J Orthop Sci (2013) 18:426–436
DOI 10.1007/s00776-013-0359-4

ORIGINAL ARTICLE

Locking plate fixation for Vancouver B1 periprosthetic femoral fractures: a critical analysis of 135 cases

Simon M. Graham · Mehran Moazen · Andreas Leonidou · Eleftherios Tsiridis

Received: 27 September 2012 / Accepted: 17 January 2013 / Published online: 19 February 2013

Abstract
Purpose The overall incidence of periprosthetic femoral fractures (PPF) is between 0.1 and 6 % of all total hip arthroplasties. Locking compression plates (LCP) have been used for the treatment of Vancouver B1 PPFs with variable results. The aim of this study is to examine the literature on locking plate failure rates, mode and reasons for failure.
Methodology A literature search was conducted for studies reporting the management of PPF of the femur with LCP fixation. The primary medical search engines used for the study were Ovid MEDLINE and EMBASE databases up to August 2012.
Results Twelve studies were identified, reporting overall union rates of 91 % in 135 fractures. Only 7 (5 %) fractures required revision surgery due to plate fracture (5) or pull out (2). Important trends in plate complications included: stress riser at the end of the plate, stress concentration in the fracture area due to rigid fixation, early loading and absence of cortical strut grafting for biological support when needed.
Conclusion LCP has been used successfully in the management of Vancouver B1 PPF. However, potential areas of improvement include, leaving the fracture site free of locking screws, therefore, not disturbing the soft tissue envelope around the fracture and also reducing plate stiffness. Adding cortical strut allografts to improve stability and bone quality, if needed, may also improve outcome. Limitations in the use of strut grafts or transverse fractures below the tip of the stem that cannot be controlled with single or double plating may require long stem revision to achieve axial stability.

S. M. Graham (✉)
Royal Liverpool and Broadgreen University Hospital, Orthopaedics, Liverpool, UK
e-mail: simonmatthewgraham@doctors.org.uk

M. Moazen · E. Tsiridis
Institute of Medical and Biological Engineering, School of Mechanical Engineering, University of Leeds, Woodhouse Lane, Leeds LS2 9JT, UK
e-mail: etsiridis@doctors.org.uk

A. Leonidou · E. Tsiridis
Department Orthopaedics and Trauma, "KAT" General Hospital, 145-61 Kifisia, Greece

E. Tsiridis
Academic Orthopaedic and Trauma Unit, Aristotle University Medical School, University Campus, 54 124 Thessaloniki, Greece

E. Tsiridis
Division of Surgery, Department of Surgery and Cancer, Imperial College London, B-block Hammersmith Hospital, Du-Cane Road, London W12 0HS, UK

Introduction

It is estimated that more than 800,000 total hip arthroplasties (THAs) are carried out every year worldwide [1], and in 2009/2010 75,465 total hip replacements were performed in England and Ireland [2]. This has resulted in an increase in the prevalence of intra- and post-operative periprosthetic fractures (PPFs) around hip prostheses, with the overall incidence between 0.1 and 6 % of all THAs [3].

Vancouver is the most commonly used classification in orthopaedic practice [4]. Type A fractures involve the trochanteric region and are subclassified into AG and AL for the greater and lesser trochanter. Type B fractures are those around the stem or slightly distal to it. Type C fractures are the distal to the stem. Type B fractures are subclassified into B1 when the implant is stable, B2 when the implant is unstable and B3 in which the bone stock is inadequate. The B2 and B3 fractures require revision to a longer stem whilst B1 fractures can be fixed with a plate.

The application of locking compression plates (LCP) in the treatment of PFF is a relatively new concept, with the first results reported in 2003 [5]. The LCPs have an advantage over conventional plates that can be applied at a distance over the periosteum, as they lock onto the plate, preserving the periosteal blood supply and, thus, enhancing fracture healing. In addition, the fixation of the locked screw to the plate provides improved angular stability to ensure secure anchoring in osteoporotic bone. Locking plates act as an “external fixator” under the soft tissue envelope, bypassing the inherent weakness of a standard external fixator, while maintaining relative fracture stability for secondary fracture healing; it could therefore be considered as an “internal fixator.” Based on these comparative advantages, locking plates have been used for the treatment of B1 periprosthetic femoral fractures [5].

