Acta Orthop. Belg., 2013, **79**, 293-300

ORIGINAL STUDY

The Thrust Plate Prosthesis : Long-term clinical and radiological results

Leon W. Diederix, Peter J.T.S. Van Winterswijk, Sander B. Schouten, Pieter A.G.M. Bakx, Jaap Huij

From the Maasstad Hospital, Rotterdam, The Netherlands

The Thrust Plate Prosthesis is a femoral implant designed for total hip arthroplasty, based on the principles of physiologic loading of the metaphysis of the proximal femur, and preserving the bone stock. This study presents the long-term clinical and radiological results of 34 patients with 36 Thrust Plate Prostheses. In a retrospective analysis, we investigated the reoperation-free survival as well as the clinical and radiological results. Mean age at operation was 51 ± 6.4 years. Mean follow-up length was 11.9 ± 1.6 years. Reoperation-free survival was 88.9%. Four (11.1%) reoperations were performed, in three patients due to aseptic loosening and in one patient because of a fracture distal to the lateral plate. Three of the reoperations were performed between 12 and 32 months postoperatively. The major complaint was pain at the lateral side of the hip (44%). Radiolucencies did not exceed 1 mm, but 35% of the hips showed resorption of the cortex directly under the thrust plate, together with cancellous bone hypertrophy at the calcar, noted in 97%.

Because of the relatively high reoperation-free survival and favourable radiological results, the Thrust Plate Prosthesis appears as a possible alternative to stemmed total hip arthroplasty, especially in relatively young patients.

Keywords : hip arthroplasty ; young patients ; survival analysis.

INTRODUCTION

The Thrust Plate Prosthesis (TPP, Zimmer, Winterthur, Switzerland) was introduced by Huggler and Jacob in 1978. This stemless femoral implant designed for total hip arthroplasty (THA) is based on the principle of physiological loading of the metaphysis of the proximal femur. Results of biomechanical studies of the TPP have confirmed the theory (*1,7,9,12*). Non-physiologic loading of the proximal femur could indeed induce aseptic loosening. Another important advantage of the TPP described by Huggler and Jacob (*12*) is the fact that the intramedullary channel is left untouched, preserving the bone stock (Fig. 1). This makes a potential revision procedure relatively less complex, as it can now be performed with a stemmed prosthesis normally used for primary THA. As younger patients are now undergoing THA, the number of revisions will increase in the coming decades. The purpose of this study was to analyse the long-term clinical and radiological results of the TPP.

■ Leon Walter Diederix, MD, Resident Orthopaedic Surgery.
■ Peter J. van Winterswijk, MD, Resident Orthopaedic Surgery.
■ Sander B. Schouten, MD, Resident Orthopaedic Surgery.
■ Pieter A. Bakx, MD, Orthopaedic Surgeon, Head of department.
■ Jaap Huij, MD, Orthopaedic Surgeon.
Maasstad Hospital, Rotterdam, The Netherlands.
Correspondence : Leon W. Diederix, Maasstad Hospital, Secretariat Orthopaedic surgery, Postbus 9100, 3079 DZ, Rotterdam, The Netherlands.
E-mail : diederix_lw@hotmail.com

No benefits or funds were received in support of this study.
The authors report no conflict of interests.

