AAOS

AMERICAN ACADEMY OF ORTHOPAEDIC SURGEONS

Locking Plates for Extremity Fractures

A Technology Overview

Adopted by the American Academy of Orthopaedic Surgeons
Board of Directors
December 6, 2008

This *Technology Overview* was prepared by an AAOS physician task force using systematic review methodology, and summarizes the findings of studies published as of April 1, 2008 on locking plates for extremity fractures. As a summary, this document does not make recommendations for or against the use of locking plates for extremity fractures. It should not be construed as an official position of the American Academy of Orthopaedic Surgeons. Readers are encouraged to consider the information presented in this document and reach their own conclusions about locking plates for extremity fractures.

The American Academy of Orthopaedic Surgeons has developed and is providing this *Technology Overview* as an educational tool. Patient care and treatment should always be based on a clinician's independent medical judgment given the individual patient's clinical circumstances.

Evidence tables displaying the raw data and information extracted for this *Technology Overview* are available in a supplemental document available on the AAOS website www.aaos.org/technologyoverviews .

Introduction

Internal fixation plates function as splints for a fractured long bone, and can perform a variety of specific mechanical functions including compression, buttress, bridging, and neutralization (protection). Both locking and non-locking plates can be used to perform any of these functions. Non-locking plates stabilize bone fragments against deforming forces by the use of friction between the plate and bone, generated by screws which compress the two surfaces together. Locking plates stabilize bone fragments by virtue of the attachment of the screw to the plate in a rigid, fixed-angle coupling, usually accomplished with threads in the screw head, plate hole, or both. This locking of screw to plate makes the fixation construct more resistant to failure by sequential screw loosening and pull out. Since all the screws in a single bone fragment are locked to the plate at fixed angles, they must fail (pull out) as a unit rather than individually and sequentially.[10, 11] This feature may be of particular advantage in osteoporotic bone with thinner cortices, where non-locking screws cannot generate as much plate-to-bone compression, so the frictional forces resisting motion are less. In addition, the fixed angle nature of the plate and screw fixation resists cantilever bending stresses, and reduces the risk of angular deformity in metaphyseal fractures which are comminuted, missing bone, or otherwise mechanically unable to share load. It has been proposed that the reduced plate-to-bone compression afforded by locking plates serves to protect the viability of the bone by maintaining microvascular circulation within the cortex and its investing tissues.[28] The clinical importance of this theoretical advantage is unproven.

Both traditional (non-locking) and locking plates can be inserted through less invasive surgical techniques, also known as “percutaneous”, “submuscular”, or “minimal incision” plating. The introduction of locking plate technology has temporally coincided with the development of these less invasive surgical techniques, but it is important to keep the two concepts separate. Newer surgical techniques which involve smaller incisions, less soft tissue dissection, less periosteal stripping, and use of intra-operative imaging or navigation are believed by many to improve healing rates and reduce complications, but they are not dependent upon the use of locking plate implants. Similarly, the theoretical biomechanical advantages of locking plates (reduced screw pull-out in osteopenic bone, reduction of cantilever bending, and reduction of angular deformity in deficient metaphyseal bone) are not dependent upon minimally invasive surgical techniques. Locking plates can be put in through traditional exposures.

Findings of Published Studies

We used systematic processes to locate published studies relevant to this topic. These processes began with the framing of three Key Questions, which appear below. We next developed article inclusion criteria (Appendix I), and then conducted systematic literature searches (Appendix II). Articles were included only if they met our *a priori* criteria. A Level of Evidence was assigned to each article included in this *Overview*.

Included Articles

Our searches identified 452 citations. Of these, 33 met all inclusion criteria and were utilized to address the questions below. Four of the studies compared the outcomes of patients receiving locking plates and patients receiving non-locking plates. One additional study compared the outcomes of patients receiving locking plates and patients receiving intramedullary nailing (for the purposes of this *Overview*, only the outcomes of the locking plate patients in this study were considered). The remaining 28 studies were case series and only reported outcomes for patients receiving locking plates. The studies were divided into seven applications; distal radius, proximal humerus, distal femur, periprosthetic femur, tibial plateau (only AO/OTA type C), proximal tibia (AO/OTA type A or C), and distal tibia. There were no studies addressing the application of locking plates for extremity fractures in patients with osteoporosis that met all of the inclusion criteria. Several published studies discuss osteoporosis in their study populations. However, none of these studies adequately report quantitative data, for the outcomes of interest to this *Overview*, in patients with osteoporosis. Our inclusion criteria specified that surrogate outcome measures, such as fracture union, would only be included in this *Overview* in the absence of patient oriented outcome measures. All studies included in this *Overview* presented patient oriented outcome measures. Therefore, surrogate outcomes are not presented.

Levels of Evidence

For distal radius fractures, two Level II randomized controlled trials (RCT) were included.[19, 25] An additional Level II comparative study,[33] which did not compare outcomes between patients receiving locking plates and patients receiving non-locking plates, was excluded along with three Level III comparative studies [24, 39, 48] and seven Level IV case series studies.[1, 2, 6, 7, 22, 32, 38]

Proximal humerus fractures were addressed with a single Level III comparative study [20] and nine Level IV case series studies.[12, 14, 17, 21, 26, 29, 31, 34, 43]

For distal femur fractures, one Level II study comparing the outcomes of patients receiving locking plates and patients receiving intramedullary nailing was included.[30] For the purposes of this *Overview*, only the outcomes of the patients receiving locking plates were considered from this study (as Level IV data). An additional seven Level IV case series studies were included.[15, 27, 35, 41, 42, 46, 47] One Level IV case series study [42] reports outcomes for a subgroup of patients from a previously published study [41] that is included in this *Overview*. For the more recent publication, only the unique, relevant outcomes are reported in this *Overview*. All relevant outcomes are reported for the previous, original study.

