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Outcomes and complications after different surgical techniques for the treatment of chronic distal biceps tendon ruptures: a systematic review and quantitative synthesis

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Hypothesis: The purpose of this study was to perform a systematic review of the available literature evaluating surgical outcomes after chronic distal biceps tendon rupture. Surgical techniques, including primary repair, autograft reconstruction, and allograft reconstruction, were compared, as well as subjective and objective clinical outcomes and complication rates.

Methods: A systematic literature search of Level I-IV studies reporting outcomes of surgically treated chronic distal biceps tendon ruptures were performed via PubMed, Cochrane Collaboration, Science Direct, and Google Scholar databases. Twenty-two papers were identified in the review, with 236 patients. A Modified Coleman Methodological Score (CMS) was determined for every article to assess study quality. Patient-reported outcomes, postoperative range of motion, flexion and supination strength, and postoperative complications were recorded. MAYO elbow scores (MEPS) were reported more consistently than the other outcome tools.

Results: No Level I or level II studies were identified in our search, and the heterogeneity of outcome measures precluded meta-analysis. Studies demonstrated mean MEPS scores ranging between 86 and 100, regardless of the surgical technique utilized. All studies reported a mean flexion-extension arc equal to or greater than 5-130°. The reported mean postoperative flexion strength was within 10% of the unaffected contralateral side. The most common complication for both direct repair and reconstruction groups was paresthesia of the lateral antebrachial cutaneous nerve [direct repair: 18–16.8%; reconstruction: 8–6.2% (allograft: 4–6%; autograft: 4–7%)]. Rerupture was uncommon and occurred in three patients who had undergone direct repair and in one patient after autograft reconstruction.

Conclusions: Surgical treatment of chronic distal biceps injuries yields favorable objective and subjective outcomes. Currently, available evidence suggests that direct repair, autograft reconstruction, or allograft reconstruction are all viable treatment options with similar outcomes.

Distal biceps tendon ruptures are a relatively uncommon injury with an annual incidence of 1.2 per 100,000, occurring most frequently in middle-aged men.[18,25,38] A complete tear of the distal biceps can lead to a decrease in supination strength of 40%-50%, as well as a 20%-30% decrease in flexion strength.[33] Therefore, many active patients elect to have their injury acutely repaired. However, patients can also present in a delayed fashion, several weeks to several months after distal biceps rupture. Surgery for chronic injuries presents a greater challenge for the surgeon secondary to tendon retraction, muscle atrophy, scar formation, and altered tissue planes that will result in difficulty in mobilizing the tendon tissue, and the potential need for complex dissection or reconstruction.[24]

First described by Boyd and Anderson, direct anatomic repair has been the preferred method for treatment of both acute and chronic distal biceps tendon ruptures when the tendon is able to be

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Institutional review board approval was not required for this systematic review.

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reduced back to the radial tuberosity tension free.[6,34] Expedient, direct repair avoids motion loss and strength deficits, which may result from delayed or prolonged nonoperative management of these injuries. In the subset of patients that are not candidates for direct repair, reconstruction with augmentation using both autograft and allograft has been described in the literature.

At this time, there is no consensus with regards to the most appropriate surgical technique for the management of these complex injuries, and much of the available literature is currently limited to single-center retrospective case series or lower levels of evidence. It would stand to reason that delayed surgical treatment may preclude straightforward, primary repair requiring a more extensile approach for reconstruction and increased risk of adverse outcomes. Beks et al.[3] examined adverse events among distal biceps repairs vs. reconstructions. In their evaluation, obesity and the surgical approach utilized were the only factors independently associated with adverse outcomes.

Distal biceps repair and reconstruction are viable surgical options with favorable clinical outcomes for the treatment of chronic distal biceps injuries. A retrospective cohort comparison between direct repair and allograft reconstruction by Hendy et al.[23] showcased similar outcomes, including failure rates and reoperation. Similarly, a systematic review by Litowski et al.[29] found no difference in outcomes between various graft types for reconstruction. To date, there is no systematic review comparing direct repair vs. reconstruction surgical outcomes for chronic distal biceps rupture.

Therefore, the purpose of this study was to evaluate and compare clinical and functional outcomes for chronic distal biceps tendon ruptures treated with delayed primary repair, autograft reconstruction, or allograft reconstruction. The secondary purpose of this study was to evaluate and report on complication types and re-rupture rates among these surgical treatment options. The authors hypothesized that the results would demonstrate safe, reproducible, and acceptable functional outcomes with similar complication rates that could be achieved regardless of the surgical technique utilized.

Materials and methods

Search strategy

A reproducible and systematic literature review was performed on February 15, 2021, according to the Preferred Reporting Items for Systematic Review and Meta-analyses (PRISMA) guidelines.[21,31] Phase 1 of the PRISMA process included a search of the PubMed, Cochrane Review, Science Direct, and Google Scholar databases for relevant peer-reviewed articles. A Boolean strategy using the following terms was applied: (distal biceps) AND (reconstruction) OR (chronic) OR (retracted) OR (autograft) OR (allograft) OR (repair). For the Cochrane database search, an additional optional filter was used with the search terms: orthopedics and trauma. The references cited in all relevant articles were also screened to identify any additional studies evaluating chronic distal biceps rupture treatment not identified in the original search. In Phase 2 of the PRISMA process, all article titles and abstracts were screened to assess their relevance. The full text of each selected study was reviewed for eligibility criteria in Phase 3. Finally, all studies underwent a systematic review in Phase 4. Heterogeneity of outcome measures precluded meta-analysis.

