Thesis

TREATMENT OF (POST)TRAUMATIC HIP OSTEOARTHRITIS WITH SHORT STEM TOTAL HIP ARTHROPLASTY

A Retrospective and Follow-Up Study

submitted by

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Graz, 25.07.2024

Declaration of Academic Integrity

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Graz, 25.07.2024 *Matthias Gruber m.p.*

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Zusammenfassung:

Titel: Behandlung (post)traumatischer Hüftgelenksarthrose mit Kurzschaftendoprothesen. Eine retrospektive Studie und Follow-up-Studie.

Hintergrund: Die Geradschaft-HTEP ist der derzeit modernste Behandlungsansatz für Patient*innen mit Schenkelhalsfrakturen, bei denen eine kopferhaltende Operation nicht möglich ist. In ausgewählten Fällen von Oberschenkelhalsbrüchen, wie auch bei posttraumatischer Hüftgelenksarthrose mit einliegendem osteosynthetischem Material kann die Anatomie eine Versorgung mittels Kurzschaft-HTEP notwendig machen, wobei die Verwendung einer Kurzschaft-HTEP mit verschiedenen potenziellen Vorteilen im Vergleich zu einer Geradschaft-HTEP einhergeht. Dazu gehören ein weniger traumatischer Zugang zur Hüfte, gute Möglichkeiten zur Rekonstruktion der Hüftgeometrie und weniger Fremdmaterial. Ziel dieser Studie ist es, einen evidenzbasierten Nachweis zu erbringen, dass die Implantation einer Kurzschaft-HTEP für junge Patient*innen mit sportlichem Anspruch eine potenzielle Alternative darstellt.

Methoden: Insgesamt wurden die Daten von 12 Patient*innen, die aufgrund einer (post)-traumatischer Hüftgelenksarthrose an der Universitätsklinik für Orthopädie und Unfallchirurgie der Medizinischen Universität Graz mit einer Kurzschaft-HTEP (ANA NOVA Proxy®) behandelt wurden, retrospektiv erhoben. Alle Patient*innen wurden prospektiv zur Teilnahme an einer klinischen und radiologischen Nachuntersuchung eingeladen. Diese umfasste Röntgenaufnahmen des Beckens und der betroffenen Hüfte sowie drei Fragebögen, den McMaster University Osteoarthritis Index (WOMAC), den Harris Hip Score (HHS) und den Barthel Index zur Bewertung von Funktionalität, Schmerzen und Mobilität. Die erzielten Ergebnisse wurden mit den bereits vorliegenden Ergebnissen von 12 Alters- und Geschlechts-gematchten Patient*innen verglichen, die mit derselben Kurzschaft-HTEP (ANA NOVA Proxy®) bei primärer Hüftgelenksarthrose behandelt wurden.

Resultate: Von den 12 Patient*innen nahmen 9 am prospektiven Teil der Studie teil. Davon war bei 5 Patient*innen während der HTEP-Implantation die Entfernung von Implantaten notwendig (DHS, PFNA) welche aufgrund vorausgegangener Taumata eingesetzt worden waren., Die restlichen 7 wiesen eine Schenkelhalsfraktur auf. Patient*innen mit (post)traumatischer Hüftgelenksarthrose hatten einen niedrigeren mittleren BMI (22.3 ± 4.3) als Patient*innen mit primärer Hüftgelenksarthrose (27.7 ± 2.9; p=0.002). Die durchschnittliche Operationszeit betrug 42.0 ± 11.4 Minuten für alle Patient*innen zusammen, wobei kein statistisch signifikanter Unterschied zwischen Patient*innen mit primärer (39.8 ± 12.2 Minuten) oder (post)traumatischer Hüftgelenksarthrose (44.3 ± 10.5 Minuten; p=0.335) bestand. Die Dauer des Krankenhausaufenthalts war zwischen den Gruppen vergleichbar (Mittelwert: 6.3 ± 1.8 Tage für (post)traumatische Hüftgelenksarthrose vs. 7.3 ± 1.3 für primäre OA; p=0.101). Alle Patient*innen mit primärer Hüftgelenksarthrose durften postoperativ voll belasten (100 %), ebenso 3 Patient*innen mit Schenkelhalsfrakturen (25,0 %). Andererseits wurde bei 6 Patient*innen (drei mit Schenkelhalsfrakturen) eine Teilbelastung mit maximal halbem Körpergewicht für 6 Wochen, bei 2 Patient*innen (beide mit Schenkelhalsfrakturen) für 4 Wochen und bei einem Patienten mit (post)traumatischer Hüftgelenksarthrose für 2 Wochen empfohlen. In der Gruppe der Patient*innen mit primärer Hüftgelenksarthrose erkrankte ein Patient im Rahmen des stationären Aufenthalts an einer Pneumonie. Ansonsten kam es zu keinen intra- oder frühpostoperativen Komplikationen. Die Ergebnisse der Fragebögen waren zufriedenstellend und mit der bisherigen Literatur vergleichbar. Beim HHS wurde im Median ein Score von 97 von maximal 100 Punkten erreicht. Beim WOMAC erreichten 8 der 9 untersuchten Patient*innen ein ausgezeichnetes Ergebnis und ein Patient ein gutes Ergebnis. Beim Barthel-Index konnten 7 Patient*innen die maximale Punktzahl von 100 Punkten erreichen, während 2 Patient*innen 95 Punkteerreichten, was ebenfalls ein ausgezeichnetes postoperatives Ergebnis darstellt.

Zusammenfassung: Patient*innen mit posttraumatischer Hüftgelenksarthrose oder Schenkelhalsfrakturen können mit einer Kurzschaft-HTEP behandelt werden. Die postoperativen Ergebnisse sind vergleichbar mit jenen einer alters- und geschlechtsgleichen Kontrollgruppen mit primärer Hüftgelenksarthrose. Unsere Ergebnisse weisen darauf hin, dass bei gewissen Patient*innen (insb. jung und sportlich aktiv) ein Kurzschaft- HTEP eine gute Alternative darstellen könnte.

Abstract:

Title: Treatment of (post)traumatic hip osteoarthritis with short stem total hip arthroplasty. A retrospective and follow-up study

Background: Straight-stem THA is currently the state-of-the-art treatment for patients with femoral neck fractures who cannot undergo head-preserving surgery. In selected cases of femoral neck fractures and post-traumatic hip osteoarthritis with osteosynthesis, the anatomy may allow treatment with a short-stem THA, which has several potential advantages over a straight-stem THA. These include a more atraumatic approach to the hip, good possibilities to reconstruct the hip geometry, and less foreign material. The aim of this study is to provide evidence that the implantation of a short-stem THA is a potential alternative for young patients with athletic aspirations.

Methods: A total of 12 patients treated with short-stem THA (ANA NOVA Proxy®) for (post-)traumatic hip osteoarthritis at the Department of Orthopaedics and Trauma, Medical University of Graz were retrospectively reviewed. All patients were prospectively invited to clinical and radiological follow-up. This included radiographs of the pelvis and the affected hip, as well as three questionnaires, i.e. the McMaster University Osteoarthritis Index (WOMAC), the Harris Hip Score (HHS) and the Barthel Index to assess functionality, pain and mobility. The results were compared with existing results from 12 age and gender matched patients treated with the same short stem THA (ANA NOVA Proxy®) for primary hip osteoarthritis.

Results: Of the 12 patients, 9 participated in the prospective part of the study. Of these, 5 patients had to have implants (DHS, PFNA) removed during THA implantation due to previous trauma. The remaining 7 patients had a fracture of the femoral neck. Patients with (post)traumatic hip osteoarthritis had a lower BMI (mean 22.3 ± 4.3) than patients with primary hip osteoarthritis (27.7 ± 2.9; p=0.002). The mean operating time was 42.0 ± 11.4 minutes for all patients together, with no statistically significant difference between patients with primary (39.8 ± 12.2 minutes) or (post)traumatic hip osteoarthritis (44.3 ± 10.5 minutes; p=0.335). The length of hospital stay was comparable between groups (mean 6.3 ± 1.8 days for (post)traumatic hip osteoarthritis vs. 7.3 ± 1.3 days for primary OA; p=0.101). All patients with primary hip osteoarthritis were able to bear full weight postoperatively (100%), as were 3 patients with femoral neck fractures (25.0%). On the other hand, 6 patients (3 with femoral neck fractures) were advised to bear partial weight with a maximum of half their body weight for 6 weeks, 2 patients (both with femoral neck fractures) for 4 weeks, and 1 patient with (post)traumatic hip osteoarthritis for 2 weeks. In the group of patients with primary hip osteoarthritis, one patient developed pneumonia during hospitalisation. Otherwise, there were no intraoperative or early postoperative complications. The results of the questionnaires were satisfying, and fully comparable with the literature so far. The median HHS score was 97 out of 100. For the WOMAC, 8 of the 9 patients examined achieved an excellent result, and one patient a good result. Regarding the Barthel Index, 7 patients achieved the maximum score of 100 points, and 2 patients achieved 95 points, also constituting an excellent postoperative result.

Summary: Patients with (post)traumatic hip osteoarthritis or femoral neck fractures can be treated with a short-stem THA. The postoperative results are comparable to those of a control group of the same age and sex with primary hip osteoarthritis. Our results suggest that a short-stem THA may be a good alternative for certain patients (especially young and physically active patients).

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List of abbreviations

A. = Artery

Aa. = Arteries

ADLs = Activities of daily living

Ant. = Anterior

ASA = American Society of Anaesthesiologists

BHR = Birmingham Hip Resurfacing

BMD = Bone mineral density

BMI = Body mass index

CI = Confidence interval

CRP = C-reactive protein

DHS = Dynamic hip screw

Hb = Haemoglobin

HHS = Harris Hip Score

HO = Heterotopic ossification

Lat. = Latin

Lig. = Ligamentum

M. = Musculus

OA = Osteoarthritis

PFNA = Proximal femoral nail

PJI = Periprosthetic joint infection

R. = Ramus

Rr. = Rami

SD = Standard deviations

Sup. = Superior

THA = Total hip arthroplasty

WOMAC = Western Ontario and McMaster Universities Osteoarthritis Index

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1. Introduction

1.1 The hip joint

The hip joint belongs to the category of ball and socket joints with 3 degrees of freedom. Since the femoral head is enclosed by the acetabulum up to its largest diameter, on the one hand providing greater safety against dislocation, but on the other hand reducing mobility, the subtype of an enarthrosis ("nut joint") is present(1). Range of motion is possible as extension and flexion around the transverse axis (anteversion and retroversion) with a radius of 10° and 130°. Abduction is possible up to 45° in the sagittal axis, and adduction up to 30° In the vertical axis, external rotation of 50° and internal rotation of 45° can be performed(2).

1.1.1 The joint members

The two articulating components of the hip joint are the glenoid cavity, the acetabulum of the hip bone *os coxae* with the cartilaginous articular surface *facies lunata*, and the femoral head *caput ossis femoris* of the femur(1).