Periprosthetic femur fractures are addressed by four Level IV case series studies.[5, 13, 16, 36]

Fractures of the tibial plateau (only AO/OTA type C) are addressed by a single Level II RCT [23] comparing the outcomes of patients receiving locking plates with a single incision and patients receiving non-locking plates with a double incision. Two additional Level IV case series studies were included as well.[18, 45]

Proximal tibia fractures (AO/OTA type A or C) are addressed by five Level IV case series studies.[4, 9, 37, 40, 44] A single Level IV case series study [8] was excluded because it was updated by a more recent article [9] that is included in this *Overview*.

Distal tibia fractures are addressed by a single Level IV case series study.[3]

Question #1: What are the indications for locking plates?

To address this question we recorded the patient enrollment criteria of the included studies. The published studies do not consistently report the same enrollment criteria. In general, published studies enrolled patients suffering acute, traumatic fractures of varying degrees or severity and typically did not enroll patients with fractures that were not amenable to adequate reduction and/or fixation. In studies with age criteria, no studies enrolled patients under the age of 18 or not of skeletal maturity. In addition, studies enrolled patients with minimal co-morbidities in their medical histories.

Question #2: Are locking plates more effective than traditional plates?

To address this question we recorded the outcomes of studies that compared locking plates to non-locking plates. Four studies investigated the differences between patients receiving locking plates and patients receiving non-locking plates. These four studies addressed the application of locking plates in distal radius,[19, 25] proximal humerus,[20] or tibial plateau fractures (only AO/OTA type C).[23] There were no statistically significant differences between locking plates and non-locking plates for patient oriented outcomes (Figure 1), adverse events, or complications.

We recorded patient oriented outcomes, adverse events, and complications from case series studies that met our inclusion criteria. Conclusions from case series studies are difficult to interpret because they lack the context that a control group provides. Further, it is difficult to use normative values to interpret the results of such studies because case series often enroll highly selected patients to whom such values may not apply. The wide variety of patient oriented outcome measures and duration to follow-up used to evaluate patients receiving locking plates in extremity fractures makes comparisons between studies difficult (Table 1).

Patient oriented outcome measures from case series studies using locking plates for proximal humerus fractures are reported in the included studies. In summary, five studies report Constant-Murley scores at various durations to follow-up (1.5 to 12 months).[14, 21, 26, 29, 31] In three studies reporting the mean Constant-Murley Score at 12 months, the scores range from 74.6 to 79.[14, 21, 29] Two studies reporting mean DASH or Quick DASH scores indicate low levels of disability 12 months post-operatively.[29, 34] Two studies reported mean operative times of 53 and 75 minutes.[26, 29]

Adverse events and complications in patients receiving locking plates for proximal humerus fractures are reported in the included studies as well. In summary, eight studies reported failure of hardware in 0% to 4% of patients,[12, 14, 20, 21, 29, 31, 34, 43] eight studies reported avascular necrosis in 0% to 7% of patients,[12, 14, 20, 21, 26, 29, 31, 34], four studies reported nerve palsy or parasthesia in 0% to 7% of patients,[14, 21, 29, 31] and six studies reported subacromial impingement in 0% to 14% of patients,[14, 20, 21, 26, 31, 34] Six studies reported implant removal in 1% to 8% of patients [14, 20, 21, 26, 29, 34] and four studies reported infections in 2% to 5% of patients.[12, 14, 26, 31] Eight studies reported reoperation rates of 6% to 16%.[12, 14, 17, 20, 21, 29, 31, 34]

Patient oriented outcome measures from case series studies using locking plates for distal femur fractures are reported in the included studies. Two studies reported mean Lysholm Scores. The first study reported a mean score of 48 at 3 months and 81 at 12 months.[30] The second study reported a mean score of 71 at 20 months.[15] The mean operative time ranged from 96 to 183 minutes in three studies.[27, 30, 41]

Adverse events and complications in patients receiving locking plates for fractures of the distal femur are reported in the included studies as well. In summary, three studies reported failure of hardware in 0% to 2% of patients [27, 30, 41] and two studies reported deep infections in 0% and 2% of patients.[30, 46] Two studies reported pulmonary embolism in 1% and 8% of patients [41, 46] and three studies reported implant removal in 3% to 26% of patients.[15, 27, 46] Four studies reported reoperation rates of 11% to 22%.[15, 41, 46, 47]

Patient oriented outcome measures from case series studies using locking plates for periprosthetic femur fractures are reported in the included studies. Two studies reported that 91% and 55% of patients returned to their previous level of activity.[13, 36] The mean operative time ranged from 90 to 104.5 minutes in three studies.[5, 13, 16]

Adverse events and complications in patients receiving locking plates for periprosthetic femur fractures are reported in the included studies as well. In summary, three studies reported failure of hardware in 0% to 21% of patients [5, 13, 36] and three studies reported reoperation rates of 14% to 29%.[5, 13, 16]

Patient oriented outcome measures from case series studies using locking plates for tibial plateau fractures (only AO/OTA type C) are reported in the included studies. One study reported a mean SF-36 physical subscale score of 29 at 6 months and 40 at 12 months.[45]

Adverse events and complications in patients receiving locking plates for tibial plateau fractures (only AO/OTA type C) are reported in the included studies as well. In summary, two studies reported failure of hardware in 0% and 18% of patients,[23, 45] three studies reported implant removal in 2% to 30% of patients,[18, 23, 45] and two studies reported irritation from hardware in 6% and 12% of patients.[23, 45] Two studies reported deep infections in 2% and 7% of patients [18, 23] and three studies reported superficial infections in 6% to 10% of patients.[18, 23, 45]

Patient oriented outcome measures from case series studies using locking plates for proximal tibia fractures (AO/OTA type A or C) are reported in the included studies. No studies used the same patient oriented outcome measure at similar durations to follow-up.