Eligibility criteria

All level I, II, III, or IV studies reporting clinical outcomes from surgically treated chronic distal biceps tendon ruptures were identified. Chronicity of the distal biceps rupture was defined as $\geq$3 weeks between the time of injury and the date of surgery, as described in prior publications.[4,7,17,22,24] Studies with a mean follow-up of less than 12 months, reporting on fewer than 4 patients with delayed presentation, published in languages other than English, containing patients with partial distal biceps tears or not clearly describing the surgical technique utilized were excluded. Studies aggregating data for acute and chronic patients without distinction between groups were also excluded. For articles evaluating the same cohort of patients at successive time points, only the most recent publication reporting the longest follow-up period was included (Fig. 1).

Data extraction

The clinical outcomes assessed include patient-reported outcomes, range of motion, flexion and supination strength, and postoperative complications. The functional outcome tools utilized included: MAYO (MAYO Elbow Performance Score), Oxford Elbow Score, DASH (Disabilities of the Arm, Shoulder, Hand), VAS (Visual Analog Scale), ASES Elbow Score, PREE (Patient-Rate Elbow Evaluation), and SANE (Single Assessment Numeric Evaluation). The data extracted from each selected study included study design, authorship, year of publication, journal, level of evidence, number of patients, age, the time between injury and surgery, mean follow-up period, the surgical technique performed, and if appropriate, graft type utilized.

Quality assessment

A modified Coleman Methodological Score (CMS) was derived for each article to assess methodological quality by two separate authors (JS & AG).[10] Averages of the two reviewers were used to assign a single score for each article. The inter-rater agreement was 81.8% between the two reviewers. The numerical score was based upon a 100-point scale, with higher scores denoting higher quality studies.

Results

Literature search

Twenty-two studies evaluating 236 patients undergoing surgical treatment for chronic distal biceps tendon rupture were included (Table I).[2,5,8,11-13,16,17,19,22,28,32,34,36,37,39-42,46] There were 10 studies for the direct repair group, with 2 of these studies reporting direct repair with lacertus fibrosus augmentation.[8,16] For the 10 direct repair studies, 0 studies were level II evidence; 4 studies, level III evidence; and 6 studies, level IV evidence, with average CMS of 51.1. There were 12 studies for the surgical reconstruction group (allograft 6; autograft 6). Of the 12 studies, 0 studies were level II evidence, 3 level III evidence, and 9 level IV evidence, with average CMS of 53.6.

Demographics

Of the 236 patients identified, 107 patients were in the direct repair group and 129 in the reconstruction group. Seventeen studies included enough information to ascertain the gender of patients. These studies had exclusively male patients with the exception to that by Morrey et al., which had one female patient. For the direct repair group, the mean age was 48.8, the mean time to surgery from injury was 2.9 months, and the mean follow-up was 28.7 months. For the reconstruction group, the mean age was 43.5, the mean time to surgery from injury was 8.5 months, and the mean follow-up was 38.8 months. Within the