1.1.1.1 The Acetabulum

The acetabulum is formed by the three hip bones, i. e. os ilium cranially, os pubis ventrally/caudally and the os ischii dorsally/caudally. The socket is covered to three quarters by a cartilage layer *fascies lunata* with a thinner wall in the center, and a thicker wall at the equator. Externally, the fibrocartilaginous labrum acetabuli additionally encloses the socket and thus forms the bony/cartilaginous socket roof. The acetabular entrance level is tilted against the sagittal plane ventrally by 24° and caudally by 40°, which is why the acetabulum points outward, anteriorly and inferiorly.(3) Because of its depth and tight ligaments, the acetabular joint is relatively resistant to dislocation.(1)

1.1.1.2 The Femur

The caput femoris (femoral head) sits medially on the collum femoris and is covered by cartilage in large parts except for the fovea capitis femoris where the *lig. capitis femoris* is attached. The femoral head is followed by the neck of the femur (*collum femoris*), which leads into the shaft (*corpus femoris*). The neck is curved ventrally and is reinforced by the *linea aspera*. At the transition from the femoral neck to the shaft, the two muscle insertion humps (apophyses), lateral to the greater trochanter and medial/dorsal to the lesser trochanter, are prominent.(4)

The greater trochanter acts as a muscle attachment point for the small external rotator muscles and the tractus iliotibialis. The trochanter minor serves as the base for the iliopsoas muscle as the most important hip flexor. This pelvitrochanteric musculature centers the femoral head in the acetabulum.(4)

Dorsally, the two trochanters are connected by the *crista intertrochanterica* and ventrally by the *linea intertrochanterica*. The angle formed by the longitudinal axis of the femoral neck with the main axis of the stem is called the centrum-collum-diaphysis angle (CCD). Normally, this angle is around 125°. An angle of less than 120° is called a coxa vara whereas an angle of more than 130° is called a coxa valga.(3) In the transverse plane, the femoral neck is rotated forward by 10-15° against the condyles. This so-called antetorsion is causative for the physiological internal torsion of the knee.(1, 3)

The *lineae aspera*, a pronounced bony longitudinal ridge, is located on the posterior side of the femur and has a medial and a lateral lip as well as a narrow, rough intermediate line. These serve as the origin and attachment point of various muscles for the hip and knee joints. At the very distal end are the femoral condyles.(5)

1.1.2 Joint capsule and ligaments

The joint capsule of the hip begins proximally immediately beyond the *labrum acetabuli* and extends further distally to the point where most of the neck of the femur lies within the joint cavity. The trochanters remain extracapsular. The synovial membrane and the underlying blood vessels that supply the femoral head are also located within the joint cavity.(1)

Ligaments of the hip can be divided into two categories. There are mechanically strong ligaments that radiate into the joint capsule from the outside and strengthen it. These include the *lig. iliofemorale* with its two parts, the *pars descedens* and *pars tranversa*, *the lig. pubofemorale*, the *lig. ischiofemorale* and the *zona orbicularis*. The main function of these structures is to restrict movement and secure the femoral head against dislocation. Additionally, there is an intra-articular ligament without any significant mechanical function, the *lig. capitis femoris*. Unlike the other ligaments, it has no movement-restricting function, but is of great importance for the blood supply of the femoral head especially during the growth period.(1, 3)

Recent evidence shows that the function of the *lig. capitis femoris* is still not fully understood and may play a greater role than originally assumed. In case of micro instability of the hip, when other stabilizers fail or are inadequate, the *lig. capitis femoris* can take on a more dominant role as a stabilizer. Additionally, it has been shown to play a role in the degeneration of the hip joint.(6, 7)

Studies indicate that presence of tears in the *lig. capitis femoris* are associated with articular cartilage damage.(8, 9) Furthermore, reconstructions of the *lig. capitis femoris* have been reported to improve function and pain in the affected hip.(10-12)

1.1.3 Vascular supply

The femoral head is mainly supplied by an extracapsular- not always closed- arterial ring from the *Rr. ascendes* of the *Aa. circumflexa medialis* and *lateralis* from the *A. profunda femoralis*. In addition, the femoral head is also supplied to a small extent by the *A. capitis femoris* via *the lig. captits femoris* through the *R. acetabularis* of the *A. obturatoria*. As mentioned above, this is important in the growing child but plays a subordinate role in adults. In the case of a femoral neck fracture, the only supply left is through the *R. acetabularis* of the *A. obturatoria* via the *lig. captits femoris*. In most cases, this leads to necrosis of the femoral head because the *A. capitis femoris* cannot ensure sufficient supply.(13) The consequence is a deformation of the caput and resulting hip osteoarthritis. In addition, the closer the fracture is to the head of the joint, the greater is the risk for femoral head necrosis.

In case femoral head preservation therapy is attempted, it should be performed within 6 hours from the trauma.

1.2 Fractures close to the hip

Proximal femoral neck fractures are typical injuries of the elderly, and Austria, due to its ageing population, is one of the countries with the highest incidence of hip fractures worldwide. They are considered the most serious injuries as they can lead to premature death, disability, chronic pain, and reduced quality of life. In addition, the risk for fracture increases exponentially with increasing age. Interestingly, incidence rates for hip fractures have slightly decreased in recent years (2008-2018) in both women and men, although there has been a notable population increase in the 50+ age groups.(14, 15)

Reasons for this could be, among others, improved nutrition in childhood and changes in smoking behaviour. There is also evidence that a higher body mass index (BMI) could be associated with a lower risk of hip fracture.(16) In women, menopausal hormone therapy may also have contributed to a decrease in incidence, as well as vitamin D, calcium, and bisphosphonate therapy in general. In line with this, research suggests that osteoporosis treatment can reduce hip fracture rates by 25% to 50% while being cost-effective.(17, 18). However, this trend may be at risk due to the rapid aging of the Austrian population.(14, 19, 20)

1.2.1 Definition and aetiology of hip fractures

By definition, femoral neck fractures represent a specific type of intracapsular hip fractures.(15) Increasing age is one of the greatest risk factors for recurrent falls. This is due to the growing morbidity in old age in combination with a decrease in coordination, musculature, and sensory perception, resulting in an enhanced tendency to fall. Secondary diagnoses such as diabetes mellitus, Parkinson's disease, or an influence of medication in connection with osteoporosis also explains the rise in falls and fractures in the elderly. Additionally, patients who suffer a hip fracture are usually frailer and have more concomitant diseases than people of the same age without hip fracture history.(4, 20, 21)

These figures, based on the "Hüft- und Knie-Endoprothetik in Österreich" report from the BMASGK (Bundesministerium für Arbeit, Soziales, Gesundheit und Konsumentenschutz), provide a detailed insight into the prevalence of femoral neck fractures in various age groups across Austria in 2016.

Considering all age groups over the age of 19, a total of 8.736 cases of femoral neck fractures were diagnosed in 2016. This number highlights the relevance and impact of this injury on the health of the Austrian population as well as its healthcare system. In the age group 20-59 years, 890 femoral neck fractures were documented, indicating a comparatively lower incidence in this younger cohort. However, these figures increased when analysing people aged 60-69 years, where 921 cases were recorded. There is a particularly marked increase in the age group 70-79 years, with a total of 2.234 documented femoral neck fractures within one year (2016). These figures emphasize the vulnerability and increased risk of this injury in this specific age category. There has also been a continued increase in femoral neck fractures among 80–84-year-olds (1.582), 85–89-year-olds (1.772), and people aged 90 and over (1.337). Of the 8.736 documented femoral neck fractures in Austria, the analysis showed that 12,4% of these cases (n=1.080) were treated with a total hip arthroplasty (THA). Notably, 43.5 % (n=3.804) received a hip hemiarthroplasty. Osteosynthesis was performed in 21.3% (n=1.855) of cases. The remaining 22.8% (n=1.997) were treated with conservative methods.(22)

Age Group	Number of Cases	Percentage of Total Cases
20-59 years	890	10.2%
60-69 years	921	10.5%
70-79 years	2.234	25.6%
80-84 years	1.582	18.1%
85-89 years	1.772	20.3%
90+ years	1.337	15.3%
Total	**8.736**	**100%**

Table 1: Distribution of femoral neck fractures by age

Treatment Methods	Number of Cases	Percentage of Total Cases
Total Hip Arthroplasty (THA)	1.080	12.4%
Hemiarthroplasty	3.804	43.5%
Osteosynthesis	1.855	21.3%
Conservative Methods	1.997	22.8%
Total	**8.736**	**100%**

Table 2: Distribution of treatment for femoral neck fractures

1.2.1.1 Osteoporosis and Dorr classification

Osteoporosis is a bone disease characterized by impaired remodelling of skeletal tissue and the resulting pathological microarchitecture. This reduction in bone density significantly increases the risk of fractures.(23) Osteoporosis is detected by measuring bone mineral density (BMD) using dual-energy X-ray absorptiometry preferably at the proximal femur. It is diagnosed when the BMD T-score is -2.5 standard deviations (SD) or less compared with the average for premenopausal women (T-score < -2.5 SD). Severe osteoporosis is characterised by the occurrence of at least one fragility fracture. The same absolute BMD value also applies to men.(24) The World Health Organisation states that each one SD decrease in BMD T-score in the femoral neck is associated with a 2.6- times greater risk of hip fracture.(25)

The quality of the femoral bone is often assessed using the Dorr classification, which is divided into three types (A-C) based on anteroposterior and lateral radiographs of the hip joint.

Type A: a sufficiently thick bone cortex in the antero-posterior and lateral views of the X-ray image and has a narrow bone canal; "champagne flute" appearance; cortical thickness index of <0.5; generally suitable for cementless stems.

Type B: moderate cortical bone with a wider canal and is intermediate between types A and C. The cortex is thin with a residual funnel shape in the anteroposterior view and the cortex in the posterior part of the femur is indistinct with a discontinuous line on the medullary side of the bone in the lateral view; cortical thickness index of 0.5 to 0.75.

Type C: extremely thin cortex with a "stovepipe shape" in the anteroposterior view and a widened medullary cavity and indistinct cortex in the lateral view, consistent with severe osteoporosis; cortical thickness index of >0.75; benefits from cemented stems due to their compromised bone quality.

The Dorr classification is based solely on an assessment of the appearance on conventional X-ray images and does not define any clear quantitative criteria. However, it is still useful for patient selection, considering cemented techniques to reduce early mechanical loosening or femoral fracture in hip replacement.(26-31)

1.2.2 Classifications of proximal femoral fractures

Depending on the location of the femoral fracture, classifications can be made to describe the type of injury more precisely. These are classified from proximal to distal in the head-, intracapsular- and the extracapsular trochanteric- and extracapsular subtrochanteric fractures. Another variant would be the subdivision into femoral head fractures, medial femoral neck fractures, lateral femoral neck fractures, pertrochanteric femoral fractures, and subtrochanteric femoral fractures.(20, 32)

1.2.2.1 Pipkin classification

The Pipkin classification is divided into four forms (I-IV) and is ideal for the classification of femoral head fractures.

Pipkin I: fracture of the calvaria caudal to the fovea capitis femoris and outside the loading zone.

Pipkin II: the fracture of the calvaria passes through the fovea capitis and within the weight-bearing zone.

Pipkin III: fracture of the calvaria (Pipkin I or Pipkin II) in combination with a medial femoral neck fracture.

Pipkin IV: fracture of the calvaria (Pipkin I or Pipkin II) in combination with an acetabular rim fracture.(33-35)

1.2.2.2 Orthopaedic Trauma Association (OTA) classification

The AO classification is a system for describing the location and characteristics of bone fractures. This classification aims to provide a globally unambiguous assignment of fractures, which enables standardized treatment. The body region (femur) is coded with the number 3. Since it is a proximal fracture location, a 1 follows. Now 3 categories describe the localization even more precisely. A indicates a fracture in the trochanteric region, B a fracture of the femoral neck, and C a fracture at the femoral head. Each group can be further subdivided. In practice, it has been shown that this subdivision may not bring further advantages in terms of treatment decision and outcome. Especially with femoral neck fractures, one may simply distinguish displaced and non-displaced intracapsular fractures.(34, 36)

1.2.2.3 Garden classification

The most commonly used classification for medial femoral neck fractures is the Garden classification. It evaluates the risk of developing avascular necrosis of the femoral head by describing the degree of dislocation of the head fragment. It distinguishes between four types of fracture.

Garden I fractures are often referred to as non-displaced and are considered stable injuries. However, they usually present with valgus impaction of the femoral head.

Garden II fractures are true non-displaced fractures in whom the fragment alignment corresponds to the shape of an uninjured femoral neck. This type is also considered non-displaced, but less stable.

Garden III and Garden IV fractures, on the other hand, are variably dislocated fracture types. In Garden III injuries, the femoral head is in contact with the femoral neck, whereas in Garden IV injuries, contact is lost due to complete dislocation.(32, 37)

1.2.2.4 Pauwels classification

This classification is based on the angle of the fracture with regards to the horizontal axis. The smaller the angle, the more likely is a supportive compression in the fracture area upon axial load. On the other hand, in case the angle is larger, shear forces can occur under axial load within the fracture area, which has a significant negative influence on bone healing. For this reason, the Pauwels classification distinguishes 3 groups.

Type I has a fracture angle <30° to the horizontal axis.

Type II has an angle of 30-50° between the fracture line and the horizontal axis.