Adverse events and complications in patients receiving locking plates for proximal tibia fractures (AO/OTA type A or C) are reported in the included studies as well. In summary, five studies reported infections in 0% to 6% of patients.[4, 9, 37, 40, 44] Two studies reported revision to total knee arthroplasty in 3% and 4% of patients,[4, 37] two studies reported irritation from hardware in 5% and 8% of patients,[4, 9] and three studies reported implant removal in 5% to 13% of patients.[4, 9, 37] Two studies reported reoperation rates in 13% and 15% of patients.[9, 40]

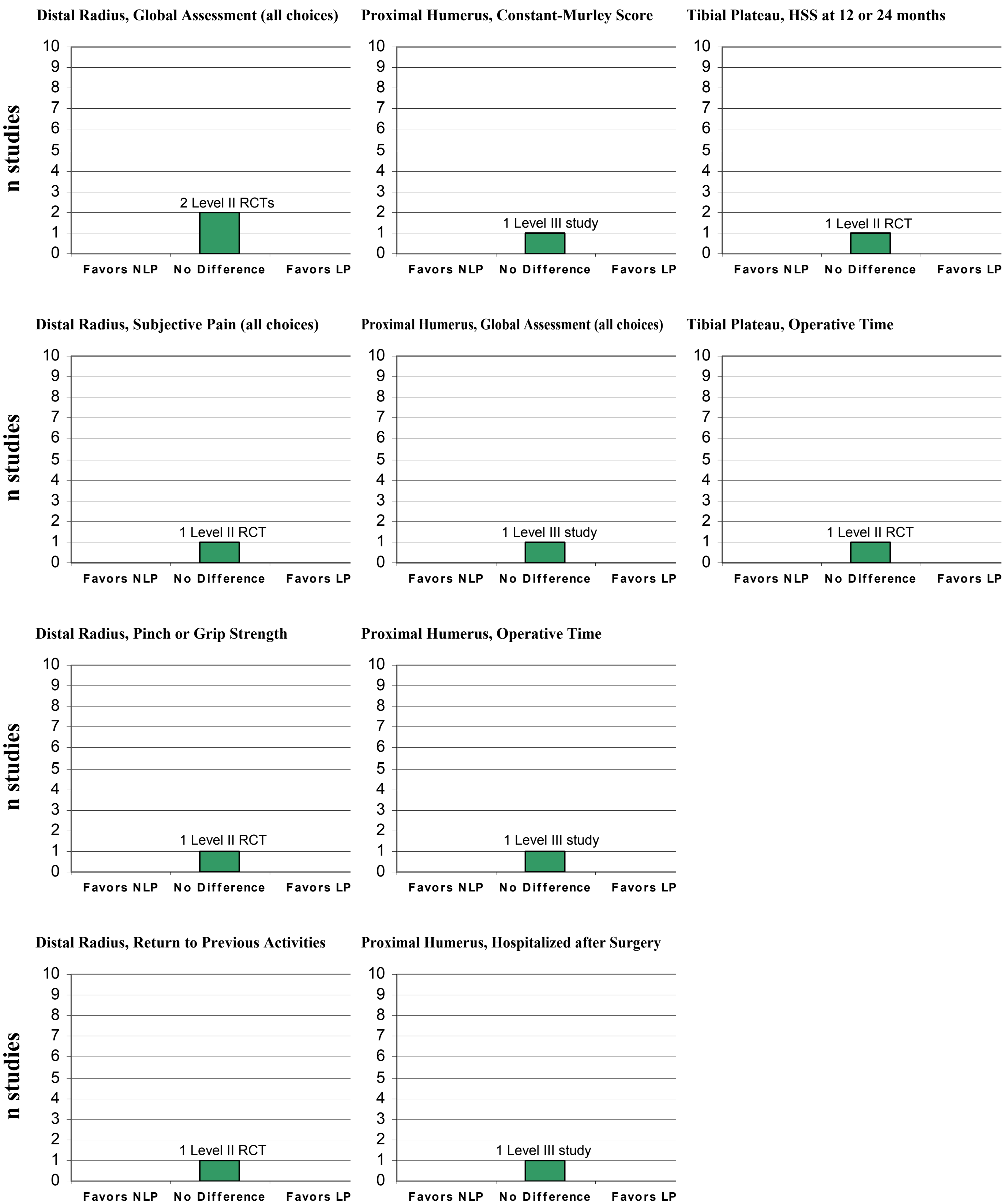
Question #3: Are locking plates cost-effective?

Our literature searches did not identify any peer reviewed cost effectiveness or cost utility studies that directly addressed this question.

As noted above, this document is not intended to convey any official AAOS position on locking plates for extremity fractures. We provide this *Technology Overview* as a service to our members in an effort to help them identify and evaluate the available published literature on this topic. We hope that our summary will assist physicians in providing the best possible care to their patients.

AAOS would like to have feedback from its members on this *Technology Overview*. To provide your feedback, please visit http://research.aaos.org/surveys/Tech-Feedback.htm.

