Original Article

Total Hip Arthroplasty by the Direct Anterior Approach Using a Neck-preserving Stem

Safety, efficacy and learning curve

Abstract

Background: The concept of femoral neck preservation in total hip replacement (THR) was introduced in 1993. It is postulated that retaining cortical bone of the femoral neck offers triplanar stability, uniform stress distribution, and accommodates physiological anteversion. However, data on safety, efficacy and learning curve are lacking. **Materials and Methods:** We prospectively assessed all patients who were operated for a THR with a short neck preserving stem (MiniHip) between 2012 and 2014. The safety and learning curve were assessed by recording operative time; stem size; and adverse events including periprosthetic fracture; paresthesia; and limb length discrepancy (LLD). The cohort was divided into equal groups to assess the learning curve effect, and the cumulative sums (CUSUM) test was performed to monitor intraoperative neck fractures. For assessment of efficacy, Oxford Hip Score (OHS) and Short Form-36 (SF-36) scores were compared preoperatively and postoperatively. **Results:** 138 patients with median age 62 years (range 35–82 years) were included with a median followup of 42 months (range 30–56 months). The minimum followup was 2.5 years. The OHS, SF-36 (physical and mental component) scores improved by a mean score of 26, 28, and 27 points, respectively. All patients had LLD of <10 mm (1.9 mm ± 1.3). Adverse events included intraoperative neck fracture (n = 6), subsidence (n = 1), periprosthetic fracture (n = 1), paresthesia (n = 12), and trochanteric bursitis (n = 2). After early modification of the technique to use a smaller finishing broach, the CUSUM test demonstrated acceptable intraoperative neck fracture risk. The second surgery group had a reduced risk of intraoperative neck fracture (5/69 vs. 1/69 P = 0.2), reduced operative time (66 vs. 61 min, P = 0.06), and increased stem size (5 vs. 6, P = 0.09) although these differences were not statistically significant. **Conclusions:** The MiniHip stem is safe alternative to standard THR with good functional outcomes but with a learning curve for the surgical technique, implants sizing, and the risk of intraoperative neck fractures.

Keywords: *Anterior, learning curve, osteoarthritis, short neck-preserving stem, total hip replacement*

MeSH terms: *Arthroplasty, hip, femoral neck fractures, osteoarthritis*

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Introduction

Osteoarthritis of the hip is one of the leading causes of disability in the aging population globally.[1] Total hip replacement (THR) has developed into a safe and functionally successful treatment of this degenerative disease,[2,3] leading to a steady rise in rate of these procedures.[4] Porous-coated, uncemented femoral stems are now routinely used in a large proportion of patients undergoing a primary THR.[5] Fixation in these stems is dependent on press-fit insertion of the implant and metaphyseal and/or diaphyseal osseointegration.[6] Despite the excellent survival of standard stem designs, they have a few shortcomings. They violate the proximal femoral bone stock (trochanteric bed) as well as the diaphysis, which may lead to proximal stress shielding and thigh pain, resulting in reduced long term implant survival.[7,8] They also hinder the development of less invasive surgical approaches such as the direct anterior approach (DAA).[6,9]

Alternative bone conserving implant concepts such as hip resurfacing (HR)[10,11] and the neck preserving or short stem (range 40–135 mm)[12] have been developed, which may overcome the limitations of standard designs. Despite excellent initial success, HR has not been widely adopted due to a high risk of neck fractures[13] and blood

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toxicity due to metal ion leech.[14] The surgical concept of femoral neck preservation was introduced with the Freeman stem in 1993.[15] Since review articles have postulated that the cortical bone of the neck not only offers primary triplanar stability and uniform stress distribution through the preserved metaphyseal cancellous bone (trabecular system and endosteal blood supply) and soft tissue[16,17] but also accommodates physiological anteversion.[9] The recent introduction of several such implants prompted the development of a classification to allow a more meaningful comparison of clinical and radiographic outcomes.[12] They are categorized, based on the extent of proximal loading and cross-sectional geometry as neck loading only, calcar loading, lateral flare calcar loading, and shortened tapered stems (Type I–IV).[12]

