The Medoff sliding plate and a standard sliding hip screw for unstable intertrochanteric fractures

A mechanical comparison in cadaver femurs

Ola Olsson[1], Frederick J Kummer[2], Leif Ceder[1], Kenneth J Koval[2], Sune Larsson[3] and Joseph D Zuckerman[2]

The Medoff sliding plate has a dual side capability along both the femoral shaft and neck to increase theoretically interfragmentary compression and load-sharing in hip fractures. We studied intertrochanteric fracture fixation in cadaveric bone to determine whether this device has a mechanical advantage over a standard sliding hip screw.

2-part and 4-part fractures were created in 12 cadaver femurs. The fractures were fixated and sequentially destabilized; bone and plate strains and fragment displacements were determined during testing, as a function of applied physiological loads before and after short-term cycling.

The Medoff sliding plate imposed a higher mean medial cortex strain than the sliding hip screw in all fracture models and at all loading levels, and the difference was statistically significant in the 2-part and in the unstable 4-part fracture models. The loading of the medial cortex region after cycling was approximately 50% higher in the Medoff samples than in the sliding hip screw samples. There were no significant differences in plate strains, fracture displacements or load to failure between the 2 devices.

These observations favor the dual sliding principle as regards providing fracture compression and load-sharing, which may explain low failure rates in clinical series of unstable intertrochanteric fractures, treated with the Medoff sliding plate.

Departments of [1]Orthopedics, Helsingborg Hospital, SE-251 87 Helsingborg, Sweden. Tel +46 42-10 00 00. Fax -10 24 50; [2]Orthopaedic Surgery and Bioengineering, Hospital for Joint Diseases Orthopaedic Institute, New York, USA, [3]Orthopedics, Uppsala University Hospital, Uppsala, Sweden
Submitted 96-11-23. Accepted 97-12-29

A new device, the Medoff sliding plate, has been developed to treat unstable intertrochanteric fractures (Medoff and Maes 1991). It has a lag screw with the same sliding capacity as a standard sliding hip screw. In addition, a second sliding capability has been added by the use of a sideplate consisting of 2 interdigitated sliding components, allowing fracture impaction along the longitudinal axis of the femoral shaft. Theoretically, this dual sliding capacity should facilitate fracture impaction and subsequently improve load-sharing. With transfer of load from the implant to the bone, a higher strain will be observed on the medial cortex. Several advantages are thereby achieved, including improved fracture stability, enhanced fracture healing, and a reduced risk of fatigue failure of the implant. These postulated advantages are supported by 2 series, including 202 elderly patients with unstable intertrochanteric fractures treated with the dual sliding plate. All fractures healed and only 1 screw penetration was observed (Lunsjö et al. 1996, Olsson et al. 1997).

The original Medoff sliding plate has a 6-hole sideplate. In this study, a modified version with a 4-hole sideplate was used (Olsson et al. 1997) (Figure 1).

This study aimed to compare the load-sharing and load-bearing capacity of the dual sliding Medoff plate with that of a standard sliding hip screw.

Material and methods

The study was performed at the Department of Bioengineering, Hospital for Joint Diseases Orthopaedic Institute, New York, USA.

12 unmatched fresh-frozen femora from North-American caucasian donors aged above 65 years were used. Matched pairs were not used, due to difficulties in obtaining fresh-frozen cadaver bones. The femora were thawed and all soft tissues removed. Radiographs in 2 planes were taken to exclude samples with morphologic abnormalities. Dual energy x-ray absorptiometry (QDR-2000 Supine Lateral X-ray

Figure 1. The Medoff sliding plate has a lag screw with similar sliding capacity as the sliding hip screw. The 4-hole lateral plate constrains a sliding element, allowing a maximum compression of 25 mm along the femoral shaft. The cortical screws are aligned in a 30° converging direction.

Bone Densitometer, Hologic, Waltham, USA) was used to determine bone mineral density in Ward's triangle. Radiographs were taken during testing, after insertion of the device and after loading to failure.

The femurs were randomized to 1 of 2 fixation groups:

1. 6 femurs for fixation with a 4-hole, 135° Medoff sliding plate (Medpac, Valencia, CA, USA).

