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Treatment Options for Tennis Elbow — An Umbrella Review

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Abstract: Introduction: The main goal of the present umbrella review was to provide the most up-to-date and evidence-based results regarding the various treatment options for tennis elbow (TE), which hopefully will significantly decrease the confusions existing in the literature. Furthermore, our study differs from past analytical studies because, as to the best of the authors' knowledge, is the first to provide independent (not in comparison to other treatment) statistical results regarding the effectiveness of each TE treatment.
Materials and Methods: Major medical databases such as PubMed, Scopus, Embase, Web of Science, Google Scholar, Cochrane Library, BIOSIS, and EBSCO were searched. The overall search process was conducted in 3 stages.
Results: A total of 40 studies met the inclusion criteria and were included in this study. Out of those 40 meta-analyses, a total of 160 primary studies were screened in order to extract the data and perform a statistical analysis.
Conclusion: The present umbrella review underlines the efficiency of injection therapies, especially autologous blood, and platelet-rich plasma, while simultaneously proving the ineffectiveness of acupuncture and shock wave therapy as treatments for TE. Furthermore, the value of other known conservative treatment modalities, such as physical therapy, has been demonstrated.

Keywords: tennis elbow, lateral epicondylitis, lateral elbow pain, treatment, orthopedics, surgery.

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Introduction

Tennis elbow (TE), lateral epicondylitis, or enthesopathy of the extensor carpi radialis origin, is a painful, degenerative condition of the tendon of the extensor carpi radialis brevis (ECRB) near its attachment site to the lateral epicondyle. It is characterized by recurring lateral elbow pain, decreased grip, mobility, and upper-limb strength [1–3]. The overall incidence is said to range between 1% to 3% in the general population [4], peaking in the fifth decade without a gender-based difference [5]. The main cause of TE remains unclear. However, it has been linked with excessive use of the extensors of the forearm [6]. The diagnosis of TE is based on medical history, ultrasonography (USG)-based examination, and physical examination. Nevertheless, treatment of the specialized diseases of the upper limb may constitute a major clinical problem [7–10].

The treatment of TE consists of both conservative (first-line treatment) and invasive procedures. The conservative treatment option consists of non-steroidal anti-inflammatory drugs, orthotic devices, exercises, and physiotherapeutic modalities, laser and ultrasound therapy, corticosteroid injections, platelet-rich plasma injections, and shock wave therapy, amongst others [11]. On the other hand, surgical treatment is reserved for a small portion of patients that do not respond to non-operative treatments [12]. These surgical procedures include the excision of lesions within the origin of the ERCB or the release of the ECRB from the lateral epicondyle region, amongst others [13].

Numerous systematic reviews and meta-analyses have been presented regarding the various treatment modalities for TE. However, the data concerning the overall efficiency and potential risks of these treatment options are vast and depend mainly on the quality of the utilized primary studies. There is a considerable amount of confusion regarding the reliability of the various treatment modalities for TE, as the results of the systematic reviews and meta-analyses that cover this topic frequently differ and, in some instances, contradict each other. Therefore, the main goal of the present umbrella review was to provide the most up-to-date and evidence-based results regarding the various treatment options for TE, which hopefully will significantly decrease existing confusions. Furthermore, our study differs from past analytical studies because, as to the best of the authors' knowledge, is the first to provide independent (not in comparison to other treatment) statistical results regarding the effectiveness of each TE treatment. This gave us the opportunity to present the effect size results in various categories, especially regarding the effect on the visual analog scale (VAS) score between the different treatment modalities, showing how much of an impact a treatment option has on the said pain scale. This may be potentially incredibly useful in clinical practice, as it allows physicians to directly compare the effectiveness of therapeutic variants. Additionally, this umbrella review aimed to provide surgeons with a single, detailed article, being a time-effective tool for their clinical practice. It is hoped that the present umbrella review may help to reduce the complications associated with the improper treatment of TE and, ultimately, lead to better patient outcomes.

Materials and Methods

To perform this umbrella review, a systematic search was performed in which all meta-analyses and systematic reviews on the treatment of the TE were looked for. Online medical databases such as PubMed, Embase, Scopus, Web of Science, Cochrane Library, Google Scholar, BIOSIS, and EBSCO were searched through. The overall search process was performed in 3 stages. (1) In the first stage, all mentioned databases were searched using the following search terms: (tennis elbow) OR (lateral epicondylitis). Neither language, date, article type, nor text availability conditions were applied. (2) Furthermore, the mentioned databases were searched once again using another set of phrases: (a) ((tennis elbow[Title/Abstract]) OR (lateral epicondylitis[Title/Abstract])) AND (treatment [Title/Abstract]) ; (b) ((tennis elbow[Title/Abstract]) OR (lateral epicondylitis[Title/Abstract])) AND (injection [Title/Abstract]) ; (c) ((tennis elbow[Title/Abstract]) OR (lateral epicondylitis[Title/Abstract])) AND (surgery [Title/Abstract]) ; (d) ((tennis elbow[Title/Abstract]) OR (lateral epicondylitis[Title/Abstract])) AND (shock wave [Title/Abstract]) ; (e) ((tennis elbow [Title/Abstract]) OR (lateral epicondylitis[Title/Abstract])) AND (physiotherapy [Title/Abstract]) ; (f) ((tennis elbow[Title/Abstract]) OR (lateral epicondylitis[Title/Abstract])) AND (laser [Title/Abstract]) ; (g) ((tennis elbow[Title/Abstract]) OR (lateral epicondylitis[Title/Abstract])) AND (counterforce brace [Title/Abstract]) ; (h) ((tennis elbow[Title/Abstract]) OR (lateral epicondylitis[Title/Abstract])) AND (acupunture [Title/Abstract]) ; (i) ((tennis elbow[Title/Abstract]) OR (lateral epicondylitis [Title/Abstract])) AND (meta [Title/Abstract]) ; (j) ((tennis elbow[Title/Abstract]) OR (lateral epicondylitis[Title/Abstract])) AND (review [Title/Abstract]) ; (k) ((tennis elbow[Title/Abstract]) OR (lateral epicondylitis[Title/Abstract])) AND (systematic [Title/Abstract]). (3) Furthermore, an additional manual search was also performed throughout all references from the initial submitted studies. The rules for conducting umbrella reviews designated by Fusar-Poli *et al.* and by Bonczar and Ostrowski *et al.* were included during this analysis [14, 15]. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) criteria were also followed. In order to minimize the potential bias and double consideration of the results, the authors have performed all statistical analyses based on the results of the primary studies from all of the meta-analyses [15]. Therefore, all primary studies of all meta-analyses were also screened in order to perform the statistical analyses.