Figure 1. Patient Oriented Outcomes from Included Controlled Trials



LP = Locking Plates; NLP = Non Locking Plates

Table 1. Patient Oriented Outcome Measures from Case Series Studies
(continued on next page)

Outcome Measure	Application	Duration of Follow-up	Author
American Orthopaedic Foot and Ankle Society (AOFAS) Score	Distal Tibia	19 months	Bahari et al [3] 2007
Blood Loss	Proximal Humerus	n/a	Laflamme et al [19] 2008
			Koukakis et al [17] 2006
	Distal Femur	n/a	Kregor et al [27] 2004
	Periprosthetic Femur	n/a	Fulkerson et al [16] 2007
Constant-Murley Score	Proximal Humerus	1.5 months	Fankhauser et al [7] 2005
		3 months	Fankhauser et al [7] 2005
			Hepp et al [14] 2008
		3-6 months	Koukakis et al [17] 2006
		6 months	Fankhauser et al [7] 2005
			Hepp et al [14] 2008
		11 months	Moonot et al [21] 2007
		12 months	Fankhauser et al [7] 2005
			Hepp et al [14] 2008
			Laflamme et al [19] 2008
		Final Follow-up	Laflamme et al [19] 2008
		nr	Sharafeldin et al [29] 2008
Disabilities of the Arm, Shoulder, and Hand (DASH) Score	Proximal Humerus	12 months	Laflamme et al [19] 2008
		Final Follow-up	Laflamme et al [19] 2008
		nr	Sharafeldin et al [29] 2008
Quick DASH Score	Proximal Humerus	12 months	Owsley et al [22] 2008
d'Aubigne and Postel Score	Periprosthetic Femur	nr	Buttaro et al [5] 2007
Functional Score	Proximal Tibia	3 years	Boldin et al [4] 2006
Hospitalized (days)	Proximal Humerus	n/a	Sharafeldin et al [29] 2008
	Distal Femur	n/a	Fankhauser et al [15] 2004
	Periprosthetic Femur	n/a	Erhardt et al [13] 2008
Hospital for Special Surgery (HSS) Score	Proximal Tibia	3 years	Boldin et al [4] 2006
	Distal Femur	Final Follow-up	Syed et al [46] 2004
Knee Society Score	Distal Femur	20 months	Fankhauser et al [15] 2004
	Proximal Tibia	3 years	Boldin et al [4] 2006

nr = not reported; n/a = not applicable

This table demonstrates the wide variety of patient oriented outcome measures which have been used in case series studies of patients receiving locking plates for extremity fractures. Few studies used the same outcome measure at similar duration of follow-up. No statistical hypothesis testing was performed by the study authors to assess the effectiveness of locking plates for any outcome of interest to this *Overview*.

Table 1. Patient Oriented Outcome Measures from Case Series Studies (continued from previous page)

Outcome Measure	Application	Duration of Follow-up	Author
Lysholm Score	Distal Femur	3 months	Markmiller et al [30] 2004
		12 months	Markmiller et al [30] 2004
		20 months	Fankhauser et al [15] 2004
Operative Time (minutes)	Proximal Humerus	n/a	Koukakis et al [17] 2006
			Laflamme et al [19] 2008
	Distal Femur	n/a	Kregor et al [27] 2004
			Markmiller et al [30] 2004
			Schutz et al [41] 2001
	Periprosthetic Femur	n/a	Buttaro et al [5] 2007
			Erhardt et al [13] 2008
			Fulkerson et al [16] 2007
	Proximal Tibia	n/a	Schutz et al [40] 2003
	Tibial Plateau	n/a	Gosling et al [18] 2005
Oxford Knee Score	Distal Femur	23 months	Wong et al [47] 2005
Pain	Distal Femur	10 weeks	Ricci et al [23] 2004
		12 months	Markmiller et al [20] 2004
		20 months	Fankhauser et al [8] 2004
		23 months	Wong et al [33] 2005
Return to Previous Activity Level	Periprosthetic Femur	Final Follow-up	Erhardt et al [13] 2008
		Final Follow-up	Ricci et al [36] 2006
SF-36 Score	Proximal Humerus	nr	Sharafeldin et al [29] 2008
	Tibial Plateau	6 months	Stannard et al [45] 2004
		12 months	Stannard et al [45] 2004
	Distal Tibia	19 months	Bahari et al [3] 2007
	Distal Femur	30 months	Ricci et al [35] 2004
Short Musculoskeletal Function Assessment (SMFA)	Proximal Humerus	12 months	Owsley et al [22] 2008
Subjective Contentment	Periprosthetic Femur	Final Follow-up	Erhardt et al [13] 2008
Weight Bearing - Full (weeks)	Distal Femur	n/a	Fankhauser et al [15] 2004
			Kregor et al [27] 2004
	Periprosthetic Femur	n/a	Ricci et al [36] 2006

nr = not reported; n/a = not applicable

This table demonstrates the wide variety of patient oriented outcome measures which have been used in case series studies of patients receiving locking plates for extremity fractures. Few studies used the same outcome measure at similar duration of follow-up. No statistical hypothesis testing was performed by the study authors to assess the effectiveness of locking plates for any outcome of interest to this *Overview*.