Early results from initial implants such as the Birmingham Mid-Head Resection,[18] the Silent Hip[19] (Type I stems), the Nanos[20] (Type IIA stem), the Gothenburg Osseointegrated Hip[21] (Type IIC stem), the Proxima[22] (Type III stem), and the Taperloc Microplasty (Type IV stem)[23] were promising with a high rate of stem survival (aseptic loosening as the end-point) and improved hip function scores. However, a recent review of short stems does not recommend their use in routine practice due to insufficient and conflicting evidence.[12] Larger studies have reported excellent stem survival and clinical results comparable to standard items for implants including the Mayo,[24,25] the METHA[26,27] (Type IIA stems), the collum-femoris preserving,[28,29] the CUT[30,31] (Type IIB stems), and the Thrust Plate Prosthesis[32,33] (Type IID stem). However, concerns of implant sizing and malalignment (offset, neck-shaft angle, and limb length correction),[34,35] broaching techniques (intraoperative fractures and stem subsidence),[9,12] stress shielding,[36-38] and absence of patients with high-grade dysplasia permit only a weak recommendation for their use.[12]

The MiniHip is a recently developed stem with a calcar loading and a curved profile (Type IIB stem). A recently published case series has reported results comparable to standard and other neck-preserving stems with improved functional outcomes and low rates of aseptic loosening after a midterm followup.[39] A radiological study evaluating 250 hips has also reported that physiological anatomy (neck-shaft angle, offset, and limb length) could be reconstructed with this prosthesis.[40] However, despite encouraging results, further assessment by independent centers is needed to build evidence of safety, long term efficacy, and to address unique technical challenges (limited surgical exposure,[9] the need to restore anatomy,[41] and minimize revision rates[42]) to support wider adoption. In our experience with the minimally invasive DAA, the exposure of the proximal femur is technically difficult and limited which could be overcome by a less invasive short stem.

We designed a prospective cohort study to describe the surgical procedure combining DAA and the neck-preserving (MiniHip) stem and to present data on its safety and clinical benefits as well as examine the learning curve effect of adopting this new technique.

Materials and Methods

Participants

For assessment of procedure safety, we included all individuals with hip joint osteoarthritis who underwent a THR by the DAA using a neck-preserving stem at a single center, between April 2012 and August 2014. All participants underwent a screening interview and examination to determine eligibility[43] [Table 1] at a specialized arthritis clinic run by the investigators. Baseline characteristics for patient (age, gender, body mass index [BMI], laterality, and diagnosis) and surgical characteristics (implant components, surgical time) were recorded. All the patients were assessed for clinical efficacy and adverse events associated with the procedure.

The AQUILA checklist for reporting methodological quality and generalizability for case series was used.[44] The University of Notre Dame Australia Human Research Ethics Committee approved the study (ND014160S). All subjects signed an informed consent.

Implant components

A Trinity cup and a MiniHip stem were used as uncemented acetabular and femoral components, respectively (Corin, UK©) [Figure 1]. The stem is a metaphyseal engaging and neck sparing short-stem prosthesis[45] based on the principle of preserving the femoral neck. It is bicoated with a 12/14 taper and is available in nine different sizes.

Table 1: Eligibility criteria

Eligibility criteria
Ipsilateral hip joint osteoarthritis
Dorr Type A/B femur[43]
Adequate bone quality

Figure 1: A photograph of implant components: MiniHip Stem and Trinity Cup

Operative procedure

The implant size was determined using X-rays for templating which subsequently determined the level of the femoral neck osteotomy.[34] The antibiotic protocol consisted of prophylactic intravenous cefazolin (2-g) at induction and for 48 h postoperatively.

Positioning is supine without traction on a standard orthopedic table that allows leg extension. All surgeries were performed using the minimally invasive DAA.[46] Acetabular preparation was done using the Corin Trinity Advanced Bearing Acetabular System. The femoral neck osteotomy partially preserved the femoral neck and was angled in relation to the piriformis fossa, thereby reestablishing the caput-collum-diaphyseal (CCD) angle, independent of that of the stem.[39] The "round the corner" technique was used for broaching which involved compression of the cancellous bone without violating the greater trochanter region.[39] A 3-point bony contact along with a full proximal femoral compartment was indicative of the final size. Clinical stability, range of motion, limb length, and radiological positioning (intraoperative radiograph) were checked once the hip was reduced after placing the trial neck and head. Final components were then placed followed by fascial and skin closure with local anesthetics infiltration.