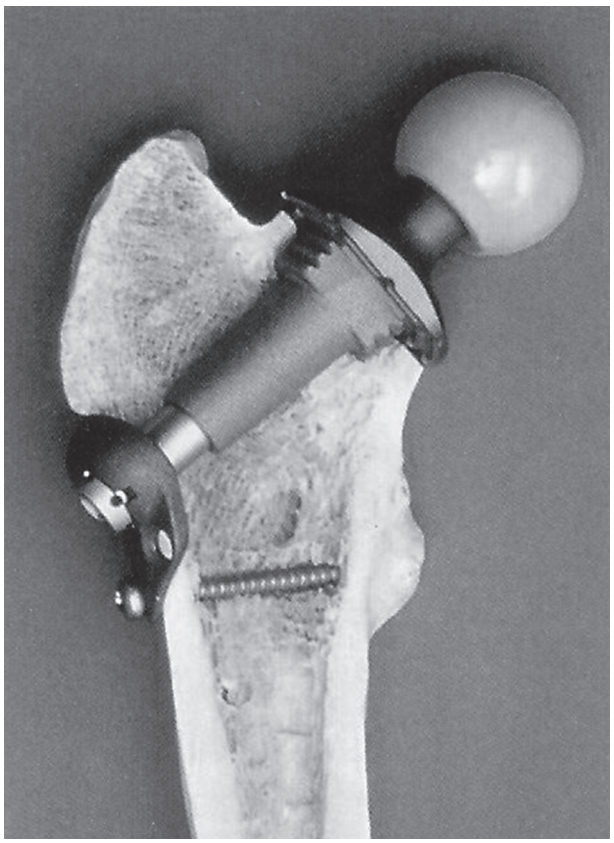

Fig. 1. — The third generation thrust plate prosthesis

Buergi *et al* have extensively described the characteristics of the TPP (*2*). The first-generation TPP underwent the following modifications in 1987 : the circular thrust plate was made oval to better fit the femoral neck, the thrust plate was made of titanium-alloy (TiAlNb) and cobalt-chromium-molybdenum (CoCrMo) instead of CoCrMo alone and the shape of the lateral plate was altered to prevent it from moving proximo-laterally and to prevent breakage of the screw-arms through which the screws were drilled. There is no hydroxyapatite coating. A total of 102 second generation TPPs were implanted between 1988 and 1991. From 1992 onward a third-generation TPP was produced. As of the 1990's it was generally accepted that a smaller head diameter would give less polyethylene wear. Therefore modification of the second generation TPP included a smaller head (28 mm) and neck diameter. To rationalize the production process, the third generation TPP consisted of a mandrel and thrust plate in one piece. The texture of the underside of the thrust plate is corundum blasted to enhance bone ongrowth. The bolt is forged CoCrMo. There are three thrust plate sizes : 44, 40 and 38 mm, and the bolt is also produced in three different lengths : 73, 81 and 89 mm.

PATIENTS AND METHODS

We performed a retrospective case series analysis between 2009 and 2013. We investigated 36 third-generation TPPs implanted in 34 patients between July 1997 and December 2000. The age range at operation was 38-61 years (mean : 51 ± 6.4 years). Of all patients 59% were male. The indication for total hip arthroplasty was primary osteoarthritis in 20 patients (56%), idiopathic femoral head necrosis in 8 (22%), hip dysplasia in 3 (8%), posttraumatic osteoarthritis in 2 (6%) and rheumatoid disease (M. Bechterew and SLE) in 3 (8%) patients. No patients were excluded from this group. We chose not to evaluate patients operated after 01-01-2000 in order to achieve a long follow-up period. All patients gave informed consent to participate in this study.

All patients had undergone at least 6 months of conservative therapy including oral analgesics, physiotherapy and weight reduction. Two orthopaedic surgeons (PB and JH) performed the operations. In all cases they aimed to create a caput-collum-diaphysis (CCD) angle of 130° ; the TPP was combined with a monoblock cementless Morscher press-fit acetabular component (Zimmer, Winterthur, Switzerland) in all cases. Head size was 28 mm.

Endpoints and secondary outcome measures

The primary endpoint was reoperation-free survival. Secondary outcome measures were clinical and radiological results. Clinical results were analysed using the Harris Hip Score (HHS) and range of motion (ROM) (*1,10,18,21*). The HHS is reported as 90-100 for excellent results, 80-89 being good, 70-79 fair, 60-69 poor, and below 60 a failure. The ROM was measured using a goniometer. PA and axial radiographs were analysed for possible radiolucencies and hypertrophy at the zones described by Fink (*6*), and for change in the CCD angle. Prosthesis loosening was defined as radiolucency exceeding 1mm. The proximal femur was divided into 13 different zones of radiolucency (Fig. 2) : 1. Radiolucency

