The role of arthroscopy in bullet removal: A systematic review of the literature

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ARTICLE INFO

Keywords:

Bullet
Intra-articular bullet
Arthroscopy

ABSTRACT

Purpose: The purpose of this study was to systematically review the literature to gain a greater understanding of the role and usage of arthroscopy in removal of retained bullet fragments. Secondly, we intend to examine the level of evidence and methodologic quality of studies reporting on this topic.

Methods: A search of PubMed, MEDLINE, and Cochrane Database of Systematic Reviews was performed using the search terms (“Arthroscopic” OR “Arthroscopy”) AND (“Bullet” OR “Gunshot” OR “Ballistic” OR “Removal”). Inclusion criteria included articles published in English reporting on arthroscopic or arthroscopically-assisted bullet removal. Studies lacking sufficient data to separate arthroscopic and open procedures were excluded. Level of evidence, study information (i.e., country, journal, etc.), and patient data was collected from each eligible article. The methodological index for non-randomized studies (MINORS) score were assigned to each article.

Results: A total of 2676 studies were identified in the initial search with 31 studies meeting criteria for inclusion in the study. Twenty-eight of the 31 studies were case reports. The MINORS score averaged 8.8 ± 1.5 (range 5–10) for included studies. Sixty-two patients were identified, the majority (94%) of whom were male with an average age of 36.2 ± 12.3 years. All 62 patients underwent successful arthroscopic bullet removal. One patient was reported to have a complication (compartment syndrome). Outcome measures were underreported in the majority of studies.

Conclusions: Our study found that very little literature exists on the role of arthroscopy in bullet removal. Of this literature, no high-quality studies exist. Based on the limited existing literature, arthroscopy appears to be a safe, reliable alternative to open surgery for bullet removal. Potential benefits of arthroscopic bullet removal exist and warrant further investigation to further define the role of arthroscopy.

Level of evidence: Level V.

1. Introduction

Gunshot wounds (GSWs) are increasingly prevalent in the United States civilian population.^{1,2} From 2005 to 2014, 750,572 nonfatal GSW victims were reported in the United States, with half affecting extremities.^{3,4} Ballistic orthopaedic injuries, such as fractures and retained intra-articular fragments, often result in increased hospital length of stays, risk of infection, healthcare costs, morbidity, and mortality.^{2,5–7} Specific to intra-articular bullet fragments, complications such as systemic lead poisoning, synovitis, infection, cartilage destruction, early arthritis, and restricted range of motion (ROM) have been described in

the literature.^{7–9} In a mice study, Carmouche et al. described delayed fracture healing and increased nonunion rate in fractures with elevated local lead levels, signifying an additional indication and benefit of bullet removal.¹⁰ Numerous techniques have been described for removal of bullets which cause pain and limited ROM, ranging from open arthrotomy to joint dislocations to arthroscopy.^{11–14} Despite numerous techniques available, there is little to no data available on optimal treatment. While arthroscopy is unproven in the removal of intra-articular bullets, potential benefits related to arthroscopic versus open procedures exist, including enhanced visualization, its minimally invasive nature, reduction in blood loss, and decreased surgical morbidity to the

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<https://doi.org/10.1016/j.jor.2020.09.019>

Received 25 August 2020; Accepted 27 September 2020

Available online 29 September 2020

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surrounding cartilaginous, neurovascular, and soft tissue structures.^{15,16}

Very little has been published regarding the role of arthroscopy in bullet fragment removal. As such, the purpose of this study was to systematically review the literature to gain a greater understanding of the role and usage of arthroscopy in removal of retained bullet fragments. Secondly, we intend to examine the level of evidence and

methodologic quality of studies reporting on this topic. Our hypothesis was arthroscopic retrieval would be a safe and viable method for intra-articular bullet removal. We also anticipated that most studies would be of a low level of evidence and poor methodologic quality in a limited number of patients.

Table 1

Study characteristics of eligible studies.

