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- A – Study Design
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Current trends in total hip arthroplasty**Key words:** total hip arthroplasty, ceramic-ceramic-articulation, navigation, minimal invasive surgery**SUMMARY**

After 20 years of application, with excellent short-term and long-term results, uncemented total hip arthroplasty (THA) is now generally regarded as the standard procedure for younger patients undergoing THA. However, expectations regarding hip replacement are continuously rising, along with the increasing number of young and active patients undergoing hip arthroplasty: a complication rate, including postoperative dislocation, close to zero, faster postoperative rehabilitation, low wear even in active patients, high durability and long term survival, etc. Demographic changes in aging societies are also leading to an increased need for cost-effective THA for the low-demand trauma patient. For high-demand patients, modern THA bearings, such as ceramic-ceramic articulations and other improved PE and metal materials, provide high durability and low wear, if the components are properly aligned. Navigation technology has been introduced in THA to ensure perfect component positioning without outliers and concomitant risk of increased wear and implant failure. Minimally and less invasive approaches are becoming increasingly popular in order to facilitate rehabilitation and fast-track surgery in younger patients. Navigation provides assistance for implant positioning in procedures with limited surgical exposure and visibility. New bone-preserving implants, such as surface replacement or short-stemmed femoral shaft prostheses, have been introduced especially for younger patients. Some of these new procedures are still under development, and the long-term results of new implant concepts have to be evaluated over the next decades. Not every modern concept will likely stand the test of time, but some will be beneficial for patients undergoing total hip arthroplasty in the future.

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BACKGROUND

More than 600.000 hip replacement procedures are performed in Europe every year, and the ratio of hip replacement ranges from one procedures per 500 inhabitants per year in Germany to one procedure per 3000 inhabitants per year in Poland. The increasing numbers of total hip arthroplasty (THA) procedures in developed societies is mainly driven by an increasing number of hip replacements in elderly people, especially in low-demand trauma patients. This is more an economical challenge than a question of improved implant designs and materials.

The expectations of younger patients are higher regarding functional outcome, activities in sports and life-style and a faster return to work.

The current trend discussion is therefore focused on THA in younger and middle aged populations.

The increasing number of THA in very young patients means that a revision of implant components will happen during the life expectancy of any of these cases. Under this aspect effort to maximize the survival of implant components include but are not limited to optimal implant positioning, reduction of wear, improved tightness of osteointegration, and minimization of implant migration. As bone remains the most important substance for long-term implant fixation, bone preservation on both the femoral and the acetabular side remains the main criterion for selection of implant designs and surgical procedures.

Several successful uncemented implants have been well established after 20 years of widespread use of uncemented total hip arthroplasty [1,2]. Excellent short term and long term results have been demonstrated. Uncemented fixation is regarded as the standard procedure for younger patients undergoing THA in most parts of the world. There is abundant evidence for good and very good results for a couple of uncemented implants, and no surgeon has to use implants or surgical procedures without this evidence any more.

Under the pressure for further improvement especially for young and very young patients some new trends have been introduced in total hip arthroplasty. These new procedures include improved bearings for reduced wear, computer-assisted techniques for superior implant positioning, minimally invasive surgical approaches for faster rehabilitation and new implant design concepts to further reduce bone loss. However, new short term and long term complications and problems might be linked to these new procedures.

Most of these new procedures and implants are still under evaluation. We should be well aware that all these "trends" are far away from representing the state of the art in modern total hip arthroplasty which is still the base for any possible improvement for the benefit of our patients.

The following overview tries to differentiate between the pros and cons of some current trends in hip arthroplasty based on the personal impression and experience with these technologies and from the personal perspective of the author who has long term experiences with a particular straight stem hip system.

MODERN TREND – NAVIGATION

Navigation technology is an accepted and well studied surgical procedure in total knee arthroplasty [3,4].

In total hip arthroplasty, many navigation systems offer navigated cup positioning or even workflows for navigation of both the positions of cup and shaft as well as the resulting geometry of the articulation. The navigation procedure monitors acetabular cup positioning in relation to the palpation of the anterior pelvic plane. Inclination and anteversion, insertion depth and shifting of head center are displayed during acetabular reaming and cup implantation. During femoral preparation a continuous monitoring of femoral antetorsion, lateral offset and leg length changes is displayed. The resulting range of motion can be calculated in depending on modular head and acetabular cup liner options [5]. (Fig 1 a and b)

Basically, there are two options for navigating the implant positioning in total hip replacement: image guided procedures and kinematic navigation. Image guided navigation systems with either pre-op CT or intra-op fluoroscopy have certain disadvantages, such as additional exposure to radiation, pre- and intraoperative time consumption and limited accuracy. The author has been using a kinematic THA navigation system since 2003, and it was possible to show that this algorithm can be easily included in the daily routine of total hip replacement

Kinematic THA Navigation is based on the registration of intraoperative landmarks and kinematic data which are acquired during the procedure. It has been developed for daily routine use with intuitive handling and is also suitable for cup navigation in less invasive approaches.