2. 6 femurs for fixation with a 4-hole, 135° Richards Classic sliding hip screw (Smith & Nephew/ Richards Manufacturing Co., Memphis, TN, USA).

The femoral shafts were osteotomized 22 cm distal to the lesser trochanter, removing the distal condyles, and potted in metal tubes, using methylmethacrylate. Each femur was fitted with 2 unidirectional strain gauges (Omega EA-06-125-AC-120, Omega Engineering, Stamford, CT, USA) using cyanoacrylate (M-bond 200 adhesive, Measurements group, Malvern, PA, USA) covered with a thin layer of protective epoxy (5 min Epoxy, Devcon Corp., Danvers, MA, USA). The strain gauges (SG) were placed, as follows (Figure 2):

SG 1: On the medial cortex of the femur above the intertrochanteric line, aligned parallel to the longitudinal axis of the femoral neck.

SG 2: On the lateral aspect of the sideplate, directly below the lateral hole of the barrel for the lag screw, aligned along the vertical axis of the plate. The same position on the sliding element of the Medoff sliding plate was used.

A digital strain indicator (Micromeasurements P-3500, Vishay Technology Inc., Greenboro, NC, USA) was multiplexed to the strain gauges.

The shaft was mounted in an angle vise at 25° adduction in the coronal plane and neutral in the sagittal plane, to simulate the anatomical loading during single leg-stance (Chang et al. 1987) (Figure 2). This vise was fixed to the table of a hydraulic testing machine (MTS, model 1321, MTS systems, Minneapolis, MN, USA). 2 digital linear displacement gauges (DG) (IDC-25E, Mitutoyo, Tokyo, Japan), with oversized plunger heads, were used to determine the true inferior displacement of the femoral head and placed as follows:

DG 1: On the inferior aspect of the femoral head, parallel to the femoral shaft.

DG 2: On the lateral aspect of the greater trochanter, perpendicular to the femoral shaft.

Sliding of the lag screws during loading was determined by measuring the distance between the head of the compression screw and the proximal lateral corner of the plate with a digital caliper. The sliding of the Medoff sideplate was measured in a similar way, using the distal ends of the sliding and the fixed components of the sideplate as reference points.

Vertical compressive loads on the femurs were applied by a flat plate mounted on the testing machine load cell. A metal cup with a smooth bottom was placed between the plate and the femoral head to function as a sliding holder.

The osteosynthesis material was then applied with standard techniques. The femoral shaft part of the Medoff sliding plate has 2 components. A 4-hole lateral plate constrains a sliding element, allowing a

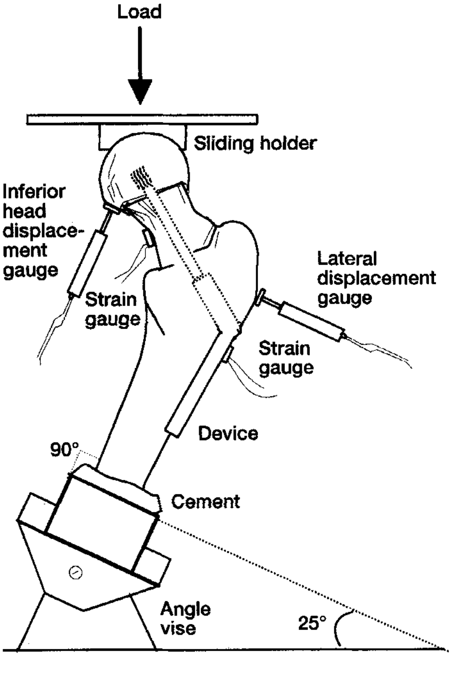

Figure 2. The test set-up with device in intact femur.

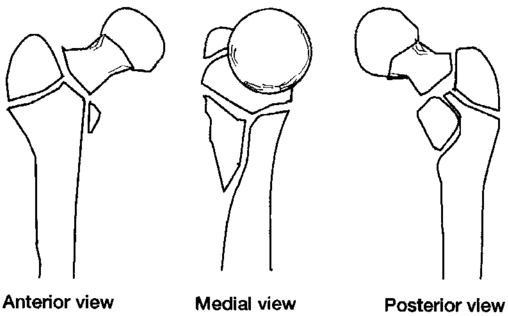

Figure 3. The 4-part fracture model in different views.

maximum compression of 25 mm along the femoral shaft. The cortical screws are aligned in a 30° converging direction (Figure 1). The entry hole for the lag screw must be enlarged distally, to allow sliding of the plate, because otherwise the barrel will impinge on the lateral cortex of the femoral shaft and prevent fracture impaction. This distal slot was made with a rongeur.