The inclusion criteria were set as follows: meta-analysis or systematic reviews, with extractable data on the treatment of the TE. The exclusion criteria were set as follows:

systematic reviews or meta-analyses without a systematic search; systematic reviews or meta-analyses that included case studies in their statistical analysis; narrative or expert reviews; abstracts; letters to the editor.

The eligibility assessment and data extraction from all the qualified studies were performed by two independent researchers. Quantitative and qualitative data regarding the treatment of TE were extracted. Any discrepancies between studies identified by the two researchers were resolved by contacting the authors of the original studies wherever possible or by consensus involving a third reviewer.

Furthermore, the quality of all meta-analyses submitted was assessed by two independent researchers. For this purpose, A MeaSurement Tool to Assess Systematic Reviews 2 (AMSTAR 2) [16] and a ROBIS tool were used [17]. Any disagreements among the authors about the assessment of the studies were resolved by consensus with a third author. Additionally, Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) working group classification was used to establish the quality of evidence for each meta-analysis included in this study [18].

Statistical analysis was performed using STATISTICA version 13.1 software (StatSoft Inc., Tulsa, OK, USA), Comprehensive Meta-analysis version 4.0 software (Biostat Inc., Englewood, NJ, USA), and MetaXL version 5.3 software (EpiGear International Pty Ltd, Wilston, Queensland, Australia). The heterogeneity of the meta-analyzes was evaluated with the I-squared statistic reported value [15, 19, 20]. The I-squared statistic was interpreted on a specific scale: (1) 0%–40% as 'might not be important', (2) 30%–60% as 'may represent moderate heterogeneity,' (3) 50%–90% as 'may represent substantial heterogeneity' and (4) 75%–100% as 'may represent considerable heterogeneity'. A p-value <0.05 and 95% confidence intervals were used to determine statistically significant differences between studied groups. If the confidence intervals between the groups overlapped, the differences were considered insignificant, while in the reverse situation, the differences were considered statistically significant. Only data from the primary studies were taken into consideration during the statistical analysis.

Results

Search Results

Initially, a total of 11,469 studies were identified from all databases searched. After removing duplicate records, 7333 articles were screened and qualified for further evaluation. Of these, 6589 were excluded, and 744 were evaluated for eligibility. Subsequently, 687 studies were excluded due to their irrelevance to our study and 17 because they were a narrative review. Finally, a total of 40 studies met the inclusion criteria and were included in this study [1, 5, 21–58]. Out of those 40 meta-analyses, a total of 160 primary studies were screened in order to extract the data and perform a statistical analysis. A flow chart summarizing the overall data collection process can be found in Fig. 1. Characteristics of submitted studies can be found in Table 1. The databases searched in the included meta-analyses can be found in Table 2.

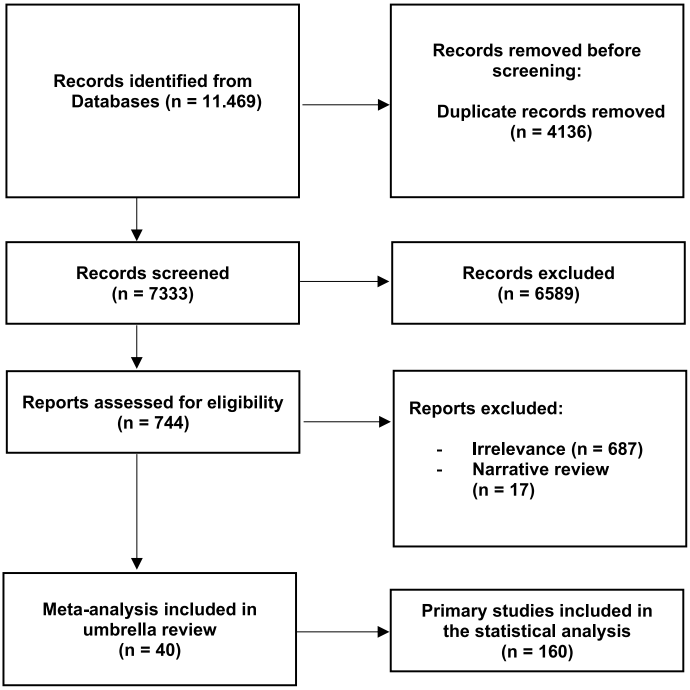

Fig. 1. Flow diagram presenting process of collecting data included in this umbrella review.

Table 1. Characteristics of studies included in this umbrella review.

First Author	Year of publication	Journal	Continent	Country
Arias-Vázquez P.I.	2022	The official Journal of the Portuguese Society of Rheumatology	North America	Mexico
Karanasios S.	2021	Clinical Rehabilitation	Europe	Greece
Chen X.T.	2021	Arthroscopy: The Journal of Arthroscopic & Related Surgery	North America	USA
Acosta-Olivo C.A.	2020	The American Journal of Sports Medicine	North America	Mexico
Chen Z.	2020	Journal of Hand Therapy	Asia	Singapore

Table 1. cont.

First Author	Year of publication	Journal	Continent	Country
Navarro-Santana M.J. (A)	2020	Clinical Rehabilitation	Europe	Spain
Navarro-Santana M.J. (B)	2020	Acupuncture in Medicine	Europe	Spain
Shahabi S.	2020	Prosthetics and Orthotics International	Asia	Iran
Simental-Mendía M.	2020	Clinical Rheumatology	North America	Mexico
Tang S.	2020	PM&R	Asia	China
Yao G.	2020	BioMed Research International	Asia	China
Yoon S.	2020	Clinical Orthopaedics and Related Research	Asia	South Korea
Zheng C.	2020	Medicine	Asia	China
Zhong Y.	2020	International Journal of Surgery	Asia	China
Zhou Y.	2020	Pain Research and Management	Asia	China
Gao B.	2019	Arthroscopy: The Journal of Arthroscopic & Related Surgery	North America	USA
Huang K.	2019	The American Journal of Sports Medicine	Asia	China
Li A.	2019	Medicine	Asia	China
Wang W.	2019	Medicine	Asia	China
Xiong Y.	2019	The Physician and Sportsmedicine	Asia	China
Xu Q.	2019	International Journal of Surgery	Asia	China
Yan C.	2019	Journal of Orthopaedic Surgery and Research	Asia	China
Chen X.	2018	The American Journal of Sports Medicine	North America	USA
Mamais I.	2018	Laser Therapy	Europe	Greece
Lin Y.C.	2017	Clinical Rehabilitation	Asia	Taiwan (R. O. C.)
Mi B.	2017	The Physician and Sportsmedicine	Asia	China
Sirico F.	2017	European Journal of Physical and Rehabilitation Medicine	Europe	Italy

Table 1. cont.