Type III is defined as an angle of >50°.(37)

In combination with the Garden classification, the Pauwels classification is a reasonably good way of assessing the biological and mechanical prerequisites for fracture healing in individual cases and guide the selection of the surgical method.(32)

1.3. Presentation of femoral neck fractures

Patients are usually unable to elevate the affected leg when lying down (loss of function) and passive movements of the hip joint cause pain. Sprains, rotations, and pressure pains may occur. Bruising marks or hematomas are usually found at the greater trochanter.(38) Unstable or dislocated fractures of the proximal femur can be recognized on inspection by shortening and external rotation of the leg. A typical sign is the sinking of the femoral head dorsally (ante-curvature malalignment of the femoral neck) due to traction of the internal rotator muscles. In submerged fractures, the fracture signs may be absent. Pain radiating into the knee joint is sometimes reported.(34)

1.4 Diagnosis of femoral neck fractures

In case a femoral neck fracture is suspected, a pelvic overview image and an image of the affected hip joint in an anterior-posterior and axial (Lauenstein) projection is essential. With the help of these X-ray images, the fracture types and stages can be classified, and the best possible treatment and therapy initiated.(34)

In addition, in the case of a pathological fractures, a complete x-ray of the femur must be performed to exclude potential osteolysis more distally. In case there is a clear clinical suspicion for fracture but X-ray images remain negative, CT scans and – if still unclear – MRI scans must be performed. Especially the latter modality has a high sensitivity for detection of non-displaced femoral neck fractures or another causes of hip pain.(38, 39)

1.5 Therapy of a femoral fracture

Several issues have to be considered in the treatment of a femoral neck fracture. These include a rapid, durable, and low-complication restoration of functionality and mobility. The preservation of the joint should be considered when reasonable and possible. Further interventions should be avoided, and therapy costs kept as low as possible. To achieve these goals, 4 procedures are available today. These include osteosynthesis, unipolar head endoprostheses, bipolar head endoprostheses, and total endoprostheses. The decision on the optimal procedure in each individual case is based on the consideration of the expected result and the complications associated with the chosen method. The determining factors include the pre-existing mobility and mental function, life expectancy, bone quality, and fracture shape. In young patients, medial femoral neck fractures are typically treated with osteosynthesis. As with all age-related indications, it is difficult to narrow down the range of indications, whereby the numerical age of the patient plays only a subordinate role. The general condition (biological age) and possible comorbidities should be in the focus of this individual decision, which in some cases also speaks for an endoprosthetic replacement in a young patient. This should be done through total endoprosthesis due to better functional results.(32, 34, 38)

1.5.1 Conservative treatment of femoral neck fractures

Conservative fracture treatment is sometimes considered for patients who are bedridden because of their general condition or who would be unlikely to survive surgery because of their overall status. There is no clear indication for conservative treatment. But even for old, frail patients, mobilization from bed would be advantageous, as otherwise the risk of thromboembolic complications, bedsores, and pneumonia increases. Furthermore, mortality is higher in patients treated conservatively and is also associated with a longer hospital stay than after surgical treatment. Often a non-displaced valgus fracture is considered stable and treated conservatively, but the risk of subsequent displacement of the fracture is high and the following surgery usually requires a joint replacement. This may not have become necessary upon primary treatment with a stable-angle implants or screws. in addition, secondary dislocations often lead to necrosis of the femoral head and pseudoarthrosis of the femoral neck. for these reasons, early treatment, including a stable femoral neck fracture, is advisable if the general condition is suitable.(37, 40-42)

1.5.2 Surgical treatment of femoral neck fractures

As already mentioned above, there are various types of surgical treatment options. In case of femoral neck fractures, the therapeutic plan should be determined individually for each patient. An immersed abduction fracture according to Garden I should be treated with a dynamic hip screw (DHS) or compression screw. This also applies to Garden II adduction fractures in younger patients. In elderly patients, a bipolar prosthesis should be used. Adduction fractures Garden III and IV are treated with DHS in the younger patient. In older patients, several possibilities also depend on life expectancy. Bipolar endoprostheses, head endoprostheses are used if the life expectancy is less than 5 years, or total endoprostheses if the life expectancy is longer. However, there are also other clear indications such as the "6P's" for an endoprosthesis. These are Paget's disease, Parkinson's disease, pathological fracture, plegia, polyarthritis, and severe osteoporosis.(34, 38)

Recent studies show that in relatively young and inactive elderly patients with a displaced femoral neck fracture, total joint arthroplasty with a double mobility cup should be considered as the primary treatment option. It offers better functional outcomes, reduces mortality and morbidity compared to a bipolar hemiarthroplasty.(43, 44)

1.5.3 Removal of implants

Surgical treatment of femoral neck fractures can sometimes result in long-term physical limitations and pain, even if the fractures have healed without complications. Reasons for implant removal include local irritation, pain, unexplained discomfort or patient request, possible carcinogenic/toxic or unknown systemic effects, and anticipated problems with late removal due to bone overgrowth. There are still no guidelines for the timing of implant removal due to a lack of evidence. However, there are recommendations for young patients to have them removed after 12 to 18 months. There is no advice for older patients and femoral head necrosis is repeatedly observed after implant removal. However, studies demonstrate that implant removal after internal fixation of a femoral neck fracture has a positive effect on the quality of life and should be performed if pain persists or functional recovery is unsatisfactory.(45-48)

1.6 Design of total hip joint prosthesis

To this day, research and work are still being done on different types and variants of hip replacement, and there are some requirements that are strived for. In general, the load should be optimally distributed in the proximal femur. Maximum preservation of the bone without compromising stability and a permanent fixation is targeted.(49, 50)

Due to the different biological conditions such as bone density, proximal femoral anatomy, and cortical-medullary ratios, an optimal choice is often challenging. This also explains the different stem lengths and designs, with various fixation mechanisms. As there is no unified or globally accepted classification, the following is an attempt to classify the different models based on their length, intended location of primary stability, and level of femoral neck osteotomy.(49)

1.6.1 Hip resurfacing arthroplasty and mid-head resection

Resurfacing the hip and resection of the mid-head are the two most bone-sparing variations of joint replacements. The most common model within the class of mid-head resection stems is the Birmingham Hip Resurfacing (BHR). This is a hip replacement that attempts to relieve the pain caused by hip osteoarthritis for a specific period of time. The focus is not necessarily on regaining a higher level of function, although studies indicate that the return to demanding activities and sports is superior to that of a THA. BHR serves much more as a bridging device for young athletic patients to reduce pain to the level of THA while preserving as much of the femur as possible. Further benefits are a low dislocation rate and a more accurate biomechanical restoration of the hip anatomy compared to total hip replacements.(51, 52)

1.6.2 Short stems

This category of prostheses includes stems with a total length of less than twice the vertical distance between the tip of the greater trochanter and the base of the lesser trochanter. In addition, based on the osteotomy height, a further subclassification can be made into sub-capital osteotomy (bone-saving directly under the femoral head) or standard osteotomy (at the level of the greater trochanter).(49)

Advantages of short stems include reduced stress shielding, limitation of proximal-distal mismatch, and reduced femoral pain. In addition, preservation of proximal bone stock is another major advantage for potential revision surgery and should be considered, especially in younger patients. In terms of the effectiveness of some short stems regarding implant survival rate, clinical results, and radiological assessment, they are nearly equivalent to the outcomes of conventional stems, although long-term studies are still needed to validate these findings.(53-55)

1.6.3 Standard stems

This category of implants includes stems with a total length greater than twice the vertical distance from the tip of the greater trochanter to the base of the lesser trochanter. Furthermore, there is another subclassification that divides standard stems into metaphyseal fixation only and those with metaphyseal and diaphyseal fixation.(49)

Standard femoral stems provide satisfactory clinical and radiographic results at long-term follow-up and have significantly contributed to the fact that THA can be considered one of the most successful surgeries of the 20th century. Yet, although the long-term results are excellent, thigh pain and stress shielding may occur and this has been linked to periprosthetic bone loss, which may contribute to late periprosthetic fractures in uncemented femoral standard stems.(53, 55-57)

1.6.4 Diaphyseal fixation stems.

As the name suggests, this category describes prostheses that anchor themselves mainly in the diaphysis. Most of these are so-called modular femoral stems that are used in complex primary THA or revision procedures. Due to their modularity, they allow easy adjustment of the required femoral anteversion or limb length. Furthermore, stable fixation in the diaphyseal part of the femur is achieved by bridging the proximal femoral bone defect.(58)

1.6.5 Cemented vs. cementless femoral prostheses

Cemented implants are durable, reproducible, and cost-effective implants. The fixation of femoral stems with modern cementing techniques can last more than 20 years without loosening in a high percentage of patients. The superiority of the long-term durability of cemented implants over cementless implants has also been confirmed in more recent data.(59-63)

However, there are studies and aspects favouring the use of cementless femoral components; for example, cementless implants have the advantage of shortening the operation time and reducing the likelihood of fat embolism or venous thromboembolic disease.(62, 64) Yet, the final fixation technique should be chosen individually, taking into consideration anatomical features, patient comorbidities, bone quality, surgeons' experience level and personal preferences.

1.7 Acetabular cups

As with stems, there are also different types of acetabular cups for hip endoprosthesis. These can be divided into cemented acetabular cups and cementless acetabular cups. Nevertheless, the optimal fixation of the new joint replacement is essential for lasting stability with all types of implants. To ensure this, three types of fixations have become established. They can be bonded (using bone cement), pressed (force and friction fit also called press-fit), or screwed into the acetabular bone stock.(65)

1.7.1 Cement acetabular cups

In case of cemented acetabular cups, the cement is applied to cancellous bone after cartilage removal and preparation of the sclerotic zone. By this the acetabular cup is subsequently anchored in the pelvis.(65)

Although there is no evidence towards superiority of cementless cups over cemented ones, most total hip arthroplasties in North America are nowadays performed with cementless cups. However, literature suggests a similar or even lower risk of revision for cemented cups compared to cementless acetabular cups and also favours the former one due to lower costs.(66, 67)

1.7.2 Cementless acetabular cups

As mentioned above, there are two types of cementless cups. The so-called press-fit cups use the elasticity of the pelvis to hold the cup, which is slightly oversized in comparison to the reamed acetabular bed, also called under shaping. As a result of the frictional connection, an equatorial clamping takes place. It should be noted that an undercut of 1-2 mm is sufficient to ensure excellent stability. Screw cups guarantee high primary stability due to the anchoring principle and are further fixed depending on the type of thread used and the screwing-in behaviour.(65)

Due to the early occurrence of pelvic osteolysis with cemented cups and revision rates close to those of a cemented cup, cementless variants are becoming increasingly attractive. Furthermore, the idea of fixation through biological integration with the ingrowth of bone on its rough surface was a convincing argument towards the use of cementless acetabular components. This method is also associated with a shorter operation time and is technically less demanding.(67)

1.8 Hemiarthroplasty of the hip

Besides THA for the treatment of femoral neck fractures, hemiarthroplasty is a viable treatment option. It suits especially older people who are less active. Two variants are used, unipolar hemiarthroplasties or bipolar hemiarthroplasties that can both be implanted with or without cement.(68, 69)

Evidence shows that THA has a superior HHS score and lower revision risk compared to a hip hemiarthroplasty. In return, the number of dislocations is higher for THA and lowest with bipolar hip arthroplasty.(70) Furthermore, a hemiarthroplasty can be performed more quickly than THA.(38) At first glance, THA seems to be the more expensive treatment method. This is true for the first 2 years postoperatively, but in the long term it appears to be the more cost-effective solution in the long term.(71)

1.8.1 The unipolar hemiarthroplasty

The unipolar hip hemiprosthesis articulates directly at the interface between the cup and the implant. Compared to the bipolar option, implantation takes less time.(72) It is also cheaper than bipolar hip hemiarthroplasty, and there are no major differences in terms of hospital stay, hip pain, implant-related complications, or intraoperative blood loss.(72, 73)

1.8.2 The bipolar hemiarthroplasty

Bipolar hemiarthroplasty implants have an intraprostatic joint that reduces movement at the interface between the bone and the prosthesis. A bipolar head articulates with an intact acetabular cup. This has the advantage of reducing erosion of the acetabulum and provides a better range of motion. Thus, hemiarthroplasties should only be used in case of none to minimal signs of (accompanying) hip osteoarthritis. Additionally, it has a lower reoperation rate, although it is associated with a longer operation time.(72, 73)

1.9 Approaches to the hip

Hip surgery has evolved over the years, with several surgical approaches to the hip joint nowadays being available, each with its advantages and disadvantages. It is important to note that the ideal surgical approach preserves soft tissues, minimizes trauma to surrounding structures and ensures rapid post-operative wound healing. For this reason, more and more minimally invasive methods have been established in recent years.