After the osteosynthesis material had been applied, a stable 2-part intertrochanteric fracture was created with a thin-bladed handsaw by cutting the circumference of the cortical bone along the intertrochanteric line. The 4-part fracture was created by removing the proximal fragment with the lag screw, cutting off and discarding the greater trochanter and cutting out a posteromedial fragment (Figure 3). In this way, a posteromedial defect was produced, in order to simulate an unstable 4-part fracture (Jensen and Michaelsen 1975, Meislin et al. 1990). For the stable 4-part fracture, the posteromedial fragment was replaced in an anatomical position and stabilized with a cerclage wire, which was placed above the plate, to avoid interfering with the sliding of the Medoff sideplate. Finally, the proximal fragment with the lag screw was replaced, the fracture was reduced and the compression screw reinserted.

Specimens were tested after each step, in the following sequence:

1. Intact femur, without device.
2. Intact femur, with device.
3. 2-part fracture.
4. 4-part fracture with posteromedial fragment in place.
5. 4-part fracture with posteromedial fragment discarded.
6. 4-part fracture with posteromedial fragment discarded, 1 000 cycles.
7. 4-part fracture with posteromedial fragment discarded, load to failure.

The femurs were loaded in 200 N increments from 400 N to 1600 N. Strain and displacement gauge readings were obtained at each level. Cyclic loading was performed on the unstable 4-part fracture, with loading from 0 to 1600 N, at a rate of 1 Hz for 1000 cycles, with displacement and strain readings obtained every 200 cycles. After cyclic loading, increasing load was continuously applied at a rate of 40 N/s, and the load/deformation curve was recorded to failure. Failure was defined as discontinuity or a marked decrease in the slope of the load/deformation curve. After testing, the femora and the devices were examined and radiographed to determine the mode of failure.

Analysis of data

Each femur served as its own control. Strains on the medial cortex in the different fracture types and loads were calculated as percentage of those on the intact femora before instrumentation. The strain on the plate in the tested fracture patterns was given as percentage of the plate strain on the intact instrumented bone. For the 7 different loading steps in each fracture model, mean strains and displacements were calculated in each sample and these values are presented, with mean and range, unless otherwise mentioned. The Mann-Whitney U-test was used to compare groups. Due to the large spread of values, statistical analysis of medial cortex and plate strain was also performed utilizing the nonparametric median test, based on a one-tailed Fisher exact probability test. These results are given for strain comparisons, unless otherwise stated. A p-value of < 0.05 was considered significant. Linear regression analysis of bone mineral density versus bone strain and versus load to failure was performed.

Results

Bone mineral density. The 2 test groups were compared, with regard to the bone mineral density. For the Medoff sliding plate, the bone mineral density was 0.65 (0.55–0.70) g/cm^2 and for the sliding hip screw, 0.61 (0.55–0.63) g/cm^2 ($p = 0.09$). Linear regression analysis of bone strains versus bone mineral density revealed no significant correlation between these parameters.

Bone strain analysis. In the intact femurs with the device mounted, the strain on the medial cortex, compared to before instrumentation, decreased slightly less for the Medoff sliding plate than for the sliding hip screw. In the unstable 4-part fracture and the 2-part fracture, the strain on the medial cortex was significantly higher for the Medoff sliding plate than for the sliding hip screw (Table). Statistical analysis of the 2 groups was also performed separately at all

