Process optimized minimally invasive total hip replacement

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Abstract

The purpose of this study was to analyse a new concept of using the the minimally invasive direct anterior approach (DAA) in total hip replacement (THR) in combination with the leg positioner (Rotex- Table) and a modified retractor system (Condor). We evaluated retrospectively the first 100 primary THR operated with the new concept between 2009 and 2010, regarding operation data, radiological and clinical outcome (HOOS). All surgeries were perfomed in a standardized operation technique including navigation. The average age of the patients was 68 years (37 to 92 years), with a mean BMI of 26.5 (17 to 43). The mean time of surgery was 80 min. (55 to 130 min). The blood loss showed an average of 511.5 mL (200 to 1000 mL). No intra-operative complications occurred. The postoperative complication rate was 6%. The HOOS increased from 43 points pre-operatively to 90 (max 100 points) 3 months after surgery. The radiological analysis showed an average cup inclination of 43° and a leg length discrepancy in a range of +/- 5 mm in 99%. The presented technique led to excellent clinic results, showed low complication rates and allowed correct implant positions although manpower was saved.

Introduction

In recent years, the importance of atraumatic procedures with an aim to fasten patient rehabilitation is still growing. Therefore, current issues in hip replacement no longer focus solely on the choice of implants, but also on less invasive approaches to the hip, which can be shown by the increasing number of publication about less invasive approaches. Trials concerning conventional hip replacements show good long term results. Minimally invasive techniques can significantly shorten rehabilitation times following total hip replacement.[1,2] There is now a general consensus that not alone the length of skin incision but the preservation of muscles and tendon insertions lead to better functional results.

Mini-posterior approaches (modified Moore approach), the direct lateral approach (Hardinge), the antero-lateral approach (modified Watson-Jones, Röttinger), the direct anterior approach (modified Smith-Petterson approach) and the direct medial approach (Thomas) have become established minimally invasive techniques (Figure 1). The aim of all these procedures is to minimize iatrogenic damage of muscle and soft tissue, to reduce blood loss and enable faster rehabilitation.[3]

For economic reasons in current clinical environment, very high expectations are placed in terms of treatment quality, short patient hospitalisation and fast rehabilitation time.

Minimally invasive techniques are used more and more frequently to reduce hospitalisation times and to save costs. Excellent outcome data and patient safety must be ensured with precise intra-operative application despite more restricted views and the increasing difficulty in recruiting staff. This has led to the development of new positioning devices and the concept of combining surgery with retractor systems.

The direct anterior approach (DAA) has been used in our department for hip surgery since 2005. This approach does not require a detachment or splitting of the abductor muscles, causes less muscle damage, thus allows the use of a navigation system and intra-operative x-ray control for excellent cup positioning.[4] The aim was to analyse our surgical concept in combination with this established approach in the first 100 patients who underwent a THR. This was achieved by standardising the surgical technique and implementing the new developed positioning device and the adjusted retractor system.

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Key words: total hip replacement, minimally invasive anterior approach, Rotex-Table, navigation system, economic reasons, ergonomic working process.

Competing interests: the development and production of the new leg positioner was realized by Condor Medicaltechnik, Salzkotten, Germany, while advice for conception and for clinical realization was mainly given from the orthopaedic department in Brig. All patent and trademark rights are lying entirely in the hands of Condor Medicaltechnik, who is selling the product, while the senior author, Dr. Ottersbach, is giving information on the website www. rotex-table.com and is reference for clinical practice. The authors don't have any contracts with the company and do not receive any financial benefits. The presented study has been approved by the local ethical committee of Hannover Medical School, which again follows the World Medical Association's Declaration of Helsinki.

Contributions: PG, acquisition, analysis and interpretation of data, study conception, design, manuscript writing; MO, conception and design; FT, conception and disign, critical revising; GA, RB, acquisition of data; BI, acquisition of data, critical revising; AO, study conception and design, analysis and interpretation of data, final approval.

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Materials and Methods

The initial results of the first 100 total hip replacements were analysed. All patients were operated using the DAA, in combination with the new developed leg-positioning device and a modified retractor system (Condor Medical Technik, Salzkotten, Germany). Included were all patients who underwent a total hip replacement between February 2009 and February 2010 with the process-optimized implantation method. To objectify patient satisfaction and quality of surgery the pre-operative and the 3 month post-operative and one year post-operative outcome were recorded using the Hip disability and Osteoarthritis Outcome Score (HOOS). The post-operative conventional x-ray images were also evaluated in terms of cup inclination, lateralisation, offset, and leg length. The inter-ischiacal line was used to measure cup inclination and leg length in comparison with the greater trochanter. Offset was defined as the distance center from femoral head to the femoral stem axis. Lateralisation was also measured from the caudal tip of the teardrop contour to the femoral stem axis.[5]

To estimate the outcome quality intra-operative blood loss, the type and frequency of complications, surgery time, time of hospitalisation and rehabilitation time were recorded.