Postoperative care and rehabilitation

Patients had a planned in-hospital stay of 3–4 days. Quadriceps rehabilitation was started on the same day of the surgery. On the 1st postoperative day, patients were allowed to mobilize weight bearing as tolerated using a forearm support frame. By the 3rd day, they progressed to independent mobilization using crutches and were discharged on oral analgesics. An outpatient rehabilitation program involved range of motion exercises, quadriceps strengthening, and progressive independent mobilization was subsequently initiated.

Clinical followup and radiographs (supine anterioposter pelvic radiograph) were performed at 1, 3, and 6 months and then yearly. Operative time was recorded in minutes from incision until skin closure. Radiographs were used to assess implant stability, bony ingrowth, and leg length discrepancy (LLD).[7] LLD was measured as the distance between a biischiatic line (inferior border of obturator foramen) and the lesser trochanters and recorded in millimeters (mm).[47]

Intraoperative complications were recorded including fractures in the cancellous bone of the partial preserved neck sustained while broaching or at the time of the final insertion of the implant. These fractures were addressed by buttressing using a circlage cable without any change in the femoral component.[48]

Nineteen adverse events defined by the American Hip Society were recorded, and severity was graded as per Sink *et al*.[49,50] These included bleeding, wound complications, thromboembolic disease, neural deficit, vascular injury, dislocation/instability, periprosthetic fracture, abductor muscle disruption, deep periprosthetic joint infection, heterotopic ossification, bearing surface wear, osteolysis, implant loosening, cup-liner dissociation, implant fracture, reoperation, revision, readmission, and death. An independent observer who was blinded to groups interpreted all radiographs.

The primary outcome for the assessment of clinical benefit was the patient-reported Oxford Hip Score (OHS) which is an internationally used validated measure for functional outcomes after THR.[51] The Short Form-36 Health Survey (SF-36) was used to evaluate the subjective health-related quality of life at baseline and yearly followup.[52] They were administered by an independent assessor**.**

Statistical analysis

The effectiveness, functional outcomes were summarised by calculating the mean and standard deviation (SD) for baseline (preoperative) and followup (postoperative), and the difference in pre- versus postoperative scores for each hip. A two-tailed paired *t*-test was used to test the null hypothesis of no difference in pre- versus postoperative functional outcomes.

To test for a learning curve effect, the population was chronologically divided into two equal groups representing the first and second groups of patients receiving the procedure (Group A and B, respectively). Differences in the patient characteristics and outcomes between the Groups A and B were assessed using a Chi-square test to compare patient gender and an independent *t*-test to compare mean age and BMI. A linear regression model was performed to compare age, sex, BMI, diagnosis, and type of femur to outcomes. Differences in outcomes between groups were assessed using a Fisher's exact test (fractures, paresthesia) and an independent *t*-test (time, stem size, and LLD). $P < 0.05$ was considered statistically significant.

The cumulative sums (CUSUM) test was used to monitor intraoperative neck fractures as a measure of the adequacy of the surgical technique.[53] The null hypothesis (H0) is that the process is in control (surgeon achieves acceptable performance), and an alternative hypothesis (H1) is that process is out of control (surgeon demonstrates inadequate performance). When the null hypothesis is rejected an alarm is raised. For the present study, the target, or the performance judged as acceptable, was a 98% success rate. Therefore, the probability P0 for the acceptable fracture rate was 2% (H0) under the null hypothesis. The probability P1for an unacceptable fracture rate was 5% (H1) under the alternative hypothesis. The limit H of the CUSUM test was set at 2.9. The CUSUM test was reset when the technique was refined to improve safety. Analyses were conducted using SPSS version 22 (IBM, New York, United States of America) statistical software.

Results

Patient characteristics

138 patients underwent the procedure between April 2012 and August 2014. There were no dropouts. Median followup time was 42 months (range 30–56 months). Patient baseline characteristics and surgical details are summarized in Table 2. The mean patient age and BMI at the time of the procedure were 62 years (range 35–82 years) and 29 kg/m^2 (range 21–39 kg/m^2), respectively. Ninety seven (70%) of the patients had clinical and radiological evidence of osteoarthritis, 39 (28%) had osteonecrosis while 2 (1%) had mild grade of hip dysplasia. Eighty three (60%) patients had a Dorr A type of femur while 55 (40%) patients had a Dorr B type of femur. The mean stem and cup size were 6 mm (range 2–9 mm), and 52 mm (range 48–60 mm), respectively. The mean operative time was 63 min (SD 17). A regression model revealed that the patient characteristics did not statistically alter the outcomes ($P > 0.05$).