Medial cortex strain in different fracture types as fraction of strain in intact femur. Mean, median, standard deviation (SD) and range values for the 7 different loading levels are used

	n	Mean	Median	SD	Range	P-value [a]
Intact bone with device						
Medoff sliding plate	6	0.85	0.80	0.17	0.71–1.17	0.72
Sliding hip screw	6	0.79	0.83	0.22	0.48–1.10	
2-part fracture						
Medoff sliding plate	6	0.63	0.59	0.23	0.34–0.94	0.04
Sliding hip screw	6	0.31	0.24	0.32	0–0.86	
4-part fracture with posteromedial fragment in place						
Medoff sliding plate	6	0.76	0.82	0.41	0.16–1.20	0.28
Sliding hip screw	6	0.42	0.35	0.29	0.09–0.90	
4-part fracture with posteromedial fragment discarded						
Medoff sliding plate	6	0.73	0.70	0.39	0.14–1.27	0.04
Sliding hip screw	6	0.39	0.46	0.30	0–0.80	

[a] Statistical comparison using the median test.

loading levels and the mean medial cortex strain for the Medoff sliding plate remained higher at all loading levels and in all fracture types (Figure 4).

In order to control for alterations in strain pattern due to the device insertion procedure in itself, the medial cortex strain in the unstable 4-part fracture was also compared to the medial cortex strain in the intact instrumented bone. A higher strain in the Medoff samples, 83 (20–113)% than in the sliding hip screw samples, 44 (0–73)%, was noted (Mann-Whitney U-test, p = 0.03).

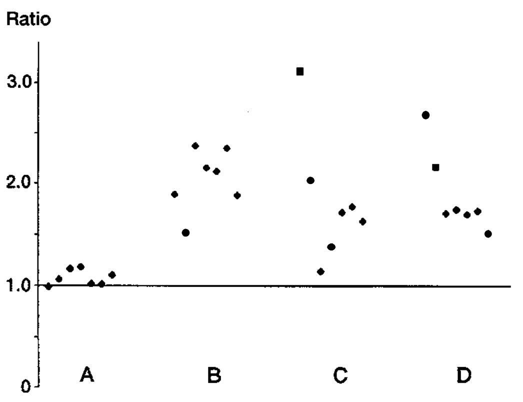

Figure 4. The medial cortex strain at all loading levels in each fracture type was calculated as a fraction of the medial cortex strain in the intact femur, and the mean value for the Medoff samples was divided by the mean value for the sliding hip screw samples. The values are given from left to right for the 7 loading levels from 400 to 1600 N for each fracture type. All values are above 1.0, since the mean strain values are higher for the Medoff samples than for the sliding hip screw samples in all fracture types at all loading levels. Square symbol denotes statistically significant difference between the 2 groups ($p < 0.05$). A) intact instrumented, B) 2-part fracture, C) 4-part fracture with posteromedial fragment in place, and D) 4-part fracture with posteromedial fragment discarded.

Plate strain analysis. 1 of the Medoff samples was excluded from plate strain analysis due to technical failure of the lateral strain gauge. The strain on the plate for the unstable 4-part fracture was 11 (1.2–23) and 4.1 (0.7–10) times the strains on the intact instrumented bone for the Medoff sliding plate and for the sliding hip screw, respectively (p = 0.5).

Cycling. 1 of the Medoff samples and 1 of the sliding hip screw samples were excluded from bone and plate strain analysis during cycling, due to failure of the strain gauges. After 1000 loading cycles, the strain on the medial cortex at 1600 N was 78 (5–125)%, when compared to the intact bone for the 5 Medoff samples. 4 sliding hip screw samples showed a mean compressive strain in the medial cortex of 54 (31–84)%, when compared to the intact bone, and 1 specimen revealed a tensile strain in the same region (p = 0.1).

The strain changes during cycling were widespread, particularly in the Medoff samples. The median medial cortex strain at 1600 N was 1.2 (0.1–26) and 0.9 (0–4.0) times the medial cortex strain at 1600 N before cycling for the Medoff sliding plate and for the sliding hip screw, respectively. The highest compressive medial cortex strain at 1600 N in the unstable 4-part fracture, before or after cycling, was determined for each sample. The Medoff samples showed a higher mean strain, 88 (45–125)%, than the sliding hip screw samples, 48 (5–95)%. The difference, however, did not reach significance (Mann-Whitney U-test, p = 0.08). During cycling, the medial cortex strain increased in 3 and decreased in 2 of the 5 Medoff samples, while it increased in 1, decreased in 3 and was unchanged in 1 of the 5 sliding hip screw samples.