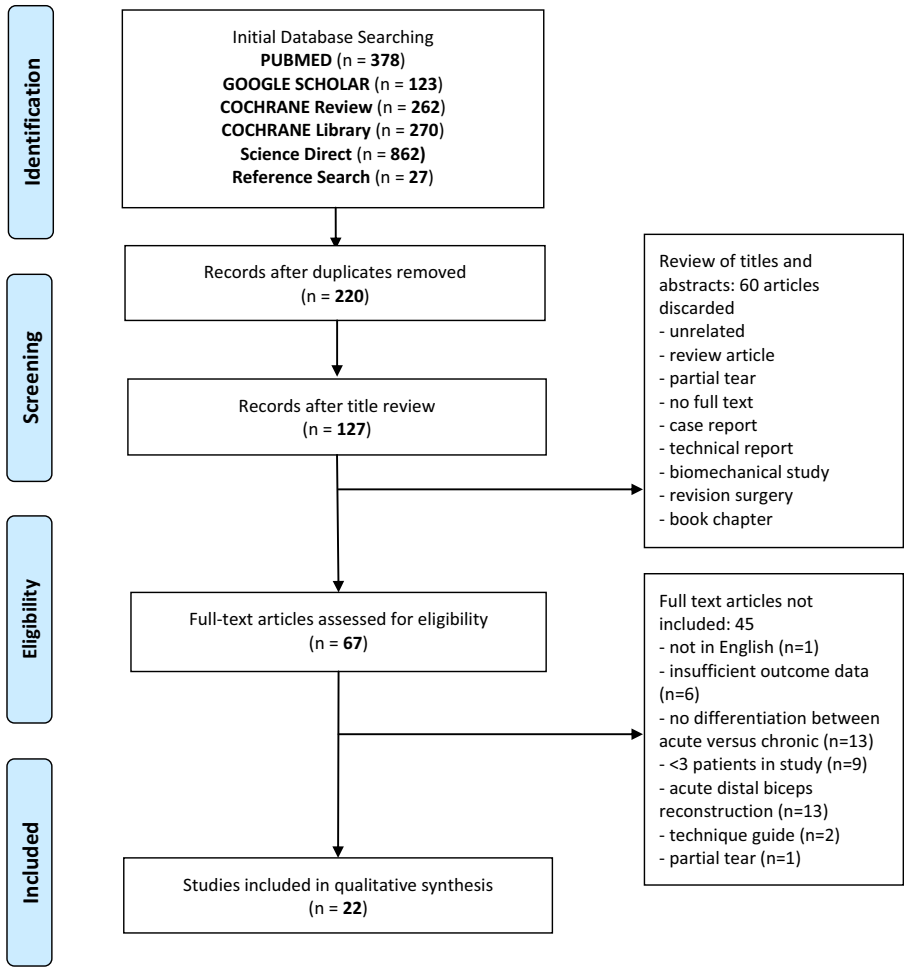

Figure 1 Prisma flow diagram project chronic distal biceps.

reconstruction group, 68 patients underwent allograft reconstruction, and 61 patients underwent autograft reconstruction. There was variability in graft choice for autograft reconstruction, including the use of semitendinosus, fascia lata, and flexor carpi radialis for autograft. Allograft reconstructions were predominantly performed using the Achilles tendon.

Patient-reported outcomes

Nineteen studies with 202 patients reported patient-reported outcomes (Table II). MEPS were reported more consistently than the other outcome tools, and all but one study demonstrated mean postoperative patient scores ranging between 92 and 100, regardless of the surgical technique utilized. Four studies reported MEPS scores for the direct repair group, while 8 (allograft 6; autograft 2) studies reported it for the reconstruction group. The average MEPS for direct repair was 98.1, and reconstruction was 95.1 (allograft 95.9; autograft 92.5). Only one study reported a lower mean MEPS score (86) in those patients who underwent semitendinosus autograft reconstruction through an anterior single-incision approach.[17]

Range of motion

Sixteen studies with 181 patients reported final, postoperative ROM for flexion, extension, supination, and pronation (Table III). Of these patients, 87 underwent direct repair, and 94 underwent reconstruction (autograft 26; allograft 68). All studies reported a mean flexion-extension arc equal to or greater than 5-130°, regardless of surgical technique utilized. The mean flexion-extension arc was 0-137 for direct repair groups and 2-135 for reconstruction.

The mean of supination-pronation arc for those undergoing direct repair was 78.2-76.8°compared to 81.4-82.5°in those undergoing either reconstruction. Dillon et al. and Zeman et al. were the only studies to demonstrate >10° loss of mean supination-pronation, and all the patients in these studies were treated with a direct repair.[13,47]

Strength outcomes

Thirteen studies with 134 patients reported on flexion and supination strength (Table IV). Of these, 44 were treated with direct repair, and 90 were treated with reconstruction (autograft 50; allograft 40). Strength testing varied per study between subjective and objective methods of evaluation. Four studies used subjective measurement to assess strength, while nine studies utilized objective measurement tools. Subjective measurement was employed more often in the distal biceps reconstruction studies than direct repair. Objective methods for measurement utilized various tools such as Lido Multijoint II, Biodex System 3 Pro, and Cybex Dynamometer. With such a large amount of heterogeneity

Table I
Study characteristics with modified Coleman score for distal biceps direct repairs and reconstruction.