Adverse events

Six (4%) of the patients had an intraoperative fracture of the preserved neck, which was managed intraoperatively (Grade 1) and did not alter the postoperative course. At a minimum of 16 months followup, 125 (91%) patients had an uneventful course with no postoperative complication. Followup X-rays of all but 1 (1%) patient illustrated no migration of implants and stable bony ingrowth. Figure 2 illustrates the standard radiological workup of a patient.

One patient (1%) had a fall 2 weeks after surgery and sustained a traumatic Vancouver AL type of periprosthetic fracture,[54] requiring surgical stabilization of the fracture with cerclage cables and implant revision to a standard porous-coated stem (Grade 3). One patient (1%) had subsidence of 6 mm within first 4 weeks after surgery, which was treated conservatively and did not require any surgical intervention (Grade 2).

Twelve (9%) patients had paresthesia in the anterolateral aspect of the thigh (Grade 2) and 2 patients (1%) suffered from trochanteric bursitis (pain/not pathological bursitis) (Grade 1), which were treated conservatively.

Clinical and functional outcomes

All the patients had a pain free hip joint throughout the range of motion at their first followup visit at 4 weeks. All patients improved on the OHS at their 24-month followup compared to baseline (score mean improvement 26, SD 6.5, $P < 0.001$, paired *t*-test) as well as the physical and mental component of SF-36 (score mean improvement 28, SD 8.9 and 27, SD 8.3, respectively, $P < 0.001$, paired *t*-test) [Table 3]. These outcomes remained consistent at their final recorded followup. All the patients in this study had an LLD of <10 mm while it was <5 mm in 85 (95%) (mean 1.9 mm SD 1.3, range 0.5–7 mm).

Learning curve effect

Group A comprised 69 patients who had surgery performed during the first 14 months of the study period (April 2012–June 2013). Group B comprised 69 patients who had surgery performed over the subsequent 14 months (July 2013–August 2014). The two groups were similar for age, gender, and BMI. The mean age for each Group (A, B) was 62 years ($P = 1$). The mean BMI was 28.8 (range 21-42.2) and 28.6 (range 21 – 39.9) kg/m^2 for Groups A and B, respectively ($P = 0.84$). There were 32 males in Group A compared to 23 in Group B ($P = 0.39$).

The outcomes for each group are shown in Table 4. Five (7%) intraoperative fractures of the preserved neck occurred in Group A and one (1%) in Group B ($P = 0.2$) [Figure 3]. The mean operative time for Group A and B was 66 (SD 18) min and 61 (SD 13) min, respectively ($P = 0.06$). The mean stem size implanted was 5 and 6 in Groups A and B, respectively ($P = 0.09$) [Figure 4]. A total of 12 (8.7%) patients had paraesthesia, including 8 (12%) in Group A and

Table 2: Baseline patient characteristics and surgical information (*n*=138)

Variable	Mean±SD	*n* (%)
Patient characteristics		
Gender		
Male	-	84 (61)
Female	-	54 (39)
Age (years)	62±10	-
Side		
Left	-	64 (46)
Right	-	74 (54)
BMI (kg/m^2)	28.7±5.8	-
Diagnosis		
Osteoarthritis	-	97 (70)
Osteonecrosis	-	39 (28)
Hip dysplasia	-	2 (2)
Surgical details		
Components		
Stem size	6±2	-
Cup size	52±2	-
Surgical time (min)	63±16	-

SD=Standard deviation, BMI=Body mass index

Table 3: Functional outcomes of patients with minimum 2-year followup (*n*=89)

Measurement tool	Mean±SD		Difference between baseline and followup	
	Baseline	Follow up	Mean±SD	*P*
OHS	19±4.8	45±4.3	26±6.5	<0.0001
Short Form-36				
Physical component summary	23±7.1	51±8.2	28±8.9	<0.0001
Mental component summary	31±7.8	58±3.4	27±8.3	<0.0001