Hip Osteoarthritis Outcome Score (HOOS)

The HOOS, first described in 2003 as an improvement to the widely used Western Ontario and MacMaster Universities Osteoarthritis Index (WOMAC) and a reliable and efficient tool to assess total hip replacements (THR), has 5 relevant parameters: Pain (P), Symptoms (S) - including impaired mobility and range of motion -, Activity limitation in daily living (A), Sport and Recreation function (SP) and Hip related quality of life (Q) (min. 0 points, max. 100 points).[6,7]

Patient positioning with the new developed leg positioner

Rotex-Table

The Rotex-Table (Condor Medical Technik, Salzkotten, Germany) is based on a vertical column, mounted on a mobile four-legged stand and connected to the extension table with an adapter mechanism (Figure 2). The Rotex-Shoe is used to secure the extremity to be operated with the system. This is the first positioning that has an anatomically beneficial design combining the use of quick-lock clips and carbon technology (Figure 3).

A motor drive, controlled by the surgeon with a foot pedal, is used to raise and lower the extremity. This function can also be applied using a switch mechanism and manually on the column. For safety reasons lowering and simultaneous extension of the extremity which can be set up via a thread pole is automatically blocked, so that extreme tissue stretching and resulting nerve damage, for example, can be avoided. External rotation of the leg is manually set by the surgeon and automatically fixed in the desired position using a finely adjustable stop mechanism.

In practice the patient's thigh is supported by an x-ray permeable positioning roll positioned at the level of the picket between the patient's legs and about 3-5 cm above the table level. This positioning roll acts as a hypomochlion, to facilitate exposure of the proximal femur when the extremity is lowered. The healthy extremity is slightly abducted.

The retractor system

A retractor system (Condor Medicaltechnik, Salzkotten, Germany) was adapted to the concept to allow a further improvement of the intra-operative process. The system is secured to the extension bar of the operating table. A curved arm is applied in a cranial-lateral plane, and a straight bar is applied distally. The retractor system is aligned with the anterior superior iliac spine. Clamps are secured to both arms, to which the usual levers are later secured, ensuring an intra-operatively stable working position (Figure 4).

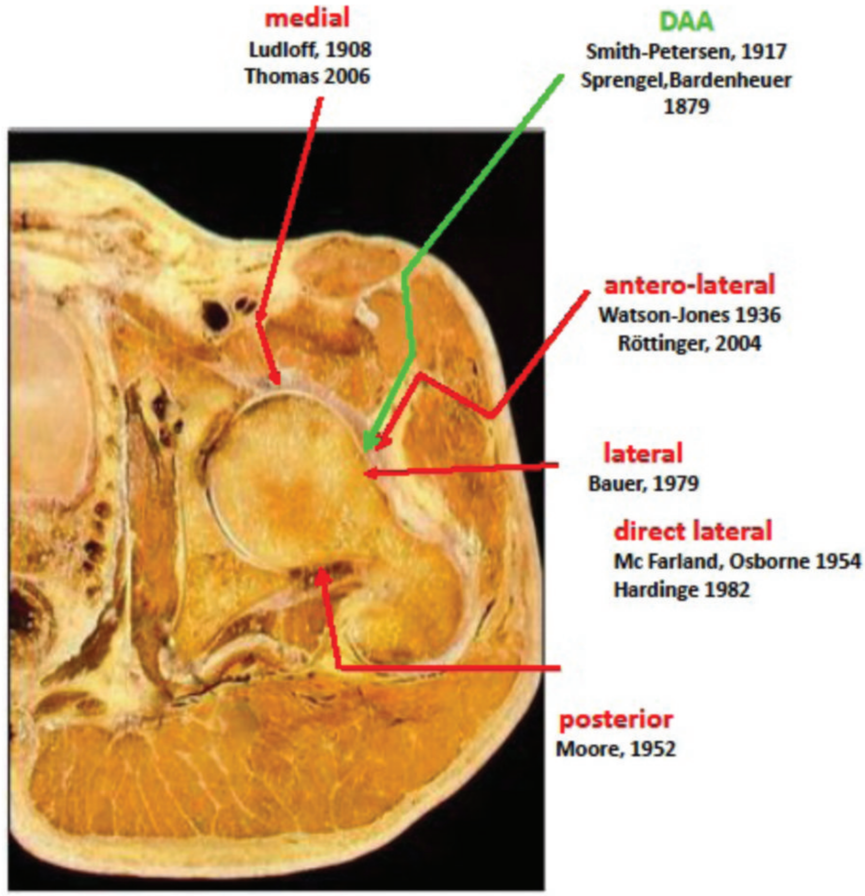

Figure 1. Approaches to the hip joint.