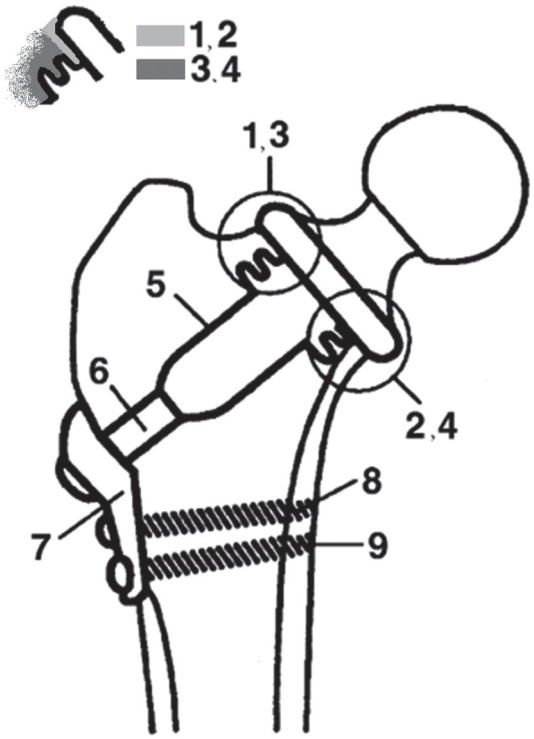

Fig. 2. — Zones of possible radiolucencies. Zones 1 and 2 correspond to the area directly under the thrust plate.

directly under the thrust plate, cranially ; 2. Radiolucency directly under the thrust plate, caudally ; 3. Radiolucency at the TPP-ribs, cranially ; 4. Radiolucency at the TPP-ribs, caudally ; 5. Radiolucency around the TPP ; 6. Radiolucency around the TPP-bolt ; 7. Radiolucency under the lateral plate ; 8. Radiolucency at the cranial plate-screw ; 9. Radiolucency at the caudal plate-screw ; A. Thinning of the cortex of the femoral neck cranially ; B. Thinning of the cortex of the femoral neck caudally ; C. Hypertrophy of the calcar ; D. Hypertrophy under the lateral plate.

Complications (dislocation, periprosthetic fracture, infection, pressure sores, thromboembolism, pneumonia, and cardiologic complications) were documented. Results of the acetabular component will not be described in this article.

Three patients were lost to follow-up. Two of them had died of causes not related to the arthroplasty. In the third case, clinical and radiological data could not be obtained ; traveling distance was the only reason for his absence. Therefore the mean HHS and ROM were calculated over 33 hips.

Statistical analysis

Statistical analysis was performed using IBM SPSS 20.0.0. Reoperation-free survival was studied with the use of a Kaplan Meier curve. HHS and ROM are presented as mean ± standard deviation (SD).

Surgical technique

Under spinal anaesthesia, the patient was placed in the lateral decubitus position. A straight lateral approach was made. Distal to the greater trochanter, the proximal attachment of the lateral vastus muscle was incised in the direction of the muscle fibers to create sufficient space for the lateral plate of the TPP under the muscle. A 4.5 mm hole was then drilled through the lateral femoral cortex. Arthrotomy was performed and the hip was dislocated anteriorly. A Kirschner wire and angle-measuring device were used to check for the possibility of having a CCD-angle of 130°. The femoral head was resected after osteotomy of the neck in a plane perpendicular to its axis. With an aiming device, a central hole was drilled from the lateral cortex through the femoral neck. The acetabulum was reamed and the acetabular component was placed. With the leg in external rotation, the size of the thrust plate was determined. The cancellous bone of the femoral neck was then compressed with a rasp. The TPP was introduced through gentle knocking to allow the bone to adapt progressively to compression. The TPP screw was fixed through the lateral plate in the thrust plate. Two cortical screws secured the lateral plate. A ceramic femoral head was placed ; the hip was relocated and checked for stability. The wound was then closed. Postoperative management consisted of 6 weeks 10% weight bearing.