The term minimally invasive procedures refers to surgical methods in whom the muscular attachments are only pushed apart instead of being released via tenotomy or intramuscular cutting. Notably, though, minimal invasiveness is defined by less trauma to the periarticular muscles and not by the length of the incision.(74, 75) The potential advantages are shorter hospitalization, faster rehabilitation, and quicker recovery due to less muscle and tendon trauma. In addition, the prospect of a cosmetically pleasing result due to the shorter incision should not be underestimated. However, all off the surgical approaches listed here are suitable for performing a safe and clinically effective THA. It is recommended that surgeons choose the approach they find easiest and have the most experience with.(76, 77)

1.9.1 The anterior approach

The anterior approach, also known as the Smith-Peterson approach, uses the muscle interval between the sartorius and tensor fasciae latae muscle. This technique has been modified over the years, which is why operations using this approach can also be performed in a minimally invasive way.(77) The incision starts approximately two transverse fingers distal and lateral to the spina iliaca ant. sup. and runs distally and medially. In the minimally invasive approach, the total length of the incision is approximately 8 cm. After cutting the superficial and deep fascia, the sartorius muscle, which is held medially, and the tensor fasciae latae muscle, which is held laterally, form the guiding structures of the further incision. When splitting the fascia, particular attention must be paid to the lateral femoral cutaneous nerve, which runs 2.5 cm distal to the spina iliaca ant. sup., as well as branches of the lateral circumflex femoral arteria in the distal portion of the approach. This procedure provides visualization and exposure of the ventral joint capsule.(78) Its advantages are an excellent overview of all anterior structures. The disadvantages include a limited view of the acetabulum and the risk of injuring the lateral femoral cutaneous nerve when the sartorius muscle is retracted laterally.(77)

1.9.2 The anterolateral approach

The anterolateral or so-called standard approach according to Watson-Jones uses a muscle gap just like the anterior approach. In this case, the slightly more lateral interval between the tensor fasciae latae muscle and the gluteus medius muscle is developed. An incision is made in the skin between the spina iliaca ant. sup. and the greater trochanter. Subsequently, the tractus iliotibialis is split longitudinally. The muscle gap between the gluteus medius muscle and the tensor fasciae latae is bluntly detached and prepared. To obtain an even better view of the joint capsule, the ventral fibres of the gluteus medius muscle can additionally be dissected.(78) The advantage is a good view of the pelvis and proximal femur. In addition, a low dislocation rate is described in literature, together with a lower overall complication rate compared to other minimally invasive procedures. A disadvantage is that patients with external rotation contractures sometimes require detachment of the external rotators.(77, 79)

1.9.3 The direct lateral approach

The direct lateral approach is also known as the transgluteal approach. Compared to the other surgical techniques, this one is – due to its technical philosophy – not minimally invasive. The incision is made centrally over the greater trochanter, after which the underlying fascia is divided. The gluteus medius muscle is exposed from distal to proximal, split, and held away. Alternatively, the muscle may be detached from the greater trochanter subperiosteally or together with a small bone fragment. The underlying gluteus minimus muscle is subsequently longitudinally incised. This enables visualization of the capsule. Despite its extent of penetration of the soft tissues, this approach is still frequently used.(78) Advantages are the good proximal axial overview, and low dislocation rate. Disadvantages include injury to the superior gluteal nerve and limited visualization of the acetabulum.(77) In addition, studies indicate that there is less patient activity at one year after a transgluteal approach compared to surgery using the direct anterior approach. In terms of hip function, no differences have been observed.(80)

1.9.4 The posterolateral approach

The posterolateral approach begins with a skin incision approximately 5 cm anterior to the posterior superior iliac spine and extends proximally over the posterior border of the greater trochanter to the gluteus maximus tendon. Inferiorly, the iliotibial tract is divided from bottom to top between the gluteus maximus and tensor fasciae latae. The greater gluteal muscle is held away, and the trochanter major is exposed, giving an excellent view of the external rotators. Together with the sciatic nerve, the rotators are now kept out of the way to expose the dorsal joint capsule. Refixation of the external rotators is not mandatory. However, a lower dislocation risk after reattachment can be observed, wherefore fixation is recommended.(78)

Advantages of this approach are its rather uncomplicated surgical technique and low bleeding tendency. Compared to the anterolateral approach, however, longer hospitalization and more pain have been reported with the posterolateral approach.(78, 81)

1.9.5 The posterior approach

The posterior approach begins with a curved skin incision approximately 3 cm distal and lateral to the posterior superior iliac spine and continues distally over the greater trochanter. Below this, the gluteus maximus is cut in the direction of the fibres extending to the dorsal parts of the iliotibial tract. In the next step, the hip joint is internally rotated, and the external rotators are separated from the greater trochanter under tension. After successful implantation of the THA, the capsule should be sutured, and the external rotators reattached to avoid spontaneous dislocation.(78) The advantage is the good view of the pelvis and femur. Disadvantages include sciatic nerve injury and the need for careful management of the posterior structures to prevent dislocation.(77)

1.10 Postoperative care

There are some general aspects to the post-operative treatment of patients after THA. One important point is effective pain management. Relieving pain and suffering leads to earlier mobilization after the surgery. As a result, the length of in-hospital stay is reduced and patient satisfaction increases.(82, 83) Preventing infections after the surgery is another key point. There are a number of risk factors that can also be minimized before the surgery and are essential for reducing prosthetic joint infections after the procedure.(84)

1.10.1 Factors associated with the length of hospitalization.

An analysis showed that the likelihood of being discharged by day five decreases with increasing age. In particular, the likelihood was 13% lower for women, 39% lower for patients with diabetes, 68% lower for patients discharged to rehabilitation centers, and 27% lower for patients who had their THA on a Friday. Factors favouring discharge to a rehabilitation facility included older age, female gender, chronic obstructive pulmonary disease, anxiety, depression, and a history of stroke. Furthermore, risk factors for 30-day readmission included male gender, obesity, and discharge to a rehabilitation center.(85-87)

1.11. Risks and complications

Although total hip arthroplasty is one of the most successful surgeries, certain associated risks have to be considered, and complications can occur.(88) These correlate with the different surgical approaches, with some of them protecting important anatomical structures better than others, wherefore relative risk for iatrogenic injuries and other complications varies. The most common complications include hip dislocation, fractures, nerve injury, abductor insufficiency, infections and heterotopic ossifications.(76, 88, 89)

1.11.1 Dislocation

Postoperative dislocation after THA is one of the most common complications accounting for an overall rate of 1.7% to 3.2%, also being the main reason for revision surgery.(90) Many risk factors for dislocation that are related to the patient and surgery itself have been identified, such as age, BMI, ASA score, alcohol consumption, cerebral dysfunction during hospitalization, rheumatoid arthritis, the length of the femoral neck, fixation of the femoral component, a smaller femoral head size, soft tissue factors such as muscular imbalance and soft tissue traction, the surgical approach and positioning of the acetabular cup(76, 91, 92)

1.11.2 Fractures

Fractures can be divided into intraoperative and postoperative. Intraoperative fractures are usually associated with difficult postoperative mobilization due to changes in loading, extended surgical time, prolonged functional recovery, and poorer patient outcomes.(76) There are certain factors that can help prevent an intraoperative fracture; particular attention should be paid to soft tissue tension that should be minimized when exposing the femur. The experience of the surgeon with the used implant is also crucial in reducing the occurrence of intraoperative complications.(76, 93)

Most postsurgical fractures result from minor previous trauma. Risk factors for patients include metabolic syndrome, osteoporosis, drug-induced bone loss, advanced age, and substance abuse. In addition, the design of the prosthetic stem has an influence on development of postoperative fractures. Metaphysically fitted femoral stems with extreme taper angles are associated with an increased risk for fracture. Furthermore, stress shielding of the proximal femur weakens the bone adjacent to the implant and creates an increase in tension that can lead to fractures.(94)

1.11.3 Abductor insufficiency

Abductor insufficiency is a common presentation resulting from a direct lateral approach. It may cause Trendelenburg gait or Trendelenburg sign, abductor weakness, peritrochanteric pain, and inefficient gait mechanics.(76, 95) The reason for the insufficiency is likely due to chronic degeneration of the gluteus medius tendon before surgery, failure of the tenotomy carried out following direct lateral approach, or irreparable tears at the time of THA in up to 20% of patients undergoing this procedure.(76, 95)

1.11.4 Nerve injury

Another possible complication is nerve damage, reported with a prevalence of 1%(96). This can occur due to direct trauma during dissection or when inserting devices such as wires or acetabular screws. Furthermore, iatrogenic nerve damage resulting from retraction, thermal injury from 32polymethylmethacrylate (PMMA; bone cement used for cementation of implants), compression from hematomas, leg lengthening, and component positioning is possible. Most commonly affected are the lateral cutaneous femoral nerve, superior gluteal nerve, femoral nerve, and sciatic nerve.(76)

1.11.5 Periprosthetic joint infection

Periprosthetic joint infection (PJI) is an infection that affects the implant and the adjacent tissues. It has a rare incidence, reported to be between 0.25 and 2.0%. Risk factors for its occurrence include obesity, rheumatoid arthritis, diabetes mellitus, male gender, and chronic pulmonary disease.(97, 98)

Prolonged surgical time is a controllable factor contributing to the risk of PJI. It is recommended to minimize the time a surgical incision remains open to ensure that the quality of the procedure is not compromised. To reduce prolonged surgical time, it is advisable to form consistent surgical teams and maintain a high annual surgical volume. These measures are aimed at reducing unnecessary interruptions and limiting the extension of the surgical time.(99)

Management of PJI usually involves prolonged systemic antibiotic treatment, debridement, and revision, which causes significant impairments to patients' quality of life.(98) Furthermore, PJI also represent a financial burden for both healthcare systems and society, as they require prolonged treatment and the utilization of hospital resources.(100)

1.11.6 Heterotopic ossification

Heterotopic ossification (HO) is one of the most common complications after primary THA. It consists of the formation of bone in soft tissues where usually no bone is present, with a highly variable incidence depending on the literature.(101) Its aetiology is largely unknown. However, some risk factors favour the occurrence of HO; these include male gender, pre-existing ossifications, and ankylosing spondylitis. Furthermore, there have been correlations between Brooker grade (this classification divides HO extent into four categories) and ASA classification, age, and body mass index.(102)

Patients typically report symptoms such as swelling, pain, and limited range of motion. Treatment is based on the severity or the patient's risk of developing HO. Asymptomatic cases detected early are monitored closely. In more advanced forms, surgical intervention may be required. This is followed by prophylactic treatment, such as drug therapy and radiotherapy, to minimize the high risk of HO-recurrence.(89, 101, 103) According to previous studies, radiation therapy proved to be the most efficient (but also side-effect-prone) treatment for prevention of HO, although the use of selective NSAIDs was described as the safest option of HO.(104) Furthermore, recent research concludes that the use of wound drains was associated with a significantly higher incidence of HO in patients undergoing primary THA. Although more postoperative dressing changes, higher VAS scores (graphical rating scale for recording the subjective perception of pain), and greater hematoma volume were seen with the non-use of drains the presence or absence of a drain showed no significant effect on long-term hip joint function.(105)

2 Material and methods

2.1 Study population

This retrospective follow-up study included all patients who were treated with a short stem THA (ANA NOVA Proxy®, ImplanTec GmbH, Moedling, Austria) for a femoral neck fracture at the Department of Orthopaedics and Trauma, Medical University of Graz between 6 March 2017 and 14 September 2018.

All these patients were prospectively invited to participate in a clinical and radiological follow-up study. Firstly, they received a letter of invitation by mail. Secondly, they were invited by telephone to take part in this follow-up study. In case the patients decided to participate in the study, they were given an appointment at the Department of Orthopaedics and Trauma, Medical University of Graz, where they gave their consent after a detailed discussion about the aims and purposes of the planned follow-up study. After obtaining written informed consent, an X-ray of the pelvis and the affected hip was taken, and the patients completed three questionnaires. These clinical and functional questionnaires include the Western Ontario and McMaster University Osteoarthritis Index (WOMAC), the Harris Hip Score (HHS), and the Barthel Index. These questionnaires have all been developed to quantify the individual symptoms and hip function of patients.

The MEDOCS (Steiermärkisches medizinisch-pflegerisches Dokumentations- und Kommunikationsnetzwerk) was used to collect patient data that included demographic information such as age and gender, as well as clinical information including ASA score, haemoglobin levels, postoperative weight bearing, length of in-hospital stay, amongst and others.