Navigation control

Two optoelectronic navigation systems were used to allow the surgeon an intra-operative control of leg length, lateralisation of the femur, and offset measuring. The open system of Medacta was used to control offset and leg length when Medacta or Mathys products were implanted. All Aesculap prostheses were performed with the Orthopilot navigation system by B. Braun (Medacta, International SA, Strada Regina, Switzerland and B. Braun, Aesculap, Tuttlingen, Germany).

Surgical technique

The 8 cm skin incision is made 1-2 cm infero-lateral to the anterior superior iliac spine following the course of the tensor *fasciae latae* muscle (Figure 5). The incision is made towards the fibula head. The subcutaneous tissue is then separated and the fascia of the tensor *fasciae latae* muscle opened and prepared between the tensor *fasciae latae* muscle and the *rectus femoris* muscle. Surrounding muscles and the cutaneus femoris lateralis nerve were preserved by a blunt preparation into the depth onto the capsule. The *rectus femoris* muscle is then medially pulled aside and the transverse branches of the femoral circumflex artery are clamped. After using the standard retractors that are connected to the condor system the surgeon has a direct view of the ventral capsular structures of the hip joint. Three Hohmann retractors are used for a good exposure of the anterio capsule. The ventral joint capsule is resected and the femoral neck is osteotomised at the planned level to remove the head. To expose the *acetabulum* two retractors are applied to the medial and lateral *acetabulum*. After cup reaming to the planned size, the cup can be implanted using x-ray and a navigation system (Figure 6).

To ensure adequate exposure of the femoral cavity, a step-by-step capsular release is performed. The surgeon initially sets external rotation of the foot to about 90°, while he is getting a feedback on the tissue tension.

The capsular release is performed in three steps: i) electric incision along the calcar to the lesser trochanter. Then the surgeon carefully externally rotates the leg further; ii) electrical incision in the extension of the osteotomised, dorsal femoral cortex to the medial boundary of the greater trochanter rotated medially in situ. The leg is then carefully further externally rotated by the surgeon and if necessary the release is extended. A

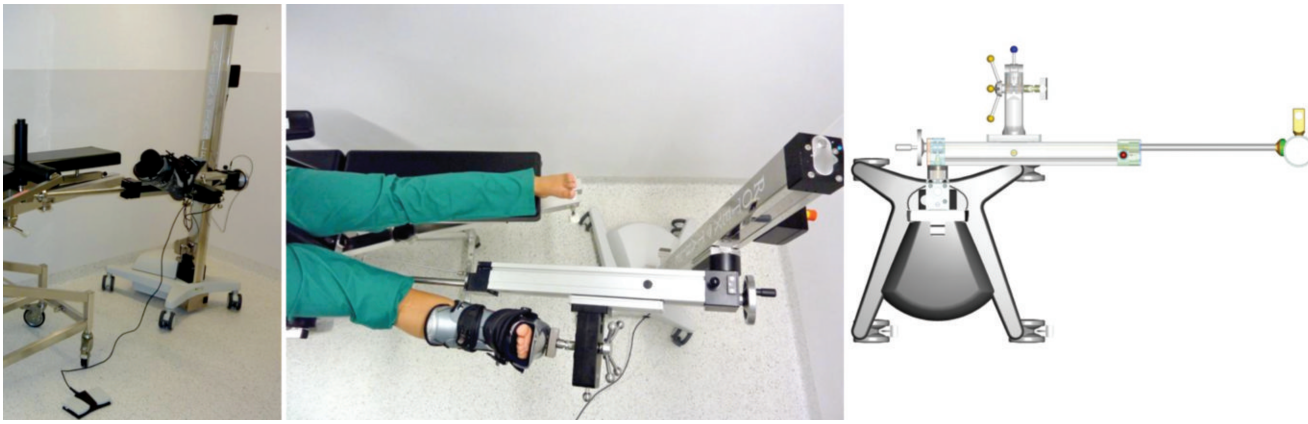

Figure 2. Rotex-table.

Figure 3. Rotex-shoe.

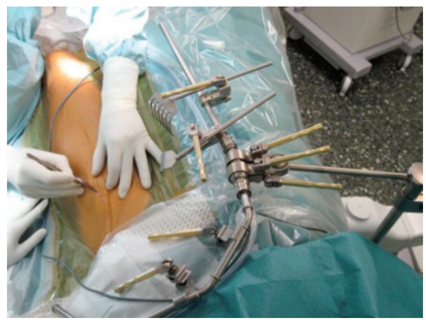

Figure 4. Condor gold line-retractor.

