in a study about “Arthroscopic soft tissue tenodesis versus bony fixation anchor tenodesis of the long head of the biceps tendon” published by Scheibel et al.[26,51] It has demonstrated its helpful support in monitoring the patient´s progress and its usage in a research setting.
In our opinion, no further modifications were necessary.

4.2 Need for the LHB-Score

Different diagnostic tests and clinical signs included in a standardized evaluation are necessary in order to diagnose precisely, as stated by Scheibel et al.[12] Clinical scores can be a useful aid in order to come up with a precise diagnosis for which a systematic approach is required.[12] Single tests do not yield reproducible results because of their ambigiuty.[12] If all maneuvers are carried out within a standardized examination and considered within a certain context, a correct diagnosis can be made in most cases.[12]

Although several shoulder scores have already been established, the LHB-Score demonstrates the necessity of entrenchment in clinical routine. Since it includes specific criteria concerning the LHB, it can be used as a tool demonstrating postoperative

progress for patients who were treated for LHB pathologies. Current data shows that there are significant postoperative improvements in all three groups, indicating that the LHB-Score also describes the general state of the shoulder.

The LHB-Score has been designed in order to evaluate pathologies concerning the LHB and is appropriate for the evaluation of patients with shoulder complaints who might need treatment of the LHB. It has not been proven that the LHB-Score can produce reliable diagnoses, and therefore one should not use the score described only. The LHB-Score must not be the only tool to indicate the treatment required. Therefore, the surgeon´s experience is essential to make a wise decision about the procedure that should be used.

4.3 The importance of scores applied to the LHB-Score

For a discussion of health status tools, an appropriate definition of health ought to be presented.[31] The World Health Organization defines health as a state of complete physical, mental and social well-being,[52] meaning that it is not only physical parameters like strength, and the absence of pain and cramping that are part of health. Psychic and emotional conditions also belong to the term health. Satisfaction with oneself, including with the shape of one´s body is part of it as well. A distally migrated biceps muscle might diminish this contentment and might reduce social activities.

A medical scientist must demonstrate responsibility to patients and their symptoms, and pay particular attention to clinical data, as Feinstein stated.[39] In his opinion, in the early 1980s, physicians focused heavily on paraclinical data and on therapies.[39] He complained that quality control was not given the importance that it should be.[39] He indicated that it was more difficult to express observations as data because not a great number of rating scales, such as scores, had been created by 1982.[39] Some rating scales already existed, but they were not suitable because of their poor repeatability.[39] Therefore, a lot of important information was omitted at that time and quality control was not adequate.[39]
Accepting the importance of clinical data, as Feinstein suggested,[39] a much better quality control can be achieved by using scores. The creation and usage of the LHB-

Score is a contribution towards the improvement of medical science resulting in a good level of care for patients. That includes understandable and repeatable examinations and evaluations of symptoms. Furthermore, with the aid of such scores, comparisons to functional states of the past and between different patients as well as several patient collectives are much easier to make. The use of well-established scores worldwide supports globalization and possible partnerships and cooperation with other clinics.
Completing a score sheet does not take as much time as a detailed description and thus improves the time-effort ratio, which is another advantage for the daily clinical routine.

Distinguishing between mild, moderate, severe and incapacitating, Feinstein advocates classification of symptom severity[39] in a manner similar to the use of the LHB-Score to rate the cosmetic effect. For the items “pain/cramps” and “strength”, the classification is even more detailed. Moreover, he emphasizes the importance of paying attention to performance status or functional capacity.[39] Applied to the LHB-Score, the function of the long head of the biceps tendon is examined by measuring elbow flexion strength.