The results obtained were compared with the results of 12 patients treated with the same short stem THA (ANA NOVA Proxy®) for primary hip osteoarthritis.

2.2. Statistical analysis and literature research

IBM SPSS Statistics via the Citrix server of the Medical University of Graz and Microsoft Excel were used for the statistical analysis. All relevant information was recorded in

Microsoft Excel. A descriptive statistical analysis of the recorded data was carried out and the information was presented as median, mean, total value, and in percentages. The data for each patient was checked for plausibility.

Using SPSS, we also performed t-tests and chi-square tests to compare variables between cases and controls and to determine any significant differences between the mean values of the two groups.

For the literature search, PubMed, a library for biomedical literature, was used. The search was conducted using MESH terms such as "total hip arthroplasty" AND "short stem".

2.3. Ethical aspects and benefits

On 29th of April 2021, the ethical committee of the Medical University of Graz confirmed the arrival of the application "Treatment of (Post)Traumatic Hip Osteoarthritis with Short Stem Total Hip Arthroplasty. Retrospective Study and Follow-Up Study." and approved it on the second of July 2021. This study is part of the above-mentioned, whereby the ethical committee did not raise an objection against the diploma thesis (EK-Number 33-462 ex 20/21). To fulfil the rules of medical data protection, patients' data was anonymized, and password protected.

Findings of this study will eventually improve knowledge about best treatment options for future patients requiring surgery for femoral neck fractures in whom head-preserving surgery is impossible.

2.4 Questionnaires

2.4.1 Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC)

The WOMAC is a commonly used and approved instrument to asses pain, stiffness, and functional limitations in patients with osteoarthritis (OA) of the lower extremities, particularly the knee and hip joints. The WOMAC was developed to quantify specific impairments and limitations associated with osteoarthritis. It can be divided into three main categories. The first category, pain, measures the degree and intensity of joint pain caused by osteoarthritis. Patients specify the extent to which they feel pain when walking, sitting, lying down, and at rest. The second category deals with stiffness. It assesses how morning stiffness and joint stiffness varies throughout the day. Stiffness is often a characteristic symptom of osteoarthritis. The last category deals with functional impairment. This category focuses on the functional impairment of the joints and measures the extent to which osteoarthritis affects daily activities and physical performance. This includes activities such as walking, climbing stairs, getting up from a sitting position and other movements. Each of these three categories consists of several questions to be answered by the patient. The answers are scored on a numerical scale. The WOMAC score is calculated as the total score for the three categories. The results range on a scale from 0 to 96, with higher scores indicating more severe symptoms and impairments and lower scores indicating satisfied patients.(106)

2.4.2 Extended WOMAC

The extended WOMAC entails 8 additional questions beyond the 24 questions of the standard WOMAC, focusing on extended symptoms and specific functionalities. The extended WOMAC thus allows a more detailed patient assessment. The results are analysed using the Likert scale. Each question is rated on a scale of 0 to 4. The question categories are pain (10 questions), symptoms (3 questions), symptoms (3 questions), stiffness (2 questions) and ADL (17 questions).

2.4.3 Harris Hip Score (HHS)

The HHS is a clinical assessment score used to evaluate functional ability and quality of life of patients with hip joint disease or following hip replacement surgery. The score is based on clinical assessments and patient information. It consists of several categories including pain, function, hip joint extension, mobility, and gait.(107)

The pain subcategory assesses the intensity of pain around the hip joint. This includes both pain at rest and during activities. Functional capacity of the hip joint is checked for aspects such as walking, climbing stairs, flexion, rotation, and extension of the hip joint. Mobility measures possible deformities or restrictions in the mobility of the hip joint. Gait in the final category examines any changes in gait or limping due to the hip problem. The HHS score ranges from 0 to 100, with higher scores indicating better hip function and quality of life. A perfect score of 100 indicates that the patient has no hip problems or impairments.(107)

2.4.4. Modified Harris Hip Score (HHS)

A modified version of the Harris Hip Score (HHS) is occasionally employed in this context, as the questionnaire is often also obtained by phone. This version excludes data on mobility and deformities collected by the examiner. This results in a reduction of the maximum number of points (100) to 95 (- 5 mobility) or 91 (- 4 deformity) points. The score is then calculated in 10-point intervals, with each interval subtracted from the starting value. The starting value is 91 or 95 points, depending on the number of points deducted.

2.4.5 Barthel Index

The Barthel Index is a standardized instrument for assessing people's everyday abilities and independence in basic activities of daily living (ADLs), particularly after an illness or injury. The Barthel Index focuses on basic ADLs that are essential for self-care. Typically, the activities assessed include independence in eating, bathing, dressing, transferring from bed to chair and vice versa, using the toilet, controlling bladder and bowel function, and walking. Each of these activities is scored on a scale ranging from 0 (complete dependence) to 100 (complete independence). The total Barthel Index score reflects the individual's independence and autonomy in the ADLs assessed. The higher the score, the more independent the patient.(108)

2.5. Blood samples

Prior to and following surgical intervention, blood samples were obtained from the patients to identify potential complications and risks, including anaemia, infection, and others. Particular attention was paid to the haemoglobin (Hb) and C-reactive protein (CRP) levels.

Studies have identified a correlation between preoperative anaemia, defined as a haemoglobin level below 12 g/dL, and an increased risk of postoperative mortality and complications in patients with hip fractures. In contrast, patients with higher haemoglobin levels at admission demonstrated improved outcomes, including shorter hospital stays, lower readmission rates and lower mortality rates.(109-112)

CRP is an important marker of inflammation in the body and is often used to monitor patients after surgery, including total hip replacement. CRP levels should normally be within the reference range (0-5 mg/dl) before surgery unless there is a known acute infection or chronic inflammation. An increase in CRP on the first postoperative day, followed by an increase on the third day and a decrease by the fifth day, indicates a normal postoperative inflammatory response.(113, 114)

3 Results

3.1 General information

Based on our inclusion criteria, a total of 12 patients were eligible to participate in the study, of whom 9 completed the entire study (physical examination and questionnaires). Further two did not wish to participate due to Covid lockdowns, and one patient had deceased upon study initiation.

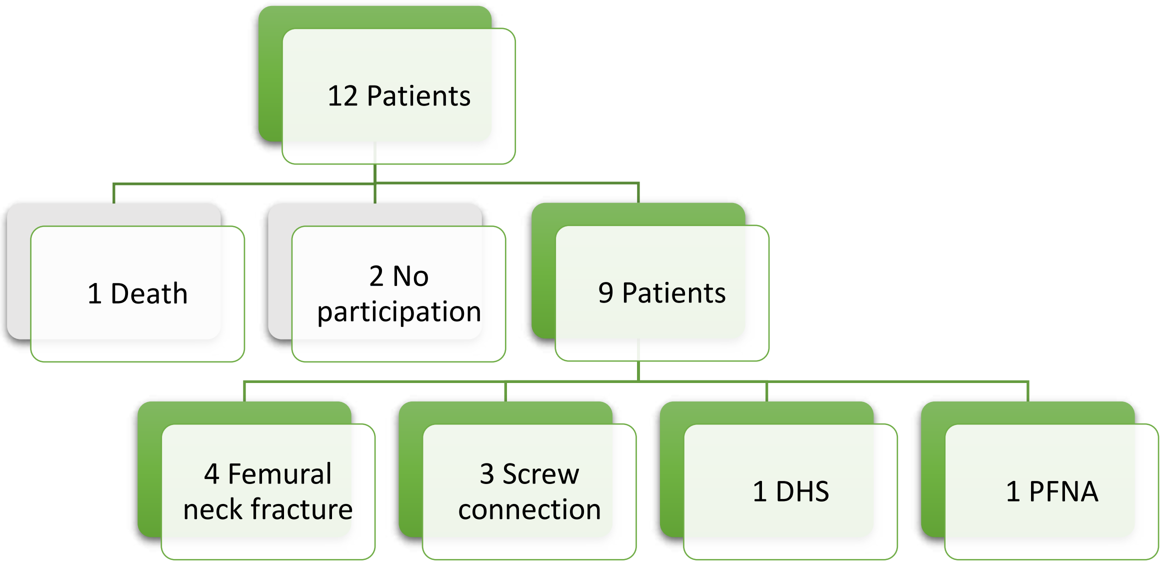

Figure 1: Patients distribution

3.2 Patient characteristics

The percentage of women in the patient population was 66.7% (8/12). The mean age on the day of surgery was 62.33 ± 9.19 years (56.50 - 68.17).

The most common indication for surgery was femoral neck fracture in 58% (n=7). Of the 5 patients with post-traumatic hip osteoarthritis, 16.7% (n=2) had a femoral neck screw, 16.7% (n=2) a dynamic hip screw (DHS) and 8,3% (n=1) a proximal femoral nail (PFNA) *in situ*. The implants were removed during the same operation in which the THA was implanted.

3.2.1 Patient BMI, ASA Score, length of hospitalization, duration of surgery, weight bearing

Patients diagnosed with (post-)traumatic hip osteoarthritis (OA) displayed a mean Body Mass Index (BMI) of 22.3 (± 4.3). The BMI spectrum among patients varied, ranging from a minimum of 16.9 to a maximum of 30.1, reflecting a diverse distribution within the studied population.

In terms of the American Society of Anaesthesiologists (ASA) score, the average score recorded was 2 (± 0.71). This standardized score offers insights into the overall health and comorbidities of the patients, contributing valuable information to the broader clinical picture.

The duration of hospitalization for these patients averaged 6.25 days (± 1.76), showcasing a range from a minimum stay of 4 days to a maximum stay of 9 days.

Surgical interventions for (post-)traumatic hip OA had an average duration of 44.3 minutes (± 10.5). The fastest surgical procedure took 33 minutes and was carried out for a femoral neck fracture, while the most extensive procedure took 73 minutes and involved removal of a dynamic hip screw and implantation of THA.

Postoperatively, the weight-bearing capacity of patients varied. Notably, full weight bearing was achieved post-surgery in 25.0% (n=3) of patients with femoral neck fractures. A larger cohort, comprising 50% (n=6) of patients, adhered to partial weight-bearing protocols, limiting themselves to a maximum of half body weight for six weeks. Furthermore, 16.7% (n=2) of patients, all with femoral neck fractures, followed a similar partial weight-bearing regimen for four weeks, while a solitary patient engaged in a two-week partial weight-bearing routine with a maximum of half body weight.

3.2.2 Approach, implants, drains

The anterolateral approach was consistently chosen as the preferred approach to the hip joint in all patients, as it enabled direct and precise surgery in the hip region.

Implant specifications showed a spectrum of cup sizes ranging from 48 to 62, with size 50 being most commonly used one in 50% (n=6) of cases. This variability in cup sizes reflects a customized approach that considers the anatomical characteristics and individual requirements of each patient.

There were also differences in the head length of the implants, with size S being most commonly implanted, accounting for 41% (n=5) of cases. The M head length was used in 25% (n=3) of cases, while the L and XL lengths were used in 16.7% (n=2) of cases each. Stem sizes, another critical aspect of hip replacement, showed a wide range, ranging from size 4 to 9, with the 7 stems being the most commonly used one in 33.3% (n=4) of cases. This choice of stem size reflects a careful consideration of biomechanical factors and individual patient characteristics.

Drains were used in two patients that were removed during one of the postoperative dressing changes. The decision to use drains was based on factors such as the extent of surgical trauma and surgeon preference to minimize the risk of hematoma formation and promote optimal wound healing.

3.2.3 Complications

The study found no intra- or early postoperative complications in patients undergoing total hip arthroplasty (THA) for posttraumatic hip osteoarthritis or femoral neck fracture.

3.2.4 Postoperative outcome (pain/mobilization/gait pattern), haemoglobin, CRP

Postoperative recovery was uneventful and without complications in all patients. Two patients reported minimal pain during the postoperative check-ups, which indicates a generally well-tolerated surgical result. In addition, the gait pattern of all patients was unremarkable, pointing to a favourable functional recovery.

As part of the preoperative anaesthetic examination, a comprehensive blood analysis was carried out in all patients before the surgery. Particular attention was paid on preoperative haemoglobin (Hb) levels. Routine haemoglobin tests were then routinely performed in all patients on the first, third, and fifth postoperative days.