Various reports have questioned the efficacy of locking plates to treat fractures, since incorrect surgical application of the plate may produce a very rigid fixation, which prevents bone healing by secondary intention [6]. Biomechanical studies question the rigidity of the construct and some authors advise less-rigid fixation around the fracture site, or the use of unicortical screws or screws for far fixation only [7]. Though this concept may appeal to the surgeon, it is occasionally disastrous when treating osteoporotic bone, with reports of plate pull-outs when unicortical screws were used [8].

We aim to assess the efficacy of locking plate fixation for the treatment of B1 PPFs focusing on failure rates and mechanism of failure, outlining improved fixation methods for optimal results.

Materials and methods

A literature search was conducted for studies reporting the management of PPF with locking plates. Medical search engines used for the study were Ovid MEDLINE (up to August 2012) and EMBASE (up to August) databases. Keywords used were “femur”, “hip”, “arthroplasty”, “locking-plate”, “revision arthroplasty”, “periprosthetic fracture” in mixed combinations to achieve the greatest possible variation. Human clinical studies only were included in the literature search. This was supplemented by manual searches of the bibliography of key papers. Cases reports were not included in the study.

Results: evaluation of failures rates and reasons for failures of locking plate fixation in Vancouver type B1 periprosthetic fractures of the hip

The search identified 13 studies that reviewed the management of Vancouver type B1 PPF of the femur with LCP [9–21] (Tables 1, 2). One multicentre prospective study by Schutz et al. [19] was excluded from the results. This was due to lack of information regarding the outcome of the six Vancouver B1 PPF that were reported in their study. This resulted in a total of 135 patients (135 fractures) managed with LCP fixation for Vancouver B1 PPF’s of the hip in 12 study groups. The majority of studies used either LCP fixation alone with an open or less-invasive skeletal stabilisation approach. Additional fixation with cortical strut grafts [12], cables or cerclage wires was also reported in conjunction with the LCP plate to aid fixation [20, 21].

In the Xue et al. [21] study, one plate failure was reported in 12 consecutive patients treated with LCP for Vancouver type B1 PPF. All patients were treated with a LCP and cerclage wires, using a minimally invasive approach. Patients were initially instructed not to weight bear, advancing to partial weight bearing at 8–12 weeks, and once union was confirmed (average 4.8 months) full weight bearing was allowed. The reported failure was in an 83-year-old female who had delayed union that required 9 months to heal, and 1 month later, sustained a fracture distal to the LCP following a fall from standing. Xue et al. [21] suggested that the reason for failure was the proximity of the LCP to the femoral condylar, creating a stress at the end of plate near to the curvature of the femoral condyles.

Kaab et al. [14] reviewed the management of 13 femoral fractures in their institute, six of which were Vancouver type B1 fractures. In five B1 cases primary fracture healing was observed without complication, but one plate failure was reported. No evidence of time to union was reported in this study. The failed LCP (plate breakage) occurred 4 months post-operatively. The authors suggested that implant failed probably due to stress concentration in the fracture area as a result of too-rigid fixation. This may have been the result of a small working length due to the placement of screws close to the fracture site. In addition, it is important to note that this plate failure was for the fixation of transverse fracture through the tip of the stem. These fractures are unstable and very difficult to control with single plates [22].

Kobbe et al. [15] assessed the functional outcome in 7 patients at a 3-year follow-up who had been managed with the less invasive stabilisation system (LISS) plate for B1 PPFs. One implant failed through screw pull-out at 23 days post operatively, in a 72-year-old patient. The authors concluded that the failed implant was insufficiently applied

Table 1 Summary of studies reporting the management of Vancouver type-B1 periprosthetic fractures of the proximal femur treated with locking plate fixation