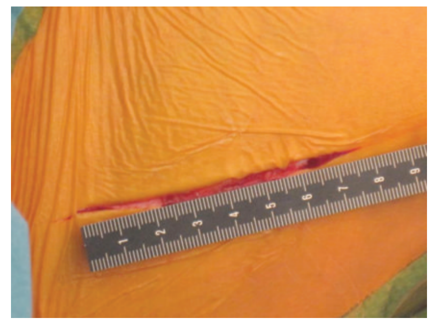

Figure 5. Skin incision.

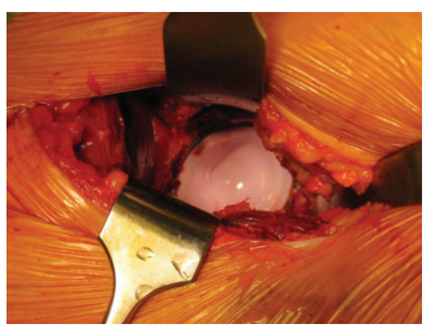

Figure 6. Cup and inlay.

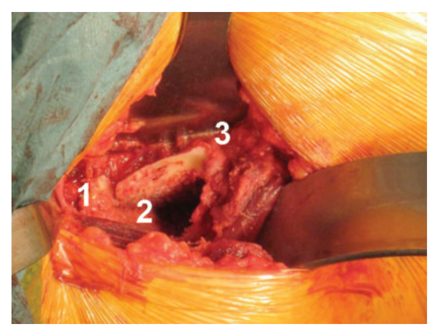

Figure 7. Femur exposure. 1: major trochanter, 2: medullary cavity, 3: minor trochanter.

bone hook is used to check if the proximal femur can be raised sufficiently. It must be possible for the greater trochanter to slide at the *acetabulum*; iii) after slightly lowering the leg while pulling on the retractor on the femur and applying a Retractor behind the greater trochanter, the third release in the region of the trochanteric fossa is performed vertical to the second release to release the dorsal capsule parts.

External rotation has to be extended before the final lowering of the leg for the preparation of the femur, until the tip of the osteotomised calcar corresponds at least to the sagittal axis of the patient and can even be positioned in slight external rotation.

The leg is now lowered with the motorised foot pedal control, while pulling with the bone hook on the femur. The leg is lowered until internal rotation of the osteotomised level of the femur can be identified and the tip of the calcar is rotated medially over the patient's sagittal axis. The stem exposure can be supported by adducting of the leg if necessary (Figure 7).

The femoral trial prosthesis can be easily repositioned following femoral preparation using the Rotex table. The extended leg must not cause joint luxation at 90° external rotation.

The procedure described above for exposing the femoral cavity and subsequent reposition can be repeated swiftly using the Rotex-Table untill implantation of the final prosthesis is performed (Figures 8, 9). These manipulations can be done by the surgeon without further assistant staff.

After implantation the fascia and skin is closed. Post-operatively patients are quickly mobilised with pain-adapted full weight bearing with underarm supports on day one.

All THR were carried out by a single surgeon with one medical assistant and one nurse.

Results

The average age of the 50 women was 70.7 (range from 51 to 92), and the average BMI was 26.4 (range from 17 to 43). The average age of the 50 men was 65.2 (range from 37 to 84) and the BMI was 26.6 (range from 21 to 34). The surgical indication in 92 cases was primary osteoarthritis, there were four cases of femroal head necrosis, two cases of secondary osteoarthritis following proximal femur fracture, one case of femoral neck fracture, and one of dysplastic osteoarthritis (Table 1). Different implants were used for THR (Table 2). The average operation time was 81 min. (range from 55 to 130 min). Intra-operative blood loss averaged 511.5 mL (range from 200 to 1000 mL). A cell saver was used in 80 cases. Eleven patients were given two erythrocyte concentrates each to treat postoperative anaemia.

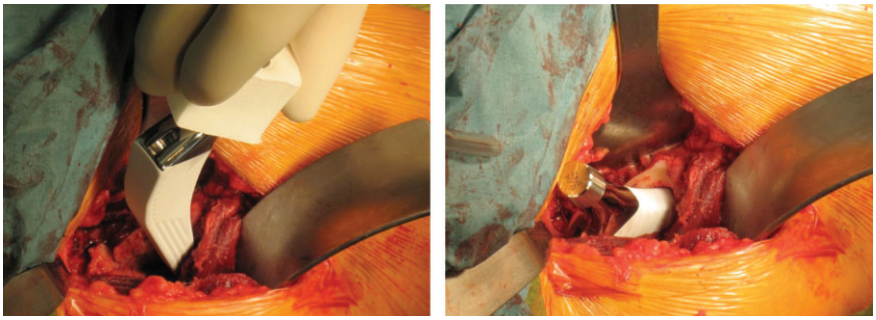

Figure 8. Shaft.