RESULTS

The follow-up period ranged from 108 to 178 months (mean : 143 months (11.9 ± 1.6 years) for patients who did not require a reoperation. Two patients died from unrelated causes. One of these two patients had undergone revision arthroplasty before his death : the other patient had no problems with the TPP. Regarding the third case that was lost to follow-up, his current orthopaedic surgeon has no clinical or radiological suspicion of aseptic loosening, 9 years postoperatively.

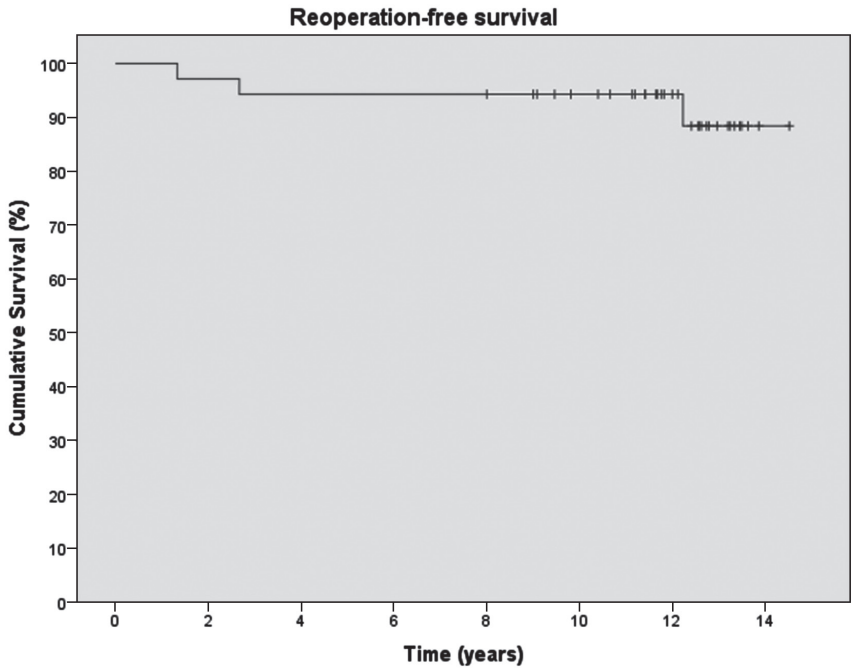

Fig. 3. — Reoperation-free survival Kaplan-Meier curve of the 36 TPPs

Primary endpoint

Reoperation-free survival was 88.9% after 11.9 years (Fig. 3). Four (11.1%) reoperations were performed ; three of these were revisions. The revisions were performed using a Cementless Spotorno (CLS) stem (Zimmer, Winterthur, Switzerland), normally used for primary total hip replacement.

The first patient who underwent a revision arthroplasty was reoperated on after 32 months. His history includes a left acetabular fracture (at the age of 44) and alcohol and nicotine use. He developed femoral head necrosis and received a TPP at the age of 48. It is unsure whether he complied with the instruction recommending partial weight bearing during the first 6 weeks. Eleven months postoperatively he returned with pain complaints. Radiological examination showed progressive varisation of the TPP. A revision arthoplasty was performed. Alcohol and nicotine use may have played a role in the aetiology of this aseptic loosening.

The second patient was 49 years of age when he received a TPP on the left side for femoral head necrosis possibly induced by steroid use ; his history included seronegative M. Bechterew. One year later, he underwent a similar arthroplasty of his right hip. One and a half months later he developed pain about the left hip. Radiological evaluation showed varisation of the left TPP. A revision arthroplasty with a CLS-stem was performed on the left hip 16 months after the index operation. This stem also had to be revised because of loosening, 41 months after implantation. An undiagnosed low-grade infection may have been the cause of the early failure of the left TPP and CLS. Before this reoperation, the serum C-reactive protein was 76 mg/l ; the diagnostic work-up did not include bone scintigraphy nor an image guided joint aspiration and culture. Peroperative culture was negative, but the femoral revision was performed after administration of (standard) pre-operative antibiotics. The revision of the CLS was performed with a larger CLS stem and bone impaction grafting. This remains successful, 7 years after the second revision.