First Author	Year of publication	Journal	Continent	Country
Qian X.	2016	PM&R	Asia	China
Arirachakara A.	2015	Journal of Orthopaedics and Traumatology	Asia	Thailand
Chou L.C.	2015	Physical Therapy in Sport	Asia	Taiwan (R. O. C.)
Dong W.	2015	British Journal of Sports Medicine	Asia	China
Tang H.	2015	Evidence-Based Complementary and Alternative Medicine	Asia	China
Weber C.	2015	BMC Musculoskeletal Disorders	Europe	Germany
Chang W.D.	2014	The American Journal of Chinese Medicine	Asia	Taiwan (R. O. C.)
Moraes V.Y.	2014	The Cochrane Library	South America	Brazil
Sayegh E.T.	2014	Clinical Orthopaedics and Related Research	North America	USA
Kalichman L.	2011	Seminars in Arthritis and Rheumatism	Asia	Israel
Buchbinder R.	2005	The Cochrane Library	Australia	Australia
Bjordal J.M.	2001	Physical Therapy Reviews	Europe	Norway
Assendelft W.J.J.	1996	British Journal of General Practice	Europe	The Netherlands

Table 2. Databases searched in the included meta-analysis.

Study		Databases						
First Author	Year	Medline (PubMed)	Scopus	Embase	Cochrane	Web of Science	Google Scholar	Others
Arias-Vázquez P.I.	2022	+	–	–	–	+	+	+
Karanasios S.	2021	+	–	+	+	–	–	–
Chen X.T.	2021	+	–	–	+	–	–	–
Acosta-Olivo C.A.	2020	+	+	+	–	+	–	–
Chen Z.	2020	+	–	+	+	–	+	+
Navarro-Santana M.J. (A)	2020	+	+	–	+	+	–	–
Navarro-Santana M.J. (B)	2020	+	+	–	+	+	–	–

Table 2. cont.

Study		Databases						
First Author	Year	Medline (PubMed)	Scopus	Em-base	Co-chrane	Web of Science	Google Scholar	Others
Shahabi S.	2020	+	+	+	–	+	–	–
Simental-Mendía M.	2020	+	+	+	–	+	–	–
Tang S.	2020	+	–	+	+	–	–	–
Yao G.	2020	+	–	+	+	+	–	+
Yoon S.	2020	+	–	+	+	–	–	–
Zheng C.	2020	+	–	+	+	+	–	–
Zhong Y.	2020	+	–	+	+	–	–	–
Zhou Y.	2020	+	–	+	+	–	–	–
Gao B.	2019	+	–	+	–	–	–	–
Huang K.	2019	+	–	+	+	+	–	–
Li A.	2019	+	–	+	+	–	–	–
Wang W.	2019	+	–	+	+	–	–	–
Xiong Y.	2019	+	–	+	+	–	–	+
Xu Q.	2019	+	–	+	+	+	–	+
Yan C.	2019	+	–	+	+	–	–	+
Chen X.	2018	+	–	–	+	–	–	–
Mamais I.	2018	+	–	+	–	–	–	–
Lin Y.C.	2017	+	+	+	–	–	–	+
Mi B.	2017	+	–	+	+	–	–	+
Sirico F.	2017	+	+	+	+	+	–	+
Qian X.	2016	+	–	+	+	+	–	–
Arirachakara A.	2015	+	+	–	–	–	–	–
Chou L.C.	2015	+	+	–	+	–	–	–
Dong W.	2015	+	–	+	+	–	–	–
Tang H.	2015	+	–	+	+	–	–	+
Weber C.	2015	+	–	+	+	–	–	–
Chang W.D.	2014	+	–	–	–	–	–	+
Moraes V.Y.	2014	+	–	+	+	–	–	+
Sayegh E.T.	2014	+	–	–	+	–	–	–
Kalichman L.	2011	+	–	+	–	+	+	–
Buchbinder R.	2005	+	–	+	–	–	–	+
Bjordal J.M.	2001	+	–	+	+	–	–	+
Assendelft W.J.J.	1996	+	–	–	–	–	–	–

Injection Therapy

The injection therapies, including platelet-rich plasma, autologous blood, corticosteroids, glycosaminoglycan, prolotherapy botulinum toxin, local anesthetics, and hyaluronic acid injections, were analyzed in several categories regarding their effect on the VAS, the disabilities of the arm, shoulder, and hand questionnaire (DASH), patient-related tennis elbow evaluation form (PRTEE), pressure pain threshold (PTT) and Mayo elbow performance score (MAYO). The greatest effect on the VAS score was found to have the PTT injection, as Hodges's G was established at 19.29 (SE = 0.49; p = 0.00). On the other hand, the weakest effect on the VAS score was found to have the hyaluronic acid injection as the Hodges's G was set to be 3.81 (SE = 0.18; p = 0.00). Detailed results in each category can be found in Table 3. For a graph illustrating the effect on the VAS score of all of the studied methods of treatment of the TE, please see Figure 2.

Table 3. Statistical results of this umbrella review on the effects of various therapeutics injected in therapy against the tennis elbow. Data were divided with respect to the assessment method used. VAS — The Visual Analogue Scale — dedicated for pain intensity assessment — from '0' (no pain) to '10' (worst pain). DASH — The Disabilities of the Arm, Shoulder and Hand questionnaire — dedicated for assessment of upper-extremity disability and symptoms — from '0' (no disability) to '100'. PRTEE — Patient Related Tennis Elbow Evaluation form — dedicated for assessment of the forearm pain and disability in patients with lateral epicondylitis — from '0' (best outcome) to '100' (worst outcome). PPT — Pressure Pain Threshold — which is defined as the least amount of force needed to cause pain — meaning that patients' with higher scores will require more force to induce the pain (higher pain tolerance). MAYO — dedicated for assessment of pain. arc of elbow motion. and stability. and a patient rating of daily function — from '0' (worst outcome) to '100' (best outcome).