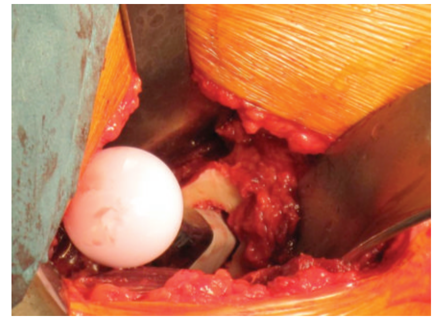

Figure 9. Final implant, 28 mm head.

All patients were mobilised on the first post-operative day with underarm supports, with full weight bearing permitted. After an average hospital stay of 8 days all patients were independently mobile with sticks, and most were already able to walk some steps without aids. Largely at the patient's request 31% of patients underwent follow-up treatment in a rehabilitation clinic following their hospital stay (Table 3).

The well-documented good clinical outcomes were also reflected in a high level of patient satisfaction. The evaluation of the HOOS in the 3 month follow-up averaged 90.96 points (value: S, P, A) and 89.59 (value: S, P, A, SP, Q). The values of category SP (sport and rehabilitation) reached 89.98 points and Q (quality of life) scored 85.02 points out of a total of 100. One year after surgery the value slightly rised to 90.88 (value: S, P, A, SP, Q). Pre-operatively the average score was only 42.43 (value: S,P,A) out of a potential score of 100.

85% of the postoperative questionnaires were available for evaluation (Table 3 and Figure 10).

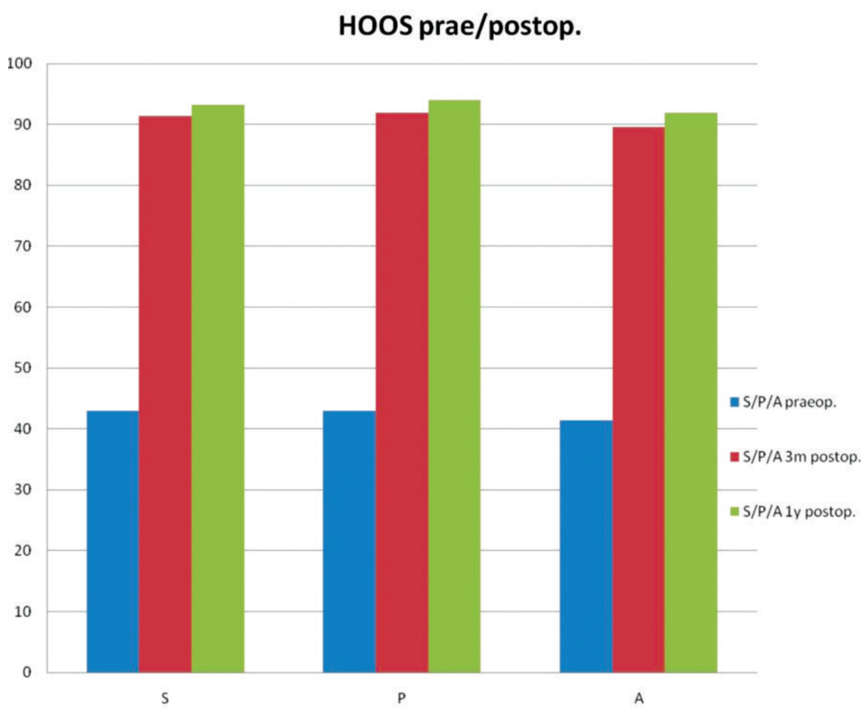

Figure 10. Pre-and post-operative Hip Osteoarthritis Outcome Score: P, pain; S, symptoms; A, activity limitation in daily living.

There were no intra-operative complications. Two patients had transient paresis of the femoral nerve. Another patient had an irritation of the lateral cutaneous femoral nerve. One case of recurrent dislocation was revised with an anterior approach, and successfully corrected by increasing the offset using the Merete system.

In one case, for an unexplained reason, the ceramic inlay fractured; this was successfully revised with the DAA. We observed one case of leg vein thrombosis despite prophylaxis with low molecular heparin. There were no further post-operative complications (Table 4).

All implantations were carried out using navigation systems. The rigid body positioning, the application of reference marks and the scanning of anatomical landmarks were successfully carried out with an anterior approach with the orthopilot from Aesculap and with the Medacta navigation system.