4.4 Tenodesis versus tenotomy versus non-surgical treatment of the LHB

Several authors, such as Romeo et al. in 2004 have dealt with the advantages of tenodesis over tenotomies.[29] Avoiding muscle atrophy, maintaining the relationship of length to tension as well as elbow flexion and supination strength, avoiding cramping and cosmetic deformities are said to be the advantages of biceps tenodesis.[29]

The study of Osbahr et al. pointed out that no statistically significant difference was found comparing biceps tenotomy and biceps tenodesis.[53] Even when evaluating only men, only women, and men versus women, no statistical significance could be found.[53] Osbahr et al. claimed that a biceps tenotomy is a reasonable alternative to a biceps tenodesis since the difference between the tenodesis group and the tenotomy group, concerning cosmetics, muscle spasms and anterior shoulder pain, was not significant.[53] This implies that both tenodesis and tenotomy yield good outcomes and patient satisfaction.

The LHB-Score comprises the tools cosmetics, muscle spasms and anterior shoulder pain which Osbahr et al. used for their studies and thus demonstrates clinical relevance.[53] Boileau et al. showed that there is no significant difference in the Constant Score, including patient satisfaction, concerning pain and function of the shoulder, regardless of whether a simple tenotomy or a tenodesis using an interference screw for fixation was performed.[10] Isolated arthroscopic biceps tenotomy or tenodesis improves symptoms in patients with massive irreparable rotator cuff tears.[10]

Considering the overall LHB-Score of patients treated with a tenodesis (group I) or whose LHB had not been surgically addressed (group III), a significant increase from the point values at the one-year follow-up to the point values at the two-year follow-up is evident (Figure 10). In contrast to these groups, patients with a tenotomy (group II) did not improve their results at the two-year follow-up. Thus, it can be assumed that, for patients recovering from tenotomy (group II), most recovery occurs in the first year after surgery, whereas for patients recovering from tenodesis (group I), a full recovery takes more time. This assumption is backed up by the fact that the total LHB-Score of group I was significantly better than the total LHB-Score of the second group at the second follow-up, which was not the case at the first follow-up. Therefore, it is very important to focus on the outcome over time.

The CS of the tenodesis group (group I) in our study changes significantly after two years compared to the one-year follow-up for the items “pain”, “ADL”, “ROM” and “strength”. Thus, one can assume that it takes more time than one year to assess the final clinical outcome.
However, the items “ADL” and “pain” of the CS demonstrate that the results for tenodesis patients (group I) improve more than those for patients without tenodesis/tenotomy (group III), which might be interpreted as an advantage of tenodesis.
This study also shows that tenodesis patients can perform “activities of daily living” significantly better than patients who have not undergone surgery on the biceps tendon.

Pain

Franceschi et al. claimed that in a study with eleven tenodesis and eleven tenotomy patients no patient suffered from bicipital pain at the follow-up which was after 47.2 months on average (range 36– 59).[48] The same applied to the study of Kelly et al. (54 tenodeses).[30] However, Kelly et al. pointed out that 38% of all included patients said that they had fatigue discomfort (soreness) of bicipital muscle after resisted elbow flexion.[30]

In the present study, every patient group complained of pain. Even patients whose LHB did not need surgical treatment felt LHB pain, pain over the bicipital groove and during the Speed test. Since the origin of the long head of the biceps muscle is at the supraglenoid tubercle and therefore intraarticular, LHB pain might occur because of various kinds of irritation of the shoulder. Thus, pain can be present even if the biceps tendon itself does not seem to be damaged.

Two years after surgery, patients without tenodesis/tenotomy achieved fewer points for the item “pain”, demonstrating that they complained more of pain compared to tenodesis patients in the LHB-Score (I ∅ 29.4 points vs. III ∅ 26.0 points) and in CS (I ∅ 14.6 points vs. III ∅ 12.4 points) ($p<0.05$), even though patients in group I showed more intraoperative findings and concomitant lesions associated with the LHB. This finding emphasizes the importance of addressing the LHB when pathologies are present.

Since the difference between tenodesis and tenotomy patients was not significant, the item “pain” is not of prime importance for either one of the surgical techniques. Otherwise, we can conclude that tenotomy is as good as tenodesis in diminishing pain.
As an advantage of the LHB-Score, the point value of “pain” can easily be compared to other groups since points are given individually in comparison to the non-operated side of each patient, considering that every patient has an individual level of pain perception.