Category	Mean	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Platelet Rich Plasma							
VAS Score							
Baseline	7.05	0.22	0.05	6.63	7.48	32.63	0.00
After 4 weeks	4.78	0.66	0.43	3.49	6.07	7.25	0.00
After 6 weeks	2.76	0.28	0.08	2.20	3.31	9.74	0.00
After 8 weeks	3.74	0.75	0.57	2.26	5.22	4.95	0.00
After 12 weeks	3.19	0.40	0.16	2.40	3.97	7.97	0.00
After 24 weeks	2.33	0.34	0.12	1.66	3.00	6.81	0.00
Last Checkup	2.40	0.26	0.07	1.88	2.92	9.10	0.00
Hodges's G	19.29	0.49	0.24	18.32	20.26	39.08	0.00
Difference in Means	4.65	0.02	0.00	4.62	4.68	269.62	0.00

Table 3. cont.

Category	Mean	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
DASH Score							
Baseline	62.42	5.57	30.98	51.51	73.33	11.21	0.00
After 4 weeks	70.66	16.52	272.93	38.28	103.04	4.28	0.00
After 6 weeks	30.59	5.06	25.64	20.67	40.52	6.04	0.00
After 8 weeks	57.09	14.42	207.83	28.83	85.34	3.96	0.00
After 12 weeks	34.85	8.45	71.43	18.28	51.41	4.12	0.00
After 24 weeks	25.54	5.53	30.62	14.69	36.39	4.62	0.00
Last Checkup	24.17	4.51	20.37	15.32	33.01	5.36	0.00
Hodges's G	7.50	0.26	0.07	6.99	8.01	28.81	0.00
Difference in Means	38.25	0.47	0.22	37.33	39.17	81.73	0.00
Modified MAYO Score							
Baseline	58.83	1.71	2.92	55.48	62.18	34.43	0.00
After 4 weeks	76.33	2.10	4.40	72.21	80.44	36.37	0.00
After 8 weeks	83.19	2.52	6.37	78.25	88.14	32.96	0.00
After 24 weeks	83.90	7.01	49.17	70.15	97.64	11.96	0.00
Last Checkup	83.84	6.21	38.52	71.68	96.01	13.51	0.00
Hodges's G	−5.47	0.29	0.08	−6.04	−4.91	−18.98	0.00
Difference in Means	−25.01	0.60	0.36	−26.19	−23.83	−41.46	0.00
Autologous Blood							
VAS Score							
Baseline	6.58	0.27	0.07	6.06	7.10	24.81	0.00
After 2 weeks	4.83	0.43	0.19	3.98	5.68	11.16	0.00
After 4 weeks	3.37	0.28	0.08	2.82	3.92	12.02	0.00
After 6 weeks	2.52	0.99	0.98	0.58	4.46	2.55	0.01
After 8 weeks	3.15	0.74	0.55	1.69	4.61	4.23	0.00
After 12 weeks	1.89	0.48	0.23	0.94	2.83	3.92	0.00
After 24 weeks	1.96	0.59	0.34	0.81	3.11	3.34	0.00
Last Checkup	2.07	0.39	0.15	1.31	2.84	5.31	0.00
Hodges's G	13.42	0.49	0.24	12.47	14.37	27.61	0.00
Difference in Means	4.51	0.03	0.00	4.44	4.58	134.13	0.00

Table 3. cont.

Category	Mean	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
DASH Score							
Baseline	45.25	6.78	46.04	31.95	58.55	6.67	0.00
After 2 weeks	36.00	4.99	24.86	26.23	45.77	7.22	0.00
After 4 weeks	21.00	1.37	1.87	18.32	23.68	15.35	0.00
After 8 weeks	16.39	10.50	110.17	–4.19	36.96	1.56	0.12
Last Checkup	12.64	6.50	42.24	–0.10	25.38	1.94	0.05
Hodges's G	4.86	0.44	0.20	3.99	5.73	10.96	0.00
Difference in Means	32.61	1.49	2.21	29.70	35.52	21.96	0.00
PRTEE Score							
Baseline	69.95	3.04	9.26	63.99	75.92	22.99	0.00
After 2 weeks	45.80	5.13	26.30	35.75	55.85	8.93	0.00
After 4 weeks	34.30	1.38	1.89	31.60	37.00	24.94	0.00
After 6 weeks	24.46	0.59	0.35	23.30	25.62	41.37	0.00
After 12 weeks	16.95	2.26	5.12	12.51	21.38	7.49	0.00
Last Checkup	16.95	2.26	5.12	12.51	21.38	7.49	0.00
Hodges's G	19.68	1.19	1.41	17.35	22.01	16.56	0.00
Difference in Means	53.00	0.45	0.20	52.11	53.89	117.06	0.00
PPT Score							
Baseline	1.37	0.26	0.07	0.87	1.87	5.38	0.00
After 4 weeks	1.84	0.20	0.04	1.45	2.23	9.28	0.00
After 8 weeks	2.20	0.09	0.01	2.02	2.38	23.37	0.00
Last Checkup	2.11	0.09	0.01	1.94	2.29	23.50	0.00
Hodges's G	–3.79	0.26	0.07	–4.30	–3.27	–14.35	0.00
Difference in Means	–0.74	0.03	0.00	–0.80	–0.68	–24.06	0.00
Corticosteroids							
VAS Score							
Baseline	6.29	0.26	0.07	5.78	6.80	24.26	0.00
After 4 weeks	3.32	0.29	0.09	2.74	3.89	11.31	0.00
After 12 weeks	3.22	0.40	0.16	2.43	4.00	8.01	0.00
Last Checkup	2.89	0.35	0.13	2.19	3.58	8.14	0.00
Hodges's G	11.10	0.21	0.05	10.68	11.51	52.07	0.00

Table 3. cont.