The third patient received a TPP for primary hip osteoarthritis on the right side at the age of 54. Six

months later, she developed a femoral fracture just a few millimeters distal to the lateral plate. The TPP plate was replaced by a longer six-hole TPP plate to bridge the fracture without revision of the TPP itself. This type of fracture has been reported earlier (*5,17,22*). She recovered without further complications.

The fourth patient, who underwent a reoperation, received a TPP at the age of 39. He had primarily undergone open reduction and internal fixation of an acetabular fracture with resection of the femoral head. He developed a slow progressive varisation of the TPP, which started 25 months postoperatively. After being asymptomatic (with a HHS of 84.2) for several years, he developed progressive pain 14.8 years postoperatively, and therefore underwent a revision procedure of the TPP.

Secondary outcome measures : clinical and radiological results

Postoperative HHS ranged from 35.9 to 100 (mean : 88.2 ± 14). Physical examination of the cohort showed the following average range of motion : flexion 109° ± 15°, extension 12° ± 10°, external rotation 29° ± 13°, internal rotation 21° ± 9°, abduction 24° ± 15°, adduction 23° ± 11°. Upon specific inquiry, 16 patients (44%) said they experienced some pain at the lateral side of the hip, mostly when lying in bed on the operated side. Something as simple as a pillow would give relief. Mean HHS of these 16 patients is 83 and one patient even has a HHS of 100.

Three patients had a HHS lower than 70. The following description includes details of these three patients.

The first patient had a HHS of 35.9 after 9 years. She received a TPP at the age of 60. Her medical history includes restrictive pulmonary disease, a coronary artery bypass, diabetes ; her BMI is 39. A traumatic dislocation of her hip occurred 7 years postoperatively ; its was reduced by closed manipulation. Nine years postoperatively the ROM of the hip was good, there were no radiological signs of loosening and the CCD angle was unchanged. Her general condition may have negatively influenced her HHS.

The second patient had a HHS of 59.7. His medical history includes multiple sclerosis (MS), a cerebral vascular accident (CVA) 7 years postoperatively, diabetes, and vascular encephalopathy. He currently lives in a nursing home. He did not mention any hip pain and could walk for 30 minutes before his CVA. Ten years postoperatively the ROM of the hip was good. His comorbidities may have influenced his HHS.

The third patient had a HHS of 63. She received a TPP at the age of 55. Her medical history includes a coronary stent and mild lumbar disc and facet degeneration. Eight years after her hip arthroplasty, she sustained a lower-leg fracture on the ipsilateral side, which was treated conservatively. She states that this has substantially influenced her mobility. She has no complaints about her TPP. The low HHS is probably caused by her limited mobility, which she claims started after her lower-leg fracture. Physical examination of the hip (9.8 years postoperatively) showed a good ROM. There were no radiological signs of loosening, and the CCD angle was unchanged.

Radiolucencies (Fig. 2) never exceeded 1 mm. Radiolucencies occurred at the following zones : directly under the thrust plate (zone 1 (16%) and zone 2 (9%), under the TPP-ribs (zone 3 (3%), and in 56% radiolucencies were seen cranial and caudal to the TPP-bolt (zone 6). Notable is the frequent change in morphology of the femoral neck (A and B in Fig. 2). Resorption of the cortex under the thrust plate occurred in 35%, both cranially and caudally. Hypertrophy of cancellous bone at the calcar was seen in all but one patient (Fig. 4). The trabecular metaphyseal bone clearly shows increased density and projects towards the TPP-ribs. Hypertrophy under the lateral plate was seen in 64%. The position of the TPP-bolt in the femoral neck was unchanged in all 36 TPPs. Mean CCD angle change during follow-up was 0.6° (95% CI : -1.3 to +2.5). A paired samples t-test showed no significant change in the CCD angles ($p = 0.517$). The TPP's that showed radiolucencies showed no clinical signs of aseptic loosening.

