Recent evidence in less invasive approaches and less invasive implants in total hip replacement

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Abstract
Total hip replacement is one of the most successful orthopaedic procedures. As there is still debate concerning the implants’ fixation and the bearing surfaces, in the last two decades many researchers focused on less invasive approaches (minimally invasive surgery-MIS), and less invasive implants (the so-called short-stems).

The aim of this report is to review the recent literature concerning the less invasive surgery in THR including MIS approaches and shortstems.

Comparative studies reveal in many cases conflicting results regarding the benefits and complications of the different MIS approaches. It seems that other factors like the surgeon’s experience or the learning curve period and not just the approach are also important.

Data concerning short stems is increasing in the last decade with promising results for some types of short stems although for most of them there are no medium- or long-term clinical results.

Introduction
Total hip replacement (THR) is a common orthopaedic procedure. Invented the previous century for the treatment of end-stage hip osteoarthritis and being one of the most successful orthopaedic procedures is referred as “the operation of the century” [1].

Despite satisfactory long-term results [2, 3] there is still debate concerning the method of implants’ fixation (cemented or uncemented), and the bearing surfaces (polyethylene, ceramic or metal) [4, 5].

In the last two decades many researchers focused on less invasive approaches (minimally invasive surgery-MIS) [6-8], less invasive implants (the so-called short-stems) [9-11] and “fast-track” or “enhanced recovery” regimes [12, 13].

Surgical Approaches to the Hip Joint
Operations of the hip joint are very common, including primary total hip replacement (THR) for osteoarthritis, revision THR for failed primary THR, treatment of proximal femoral fractures with either hemi-arthroplasty or fracture fixation, fixation of fractures of the acetabulum, treatment of infections, tumors, and congenital hip disease.

The surgical approaches to the hip are classified on the basis of the approach to the capsule of the hip joint into anterior, posterior, anterolateral, lateral, and medial approach. The following description of the approaches is based on the existing literature [14-16] [Figure 1, 2].

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Anterior approach

The anterior approach is also called direct anterior approach, iliofemoral approach, Hueter approach or Smith-Petersen approach. It seems that it was described by Hueter in 1885, modified and popularized by Smith-Petersen in 1949 and Judet and Judet in 1950. The MIS anterior approach is commonly used in MIS THR [17,18].

Anterolateral approach

It was described by Watson-Jones in 1936 and modified by Harris in 1967. A modified MIS anterolateral approach with no abductors muscle detachment has been used by many authors [19,20].

Lateral approach

The lateral approach (also called direct lateral) was described by McFarland and Osborne in 1954 and modified by Bauer in 1979 and Harding in 1982. Modifications and mini incision approach have also been described [21-23].

The lateral trans-trochanteric approach involves osteotomy of the greater trochanter and the osteotomized part of bone and includes proximal retraction of the attachment of gluteus medius and minimus [24].

Posterior approach

The posterior approach is also called “Southern approach”, and it was described by Lengebeck in 1874, modified by Kocher in 1907, and popularized by Moore in 1957. Mini incision posterior or modified MIS approaches have been described by many authors [25-27].

Supercapsular Percutaneously Assisted Total Hip (SuperPATH)

This “micro-superior” approach is a combination of Superior Capsulotomy described by Murphy in 2004 and percutaneously assisted total hip arthroplasty (PATH) described by Penenberg et al in 2008 [28] [figure 3].

Figure 3. THR using SuperPATH approach. S: The supercapsular approach. P: The entry point for the percutaneous assisted preparation and insertion of the acetabular component (from the authors’ series).

Medial approach

It was described by Ludloff in 1908 and modified by Ferguson in 1973 and it was mainly used for open reduction of congenital dislocation of the hip.

regulation is triggered by the nuclear translocation of nuclear factor.

The aim of this report is to review the recent literature concerning the less invasive surgery in THR including MIS approaches and short-stems, focusing on comparative studies, systematic reviews and meta-analyses.

Methods of literature search

A systematic review of the English literature was done by using PubMed, OVID and Google database using the key words “Hip joint”, “Hip approaches”, surgical approaches”, “and MIS ”,” Less invasive surgery ”, “Short stems”. Selected articles included comparative studies, systematic reviews and meta-analyses concerning the clinical results of different surgical approaches of the hip and the use of short stems.