Cramps

Comparing tenodesis to tenotomy in 2010, Koh et al. noted mild cramping in two out of 43 tenodesis patients (5%) and in four out of 41 tenotomy patients (10%).[43] These data are not that close to the results of our patient collective at the two-year follow-up (tenodesis 0% vs. tenotomy 12.5% vs. without tenodesis/tenotomy 0%).
In the tenotomy group of Delle Rose et al., 16.6% of the patients suffered from cramps in the biceps muscle in a mean post-operative time of one month.[54] But it might be questionable whether a follow-up time of one month is long enough to evaluate cramping precisely. Boileau et al. mentioned no significant difference in cramps between the tenodesis and the tenotomy group.[10] That applies to our study as well. Some authors, such as Sentürk et al., did not mention cramping at all, perhaps considering it to be not that important.[44] Considering that not even tenotomy patients had significantly less points for cramps postoperatively and taking into account the results of other studies, one must conclude that cramps do not play an important role.[10,44] Avoiding cramps is nonetheless said be an advantage of tenodesis over tenotomy.[29]

Cosmetics

As described by Walch et al., elderly patients in particular have a low rate of perception of a possible biceps muscle deformity.[55] Moreover, they pointed out that a good cosmetic result was more important to younger patients and that gender does not significantly affect the patient-dependent evaluation of biceps deformity.[55]

Regarding our results, we conclude that patients have a lower rate of perception of biceps deformities than examiners. Both had to evaluate the “Popeye” sign in this study. Tenodesis patients as well as tenotomy patients gave themselves significantly higher scores than the examiners ($p<0.05$). The greatest difference was noted for patients who had received a tenotomy (12.8 points (range 5-15 points) for patient-dependent and 9.7 points (range 5-15 points) for examiner-dependent cosmetic results).
Thus, patients, especially elderly people, pay more attention to other criteria than to the outer shape of their arm, whereas patients who attach great importance to the cosmetic

aspect opt instead for a tenodesis. In the present study, three of 16 tenotomy patients (18.8%) (group II) who were evaluated after two years noticed a mild “Popeye” sign, whereas a moderate “Popeye” sign was obvious to two of them (12.5%). A further five (31.3%) had a “Popeye” sign according to the examiner but they claimed to have no biceps deformity. All in all, 68.8% of all tenotomy patients (ten of 16) showed a “Popeye” sign, objectively.

It is understandable that the patient´s risk of showing a “Popeye” sign will be higher if the long head of the biceps tendon is not attached any more than if it is fixed again, as it is in tenodesis patients. However, a “Popeye” sign will only be present if auto-tenodesis does not occur in tenotomy patients. Even though an examiner- or patient-dependent “Popeye” sign was noted, the patients were not bothered by this deformity as they communicated at the follow-ups.

According to Kelly et al., 70% of their patients who underwent a tenotomy had a “Popeye” sign after surgery.[30] That is close to our results (62.5%, ten of 16 tenotomy patients). Delle Rose et al. recently found that a “Popeye” sign occurred in 37.5% of patients who had received a tenotomy and in 5.3% of patients treated with a tenodesis.[54] Compared to the tenotomy patients in our study, this is a much lower percentage. Contrary to our collective, 82.7% of men and 36.5% of women had a muscle belly retraction in the study of Kelly et al.[30] A “Popeye” sign was obvious in 58.3% of women (seven out of twelve) and in 75% of men (three out of four) in our study. The difference in the presence of the “Popeye” sign in different genders was higher in the study of Kelly et al.[30] In discussing this issue, we must take into consideration that we treated only five men with a tenotomy. Four of them came to the two-year follow-up. This is a small group of patients, however, choosing the best surgical method for everyone was our priority.