No septic complications occurred, although two patients were successfully treated for a superficial cellulitis with oral antibiotics. One traumatic dislo-

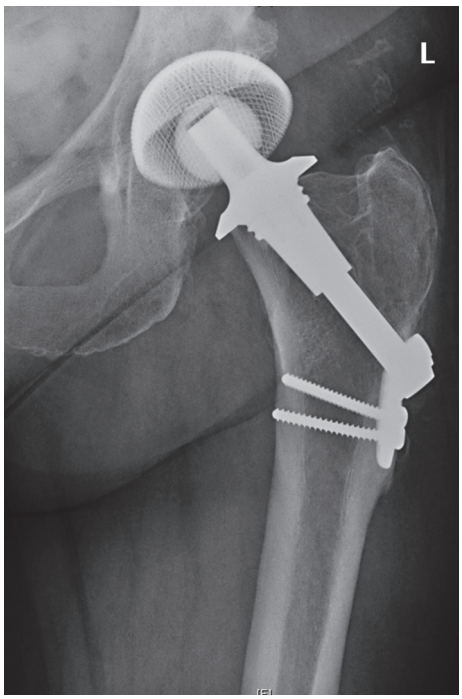

Fig. 4. — Radiograph X-ray of a TPP ; hypertrophy of cancellous bone at the calcar.

cation occurred, 7 years postoperatively ; closed reduction took place. Pressure sores occurred in 5 patients (14%). This did not delay rehabilitation. We assume that early weight bearing could possibly prevent this complication (*21*). No other (pulmonary, cardiac or thromboembolic) complications occurred.

DISCUSSION

Physiological loading of the proximal femur and preservation of the intramedullary channel are important in THA, especially in young patients. This can be achieved with the TPP. The reoperation-free survival was 88.9% with a mean follow-up of 11.9 years in this series. Our 10-year reoperation-free survival rate was 91.7%, which complies with the criteria of the National Institute for Health and Clinical Excellence (*15*). This is a favourable result, considering that our population was relatively young and active. The learning curve of the two surgeons involved should also be taken into account. Our reoperation rate is reasonably low, considering our longer follow-up (Table I). The Swedish Hip Arthroplasty Register of 2010 showed a reoperation-free survival of approximately 94% after 12 years for conventional THAs (*8*). The Norwegian Arthroplasty Register 2010 showed a reoperation-free survival of approximately 87% after 12 years (*16*).

Comparing our results with the TPP to other short-stemmed total-hip prostheses, in 2011 Ettinger *et al* showed a higher reoperation-free survival rate of 100% of the Nanos prosthesis (Smith & Nephew, London, UK) at a mean follow-up of 52 ± 0.7 months, in a case series with a mean age of 63 ± 8.3 years (*4*). Toth *et al* presented a study in 2010 of 41 cases that received the Proxima prosthesis (DePuy, Warsaw, IN, USA). Mean age was 49 years and mean follow-up was 26 months. No aseptic loosening took place ; merely one intra-operative fracture was treated with internal plate fixation (*20*).

A weakness of our study is that it is a retrospective analysis of a small number of arthroplasties. A potential bias also lies in the fact that the authors themselves performed the analysis. More specifically, the hypertrophy measurements were made on conventional X-ray films, whereas Dual-emission X-ray absorptiometry (DEXA) would have been more precise. However, the bias mentioned above could not have influenced the reoperation rate.

Three out of four revisions occurred early, between 12 and 32 months postoperatively. Possibly patient selection could prevent these early failures. Niggemeyer *et al* showed that patients with rheumatoid disease have a higher risk of TPP failure (*17*). Because our three early failures were very dissimilar, and because our cohort is small, we are reluctant to advise as to which patients definitely should not receive a TPP.