Author	Year	Study Type	Level of Evidence	Country of Origin	Journal of Publication	Joint	Sample Size (N)	% Male	Mean Age	Time from injury to intervention (time unit)	Mean Follow Up (Months)	Other Injuries
Fournier ¹³	2019	Case Report	V	United States	<i>JBJS Case Connector</i>	Hip (Prosthetic)	1	100	51	NR	12	No
Ferro ¹⁴	2019	Case Report	V	Brazil	<i>Open Med Case Report</i>	Hip	1	100	35	NR	27	Yes
Gurpinar ¹⁷	2018	Case Report	V	Turkey	<i>J Pakistan Med Assoc</i>	Hip	1	100	48	NR	NR	No
Çatma ¹⁸	2016	Case Report	V	Turkey	<i>J Ortho Case Reports</i>	Hip	1	100	32	2 (days)	33	No
Keskinbora ¹⁹	2016	Case Report	V	Turkey	<i>Clin Ortho Surg</i>	Knee	1	100	42	4 (hours)	1.5	No
Galland ²⁰	2015	Case Report	V	France	<i>Case Rep Orthop</i>	Shoulder	1	100	57	26 (years)	24	No
Ejnisman ²¹	2014	Case Report	V	Brazil	<i>BMJ Case Rep</i>	Scapulothoracic	1	100	55	18 (months)	2	No
Kaya ²²	2013	Case Report	V	Turkey	<i>Eurasian J Med</i>	Hip	1	100	33	1 (week)	0.5	Yes
Al-Asiri ²³	2012	Case Report	V	Canada	<i>J Surg Tech Case Report</i>	Hip	1	100	36	NR	NR	Yes
Sozen ²⁴	2010	Case Report	V	Turkey	<i>Hip Int</i>	Hip	1	100	24	3 (days)	2	No
Gupta ²⁵	2009	Case Report	V	India	<i>Indian J Orthop</i>	Hip	1	100	18	4 (months)	13	No
Lee ²⁶	2008	Case Series	IV	United States	<i>J Trauma</i>	Knee (5), Hip (4), SI(1)	10	100	22	NR	NR	NR
Mahirogullari ²⁷	2007	Case Report	V	Turkey	<i>Arthroscopy</i>	Shoulder	1	100	21	NR	1	No
Singleton ²⁸	2005	Case Report	V	United States	<i>Arthroscopy</i>	Hip	1	100	32	3 (days)	12	Yes
Otero ²⁹	2004	Case Report	V	France	<i>Arthroscopy</i>	Shoulder	1	100	30	3 (days)	3	Yes
Tarkin ³⁰	2003	Case Report	V	United States	<i>Arthroscopy</i>	Shoulder	2	100	22	NR/1 (day)	2.6	Yes (1)
Gutiérrez ³¹	2003	Case Report	V	Chile	<i>Arthroscopy</i>	Knee	1	100	25	4.5 (years)	0.5	No(1)
Mineo ³²	2003	Case Report	V	United States	<i>Arthroscopy</i>	Hip	1	100	17	NR	24	Yes
Cho ³³	2002	Case Report	V	United States	<i>Arthroscopy</i>	Knee	1	100	70	1 (day)	24	Yes
Teloken ³⁴	2002	Case Report	V	Brazil	<i>Arthroscopy</i>	Hip	1	100	33	5 (days)	18	No
Meyer ³⁵	2002	Case Report	V	United States	<i>J Orthop Trauma</i>	Hip	1	100	27	16 (hours)	12	No
Peterson ³⁶	2002	Case Report	V	Germany	<i>Arch Orthop Trauma Surg</i>	Knee	1	100	29	NR	6	No
Jamdar ³⁷	2001	Case Report	V	England	<i>Arthroscopy</i>	Elbow	1	100	55	6 (weeks)	NR	No
Jazrawi ³⁸	1999	Case Report	V	United States	<i>Arthroscopy</i>	Subtalar	1	0	33	9 (months)	12	No
Cory ³⁹	1998	Case Report	V	United States	<i>Arthroscopy</i>	Hip	1	100	45	3 (days)	12	No
Tornetta ⁴⁰	1997	Case Series	IV	United States	<i>J Ortho Trauma</i>	Knee	19	85	44	NR	0.75	Yes
Bolanos ⁴¹	1996	Case Report	V	United States	<i>JBJS</i>	Knee	1	0	41	23 (years)	18	Yes
Latosiewicz ⁴²	1995	Case Report	V	Poland	<i>Arthroscopy</i>	Knee (B/L)	1	100	25	5 (years)	NR	Yes
Goldman ⁴³	1987	Case Report	V	United States	<i>J Trauma</i>	Hip	1	100	22	1 (year)	NR	No
White ⁴⁴	1987	Case Report	V	United States	<i>J Trauma</i>	Knee	1	100	58	3 (days)	1.5	No
Parisien ⁴⁵	1984	Case Series	IV	United States	<i>Clin Ortho Relat Res</i>	Knee	4	100	39	NR	16.5	NR