Improved accuracy and a reduction of outliers could be shown both in cadaver studies [6] and in a clinical setup [7]. It could also be demonstrated that navigation adds to the accuracy of cup positioning even for experienced surgeons and that the gain in accuracy through using navigation exceeds the gain in accuracy resulting from the increasing experience of the individual surgeon. These data underline the benefits of navigation technologies not only for residents during surgical education [7].

In contrast to navigation in total knee arthroplasty where it is easy to define a uniform optimal implant position, hip navigation addresses the individual anatomical situation of every patient. An individual decision has to be made, based on a distinctive understanding of the preoperative geometry of the hip and the intraoperative options with the implant components, which are available during the procedure. The integration of image data might be helpful in dedicated cases but would cost additional surgery time.

The actual limitations of navigation technology include the difficulty of palpation of the anterior pelvic plane especially in a lateral patient position, the additional surgical time of 10-15 minutes (cup navigation less than 10 min) and the fact that stem navigation is not yet optimized for minimally invasive surgical approaches.

Navigation might become increasingly important with the upcoming use of minimal invasive hip approaches



Fig. 1a. Workflow of kinematic THA navigation

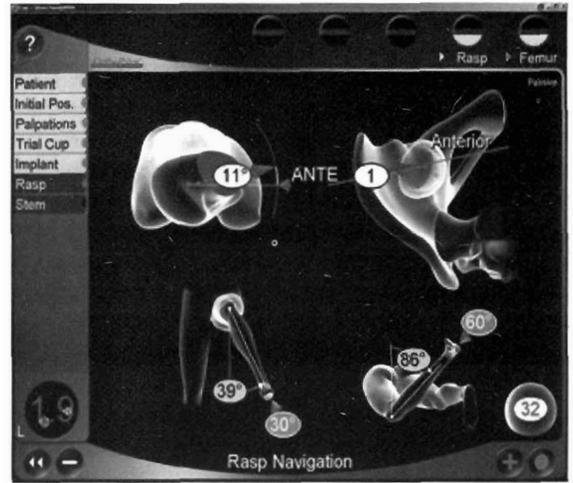
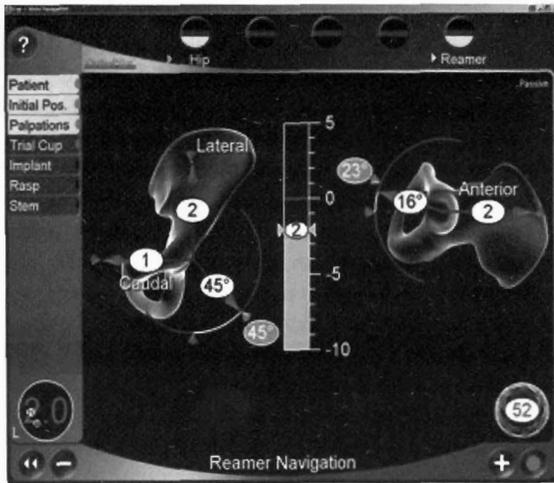


Fig. 1b. Navigation display during acetabular and femoral bone preparation

which all have some limitations regarding exposure of anatomical landmarks and orientation of endoprosthetic devices.

MODERN TREND – MINIMALLY INVASIVE SURGERY

Basically, less invasive implantation of total hip components is made possible by modifying of different surgical hip accesses, including posterior, lateral, antero-lateral and anterior approaches [8,9,10]. Both single and double

incision approaches have been published [11,12]. Some new minimally invasive procedures require an extended learning curve, especially when using a very uncommon approach such as the double-incision techniques. Another important practical aspect is whether an approach can be extended in the case of any intraoperative difficulty or complication. Appropriate patient selection (at least during the learning curve) and the experience and skill of the surgeon are the key factors for the successful application of minimally invasive approaches.

Statistically significant improvements such as reduced of blood loss or a better and faster rehabilitation process,

could not yet be shown in comparative reports, but there is a trend towards better results after the first weeks in several studies. Short term results also seem to depend on the expectations of individual patients and cooperation during the postoperative rehabilitation program. After 3 months no study could demonstrate any advantage for minimally invasive approaches [13].

We have learned in recent years to make the standard approaches which we have been using smaller and smaller. Despite the fact that minimally invasive procedures are becoming increasingly popular, a definition of "minimally invasive" has not yet been established, but it seems to be accepted that the length of the skin incision is far less important than disruption of muscles, impairment of soft-tissue vascularisation and innervation, and preservation of bone. On the other hand, the popularity of minimally invasive orthopedic surgery is also market-driven, and the length of the skin-incision is the only parameter that can be measured and compared directly by the patients themselves.