One of the 12 patients required an erythrocyte concentrate transfusion on the first postoperative day. The initial haemoglobin level was 10.4 g/dL and had dropped to 7.1 g/dL on the first postoperative day. The immediate intervention led to a sufficient increase in haemoglobin levels: postoperative day 2 - Hb: 8.9 g/dl, postoperative day 3 - Hb: 9.8 g/dl, and postoperative day 5 - Hb: 9.5 g/dl.

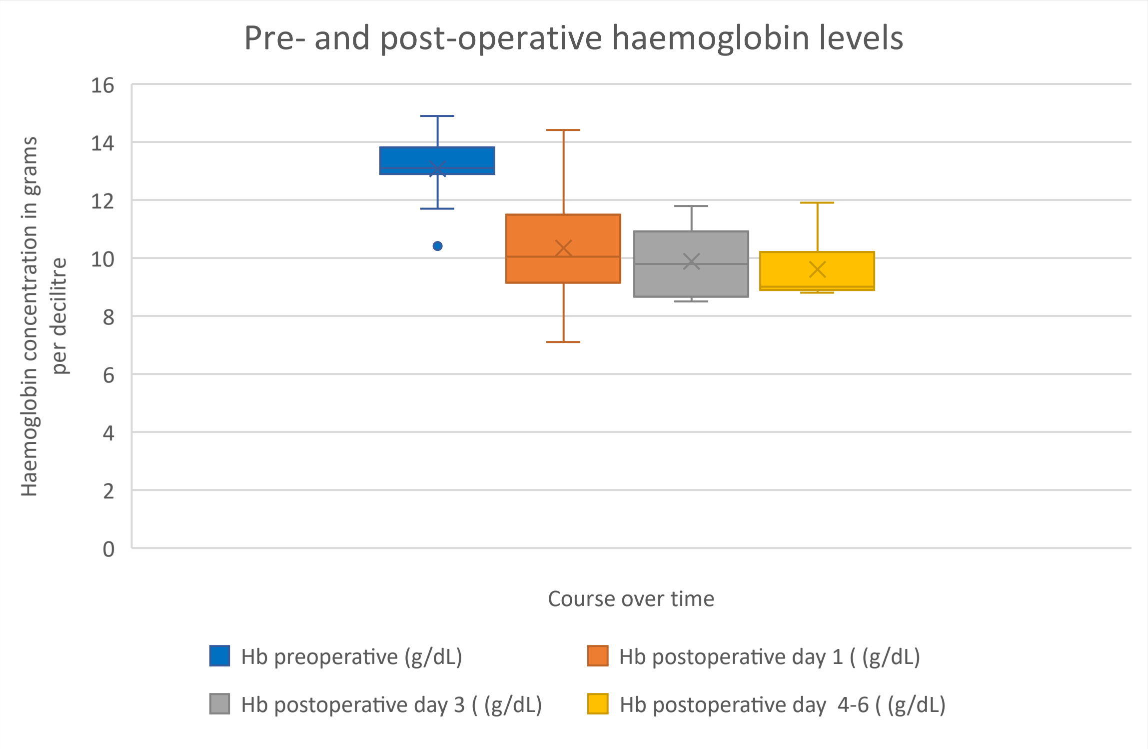

Figure 2: Pre- and post-operative haemoglobin levels

Preoperatively, Hb values ranged from 10.4 g/dl to 14.9 g/dl with a median of 13.1 g/dl. On the first post-operative day, the values dropped to a median of 10.1 (range of 7.1 g/dl to 14.4 g/dl) due to blood loss and fluid shift during the procedure. On the third day, haemoglobin levels were still low, with median values of 9.8 (range 8.5 g/dl to 11.8 g/dl). A stabilization of Hb levels to a median of 9.0 (range 8.8 g/dl and 11.9 g/dl) was observed in most patients on postoperative days 4 to 6. As expected, and typical following of major surgery, there was a relevant drop in haemoglobin after surgery. The slight increase on days 3 to 6 indicates that the body is starting to recover, and haemoglobin production has resumed.

In addition to haemoglobin levels, C-reactive protein (CRP) was measured preoperatively and on days one, three and five postoperatively.

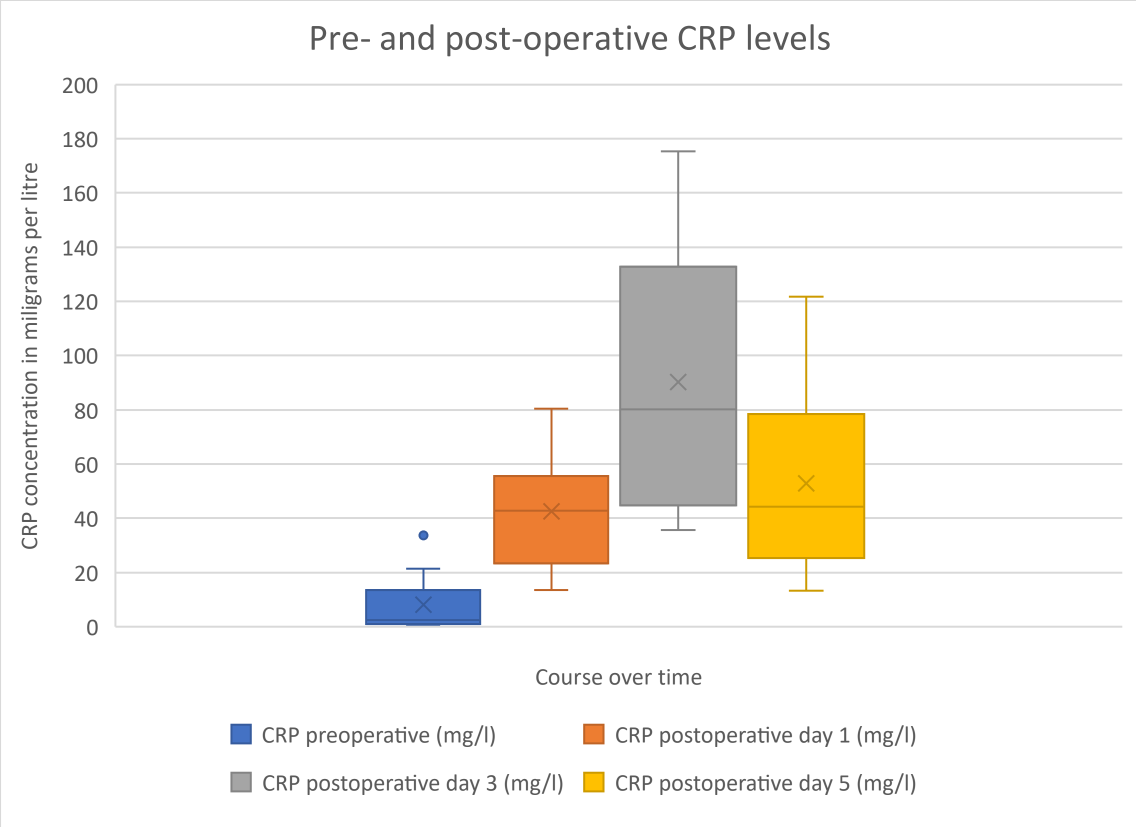

Figure 3: Pre- and post-operative CRP levels

As expected, the preoperative CRP levels were low, with a minimum of 0.6 mg/l and a maximum of 33.6 mg/l and a median of 2.6 mg/l. After surgery, CRP levels were elevated, reflecting the body's inflammatory response to the intervention. On the first postoperative day, CRP levels ranged from 13.4 mg/l to 80.3 mg/l with a median of 42.6 mg/l. On the third day postoperatively, levels reach their peak with a median value of 80.2 mg/l and range between 35.6 mg/l and 175.4 mg/l. On the fifth day, a decrease in CRP levels was visible, with a median of 44.2 mg/l (range: 13.2 mg/l – 64 mg/l). These changes in CRP levels are typical of the recovery process following total hip arthroplasty and reflect the natural inflammatory response and subsequent healing.

3.2.5 Outcome of the Harris Hip Score

Of the twelve patients eligible, one had died before study initiation, two refused to participate due to the COVID situation, and two further patients only participated by letter. A complete

HHS could therefore be ascertained from 7 patients. The median of the group is therefore 97 (range: 59 – 100 points) and corresponds to an excellent result.

	Pain:	ADL:	Gait:	Deformities:	Mobility:	Total:
n1	44	14	30	4	5	97
n2	30	14	27	4	5	80
n3	44	14	33	4	5	100
n4	44	14	33	4	5	100
n5	20	10	21	4	4	59
n6	44	14	33	4	5	100
n7	40	14	23	4	5	86

Table 3: HHS categories

3.2.5.1 Outcome of the Harris Hip Score in relation to pain

Upon closer examination of the test results, it was observed that five patients reported no pain (44 out of 44 points). Two patients reported slight pain (40 out of 44 points), one patient reported minor pain (30 out of 44 points), and one patient reported moderate pain (20 out of 44 points).

3.2.5.2 Outcome of the Harris Hip Score in relation to activities of daily living

In the Activities of Daily Living (ADL) category, eight patients achieved the maximum score of 14 points. One patient reported one limitation, thus reaching 10 out of 14 possible points.

3.2.5.3 Outcome of the Harrison Hip Score in relation to gait

Upon gait analysis, five patients achieved the maximum score of 33 points. One patient scored 30 points, another 27 points, one 23, and another patient 21 out of the possible 33 points.

3.2.5.4 Outcome of the Harris Hip Score in relation to deformities

Regarding presence of deformities, no adduction contracture, internal rotation contracture, flexion contracture, or leg length difference exceeding 3 cm was recorded in any of the patients. Consequently, all patients scored 4 points, representing the maximum possible score in this category.

3.2.5.5 Outcome of the Harrison Hip Score in relation to mobility

In the category of mobility, six patients achieved a maximum score of five points, corresponding to a range of 300-210° of mobility in all planes. One patient achieved four points, which corresponds to a range of 209-160° of mobility.

3.2.5.6 Outcome of the modified Harrison Hip Score

The results for the modified HHS show a median score of 88 for the nine patients analysed. This is considered an excellent result.

	Pain:	**ADL:**	**Gait:**	**Total:**
n1	44	14	30	88
n2	44	14	33	91
n3	30	14	27	71
n4	44	14	33	91
n5	40	14	33	87
n6	44	14	33	91
n7	20	10	21	51
n8	44	14	33	91
n9	40	14	23	77

Table 4: Modified HHS categories

3.2.6 Outcome of the standard WOMAC (24 questions)

A total of nine patients completed the WOMAC score. The overall result was an excellent outcome in eight patients (0-19 points) and a good outcome in one patient (20-39 points). Notably, the patient who reported a good outcome had already experienced a severe limitation as a consequence of a high-speed trauma prior to the surgical intervention. This limitation did improve following the surgery.

	Stiffness (0-8):	Pain (0-20):	ADL (0-68):	Total (96):
n1	0	0	2	2
n2	0	0	0	0
n3	1	1	3	5
n4	0	0	0	0
n5	1	3	3	7
n6	0	0	0	0
n7	3	5	24	32
n8	0	0	0	0
n9	0	0	4	4

Table 5: Outcome of the WOMAC score

3.2.6.1 WOMAC results in its categories

In the stiffness category, eight patients reported little to no stiffness (0-2 points) and one patient moderate stiffness (3-5 points).

Regarding pain, all patients reported little or no pain (0-5 points).

In the ADL category, eight patients achieved good physical function and carried out most activities of daily living without great difficulty (0-20 points). One patient reported on moderate difficulty in performing activities of daily living (21-50 points).

3.2.6.2 Outcome of the extended WOMAC (32 questions)

The overall score for 8 patients (0-25 points) was excellent. They reported on a very low level of symptoms and limitations and were hardly restricted in their daily activities. One patient (26-51 points) reported on a low level of symptoms and limitations. He experienced mild discomfort and had some limitations in certain activities but could manage most daily tasks without difficulty.

	Stiffness (0-8):	Pain (0-40):	ADL (0-68):	Symptoms (0-8):	Total (128):
n1	0	1	2	0	3
n2	0	0	0	0	0
n3	1	2	3	2	8
n4	0	0	0	0	0
n5	1	4	3	0	8
n6	0	0	0	0	0
n7	3	12	24	1	40
n8	0	0	0	0	0
n9	0	2	4	1	7

Table 6: Outcome of the extended WOMAC

3.2.7 Outcome of the Barthel Index

The Barthel Index is used to assess independence in activities of daily living. Most patients (n=7) achieved a maximum score of 100, which indicates complete independence. This means that they are able to carry out all the activities of daily living without needing assistance by others.