SD=Standard deviation, OHS=Oxford Hip Score

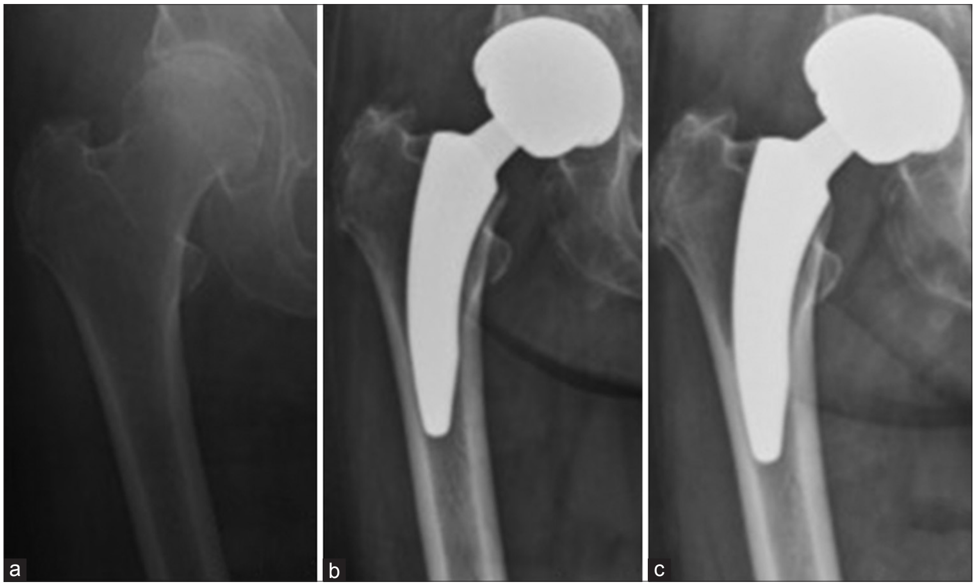

Figure 2: (a) Preoperative radiograph of the right hip anteroposterior view of a 71-year-old woman who presented with severe pain and discomfort secondary to osteoarthritis showing severe joint space narrowing, sclerosis, osteophyte, and cyst formation (b) Radiograph at 4 weeks postoperatively showing treatment of primary right total hip replacement with a size 7 MiniHip (c) Radiograph at 2 years postoperatively showing well-fixed components in satisfactory position and alignment. The patient had an Oxford Hip Score of 46 at 36 months postsurgery