Appendix I: Inclusion Criteria

We used the following criteria to determine whether studies should be included in this systematic review:

1. Study must be of humans.
2. Study must have enrolled 10 or more patients in each of its groups.
3. Study must have been published in 1985 or later.
4. Study must be published in English.
5. Study must be a full report, published in a peer-reviewed journal. Meeting abstracts, traditional reviews, and text chapters were not included. Manufacturer marketing information was also excluded.
6. Study must quantitatively express its results.
7. Study must enroll patients prospectively or consecutively
8. Study must be of fractures of an extremity and investigate the use of a locking plate for one the following applications:
    - distal radius
    - proximal humerus
    - proximal and distal femur
    - proximal and distal tibia
    - osteoporotic bone
    - periprosthetic fracture
    - metaphyseal fracture with comminution or bone loss (i.e. tibial plateau)
9. If there are duplicate publications of the same study, the most recent publication will be included unless the earlier publication contains information not in the later one. In this latter case, both publications will be included.
10. Only studies of the highest level of available evidence will be included, assuming that there are two or more studies of that higher level. For example, if there are two Level II studies that address the question/application, Level III and IV studies will not be included. If there is only one Level II study, Level III studies will be included.
11. Comparative studies must investigate the differences between locking plates and non-locking plates. For other comparisons (i.e. severity of fracture, operative technique) the locking plates group will be treated as case series data (Level IV).
12. Studies with quantitative data for patient-oriented outcomes will take precedence over studies with quantitative data on surrogate outcomes. However, if no patient-oriented outcomes are available that address the question/application, we will include data on surrogate outcomes. The surrogate outcomes we will examine are:
    - union
    - fixation failure
    - alignment

Appendix II: Databases Searched and Search Strategies

To identify studies for this *Overview* we searched PubMed, EMBASE, CINAHL, and the Cochrane Central Register of Controlled Trials through April 1, 2008.

Our PubMed search strategy was:

locking compression plate* OR ((locked OR locking) AND (plating OR plate OR plates)) OR peri-loc OR less invasive stabilizing system NOT "comment"[Publication Type] NOT "editorial"[Publication Type] AND (("1"[EDat]:"2008/04/01"[EDat]) AND (English[lang])) AND (("2000/1/1"[PDat]:"3000"[PDat]) AND (Humans[Mesh]) AND (English[lang]))

This search identified 328 citations.

Our EMBASE search strategy was:

locking compression plate* OR ((locked OR locking) AND (plating OR plate OR plates)) OR peri-loc OR less invasive stabilizing system

limited to English, human, and 2000-2008

This search identified 102 additional citations.

Our CINAHL search strategy was:

locking compression plate* OR ((locked OR locking) AND (plating OR plate OR plates)) OR peri-loc OR less invasive stabilizing system

limited to 2000-2008
This search identified 18 additional citations.

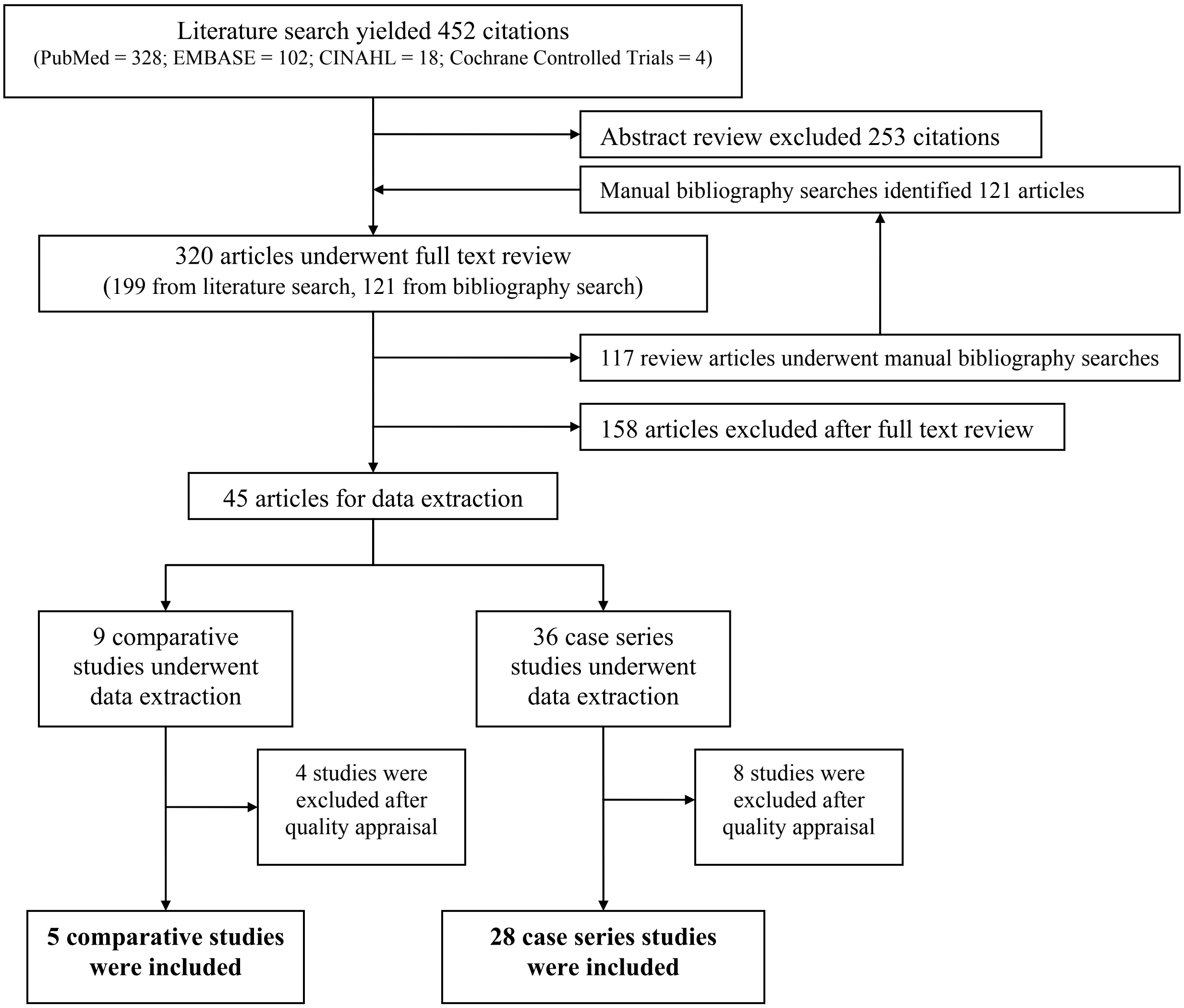
Our Cochrane Central Register of Controlled Trials search strategy was:

Locking plate OR locked plating OR peri-loc OR locking compression plate OR less invasive stabilizing system.

This search identified 4 additional citations.

A total of 452 citations were identified by our literature search. The bibliographies of review articles identified by the literature search were manually searched for potentially relevant citations.

Appendix III: Study Attrition



Appendix IV: Documentation of Approval

AAOS Task Force Draft Completed	July 2008
Manufacturer Review Completed	August 20, 2008
AAOS Guidelines and Technology Oversight Committee	August 23, 2008
AAOS Evidence Based Practice Committee	August 23, 2008
AAOS Council on Research Quality Assessment and Technology	October 20, 2008
AAOS Board of Directors	December 6, 2008

AAOS Bodies that Approved this Technology Overview

Guidelines and Technology Oversight Committee
The AAOS Guidelines and Technology Oversight Committee (GTOC) consists of sixteen AAOS members. The overall purpose of this Committee is to oversee the development of the clinical practice guidelines, performance measures, health technology assessments, and utilization guidelines.

Evidence Based Practice Committee
The AAOS Evidence Based Practice Committee (EBPC) consists of ten AAOS members. This Committee provides review, planning, and oversight for all activities related to quality improvement in orthopaedic practice, including, but not limited to evidence-based guidelines, performance measures, and outcomes.

Council on Research, Quality Assessment, and Technology
To enhance the mission of the AAOS, the Council on Research, Quality Assessment, and Technology promotes the most ethically and scientifically sound basic, clinical, and translational research possible to ensure the future care for patients with musculoskeletal disorders. The Council also serves as the primary resource to educate its members, the public, and public policy makers regarding evidenced-based medical practice, orthopaedic devices and biologics regulatory pathways and standards development, patient safety, occupational health, technology assessment, and other related areas of importance.

The Council is comprised of the chairs of the AAOS Biological Implants, Biomedical Engineering, Evidence Based Practice, Guidelines and Technology Oversight, Occupational Health and Workers' Compensation, Patient Safety, Research Development, and US Bone and Joint Decade committees. Also on the Council are the AAOS second vice-president, representatives of the Diversity Advisory Board, the Women's Health Issues Advisory Board, the Board of Specialty Societies (BOS), the Board of Councilors (BOC), the Communications Cabinet, the Orthopaedic Research Society (ORS), the Orthopedic Research and Education Foundation (OREF), and three members at large.

Board of Directors
The 17 member AAOS Board of Directors manages the affairs of the AAOS, sets policy, and determines and continually reassesses the Strategic Plan.

Task Force

Jeffrey Anglen, MD, Chair
Indiana University Medical Center
Department of Orthopaedic Surgery, Suite 600
541 Clinical Drive
Indianapolis, IN 46202

Richard F. Kyle, MD
Hennepin County Medical Center
Ortho Dept.
701 Park Avenue South, G2
Minneapolis, MN 55415-1829

John Lawrence Marsh, MD
University of Iowa Hospital
Dept. of Orthopaedics
Iowa City, IA 52242

Walter W. Virkus, MD
Rush University Medical Center
1725 W. Harrison, Ste. 440
Chicago, IL 60612

Guidelines and Technology Oversight Chair
William C. Watters III, MD
6624 Fannin #2600
Houston, TX 77030

Evidence Based Practice Committee Chair
Michael Warren Keith, MD
2500 Metro Health Drive
Cleveland, OH 44109-1900

AAOS Staff
Charles M. Turkelson, PhD
Director of Research and Scientific Affairs
6300 N. River Road
Rosemont, IL 60018

Janet L. Wies, MPH
Manager,Clinical Practice Guidelines
6300 N. River Road
Rosemont, IL 60018

Kevin M. Boyer
Research Analyst, Clinical Practice Guidelines
6300 N. River Road
Rosemont, IL 60018

AAOS Medical Librarian
Richard McGowan, MLS

AAOS Graduate Interns (Summer 2008)
Laura Raymond
Laura Braeunig, MA

Reference List

(1) Arora R, Lutz M, Fritz D, Zimmermann R, Oberladstatter J, Gabl M. Palmar locking plate for treatment of unstable dorsal dislocated distal radius fractures. *Arch Orthop Trauma Surg* 2005 July;125(6):399-404.

(2) Arora R, Lutz M, Hennerbichler A, Krappinger D, Espen D, Gabl M. Complications following internal fixation of unstable distal radius fracture with a palmar locking-plate. *J Orthop Trauma* 2007 May;21(5):316-22.

(3) Bahari S, Lenehan B, Khan H, McElwain JP. Minimally invasive percutaneous plate fixation of distal tibia fractures. *Acta Orthop Belg* 2007 October;73(5):635-40.