Key: B/L= bilateral; NR= not reported

2. Methods

2.1. Study selection (inclusion and exclusion criteria)

Eligible articles included those that were published in English and included patient data on arthroscopic or arthroscopically-assisted removal of bullet fragments. Studies lacking sufficient patient data to separate arthroscopic removal from open, or bullet removal from other intra-articular debris were excluded. Review articles without primary data were also excluded (Table 1).

2.2. Literature search

A comprehensive search of multiple electronic databases was performed by two independent authors, consistent with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. PubMed, MEDLINE and Cochrane Database of Systematic Reviews were searched using the following search strategy: (“Arthroscopic” OR “Arthroscopy”) AND (“Bullet” OR “Gunshot” OR “Ballistic” OR “Removal”).

2.3. Study selection and data abstraction

Two authors independently screened article titles for possible inclusion. Abstracts remaining were then reviewed to determine study eligibility (Fig. 1). If any uncertainty was present, the full manuscript was reviewed. A third author settled any discrepancies that arose.

Study information and methodology were collected from articles, including study design, number of patients included, follow-up duration, country of origin, journal and year of publication. Patient demographic

information collected included age and sex. Data related to the injury, such as associated fracture, time from injury to intervention, antibiotic prophylaxis, and other associated injuries were collected. Treatment and outcome data obtained included joint involved, arthroscopic-only or arthroscopic-assisted procedure, bullet retrieval technique, discharge time after operation, complications, and recorded outcome. For reported outcomes, commonly identified variables were used, including wound complication or infection, follow-up imaging, pain, and ROM. Data was input into Microsoft Excel (Redmond, Washington, USA) for collection and analysis.

2.4. Risk of bias assessment

Studies were assigned a level of evidence using the criteria established by the *Journal of Bone and Joint Surgery*.⁴⁶ Studies were then subsequently graded by two independent authors (CC and EG) with the Methodological index for non-randomized studies (MINORS) criteria: a validated study grading criterion.⁴⁷ A kappa value of 0.98 was obtained between the two authors for MINORS criteria, with any discrepancy settled by a third author (BB). This score assesses methodology of papers with 12 criteria, giving a total score 0 to 24, with higher scores correlating to higher quality studies.

2.5. Data analysis

Primary outcome measures included successful arthroscopic bullet retrieval, post-operative pain and ROM, and any complications encountered. Reported variables (i.e. age, antibiotic prophylaxis, time from injury to intervention, etc.) were tabulated with an input response of “Not Reported” or “NR” when the study did not provide sufficient

Fig. 1. Flow diagram summarizing the literature search, screening, and selection process.

data. Descriptive statistics were calculated with categorical data presented as frequency with percentages and continuous data as means. Weighted means were calculated for all parameters. Studies that did not report an outcome were not included in the calculation of that adjusted mean.

3. Results

3.1. Literature review

A total of 2676 studies were identified from the initial search (Fig. 1). After screening the titles and abstracts, 31 studies met criteria for inclusion (Table 1). The United States produced the most studies (14), with *Arthroscopy* being the most commonly publishing journal (12). Included studies consisted of 28 case reports. The other three studies were all retrospective case series'. Outcome data reported in the studies varied greatly.