The high mean ROM and a mean HHS of 88.2 shows a good clinical result. Obviously, this has been positively influenced by the relatively young age of our patients. Pain at the lateral side of the hip occurred frequently. This has been described earlier (as “leash pain”), and should preferably not be treated surgically (*2,19*). We acknowledge that the 44% occurrence of leash pain is a substantial part of our case series, but it seems to have a minimal effect on the HHS of these patients. In contrast to our result,

Table I. — Reoperation-free survival of the current study in comparison to the literature

Reference	Mean follow-up / follow-up range (months)	Reoperation free survival (n)
Corner *et al* (3)	71	95% (41)
Buergi *et al* (2)	58	98.1% (102)
Ishaque *et al* (11)	72	95.1% (70)
Jacob *et al* (13)	72-144	98% (102)
Fink *et al* (6)	26	97.2% (214)
Karatosun *et al* (14)	28-87	95.8% (71)
Zelle *et al* (23)	26	93.1% (58)
Niggemeyer *et al* (17)	120	73.8% (47)
Yasunaga *et al* (22)	156	97% (87) and 90.3% (79)
Current study	*143 (108-178)*	*88.9% (36)*

Yasunaga found only 2.7% of patients with lateral thigh pain (*22*). A more meticulous placement of the lateral plate under the lateral vastus muscle might prevent this complication. We believe that the discomfort is caused by the prominence of the lateral plate, and not by micromotion.

In theory, the TPP has a risk for impingement because of the broad thrust plate, cranially. However, we have not encountered this problem.

The interesting osseous morphological changes that characterise the TPP have been described extensively (*2,6,11,14,19,23*). Our radiological findings reflect these results. Adaptive bone remodelling of zones A and B (Fig. 2) has caused cancellous bone hypertrophy of the calcar in all but one of our patients. Formation of trabeculae in the direction of the TPP-ribs was clearly seen. The atrophy seen directly under the thrust plate and hypertrophy at the calcar indicates that the function of the thrust plate may itself be only temporary. Directly postoperatively the lateral plate and the thrust plate give compression and therefore fixture of the TPP onto the femoral neck (primary stability), until full ingrowth of cancellous bone onto the ribs of the TPP has taken place (secondary stability) (*14*). We believe the effect of bone remodelling, particularly the hypertrophy at the calcar, is of high value in the case of possible revision arthroplasty. Furthermore, radiolucency around the TPP-bolt might have been prevented with a hydroxyapatite coating.

Our findings are in line with most of those in earlier studies on the TPP. Our results have shown a favourable reoperation-free survival rate, good functional results and valuable radiological changes in a young and demanding patient group. Therefore we continue considering this implant as an alternative to stemmed total hip prosthesis for young patients.

REFERENCES

1. **Bereiter H, Buergi M, Schenk R.** Finite element investigations of the proximal femur after implantation of the thrust plate prosthesis compared with findings in a postmortem histological specimen and in radiological follow-up examinations. In : Huggler AH, Jacob HAC (eds). *The Thrust Plate Hip Prosthesis*. Springer, Berlin, 1997, pp 48-62.
2. **Buergi ML, Stoffel KK, Jacob HA, Bereiter HH.** Radiological findings and clinical results of 102 thrust plate femoral hip prostheses : a follow-up of 2 to 8 years. *J Arthroplasty* 2005 ; 20 : 108-117.
3. **Corner JA, Rawoot A, Parmar HV.** The thrust plate prosthesis in the treatment of osteoarthritis of the hip. Clinical and radiological outcome with minimum 5-year follow-up. *Hip Int* 2008 ; 18 : 88-94.
4. **Ettinger M, Ettinger P, Lerch M *et al.*** The NANOS short stem in total hip arthroplasty : a mid-term follow-up. *Hip Int* 2011 ; 21 : 583-586.
5. **Fink B, Siegmuller C, Schneider T *et al*.** Short- and medium-term results of the thrust plate prosthesis in patients with polyarthritis. *Arch Orthop Trauma Surg* 2000 ; 120 : 294-298.
6. **Fink B, Wessel S, Deuretzbacher G, Protzen M, Ruther W.** Midterm results of "thrust plate" prosthesis. *J Arthroplasty* 2007 ; 22 : 703-710.
7. **Fottner A, Schmid M, Birkenmaier C *et al.*** Biomechanical evaluation of two types of short-stemmed hip prostheses compared to the trust plate prosthesis by three-dimensional measurement of micromotions. *Clin Biomech* 2009 ; 24 : 429-434.

