Original Article
https://doi.org/10.17816/2311-2905-1997

Biceps Brachii Distal Tendon Ruptures: Conservative and Surgical Treatment Outcomes

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Background. Interest in the study of the distal biceps brachii tendon ruptures in the recent decade has been caused by the development of instrumental diagnostic methods, the new sports disciplines appear and by the technological workplace environment complication. The main concepts of treatment depend on the injury term, the tendon tissue damage area, the patient functional needs and his/her professional activities, the comorbidity index (CCI), so the concepts are divided into two: conservative and surgical.

The aim of the study — to identify the most effective method of treating patients with a biceps brachii distal tendon rupture.

Methods. The study included 58 patients (all men) with a biceps brachii distal tendon injury. They were divided into groups depending on the concept of treatment: a conservative treatment group — 20 (34%) patients and a surgical treatment group — 38 (66%). The surgical treatment group was also divided into subgroups according to surgical approaches, reinsertion methods and types of fixation. Patients underwent physical tests (O'Driscoll, Ruland, et al.), ultrasound to compare the proximal radio-ulnar space, degree of muscle retraction, lacertus fibrosus involvement, and MRI of the elbow joint. The functional scales VAS, DASH and ASES were used to evaluate the obtained results. The results of instrumental diagnostic methods were evaluated with the L. Perera (2012) and J. Fuente (2018) classifications.

Results. Evaluation of the results in the groups of surgical (Ns) and conservative (Nc) treatment according to functional scales after 6 (VAS, DASH) and 36 months (ASES) revealed: a decrease in subjective pain score ≤ 1 point, a decrease in DASH to 21 and 43 points (statistically significant decrease in both groups $p<0.001$, difference between groups $p = 0.005$), ASES: 91 and 71 points (dynamics in both groups and difference between groups $p <0.001$). Minimally invasive approaches compared with open access (nD) showed better functional outcomes according to the DASH scale: nBA vs nD — $p = 0.006$; nMA vs nD — $p = 0.013$ after 6 months, and according to the ASES scale: nBA vs nD — $p = 0.007$; nBA vs nD — $p= 0.002$ after 36 months. An reinsertion methods intragroup analysis revealed the achievement of peak indicators by ≤ 6 weeks without complications in the anatomical variant according to the VAS: nBA vs nMA — $p = 0.264$; DASH: nBA vs nMA — $p = 0.856$; ASES — nBA vs nMA $p = 0.179$.

Conclusion. Comparison within subgroups made it possible to identify the most effective technique — combination of minimally invasive access with an anatomical version of intracanal fixation with a cortical button. This technique has shown to have a low risk of postoperative complications.

Keywords: elbow joint, biceps brachii, lacertus fibrosus, distal tendon, sports medicine, surgical approach, cortical button.

Cite as: Medvedchikov A.E., Anastasieva E.A., Korytkin A.A., Lukinov V.L., Kirilova I.A. [Biceps Brachii Distal Tendon Ruptures: Conservative and Surgical Treatment Outcomes]. *Travmatologiya i ortopediya Rossii* [Traumatology and Orthopedics of Russia]. 2022;28(4):114-125. (In Russian). https://doi.org/10.17816/2311-2905-1997.

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Submitted: 04.10.2022. Accepted: 09.12.2022. Published: 16.12.2022.

Научная статья
УДК 616.747.21-001.33-08
https://doi.org/10.17816/2311-2905-1997

Результаты консервативного и хирургического лечения пациентов с разрывом дистального сухожилия двуглавой мышцы плеча

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Актуальность. Интерес к изучению разрывов дистального сухожилия двуглавой мышцы плеча (ДСДМП) в последнее десятилетие вызван развитием методов инструментальной диагностики, появлением новых спортивных дисциплин и усложнением технологической среды на рабочих местах. Основные концепции лечения зависят от сроков давности травмы, площади поражения сухожильной ткани, функциональных запросов пациента и его профессиональной деятельности, индекса коморбидности и делятся на консервативную и хирургическую.
Цель исследования — выявить наиболее эффективный метод лечения больных с разрывом дистального сухожилия двуглавой мышцы плеча.
Материал и методы. В исследования были включены 58 пациентов (все мужчины) с повреждением ДСДМП, которые были разделены на группы в зависимости от концепции лечения: группу консервативного лечения (Nc) — 20 (34%) пациентов и группу хирургического лечения (Ns) — 38 (66%). Группа хирургического лечения была разделена также на подгруппы: nD — открытый анатомический вариант с доступом Dobbie; nBA — малоинвазивный неанатомический вариант с доступом Boyd–Anderson; nMA — малоинвазивный анатомический вариант с передним доступом. Пациентам проводились физикальные тесты (O'Driscoll, Ruland и др.), УЗИ с целью сравнительного измерения проксимального радио-ульнарного пространства, степени мышечной ретракции, вовлеченности lacertus fibrosus, а также МРТ локтевого сустава. Для оценки полученных результатов использовались шкалы VAS, DASH и ASES. Результаты инструментальных методов диагностики оценивались с классификациями L. Perera (2012) и J. Fuente (2018).
Результаты. Оценка результатов в группах Ns и Nc по функциональным шкалам, DASH) и 36 мес. (ASES) позволила выявить: через 6 мес. по VAS — снижение выраженности болевого синдрома ≤ 1 балла, по DASH через 6 мес. — снижение до 21 и 43 баллов (в обеих группах $p<0,001$; разница между группами $p = 0,005$; по ASES через 36 мес. — 91 и 71 балл (динамика в обеих группах, разница между группами $p<0,001$). При использовании малоинвазивных доступов в сравнении с открытым доступом (nD) были получены лучшие функциональные результаты: по шкале DASH через 6 мес. — nBA vs nD $p = 0,006$; nMA vs nD $p = 0,013$; по шкале ASES через 36 мес. — nBA vs nD $p = 0,007$ и nBA vs nD $p = 0,002$. Результаты внутригруппового анализа способов реинсерции: по VAS — nBA vs nMA $p = 0,264$; по DASH — nBA vs nMA = 0,856; по ASES — nBA vs nMA $p = 0,179$. Пиковые показатели без осложнений были достигнуты в срок ≤ 6 нед. при анатомическом варианте.
Заключение. Сравнение внутри подгрупп позволило выделить наиболее эффективную методику в виде комбинации малоинвазивного доступа с анатомическим вариантом интраканальной фиксации кортикальной пуговицей, обладающую низким уровнем рисков развития послеоперационные осложнений.