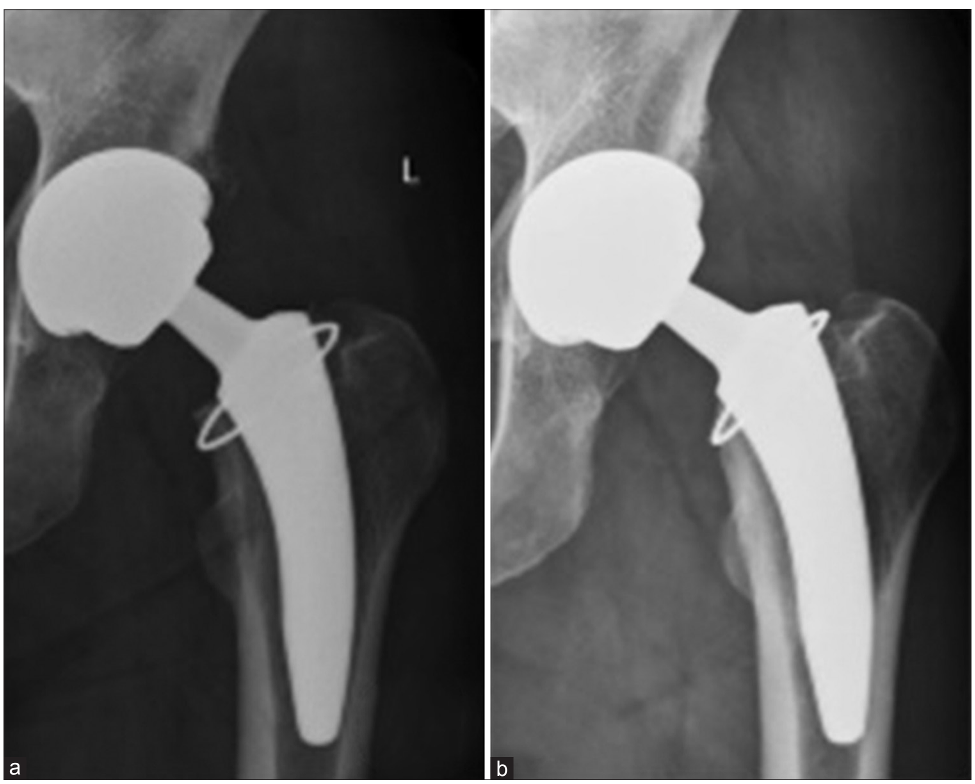

Figure 3: (a) Radiograph of the left hip anteroposterior view of a 57-year-old man at 4 weeks postoperatively showing treatment of primary left total hip replacement with a size 9 MiniHip and a cerclage cable to fix the intraoperative fracture of the preserved neck (b) Radiograph at 2 years postoperatively showing well-fixed components in satisfactory position and alignment. The patient had an Oxford Hip Score of 48 at 24 months postsurgery

reported mean improvements in OHS and Hip disability and Osteoarthritis Outcome Scores (HOOS) of 25 points and 60 points, respectively, from baseline at 12 months, and a 98% survival rate with 2 revisions reported secondary to aseptic loosening.[39] A radiological study using the MiniHip stem in 246 patients reported physiological reconstruction of the hip (CCD angle, offset) as well as restoration of the leg length (LLD – 9 ± 3 mm).[40] More recently, a comparative study of the MiniHip stem using the DAA compared with HR reported a comparable improvement in

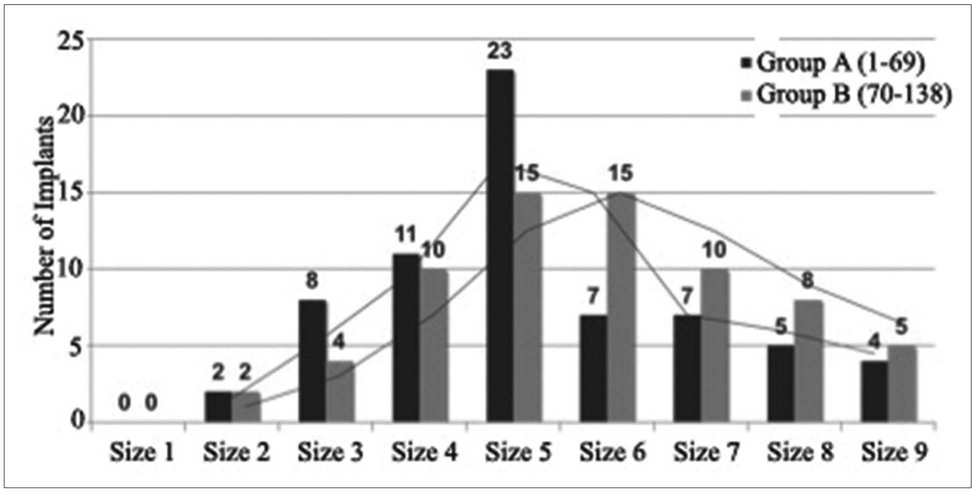

Figure 4: Bar diagram showing distribution of implanted stem sizes (1–9) for the first and second surgery group