Category	Mean	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Difference in Means	3.40	0.02	0.00	3.37	3.43	210.71	0.00
DASH Score							
Baseline	51.25	4.71	22.18	42.02	60.48	10.88	0.00
After 4 weeks	37.72	6.67	44.54	24.64	50.80	5.65	0.00
After 8 weeks	37.82	9.07	82.30	20.04	55.60	4.17	0.00
After 12 weeks	30.87	4.35	18.96	22.33	39.40	7.09	0.00
Last Checkup	32.40	4.35	18.89	23.88	40.92	7.46	0.00
Hodges's G	4.08	0.16	0.03	3.75	4.40	24.73	0.00
Difference in Means	18.85	0.47	0.22	17.93	19.77	40.05	0.00
PRTEE Score							
Baseline	55.07	8.49	72.13	38.42	71.71	6.48	0.00
After 2 weeks	27.61	8.05	64.80	11.83	43.39	3.43	0.00
After 12 weeks	25.08	3.41	11.66	18.39	31.78	7.35	0.00
Last Checkup	19.74	7.12	50.74	5.77	33.70	2.77	0.01
Hodges's G	4.50	0.23	0.05	4.05	4.95	19.54	0.00
Difference in Means	35.33	0.96	0.92	33.45	37.21	36.77	0.00
Modified MAYO Score							
Baseline	49.52	2.67	7.11	44.29	54.74	18.57	0.00
After 4 weeks	71.79	2.16	4.66	67.55	76.02	33.24	0.00
After 8 weeks	75.74	2.10	4.41	71.62	79.86	36.05	0.00
Last Checkup	74.95	2.45	6.02	70.14	79.76	30.54	0.00
Hodges's G	–9.85	0.72	0.52	–11.27	–8.43	–13.60	0.00
Difference in Means	–25.43	0.51	0.26	–26.43	–24.43	–49.62	0.00
Glycosaminoglycan							
VAS Score							
Baseline	6.28	0.29	0.08	5.71	6.85	21.58	0.00
After 6 weeks	3.02	0.39	0.15	2.26	3.80	7.75	0.00
After 12 weeks	3.48	0.47	0.22	2.16	3.98	6.58	0.00
Last Checkup	3.31	0.48	0.23	2.36	4.24	6.90	0.00
Hodges's G	7.39	0.75	0.56	5.92	8.85	9.90	0.00
Difference in Means	7.49	0.76	0.57	6.01	8.97	9.90	0.00

Table 3. cont.

Category	Mean	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Prolotherapy							
VAS Score							
Baseline	5.52	0.61	0.37	4.33	6.72	9.08	0.00
After 2 weeks	5.07	0.50	0.25	4.09	6.04	10.15	0.00
After 8 weeks	3.93	0.91	0.83	2.15	5.72	4.32	0.00
After 12 weeks	1.97	0.45	0.20	1.09	2.85	4.39	0.00
Last Checkup	1.98	0.68	0.47	0.64	3.32	2.90	0.00
Hodges's G	5.47	0.24	0.06	5.01	5.94	23.00	0.00
Difference in Means	3.54	0.07	0.00	3.40	3.68	50.19	0.00
PRTEE Score							
Baseline	45.24	13.63	185.87	18.52	71.96	3.32	0.00
After 4 weeks	36.63	8.06	65.00	20.83	52.44	4.54	0.00
After 8 weeks	28.77	2.76	7.64	23.35	34.19	10.41	0.00
Last Checkup	16.20	5.14	26.40	6.13	26.27	3.15	0.00
Hodges's G	2.77	0.22	0.05	2.33	3.21	12.35	0.00
Difference in Means	29.04	1.68	2.81	25.76	32.32	17.33	0.00
Botulinum toxin							
VAS Score							
Baseline	6.41	0.90	0.81	4.65	8.17	7.14	0.00
After 2 weeks	5.24	0.03	0.00	5.18	5.30	160.81	0.00
After 4 weeks	3.19	0.75	0.56	1.72	4.66	4.27	0.00
After 12 weeks	3.13	0.46	0.21	2.24	4.03	6.86	0.00
Last Checkup	2.16	0.82	0.68	0.55	3.77	2.63	0.01
Hodges's G	4.92	0.23	0.05	4.47	5.38	21.36	0.00
Difference in Means	4.25	0.10	0.01	4.06	4.44	42.96	0.00
Local Anesthetics							
VAS Score							
Baseline	6.54	0.78	0.61	5.01	8.07	8.39	0.00
After 4 weeks	4.81	0.32	0.10	4.18	5.44	14.93	0.00
After 24 weeks	2.89	1.28	1.63	0.39	5.40	2.26	0.02
Last Checkup	2.87	0.95	0.91	1.00	4.73	3.01	0.00

Table 3. cont.

Category	Mean	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Hodges's G	4.22	0.21	0.05	3.80	4.64	19.78	0.00
Difference in Means	3.67	0.10	0.01	3.47	3.87	35.58	0.00
Hyaluronic Acid							
VAS Score							
Baseline	6.86	1.65	2.74	3.61	10.10	4.14	0.00
After 12 weeks	2.50	0.11	0.01	2.29	2.70	23.65	0.00
Last Checkup	2.40	0.11	0.01	2.20	2.61	22.76	0.00
Hodges's G	3.81	0.18	0.03	3.46	4.15	21.61	0.00
Difference in Means	3.81	0.18	0.03	3.47	4.16	21.61	0.00

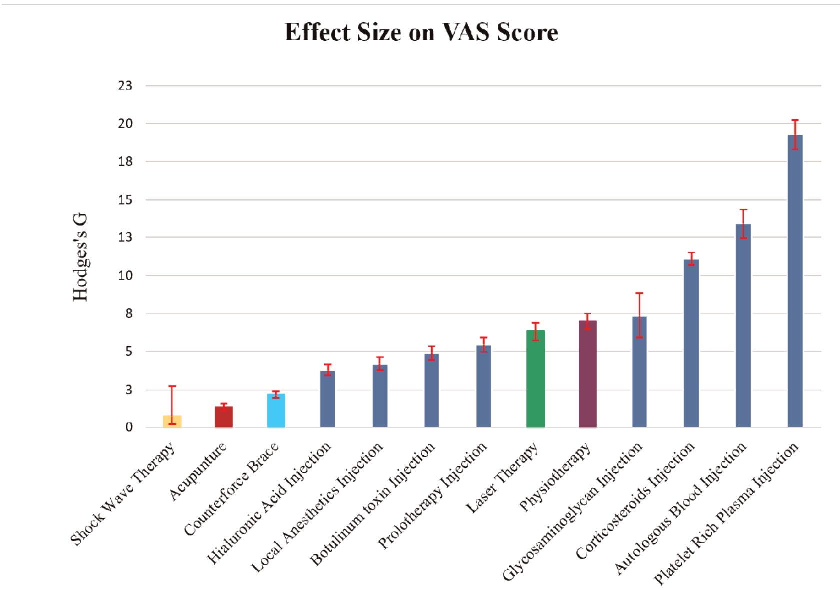

Fig. 2. Graph, illustrating the effect on the visual analog scale (VAS) score of all the studied methods of treatment of the tennis elbow.

Surgery

A comparison of outcomes between open and arthroscopic TE surgery has been performed. The higher odds of complications and surgery failure were found to be in the arthroscopic approach. However, it must be noted that none of the results were statistically significant (p >0.05). Furthermore, the arthroscopic approach was found to be a longer method as the difference in means was found to be −11.45 (SE = 0.52; p = 0.00). For more detailed results, please see Table 4.