(4) Boldin C, Fankhauser F, Hofer HP, Szyszkowitz R. Three-year results of proximal tibia fractures treated with the LISS. *Clin Orthop Relat Res* 2006 April;445:222-9.

(5) Buttaro MA, Farfalli G, Paredes NM, Comba F, Piccaluga F. Locking compression plate fixation of Vancouver type-B1 periprosthetic femoral fractures. *J Bone Joint Surg Am* 2007 September;89(9):1964-9.

(6) Chiang PP, Roach S, Baratz ME. Failure of a retinacular flap to prevent dorsal wrist pain after titanium Pi plate fixation of distal radius fractures. *J Hand Surg [Am]* 2002 July;27(4):724-8.

(7) Chung KC, Watt AJ, Kotsis SV, Margaliot Z, Haase SC, Kim HM. Treatment of unstable distal radial fractures with the volar locking plating system. *J Bone Joint Surg Am* 2006 December;88(12):2687-94.

(8) Cole PA, Zlowodzki M, Kregor PJ. Less Invasive Stabilization System (LISS) for fractures of the proximal tibia: indications, surgical technique and preliminary results of the UMC Clinical Trial. *Injury* 2003 August;34 Suppl 1:A16-A29.

(9) Cole PA, Zlowodzki M, Kregor PJ. Treatment of proximal tibia fractures using the less invasive stabilization system: surgical experience and early clinical results in 77 fractures. *J Orthop Trauma* 2004 September;18(8):528-35.

(10) Dickson KF, Munz JW. Locked plating: Biomechanics and biology. *Techniques in Orthopaedics 22(4)()(pp E1-E6), 2007 Date of Publication: Dec 2007* 2007;(4):E1-E6.

(11) Egol KA, Kubiak EN, Fulkerson E, Kummer FJ, Koval KJ. Biomechanics of locked plates and screws. *J Orthop Trauma* 2004 September;18(8):488-93.

(12) Egol KA, Ong CC, Walsh M, Jazrawi LM, Tejwani NC, Zuckerman JD. Early Complications in Proximal Humerus Fractures (OTA Types 11) Treated With Locked Plates. *J Orthop Trauma* 2008 March;22(3):159-64.

(13) Erhardt JB, Grob K, Roderer G, Hoffmann A, Forster TN, Kuster MS. Treatment of periprosthetic femur fractures with the non-contact bridging plate: a new angular stable implant. *Arch Orthop Trauma Surg* 2008 April;128(4):409-16.

(14) Fankhauser F, Boldin C, Schippinger G, Haunschmid C, Szyszkowitz R. A new locking plate for unstable fractures of the proximal humerus. *Clin Orthop Relat Res* 2005 January;(430):176-81.

(15) Fankhauser F, Gruber G, Schippinger G et al. Minimal-invasive treatment of distal femoral fractures with the LISS (Less Invasive Stabilization System): a prospective study of 30 fractures with a follow up of 20 months. *Acta Orthop Scand* 2004 February;75(1):56-60.

(16) Fulkerson E, Tejwani N, Stuchin S, Egol K. Management of periprosthetic femur fractures with a first generation locking plate. *Injury* 2007 August;38(8):965-72.

(17) Gardner MJ, Weil Y, Barker JU, Kelly BT, Helfet DL, Lorich DG. The importance of medial support in locked plating of proximal humerus fractures. *J Orthop Trauma* 2007 March;21(3):185-91.

(18) Gosling T, Schandelmaier P, Muller M, Hankemeier S, Wagner M, Krettek C. Single lateral locked screw plating of bicondylar tibial plateau fractures. *Clin Orthop Relat Res* 2005 October;439:207-14.

(19) Hahnloser D, Platz A, Amgwerd M, Trentz O. Internal fixation of distal radius fractures with dorsal dislocation: pi-plate or two 1/4 tube plates? A prospective randomized study. *J Trauma* 1999 October;47(4):760-5.

(20) Handschin AE, Cardell M, Contaldo C, Trentz O, Wanner GA. Functional results of angular-stable plate fixation in displaced proximal humeral fractures. *Injury* 2008 March;39(3):306-13.

(21) Hepp P, Theopold J, Voigt C, Engel T, Josten C, Lill H. The surgical approach for locking plate osteosynthesis of displaced proximal humeral fractures influences the functional outcome. *J Shoulder Elbow Surg* 2008 January;17(1):21-8.

(22) Infanger M, Baum E, Grimm D, Ertel W. Palmar Reduction And Internal Fixation For Displaced Intraarticular Fractures Of The Radius With Locking Compression Plate: Operative Strategy Lead To Functional Treatment. *J Orthopaedics* 2006;3(3).

(23) Jiang R, Luo CF, Wang MC, Yang TY, Zeng BF. A comparative study of Less Invasive Stabilization System (LISS) fixation and two-incision double plating for the treatment of bicondylar tibial plateau fractures. *Knee* 2008 March;15(2):139-43.

(24) Jubel A, Prokop A, Andermahr J, Orth B, Rehm KE. Functional outcome following fixed-angle volar plating or intrafocal K-wire fixation for extraarticular fractures of the distal part of the radius: A retrospective analysis of treatment outcomes. *Eur J Trauma* 2005;31(1):44-50.

(25) Koshimune M, Kamano M, Takamatsu K, Ohashi H. A randomized comparison of locking and non-locking palmar plating for unstable Colles' fractures in the elderly. *J Hand Surg [Br]* 2005 October;30(5):499-503.