Ключевые слова: локтевой сустав, бицепс плеча, *lacertus fibrosus*, дистальное сухожилие, спортивная медицина, хирургические доступы, кортикальная пуговица.

Медведчиков А.Е., Анастасиева Е.А., Корыткин А.А., Лукинов В.Л., Кирилова И.А. Результаты консервативного и хирургического лечения пациентов с разрывом дистального сухожилия двуглавой мышцы плеча. *Травматология и ортопедия России*. 2022;28(4):114-125. https://doi.org/10.17816/2311-2905-1997.

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Рукопись получена: 04.10.2022. Рукопись одобрена: 09.12.2022. Статья опубликована: 16.12.2022.

BACKGROUND

The interest in studying of the distal biceps tendon (DBT) ruptures is primarily due to the intensive development of imaging methods and digital analysis of the musculoskeletal system biomechanics, the emergence of new sports disciplines and the technological environment complexity in modern industries, stable public interest in bodybuilding.

The incidence of DBT ruptures in the USA ranges from 2.55 to 5.35 clinical cases per 100,000 population per year [1]. As a rule, these injuries are the result of spontaneous eccentric impact of forces on the supinated forearm of the dominant upper limb (86%) in the position of 90° flexion in the elbow joint [2, 3]. There is practically no gender modality — more than 95% of those seeking specialized help are middle-aged men (46.3 years old) involved in manual labor, military personnel, as well as professional athletes of contact and strength sports [4, 5]. The main predictors of injury include smoking, BMI ≥25, taking anabolic androgenic steroids and statins, elbow joint arthrosis, pre-existing tendinosis or mucoid degeneration of DBT [6].

In the historical context, the rarity of DBT ruptures is indicated by the fact that in the 36 years since the first clinical case publication by A.B. Johnson in 1891, there has not been a single mention of this pathology in the scientific literature [7]. Then T.M. Biancheri in 1925 investigated the frequency and typology of the biceps tendon injuries: 96% were attributed to ruptures of the proximal long head, 1% of cases were accompanied by provocation of the proximal short head and, accordingly, the distal tendon ruptures amounted to 3% [8].

Due to the rare occurrence and lack of uniform clinical and diagnostic algorithms, most of the recorded injuries are full-layered (avulsive) ruptures with a violation of the bone-tendon junction of the radial tuberosity, both with and without the cortical layer fragment. Partial ruptures are less common and include interstitial disorders united by a single paratenon of short and long heads. The case of partial rupture was published by K. Nielsen only in 1987 [9]. At the moment, such ruptures are estimated by the cross-sectional area of tendon tissue using imaging instrumental diagnostics. Clinical cases of partial DBT lacerations, which make up less than 50% of the section, have positive prospects for conservative treatment, and lesions affecting more than 50% are potentially considered as indications for surgical treatment of population active categories. Close attention should also be paid to the anatomical role of lacertus fibrosus as a DBT dynamic stabilizer, repair of which, according to recent data, is important for preventing relapses [10].

Introduction of imaging methods into clinical practice, such as 1.5–3.0 Tl MRI and MSCT with 3D reconstruction, targeted clinical tests (supination-pronation, passive pronation test of the forearm, O'Driscoll test, Ruland test, measurement of biceps flexion interval and biceps fold coefficient, lacertus fibrosus flexure test) and clinical-diagnostic algorithms allow doctors to accurately determine the concept of treatment at the pre-hospital stage [2]. On the other hand, a variable set of minimally invasive options (double incision, flexible instrumentation) and the evolution of cortical implants make surgery safer, and the "anatomical" classification of L. Perera [11] and the "diagnostic" classification of J. Fuente [12] provide a differentiated approach for ruptures combined with lacertus fibrosus or pronounced muscle retraction, increasing the final effectiveness of the method [13, 14, 15, 16].

Before the start of the study, a null hypothesis was determined about comparatively better functional results after surgical treatment, depending on the chosen approach to fossa cubitalis, the method of reinsertion (anatomical and non-anatomical) and the type of implant.

The aim of the study was to identify the most effective method of patients with DBT rupture treatment.

METHODS

Research design

A retrospective comparative cohort study of the medical records in the Tsivyan NNIITO of the Ministry of Health of Russia and ANO "Clinic NIITO" in the period from 2012 to 2022 was conducted.