Table 4. Statistical results of this umbrella review regarding the comparison of outcomes between open and arthroscopic tennis elbow surgery. Odds and risk ratios (OR; RR) refer to a chance of occurrence of complication / surgery failure in open release, in reference to the arthroscopic one. Difference in means — DM. Hedges' G — HG. Surgical times were measured in minutes.

Category	Higher Chances In	Odds Ratio / Risk Ratio	Lower limit	Upper limit	Z-Value	p-Value
Complication rate OR	Arthroscopic	0.60	0.09	3.79	−0.55	0.59
Complication rate RR	Arthroscopic	0.61	0.10	3.63	−0.54	0.59
Surgery Failure OR	Arthroscopic	0.93	0.38	2.28	−0.16	0.87
Surgery Failure RR	Arthroscopic	0.94	0.40	2.19	−0.15	0.88

Category	Longer Method	DM / HG	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Surgery Time [min] (DM)	Arthroscopic	−11.45	0.52	0.27	−12.48	−10.43	−21.92	0.00
Surgery Time [min] (HG)	Arthroscopic	−2.95	2.06	4.23	−6.98	1.08	−1.44	0.15

Shock Wave Therapy

The outcomes of the usage of shock wave therapy as the treatment for TE were analyzed in several categories regarding its effect on VAS, PRTEE, DASH scores, maximal grip strength, pain-free grip strength, and the Thomsen test. Shock wave therapy was found to be the least effective option when it comes to the reduction of the VAS score as the absolute value of the Hodges's G, at the end of the therapy, was set to be 0.79 (SE = 0.29; p = 0.01). For more detailed results, please see Table 5.

Table 5. Statistical results of this umbrella review regarding the outcomes of shock wave therapy for tennis elbow. The results were presented as differences in means (DM) and Hedges' G (HG) measured between treated patients and a control group on different timepoints of the therapy. Each analyzed result from the primary studies was checked whether the patients had no statistical differences on the baseline point. In case of such differences found, the study was excluded from further analysis. The results should be interpreted as a scaled effect of shock wave therapy in reference to the control group in each category. VAS — The Visual Analogue Scale — dedicated for pain intensity assessment — from '0' (no pain) to '10' (worst pain). DASH — The Disabilities of the Arm. Shoulder and Hand questionnaire — dedicated for assessment of upper-extremity disability and symptoms — from '0' (no disability) to '100'. PRTEE — Patient Related Tennis Elbow Evaluation form — dedicated for assessment of the forearm pain and disability in patients with lateral epicondylitis — from '0' (best outcome) to '100' (worst outcome).

Timepoints of the therapy	DM / HG	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
VAS Score							
Short Time after the start DIM	−0.09	0.13	0.02	−0.35	0.16	−0.71	0.48
Short Time after the start HG	−0.12	0.12	0.01	−0.35	0.12	−0.99	0.32
Middle of the therapy DIM	−1.79	1.02	1.05	−3.80	0.22	−1.75	0.08
Middle of the therapy HG	−1.52	0.61	0.37	−2.70	−0.33	−2.50	0.01
End of the therapy DIM	−1.09	0.55	0.31	−2.18	−0.01	−1.97	0.05
End of the therapy HG	−0.79	0.29	0.08	−1.35	−0.22	−2.74	0.01
PRTEE Score							
Short Time after the start DIM	−1.64	3.37	11.34	−8.24	4.96	−0.49	0.63
Short Time after the start HG	−0.13	0.19	0.03	−0.50	0.24	−0.69	0.49
End of the therapy DIM	−6.17	4.26	18.19	−14.53	2.18	−1.45	0.15
End of the therapy HG	−0.28	0.20	0.04	−0.67	0.12	−1.38	0.17
DASH Score							
Short Time after the start DIM	−11.20	10.07	101.43	−30.93	8.54	−1.11	0.27
Short Time after the start HG	−2.19	1.59	2.52	−5.31	0.92	−1.38	0.17
Middle of the therapy DIM	−12.42	9.66	93.27	−31.34	6.51	−1.29	0.20
Middle of the therapy HG	−3.72	1.86	3.46	−7.37	−0.08	−2.00	0.05
End of the therapy DIM	−13.09	8.17	66.67	−29.10	2.91	−1.60	0.11

Table 5. cont.

Timepoints of the therapy	DM / HG	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
End of the therapy HG	−3.06	1.24	1.54	−5.49	−0.62	−2.46	0.01
Maximal Grip Strength							
Short Time after the start DIM	3.54	1.43	2.05	0.73	6.34	2.47	0.01
Short Time after the start HG	0.31	0.14	0.02	0.03	0.59	2.18	0.03
Middle of the therapy DIM	3.10	4.04	16.32	−4.82	11.02	0.77	0.44
Middle of the therapy HG	0.30	0.40	0.16	−0.49	1.09	0.74	0.46
End of the therapy DIM	3.01	1.30	1.70	0.45	5.56	2.31	0.02
End of the therapy HG	0.25	0.12	0.01	0.02	0.48	2.12	0.03
Pain-free Grip Strength							
Short Time after the start DIM	4.42	4.42	19.52	−4.24	13.08	1.00	0.32
Short Time after the start HG	1.02	0.95	0.89	−0.84	2.87	1.08	0.28
End of the therapy DIM	3.57	3.25	10.59	−2.81	9.95	1.10	0.27
End of the therapy HG	0.52	0.54	0.29	−0.53	1.57	0.97	0.33
Thomsen Test Result							
Short Time after the start DIM	0.03	0.52	0.27	−1.00	1.06	0.06	0.95
Short Time after the start HG	0.04	0.24	0.06	−0.42	0.50	0.18	0.86
Middle of the therapy DIM	−1.30	0.98	0.96	−3.23	0.62	−1.33	0.18
Middle of the therapy HG	−0.89	0.53	0.29	−1.94	0.15	−1.67	0.09
End of the therapy DIM	−1.45	0.91	0.83	−3.24	0.33	−1.60	0.11
End of the therapy HG	−0.92	0.41	0.17	−1.72	−0.11	−2.24	0.03

Physiotherapy

The effect of physiotherapy on the VAS score has been analyzed. The Hodges's G after 52 weeks of regular physiotherapy was found to be 7.00 (SE = 0.26; p = 0.00). For more detailed results, please see Table 6.