We also used an image converter to check intra-operative positioning of the cup and stem. An ideal cup position was achieved in the majority of cases, as shown in the post-operative measurements on the conventional x-ray images. The cup inclination calculated from these results corresponded to the Lewinnek safe zone at an average of 43.2°, +/- 4.36, (33° - 48°). There was no standardized measuring of the cup antetorsion. Leg length, lateralisation and offset were determined pre-operatively and then post-operatively by measuring the x-ray images. The results were as follows: Pre-operative / post-operative offset 45.8 mm/46.3 mm; Pre-operative / post-operative lateralisation 75 mm/74 mm.

Radiological measuring of leg length confirmed an almost equal length of both legs in 99 cases (difference of +/- 5 mm). There was only one case where there was a relevant difference of -8 mm to the other leg (Table 5).

Discussion

This study report on the results following minimally invasive, process optimized implantation of 100 total hip replacements, using the DAA. The DAA is an approach with a long development history. Based on the first description by Sprengel in 1878 and Bardenheuer in 1907 of the anterior approach over 100 years ago,[8,9] Smith-Peterson published his results in 1917 and 1948.[10,11] There were further modifications, such as Berger's minimally invasive *two incision* technique.[12,13] However, this operative procedure has not gained acceptance. In its place the significance of the *single incision* technique with the anterior approach increased. In 2003 Kennon *et al.* published a retrospective study with a study population of 2132, where the senior authors were able to reflect on experience with over 6000 implanted primary hip replacements.[14,15] DiGioia[16] reported on the navigation controlled anterior single-incision technique. Further publications by Matta, Kennon and DiGioia, Rachbauer and others confirm the benefits of the direct anterior approach.[16-20] The DAA is a low intensity approach. Compared with other approaches the gluteus medius is bypassed with a safety distance and its nerves are also preserved.

When the femoral head has been removed, the DAA also results in an excellent view of the *acetabulum*, which can then be precisely assessed and prepared. With the patient in a supine position, intra-operative radiological control of the cup positioning is facilitated on the one hand, and the navigation can be optimally integrated into the procedure. Another advantage of the DAA is that if revision surgery is required, even in the case of periprosthetic infection, where the prosthesis or components need to be replaced, this can be done with very little trauma, as there is minimum compromise to the soft tissue. Only periprosthetic fractures require an additional lateral incision, which can, however, be made distally to the gluteal muscles.

Femur exposure to apply the rasp and stem are considered to be a surgical challenge when using the DAA. This challenge was tackled by using a standardized release technique and by the development of the new leg positioning system, Rotex-Table. This allows the surgeon to carry out the surgery safely, even in cases of difficult anatomical conditions or in muscular patients.

The products currently on the market did not meet our requirements, as they required positioning staff for the routine use of the positioning aids, which is often difficult to put into practice with a changing surgical team. We also considered it essential that the surgeon should have feedback on the tissue tension resulting from external rotation and to enhance the adjustment options for the leg position. This was possible due to the development of the Rotex-Table. One essential advantage of the Rotex-Table compared to other systems is the direct operation and handling of the table by the surgeon himself. The surgeon can feel the increasing tissue tension with the very finely adjusted external rotation and adjust his release techniques; this provides a greater level of confidence and patient safety. No fractures were reported in the observation period in the stem preparation. An infinitely variable electric foot control allows the surgeon to lower the extremity.

The combination of positioning aid and retractor system, led to a static situs and repeatable operation steps which enabled a more ergonomic working process.

Table 1. Demographic data.

Parameter	Patient data
Hips (n)	100
Age (years)+/- SD, Range	68 +/- 11.8 (37-92)
Gender (m/f)% m	50
Side (right/left)% right	56
Height (cm)+/- SD, Range	169 +/- 8.7 (143-188)
Weight (kg)+/- SD, Range	77 +/- 15.5 (45-115)
BMI (kgm^2)	26.5 +/- 4.9 (17-43)
Navigated hips (%)	100
Pre-operative diagnoses (5)	
Osteoarthritis	92
Dysplasic Osteoarthritis	1
Avascular necrosis	4
Proximal femur fracture / post-traumatic osteoarthritis	3

Table 2. Implants used.

Implant	Number of cases
Quadra-H, Versafit-Cup, ceramic-on-ceramic, cementless, (Medacta, Switzerland)	65
Metha short stem, PlasmaCup, ceramic-on-ceramic, cementless (BBraun, Aesculap, Germany)	21
Excia stem, plasma cup, ceramic-on-ceramic, cementless (BBraun, Aesculap, Germany)	4
Twinsys stem, Selexys Cup, ceramic-on-ceramic (Mathys, Germany)	8
Excia stem, PE cup , metal head (BBraun, Aesculap, Germany)	2

Table 3. Operative data, clinical results.