Study	Method of fixation	No. patients	Time period	Follow up	Rehabilitation	Plate complication	Number of united fractures without complications	Mean union time (weeks)	Plate failure rate (%)	Conclusion
Xue et al. [21] Locking compression plate and cerclage band for type B1 periprosthetic femoral fractures	LCP	12	January 2003–June 2007	30.1 months	None weight /partial weight bearing until radiological evidence of union	1 VC1 fracture at 10 months	11	19	8.3	11 full unions without complications 1 VC1 treated conservatively with successful union
Wood et al. [20] Locking compression plates for the treatment of periprosthetic femoral fractures around well-fixed total hip and knee implants	LCP	9	2004 and 2006	24 months	None weight /partial weight bearing until radiological evidence of union	Nil	9	24	0	9 full unions without complications
Bryant et al. [11] Isolated locked compression plating for Vancouver type B1 periprosthetic femoral fractures	LCP	10	January 2002–December 2005	6.3 months	None weight /partial weight bearing until radiological evidence of union	Nil	10	17	0	10 full unions without complications
Anakwe et al. [10] Osteoporotic periprosthetic fractures of the femur in elderly patients: Outcome after fixation with the LISS plate	LCP	4	2003–2006	Not stated	None weight /partial weight bearing until radiological evidence of union	1 plate removed due to infection	3	32	0	3 full unions without complications One plate removed due to infection
Kumar et al. [16] Less invasive stabilisation system for the management of periprosthetic fractures around hip arthroplasty	LCP	10	September 2001–March 2005	Not stated	None weight /partial weight bearing until radiological evidence of union	1 plate failure at 17 days following fall. 1 proximal screw loosening and plate lift off. No lose of reduction of fracture	8	18.2	20	8 full unions without complications. 1 Proximal screw loosening and plate lift off 1 plate failure due to fall

Table 1 continued

Study	Method of fixation	No. patients	Time period	Follow up	Rehabilitation	Plate complication	Number of united fractures without complications	Mean union time (weeks)	Plate failure rate (%)	Conclusion
Ebraheim et al. [13] Fixation of periprosthetic femoral shaft fractures adjacent to a well-fixed femoral stem with reversed distal femoral locking plate	LCP	13	September 2005–October 2006	18 months	None weight /partial weight bearing until radiological evidence of union	Nil	13	14	0	13 full unions without complications
Kobbe et al. [15] Less invasive stabilisation system (LISS) for the treatment of periprosthetic femoral fractures: a 3-year follow-up	LCP	7	1998–2001	34 months	Full weight bearing	1 plate failure at 23 days	6	Not stated	14.2	6 full unions without complications One plate failure at 23 days
Buttaro et al. [12] Locking Compression Plate Fixation of Vancouver type-B1 periprosthetic femoral fractures	LCP 9: LCP alone 5: LCP and strut allografts	14	November 2003–May 2005	20 months	Early mobilization and walking with two crutches or a walker and toe-touch weight-bearing on the involved side for forty-five days	3 plate fractures 3 plate pull outs	8	21.6	42.8	8 full unions without complications 3 plate fractures 3 plate pullouts
Chakravarthy et al. [9] Locking plate osteosynthesis for Vancouver type B1 and type C periprosthetic fractures of femur: a report on 12 patients	LCP	6	January 2004 and March 2005	12.7 months	3-partial weight bearing for 6 weeks and then fully weight bear 1-partial weight bearing for 12 weeks and then fully weight bear 2-fully weight bearing immediately	Nil	6	20	0	6 full unions without complications

Table 1 continued

Study	Method of fixation	No. patients	Time period	Follow up	Rehabilitation	Plate complication	Number of united fractures without complications	Mean union time (weeks)	Plate failure rate (%)	Conclusion
Kaab et al. [14] Stabilisation of periprosthetic fractures with angular stable internal fixation: a report of 13 cases.	LCP	6	October 1999 and February 2002	21 months	Not stated	1 plate fracture at 4 months	5	Not stated	16.6	5 full unions without complications 1 plate fracture
O'Toole 2005 Low complication rate of LISS for femur fractures adjacent to stable hip or knee arthroplasty	LCP	3	July 1 2001–July 1 2003	Not Stated	Not stated	Nil	3	Not stated	0	3 full unions without complications. Although 2 deaths were reported in study it is not stated if it was the patients with VB1 fractures, but all deaths were due to medical conditions
Ricci et al. [18] Indirect reduction and plate fixation, without grafting for periprosthetic femoral shaft fractures about a stable intramedullary implant.	LCP	41 originally 50 but 4 died and 5 had inadequate follow up	Not stated	24 months	None weight /partial weight bearing until radiological evidence of union	Nil	41	12	0	41 full unions without complications