Patients

The study group included 58 patients (all men) with DBT rupture. The ranking by age was 29-58 years (43 [34; 51]). All patients initially applied to the Clinical Diagnostic Center with complaints of

pain, fossa cubitalis ecchymosis, decreased maximum strength during loads and arm deformity, range of motions limitation in the injured elbow joint. The patients were divided into groups depending on the type of injury, its limitation period, and the type of treatment performed.

According to the type of injury, patients were registered in the database as sports, household and when performing physical labor. According to the prescription of the injury and the corresponding pathogenesis of inflammatory changes, the terms of contacting a specialist were conditionally determined: 1) inflammatory changes <21 days; 2) degenerative changes >21 days; and 3) pathological changes 12 weeks.

The main cohort of patients was divided into two groups according to the treatment concept, and the surgical group was also divided into three subgroups according to surgical approach and reinsertion methods. The patients of the surgical treatment group were divided into subgroups depending on the type of implant used in order to conduct an intra-group analysis of the strength properties of fixation and the level of postoperative complications (Fig. 1).

Examination of patients

According to a pre-determined algorithm for choosing treatment tactics in DBT ruptures, patients underwent physical tests: O'Driscoll, Ruland, supination-pronation, comparative isokinetic (DC-100 wrist dynamometer), measurements of the biceps flexion interval were carried out, the biceps fold coefficient was calculated. In order to determine the level of tendon injury, measurement of the proximal radioulnar space (PRUS), lacertus fibrosus provocation and the degree of biceps fatty degeneration in 49 (84.5%) cases, comparative ultrasound diagnostics of elbow joints by volar/dorsal approaches was performed and in 10 cases (15.5%) — MRI of the elbow joint 1.5–3.0 Tl (2). In 2 (3.4%) cases, electroneuromyography was performed when neuropathy was suspected.

Ultrasound of the injured and intact elbow joints with volar and dorsal approaches was chosen as a control instrumental study after treatment in 52 (89.6%) cases due to its availability. The absence of secondary lesion and biceps muscle retraction was regarded as a positive result of treatment. Postoperative complications were entered into the database and structured into four indicators for intergroup analysis on days 30 and 90: heterotopic ossification, neuropathy, stiffness (desmogenic contracture), muscle hypotrophy. At the same time, the relative values characterizing the frequency of occurrence or proportion were expressed as a percentage.

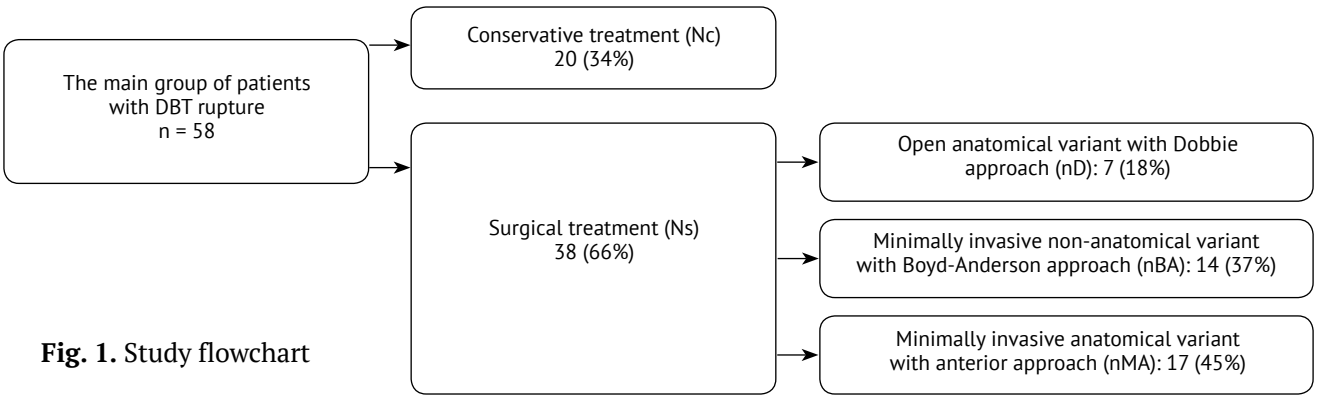

Fig. 1. Study flowchart

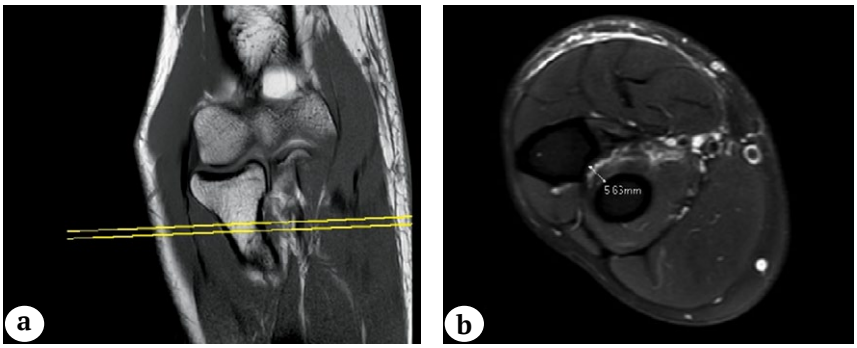

Fig. 2. Radio-ulnar space measurement example during appointment of patient with the distal biceps brachii tendon rupture:
a, b — MRI (the middle third level of the "foot-print" of radial tuberosity)