Operating time+/- SD, Range	81 +/- 14.6 (55-130)
Navigated hips (%)	100
Cell saver (yes/no)% yes	80
Estimated peri-operative blood loss (mL)+/- SD, Range	511.5 +/- 189 (200-1000)
Post-operative transfusion of max 2 erythrocyte concentrates (%)	11
Hospitalisation time (days)+/- SD, Range	8.5 +/- 3.6 (4-26)
Mobilisation on crutches on 2nd post-operative day (%)	98
Mobilisation on crutches within hospitalisation time (%)	100
Rehabilitative follow-up treatment	31
HOOS pre-operative (S, P, A)	42.43 +/- 14.6 (23.3-76)
HOOS 3 months post-operative (S, P, A, SP, Q)	89.59 +/- 10.4 (49.4-100)
HOOS 1 year post-operative (S, P, A, SP, Q)	90.88 +/- 9.6 (52.8-100)

HOOS, Hip Osteoarthritis Outcome Score; P, pain; S, symptoms; A, activity limitation in daily living; SP, Sport and Recreation function; Q, Hip related quality of life.

Testing the stability of the trial prosthesis can be carried out by the surgeon without assistance. Because the Rotex-Table allowes a freely movable leg in several axis, luxation tests in extension and flexion with simultaneously rotation and traction or loading can be realized. For further tests the foot section attached to the Rotex-Table can also be temporarily disconnected.

An extension shoe has been developed to secure the foot; this has an anatomical liner and a carbon shell with velcro fastening. This is connected into the holder of the Rotex-Table, allowing individually adjusted and atraumatic leg positioning, thereby avoiding pressure and nerve damage. This also rules out the risk of rotation strain in the upper ankle joint. In our analysis no bearing damages or other complications with the device had to be noticed.

The portable system can be simply connected to operating tables from various manufacturers and allows space-saving storage. To optimize the working process and to make it more ergonomic, we combined its use with a retractor system adjusted with the use of special extensions. It is simple to use and, first and foremost, ensures a reproducible, static working position with the standard levers. This means that one or even two assistants can be saved, reducing the surgical team to a minimum of a surgeon and one surgical nurse, thereby minimizing the cost of surgery. The procedure is therefore economically favourable, as there is no need for an assistant to operate the positioning table or for a second surgical assistant to be present. An exact cost calculation depends on the hospital and varies from case to case.

If this advantage is not only seen from an economical point of view, the fact that the surgeon is *hands free* provides perfect conditions for training an assistant.

The combination of systematic surgical technique, the new positioning system and the retractor system has produced a successful overall concept, providing economical and ergonomic solution and above all, ensuring a very high level of patient satisfaction. This fact was shown in the evaluation with the HOOS. The HOOS has specific questions to assess patient limitations resulting from osteoarthritis and post-operative results, with questions concerning sport, rehabilitation and quality of life. Therefore the HOOS is considered to be more sensitive than the widely used Harris Hip Score (HHS)[20] and was also favoured above the Hip Outcome Score (HOS) in a current study to assess results following THR.[21]

We consider the average operating time of 81 min., with 15-20 min. on average required for navigation, to be compareble with other studies. In the literature there are plenty of examples of comparable results, but also poorer results. Woolson *et al.* stated an average time of 164 min.[22] for THR with the DAA with a conventional extension table. Kennon *et al.* have an operating time of 131 min.[23] in their 2004 study. Times are similar to those of surgery carried out with other minimally invasive approaches, as shown in the study by Rittmeister and Peters, who report an average time of 80 min. with the minimally invasive posterior and classic anterolateral approach,[24] while Laffose *et al.* report on a time range from 45 to 150 min. with a posterior and anterolateral minimally invasive approach.[25] We believe the longer operating time, with an extra 15-20 min. for navigation, is justified as this method for instance aims to reduce pre- and post-operative leg length and offset or lateralization differences.[26,27]

Blood loss in our study was 511 mL and is also in an acceptable range. Laffosse described blood loss to be approximately 540 mL for the anterolateral minimally invasive approach and 450 mL for the posterior mini-invasive approach.[26] Haaker *et al.* also report on 100 hips operated with the DAA using conventional extension aids and navigation and blood loss was calculated at approximately 690 mL.[28]

Table 4. Complication rates.

Intra-operative complications	0
Post-operative complications (%)	6
Re-operation rate (%)	2
Cup loosening	0
Stem loosening	0
Inlay fracture	1
Hip instability	1
Nerve irritations (Motor temporary / sensitive persistent after 3 months)	2/1
Subsequent bleeding requiring revision surgery	0
Impaired wound healing	0
Venous thrombosis	1
Pulmonary embolism	0
Infection	0

Table 5. Radiology results.