Two patients scored 95 points each, indicating minor limitations. However, these were due to urological problems and not owing to limitations in mobility or hip function. Therefore, their ability to manage daily activities independently was largely unaffected.

Overall, the Barthel Index results show that all 9 patients had a very good recovery after the surgery. The vast majority of patients were able to regain their full independence, which is a good indicator of the treatment’s effectiveness and quality of follow-up care. The slight limitations in the two patients with 95 points, caused by urological problems, were already present preoperatively and are most likely not related to the surgery itself.

3.2.8 Radiographic examples

Figure 6 shows the radiographs of a 62-year-old male patient with a femoral neck fracture and coxarthrosis: **A** preoperatively; **B** postoperative day 1 after THA; **C** follow-up after 5 years (no signs of loosening).

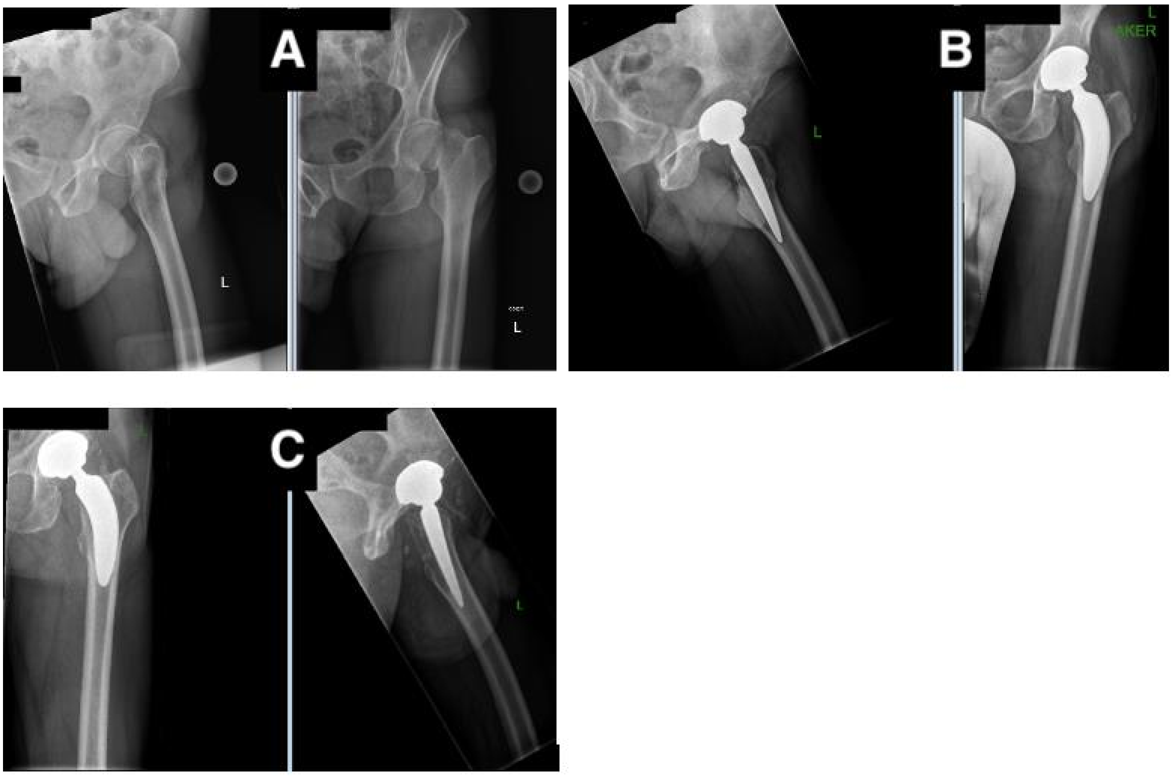

Figure 4: Radiographic example 1

Figure 7 shows the radiographs of an 85-year-old male patient with a 3-point screw fixation and secondary coxarthrosis: **A** preoperatively; **B** postoperative day 1 after THA; **C** follow-up after 5 years (no signs of loosening)

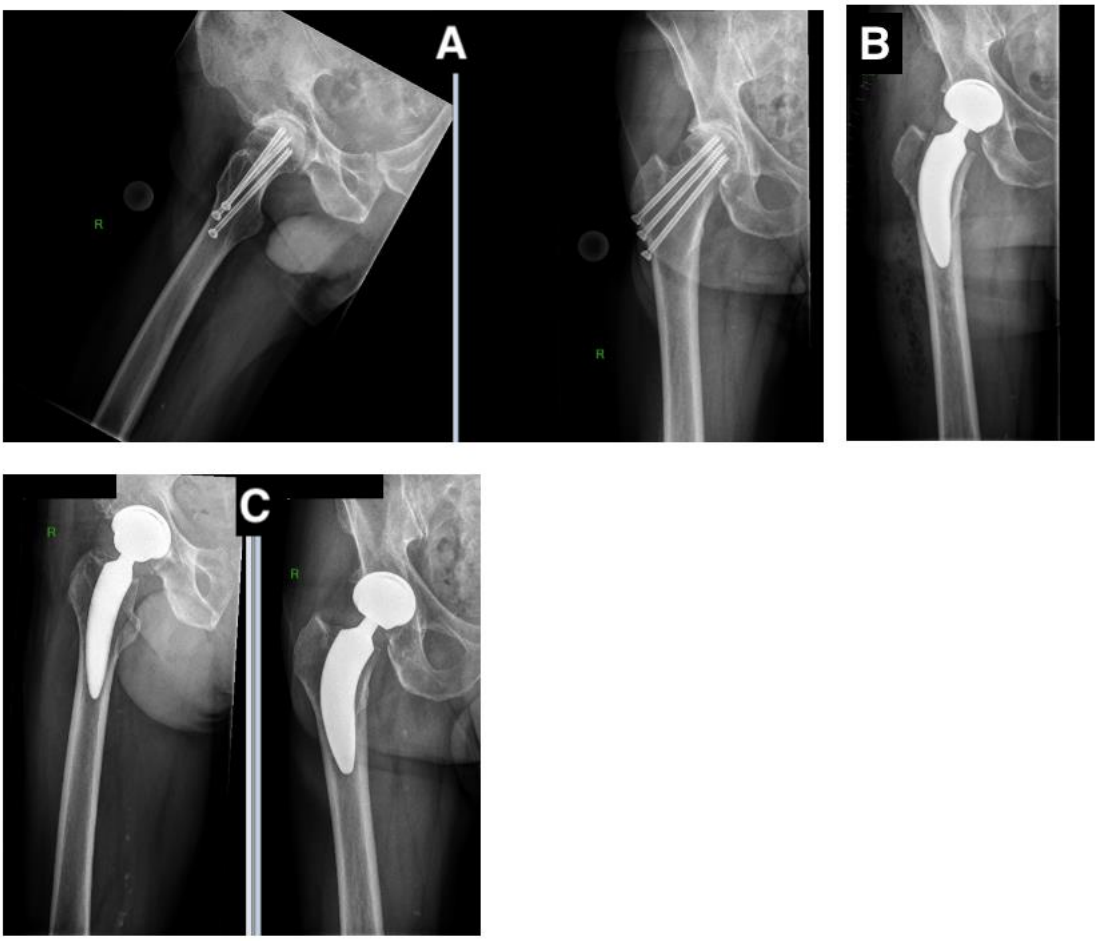

Figure 5: Radiographic example 2

Figure 8 shows the radiographs of a 55-year-old male patient with screw/plate fixation and secondary osteoarthritis: A preoperative; B postoperative day 1 after THA; C follow-up after 5 years (no signs of loosening).

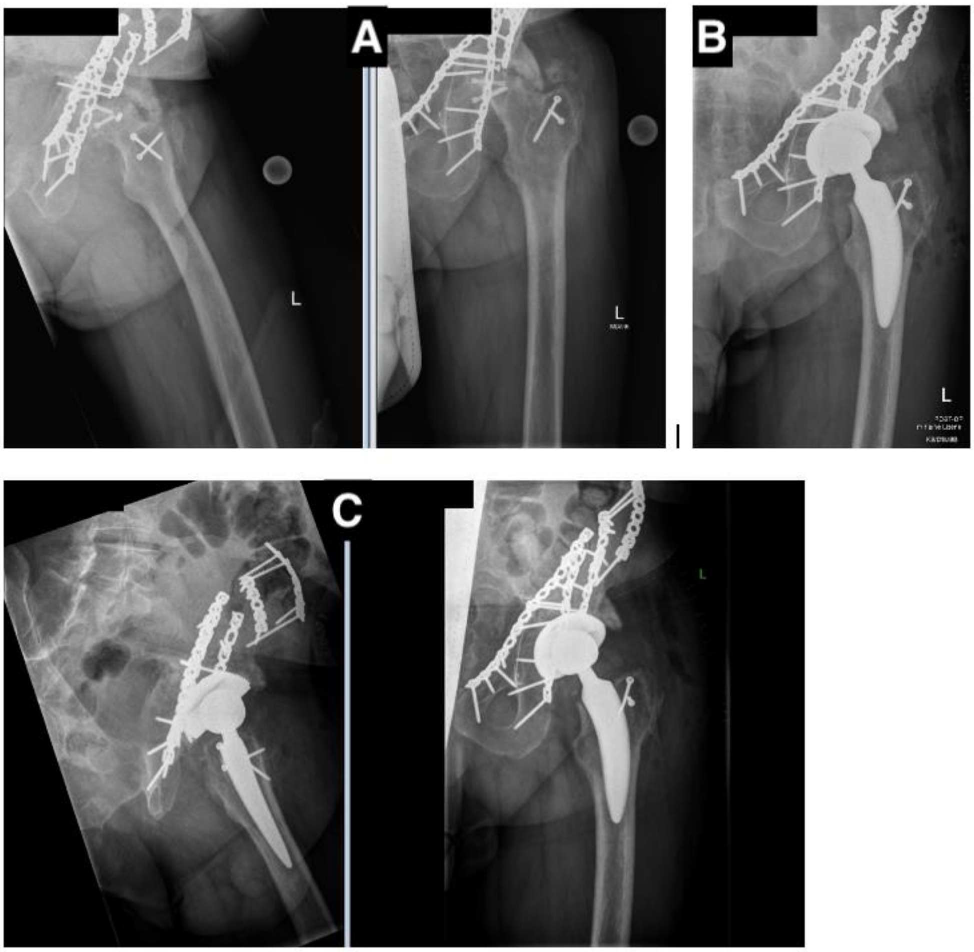

Figure 6: Radiographic example 3

3.3. Patient characteristics of the control group and comparisons

As previously stated, the newly obtained data from patients with (post)traumatic hip osteoarthritis were compared with the results of 12 age- and gender-matched patients treated with the same THA design (ANA NOVA Proxy®) for primary hip osteoarthritis.

Thus, the gender distribution of the control group was identical to that of the study group, with eight females (66.7%) and four males (33.3%).

The mean age of the control group was 61.9 years, with a standard deviation of 10.6 years (range, 55.2 - 68.6 years). To determine whether there is a significant difference in the mean age between the control group and the (post)traumatic group (mean age 62.3 years, ± 9.2 years (56.5 - 68.2), an independent t-test was performed. The calculated p-value of 0.919 indicates that matching by age (and gender) was sufficient.

Age (years):	Mean	Std. Err.	Std. Dev.	95% Conf. Interval
(Post)traumatic group (n=12)	62.3	2.7	9.2	56.5 - 68.2
Control group (n=12)	61.9	3.1	10.6	55.2 - 68.6

Table 7: Age distribution of the patient collective

3.3.1 Comparison of the BMI and ASA scores of patients

The control group had an average BMI of 27.7 (± 2.9). The BMI spectrum among patients varied, ranging from a minimum of 23.8 to a maximum of 32.2, while the (post)traumatic group has an average BMI of 22.3 (± 4.3). Consequently, patients in the (post)traumatic group had a statistically significantly lower BMI than the control group (p-value = 0.002).

BMI (kg/m^2):	Mean	Std. Err.	Std. Dev.	95% Conf. Interval
(Post)traumatic group (n=12)	22.3	1.2	4.3	19.6 - 25.0
Control group (n=12)	27.7	0.8	2.9	25.9 - 29.5

Table 8: BMI distribution of the patient collective

The analysis of the ASA classifications in the two groups revealed differences in the distribution of risk categories. In the (post)traumatic group, 25% (n=3) of patients were classified as ASA 1, 50% (n=6) as ASA 2, and 25% (n=3) as ASA 3. There were no patients with ASA 4. The median score was 2 (± 0.7). In contrast, 8.3% (n=1) of patients in the control group were ASA 1, 50% (n=6) ASA 2, 33.3% (n=4) ASA 3 and 8.3% (n=1) ASA 4, resulting in a total median score of 2 (± 0.8).

