Outcomes of Manipulation Under Anesthesia Versus Surgical Management of Combat-Related Arthrofibrosis of the Knee

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The purpose of this study was to compare the outcomes of manipulation under anesthesia (MUA) to arthrolysis for combat-related arthrofibrosis. Sixty-one knees in 56 patients who underwent treatment for arthrofibrosis secondary to lower extremity trauma were reviewed. Knee range of motion preoperatively, postoperatively, and at follow-up was analyzed. The primary outcome measure was the difference in knee arc of motion between the two cohorts. Forty-one knees (67.2%) underwent MUA and 20 knees (32.8%) were managed operatively. There was no difference in the preoperative arc of motion. Knees that underwent MUA had significant improvements in arc of motion compared to knees that underwent arthrolysis (106.3° vs. 82.3°) at a follow-up of 2 years ($p = .008$). The complication rate was greater in knees that underwent arthrolysis (40%) compared to knees that underwent MUA (12.2%; $p = .04$). In conclusion, knees that underwent MUA demonstrated significant improvements in arc of motion at 2-year follow-up with fewer complications. (Journal of Surgical Orthopaedic Advances 22(1):36–41, 2013)

Key words: arthrofibrosis, arthrolysis, knee range of motion, manipulation under anesthesia

Loss of motion in the knee following surgery or a traumatic insult is a challenging clinical problem for both the surgeon and the patient (1) and is a common clinical entity in the setting of combat-related injuries to the lower extremity. Knee stiffness has been defined as a flexion contracture of greater than 15° or an arc of motion of less than 70° (2, 3). This loss of motion can adversely affect a patient's ability to perform activities of daily living. Prior studies incorporating gait analysis have shown that 67° of knee flexion is required in the swing phase of walking, 83° is required to ascend stairs, 90° is required to descend stairs, and 93° is required to rise from a standard chair (4). As little as 5° of extension loss can produce a noticeable limp during ambulation, strain the quadriceps muscle, and contribute to patellofemoral pain (4).

The causes of arthrofibrosis are numerous but can usually be traced to a traumatic event, intra-articular or ligament knee surgery, knee arthroplasty, or infection (5–8). Accepted treatment modalities include both closed (physical therapy, manipulation under anesthesia) and open operative (arthroscopic lysis of adhesions, open lysis of adhesions, quadricepsplasty) options. Although the literature includes many reports on the treatment of arthrofibrosis after intra-articular or ligament reconstruction knee surgery and knee arthroplasty (5–7, 9–12), there are no reports comparing manipulation under anesthesia (MUA) to arthrolysis for the treatment of knee arthrofibrosis secondary to civilian or combat-related trauma to the lower extremity.

The purpose of this study was to evaluate and compare the clinical outcomes of closed MUA to arthrolysis for knee arthrofibrosis secondary to combat-related trauma. Specifically, the aim was to describe the demographic and injury-related factors in the two cohorts, determine the difference between treatment outcomes, and determine the difference in the rate of medical complications.

Materials and Methods

After approval by our institutional review board, a retrospective review of all patients at our institution who underwent closed MUA or open operative treatment for stiffness of the knee after sustaining combat injuries to the lower extremity while deployed in support of Operation

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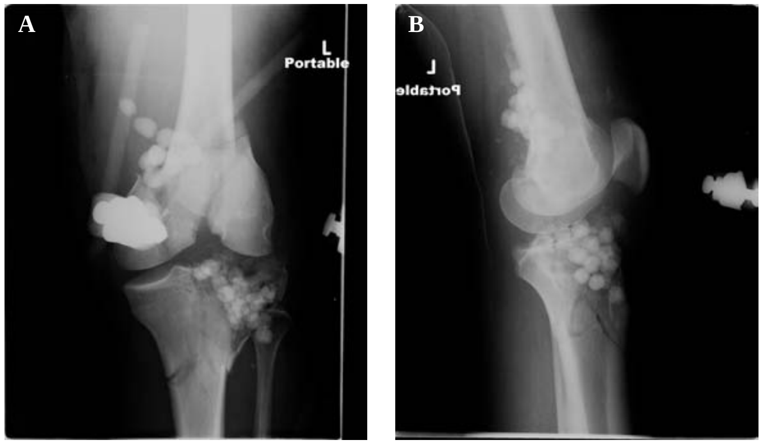

FIGURE 1 Anteroposterior (**A**) and lateral (**B**) radiographs demonstrating a comminuted, intra-articular, distal femur and bicondylar tibial plateau fractures with antibiotic beads secondary to a high-energy blast.