3.2. Study quality

The MINORS score for the 31 studies averaged 8.9 ± 1.5 (range 5–10). No included study had a comparison group of open arthrotomy for bullet removal. Also, all studies were retrospectively performed, lacking any prospective or randomized data. Given that many of these studies were case reports or small case series, adequate statistical analyses were impossible to perform. The studies were largely uniform in the absence of these essential components of high-quality studies.

3.3. Patient demographics

The 31 eligible studies included 62 patients with 63 joints embedded with bullets. Mean age was 36.2 ± 12.3 years (range 13–70) with 92% (58) of patients being male. The most commonly reported joint involved was the knee (36), followed by the hip (18; 1 prosthetic). Time from injury to intervention was reported in 21 (67.7%) studies and ranged from 4 h to 26 years (average 204.9 ± 629.1 weeks). Mean adjusted follow-up time was 7.3 ± 9.1 months for the 25 (80.6%) studies that reported this variable. There were 29 patients who were noted to have other injuries. Associated fractures and/or chondral defects were reported in 27 (43.5%) patients.

3.4. Outcomes

Operative treatment was performed on all 62 patients. Of the 21 studies that stated time from injury to intervention, 13 reported removing the bullet acutely, defined as within one week of injury. There were 11 (17.5%) bullets removed in an arthroscopic-assisted fashion with a small arthrotomy incision, while the remainder (82.5%) required no additional incisions. Mechanisms of arthroscopic bullet retrieval included grasper (15), rongeur (3), threaded guidewire (2), and shaver (1). Approximately, one-third of patients (30.6%) were noted to receive IV antibiotics (first-generation cephalosporin), while all other cases did not report the use or disuse of antibiotic prophylaxis. Only one direct complication of surgery was reported in Keskinbora et al.¹⁸ with compartment syndrome immediately post-op treated by four-compartment fasciotomy which was closed three days later. Three patients underwent reoperation: one patient for compartment syndrome fasciotomy closure, one patient for femoral head chondral defect repair two years after initial operation, and one failed attempt at arthroscopic bullet retrieval with successful subsequent arthroscopic attempt.^{18,19,43} Only 10 (16%) patients were noted to have documented day of discharge after surgery, averaging post-operative day (POD) 2.8 (range 1–10).

Reported outcomes varied substantially in the 31 studies. Only two studies reported validated outcome measures in the Constant score of 90 and 98.^{20,29} No wound complication or infection was noted in 30 (48.4%) patients. The remaining 32 patients had no reported data

specifying wound complication or infection. Only 10 patients had documented imaging follow-up. Three patients reported postoperative pain ranging from “discomfort” to “mild.” Full ROM was reported in 13 patients, limited ROM noted in three, “functional” ROM in one, and the variable went unreported for 45 patients. One quarter of studies focused on the surgical procedure itself and did not report any of the variables we gathered for outcome of the patient. Full surgical and outcome details are listed in Table 2 (Table 2).

4. Discussion

The purpose of this study was to systematically review the literature related to arthroscopic bullet removal with a specific interest in assessing the role and utility of arthroscopy on successful bullet removal. Secondly, level of evidence and methodologic quality of the available studies was evaluated and analyzed.

This study is the largest systematic review evaluating outcomes following arthroscopic bullet removal, encompassing 62 patients in 31 studies. Our patient population was predominantly male at 94% and relatively young with an average age of 36 years. This demographic data corresponds with what has been previously published by the Department of Justice and the CDC for the groups that sustain the most gunshot injuries.^{3,4} Common reported indications for intra-articular bullets removal included pain, loss of range of motion, and lead poisoning which one patient presented with.⁴¹ These findings are similar to those previously reported by Nguyen et al. and others.^{7–9} There was no significant difference detected among outcomes of patients who underwent arthroscopic-only bullet removal versus arthroscopic-assisted bullet removal (with mini-arthrotomies).