62 % of tenotomy patients in the study of Boileau et al. showed this disadvantage.[10] Only 3% of the tenodesis group had a muscle belly retraction.[10] Deformities of the biceps muscle after tenotomy occurred less frequently in the works of Koh et al., but more frequently after tenodesis (9% in the tenodesis group and 27% in the tenotomy group)[43]. Osbahr et al. found that there was no significant difference in the cosmetic appearance between tenotomy and tenodesis patients.[53]

The cosmetic outcome in the different studies referred to is varied.[10,43,53] Distinguishing between mild, moderate and severe “Popeye” sign is essential in order to compare patients to each other. Moreover, examiners need to be trained to evaluate the cosmetic outcome in the same way.
Although there are authors who claim that no “Popeye” sign occurred in their collective,[44,48] one should note that muscle deformities can also happen to patients treated with a tenodesis and to patients who have had neither a tenodesis nor a tenotomy, which might be due to a lack of strain and exercise as well as to a failure of LHB tenodesis. That can explain the significantly worse outcome for tenodesis patients (preop.: 30.0 points vs. 1 year postop.: 28.7 points (range 20-30 points) vs. 2 years postop.: 28.9 points (range 20-30 points)) ($p<0.05$).

Before the study began, we assumed that the frequency of the “Popeye” sign in the tenotomy group would depend to a large extent on the muscle mass as well as on the subcutaneous fat and thus on the patient´s physical fitness, age and gender. Women have a larger amount of fat underneath their skin in relation to their whole body weight and usually have less muscle mass than men, and thus women are more likely to have a tenotomy. For this reason there are more women in the tenotomy group.

Moreover, we thought that the same would be applicable to elderly people since their muscle mass can have declined, as well as to generally untrained people, because a muscle belly retraction might not be that apparent in these patients. Furthermore, elderly people usually have a lower demand for a strong biceps strain which is another important criterion tending towards a tenotomy instead.
Further studies should focus on this topic more precisely to check and confirm our conclusions that low muscle mass and more subcutaneous fat leads preferentially towards a tenotomy.
We consider our assumption to be correct. Patients were not concerned about the muscle belly retraction and did not suffer from it in particular. Because the decision about a tenotomy was made on a reasonable basis, no severe “Popeye” sign was noticed. Moderate “Popeye” signs were recognized only in a few cases. No patient complained about it. This might imply that the indication for a tenotomy was appropriate with regards to the cosmetic result.

An absent “Popeye” sign might be due to a phenomenon called auto-tenodesis which keeps the muscle from migration as the biceps tendon is held in the bicipital groove.[8] This process can happen after a tenotomy or after tenodesis. Therefore, not every patient treated with a tenotomy will get a “Popeye” sign even though there may be little subcutaneous fat. In the majority of patients in which a biceps tenotomy was performed, we note that the cosmetic appearance of the biceps muscle does not play an important role.

The items “pain” and “cramps” are more important to patients. But the results of these items did not indicate a tenodesis over a tenotomy in general because there was no significant difference comparing the two-year follow-up results of “pain” and “cramps” for groups I and II. Therefore, a biceps tenotomy can be a reasonable alternative to a biceps tenodesis in patients with refractive and chronic bicipital pain, as Osbahr et al. noted.[53]

Since the Constant Score lacks this item, it is not possible to compare data about this topic with the results of another score. No score dealing with this issue is known. Thus, we encourage scientists and examiners to include our score in their studies for this and the following reasons. One cannot tell how apparent the biceps muscle retraction was because other authors simply distinguished between a positive or negative “Popeye” sign and did not mention the severity of the cosmetic deformity.[10] Again, we recommend the usage of this score developed especially for biceps pathologies to compare and discuss the outcomes of various studies, e.g. concerning biceps muscle retraction.

4.5 Strength

Two remarkable results concerning elbow flexion strength were noted in this study. First of all, no group was superior to another one at the same time.
Even though the long head of the biceps muscle was cut in tenotomy patients, they did not show a significantly reduced elbow flexion strength compared to the tenodesis group or to patients whose LHB was not addressed during surgery.
If the biceps muscle is attached to the scapula only with the short head, instead of with two heads, it is likely to have diminished elbow flexion strength, because both heads are

relevant for elbow flexion.[5] Nonetheless, one can assume that one intact biceps head is enough to fulfill its function. Moreover, it is possible that this function is supported by the brachialis muscle, brachioradialis muscle, extensor carpi radialis longus muscle and pronator teres muscle (humeral head) more than before surgery. In addition, auto-tenodesis might have contributed to the similar results among the groups.