For total hip replacement a direct anterior approach to the hip joint could be shown to provide quick and easy access to the hip joint [14,15].

The direct anterior approach is basically a modified Smith-Peterson approach to the hip joint (Fig. 2). Independent from the length of the skin incision, no muscular dissection is necessary in order to expose the hip joint. It is the shortest and most direct way to the hip joint and, independent of the length of the skin incision, no injury to hip abductor muscles occurs, which is to some extent common to all other lateral or anterolateral approaches. The access is made through an area where there is less subcutaneous fat even in obese patients and it is easy to position the patient on the OR table without the need for special traction or positioning tools. Easy orientation is possible, particularly for surgeons familiar with the lateral approach in the supine position. This is the case especially for the acetabulum, which can be visualized quite well, but control of the femoral implant position is somewhat more difficult [15].

As no benefit has been proven for any of these minimally invasive approaches after 3 months, it is crucial not to have any disadvantage in terms of implant positioning. Limited visibility and exposure of anatomical landmarks might increase the risk of implant malalignment, thus leading to an inferior long term result in terms of wear and durability. Navigation might be the clue to this problem, but navigation procedures which can be adapted to minimally invasive implantation of the femoral shaft are still under development [16].

MODERN TREND – NEW IMPLANT CONCEPTS

Surface replacement and shorter hip stems have been introduced as bone preserving implant concepts in several European countries. Both implant concepts are designed to meet the special situation and demands for hip replacement in younger patients. The idea is to provide a solution which is less bone consuming than standard procedures, so that the first revision resembles a primary intervention rather than a revision (Fig. 3). Those concepts, however, have not yet been proven and long term results are still unavailable for all but the very first implants [17,18,19,20,21].

Surface replacement and short hip stems are based on different experiences and biomechanical concepts on the femoral side. The implant options on the acetabular side differ significantly as surface replacement is only possible with a metal on metal implant technology. Short stems can be combined with standard acetabular cups and articulations.

The advantage of surface replacement is minimal femoral bone resection and the application of metal on metal technology with large head diameters. The natural biomechanics are restored. The disadvantages include the possible adverse effects of metal ions release, the reduced acetabular options in case of revision surgery, the more invasive primary intervention and the danger of femoral neck fractures [22].

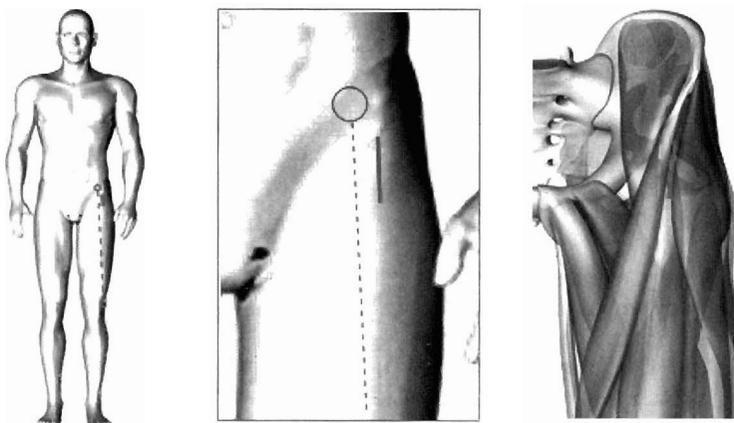


Fig. 2. Direct anterior MIS hip approach in supine patient position



Fig. 3. Bone preserving THA implant concepts

Surface replacement may be indicated in the young and active patient (male < 65, female < 60 yrs.) with good bone quality. Contraindications are metal allergy, kidney insufficiency, dysplasia, femoral head necrosis and anatomical variations with a short femoral neck or varus deformity. The exact positioning of the femoral component is a crucial key factor in surface replacement [22] and several navigation systems support femoral preparation and implant positioning.

Short hip stems are based on the concept of proximal implant fixation; bone preservation includes a higher resection of the femoral neck. The procedure is far less invasive than surface replacement and is suitable for all minimally invasive approaches. Navigation technology is available for perfect positioning and a well balanced decision regarding neck length and offset options of modular systems. Disadvantages include the fact that most implant designs are at the very beginning of clinical evaluation, positioning of the femoral component without the aid of navigation might be difficult for surgeons trained with straight stems and the higher femoral neck resection can limit acetabular exposure.

Indications for shorter hip stems might be osteoarthritis in the young (male < 65, female < 60 yrs.) and active patient and contraindications for surface replacement. Good bone quality is essential, but the procedure is possible in cases of femoral head necrosis given that no bone marrow edema in the metaphysis can be demonstrated by MRI. Short stems cannot be used in cases with varus and severe dysplastic valgus deformities. Anatomical variations with short femoral neck length may result in leg lengthening [20,21].