Less invasive approaches or MIS

Surgery is by definition invasive. Minimally Invasive Surgery (MIS) or Minimally Incision Surgery is a Less Invasive Surgery (LIS) where operations are performed with emphasis reduction of skin incision length and decreased soft-tissue dissection and may be a modification of an existing standard approach or an entirely novel approach [29].

Less invasive procedures are aiming to cause less tissue damage, less pain, less functional impairment, shorter hospital stay and better cosmetic appearance [17,18,31].

On the other hand, the limited visibility may result in longer operating time, increased blood loss, and higher rates of complications, including periprosthetic fractures, nerve damage, wound healing problems, and component malposition [32-35].

Mini incisions

Although there is no agreement about the length of skin incision in standard approaches (more than 12 or 14 cm) and less or minimally invasive approaches (less than 12 or 10 cm), any surgical approach of the hip could be performed using either a standard or a less or mini incision.

Chimento et al. [36] in a prospective randomized study found that a small incision (8 cm) resulted in less blood loss and better early function compared to 15 cm incision, while all other parameters and complications were similar.

A more recent randomized study compared the results after THR using the same approach with either a small incision (10 cm or less) or a standard incision (14 cm or more). The small incision significantly reduced blood loss and the need for morphine analgesia-while the functional recovery was similar [37].

A recent meta-analysis found that limited incision results in better short-term recovery compared to standard incision THR [38], but another meta-analysis found that while the posterior minimal incision THR results in a significant decrease in surgical duration, blood loss and hospital stay, it is not clear whether mini incision THR in general is superior to standard incision THR [39].

MIS approaches

Apart from the skin incision, the damage caused in other soft tissues (fascia, muscles, tendons) and the risk of complications from nerves and vessels also determines the invasiveness of the procedure.
Some authors believe that the Anterior Hip Approach should be the only MIS approach because it involves no muscle incision while all other hip approaches can be LIS but not MIS as in all of them one or more muscles have to be incised [40]. The anterior approach is also called Muscle Sparing Approach (MSA™) [17].

Nevertheless, it has been shown in cadaveric studies that even with the anterior MIS a muscle damage was observed in a significant number of cases (8% of the gluteus minimus, 31% of the tensor fascia latae muscle, 12% of the rectus femoris and in 50% the piriformis or conjoined tendon was transected) [41]. In posterior MIS, apart from the intentional detachment of the piriformis and conjoined tendon, a measurable damage to the abductor muscles and gluteus minimus tendon in each specimen was observed [41].

**Anterior MIS approach (AMIS) or Direct Anterior Approach (DAA)**

Recent systematic reviews have shown that the THR via an MIS or DAA can be successfully performed, but it is not without complications [42] and, although it provides benefits in the early postoperative period (faster postoperative recovery) compared to other approaches, there is a learning curve that is not to be [43].

It seems that the ”learning curve” requires between 50 and 100 cases. While no learning effect after 46 cases was found in one study [12], a multicenter observational study found a decline in complications in surgeons with experience greater than 100 cases [31].

**AMIS approach versus other approaches**

A comparative study measuring biochemical markers of muscle damage suggested that anterior hip approach results in less muscle damage compared to the posterior approach [44]. A clinical comparative study found that when using anterior approach, patients had earlier mobilization and discharge but more often lateral cutaneous nerve damage and fracture, compared to the posterior approach [45]. Barrett et al. [46] in a prospective randomized study found better physical function and less pain during the early postoperative phases in patients undergoing THR via anterior approach (DAA) compared to those with a posterolateral approach. Similarly, another comparative clinical study found that the anterior approach results in improved physical function at 3 months after surgery but greater blood loss and likelihood of blood transfusion compared to the posterior approach [47]. The rate of THR dislocation after anterior approach was significant less than that of THR via a posterior approach in a comparative study with a follow-up of 5 to 9 years [48]. Finally, the results of a recent meta-analysis showed a significant difference in favor of the anterior approach, in terms of length of stay and dislocation and in some studies lower postoperative pain and better function, but the final conclusion was that ”current evidence comparing outcomes following anterior versus posterior THA does not demonstrate clear superiority of either approach” [49].