Study	Year	Journal	Study design	Level of evidence	CMS	# Of patients	Technique	Approach	Age, mean yr.	Time from injury to surgery, mean mo.*	Follow up, mean mo.*
Direct Repair											
Anakwenze et al[2]	2013	J Athl Train	Retrospective Cohort	III	42	6	Direct Repair	Two-Incision	48.1	1.8	25.3
Bosman et al[5]	2012	J Shoulder Elbow Surg	Case Series	IV	64	5	Direct Repair	Two-Incision	47.2	2.8	20.2
Caputo et al[8]	2016	J Shoulder Elbow Surg.	Case Series	IV	49	11	Direct Repair w/ Lacertus Fibrosus	Anterior Single-Incision	44.0	4.1	23.0
Dillon et al[13]	2011	Hand (N Y).	Retrospective Cohort	III	61	9	Direct Repair	Anterior Single-Incision	54.2	>1.5	28.6
Fontana et al[16]	2016	Musculoskelet Surg	Case Series	IV	54	4	Direct Repair w/ Lacertus Fibrosus	Anterior Single-Incision	45.0	3.3	44.3
Goljan et al[19]	2016	Hand (N.Y.)	Case Series	IV	49	9	Direct Repair	Anterior Single-Incision	52.4	2.3	5.1/ 16.0 (clinic/phone)
Haverstock et al[22]	2017	J Shoulder Elbow Surg	Case Control	III	35	8	Direct Repair	Anterior Single-Incision	48.0	1.3	48.0
						8	Direct Repair	Two-Incision			
Morrey et al[34]	2014	J Shoulder Elbow Surg	Case Control	III	51	19	Direct Repair	Two-Incision	50.0	5.3	>12.0
Terra et al[41]	2016	Rev Bras Ortop	Case Series	IV	55	8	Direct Repair	Anterior Single-Incision	47.5	2.6	14.0
Zeman et al[47]	2020	J Shoulder Elbow Surg	Case Series	IV	51	20	Direct Repair	Anterior Single-Incision	52	2.5	26
Reconstruction											
Darlis et al[12]	2006	J Shoulder Elbow Surg	Case Series	IV	59.5	7	Achilles Allograft	Anterior Single-Incision	38.0	7.0	29.0
Phadnis et al[36]	2016	J Shoulder Elbow Surg	Case Series	IV	71	21	Achilles Allograft	Anterior Single-Incision	44.0	24.7	15.0
Sanchez-Sotelo et al[39]	2002	J Bone Joint Surg Am	Case Series	IV	46	4	Achilles Allograft	Two-Incision	39.0	10.7	33.9
Snir et al[40]	2013	Am J Sports Med	Case Series	IV	53.5	16	Allograft (Mixed)†	Anterior Single-Incision	46.9	5.0	21.0
						2	Achilles Allograft	Two-Incision			
Goyal et al[20]	2020	J Shoulder and Elbow Surg	Case Series	IV	44.5	11	Achilles, Tibialis Anterior, Semitendinosus Allograft‡	Single or Two-Incision	50.0	5.0	46.0
Cross et al[11]	2014	Int Orthop	Case Series	IV	54	7	Tibialis Anterior Allograft	Anterior Single-Incision	44.0	6.3	16.0
Ribeiro et al[37]	2017	Revista Brasileira de Ortopedia	Case Series	IV	53	4	Semitendinosus Autograft	Two-Incision	37.8	8.3	15.0
Frank et al[17]	2019	J Shoulder Elbow Surg.	Retrospective Cohort	III	55	19	Semitendinosus Autograft	Anterior Single-Incision	46.0	9.5	45.0
Wiley et al[46]	2006	J Shoulder Elbow Surg	Case Control	III	56	7	Semitendinosus Autograft	Two-Incision	49.0	4.3	63.0
Morrell et al[32]	2012	Tech Hand Up Extrem Surg	Case Series	IV	44	12	Fascia Lata Autograft	Anterior Single-Incision	41.8	6.6	14.5
Levy et al[28]	2000	Am J Sports Med	Case Series	IV	51	5	Flexor Carpi Radialis Autograft	Anterior Single-Incision	41.0	>3.0	34.0
Vastamaki et al[42]	2008	Clin Orthop Relat Res	Retrospective Cohort	III	56	14	Autograft (Mixed)§	Anterior Single-Incision	44.8	5.9	133.2

CMS, Coleman Methodological Score.
*4 weeks = 1 month.
†Mixed 15 Achilles, 1 Anterior Tibialis, 1 Semitendinosus, 1 Gracilis with Anterior Tibialis.
‡Mixed 1 Achilles, 1 Anterior Tibialis, 9 Semitendinosus.
§Mixed 7 Plantaris Longus, 6 Long Extensors 2/3 Toes, 1 Palmaris Longus.

Table II
Patient-reported outcomes for chronic distal biceps direct repair and reconstruction.

Study	Year	Technique	Satisfaction/SANE	MEPS, mean	DASH/Quick dash, mean	PREE, mean	Other, mean
Direct Repair							
Anakwenze et al[2]	2013	Direct Repair	–	–	6.8	–	–
Bosman et al[5]	2012	Direct Repair	96%	100.0	3.3	–	–
Dillon et al[13]	2011	Direct Repair	–	–	–	–	ASES Elbow Score = 99.2
Fontana et al[16]	2016	Direct Repair w/Lacertus Fibrosus	–	95	–	–	–
Goljan et al[19]	2016	Direct Repair	93%	–	4.8	–	–
Haverstock et al[22]	2017	Direct Repair	–	–	3	4	ASES pain = 2/ASES Function = 35/ASES Satisfaction = 10
Terra et al[41]	2016	Direct Repair	–	97.5	–	–	Pain VAS = 0.8
Zeman et al[47]	2020	Direct Repair	–	100			ASES = 97/OES = 48/VAS = 0
Reconstruction							
Darlis et al[12]	2006	Achilles Allograft	–	97	–	–	–
Phadnis et al[36]	2016	Achilles Allograft	–	92.9	4	–	OES = 44.7
Sanchez-Sotelo et al[39]	2002	Achilles Allograft	–	100	–	–	–
Snir et al[40]	2013	Allograft - Mixed*	–	94.2	7.5	–	–
Goyal et al[20]	2020	Allograft - Mixed†	94%	97.3	5.8	–	Pain VAS = 0.6
Cross et al[11]	2014	Tibialis Anterior Allograft	–	94	6.7	–	–
Wiley et al[46]	2006	Semitendinosus Autograft	93%	–	–	–	–
Frank et al[17]	2019	Semitendinosus Autograft	88%	86	7	14	–
Morrell et al[32]	2012	Fascia Lata Autograft	–	–	–	–	–
Levy et al[28]	2000	Flexor Carpi Radialis Autograft	–	–	–	–	–
Vastamaki et al[42]	2008	Autograft - Mixed‡	–	99	–	–	–

*Mixed 15 Achilles, 1 Anterior Tibialis, 1 Semitendinosus, 1 Gracilis with Anterior Tibialis.
†Mixed 1 Achilles, 1 Anterior Tibialis, 9 Semitendinosus.
‡Mixed 7 - Plantaris Longus, 6 Long Extensors 2/3 Toes, 1 Palmaris Longus.