8. **Garellick G, Karrholm J, Rogmark C, Herberts P.** Swedish Hip Arthroplasty Register annual report 2010.
9. **Goto T, Yasunaga Y, Takahashi K, Ochi M.** Biomechanical analysis and quantitative analysis of bone scintigraphy on thrust plate hip prosthesis. *Arch Orthop Trauma Surg* 2004 ; 124 : 357-362.
10. **Harris WH.** Traumatic arthritis of the hip after dislocation and acetabular fractures : treatment by mold arthroplasty : an end-result study using a new method of result evaluation. *J Bone Joint Surg* 1969 ; 51 : 737-755.
11. **Ishaque BA, Wienbeck S, Basad E, Stürz H.** [Clinical and radiological results of the thrust plateprosthesis in patients with aseptic necrosis of the femoral head.] (in German). *Z Orthop Ihre Grenzgeb* 2005 ; 143 : 622-630.
12. **Jacob HAC.** Biomechanical principles and design details of the thrust plate prosthesis. In : Huggler AH, Jacob HAC (eds). *The Thrust Plate Hip Prosthesis*. Springer, Berlin, 1997, pp 25-47.
13. **Jacob HAC, Bereiter HH, Buergi ML.** Design aspects and clinical performance of the thrust plate hip prosthesis. *Proc Inst Mech Eng H* 2007 ; 221 : 29-37.
14. **Karatosun V, Unver B, Gunal I.** Hip arthroplasty with the thrust plate prosthesis in patients of 65 years of age or older : 67 patients followed 2-7 years. *Arch Orthop Trauma Surg* 2008 ; 128 : 377-381.
15. **Lankester BJA, Smith LK, Spencer RF.** Total hip replacement and NICE : new guidelines need to address several areas of uncertainty. *BMJ* 2005 ; 330 : 318-319.
16. **Nasjonalt Register for Leddproteser.** The Norwegian Arthroplasty Register. 2010.
17. **Niggemeyer O, Steinhagen J, Ruether W.** Lont-term results of the thrust plate prosthesis in patients with rheumatoid arthritis : a minimum 10 year follow-up. *J Orthop Sci* 2010 ; 15 : 771-780.
18. **Soderman P, Malchau H.** Is the Harris hip score system useful to study the outcome of total hip replacement ? *Clin Orthop Relat Res* 2001 ; 384 : 189-97.
19. **Steens W, Daele R, Simon U, Goetze C.** Clinical and radiological mid-term results of the thrust plate prosthesis. *Int Orthop* 2009 ; 33 (6) : 1519-1524.
20. **Toth K, Mecs L, Kellermann P.** Early experience with the DePuy Proxima™ short stem in total hip arthroplasty. *Acta Orthop Belg* 2010 ; 76 : 613-618.
21. **Unver B, Karatosun V, Gunal I, Angin S.** Comparison of two different rehabilitation programmes for thrust plate prosthesis : a randomized controlled study. *Clin Rehabil* 2004 ; 18 : 84-91.
22. **Yasunaga Y, Yamasaki T, Matsuo T *et al*.** Clinical and radiological results of 179 thrust plate hip prostheses : 5-14 years folluw-up study. *Arch Orthop Trauma Surg* 2012 ; 132 : 547-554.
23. **Zelle BA, Gerich TG, Bastian L *et al*.** Total hip arthroplasty in young patients using the thrust plate prosthesis : clinical and radiological results. *Arch Orthop Trauma Surg* 2004 ; 124 : 310-316.