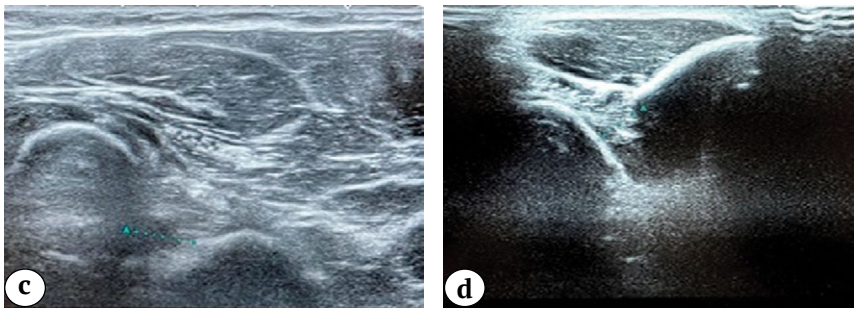

Fig. 2. Radio-ulnar space measurement example during appointment of patient with the distal biceps brachii tendon rupture: c, d — US (volar and dorsal accesses in pronation and supination positions of the forearm)

Evaluation of results

To evaluate the results obtained, the functional scales VAS, DASH and ASES were used. Additionally, the degree of biceps muscle retraction and involvement of lacertus fibrosus were compared with the above classifications of L. Perera and J. Fuente.

Conservative treatment

Conservative treatment was carried out in 20 cases only with partial ruptures (less than 50% of the tendon cross-section, which were detected by ultrasound or MRI) without muscle retraction 0-1 degree according to the classification of L. Perera. The Nc group included patients younger than 30 and older than 60 years engaged in intellectual work, with a high comorbidity index (Charlson ≥3 points), the presence of severe osteoporosis according to densitometry (T-criterion ≥-2.5), as well as with prolonged use of corticosteroids or other hormonal therapy.

Patients were prescribed an orthopedic regimen (restriction of rotation, flexion/extension, power loads after 6 weeks), immobilization with a sling bandage or a stabilizing kinesiotape. With severe edema, from the 1st to the 14th day, patients underwent cryotherapy with the Kryotur apparatus (TUR Therapietechnik GmbH, Germany). Since 2018, in 8 (40%) cases, the method of cellular regeneration was used by introducing platelet-rich plasma (PRP) in the course of palpable DBT. After 3 weeks nonsteroidal anti-inflammatory drugs (NSAIDs), individual kinesiotherapy with load potentiation and physiotherapy procedures were prescribed [17].

Surgical technique

Indications for surgical treatment were the presence of a characteristic trauma in the anamnesis, at least two positive targeted clinical tests (Ruland, O'Driscoll, comparative kinetic test DC-100) and DBT rupture, confirmed by one or more instrumental diagnostic methods.

In the Ns group, 38 patients with complete rupture and any degree of biceps muscular retraction required the restoration of the "footprint" of both tendon heads by surgical approaches Dobbie, Boyd – Anderson or minimally invasive anterior approach (anterior "double incision" approach) in combination with variable implants: anchor fixators — 4 (10%) cases, cortical button — 30 (79%), combination of cortical button and interference screw — 3 (8%) and ligature type — 1 (2%).

Postoperative management of patients

The rehabilitation program of the underwent surgery patients implied immobilization with a sling bandage until the sutures were removed, followed by kinesiotaping in a stabilizing version, early passive (from the 2nd week Kinetec Centura) and active movements (from the 4th week) in the elbow and shoulder joints, limitation of axial and traction load (horizontal bar, bars) on the upper limb for 12 weeks, physiotherapy (cryotherapy from the 1st to the 7th day, electromyostimulation of the biceps / triceps and deltoid muscles after achieving symmetrical range of motion), NSAIDs, manual kinesiotherapy.

In the late postoperative period (8-12 weeks), training in the pool and physical therapy with an instructor, using dumbbells from 1 kg with a weekly increase in loads. The achievement of symmetrical function during a comparative examination of both elbow joints according to the parameters of goniometry, dynamometry (DC-100) and functional scales was observed within 6-12 weeks since the surgery.

Statistical analysis

Empirical distributions of continuous indicators of age, duration of hospitalization, duration of disability, VAS, DASH and ASES scores were studied in groups for agreement with the law of normal distribution using the Shapiro-Wilk criterion. The comparability of variances was checked using Fischer's F-test. Only the terms of hospitalization and disability turned out to be normally distributed, so the comparison of continuous indicators was carried out using nonparametric criteria. To compare the indicators between groups at one time point, the Mann-Whitney U–test was used, and the dynamics of indicators within groups between time points was compared using the Wilcoxon criterion. Normally distributed indicators were described as mean ± standard deviation — M±SD, abnormally distributed — in the form of median — Me (Q1; Q3). Binary indicators of the number of events were described as the number of events and a percentage of the group size — n (%). For categorical indicators of the degrees of biceps muscular retraction, the number of patients with each degree and the percentage of the total number — n (%) were given. Binary and categorical indicators were compared between groups using the exact two-sided Fisher criterion. The dynamics of binary indicators was compared using the McNemar criterion. For all achieved p-levels, if necessary (when comparing more than two groups and degrees of biceps muscle retraction), correction for multiple comparisons by the Benjami-Hochberg method is made. Statistical hypotheses were tested at a critical significance level of p = 0.05, i.e. the difference was considered statistically significant at p<0.05.