Furthermore, this study shows that no significant improvements in elbow flexion strength were achieved at the two-year follow-up compared to the point values at the one-year follow-up, which implies that elbow flexion is not dependent on the operative technique, since differences in other subitems are still present. Otherwise, differences in function might not be detected with elbow flexion strength measurement. There might be differences in supination strength between the one-year and the two-year follow-ups. Measuring only elbow flexion strength and dispensing with supination strength might be a limitation of the LHB-Score. However, we decided to include a common and reliable strength measurement, which is easy to use.

For the above-mentioned reasons, elbow flexion strength does not play an important role in deciding between a tenodesis or a tenotomy. Tenodesis is not superior to tenotomy in respect of elbow flexion strength after surgery. The short biceps tendon seems to be enough to ensure flexion strength together with other muscles.

Contrary to the values for the LHB-Score, abduction strength measured by the Constant Score is higher for tenotomy and tenodesis patients at the two-year follow-up compared to the one-year follow-up. It implies that the delta muscle and the supraspinatus muscle still improve in function one year after surgery, considering that many patients had surgical treatment of the supraspinatus tendon. Nevertheless, just like in elbow flexion strength, two years after surgery, no significant deficiency was found for any group. This fact supports the findings of Boileau et al.[10] According to Boileau et al. there was no significant difference in the Constant Score including patients´ satisfaction concerning pain and function of the shoulder regardless of whether a simple tenotomy or a tenodesis, using an interference screw for intraosseous fixation, was performed.[10] They did not take elbow flexion strength into account but only abduction strength as part of the Constant Score.[10]

4.6 Contralateral shoulder

Since the LHB-Score of the contralateral shoulder did not change significantly, the condition of the non-operated side was stable over time. This is very important in order to compare the operated side to the contralateral side as a control.
Moreover, the postoperative values at the two-year follow-up of the LHB-Score do not differ significantly between the three groups. This consistency in pre- and postoperative results for the contralateral side allows the comparison of groups to each other.

Due to pain and a reduced level of physical activity, the contralateral shoulder might have had less stress than usual. On the other hand, patients reported that they used their contralateral side even more than before in daily life to compensate for the operated side.
Signs of wear resulted in pain on the other side, explaining the significant differences in pre- and postoperative results within the Constant Score. Thus, physiotherapy is important in order to avoid a loss of function. That corresponds with the fact that active patients have better results.

4.7 The significance of the LHB-Score

The number of authors who have dealt with parameters included in the LHB-Score demonstrates the impact that the LHB-Score could have once established in orthopedic clinical routine and research.[9,10,16,27,56,57] The following authors have dealt with various criteria included within the LHB-Score, underlining the importance of these items.
Zhang et al.[57], Karataglis et al.,[58] and Biz et al.[59] were concerned with the “Popeye” sign and thus paid attention to the appearance of the upper arm, which might be relevant for patients. LHB pain was an issue for Snir et al.[60], Ng et al.[61], Delle Rose et al.[54] and Pill et al.[62] for instance. David et al. paid attention to cramping and early fatigue of patients after arthroscopic suprapectoral tenodesis of the long bicipital head.[63]

Many studies may have been enhanced if the LHB-Score had been used in examining patients. Furthermore, a great number of scientists can benefit from it in their future work and projects.