Iraqi Freedom (OIF) or Operation Enduring Freedom (OEF) between July 2005 and April 2010 was performed. Indication for treatment was a flexion contracture of greater than 15° or knee range of motion of less than 70°. Patients were eligible for the study if they were an active duty service member who sustained combat-related lower extremity trauma and met the diagnostic criteria for arthrofibrosis. Those who developed arthrofibrosis or stiffness secondary to noncombat-related trauma (i.e., joint arthroplasty, ligament reconstruction, or arthroscopic surgery) were excluded. Recorded demographic variables included age, gender, location, type, and mechanism of injury, and Injury Severity Score.

Lower extremity injuries included both fractures (Figs. 1 and 2) and amputations. Fractures were initially stabilized with splint immobilization or external fixation. Extremity injuries with associated open wounds were managed with serial debridements until definitive wound closure or soft tissue coverage. Appropriate preoperative planning for fracture fixation was also performed. Multiple types of fixation were utilized for definitive management to include flexible nails, intramedullary nails, wiring, and plate osteosynthesis.

The method of treatment for arthrofibrosis was at the discretion of the attending surgeon. Operative treatment methods for arthrolysis included arthroscopic or open lysis of adhesions with or without quadricepsplasty. Arthroscopic lysis of adhesions included debridement of the suprapatellar pouch, medial and lateral gutters, and the intercondylar notch. In knees that underwent open lysis of adhesions, similar techniques were utilized to debride scar tissue from the knee. MUA was performed under general anesthesia with adequate muscle relaxation and the ipsilateral hip flexed to 90°. The leg was held close to the knee joint and progressive force was applied until audible and palpable lysis of adhesions occurred. The knee was held in this position and the procedure repeated as necessary. Immediately postoperatively, patients in both treatment groups began active-assisted and passive range-of-motion exercises with the use of regional anesthesia

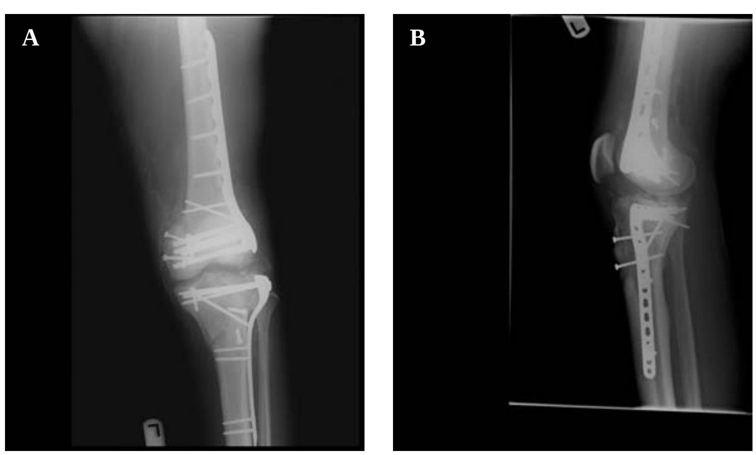

FIGURE 2 Anteroposterior (**A**) and lateral (**B**) radiographs following open reduction and internal fixation.

catheters and continuous passive motion. The ranges of motion before and after treatment and at follow-up were measured using a goniometer by an independent physiotherapist. The primary outcome measure was the difference in knee arc of motion between the two cohorts. Secondary outcome measures included the difference in complication rates and other adverse events.

Statistical differences between mean continuous variables were evaluated with use of a Student *t* test. The two-sample *t* test was used for comparison of range of motion before and after treatment as well as at follow-up. Associations between categorical variables were studied with the Fisher exact test or chi-squared analysis as appropriate. A power analysis demonstrated that a minimum sample size of 36 subjects was required to compare differences between the treatment groups (alpha = .05, power = .80). Statistical analysis was performed using JMP v. 9.0 (SAS, Cary, NC). A two-tailed p value of $<.05$ was considered statistically significant. Data are presented as mean ± standard deviation unless otherwise stated.