The median tensile plate strain at 1600 N after 1000 loading cycles was for the Medoff sliding plate 4.4 (1.5–28) times and for the sliding hip screw 2.7 (1.2–19) times the plate strain on the intact instrumented bone ($p = 0.5$). In 1 of the Medoff samples, compressive plate strain was noted. During cycling, the median plate strain increased 1.1 (0.9–2.7) times for the Medoff sliding plate and 1.5 (0.5–2.2) times for the sliding hip screw ($p = 0.5$).

Displacement analysis. The inferior head and lateral shaft displacements were not statistically different in the 2 groups in any fracture type or at any loading level. In the unstable 4-part fracture, the inferior head displacement was 0.6 (0.2–1.0) mm for the Medoff sliding plate and 0.9 (0.3–1.5) mm for the sliding hip screw. The lateral shaft displacement was 1.0 (0.4–1.8) mm for the Medoff sliding plate and 1.1 (0.7–1.7) mm for the sliding hip screw.

Lag screw sliding. After completion of the static loading sequence, the sliding of the lag screw at 1600 N loading was 0–0.1 mm for both groups in the unstable 4-part fracture. After cyclic loading, the lag screw slid an additional 0.8 (0–3.6) mm in the Medoff sliding plate and 1.0 (0–2.9) mm in the sliding hip screw.

Plate sliding. The total sliding of the Medoff sideplate was less than 1 mm during the static loading sequence with no apparent relation to fracture type. During cycling, the Medoff sideplate slid an additional 4.0 (0.2–12.8) mm.

Maximum load to failure. The maximum load to failure was 3050 (2000–4200) N for the Medoff sliding plate and 3450 (2350–4400) N for the sliding hip screw ($p = 0.3$). Linear regression analysis of load to failure versus bone mineral density revealed no significant correlation.

Mode of failure. 2 of the Medoff sliding plate specimens failed at 2900 N and 3700 N, respectively, by fracturing through the distal surface of the 4-part fracture osteotomy, engaging the slot created for the plate sliding. A third specimen failed at 2000 N by dislocation of the proximal fragment in varus and superior cut-out of the lag screw. In a fourth sample, the lag screw was slightly bent at 3000 N, no other failure being observed. In the remaining 2 bones, the loading was stopped at 2500 N and 3000 N, respectively, due to a sudden drop in the load/deformation curve, but no failure of bone or device was observed.

3 of the sliding hip screw specimens failed at 3350 N, 3375 N and 3875 N, respectively, by bending of the lag screw. In a fourth sample, the proximal fragment fractured at 3375 N. In the remaining 2 samples, the testing was stopped at 2350 N and 4400 N, respectively, due to a sudden drop in the load-displacement curve. However, no failure of bone or device could be observed.

Discussion

The sliding hip screw provides dynamic fixation to facilitate interfragmentary stress transfer and load-sharing (Jensen et al. 1978, Goodship and Kenwright 1985, Larsson et al. 1988) and its use has resulted in a substantial reduction of technical failures and healing disturbances, in comparison to previous fixed devices such as the blade plate (Jacobs et al. 1976, Simpson et al. 1989). However, the sliding hip screw tends to unload the medial cortex of the femur in unstable fractures (Mahomed et al. 1994), and complications such as superior cut-out of the femoral head or penetration of the lag screw into the hip joint remain a problem in the fixation of the unstable fractures (Davis et al. 1990, Pitsaer and Samuel 1993).

The importance of load-sharing in devices used for fixation of unstable intertrochanteric fractures has been emphasized by several authors (Jarrett et al. 1984, Chang et al. 1987, Larsson et al. 1988, Mahomed et al. 1994). Our study suggests that the Medoff sliding plate offers more effective stress transfer to the fracture surfaces of the proximal medial femur than the sliding hip screw. Theoretically, the healing should be enhanced, whereas the risk of cut-out, penetration of the lag screw or other types of hardware failure should decrease.