Even though there was significant heterogeneity in the patient outcomes reported in these studies, the outcomes were reported as satisfactory with only one major complication of compartment syndrome following knee arthroscopy and arthroscopic bullet retrieval.¹⁹ Keskinbora et al. reported that, while their patient had decreased pain and range of motion due to swelling from the gunshot injury, no signs of compartment syndrome were noted preoperatively. Neurovascular examinations were intact without deficit. Immediately after tourniquet release, the authors noted swelling in the anterolateral leg and pulse deficiency in the dorsalis pedis pulse of the operative leg. They immediately performed a four-compartment fasciotomy which was closed three days later without further complication. Potentially contributing factors for this complication in this case included lower leg soft tissue injury, fluid extravasation from arthroscopic treatment, and tourniquet use.⁴⁸ For this case of compartment syndrome, a specific causative factor was not identified.

When compared to open procedures for numerous orthopaedic conditions, arthroscopy demonstrates lower complication and faster rehabilitation rates.^{49,50} A recent study by Alvarez et al. discussed arthroscopic reduction and internal fixation of tibial plateau fractures, noting benefits of arthroscopic treatment including clear visualization of articular surface, less invasiveness, and the opportunity for multiple interventions such as meniscal or cartilage repair at time of the index operation.¹⁵ Botser et al. compared open surgical hip dislocation with arthroscopic treatment for femoroacetabular impingement and highlighted lower complication rates, higher rate of return to sport for professional athletes, and greater increase in modified Harris hip score, providing a validated scoring measure, favoring arthroscopic treatment.⁴⁹ In the original technique article by Ganz et al. regarding surgical dislocation of the hip, complications including heterotopic ossification in 37% of patients and ‘saddleback deformity’ of subcutaneous fat from closure of the incision were noted.⁵¹ These complications are uncommon in arthroscopy.⁵²

Maquingo et al. reported a prospective case series of ten patients treated with surgical hip dislocation for removal of retained intra-articular bullets in the hip.⁵³ In this series, average blood loss was noted to be 255 ml, wound infection in one patient was noted following

Table 2
Surgical and outcomes data.

Author (Year)	Sample Size (N)	Joint	Arthroscopy only	Reoperation (Reason)	Length of Stay (Days)	Complications	Bullet Retrieval Method	Wound/ infection reported	Imaging Follow-up Available	Post Op Pain Reported	Range of Motion
Jamdar ³⁷ (2001)	1	Elbow	Yes	No	NR	No	NR	NR	NR	No	Full
Fournier ¹³ (2019)	1	Hip (Prosthetic)	Yes	No	1	No	NR	No	Yes	NR	NR
Ferro ¹⁴ (2019)	1	Hip	Yes	No	NR	No	NR	No	Yes	Yes	Full
Gurpinar ¹⁷ (2018)	1	Hip	Yes	No	NR	No	grasper	NR	NR	NR	NR
Çatma ¹⁸ (2016)	1	Hip	Yes	Yes (chondral repair)	NR	No	grasper	NR	Yes	Yes	Full
Kaya ²² (2013)	1	Hip	Yes	No	NR	No	grasper	NR	NR	NR	NR
Al-Asiri ²³ (2012)	1	Hip	Yes	No	NR	No	grasper	NR	Yes	NR	NR
Sozen ²⁴ (2010)	1	Hip	Yes	No	NR	No	grasper	NR	NR	NR	NR
Gupta ²⁵ (2009)	1	Hip	Yes	No	NR	No	grasper	NR	NR	NR	Limited
Singleton ²⁸ (2005)	1	Hip	Yes	No	NR	No	grasper threaded tipped guide pin	NR	Yes	No	Full
Mineo ³² (2003)	1	Hip	Yes	No	1	No	NR	NR	NR	NR	NR
Teloken ³⁴ (2002)	1	Hip	Yes	No	NR	No	shaver	NR	Yes	No	Full
Meyer ³⁵ (2002)	1	Hip	Yes	No	NR	No	ronguer	No	NR	NR	NR
Cory ³⁹ (1998)	1	Hip	Yes	No	NR	No	ronguer	NR	Yes	No	Full
Goldman ⁴³ (1987)	1	Hip	Yes	Yes (bullet retrieval)	NR	No	NR	NR	NR	NR	NR
Lee ²⁶ (2008)	10	Hip (4), Knee (5), Sacroiliac (1)	Yes	No	1(1); 2 (1) NR (9)	No	threaded guidewire (1), rongeur (1), NR (8) grasper	NR	NR	NR	NR
Keskinbora ¹⁹ (2016)	1	Knee	Yes	Yes (fasciotomy closure)	NR	Compartment syndrome		No	Yes	NR	NR
Gutiérrez ³¹ (2003)	1	Knee	Yes	No	NR	No	grasper	NR	NR	No	NR
Cho ³³ (2002)	1	Knee	Yes	No	2	No	grasper	NR	NR	NR	Full
Peterson ³⁶ (2002)	1	Knee	Yes	No	NR	No	grasper	No	NR	NR	Full
Tornetta ⁴⁰ (1997)	19	Knee	Yes (12) No (7)	No	3	No	Mini-arthrotomy (7), NR (12)	No	NR	NR	NR
Bolanos ⁴¹ (1996)	1	Knee	Yes	No	NR	No	NR	NR	NR	Yes	NR
Latosiewicz ⁴² (1995)	1	Knee (B/L)	Yes	No	5	No	NR	NR	NR	NR	NR
White ⁴⁴ (1987)	1	Knee	Yes	No	NR	No	grasper	No	NR	NR	0-90 flexion
Parisien ⁴⁵ (1984)	4	Knee	No	No	10 (1); NR (3)	No	Mini-arthrotomy	No	NR	No(1) NR (3)	Full (3) Lack extension (1) Full
Ejnisman ²¹ (2014)	1	Scapulo-thoracic	Yes	No	NR	No	grasper	No	NR	No	Full
Galland ²⁰ (2015)	1	Shoulder	Yes	No	1	No	grasper	NR	NR	No	NR
Mahirogullari ²⁷ (2007)	1	Shoulder	Yes	No	NR	No	NR	NR	NR	No	NR
Otero ²⁹ (2004)	1	Shoulder	Yes	No	NR	No	grasper	NR	NR	NR	NR
Tarkin ³⁰ (2003)	2	Shoulder	Yes	No	2 (1); NR (1)	No	NR	NR	Yes(1) NR (1)	No(1) NR (1)	Functional (1) NR (1) Full
Jazrawi ³⁸ (1999)	1	Subtalar	Yes	No	NR	No	grasper	NR	Yes	No	Full