Table 2 Description and explanation by authors for the reported failures of Vancouver type-B1 periprosthetic fractures of the proximal femur treated with locking plate fixation

Study	Plate complication	Type plate failure/PPF	Time since fixation	Management of plate complication	Result	Authors explanation
Xue et al. [21] Locking compression plate and cerclage band for type B1 periprosthetic femoral fractures	Patient 1: VC fracture at 10 months due to non union	VC1	10 months	Immobilization in plaster cast	Fracture united 4 months after second fixation	The end of 16-hole plate was too close to the femoral condylar, creating a potential stress at the end of plate. More attention should be paid to such stress concentration areas
Wood et al. [20] Locking compression plates for the treatment of periprosthetic femoral fractures around well-fixed total hip and knee implants	Nil	–	–	–	–	–
Bryant et al. [11] Isolated locked compression plating for Vancouver type B1 periprosthetic femoral fractures	Nil	–	–	–	–	–
Anakwe et al. [10] Osteoporotic periprosthetic fractures of the femur in elderly patients: outcome after fixation with the LISS plate	Patient 1: plate removed due to infection	–	Not stated	Patient 1: removal of plate	Patient 1: union	None given
Kumar et al. [16] Less invasive stabilisation system for the management of periprosthetic fractures around hip arthroplasty	Patient 1: plate failure at 17 days due to fall Patient 2: proximal screw loosening and plate lift off. No loose reduction of fracture	Not stated	Patient 1: 17 days Patient 2: not stated	Patient 1: LISS plate fixation Patient 2: conservative	Patient 1: union at 24 weeks Patient 2: union at 18 weeks	None given
Ebraheim et al. [13] Fixation of periprosthetic femoral shaft fractures adjacent to a well-fixed femoral stem with reversed distal femoral Locking plate	Nil	–	–	–	–	–
Kobbe et al. [15] Less invasive stabilisation system (LISS) for the treatment of periprosthetic femoral fractures: a 3-year follow-up	Patient 1: plate pull-out at 23 days post fully weight bearing	Plate pull out proximally following early weight bearing	Patient 1: 23 days	Patient 1: LISS plate fixation and cerclage cable	Union	After analysis we concluded that implant failure was due to errors in the application of the LIS-System, neglecting the bridging principle of the LISS apparatus. Patients also full weight bearing

Table 2 continued

Study	Plate complication	Type plate failure/PPF	Time since fixation	Management of plate complication	Result	Authors explanation
Buttaro et al. [12] Locking compression plate fixation of Vancouver type-B1 periprosthetic femoral fractures	3 plate fractures 3 plate pull outs Patient 1: plate fracture Patient 2: plate fracture Patient 3: plate fracture Patient 4: plate pull out Patient 5: plate pull out Patient 6: plate pull out	Not stated	Patient 1: 6 months Patient 2: 8 months post op' Patient 3: 12 months Patient 4: 1 month Patient 5: 6 months Patient 6: 45 days	Patient 1: fixed with LCP and struts Patient 2: LCP and struts Patient 3: LCP and struts Patient 4: impaction grafting and long-stem prosthesis Patient 5: conservative Patient 6: conservative	Patient 1: union at 3 months post second op (9 months total) Patient 2: union at 6 months (14 months in total) Patient 3: union at 12 months (2 months in total) Patient 4: union 3 months post second op (4 months in total) Patient 5: union at 6 months Patient 6: union at 12 months	Patients 1-3 were all full weight bearing post op. All of the failures except one were observed in patients in whom a cortical strut allograft had not been used. Lack of double cerclage wires may have resulted in plate pull out in 3 cases
Chakravarthy et al. [9] Locking plate osteosynthesis for Vancouver type B1 and type C periprosthetic fractures of femur: a report on 12 patients	Nil	–	–	–	–	–
Kaab et al. [14] Stabilisation of periprosthetic fractures with angular stable internal fixation: a report of 13 cases	Patient 1: plate fracture at 4 months	Patient 1: fracture of plate bridging original fracture site	Patient 1: 4/12	Patient 1: replacement with a uncemented Wagner revision stem and cerclage wires. Patient went onto union	Full union	The implant failure was probably due to stress concentration in the fracture area due to a too rigid fixation of the LISS by using too many screws
O'Toole R 2005 Low complication rate of LISS for femur fractures adjacent to stable hip or knee arthroplasty	Nil	–	–	–	–	–