Table III
Range of motion outcomes for chronic distal biceps direct repair and reconstruction.

Study	Year	Technique	Flexion, mean	Extension, mean	Supination, mean	Pronation, mean
Direct Repair						
Anakwenze et al[2]	2013	Direct Repair	153.3	0.0	80.0	80.0
Bosman et al[5]	2012	Direct Repair	132.0	−1.6*	79.0	82.0
Caputo et al[8]	2016	Direct Repair w/ Lacertus Fibrosus	138.0	0.7	80.7	79.3
Dillon et al[13]	2011	Direct Repair	134.7	0.9	67.9	72.4
Goljan et al[19]	2016	Direct Repair	130.6	0.0	-	-
Morrey et al[34]	2014	Direct Repair in >60^0 Flexion	138.2	2.1	80.5	77.1
Terra et al[41]	2016	Direct Repair	133.1	−2.5*	88.2	82.5
Zeman et al[47]	2020	Direct Repair	132.0	3.0	71.0	64.0
Reconstruction						
Darlis et al[12]	2006	Achilles Allograft	145.0	2.9	86.0	83.0
Phadnis et al[36]	2016	Achilles Allograft	no deficit	2 pt had 5 degree extensor loss	no deficit	no deficit
Sanchez-Sotelo et al[39]	2002	Achilles Allograft	135.0	0.0	82.5	83.8
Snir et al[40]	2013	Allograft (Mixed)†	137.2	2.5	85.6	83.6
Goyal et al[20]	2020	Allograft - Mixed†	130.0	0.0	76.0	75.0
Cross et al[11]	2014	Tibialis Anterior Allograft	134.0	4.0	80.0	82.0
Morrell et al[32]	2012	Fascia Lata Autograft	131.0	5.0	80.0	87.0
Vastamaki et al[42]	2008	Autograft (Mixed)‡	132.0	0.0	80.0	83.0

*negative integers denote hyperextension.
†15 Achilles, 1 Anterior Tibialis, 1 Semitendinosus, 1 Gracilis with Anterior Tibialis.
‡7 Plantaris Longus; 6 Long Extensors 2/3 Toes; 1 Palmaris Longus.

utilized to measure strength between each study, a direct comparison between direct repair and reconstruction would not be feasible.

The majority of studies reported the mean postoperative flexion strength to be within 10% of the unaffected side, regardless of the surgical technique utilized. One study did not provide a percentage comparison for the flexion strength to the contralateral side. Most studies reported supination strength within 15% of the contralateral side, regardless of surgical technique. Again, one study did not provide a percentage comparison for supination strength to the contralateral side. Postoperative strength loss greater than 20% occurred in 4 out of 134 patients for flexion and 8 out of 134 patients for supination, and these patients were treated with a direct repair.[8,13,20]

Complications and morbidity

Twenty-two studies reported on postoperative complications (Table V). Two studies reported no complications observed during mean follow-up periods of 25.3 months and 33.9 months.[2,39] Of the twenty remaining studies, the most commonly reported complications were paresthesia of the lateral antebrachial cutaneous nerve [total 26 (11.0%): direct repair 18 (16.8%); reconstruction 8 (6.2%)]. Additionally, paresthesia of superficial radial nerve [total 6

Table IV
Strength outcomes for chronic distal biceps direct repair and reconstruction.

Study	Year	Technique	Method of evaluation		Strength vs contralateral side	
					Flexion	Supination
Direct Repair						
Caputo et al[8]	2016	Direct Repair w/Lacertus Fibrosus	Subjective	Gross Motor	4.9 out of 5	4.6 out of 5
Dillon et al[13]	2011	Direct Repair	Objective	BTE Work Simulator	105.0%	103.0%
Haverstock et al[22]	2017	Direct Repair	Objective	Biodex System 3 Pro	99.0%	80.0%
Terra et al[41]	2016	Direct Repair	Objective	Lafayette Manual Muscle Testing System	79.3%	89.8%
Reconstruction						
Darlis et al[12]	2006	Achilles Allograft	Subjective	Gross Motor	5 out of 5	5 out of 5
Sanchez-Sotelo et al[39]	2002	Achilles Allograft	Subjective	Gross Motor	comparable 2/4; decreased 2/4	comparable 2/4; decreased 2/4
Snir et al[40]	2013	Allograft (Mixed)*	Subjective	Gross Motor	4.7 out of 5	4.7 out of 5
Goyal et al[20]	2020	Allograft - Mixed†	Objective	Biodex Dynamometer	88%	77%
Frank et al[17]	2019	Semitendinosus Autograft	Objective	Biodex System 3 Pro	90.0%	78.0%
Wiley et al[46]	2006	Semitendinosus Autograft	Objective	Lido WorkSet	1.1	1.1
Morrell et al[32]	2012	Fascia Lata Autograft	Objective	Cybex Dynamometer	86.0%	87.0%
Levy et al[28]	2000	Flexor Carpi Radialis Autograft	Objective	Lido Multijoint II Machine	97.0%	109.0%
Vastamaki et al[42]	2008	Autograft (Mixed)‡	Objective	Lido Multijoint II Machine	94.0%	84.0%