Nagata et al. [50] in a comparative clinical study found a more rapid recovery for hip function and gait ability after MIS-THR via an anterior approach when compared to a mini-posterior approach.

A prospective randomized study compared the results after anterior approach (modified Smith-Peterson) to those after lateral approach. It was found that the direct anterior approach has specific early (and short-term) outcome benefits for patients as compared with a direct lateral approach for THR, with no difference in other outcome measures or complications [51]. Pogliacomi et al. [52] compared the outcomes in patients undergoing THR using the anterior mini-invasive approach to those undergoing the standard lateral THR approach. It was found that, although operating time was significantly longer, all other parameters (hospital stay, blood loss, transfusion and pain) were significantly lower in anterior approach, while complications, functional outcome and component positioning were similar after one year. The authors concluded that the anterior MI approach is a safe procedure during the learning curve of an experienced hip surgeon. The mid-term clinical outcomes after THR via a minimally invasive direct anterior approach were compared to those after a direct translucetal lateral approach in a follow-up time of 3.7 to 5.5 years respectively [53]. The outcomes regarding functionality, pain, quality of life and daily activity were comparable although the authors observed a higher incidence of lateral femoral cutaneous nerve impingement (4.3%) using the direct anterior approach [53]. Finally a recent meta-analysis found that the recovery is faster and the hospital stay is shorter in patients undergoing THR via an anterior approach compared to the lateral approach, but the available evidence is still insufficient to conclude whether the DAA or lateral approach is superior for total hip arthroplasty [54].

A gait analysis study found a statistically significant early improvement in gait parameters in patients undergoing minimally invasive anterior compared to anterolateral approach [55].

The postural parameters of patients operated with the anterior, modified anterolateral and posterior minimally invasive approaches were compared to those of asymptomatic subjects at short-term follow-up [56]. It was found that the posterior approach had the smallest impact on postural parameters in the first 2 postoperative months, while patients operated on with the anterior or anterolateral approach showed significant differences from asymptomatic subjects in postural parameters. According to the authors, the hypothesis that the anterior and anterolateral approaches for THA are less disruptive for postural parameters compared to the posterior approach was not confirmed.

A recently published cadaveric study showed that the so-called direct superior approach caused less soft-tissue damage than the direct anterior approach after performing a THR [57].

**Surgical approach and enhanced recovery or advanced pain and rapid rehabilitation protocols**

Two clinical studies have looked at the influence of the “enhanced recovery” or “advanced pain and rapid rehabilitation” protocols on the clinical outcome in MIS compared to standard approaches [58, 59].

Using the same advanced pain and rapid rehabilitation protocols in patients undergoing a direct anterior approach or a mini-posterior approach for THR, no difference was found in post-operative pain, recovery, hospital stay, complications and components alignment between the two groups, while the mean operative time was longer in anterior approach [58]. The authors concluded that factors other than surgical approach may be more important in terms of influencing early recovery after THR [58].

Similarly, when an ‘enhanced recovery’ pathway is used in patients undergoing THR, no difference in clinical outcome (including hospital stay, pain the up to the third post-operative day and complications) was found between direct anterior and posterior approaches [59]. The rate of periprosthetic femoral fractures in direct
anterior approach was significantly higher, even in the hands of experienced surgeons. The authors concluded that direct anterior approach is not superior to posterior approach when 'Enhanced Recovery' pathway is used.

**MIS anterolateral approach (modified Watson-Jones approach) and other approaches**

A prospective randomized study revealed no significant midterm (4 years) clinical and functional benefit for patients who underwent a THR through a minimal invasive anterolateral in comparison with the patients where a conventional anterolateral approach was used. The only significant difference was the postoperative pain; MIS patients reported less postoperative pain in comparison with the conventional group [20]. Similarly MRI and clinical assessment of the abductor power after 4 years revealed no difference between patients in the MIS anterolateral and conventional anterolateral group [60].