Cup inclination (angle°)	43.2 +/- 4.36 (33-48)
Offset: Pre-operative / post-operative (mm) Diff. Offset (post.-pre.,)	45.8/46.3 +1.26 +/- 4.97
Diff. Lateralisation Pre-operative - post-operative (mm)	75/74 +0.04 +/- 5.90
Difference in leg length (%)+/- 5mm (to -8mm)	99 (1)

The average post-operative hospitalization time was 8 days, and as such is considered to be relatively long. This was partially extended by waiting times for planned rehabilitation or from a social aspect it was considered that it was unfavourable to insist on discharging patients from hospital as soon as they had achieved independent mobility.

The clinical success is shown not only in the HOOS results listed below, but also in the rapid mobility restoration of patients. We started on the first post-operative day with pain-adapted full load bearing with instruction from a physiotherapist, and so most patients were fully mobile with sticks after 3-4 days and some were already able to walk without aids. This is definitely a result of the complication free wound healing, and the minimally invasive nature of the DAA. While all authors agree that early mobilization is necessary, we do not believe early discharge from hospital within the first post-operative hours or days to be generally practical.[29,30] Despite the fact that the surgery is minimally invasive, there is still the risk of thrombosis and the chance of a drop in HB, although we did not need to carry out a single re-operation for secondary haemostatis or haematoma or seroma drainage.[31] The patient also needs the appropriate outpatient rehabilitative structure and care to ensure *rapid recovery*.

The complication rate of 6% in our patient group can be considered low and is not higher than rates reported in other studies. Searching through the literature the variety of complication rates in minimally invasive THA is high so we could find slightly better or worse results in comparable studies. Haaker *et al.*,[28] in the 100 patient study already cited above, reported one case of instability, one femoral fissure, 3 cases of impaired wound healing, one case of via falsa with stem positioning with the anterior surgical technique (6% complication rate), while Rachbauer *et al.* could report only a 3% rate in 100 patients (one fissure of prox. Femur, one perforation of the *acetabulum* and one deep infection), having very good results with the DAA.[20] With other minimally invasive procedures there were even higher complication rates, as shown in a study by Missouri, who reported on the implantation of 89 primary prostheses using the two-incision technique, where there were 7 femoral fractures, 4 cases of stem loosening, 1 case of luxation and 1 case of damage to the femoral nerve, as well as further dermal nerve damage and 2 cases of impaired wound healing (complication rate >13%).[32] The complication rate stated in the same study using the minimally invasive anterolateral technique is much lower, standing at 6%, although this still includes femur fractures, loosening and luxation. In a study by Rittmeister using the anterolateral approach the complication rate was 8% and approximately 9% using the minimally invasive posterior approach.[25] Also using the minimally invasive anterolateral approach with only 35 THRs there were 4 trochanter fractures, one fracture of the calcar, 3 viae falsae and one cup loosening, while with the posterior minimally invasive approach there was only one femur fracture with a similar number of cases.[26] In a further study involving 27 patients using the anterior approach Wohlrab *et al.* reported one fracture and six peripheral nerve lesions.[33] This shows that the complication rate varies greatly from one study to the next and is in most cases not to be considered to depend on the approach. The cause for this is often the surgeon's learning curve. A femoral stem fracture or malpositioning of the prosthesis stem did not arise in our patient population, a fact we attribute to the systemised femur exposure in combination with the positioning system and intra-operative x-ray and navigation control. We observed two cases of temporary motor weakness of the femoral nerve, and a sensitive irritation of the lateral femoral cutaneous nerve, which was still present at the three-month follow-up. The latter is a classic complication of the DAA, but we believe it can be avoided by making the skin incision 1-2 cm lateral of the spina, and staying strictly within the fascia of the tensor *fasciae latae* muscle.

In general, the literature on hip replacement figures quotes a temporary and permanent nerve damage rate of 0.5% for primary joint replacement for coxarthritis and 2.3% in patients with hip dysplasia.[34]

Conclusions

The aim was to analyse a new concept of using the the minimally invasive direct anterior approach (DAA) in THR in combination with the leg positioner (Rotex-Table) and a modified retractor system (Condor). Furthermore, we wanted to evaluate the efficiency, ergonomic and financial effective of our procedure.

For a good surgical outcome it is important to standardise the working processes and to facilitate the much criticised difficult exposure of the proximal femur in the DAA. This has been achieved by developing and using the Rotex-Table and systematic release techniques, and by using an adapted retractor system. As well as significantly simplifying the process, we have also succeeded in developing a standardized operation sequence, where it has been possible to reduce costs by eliminating the need for the assistant and positioning staff without having a negative impact on the quality of treatment.

As our clinical observations on the first 100 patients illustrate, the process-optimised hip replacement results in great patient satisfaction and low complication rates as well as excellent implant positioning.

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