Table 2 continued

Study	Plate complication	Type plate failure/PPF	Time since fixation	Management of plate complication	Result	Authors explanation
Ricci et al. [18] Indirect reduction and plate fixation, without grafting for periprosthetic femoral shaft fractures about a stable intramedullary implant	Patient 1: most proximal cable broke but no intervention and union at 12 weeks Patients 2 and 3: fracture of one distal screw with no issues with union	No fracture just hardware failure	Not stated	All healed with no intervention	Union at 10–12 weeks	Hardware failure

proximally around the femoral stem and, thus, failed through pull out of those screws.

High LCP failure rates of 42.8 % (6 out of 14) were reported in the Buttaro et al. [12] study. 14 patients with B1 PPFs, three following primary and eleven revision hip arthroplasty, were treated with LCP. None of the procedures were performed with the use of minimally invasive techniques. Lateral LCPs were utilised alone (nine patients) or in combination with strut allografts (five patients). Eight fractures healed uneventfully at an average of 5.4 months (range 3–12 months). Three of the fractures treated with LCP alone resulted in non-union and plate failure at 6, 8 and 12 months. A further three patients presented with LCP pull-out. Buttaro et al. [12] raised concerns about the use of LCP for B1 PFFs and suggested that LCPs alone do not offer advantages over other types of plates in the treatment of type B1 periprosthetic hip fractures.

A larger cohort by Kumar et al. [16] presented 18 PPFs treated with LISS plates, 10 of which were type B1 fractures. All patients were allowed to partially weight bear soon after surgery, but full weight bearing was not commenced until patients were pain free and there was bridging callus across at least one cortex of the femur. Three patients died during the follow-up period, from unrelated causes, and were excluded from the final results. The 15 surviving patients had satisfactory fracture union, with a mean union time of 18.2 weeks. Two complications occurred; one patient required revision to another LISS plate 17 days post-surgery due to plate failure from a fall and in another patient the plate was pulled off proximally without losing reduction and the fracture was healed eventually.

In one of the largest studies performed, by Ricci et al. [18], of 50 consecutive patients, all with Vancouver type B1 femoral shaft fractures treated with a single large-fragment locking plate and no structural allograft, no failures were reported. Four patients died in the early post-operative period, and five had inadequate follow-up. The remaining 41 patients were evaluated clinically and radiographically for an average of 24 months. All fractures healed in satisfactory alignment at an average of 12 weeks (range 7–23 weeks) after the index procedure. One patient had one fractured cable and two others had one fractured screw, but all of the fractures healed without evidence of implant loosening or malalignment. Additionally, 30 of the 41 patients returned to their baseline ambulatory status. Similarly, Bryant et al. [11] reviewed 19 consecutive patients who were treated for Vancouver type B1 periprosthetic femur fracture at their institution over a 48-month period, and 10 of these were included in the final study sample. Patients were kept non-weight bearing for 4–6 weeks, progressed to partial weight bearing and then full weight bearing by 12 weeks, when there was radiographic evidence of fracture union. All patients achieved successful union, with a mean time to union of 17 weeks (range 12–27 weeks) and all were walking with or without the use of an assistive device, without pain, at their most recent follow-up visit.

Several published case series reported favourable results using LCP from different manufacturers for the treatment of B1 PFFs with an average time to fracture healing ranging between 3 and 6 months, the numbers, however, were small for the authors to reach firm conclusions [9, 10, 13, 17, 20].