Results

Analyses of demographic-dependent variables and univariate associations are summarized in Tables 1 and 2. Ninety-two patients underwent treatment for arthrofibrosis of the knee during the study period. Of these, 56 patients met the inclusion criteria. Thirty-six (64.3%) patients underwent closed MUA and 20 patients (35.7%) underwent arthrolysis. A total of 61 knees in the 56 patients were evaluated. Of the 61 knees, 41 (67.2%) underwent closed manipulation and 20 (32.8%) were managed operatively. Sixteen knees underwent open lysis of adhesions and four knees underwent arthroscopic lysis of adhesions in the operative treatment group. Three of the 16 knees that underwent open arthrolysis underwent formal quadricepsplasty. The average age of patients who underwent MUA was 25.8 (range, 22–34) years compared to 27.2 (range, 22–36) years for patients who underwent arthrolysis ($p = .43$). The duration from injury to treatment and duration of follow-up was similar between the two groups (2.6 ± 1.6 vs. 3.8 ± 2.7 months; $p > .05$). Additionally, there was no difference in Injury Severity Score, mechanism of injury, injury type, or injury location ($p > .05$).

Manipulation Under Anesthesia

An intra-articular fracture was present in 35 of 41 (85.4%) knees that underwent MUA. Stiffness in three knees (7.3%) occurred postoperatively after a transtibial amputation. The range of knee movement improved from a mean of 0.8° to 48.9° in the premanipulation period to 3.1° to 109.4° at follow-up. At final follow-up, the mean arc of motion was 106.3°. The mean improvement in the arc of motion from premanipulation at follow-up was 54.4° ($p < .001$).

TABLE 1 Patient demographics

	No. of Patients ($N = 56$)	MUA ($N = 36$) (64.3)	Open ($N = 20$) (35.7)	p Value
Age (years)		25.8 ± 6.7	27.2 ± 6.1	.43[a]
Gender				.29[b]
Male	53	35 (97.2)	18 (90.0)	
Female	3	1 (2.8)	2 (10.0)	
Combat theater				.266[c]
OIF	25	17 (47.2)	8 (40.0)	
OEF	31	19 (52.8)	12 (60.0)	
Injury Severity Score		31.6 ± 11.8	30.3 ± 8.7	.43[a]

Note: Demonstrates univariate relationships between patient demographics in the treatment groups. The values are given as the number with the percentage in parentheses.
[a]Student *t* test.
[b]Fisher exact test.
[c]Chi-square test.

Arthrolysis

An intra-articular fracture was present in 18 of 20 (90%) knees that underwent arthrolysis. The range of knee movement improved from a mean of 4.4° to 47.2° in the preoperative period to 4.9° to 87.2° at follow-up. At follow-up, the mean arc of motion was 82.3°. The mean improvement in the arc of motion from the preoperative period to follow-up was 40.3° ($p < .001$). There was no difference in intra-operative arc of motion immediately following intervention and at follow-up in knees that underwent arthroscopic lysis of adhesions compared to knees that underwent open lysis of adhesions ($p = .34$).

Comparison of Manipulation Under Anesthesia to Arthrolysis

Both closed and open treatment options yielded significant gains in intra-operative knee arc of motion immediately following intervention and at final follow-up. However, knees that underwent MUA demonstrated significant improvements in motion compared to knees that underwent arthrolysis. There was no difference in the mean arc of motion preoperatively in the knees that underwent manipulation compared to knees that underwent arthrolysis ($46.3° \pm 22.5°$ vs. $41.8° \pm 21.1°$; $p > .05$). At final follow-up, knees that underwent MUA had significant improvements in mean arc of motion compared to knees that underwent arthrolysis ($106.3° \pm 28.8°$ vs. $82.3° \pm 30.0°$; $p = .008$). Four knees (9.8%)