Table 6. Statistical results of this umbrella review regarding the outcomes of physiotherapy for tennis elbow. VAS — The Visual Analogue Scale — dedicated for pain intensity assessment — from '0' (no pain) to '10' (worst pain).

Category	Mean	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
VAS Score							
Baseline	5.39	0.71	0.50	4.00	6.77	7.64	0.00
After 3 weeks	2.63	2.04	4.16	−1.37	6.63	1.29	0.20
After 6 weeks	2.31	0.52	0.28	1.28	3.34	4.40	0.00
After 12 weeks	2.07	0.67	0.45	0.76	3.39	3.09	0.00
After 26 weeks	1.67	0.62	0.38	0.45	2.88	2.69	0.01
After 52 weeks	1.25	0.43	0.19	0.41	2.10	2.90	0.00
Hodges's G	7.00	0.26	0.07	6.49	7.50	27.16	0.00
Difference in Means	4.14	0.06	0.00	4.03	4.25	72.52	0.00

Laser Therapy

The effects of laser therapy on VAS score and grip strength test were analyzed. The Hodges's G was found to be 6.35 (SE = 0.30; p = 0.00). For more detailed results, please see Table 7.

Table 7. Statistical results of this umbrella review regarding the outcomes of laser therapy for tennis elbow. VAS — The Visual Analogue Scale — dedicated for pain intensity assessment — from '0' (no pain) to '10' (worst pain).

Category	Mean	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
VAS Score							
Baseline	6.13	0.51	0.26	5.12	7.14	11.94	0.00
After 2 weeks	4.40	0.35	0.12	3.72	5.08	12.65	0.00
After 6 weeks	4.30	0.19	0.04	3.93	4.67	22.66	0.00
Last Checkup	2.60	0.61	0.37	1.40	3.79	4.25	0.00
Hodges's G	6.35	0.30	0.09	5.76	6.93	21.20	0.00
Difference in Means	3.53	0.07	0.00	3.40	3.66	51.70	0.00
Grip Strength Test							
Baseline	29.43	4.39	19.30	20.82	38.04	6.70	0.00
Last Checkup	39.59	6.42	41.17	27.01	52.16	6.17	0.00
Hodges's G	−1.84	0.18	0.03	−2.19	−1.49	−10.32	0.00
Difference in Means	−10.16	0.82	0.68	−11.78	−8.54	−12.32	0.00

Counterforce Brace

The outcomes of the usage of the counterforce brace as the treatment for TE were analyzed in several categories regarding its effect on VAS and DASH scores and the grip strength test. After 6 weeks, it was found to have a moderate effect on the VAS score, as the Hodges's G was found to be 2.19 (SE = 0.10; p = 0.00). For more detailed results, please see Table 8.

Table 8. Statistical results of this umbrella review regarding the outcomes of counterforce brace for tennis elbow. VAS — The Visual Analogue Scale — dedicated for pain intensity assessment — from '0' (no pain) to '10' (worst pain). DASH — The Disabilities of the Arm. Shoulder and Hand questionnaire — dedicated for assessment of upper-extremity disability and symptoms — from '0' (no disability) to '100'.

Category	Mean	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
VAS Score							
Baseline	4.55	0.41	0.17	3.74	5.37	11.02	0.00
After 6 weeks	3.30	0.76	0.58	1.81	4.78	4.35	0.00
Hodges's G	2.19	0.10	0.01	1.99	2.39	21.82	0.00
Difference in Means	1.25	0.05	0.00	1.16	1.34	27.33	0.00
DASH Score							
Baseline	43.86	1.97	3.87	40.01	47.72	22.29	0.00
After 6 weeks	35.98	2.63	6.91	30.83	41.13	13.69	0.00
Hodges's G	3.38	0.25	0.06	2.89	3.86	13.65	0.00
Difference in Means	7.88	0.37	0.14	7.16	8.60	21.31	0.00
Grip Strength Test							
Baseline	29.40	4.16	17.29	21.25	37.55	7.07	0.00
After 4 weeks	32.52	3.46	11.94	25.75	39.29	9.41	0.00
Hodges's G	−0.81	0.11	0.01	−1.03	−0.59	−7.27	0.00
Difference in Means	−3.12	0.41	0.17	−3.93	−2.31	−7.56	0.00

Acupuncture

The outcomes of acupuncture as the treatment for TE were analyzed regarding its effect on VAS and DASH scores. The Hodges's G was found to be 1.37 (SE = 0.12; p = 0.00). For more detailed results, please see Table 9.

Table 9. Statistical results of this umbrella review regarding the outcomes of acupuncture for tennis elbow. VAS — The Visual Analogue Scale — dedicated for pain intensity assessment — from '0' (no pain) to '10' (worst pain). DASH — The Disabilities of the Arm. Shoulder and Hand questionnaire — dedicated for assessment of upper-extremity disability and symptoms — from '0' (no disability) to '100'.

Category	Mean	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
VAS Score							
Baseline	5.30	1.41	1.99	2.53	8.06	3.75	0.00
Last Checkup	3.49	1.21	1.46	1.12	5.86	2.88	0.00
Hodges's G	1.37	0.12	0.01	1.14	1.61	11.65	0.00
Difference in Means	1.81	0.14	0.02	1.54	2.08	12.96	0.00
DASH Score							
Baseline	44.09	7.70	59.35	28.99	59.19	5.72	0.00
Last Checkup	29.69	9.86	97.24	10.36	49.01	3.01	0.00
Hodges's G	1.62	0.17	0.03	1.28	1.96	9.31	0.00
Difference in Means	14.40	1.34	1.80	11.77	17.03	10.74	0.00

Discussion

Numerous conservative treatment options have been implemented for TE. However, their mechanism of action and effectiveness vary significantly. Physical therapy and activity modifications are one of the classical first-line therapies for TE [59]. These include stretching exercises, mobilization, eccentric epicondylar muscle strengthening exercises, deep transverse friction massage, counterforce braces, and other physical modalities, such as shockwave, laser, and acupuncture therapies, amongst others [60]. In a meta-analysis conducted by Bisset *et al.* [59], no firm conclusions were provided about the effectiveness of stretching exercises. However, mobilization, as well as eccentric epicondylar muscle strengthening exercises, have proven to be beneficial [61]. Our umbrella review shows that physiotherapy decreases the VAS score considerably over time (Table 7), proving itself as a useful alternative for the treatment of TE. However, the use of a counterforce brace decreased the VAS score significantly weaker (Table 9).