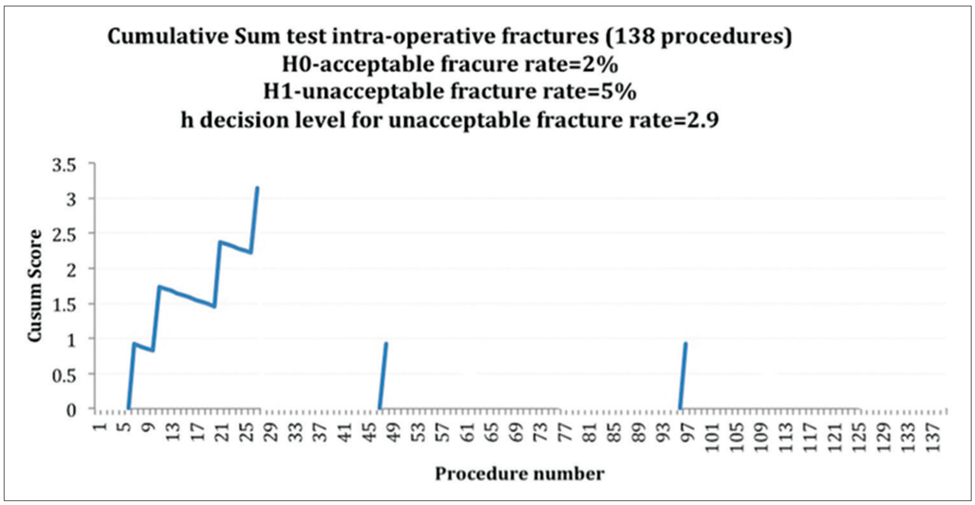

Figure 5: A line diagram showing the cumulative sums test for the inadequacy of the total hip replacement based on intraoperative fractures. The cumulative sums was reset after the first 25 patients

Table 4: Assessment of the learning curve

Factors assessed	Group A (patient 1-69)	Group B (patient 70-138)	*P*
Intraoperative neck fractures *n* (%)	5 (4)	1 (1)	0.21
Operative time (min), mean±SD	66±18	61±13	0.06
Stem size, mean±SD or median (range)	5±2	6±2	0.09
Paresthesia, *n* (%)	8 (6)	4 (3)	0.37
Limb length discrepancy (mm), mean±SD	2±1.3	2±1.3	0.68

SD=Standard deviation

4 (6%) in Group B (*P* = 0.37). The LLD was 2 mm (SD 1.4) and 2.1 mm (SD 1.4) in Groups A and B, respectively (*P* = 0.68).

In total, 6 (4%) intraoperative neck fractures occurred. The CUSUM test shows an alarm was raised after the 25th procedure. During this initial cohort, the technique was refined touse a one size smaller finishing broach, and subsequently, the periprosthetic fracture rate was monitored as being within the acceptable range [Figure 5].

Discussion

This study represents the largest prospective cohort reported to date to assess the safety and clinical benefits of the THR using the minimally invasive direct anterior internervous approach and the MiniHip neck sparing implant design. We demonstrate the feasibility of using this novel technique in a broad population of patients. This series also documents operative time and adverse event rates over time to describe the learning curve when a surgeon unfamiliar with the surgical technique adopts the procedure.

Few observational case series have reported clinical outcomes for THR's using the MiniHip implant since it was introduced. The largest of these, a multicenter prospective case series using the MiniHip in 180 patients

Table 5: Studies combining short stem and direct anterior approach and MiniHip stem

Study	Name of stem design	Surgical approach	Number of hips	Mean followup time (year)	Aseptic stem survival (%)	Overall survival (%)	Postoperative (mean hip score)	Intraoperative fracture, *n* (%)	Stem subsidence (%)	Weight bearing protocol
Molli *et al.*[23]	Taperloc Microplasty	Direct anterior	269	2.5	99.6	98.9	83 (HHS)	2 (0.4)	-	FWB
Jerosch *et al.*[40]	MiniHip	Antero-lateral	180	2.1	98	-	46 (OHS)	-	1.7	NS
Dettmer *et al.*[55]	MiniHip	Direct anterior	73	1.4	99	98	Improved	2 (1.5)	-	FWB
Khemka *et al.*	MiniHip	Direct anterior	138	2.3	100	99	45 (OHS)	6 (7)	1	FWB

HHS=Harris Hip Score, OHS=Oxford Hip Score, FWB=Full weight bearing, NS=Not specified

the HOOS scores and a 97.3% survival rate with two cases of loosening at 1.5-year mean followup for 70 patients receiving the MiniHip group.[55]

Our clinical and functional results are consistent with the findings of the previous studies. The improvement in OHS and the SF-36 scores indicates that the procedure provides a clinically and statistically significant improvement in health-related quality of life. The gender distribution and wide age range of included patients from 35 to 82 years helps to demonstrate the safety of procedure in older adults as well as the elderly, both for men and women and not necessarily only for a specific group (young and active) of patients. Few studies have demonstrated a higher risk of complications in obese patients undergoing THR. One such study of 210 patients (79 with a BMI >30) undergoing THR using the DAA demonstrates that major and wound complications were both significantly increased in the obese group (odds ratio, 8.8 and 3.6, respectively).[56] One-third of patients in our study had a BMI >30 with no major adverse events or wound complications observed indicating the procedure is also feasible in obese patients. Overall, our results suggest the procedure can be used as an alternative to THR using standard stems/hip replacement prostheses without limitations based on age, gender, and BMI.