All statistical calculations were performed in the RStudio program (version 2021.09.2 Build 382 — © 2009-2022 RStudio, Inc., USA) in the R language (v. 4.0.2).

RESULTS

For a checkup in 6 and 36 months 52 (90%) patients of groups Nc and Ns showed up. Six (10%) patients could not come, but each of them reported a subjective good result of treatment during online correspondence and was tested using the VAS, DASH questionnaires after 6 months and ASES 36 months with mandatory registration of indicators in the study database.

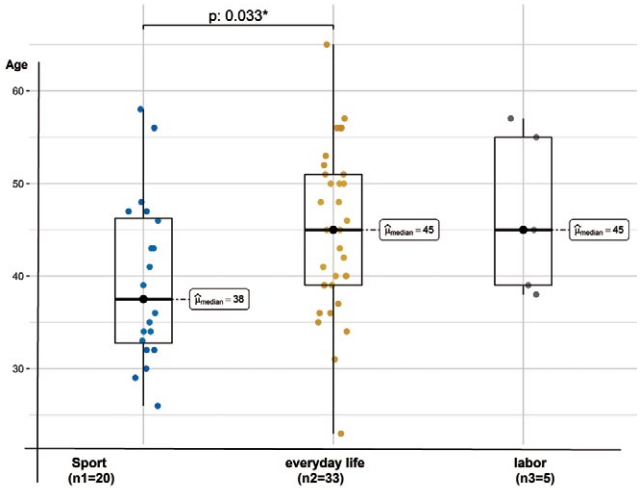

Fig. 3. Age parameters of the patients, depending on the type of the injury: n1 — sport; n2 — everyday life; n3 — industrial accident

The distribution of patients by age and type of injury is shown in Figure 3.

There were more patients with DBT injury who applied in the first 3 weeks — Nc = 18 (90%) and Ns = 20 (53%), (p = 0.008) compared to those who applied after 3-6 weeks. — Nc = 2 (10%) and Ns = 10 (26%), (p = 0.187) and 12 weeks. — Nc = 0 (0%), Ns = 8 (21%), (p = 0.041), respectively.

The degree of biceps muscle retraction was assessed by ultrasound or MRI results, then checked with the Perera and Fuente classifications:

0 degree — Nc = 12 (60%); Ns = 0 (0%), p<0.001;
1 degree — Nc = 6 (30%); Ns = 13 (34%), p >0.999;
2 degree — Nc = 0 (0%); Ns = 11 (29%), p = 0.011;
3 degree — Nc = 2 (10%); Ns = 14 (37%), p = 0.035.

In a single clinical case, a combination of injury period factors (>12 weeks) and a high degree of muscle retraction (3 degree) required the use of autograft technique*.

During the analysis of control ultrasound and MRI results with measurements of the PRUS and the volume of osseointegration of the tendon-bone zone of operated patients in the nD, nBA and nMA subgroups, a combination was proposed combining minimally invasive anterior approach "double incision" with minimal contact with neurovasal structures and a modified

*Patent for invention 2745408 C1. Method of surgical treatment of long-standing and repeated rupture of the distal biceps tendon / Medvedchikov A.E., Kirilova I.A., Anastasieva E.A.

method of fixation with a cortical button [18, 19]. Our variant implied suturing of the tendon stump with a braided non-absorbable tape, the formation of a "sliding loop" in the cortical button, which is considered a "reference" in terms of stiffness and biomechanics, which is important, given the possibility of repeated injury of the elbow joint in young patients involved in sports [15] (Fig. 4).

The postoperative period in 38 cases proceeded without septic complications. The average period of hospitalization was 2.5 bed days. The duration of disability in intellectual work patients was 33.5±0.5 days, in physically active patients or athletes — 45.5± 0.71 days.

Evaluation of the treatment results of all 58 patients was performed after 6 months on the VAS, DASH scales and after 36 months on the ASES scale and showed a decrease in the severity of pain to ≤ 1 point. DASH scores in the Ns and Nc groups decreased to 21 and 43 points ($p<0.001$), the difference between the groups after 6 months was statistically significant ($p = 0.005$) (Fig. 5). ASES scores were 91 and 71 points ($p<0.001$), which confirms the null hypothesis about the best functional results after surgical reinsertion of DBT (Fig. 6).

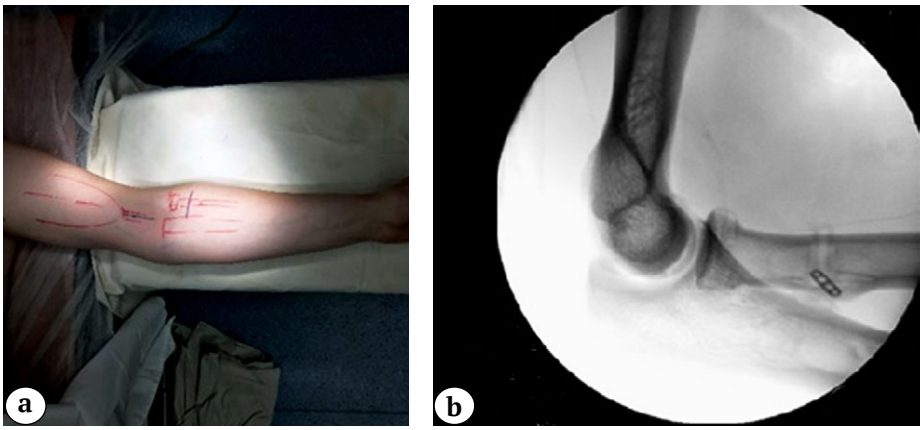

Fig. 4. Patient 41 y.o., Ns group, nMA:
a — planning of surgical approach;
b — intraoperative X-ray control