TABLE 2 **Comparison of treatment groups**

	No. of Knees ($N = 61$)	MUA ($N = 41$) (67.2)	Open ($N = 20$) (32.8)	p Value
Mechanism of injury				.54[a]
Ballistic	3	3 (7.3)	0	
Blast	58	38 (92.7)	20 (100)	
Injury type				.54[a]
Fracture	58	38 (92.7)	20 (100)	
Amputation	3	3 (7.3)	0	
Injury location				.15[b]
Femur	34	22 (53.7)	12 (60.0)	
Tibia	16	9 (21.9)	7 (35.0)	
Both	11	10 (24.4)	1 (5.0)	
Duration from injury to treatment (months)		2.6 ± 1.6	3.8 ± 2.7	.1[c]
Preoperative arc of motion		46.3 ± 22.5	41.8 ± 21.1	.44[c]
Postoperative arc of motion		97.9 ± 27.2	83.5 ± 30.0	.08[c]
Final arc of motion		106.3 ± 28.8	82.3 ± 30.0	.008[c]
Duration of follow-up (months)		24.1 ± 12.4	27.1 ± 15.1	.46[c]
Reoperation				.98[a]
No	55	37 (90.2)	18 (90.0)	
Yes	6	4 (9.8)	2 (10.0)	

Note: Demonstrates univariate relationships between the treatment groups. The values are given as the number with the percentage in parentheses.
[a]Fisher exact test.
[b]Chi-square test.
[c]Student *t* test.

underwent repeat manipulation because of continued stiffness compared to two (10.0%) knees that underwent repeat arthrolysis. There was no difference in the reoperation rate between the two treatment options ($p > .05$).

Complications

The complication rate was significantly greater in knees that underwent open treatment (40%) compared to knees that underwent MUA (12.2%; $p = .04$) (Table 3). There were three deep postoperative wound infections (15.0%) in the open treatment group that were managed with serial debridements and intravenous antibiotics. Postoperative wound complications (dehiscence and hematoma formation) were also greater in the open treatment group. There were three ruptures of the patellar ligament (7.3%) in knees that underwent MUA and one iatrogenic supracondylar femur fracture in the open treatment group. All three knees that sustained an iatrogenic rupture of the patellar ligament following manipulation underwent primary repair within 7 days of the injury. The final arc of knee motion in these knees was significantly less than the MUA cohort without rupture of the extensor mechanism (87.3° vs. 105.7°; $p = .04$). Conversely, there was no difference in the final arc of motion in the arthrolysis knees that developed a postoperative infection or wound complication compared to those knees that did not (89.2° vs. 92.4°; $p = .78$).

TABLE 3 **Complications**

	MUA ($N = 41$)	Open ($N = 20$)	p Value
Wound dehiscence	2 (4.9)	3 (15.0)	.31[a]
Hematoma	0 (0)	1 (5.0)	.32[a]
Patellar tendon/ligament injury	3 (7.3)	0 (0)	.54[a]
Fracture	0 (0)	1 (5.0)	.33[a]
Infection	NA	3 (15.0)	NA
Total	5 (12.2)	8 (40)	.04[b]

Note: Complication rates between the treatment groups. The values are given as the number with the percentage in parenthesis. NA, nonapplicable.
[a]Fisher exact test.
[b]Student *t* test.

Discussion

Loss of knee range of motion is a common problem following lower extremity trauma, especially in the setting of complex blast or ballistic injuries. In this retrospective analysis, 61 knees were identified in 56 patients who underwent treatment for posttraumatic arthrofibrosis. Knees that underwent closed MUA demonstrated significant improvements in arc of motion at 2-year follow-up with a lower complication rate compared to knees that underwent arthrolysis. To our knowledge, this represents the only report comparing MUA to arthrolysis for the treatment of knee arthrofibrosis secondary to traumatic injury to the lower extremity, which makes the findings of this study clinically significant.

The degree of osseous and soft injury about the knee contributes significantly to the pathogenesis of arthrofibrosis and subsequent loss of motion. Furthermore, high-energy injuries and intra-articular fractures have also been associated with increased rates of stiffness (1, 8, 13). All patients in the present series sustained high-energy penetrating blast or ballistic injuries leading to extensive soft tissue wounds and lower extremity trauma. The management of these injuries was further complicated by severe additional injuries in a majority of patients. This is reflected in the relatively high mean Injury Severity Scores in both treatment groups. Additionally, an intra-articular fracture was present in 85% of knees that underwent MUA and 90% of knees that underwent open operative treatment, further contributing to loss of motion.