The LHB-Score may be successful in various clinical fields dealing with the long head of the biceps muscle. Different surgeons and various ways of operating on patients are influenced by this muscle, for it affects many shoulder pathologies such as lesions of the supraspinatus muscle, subscapularis muscle and infraspinatus muscle.[10] Moreover, the tendon is often injured itself when pain and/or loss in function are present and therefore is a generator of pain and loss of function.[2] Scores detecting changes are necessary for investigators, especially when a treatment results in important changes.[31]

4.8 The superiority of the LHB-Score for biceps issues

This study demonstrates that tenotomy and tenodesis are reflected by the LHB-Score. One can easily describe the outcome of patients undergoing different kinds of treatment for the LHB. With regard to elbow flexion strength, it might be advantageous that points are given for this criterion in comparison to the contralateral side. The contralateral side is a point of reference for each patient individually. The Constant Score is not designed in the same way.[35] Moreover, the Constant Score measures strength of abduction[35] in which the deltoid muscle and the supraspinatus muscle are involved to a high degree.[5]
As a general shoulder score, the Constant Score[35] shows certain differences directing attention to subjects other than the LHB-Score. Since the Constant Score[35] has not been designed to evaluate biceps pathologies in particular, it may not detect subtle biceps-specific concerns such as the “Popeye” sign, in contrast to the LHB-Score. The LHB-Score is much more appropriate for evaluating patients whose biceps tendon is affected or might need treatment.
According to Pope et al., the proportion attributed to range of motion in calculating the Constant Score is too large, correlating poorly with shoulder function.[64] The Constant Score may be useful to a limited extend only. A more specific score, especially for certain structures, is needed. The LHB with its specifics is not adequately reflected in the Constant Score.

A score must be easy and quick to use, without the need for sophisticated equipment, as stated by Constant et al.[65] This is very much the case with the LHB-Score, for its items can be applied quickly and easily using common devices. For all of the reasons mentioned, the LHB-Score is designed in this way.

However, some limitations of the LHB score must be acknowledged. The supination strength is not included. Additionally the study shows, that the specificity of the LHB - Score is limited by overlapping symptoms due to concomitant shoulder pathologies like rotator cuff tears. This became apparent, because it was not possible to distinguish between patients with arthroscopically proven LHB pathologies (groups I and II) and patients with typical LHB symptoms in whom pathologies are absent (group III).
Apart from its strengths, the study has limitations as well. Intra- and interobserver reliability has not been confirmed. Further studies testing inter-observer reliability and intra-observer reliability need to be contemplated. It would be advantageous to evaluate a larger collective of patients who have received biceps treatment as well as healthy volunteers with the LHB score. Moreover, one should consider a testing protocol using blind examiner tests.

The LHB-Score may be enhanced over time, but it should continue to be applied until a more appropriate version is available. The LHB-Score has already been successfully used as a tool showing postoperative progress.[26,51]
For LHB pathology, we recommend evaluation with the LHB-Score, since it provides biceps-specific items like “Popeye” deformity, cramps and strength of flexion, demonstrating clinical progress. Moreover, the LHB-Score describes the overall state of the shoulder as well.

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Mein Lebenslauf wird aus datenschutzrechtlichen Gründen in der elektronischen Version meiner Arbeit nicht veröffentlicht.

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Word of thanks

I hereby thank everyone who enabled me to produce this work. This thesis would not have been possible without the support of numerous people at Charité-Universitaetsmedizin Berlin and Center for Musculoskeletal Surgery (CMSC) in Berlin.

First, I would like to thank Univ.-Prof. Dr. med. Markus Scheibel for providing the topic of my work. His ongoing support, supervision and critical expertise have been invaluable for the genesis of this thesis. The constructive advice he provided was essential to this work and inspired me with confidence.

I gratefully acknowledge all former and current members of the study group, especially Dr. med. Maximilian Kerschbaum, Dr. med. Christian Gerhardt, Martin Bartsch, David Krüger and Jianhai Chen, who supported this work with valuable feedback and explanations about orthopedic methods.

I thank Anna Wilson and Ruslan Tulburg for their support in translation.
I would like to thank my parents and teachers for providing me with great education and for the freedom to pursue my own ideas and goals.
Furthermore,I thank my husband and friends, who supported me throughout this process with encouragement.