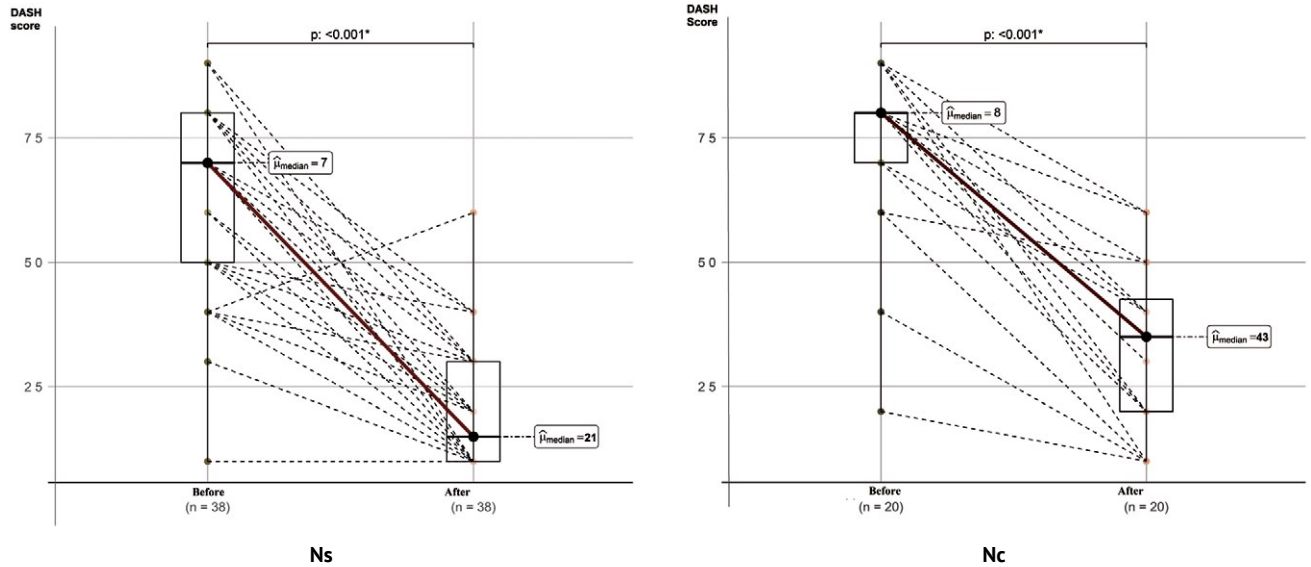

Fig. 5. Treatment outcomes in Ns and Nc groups using DASH in 6 month, scores

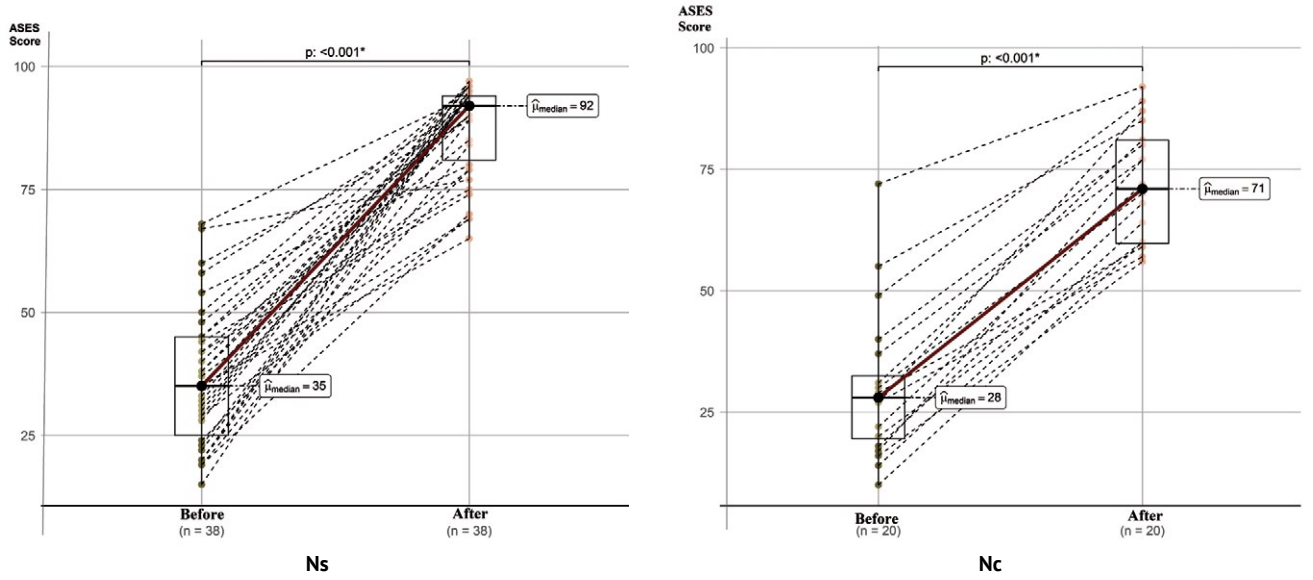

Fig. 6. Treatment outcomes in Ns and Nc groups using ASES in 36 month, scores

Within subgroups with different surgical approaches, methods of anatomical and non–anatomical reinsertion (38 operated patients), the results were:

- on the VAS after 6 months: nD decreased from 6 to 2 points (p = 0.022); nBA from 6.5 to 1 point (p = 0.001); nMA from 6 to 0 points (p<0.001);

– on the DASH scale: nD from 76 to 31 points (p = 0.022); nBA from 71 to 17 points (p = 0.001); nMA from 74 to 14 points (p<0.001);

– on the ASES scale after 36 months: nD from 37 to 79 points (p = 0.016); nBA from 38 to 91 points (p = 0.001); nMA from 31 to 94 points (p <0.001).

These indicators reflect the influence of surgical approach and the method of DBT reinsertion on the functional state of the kinematics of the elbow joint in the medium and long term.

In statistical analysis of data 6 months after surgery, minimally invasive approches showed better functional results compared to the open variant:

DASH: nBA vs nD — p = 0.006; nMA vs nD p = 0.013;

ASES: nBA vs nD — p = 0,007; nBA vs nD p = 0,002.

Comparing the pMA and the nBA, we noted insignificant differences only after 36 months.

Of the 31 minimally invasive surgeries, 14 (37%) non-anatomical DBT reinsertions were registered. Regardless of the type of implant, these patients were found to have any complications (stiffness, elbow joint arthrosis, synostosis of the PRUS, residual pain syndrome) and questionable prospects for early return to sports and work activity, reaching peak functional indicators with comparative morphometry (goniometry, DC-100) after 9-12 weeks. Accordingly, 17 (45%) operations with anatomical reinsertion of DBT were performed. Results for the above indicators:

VAS: nBA vs nMA — p = 0,264;

DASH: nBA vs nMA — p = 0,856;

ASES: nBA vs pMA — p = 0.179.

We revealed the achievement of peak indicators with comparative morphometry (goniometry, DC-100) and readiness for physical labor, as well as for sports training by the time of ≤ 6 weeks without the above negative events.

Complications

The presence of complications in the Ns group was assessed on the 30th and 90th days after surgery, after which an intergroup analysis was performed (Tab. 1).

Transient neuropathy of the lateral cutaneous nerve of the forearm, detected clinically and according to ENMG data in the first 30 days, was completely disappeared after the administration of ipidacrine hydrochloride by the 90th day. Muscle hypotrophy was determined by morphometry, dynamometry DC-100 and resolved after electromyostimulation after 30 days. The stiffness of the elbow joint was assessed using goniometry and was eliminated after the appointment of sequential hardware mechanotherapy (Kinetec

Table 1

Postoperative complications in subgroups of surgical approaches for up to 30 days

Complication	Subgroup		
	nD	nBA	nMA
Transient neuropathy of the lateral cutaneous nerve of the forearm	0 (0%)	2 (14%)	0 (0%)
Muscle hypotrophy	7 (100%)	7 (50%)	7 (41%)
Desmogenic contracture	7 (100%)	5 (36%)	5 (29%)
Heterotopic ossification	7 (100%)	0 (0%)	0 (0%)

Centura), then manual kinesiotherapy by the 90th day. In the operated patients, heterotopic ossification was diagnosed according to MRI data and persisted throughout the study period.

Damage to the posterior interosseous nerve (PIN) was not detected. The Dobbie open surgical approach method has high risks of developing short- and medium-term complications (>90 days), while the minimally invasive Boyd-Anderson variant was accompanied by transient neuropathy in two cases.

Six months after treatment, 52 (89.6%) patients of the Nc and Ns groups underwent ultrasound of the injured and intact elbow joints with volar and dorsal approaches due to its accessibility. The remaining 6 (10.4%) patients underwent MRI at their own request. In all cases, there was no biceps muscle retraction, signs of tendinosis, mucoid degeneration of the tendon. There were no relapses of the DBT rupture in the period from 2012 to 2022.

DISCUSSION

The concepts of the treatment of DBT ruptures vary depending on the period of injury, the area of the tendon lesion, the presence of morphological deviations of the elbow joint (heterotopic ossification, arthrosis, neuropathy), the comorbidity index and functional requirements of the patient and are divided into conservative and surgical [2, 5, 11, 14, 20, 21]. The rarity of the nosological form and the lack of unified clinical and diagnostic treatment algorithms prompted us to conduct a study covering period of ten years. In our opinion, partial ruptures less than 50% of the cross-section of the DBT, detected by ultrasound or MRI methods in patients younger than 30 or older than 60 years engaged in intellectual work, with the injury period less than 3 weeks and without muscle retraction, they can respond well to conservative treatment. In these cases, we can expect a decrease in the maximum supination force by an average of 40% (26-60%), and the maximum flexion force by an average of 20% (0-40%). In the study Y. Tomizuka et al., performed on 86 cadaver models with ruptures of more than 50% of the DBT thickness, 76% of failures with cyclic loads on the elbow joint are reported; probably, in clinical practice, such cases would have received better functional results using an alternative method [22].