Manipulation under anesthesia has been a well-accepted treatment modality for knee stiffness following total knee arthroplasty with good to excellent results (1, 5, 14, 15). However, reports of its utility in improving knee range of motion secondary to a traumatic insult are limited. In the present series, knee range of motion demonstrated significant improvement immediately following MUA and at a mean follow-up of 2 years. The mean improvement in the arc of motion at follow-up of 54.4° compares favorably with other reports in the literature (5, 15, 16). Furthermore, knees that underwent MUA demonstrated significant gains in arc of motion compared to knees that underwent arthrolysis. Theoretically, MUA leads to the disruption of early, immature adhesive tissue. As such, the timing of manipulation following trauma or intra-articular surgery is crucial to the eventual outcome. However, controversy exists in the literature as to the ideal timing of MUA (5). Mariani et al. demonstrated that most adhesive tissue organizes during the first 6 months and thus manipulation under anesthesia is likely to be more effective earlier in the treatment course because of less mature scar tissue formation about the knee (17). In the present series, the average time from injury to treatment in the knees that underwent MUA was 2.6 months compared to 3.8 months in the knees that underwent arthrolysis. Although this finding was not statistically significant, it may help account for increased gains in motion in knees that underwent MUA.

Operative treatment of arthrofibrosis included arthroscopic or open arthrolysis of adhesions with three patients undergoing concomitant quadricepsplasty. This treatment modality allows for direct visualization of the scar tissue, affording the surgeon the ability to directly assess and debride the offending adhesive tissue as opposed to simply breaking it up. However, operative management yielded inferior results when compared to MUA at a mean follow-up of 2 years in the present series. Similar findings have been reported in patients who undergo arthrolysis for stiffness following knee arthroplasty (5, 18). It can be theorized that the additional burden of operative intervention to already highly traumatized tissues may produce a profound inflammatory response leading to upregulation of the cascade of events at the cellular level that led to the development of stiffness following the initial injury (17). The continued deposition of fibrous adhesive tissue has been shown to further restrict joint range of motion (11). This is reflected in the observation that patients who underwent MUA gained motion from immediately postintervention to follow-up, whereas patients who underwent arthrolysis lost motion gained at the time of the procedure. The ensuing postoperative pain and edema following operative management may further limit the aggressive postoperative rehabilitation needed to maintain the gains of motion obtained at the time of surgery. It can be further reasoned that this limitation of rehabilitation in conjunction with the time needed to allow for healing of the operative sites may contribute to inferior results following arthrolysis compared to MUA immediately postoperatively and at follow-up.

In the present series, the complication rate was significantly greater in knees that underwent arthrolysis when compared to knees that underwent MUA. The overall complication rate of 40% in knees that underwent arthrolysis is higher than that reported in the literature (5, 11, 18, 19). This may be a reflection of the high-energy penetrating injury mechanism in this patient cohort and the associated complexity of the soft tissue injury as well as the open nature of the procedure. As a result, three patients who underwent open operative management developed a deep infection with culture-positive *Acinetobacter baumannii*, a common pathogen uniquely prevalent in open wounds of war-wounded service members. They were managed with serial wound debridements and culture-directed antibiotic therapy. One patient sustained a supracondylar femur fracture following removal of a distal femoral plate 6 months postinjury. He was treated with revision fixation and achieved eventual union. Despite the increased complication rate, patients who developed a complication had similar arc of motion at final follow-up compared to those who did not develop a complication.

The overall complication rate following MUA in the present series of 12% is higher than the rate of 3% to 5% reported in the literature (14–16). Complications secondary to manipulation are often related to the force required to overcome intra-articular adhesions. As a result, three patients sustained iatrogenic rupture of the patellar ligament, and two patients had dehiscence of operative wounds. Although knees that underwent MUA had better arc of motion and a lower complication rate, the complications associated with these injuries, namely rupture of the extensor mechanism, were more severe and resulted in decrease arc of motion following repair.

The injuries presented in this series are complex and rarely seen in the civilian population. They are predominantly the result of high-energy blasts that exact an extensive toll on osseous structures and the surrounding soft tissues. However, our patients are young and highly motivated and are in excellent physical health with a high capacity for healing. In addition, wounded service members have unique access to physiotherapy resources and undergo aggressive postoperative rehabilitation to regain function and mobility. As a result, this represents a unique and distinct patient population and the findings of this study may not be applicable to all who develop arthrofibrosis following a traumatic insult. Furthermore, the data review was retrospective, which introduces inherent biases. However, to our knowledge, this sufficiently powered report with adequate 2-year follow-up represents the only study to date in the literature comparing treatment modalities for arthrofibrosis secondary to trauma.