Discussion

A total of 135 patients (135 fractures) were included from 12 studies [9–18, 20, 21]. There were 123 successful unions and 12 plate complications. Five plate fractures were reported, 3 of which were in one study group, all of which required revision surgery. There were 5 plate pull-outs, again 3 of which were in one study, and only 2 of which required revision surgery. Other complications included removal of a plate due to infection [10] and one VC fracture distal to the plate which required cast immobilization [21]. Besides the study by Buttaro et al. [12] who found a high rate of failure (42.8 %) in a prospective study design, other case series reported lower rates of LCP failures, indicating, however, a common mode of plate failure [9–11, 13–18, 20, 21]. Of the 12 studies reviewed, excluding infection, seven studies, analysing 82 patients, reported no plate failure [9–11, 13, 17, 18, 20] Not all authors reported union times in their series [14, 15, 17], however, the majority did with healing results ranging from 12 to 32 weeks [9–11, 13–16, 21]. The average union time for those treated fractures that were eventually healed was of 20 weeks [9–18, 20, 21].

Based on the available data we have identified three common reasons for failure of the management of Vancouver B1 fractures of the hip with LCP, namely: fracture across empty screw holes [12, 14]; bone fracture at the end of the plate due to a stress riser [21]; and screw pull-out [12, 15]. Whilst stress risers at the end of the plate are the unavoidable sequel of the surgical application, the mode of fixation by leaving empty screw holes or applying bi or unicortical screws is a matter of surgeon's choice.

Failure across the empty screw holes could have been the result of stress concentration in this region [12, 13]. This could be due to a too-rigid or too-flexible fixation. Both scenarios can prevent callus formation, due to either lack of [12, 14] or excessive movement [23] at the fracture site, which can ultimately lead to mechanical fatigue and subsequently failure of the plate [7]. The optimum fracture movement for promotion of callus formation is not yet known; however, there seems to be a consensus that fracture movement in the range of 0.15 and 1 mm promotes healing [24]. The amount of strain (i.e., relative deformation) optimally ranges between the minimum required for the induction of callus and the maximum which allows bony bridging [24]. Very small amounts of strain induce callus formation. Strain values up to 2 % are tolerated by lamellar bone tissue, up to 10 % are tolerated by the three-dimensional configuration of woven bone and between 10 and 30 % induction of resorption prevails [24].

Stoffel et al. [25] have suggested that leaving one or two screw holes on either side of the fracture can lead to the desired movement at the fracture site. Likewise, Ahmad et al. [26] suggested that placing the plate at or less than a 2 mm gap from bone provides a stable condition for bone healing. Several alternative strategies have also been recommended to reduce the rigidity of the locking plates, such as application of far-locking and dynamic-locking screws. On the other hand, application of screw head inserts into the empty screw hole across the fracture site has been shown to increase the fatigue life of the plate [27]. Study of Moazen et al. [7] highlighted the importance of fixation rigidity in periprosthetic femoral fracture fixation. Moazen et al. [7] demonstrated that increasing the rigidity of the fixation can be detrimental to secondary fracture healing process and may even cause failure of the fixation due to mechanical fatigue of the fixation device. Their results show that bridging length may play a bigger role than thickness or mechanical properties of the plate. In reducing the stiffness of the fixation method while several approaches can be considered, it is crucial to keep the strength of the fixation methods as such that the construct does not fail under fatigue loading. In summary, Moazen et al. [7] suggests that stainless steel plates with larger bridging length may lead to better clinical outcome than the titanium plates with shorter bridging length. Further research is required to assess the effectiveness of these new concepts in the case of periprosthetic fracture fixations, without doubt however too rigid fixation counteracts fracture healing and must be avoided.

Fracture at the end of LCP could be a result of high contact pressure (stress riser) on the bone from the plate end [21]. Several studies have addressed the effect of the bone and plate interface [28] and it is well accepted that the plate-bone gap preserves the periosteal blood supply to the fracture site promoting healing. Similarly it can also prevent a stress riser effect on the bone at the plate end. Anatomical plate designs to fit femoral curvatures and adequate plate length to bypass the fracture site and overlap the tip of the femoral implant must be used to prevent non union and plate metal fatigue fractures.

Screw pull-out occurs as a result of the dynamic loading due to daily activities that is imposed on the screw threads and bone interface [12, 15]. This type of failure is of higher risk in the case of periprosthetic femoral fractures, because of the poor bone quality frequently present in the elderly population or in the presence of a long standing unstable femoral stem in situ. The pre-operative radiograph is occasionally misleading for the stability of the stem and intra-operative assessment must always be done. It is important to emphasize that shifting from single plating for a B1 fracture to a full-blown revision of the stem for a B2 is frequently an intra-operative decision for which the surgeon must be equipped and trained to perform.