Reports concerning the results after an MIS anterolateral approach (modified Watson-Jones approach) in comparison to the lateral or modified lateral approach reveal conflicting evidence. A study of gait kinematics (gait analysis and electromyography) showed no significant benefit for patients who underwent a total hip arthroplasty through a MIS anterolateral approach in comparison with those who were managed with a lateral (transgluteal) approach in the early postoperative period (three months) [61]. A recently published comparative clinical study found that patients who were treated with the MIS anterolateral approach (muscle-sparing technique) had faster recovery with less pain, shorter hospital stay and were more satisfied with the operation outcome compared to the patients operated with modified direct lateral approach [62]. A MRI study in patients undergoing THR via a MIS anterolateral or a lateral (modified) approach has found muscle and tendon damage in both groups but more often in the lateral approach group along with poorer clinical outcome and a higher serum myoglobin concentration at 6 and 24 h postoperatively compared to the MIS group [63]. A randomized, prospective study with a 3.5 years follow-up period found no significant long-term advantage to the MIS anterolateral approach in comparison to the conventional lateral approach [64]. In the MIS group blood loss was greater and the duration of surgery was longer, but the skin incision was smaller and there was a significantly lower rate of patients with a positive Trendelenburg sign after six weeks postoperatively [64]. Ilnmann et al. [65] studied the components positioning using the MIS anterolateral approach in comparison to the lateral approach. It was found that while the results for the stem position are comparable between the two groups, there is a higher risk of cup malpositioning for inclination and anteversion using the MIS anterolateral approach compared to the lateral approach.

Three randomized comparative studies found no advantage of using the MIS anterolateral approach in comparison to the MIS lateral approach or to MIS posterolateral approach. Two studies found no difference in hip scores, and complication rates at 1-year follow-up between the MIS anterolateral and MIS lateral groups [66, 67]. In the first study in the MIS anterolateral approach group the blood loss was less but the operative time was longer [66], while the second study found that the muscle strength recovery of hip abduction at 6 weeks after surgery was better, and creatine kinase level at 1 day after surgery was lower in the MIS anterolateral that in the MIS lateral group [67]. Greidanus et al. [68] reported the results of a prospective randomized controlled trial in patients (from three Canadian centers) undergoing primary THA receiving either the MIS anterolateral or the surgeon’s preferred approach (MIS direct lateral or MIS posterolateral). After a mean follow-up of 30 months, a similar quality-of-life patient-reported satisfaction level was found but an increased risk of site-specific complications (femoral stem subsidence and femoral fracture) requiring revision with the MIS anterolateral group was reported.

**MIS posterior and other approaches**

A systematic review and meta-analysis of the mini-incision versus standard posterior approach have shown a reduced operating time, less blood loss, shorter length of hospital stay, and a better early functional improvement in the mini-incision group in comparison to the standard group [69].

In a comparative prospective study the medium-term clinical and radiographic results and the complication rates were similar between the patients who underwent total hip arthroplasty by means of the posterior minimally invasive access and those with the traditional lateral approach [70].

**MIS approaches and hip dislocation after THR**

Dislocation after a THR is a devastating complication and one of the reasons for revision THR.

Data from hip arthroplasty registries have shown that THR dislocation is more common after posterior approaches compared to lateral or antero-lateral approaches and it seems that the approach is more important than the size of the femoral head [71].

Furthermore an analysis of a large number of cases (78,098 operations in the Swedish Hip Arthroplasty Register) found that the MIS procedures (along with posterior approach, THRs for osteonecrosis or femoral neck fractures and operations in men) were associated with a higher risk of revision due to dislocation compared with the direct lateral approach [72].

**Less invasive stems or short-stems**

Recent epidemiological studies have shown that the prevalence of THR is rising overtime and that THR is the prevailing choice for young patients [73, 74].

The use of uncemented implants is the procedure of choice in some countries while their use is increasing even in countries where traditionally the cemented THR has been successfully performed for decades [75-77].

Despite the excellent long term results of currently in use uncemented stems [78-81], there is a concern about the periprosthetic fractures, thigh pain, proximal stress shielding and most importantly about the loss of bone stock in revision surgery in patients where a standard length stem has been used [81-84].

The use of short stems started more than 30 years ago and the idea behind the short-stems femoral prosthesis is the fact that (a) they facilitate more physiological (proximal) bone loading and hopefully prove less stress-shielding, (b) they are less invasive as less bone is removed during the implantation, (c) the removal of the prosthesis is easier and less bone is damaged during the subsequent revision (preservation of bone stock), (d) the thigh pain caused by the standard stems can be avoided, (d) the proximal-distal mismatch concerns can be eliminated, and (e) they could facilitateof MIS procedures.