(26) Koukakis A, Apostolou CD, Taneja T, Korres DS, Amini A. Fixation of proximal humerus fractures using the PHILOS plate: early experience. *Clin Orthop Relat Res* 2006 January;442:115-20.

(27) Kregor PJ, Stannard JA, Zlowodzki M, Cole PA. Treatment of distal femur fractures using the less invasive stabilization system: surgical experience and early clinical results in 103 fractures. *J Orthop Trauma* 2004 September;18(8):509-20.

(28) Kubiak EN, Fulkerson E, Strauss E, Egol KA. The evolution of locked plates. *J Bone Joint Surg Am* 2006 December;88 Suppl 4:189-200.

(29) Laflamme GY, Rouleau DM, Berry GK, Beaumont PH, Reindl R, Harvey EJ. Percutaneous Humeral Plating of Fractures of the Proximal Humerus: Results of a Prospective Multicenter Clinical Trial. *J Orthop Trauma* 2008 March;22(3):153-8.

(30) Markmiller M, Konrad G, Sudkamp N. Femur-LISS and distal femoral nail for fixation of distal femoral fractures: are there differences in outcome and complications? *Clin Orthop Relat Res* 2004 September;(426):252-7.

(31) Moonot P, Ashwood N, Hamlet M. Early results for treatment of three- and four-part fractures of the proximal humerus using the PHILOS plate system. *J Bone Joint Surg Br* 2007 September;89(9):1206-9.

(32) Orbay JL, Fernandez DL. Volar fixation for dorsally displaced fractures of the distal radius: a preliminary report. *J Hand Surg [Am]* 2002 March;27(2):205-15.

(33) Oshige T, Sakai A, Zenke Y, Moritani S, Nakamura T. A comparative study of clinical and radiological outcomes of dorsally angulated, unstable distal radius fractures in elderly patients: intrafocal pinning versus volar locking plating. *J Hand Surg [Am]* 2007 November;32(9):1385-92.

(34) Owsley KC, Gorczyca JT. Displacement/screw cutout after open reduction and locked plate fixation of humeral fractures. *J Bone Joint Surg Am* 2008 February;90(2):233-40.

(35) Ricci AR, Yue JJ, Taffet R, Catalano JB, DeFalco RA, Wilkens KJ. Less Invasive Stabilization System for treatment of distal femur fractures. *Am J Orthop* 2004 May;33(5):250-5.

(36) Ricci WM, Loftus T, Cox C, Borrelli J. Locked plates combined with minimally invasive insertion technique for the treatment of periprosthetic supracondylar femur fractures above a total knee arthroplasty. *J Orthop Trauma* 2006 March;20(3):190-6.

(37) Ricci WM, Rudzki JR, Borrelli J, Jr. Treatment of complex proximal tibia fractures with the less invasive skeletal stabilization system. *J Orthop Trauma* 2004 September;18(8):521-7.

(38) Ring D, Jupiter JB, Brennwald J, Buchler U, Hastings H. Prospective multicenter trial of a plate for dorsal fixation of distal radius fractures. *J Hand Surg [Am]* 1997 September;22(5):777-84.

(39) Schmelzer-Schmied N, Wieloch P, Martini AK, Daecke W. Comparison of external fixation, locking and non-locking palmar plating for unstable distal radius fractures in the elderly. *Int Orthop* 2008 January 12.

(40) Schutz M, Kaab MJ, Haas N. Stabilization of proximal tibial fractures with the LIS-System: early clinical experience in Berlin. *Injury* 2003 August;34 Suppl 1:A30-A35.

(41) Schutz M, Muller M, Krettek C et al. Minimally invasive fracture stabilization of distal femoral fractures with the LISS: a prospective multicenter study. Results of a clinical study with special emphasis on difficult cases. *Injury* 2001 December;32 Suppl 3:SC48-SC54.

(42) Schutz M, Muller M, Regazzoni P et al. Use of the less invasive stabilization system (LISS) in patients with distal femoral (AO33) fractures: a prospective multicenter study. *Arch Orthop Trauma Surg* 2005 March;125(2):102-8.

(43) Sharafeldin KN, Quinlan JF, Corrigan J, Kelly IP. Functional follow-up of locking plate fixation of fractures of the proximal humerus. *European Journal of Orthopaedic Surgery and Traumatology 18(2)()(pp 87-92), 2008 Date of Publication: Feb 2008* 2008;(2):87-92.

(44) Stannard JP, Wilson TC, Volgas DA, Alonso JE. Fracture stabilization of proximal tibial fractures with the proximal tibial LISS: early experience in Birmingham, Alabama (USA). *Injury* 2003 August;34 Suppl 1:A36-A42.

(45) Stannard JP, Wilson TC, Volgas DA, Alonso JE. The less invasive stabilization system in the treatment of complex fractures of the tibial plateau: short-term results. *J Orthop Trauma* 2004 September;18(8):552-8.

(46) Syed AA, Agarwal M, Giannoudis PV, Matthews SJ, Smith RM. Distal femoral fractures: long-term outcome following stabilisation with the LISS. *Injury* 2004 June;35(6):599-607.

(47) Wong MK, Leung F, Chow SP. Treatment of distal femoral fractures in the elderly using a less-invasive plating technique. *Int Orthop* 2005 April;29(2):117-20.

(48) Wright TW, Horodyski M, Smith DW. Functional outcome of unstable distal radius fractures: ORIF with a volar fixed-angle tine plate versus external fixation. *J Hand Surg [Am]* 2005 March;30(2):289-99.