Compared to the intact bone without the device, the mean strain in the medial cortex in the unstable 4-part fracture was almost twice as high for the Medoff sliding plate as for the sliding hip screw. Other investigators (Chang et al. 1987, Meislin et al. 1990, Rosenblum et al. 1992, Choueka et al. 1995) have reported comparable medial cortex strains for the sliding hip screw, using similar test models. A corresponding unloading of the proximal medial femur in an unstable intertrochanteric fracture model has also been shown for the Gamma nail (Mahomed et al. 1994) and for a long stem intramedullary hip screw (Bostrom et al. 1995). Even with the implanted devices in intact bone, relatively more strain was borne by the bone with the Medoff sliding plate than with the sliding hip screw. A possible reason for this observation is that the sliding hip screw is stiffer than the Medoff sliding plate, thereby unloading the bone more.

The observed median plate strain was insignificantly higher for the Medoff sliding plate than for the sliding hip screw. In this experiment, the distal surface of the plate barrel of the sliding hip screw device rested on intact cortical bone of the lateral femoral shaft, whereas the plate barrel of the Medoff sliding plate device lacked this support due to the distal enlargement of the lag screw entry hole. Therefore, the lever arm of the tensile force applied to the plate laterally during loading is longer for the Medoff sliding plate, which may contribute to the amount of tensile plate strain in this test model. In a mechanical test of subtrochanteric fractures, 3–4 times higher plate strain was recorded for sliding hip screws compared to the Medoff sliding plate (Medoff and Maes 1990). In this test, distal enlargement of the lag screw entry hole was not made for any of the devices.

In our experiment, sliding of the Medoff side plate was negligible during static loading, probably due to medial bone contact in the fracture model. However, during cyclic loading, additional plate sliding took place, which appeared to reflect the observed increase in medial cortex strain. The Medoff sliding plate allowed controlled fracture impaction, whereas with the sliding hip screw, the strain in the bone during cyclic loading was gradually reduced. Cyclic loading is considered to reflect better the clinical situation, where the dynamic forces applied to the hip during ambulation impose repetitive compressive loading on the medial cortex, while the lateral cortex is under tension (Mahomed et al. 1994).

Although fracture compression, as indicated by bone strains, increased with the Medoff sliding plate, this was not reflected in an increased load to failure. Our loads to failure were lower than those reported with the sliding hip screw (Mahomed et al. 1994, Choueka et al. 1995). In the latter study, the embalmed sliding hip screw samples failed from cut-out of the lag screw in almost all cases, while the lag screws in the present study were only slightly bent or showed no gross failure following testing. This is probably explained by our definition of failure, as the testing was stopped when a marked change in the slope of the load/deformation curve occurred, i.e., a sudden movement of the bone-implant construct took place.

2 of the Medoff sliding plate specimens failed from fracturing through the lag screw entry hole. The surgical technique requires distal enlarging of the hole, thus removing more intact cortical bone than with the sliding hip screw. This procedure may reduce the strength of the bone and possibly increase the risk of fracture. We have not observed this complication in our published clinical studies, including more than 300 cases followed for at least 1 year (Lunsjö et al. 1995, 1996, Olsson et al. 1997).

No significant differences between the Medoff and the sliding hip screw samples could be found regarding displacements of the femoral head or shaft or sliding of the hip screw. The fracture model used in this experiment was designed to simulate an unstable intertrochanteric fracture, but did not allow fracture displacements as large as that usually seen clinically in unstable fractures (Gundle et al. 1995).

Limitations of this study were:

1. Fewness of samples, due to difficulties in obtaining fresh-frozen cadaver bones and, therefore, matched pairs were not used.

2. Great sensitivity of strain measurements to the placement of the strain gauges as well as to the number and location of contact points between the fracture surfaces, which may account for the large scattering of measurements in both the Medoff and the sliding hip screw samples.

3. The mean bone mineral density was slightly higher for the Medoff samples, but the difference was not statistically significant and did not correlate to bone strain values or load to failure, according to linear regression analysis.

In conclusion, compared to a standard sliding hip screw, the Medoff sliding plate appears to offer advantages in providing improved load-sharing capability, thanks to the dual sliding principle.

Acknowledgments

This study was supported by grants from the Stig and Ragna Gorthon Foundation, Helsingborg, Sweden, and from the Clinical Research Foundation of Malmöhus County Council, Sweden.