Anatomical and MRI studies show the expansion of the native DBT of the radial tuberosity area from ± 5.3 mm to ±19.4 mm of the tendon-muscle junction with an average tendon length of 69 mm. The zone of tendon attachment to the bone has variable parameters of length 14-21 mm and width (2-10 mm), as well as a C-shaped configuration [3, 23, 24]. At the moment of moving the forearm from the supination position to the pronation position, there is a narrowing of PRUS up to ≤ 45%, which leads to mechanical impingement of the DBT without static and dynamic effort of the surrounding muscles, being the primary cause of rupture of single tendon fibers. The average values of the PRUS in the neutral position are 8.8 ±4.0 mm, the pronation is 7.8±3.9 mm, making the zone "problematic" when choosing the reinsertion method [3].

Histopathological studies of the injured area show an increased content of proteoglycans, type III collagen, matrix metallopeptidase-1 and matrix metallopeptidase-3 in the tendon stump and radial tuberosity, and disorganized fiber arrangement, which may indicate previously suffered bursitis or tendinopathy [25]. Together, the

dynamic change of the PRUS and the complexity of the attachment area anatomy under cyclic loads contribute to the formation of a zone of hypovascularization and hypooxygenation of DBT tissues, which is a secondary cause of degenerative rupture [24, 25]. Thus, surgeons should avoid bone positioning of the tendon stump, which is typical for methods using anchor and ligature fixators both during primary and revision reinsertion [15, 26].

Due to a thorough study of the neurovasal architectonics of fossa cubitalis and digital analysis of the biomechanics of the elbow joint (dynamic changes of the PRUS), regardless of the method of reinsertion and the type of implant, surgical treatment with open or minimally invasive approach leads to a high degree of subjective patient satisfaction, low pain and excellent functional results [27]. However, despite the optimism, the method has a 25% frequency of general postoperative complications, 4.6% of which are serious (neuropathy, PIN, LABCN, repeated tendon rupture, synostosis of PRUS, etc.) [6].

The generally accepted volar approach to fossa cubitalis by Dobbie was critically evaluated, as well as the most common minimally invasive approach known to us — access by Boyd-Anderson [2, 6, 16]. Both in combination with the bone positioning of the retracted DBT do not give a strong fixation, increase the risks of contact with neurovasal structures (PIN/LABCN, etc.) and ultimately lead to unsatisfactory results [28]. Also in our clinical practice, the technical difficulty of using a cortical button from the Boyd – Anderson approach, developed for ligature fixation after tendon insertion through the interosseous membrane of the forearm, was revealed. Therefore, 37% of patients underwent tendon transposition according to the technology and the formation of channels on the lateral surface of the radial bone diaphysis.

The ratio of surgical approaches, reinsertion methods and types of implants as possible predictors of repeated rupture, as well as the analysis of the role of osseointegration of the attachment area of radial tuberosity during a ten-year study allowed us to identify the most effective method of DBT anatomical reinsertion, combining minimally invasive principles and a high level of intracanal tendon-bone junction. The nontrivial approach of this method critically reduces the risks of complications in the form of relapse, synostosis of PRUS, heterotopic ossification and desmogenic contracture of the elbow joint in patients engaged in physical labor, or athletes at the peak of their careers in terms of 30 and 90 days. Patients underwent surgery using this method are able to show comparatively better functional results in terms of 6 to 36 months after treatment. The results of surgical treatment of 38 patients with DBT rupture obtained during the study, in general, have no discrepancies with the literature data on this issue and encourage the authors to further search for solutions to reduce the number and severity of postoperative complications, develop other methods of fixation, and reduce the duration of rehabilitation.

Study limitations

A small number of patients were included in the study, which is due to the rarity of the nosological form and could affect the results. The comparative analysis of the results was carried out on our own clinical material within the same clinical base.

CONCLUSION

Improvement of patients with DBT rupture treatment results is possible with an adequately chosen method of treatment, taking into account the period of the injury, the area of the tendon lesion, the patient's need for physical activity, the risks of surgery and predictors of adverse outcomes. Conservative treatment is relevant in cases of partial ruptures in patients with intellectual work and the elderly, while modern minimally invasive interventions with short rehabilitation periods are more suitable for active categories of patients. Comparison of surgical approaches, reinsertion methods and types of implants allowed us to identify the most effective technique. The combination of minimally invasive approach with the option of intracanal fixation with a cortical button is distinguished by anatomicity, strength, ease of implementation, which together reduces the number of complications compared to conventional methods of treatment, and also makes it possible to improve the quality of patient life in a short time.

DISCLAIMERS

Author contribution

Medvedchikov A.E. — conception and design of the study, collection and processing of data, writing and editing the draft.

Anastasieva E.A. — collection and processing of data, text editing.

Korytkin A.A. — text editing.

Lukinov V.L. — collection and statistical processing of data, text editing.

Kirilova I.A. — text editing.

All authors have read and approved the final version of the manuscript of the article. All authors agree to bear responsibility for all aspects of the study to ensure proper consideration and resolution of all possible issues related to the correctness and reliability of any part of the work.

Funding source. State budgetary.

Competing interests. The authors declare that they have no competing interests.

Ethics approval. Not applicable.

Consent for publication. Written consent was obtained from the patients for publication of relevant medical information and all of accompanying images within the manuscript.

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