In conclusion, both closed and open treatment options yielded significant gains in knee arc of motion immediately following intervention and at follow-up. However, knees that underwent closed manipulation under anesthesia demonstrated significant improvements in arc of motion at 2-year follow-up with a lower complication rate compared to similar knees that underwent arthrolysis. Although the potential complications are more severe and may lead to decrease motion following intervention, manipulation under anesthesia is generally a safe and effective treatment modality for patients with arthrofibrosis secondary to trauma.

References

1. Magit, D., Wolff, A., Sutton, K., et al. Arthrofibrosis of the knee. J. Am. Acad. Orthop. Surg. 15(11):682–694, 2007.
2. Kim, J., Nelson, C. L., Lotke, P. A. Stiffness after total knee arthroplasty. Prevalence of the complication and outcomes of revision. J. Bone Joint Surg. Am. 86(7):1479–1484, 2004.
3. Christensen, C. P., Crawford, J. J., Olin, M. D., et al. Revision of the stiff total knee arthroplasty. J. Arthroplasty 17(4):409–415, 2002.
4. Laubenthal, K. N., Smidt, G. L., Kettelkamp, D. B. A quantitative analysis of knee motion during activities of daily living. Phys. Ther. 52(1):34–43, 1972.
5. Fitzsimmons, S. E., Vazquez, E. A., Bronson, M. J. How to treat the stiff total knee arthroplasty?: a systematic review. Clin. Orthop. Relat. Res. 468(4):1096–1106, 2010.
6. Vander Have, K. L., Ganley, T. J., Kocher, M. S., et al. Arthrofibrosis after surgical fixation of tibial eminence fractures in children and adolescents. Am. J. Sports Med. 38(2):298–301, 2010.
7. Aglietti, P., Buzzi, R., De Felice, R., et al. Results of surgical treatment of arthrofibrosis after ACL reconstruction. Knee Surg. Sports Traumatol. Arthrosc. 3(2):83–88, 1995.
8. Smith, E. L., Banerjee, S. B., Bono, J. V. Supracondylar femur fracture after knee manipulation: a report of 3 cases. Orthopedics 32(1):18, 2009.
9. Daoud, H., O'Farrell, T., Cruess, R. L. Quadricepsplasty. The Judet technique and results of six cases. J. Bone Joint Surg. Br. 64(2):194–197, 1982.
10. Jackson, R. W. The role of arthroscopy in the management of the arthritic knee. Clin. Orthop. Relat. Res. 101:28–35, 1974.
11. Sprague, N. F., III, O'Connor, R. L., Fox, J. M. Arthroscopic treatment of postoperative knee fibroarthrosis. Clin. Orthop. Relat. Res. 166:165–172, 1982.
12. Wang, J. H., Zhao, J. Z., He, Y. H. A new treatment strategy for severe arthrofibrosis of the knee. Surgical technique. J. Bone Joint Surg. Am. 89(suppl. 2 pt.1):93–102, 2007.
13. Shelbourne, K. D., Patel, D. V., Martini, D. J. Classification and management of arthrofibrosis of the knee after anterior cruciate ligament reconstruction. Am. J. Sports Med. 24(6):857–862, 1996.
14. Papagelopoulos, P. J., Sim, F. H. Limited range of motion after total knee arthroplasty: etiology, treatment, and prognosis. Orthopedics 20(11):1061–1065; quiz 1066–1067, 1997.
15. Fox, J. L., Poss, R. The role of manipulation following total knee replacement. J. Bone Joint Surg. Am. 63(3):357–362, 1981.
16. Daluga, D., Lombardi, A. V., Jr., Mallory, T. H., et al. Knee manipulation following total knee arthroplasty. Analysis of prognostic variables. J. Arthroplasty 6(2):119–128, 1991.
17. Mariani, P. P., Santori, N., Rovere, P., et al. Histological and structural study of the adhesive tissue in knee fibroarthrosis: a clinical-pathological correlation. Arthroscopy 13(3):313–318, 1997.
18. Mont, M. A., Seyler, T. M., Marulanda, G. A., et al Surgical treatment and customized rehabilitation for stiff knee arthroplasties. Clin. Orthop. Relat. Res. 446:193–200, 2006.
19. Johnson, D. R., Friedman, R. J., McGinty, J. B., et al. The role of arthroscopy in the problem total knee replacement. Arthroscopy 6(1):30–32, 1990.