Potential disadvantages or drawbacks include (a) possible decreased initial stability, (b) difficulties in obtaining optimal sizing and
(c) the limited reports of medium- or long-term clinical results.

**The length of the stems**

The geometric characteristics (length, cross-section geometry), surface characteristics, and material properties (metallurgy) characterize each stem (stem’s identity) and its behavior in vivo [85].

The length of a specific femoral stem design that is required for a long term survival is not well defined and it seems that the length of each stem is based on the average length at the time of its design [85, 86].

There is no universally accepted classification of the femoral stems. The different reported classifications of the femoral stems are based on the length of the stem, the fixation principles and the level of the neck osteotomy [85, 87, 88].

**Clinical results of short stems**

The term “short-stem” is used for a variety of implants and all short stems are not equal. It has been proposed that the length for the standard or conventional stems is about 150 mm while for the short stems is less than 120 mm [89-91] [Figure 4].

Evidence from finite element analysis have shown that femoral stems with a length of less than 105 mm can provide satisfactory initial stability [92] and clinical data make authors suggest that a diaphyseal portion may not be necessary for excellent clinical and radiological results [93-95].

Combining the existing classifications of short stems [87, 88, 95] we propose the classification in 4 types [Figure 5]. Type 1 “collum stem”, type 2 “partial collum stem”, type 3 “trochanter-sparing stem” and type 4 “trochanter- harming stem”.

Clinical evidence with a short-term follow-up (less than 5 years for most of the studies) show excellent results for most of the type 2, 3 and 4 stems but not for type 1 stems [85, 87, 88, 96, 97]. The number of studies concerning the type 1 “collum stem” is small with the short- to medium-term follow-up and the overall survival rate being not satisfactory [97].

Clinical studies with a follow-up of more than 10 years are limited and are referred to specific stem designs [98-102].

Furthermore randomized controlled trials have shown promising results for the short stems in comparison to standard stems [100, 103-112]. A recent meta-analysis found that the clinical and radiological results of the short stems were the same with those of standard stems with a reduced incidence of thigh pain in the short stem group [109].

The evidence concerning the proximal stress-shielding or bone loss is not uniform. Although proximal load transfer is more pronounced after short stem implantation compared to standard stems, it seems that the stress-shielding phenomenon is not completely resolved and it depends on the implants’ designs [105, 108, 110, 111].

Surgical technique is different from that of standard stems and is also different among the different short stems depending on the design or the type of any particular short stem. Therefore the operation is more demanding with an increased risk for wrong sizing and implant malalignment. It is the authors’ opinion based on his experience with short stems that the use of intraoperative fluoroscopy eliminates the risk of both implant wrong sizing and malalignment [Figure 6].

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**Figure 4.** Bilateral THR with a standard stem on the left side and a short stem (MINIMA, Lima Corp.) on the right side (from the authors’ series).

**Figure 5.** The proposed classification based on the existing classifications of short stems (96,97,104). 1: Type 1 “collum stem”, 2: Type 2 “partial collum stem”, 3: Type 3 “trochanter-sparing stem”, 4: Type 4 “trochanter- harming stem”, including 4a the “ultra-short stem” and 4b the short version of standard stem.

**Figure 6:** Intraoperative fluoroscopy in order to obtain correct sizing and proper alignment in short stem THR (from the authors’ series).
Data concerning cemented short stems is limited to one particular stem [112, 113] with similar results compared to the standard stem of the same design [112].

In conclusion, data concerning short stems is increasing the last decade, although for most of them there are no medium- or long-term results. Some authors may argue that the medium and long-term clinical results of standard length uncemented stems are excellent and there is no much room for improvement using short-stems. This could be partly true but long-term data exists only for a limited number of standard stems and it should not be extended to other stems with similar design. It is well-known that even small changes in implants’ design may have enormous changes in its biomechanical properties or biological response. Similarly, the promising results of some short stems should not be extended to other types or designs of short stems until clinical evidence is available.

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