In the case of a B1 fracture in an osteoporotic femur, the surgeon must balance the decision between using biocortical screws at an angle to avoid the stem proximally increasing the risk of iatrogenic stem instability and, if present, jeopardizing the integrity of the cement mantle or using unicortical screws and increasing the risk of screw pull-out due to a shorter length of screw in the bone. Biomechanical studies have shown that application of additional support to the plate, in the form of either cable or wires, can increase the stability of the constructs [7]. In the study by Buttaro et al. [12] the authors suggested that cortical strut allografts should be incorporated into all LCP fixation of Vancouver B1 fractures and reported that all of the failures in their study, except one, were observed in patients in whom a cortical strut allograft had not been used. Haddad et al. [29] also reported that cortical onlay strut allografts act as biological bone plates serving both a mechanical and a biological function and recommended the use of cortical struts in conjunction with a compression plate for the treatment of B1 fractures. Recent reports advocate revision to a long stem for B1 fracture when the fractures is not easily controlled by a single or even double plate as for example in the case of a transverse or short oblique fracture below the tip of the stem in situ [12, 22].

Post-operative rehabilitation is an important factor in the healing process that can be largely patient specific and, at times, out of the surgeon's control. Animal studies have shown that early and full weight bearing delays fracture healing [30] and can potentially reduce the fatigue life of the plates in humans. In fact, one of the important factors to note in the studies by Buttaro et al. [12] and Kobbe et al. [15], is that the authors highlighted possible early loading as a factor in plate breakage in two cases [12], and three cases [15], respectively. In contrast, in five studies that reported no failures [10, 11, 13, 20] patients were only permitted to partially or fully weight bear post-operatively. Early loading of the patient post fixation maintains patient's autonomy; however, evidence to date, although drawn from limited studies, suggest partially weight bearing in the initial post-operative period until union is confirmed radiologically, in order to prevent plate failure [10, 11, 13, 20].

Fracture configuration as well as its anatomic location is an extremely important contributor to the failure of locking plate fixation. The surface area for union of a transverse fracture below the tip of the stem is very different and obviously much smaller to a long spiral fracture extending from the middle of the stem down. The configuration of the fracture around the stem will determine the type of fixation the surgeon may choose and the need for either axial stability provided by a long stem revision in the case of a transverse fracture [12] or the need for biological augmentation with some form of allograft in the case of a long spiral fracture in an osteoporotic environment [29].

A significant limitation of the existing literature is the small number of participants in the reported studies. One of the reasons being that LCP were only released for clinical application in 2000. Another limitation is the retrospective design of the studies, which is unavoidably the practice in surgical literature for obvious ethical reasons.

The PPF are technically challenging and require the skill for trauma and revision hip arthroplasty in the same setting. In summary, with the data available, we propose the following areas of attention: (1) limiting the stiffness of LCP by leaving empty the screw holes around the fracture site; (2) biological application of the LCP in order not to disturb the fracture area and the soft tissue envelope; (3) additional fixations such as cables with unicortical screws and cortical strut allografts in the case of poor bone quality; (4) plates long enough to overlap the stem in situ (5) long stem revision for transverse fractures below the tip of the stem may provide a more viable option compared to single plating; and (6) partial weight bearing of patients post-operatively until full union has been confirmed radiologically. To the best of our knowledge this is the first comprehensive study to indicate, through published reviewed data and also author's published personal experience both clinical and experimental, that single locking plating of B1 periprosthetic femoral fracture is troublesome. Additional research is required to test the application of recently developed concepts such as far- and dynamic-locking screws as well as a threaded screw head insert in the case of periprosthetic fracture fixations. It would also be of benefit to carry out further prospective studies on larger population groups, taking into account fracture configuration, to clarify the benefits of the use of cortical strut grafts as additional biological fixator's or the long stem revision for the transverse fractures below the tip of the stem. Additionally, LCP failure mode can be tested based on the reported evidence and further work using finite element analysis may shade light for the better application of LCP [7].

Conflict of interest The authors declare that they have no conflict of interest.

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