*Mixed 15 Achilles, 1 Anterior Tibialis, 1 Semitendinosus, 1 Gracilis with Anterior Tibialis.
†Mixed 15 Achilles, 1 Anterior Tibialis, 1 Semitendinosus, 1 Gracilis with Anterior Tibialis.
‡Mixed 7 Plantaris Longus, 6 Long Extensors 2/3 Toes, 1 Palmaris Longus.

Table V
Complications and morbidity for chronic distal biceps direct repair and reconstruction.

Study	Year	Technique	Complications
Direct Repair			
Anakwenze et al[2]	2013	Direct Repair	no complications
Bosman et al[5]	2012	Direct Repair	2 superficial infections, 1 hypertrophic scar
Caputo et al[8]	2016	Direct Repair w/Lacertus Fibrosus	2 reruptures
Dillon et al[13]	2011	Direct Repair	4 paresthesia (LACN)
Fontana et al[16]	2016	Direct Repair w/Lacertus Fibrosus	2 paresthesia (SRN)
Goljan et al[19]	2016	Direct Repair	3 paresthesia (1 persistent LACN, 1 carpel tunnel syndrome, 1 cervical spine radiculopathy)
Haverstock et al[22]	2017	Direct Repair	9 paresthesia (8 LACN, 1 Other), 1 stiffness
Morrey et al[34]	2014	Direct Repair in $>60^0$ Flexion	2 paresthesia (LACN), 1 rerupture
Terra et al[41]	2016	Direct Repair	1 paresthesia (LACN)
Zeman et al[47]	2020	Direct Repair	3 paresthesia (LACN)
Reconstruction			
Darlis et al[12]	2006	Achilles Allograft	1 heterotopic ossification
Phadnis et al[36]	2016	Achilles Allograft	2 parethesia (LACN)
Sanchez-Sotelo et al[39]	2002	Achilles Allograft	no complications
Snir et al[40]	2013	Allograft (Mixed)*	2 neuropraxia (PIN); 4 mild chronic antecubital fossa pain
Goyal et al[20]	2020	Allograft Mixed†	2 paresthesia (LACN, cubital tunnel syndrome)
Cross et al[11]	2014	Tibialis Anterior Allograft	1 paresthesia (LACN)
Frank et al[17]	2019	Semitendinosus Autograft	3 paresthesia (LACN), 1 rerupture
Ribeiro et al[37]	2017	Semitendinosus Autograft	1 paresthesia (LACN)
Wiley et al[46]	2006	Semitendinosus Autograft	1 cosmetic deformity; 2 palpable hypertrophy at woven graft site
Morrell et al[32]	2012	Fascia Lata Autograft	4 paresthesia (SRN), 1 superficial wound dehiscence
Levy et al[28]	2000	Flexor Carpi Radialis Autograft	2 superficial adhesions
Vastamaki et al[42]	2008	Autograft (Mixed)‡	1 graft site neuroma, 2 heterotopic ossification

LACN, lateral antibrachial cutaneous nerve; *SRN*, superficial radial nerve; *PIN*, posterior interosseous nerve.
*Mixed 15 Achilles, 1 Anterior Tibialis, 1 Semitendinosus, 1 Gracilis with Anterior Tibialis.
†Mixed 15 Achilles, 1 Anterior Tibialis, 1 Semitendinosus, 1 Gracilis with Anterior Tibialis.
‡Mixed 7 Plantaris Longus, 6 Long Extensors 2/3 Toes, 1 Palmaris Longus.

(2.5%): direct repair 2 (1.9%); reconstruction 4 (3.1%)] and neuropraxia of posterior interosseous nerve (total 2 (0.8%): both direct repair) were reported. A total of 4 re-ruptures were reported in 3 studies [direct repair 3 (2.8%); reconstruction with semitendinosus autograft 1 (0.8%)]. Other uncommon complications included heterotopic ossification, superficial adhesion, superficial infection, hypertrophic scar, chronic pain, wound dehiscence, and cosmetic deformity. Interestingly, cosmetic deformity (1 case), wound dehiscence (1 case), and heterotopic ossification (3 cases) complications, while rare, were reported only in patients who had undergone reconstruction rather than direct repair.

Discussion

In our review of 236 patients, we found no difference in both outcome and overall complication rates between the direct repair group (107 patients) compared to the graft augmentation group (129 patients), with a majority of the patients reporting between 92

Table VI
Chronic distal biceps rupture: direct repair vs reconstruction-master table.