The potential efficiency of other physical therapies, including acupuncture, shock wave, and laser therapy, has been discussed extensively. Acupuncture is widely used for analgesia caused by numerous pathologies, including TE [62]. The effectiveness of acupuncture for TE was analyzed in a systematic review and meta-analysis conducted by Zhou *et al.* [62]. In the study, they concluded that acupuncture appeared to be a superior treatment to drug or blocking therapy. However, our umbrella review demonstrated that acupuncture has a minimal effect on the VAS score compared to other available therapies. Shock wave therapy, or extracorporeal shock wave therapy (ESWT), is a recently introduced modality used for TE. However, its actual usefulness is highly controversial. The meta-analyses concerning this treatment modality have presented various results, with some stating that ESWT is a useful technique for TE [63] and others that it has no therapeutic effect [64]. The present umbrella review has considered all the available data in the literature, and our conclusion is that ESWT has the lowest effect on the VAS score compared to any other treatment modality available for TE. Therefore, due to the lack of evidence of the usefulness of both acupuncture and ESWT as treatments for TE, their use in this pathology should be reevaluated. Laser therapy has attracted considerable interest as a possible treatment option for TE. Various studies have discussed the effectivity of this therapeutic modality in TE [22, 31, 65]. The said reviews often concluded that it was not possible to demonstrate either benefit or lack of effect of this treatment modality in TE, mainly due to insufficient evidence. Moreover, some studies have also presented ESWT as a more effective option compared to laser therapy, such as the prospective study conducted by Turgay *et al.* [66]. The present umbrella review, demonstrates that laser therapy is a relatively effective modality, having a more significant effect on the VAS score compared to acupuncture and ESWT (Fig. 2).

Numerous injectables have been used in the treatment of TE. Among them, corticosteroid injections are the most common [67]. Corticosteroid injections have been described as effective in reducing pain and improving the functionality of the affected limb in the short term [36]. However, the efficiency of the said therapeutic modality beyond eight weeks has been debatable [68]. Historically, TE was thought to be an inflammatory pathology; hence, the mechanism of corticosteroid injections was clear, namely, acting as an anti-inflammatory modality [68]. However, it has been demonstrated that there are no inflammatory cells in pathologic specimens of TE [69]. Hence, TE may be better characterized as a tendinopathy. Moreover, relatively recent studies have theorized that the mechanism of corticosteroids as a treatment for TE (especially regarding relief of pain) may be of a neurogenic origin [68, 70]. Injections of glycosaminoglycan have also been used as a treatment for TE, mainly due to its function in inhibiting clotting factor formation as well as catabolic enzymes in connective tissue [71]. However, their efficiency has been up to debate [68]. Autologous blood injection has been analyzed as a possible treatment option for TE in various randomized control trials [72, 73]. Systematic reviews and meta-analyses have presented various conclusions regarding the clinical efficiency of this treatment modality [36, 74]. Studies in the past have demonstrated that autologous blood injections may trigger an inflammatory reaction around the affected tendon, which promotes tissue healing with both humoral and cellular mediators [36, 75]. The popularity of platelet-rich plasma injections as treatment for various musculoskeletal pathologies has increased dramatically during the last decades. Various reports have demonstrated the efficacy of this treatment option, improving pain, disabilities scores, and pressure pain threshold [50, 76, 77]. Platelet-rich plasma works by providing a high concentration of platelets and platelet-derived growth factors to the affected tendon, increasing the efficacy of the healing process in that area [36]. Our umbrella review demonstrates that the top three most effective conservative treatment modalities for TE are, from lowest to highest efficacy, corticosteroid, autologous blood, and platelet-rich plasma injections. These results comply with the conclusions of previous meta-analyses comparing these modalities [36].

When conservative management fails to treat TE, surgical treatment may be indicated. Only a minority of people (approximately 10%) with persisting symptoms of TE undergo surgery [11]. The three most common surgical techniques used are open, arthroscopic, and percutaneous approaches [67]. The open release is the most frequently performed technique, mainly because it provides the greatest visualization of the affected area. The percutaneous release consists of visualizing and dividing the common extensor origin, not directly repairing the ERCB, nor removing any pathological tissue [78]. Nevertheless, the incision performed in this procedure is small, and the recovery time is relatively short [67]. The arthroscopic technique is more frequently indicated in patients with concomitant intra-articular pathology [67]. Moreover, it has been described as a more technically complex procedure, especially when compared to the open and percutaneous approaches [78]. The present umbrella review demonstrates the differences between the open and arthroscopic techniques for TE (Table 4). Our results show that arthroscopic release is associated with a higher rate of complications and a higher probability of surgical failure. Furthermore, the said technique is associated with longer operating times. However, it is crucial to note that the experience and skill of the surgeon performing these surgeries have an immense role in the clinical efficiency of the said techniques [79].

When encountering TE in the clinical setting, it may be feasible to combine the various conservative treatment modalities, such as autologous blood injections and physiotherapy, in order to treat this pathology as efficiently as possible. The present umbrella review provides the most relevant and up-to-date data regarding the treatment of TE in the available literature, making it the ultimate evidence-based tool for physicians treating this pathology. However, one must keep in mind the importance of patient cooperativity in treating TE. Although the injection of platelet-rich plasma has been proven to be the most effective treatment modality, if the treated patient does not comply with the physician's recommendations (concerning immobilization, physiotherapy, etc.), the results of said treatment may be poor. Therefore, to minimize the need for implementing invasive treatment options, the significance of patient cooperativity post-treatment must be underlined by the physician.

The present study is not without limitations. It may be burdened with potential bias, as the accuracy of the results of the present umbrella review strictly depends on the quality of the evaluated studies. Some of the analyses were rejected from the statistical analysis due to insufficient amount of data in the literature and the substantial concerns regarding the potential bias. Additionally, in order to minimize the potential overinterpretation of the data extracted from the primary studies, some of the results of this umbrella review are gathered in specified time variations, even though it limits the clinical use. Although not without limitations, our umbrella review attempts to estimate the most detailed statistical results regarding each treatment option for TE, based on the data from the literature that meet the requirements of evidence-based medicine.

Conclusion

The present umbrella review underlines the efficiency of injection therapies, especially autologous blood, and platelet-rich plasma injections, while simultaneously proving the ineffectiveness of acupuncture and shock wave therapy as treatments for TE. Furthermore, the value of other known conservative treatment modalities, such as physical therapy, has been demonstrated. It is thought that the present study delivers the most comprehensive and up-to-date data regarding the various treatments of TE in the available literature, making it the ultimate evidence-based tool for physicians treating this pathology.

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Conflict of interest

None declared.

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