Key: NR= not reported; B/L= bilateral;

surgery, and average length of stay was noted to be 12.8 days for these 10 patients. None of the 62 patients in our study were noted to have an infection compared to the 10% infection rate in the cohort by Maquingo et al. While length of stay post-operatively was under reported in our study (16%), our average post reported discharge of POD 2.8 was

significantly decreased from the surgical dislocation group average of POD 12.8. This is consistent with other studies, such as Johns et al., who report decreased length of hospital stay in arthroscopic patients when compared to open procedures.⁵⁴ Howse et al. highlights that hip arthroscopy for bullet retrieval, when compared to open arthrotomy,

allows for expedited recovery because of its minimally invasive nature to a joint that has already sustained a traumatic insult.¹⁶ Fournier et al. described arthroscopic removal of bullet debris from a prosthetic hip due to wound healing concerns secondary to monoclonal antibody infusion.¹⁴ In cases of bullet remnants in the hip, arthroscopic removal is a viable alternative to open arthrotomy with possible surgical dislocation.^{14,17,23}

Weaknesses inherent to systematic reviews were present in our study. The quality of data gathered was determined by reporting authors, limiting the amount of information the authors of this study could collect. The significant heterogeneity of outcomes reported in the eligible studies limited our ability to pool data. Additionally, the uniformity of these studies was contained to low levels of evidence, lack of long-term follow-up, lack of control groups and an absence of reliable, validated outcome scores.

5. Conclusion

There is a dearth of high-quality literature describing the outcomes following arthroscopic bullet removal. Large, prospective cohort studies of patients undergoing arthroscopic versus open bullet removal would further clarify any benefit that may be gained with arthroscopy. Additionally, the use or development of specific patient reported outcome measures validated among patients undergoing intra-articular foreign body removal would allow for future studies to be adequately compared.

Declaration of competing interest

None of the authors have any relevant conflict of interests to declare.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jor.2020.09.019>.

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