Outcome results	Direct repair (n = 107)	Reconstruction (n = 129)
Demographics		
Age	48.8	43.5
Time from Injury to Surgery	2.9	8.5
Follow-up Time (months)	28.7	38.8
Functional Outcome Scores		
Satisfaction/SANE (n)	94.5%	91.7%
MEPS (n)	98.1	95
DASH/Quick Dash (n)	4.5	6
PREE (n)	4	14
Range of Motion		
Flexion(°)	136.5	134.9
xtension(°)	0.3	2.1
Supination(°)	78.2	81.4
Pronation(°)	76.8	82.5
Complications	n(%)	n(%)
Superficial infections	2 (1.9%)	–
Wound dehiscence	–	1 (0.8%)
Graft Site neuroma	–	1 (0.8%)
Hypertrophic scar	1 (0.9%)	4 (3.1%)
Paresthesia (LACN)	18 (16.8%)	8 (6.2%)
Paresthesia (SRN)	2 (1.9%)	4 (3.1%)
Neuropraxia–posterior interosseous nerve	–	2 (1.6%)
Heterotopic Ossification	–	3 (2.3%)
Chronic antecubital fossa pain	–	4 (3.1%)
Stiffness	–	–
Cosmetic deformity	–	1 (0.8%)
Re-rupture	3 (2.8%)	1 (0.8%)

Weighted Mean demographics, functional outcome scores, range of motion, complications and re-ruptures (n,%) between direct repair and reconstruction techniques for distal biceps ruptures.

to 100 on the MEPS (Table VI). The outlier, Frank et al. utilized a semitendinosus autograft reconstruction through an anterior single-incision approach and found a similar range of motion, elbow supination, flexion strength, DASH, as well as SANE scores. However, the direct repair group did have better patient-rated elbow evaluation and Mayo elbow performance index compared to the reconstruction group.[17] Overall, we found that the mean MEPS score for distal biceps direct repair was between 95-100. For distal biceps reconstruction studies, it was 86-100 (allograft 92.9-100; autograft 86-99). In comparison, during their systematic review of acute distal biceps repairs with cortical button fixation, Panagopoulos et al. reported mean MEPS scores ranging from 77.8 to 100. The recorded DASH scores ranged from 0 to 5.2 in that study.[35] Mean DASH scores ranged from 3 to 6.8 for the direct repair group and 4 to 7.5 for the graft augmentation group in our systematic review.

We also found that postoperative range of motion was remarkably similar between the distal biceps repair and reconstruction groups. With a mean final flexion range of 130-153 degrees in the direct repair group and 131-145 degrees in the graft augmentation group. In a systematic review of direct acute repairs using a cortical button by Panagopoulos et al., they found that mean final flexion in 7 studies ranged from 134-147 degrees. They found that 10.5% of patients examined had a >30° deficit for flexion/extension, and 17.5% had >30° deficit for supination/pronation when compared to the contralateral side.[35] The mean range of motion among the studies included in this systematic review showed no deficit of >30° between the two groups, nor was it noted by the authors of the studies.

When analyzing the strength outcomes postoperatively for the patients included in our study, the majority of studies reported operative extremity flexion strength to be within 15% of the contralateral side. Terra et al. (direct repair utilizing anterior single-incision technique) indicated a 21% decrease in flexion strength postoperatively.[41] Four out of thirteen studies reported decreased supination strength >15% for the operative extremity [direct repair Haverstock et al.[22] (80%); allograft Goyal et al.[20] (77%); autograft Frank et al.[17] (78%), Vastamaki et al.[42] (84%)]. Panagopoulos et al. reported diminished flexion and/or supination strength >30% compared to the contralateral side in 17.5% of patients examined.[35] Their systematic review encompassed 7 studies of acute distal biceps repairs with a total of 97 patients.

In our review, the overall complication rate was 59 out of 236 total patients [direct repair 29/107 (27%); reconstruction 30/129 (27%)]. In distal biceps injuries treated both acutely and chronically, the most reported complication after surgery was paresthesia of the lateral antebrachial cutaneous nerve.[1,3,14,27,29,30,44,45] Among the studies examined in this systematic review, postoperative paresthesia was reported in 38 of 236 (16.1%) patients reflected in these studies, with lateral antebrachial cutaneous nerve paresthesia having 26 reported cases [direct repair 18 (16.8%); reconstruction 8 (6.2%)]. Panagopoulos et al. found with their review of acute direct distal biceps repairs that 15 out of 105 patients (14.2%) had the complication of paresthesia.[35] Similarly, Kodde et al[26] performed a systematic review of distal biceps fixation techniques and approaches and found the complication of neuropraxia in 147 of 1074 patients examined (13.7%). Last, Litowski et al[29] who examined only chronic distal biceps reconstructions utilizing allograft or autograft, found reported complications in 37 of 143 (25.9%) of patients examined. The lateral antebrachial cutaneous nerve was the most common paresthesia in all three studies.[26,29,35]

The breakdown by surgical technique for lateral antebrachial cutaneous nerve paresthesia was 46.2% of cases for anterior single-incision technique, 11.5% of cases for two-incision technique, and 30.1% of cases unspecified as to which technique was utilized. In Kodde et al,[26] the breakdown by surgical technique for lateral antebrachial cutaneous nerve paresthesia was 75 cases for anterior single-incision technique and 14 cases for two-incision technique. For re-ruptures postoperatively, 4 total cases were reported (3 direct repair/1 reconstruction with semitendinosus autograft) in the studies we examined. The surgical techniques utilized were 3 anterior single-incision and 1 two-incision technique utilizing semitendinosus autograft. Kodde et al[26] reported 20 cases of rerupture in utilizing 16 anterior single-incision and 4 two-incision techniques.