It has been demonstrated for some conventional femoral implants that they can provide predictable excellent clinical results and long term survival. The preservation of proximal femoral bone stock can be achieved by a bone-preserving surgical technique and appropriate instrumentation. High primary stability corresponds to superior long term stability [23]. Even more important, bone preservation has to be maintained over the years – what counts is the

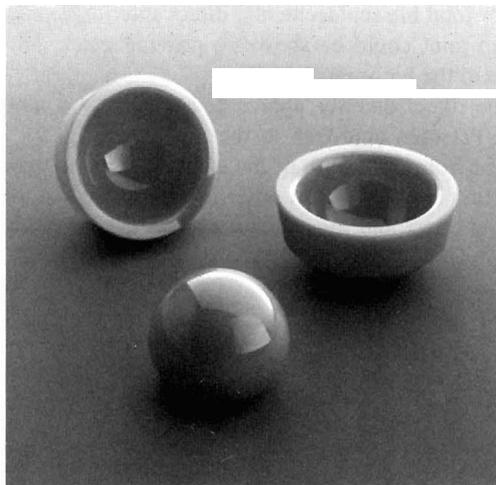


Fig. 4. Modular ceramic inserts for larger head diameters

amount of bone available for the first revision and not the amount of bone immediately after the initial implantation. It could be demonstrated that the concept of proximal load transfer in a conventional straight stem leads to maintenance of the proximal femoral bone stock for well over a period of 15 years and more (figure 4) [2,24].

When choosing surface replacement or a short stem, the patient has to be well informed about the level of evidence and the option of receiving an implant with proven excellent results as an alternative.

MODERN TREND – THA ARTICULATION OPTIONS

As wear and the propagation of wear particles remains a main issue for long term durability of total hip arthroplasties, there are tremendous efforts going on to improve the materials for articulation surfaces. With many combinations of traditional and recently developed materials,

including conventional and highly crosslinked polyethylene, metal-on-metal, and different ceramics available, the option to choose from are getting increasingly complex. Many bearing surface options, such as metal on metal, highly crosslinked polyethylene and new composite ceramics have been developed during the past five years (fig. 5). The surgeon has somehow to decide about his preference and experience for a material combination for head and cup implants – for young and middle-aged patients [25].

In addition the actual trend in material developments is strongly influenced by increased head diameters for improved hip function and dislocation stability. The preferred head diameter has changed from 32 mm in the 1980s to 28 mm in the 1990s and back to larger diameter up to 36 mm and even larger in metal on metal THA. However larger head diameters are not available for all cup sizes, all material combinations and all implant designs. The desire for a larger head diameter should never lead to a decision towards bigger acetabular cup sizes, as additional bone loss in the acetabulum limits press-fit implant fixation and can cause severe problems in case of revision.

Since 1997, the author has been using ceramic on ceramic THA in young and active patient up to 70 years, ceramic on conventional polyethylene for patients in their seventies and metal heads for patients over 80. Recently the 32 mm diameter heads for the ceramic on ceramic articulation have been preferred and 36 mm implants are also used in special cases in appropriate cup sizes.

The major advantages of ceramic-ceramic is the fact that this articulation provides lowest wear rates compared with other material options in ceramic on ceramic THA, which is even lower than highly crosslinked PE [26]. Implants and ceramic material at least delivered by one leading manufacturer. The disadvantages include the fracture

risk of 2 in 10.000 either for a ceramic head or a ceramic cup insert, the need for perfect acetabular implant positioning in case of ceramic on ceramic THA and the fact that 36 mm ceramic inserts are available only starting from a cup size of 50 mm and higher [27].

CONCLUSION

Hip arthroplasty in young patients is on the increase – but this should not lead us to an uncritical use of less evidence based methods and implants. Some new implant concepts in hip arthroplasty are not yet supported by sufficient clinical evidence and have to stand the test of time. If we make use of these experimental concepts we must clearly communicate this nature of the procedure to the patient.

Bone preservation has always been an important issue in THA and is more than a current trend in arthroplasty. The proximal load transfer concept leads to preservation of the bone of the proximal femur. Soft tissue preservation is an important issue for patients to benefit from increased joint stability and a quicker rehabilitation process. Most modern trends in THA can be well met through evolution of established implants, thus providing evidence for excellent long-term results.

Some promises of "fast track" and "minimally invasive" surgery will come true, when navigation and minimal approaches come together [16].

What counts is not the result after 17 days but the result after 17 years. Continuous innovation is necessary, but we have to remain critical, cautious and honest – implanting endoprosthetic devices in patients is different from developing and marketing those devices.

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