The DAA has become increasingly popular with the development of implant concepts such as the short stem. Recently, Molli *et al.*[23] reported >98% implant survival at 2 years with the use of a short stem (Taperloc) and DAA [Table 5]. More recently, a comparative study of the MiniHip stem using the DAA compared with HR has reported on the adverse events including risk of aseptic loosening, periprosthetic fractures, and revision rates.[55] The present study adds to the body of evidence not only about the safety of the MiniHip short stem implant but also its combination with the DAA [Table 5].

At a median followup of over 2 years, we observed no cases of aseptic loosening and low risk of postoperative complications. Subsidence detected in the 1 patient at the 4 weeks followup was a result of under sizing. The patient was clinically asymptomatic, hence, was treated conservatively with 4 weeks of partial weight bearing and thus stratified as Grade 2. The subsidence subsequently stabilized with metaphyseal osseointegration. In the one patient with a periprosthetic fracture, the fracture resulted from a significant fall 4 weeks after surgery. The implant was revised to a standard stem, and the fracture was stabilized using cerclage cables and thus stratified as a Grade 3 complication. At the final followup, this patient had an OHS of 48 with pain-free range of motion at the hip. Our results indicate that limb length was adequately restored in all the patients (100% <10 mm), with 85 patients having an LLD <5 mm.

The retention of the femoral neck produces an oval-shaped intramedullary opening compared to the standard surgical technique and thus presents a particular challenge for broaching and sizing of the stem. Lombardi *et al.* in their report on their experience with >600 short stem THR's, suggested that the surgeon should be aggressive with sizing, using broaches to rasp and pushing the stem into valgus.[57] We used this technique along with the broaching technique described by Jerosch *et al.*[39] In this present study, during the adoption of this surgical technique, we encountered 6 intraoperative neck fractures, which were a result of the penultimate finishing broach before the definitive implantation. These patients required stabilization using circlage cables [Figure 3] but did not alter the patient's postoperative recovery or rehabilitation. To help avoid these fractures, the surgeon altered the technique using a one size smaller finishing broach with a subsequent reduction in the incidence of fractures. As the surgeon became more familiar with the technique and more confident with broaching, 55% of patients in Group B received stems of a higher size (size 6 or more) compared to 30% of the patients in Group A [Figure 4]. Aggressive broaching/sizing may contribute to the absence of subsidence/aseptic loosening.

The main strength of this study is that it is the first to assess the combined surgical techniques of the neck-preserving stem and the DAA. The findings are valuable to inform the development of minimally invasive surgical approaches and new implant concepts to make potential revisions easier. It appears from our study that minimal variations in the surgical technique that may be considered trivial can induce some substantial changes in the health care. We also demonstrate the use of the CUSUM test to monitor the safety of introducing the THR using the MiniHip stem. The implementation of a CUSUM test to monitor failure rates against a predefined "acceptable standard" can help surgeons to appreciate their level of performance and initiate changes to improve performance if required.

A limitation of this study is the relatively short followup time, which precludes assessment of the long term survival of the implant especially changes in bone density over time, which was not explored. Second, the senior surgeon in this study is a high-volume hip surgeon, thus the learning curve evaluated is of this single surgeon, and may not be directly applicable in different practice settings, and may not reflect the learning curve of other surgeons.

The clinical implications of our findings are that the bone-sparing features of this implant may overcome the challenges and disadvantages of standard surgical techniques. Further, larger prospective multicenter studies with long term followup will be needed to estimate the long term benefits and risks of the procedure compared to standard THR. We recommend future surgeons adopting this surgical technique be supervised in their first 25 procedures, in particular, to support learning of the broaching technique and appropriate sizing.

Conclusions

These midterm results demonstrate the clinical and functional benefits of the neck-preserving stem and suggest these benefits are achieved with a low risk of complications. Further, studies are needed to monitor long term survival and bone remodeling. There does appear to be a learning curve for the surgical technique, with risk of complications, operative time, and implants sizing improving with experience.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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