Additionally, Kodde et al reported an 11.5% incidence of heterotopic ossification (HO) formation postoperatively, with the predominant share of those coming from the anterior single-incision technique (113 of 124; 91.1%). In contrast, we only found a 2.3% incidence of HO cases in our systematic review and all three cases were within the reconstruction group using anterior single-incision technique. One might reasonably predict a higher frequency of HO following repair or reconstruction of chronic injuries secondary to the degree of soft tissue dissection required for tissue or tendon mobilization. It remains unclear whether underreporting of complications might be a reason for lower-than-expected HO rates in these studies.[9,43] Haverstock et al. indicated they did not obtain imaging to assess for heterotopic ossification because the range of motion was not functionally limited.[22]

There was inconsistent reporting of the degree of biceps tendon retraction, the constitution of the lacertus fibrosis, and the degree of elbow flexion required for direct repair. Worth consideration in the evaluation of chronic distal biceps tendon rupture treatment is the constitution of the lacertus fibrosis. An intact lacertus fibrosis may limit tendon retraction and allow for primary repair regardless of injury acuity. Tendon retraction severity and lacertus fibrosis continuity were rarely characterized in the examined studies but could play a substantial role in outcome variability. This

information may also provide a further area of examination to better determine acceptable parameters for proceeding successfully with direct repair vs. the decision to convert to reconstruction with a graft.

Additionally, we found differences in temporal categorization of distal biceps tendon ruptures with wide variation in defining acute vs. chronic injuries. Flint et al. suggested that an acute injury was <6 weeks while a chronic injury was >12 weeks from the time of injury to the date of surgery.[15] Frank et al. found no standard definition for subacute, delayed, or chronic within the literature review but considered delayed repair as >3 weeks from injury.[17] When viewed together, these two articles highlight the variability in the clinical definition of chronicity. We used >3 weeks in this systematic review as the definition of chronic or delayed distal biceps rupture; however, without an accepted standard, reported surgical results for the treatment of chronic distal biceps tendon ruptures could be skewed due to the variability in the definition of chronic tears.

Finally, there appears to be a discrepancy between time to surgery after injury between the direct repair vs reconstruction groups. On average, the direct repair group's time to surgery after initial injury was 2.9 months vs. the reconstruction group, which was 8.5 months. This could signify a potential selection bias for surgeons to select direct repair or reconstruction solely based upon the time frame from injury as opposed to intraoperative assessment. Typically speaking, the assessment of whether a direct repair is feasible occurs intraoperatively with mobilization of the bicep tendon down to the insertion point with the elbow flexed. The evaluation is focused on how much tension is on the tendon during the facilitation of the repair. Augmentation with allograft or autograft reconstruction is selected when apparently too much tension is placed on that repair. If the decision for direct repair vs. reconstruction is based upon intraoperative evaluation, the average time to surgery after injury for the two groups could be suggestive of the potential average cut-off point for the feasibility of performing a direct repair.

This paper has several limitations. Significant variability in outcome measurement and reporting provided limitations to this systematic review. Manual strength testing, which is inherently subjective, was performed using different scales. Objective strength testing methods varied with multiple machines, which limited our ability to draw conclusions about differences in postoperative strength by repair technique. Some studies provided individual data, while others reported only aggregate means. These factors contributed to the difficulty in producing an objective means of comparison between patients in different studies. All the included studies were Level III or IV evidence and reported on a relatively small number of patients, subjecting the analysis and interpretation to treatment bias. There also was heterogeneity in reporting of patient sex, the definition of chronic vs. acute injury, description of tendon retraction severity, and the repaired-to-reconstructed ratio. The degree of elbow flexion, which was required for direct repair, was not routinely reported. Ultimately, the heterogeneity of reported outcome measures precluded the ability to perform a meta-analysis comparing the surgical techniques.

Conclusions

Surgical treatment of chronic distal biceps tendon ruptures generally produces favorable clinical outcomes regardless of surgical technique, including direct repair, reconstruction, or graft (autograft vs. allograft) choice. Clinical results and complications appear comparable of directly repaired to the reconstruction of distal chronic biceps tendon ruptures. The authors of this study recommend early surgical intervention when applicable. However, based on the data presented, either option for direct repair or reconstruction with allograft or autograft is acceptable of chronic distal biceps rupture and will provide comparable results. Future examination of this topic should put less emphasis on the chronicity of the injury. Emphasis should instead be placed upon the severity of tendon retraction, the integrity of lacertus fibrosus, and the degree of elbow flexion required to complete direct repair. If the distal biceps tendon is able to reach the radial tuberosity tension free, the direct repair technique is a reasonable option despite the chronicity of the injury. However, if significant tension is needed for the tendon to reach the tuberosity, then either autograft or allograft reconstruction is recommended to optimize patient outcomes.

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Supplementary data

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