References

Bostrom M P, Lyden J P, Ernberg J J, Missri A A, Berberian W S. A biomechanical evaluation of the long stem intramedullary hip screw. J Orthop Trauma 1995; 9: 45-52.

Chang W S, Zuckerman J D, Kummer F J, Frankel V H. Biomechanical evaluation of anatomic reduction versus medial displacement osteotomy in unstable intertrochanteric fractures. Clin Orthop 1987; 225: 141-6.

Choueka J, Koval K J, Kummer F J, Crawford G, Zuckerman J D. Biomechanical comparison of the sliding hip screw and the dome plunger. J Bone Joint Surg (Br) 1995; 77: 277-83.

Davis T R C, Sher J L, Horsman A, et al. Intertrochanteric femoral fractures: mechanical failure after internal fixation. J Bone Joint Surg (Br) 1990; 72: 26-31.

Goodship A E, Kenwright J. The influence of induced micromovement upon the healing of experimental tibial fractures. J Bone Joint Surg (Br) 1985; 67: 650-5.

Gundle R, Gargan M F, Simpson A H. How to minimize failures of fixation of unstable intertrochanteric fractures. Injury 1995; 26: 611-4.

Jacobs R R, Armstrong H J, Whitaker J H, et al. Treatment of intertrochanteric hip fractures with compression screw and nail plate. J Trauma 1976; 16: 599-603.

Jarrett P J, Fleming L L, Whitesides Jr T E. The stable internal fixation of peritrochanteric hip fractures. In: Fractures of the hip. 1984 AAOS Instructional course lectures. Vol XXXIII: 203-17.

Jensen J S, Michaelsen M. Trochanteric femoral fractures treated with McLaughlin osteosynthesis. Acta Orthop Scand 1975; 46: 795-803.

Jensen J S, Tondevold E, Mossing N. Unstable trochanteric fractures treated with the sliding screw-plate system. A biomechanical study of unstable trochanteric fractures III. Acta Orthop Scand 1978; 49: 392-7.

Larsson S, Elloy M, Hansson L I. Fixation of unstable trochanteric hip fractures. A cadaver study comparing three different devices. Acta Orthop Scand 1988; 59 (6): 658-63.

Lunsjö K, Ceder L, Stigsson L, Hauggaard A. One-way compression along the femoral shaft with the Medoff sliding plate. The first European experience of 104 intertrochanteric fractures with a 1-year follow-up. Acta Orthop Scand 1995; 66 (4): 343-6.

Lunsjö K, Ceder L, Stigsson L, Hauggaard A. Two-way compression along the shaft and the neck of the femur with the Medoff sliding plate. One-year follow-up of 108 intertrochanteric fractures. J Bone Joint Surg (Br) 1996; 78: 387-90.

Mahomed N, Harrington I, Kellam J, Maistrelli G, Hearn T, Vroemen J. Biomechanical analysis of the Gamma nail and sliding hip screw. Clin Orthop 1994; 304: 280-8.

Medoff R, Maes K. A new implant for the fixation of the high subtrochanteric and unstable intertrochanteric fracture of the hip. Orthop Trans 1990; 14: 671.

Medoff R, Maes K. A new device for the fixation of unstable pertrochanteric fractures of the hip. J Bone Joint Surg (Am) 1991; 73: 1192-9.

Meislin R J, Zuckerman J D, Kummer F J, Frankel V H. A biomechanical analysis of the sliding hip screw: a question of plate angle. J Orthop Trauma 1990; 4: 130-6.

Olsson O, Ceder L, Lunsjö K, Hauggaard A. Biaxial dynamization in unstable intertrochanteric fractures. Good experience with a simplified Medoff sliding plate in 94 patients. Acta Orthop Scand 1997; 68 (4): 327-31.

Pitsaer E, Samuel A W. Functional outcome after intertrochanteric fractures of the femur. Does the implant matter? A prospective study of 100 consecutive cases. Injury 1993; 24: 35-6.

Rosenblum S F, Zuckerman J D, Kummer F J, Tam B S. A biomechanical evaluation of the Gamma Nail. J Bone Joint Surg (Br) 1992; 74: 352-7.

Simpson A H R W, Varty K, Dodd C A F. Sliding hip screws: modes of failure. Injury 1989; 20: 227-31.