Consequently, patients in the (post)traumatic group tended towards lower ASA scores, while patients in the control group had higher ASA scores. However, no statistical significant difference was present (Pearson's chi-squared test; p=0.543).

ASA	(Post)traumatic group	control group	Total
1	3	1	4
	25%	8.3%	16.67%
2	6	6	12
	50%	50%	50%
3	3	4	7
	25%	33.3%	29.19%
4	0	1	1
	0%	8.3%	4.17%
Total:	12	12	24
	100%	100%	100%

Table 9: ASA Scores of the patient collective

3.3.2 Comparison of the length of hospitalization, duration of surgery and postoperative weight bearing

The mean length of hospitalization in the control group was 7.3 days (± 1.3), with a minimum stay of 6 days and a maximum stay of 13 days. However, the patient with the longest hospitalization developed pneumonia during his stay, necessitating a longer in-hospital stay than indicated by the orthopaedic perspective alone. In comparison, the average length of stay was 6.3 days (± 1.8) in the (post)traumatic group. No statistically significant differences between the two groups in terms of hospitalization length was found (t-test; p=0.101).

Length of hospitalization (days):	Mean	Std. Err.	Std. Dev.	95% Conf. Interval
(Post)traumatic group (n=12)	6.3	0.5	1.8	5.1 - 7.4
Control group (n=12)	7.3	0.4	1.3	6.5 - 8.2

Table 10: Length of hospitalization in-between the patient collective

The mean duration of the surgical intervention in the control group was 39.8 minutes (± 12.2). In contrast, the mean duration of surgery in the post-traumatic group was 44.3 minutes (± 10.5). Therefore, the surgical time was comparable between the two groups (p=0.335).

Duration of surgery (m):	Mean	Std. Err.	Std. Dev.	95% Conf. Interval
(Post)traumatic group (n=12)	44.3	3.0	10.5	37.7 - 5.0
Control group (n=12)	39.8	3.5	12.2	32.0 - 47.5

Table 11: Duration of surgery in between the patient collective

When comparing those patients with femoral neck fracture to the control group in terms of surgical time, likewise no significant difference became evident (p=0.913).

Surgery duration (m):	Mean	Std. Err.	Std. Dev.	95% Conf. Interval
Femoral neck fracture (n=7)	40.3	1.6	4.4	36.3 - 44.3
Control group (n=12)	39.8	3.5	12.2	32.0 - 47.5

Table 12: Duration of surgery femoral neck fractures vs. control group

All patients in the control group were permitted to bear full weight postoperatively, as were three patients with femoral neck fractures (25.0%). Conversely, six patients (three with femoral neck fractures) were instructed to bear partial weight with a maximum of half their body weight for six weeks, two patients (both with femoral neck fractures) for four weeks, and one patient from the (post)traumatic group for two weeks.

3.3.3 Comparison of the approach, implants and drains of the patients

Both patients in the (post)traumatic and control groups underwent surgery via an anterolateral approach, albeit in those with additional hardware removal, an extension of the surgical field sometimes became necessary.

The most frequently utilized implant cup sizes in the control group were 54 (n=5; 41.7%) and 52 (n=4; 33.3%). Head length size S was most commonly used (n=8; 66.7%). The M head length was used in 2 cases (16.7%), and the L length in 1 (8.3%). No XL head lengths had been used.

In the control group, stem sizes used ranged from size 4 to 8, with size 6 being most frequently used (n=5; 41.7%). Furthermore, size 7 stems were implanted in 3 (25.0%), size 8 in 2 patients (16.7%), and size 4 and 5 in one each (8.3%).

In comparison to the study group, three patients in the control group received a drainage, that was removed during the first postoperative dressing change, usually scheduled at the 2nd postoperative day.

3.3.3 Complications, post-operative outcome (pain/mobilization/gait pattern) and haemoglobin in the control group

No intraoperative complications were observed in the control group of patients undergoing primary THA.

Postoperative recovery was uneventful and without complications in the majority of patients. Overall, a satisfactory functional recovery was achieved. One patient reported a slight limp and another one reported on pain in the ipsilateral knee.

None of the patients in the control group required perioperative erythrocyte concentrate transfusions.

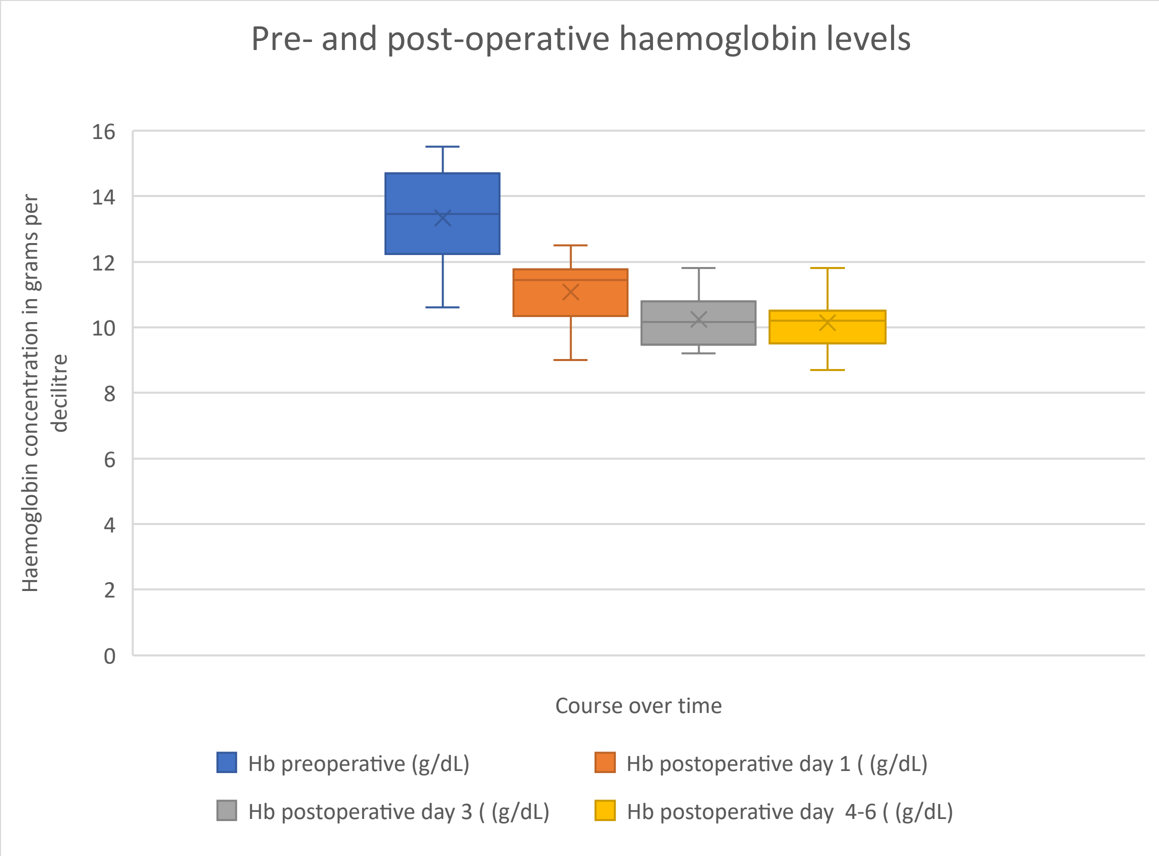

Figure 7: Pre- and post-operative haemoglobin levels in the control group

In the control group, preoperative Hb levels ranged from 10.6 g/dl to 15.5 g/dl, with a median of 13.5 g/dl. On the first postoperative day, the values decreased to a median of 11.5 g/dl (range, 9.0 g/dl – 12.5 g/dl). On the third postoperative day, the values ranged between 9.2 g/dl and 11.8 g/dl (median: 10.2 g/dl). On days 4 to 6, Hb levels had stabilized at a median of 10.2 g/dl (range, 8.7 g/dl – 11.8 g/dl).

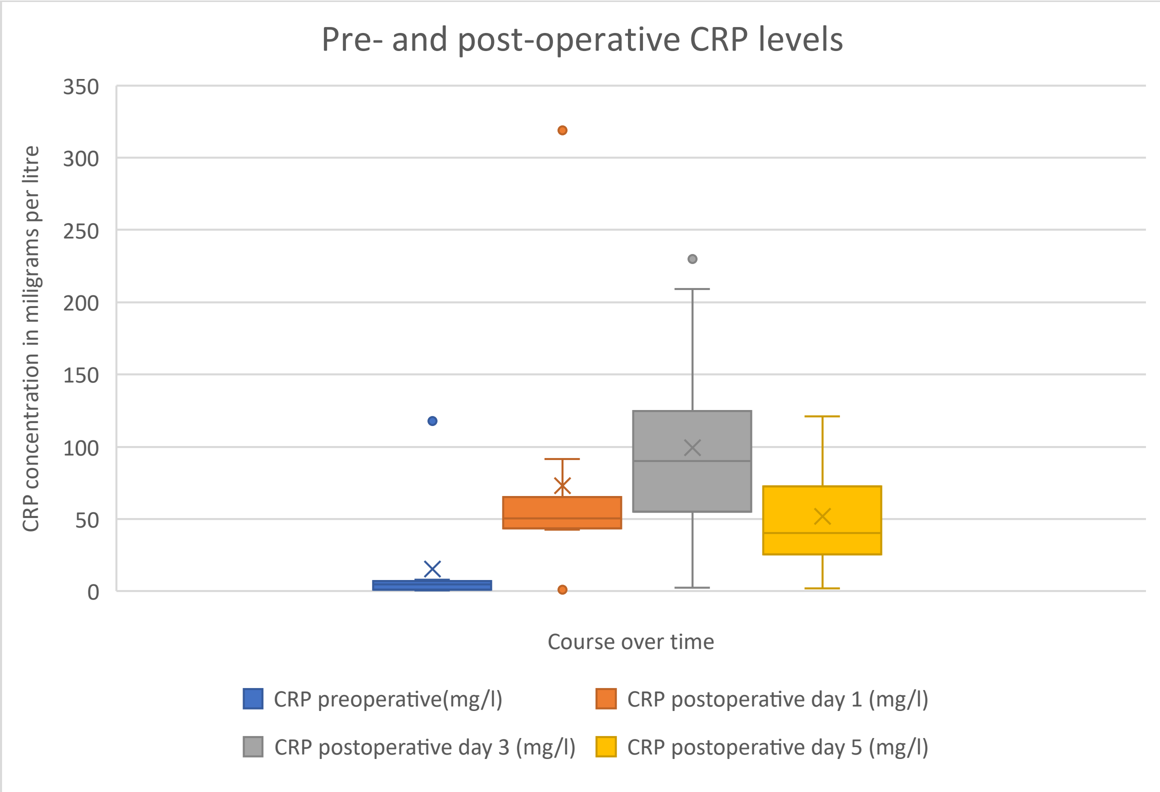

Figure 8: Pre- and post-operative CRP levels in the control group

As expected, preoperative CRP levels were within normal range in the control group, with a minimum of 0.6 mg/l, a maximum of 118 mg/l, and a median of 4.9 mg/l. The unusually high preoperative level of 118 mg/l indicates a pre-existing inflammatory or infectious response prior to surgery. After the surgical intervention, a notable elevation in CRP levels was present, being attributed to the body's inflammatory response to the procedure. On the first postoperative day, median CRP levels were 50.7 mg/l, ranging between 1 mg/l and 318.9 mg/l. On the third day following surgery, median CRP levels were 90 mg/l (range, 2.3 mg/l – 230 mg/l). On the fifth postoperative day, CRP levels have fallen to a median of 40.4 mg/l (range, 2.1 mg/l – 121 mg/l). CRP dynamics of the control group are overall comparable to the study group, with a peak at the third postoperative day, followed by a distinct decrease up to the 5th day following surgery.

4 Discussion

4.1.1 Gender distribution

Both groups had an equal gender distribution, consisting of eight women and four men. This ensures a balanced analysis of the results in terms of gender differences. The selection of the patient population is also in line with literature, showing a higher incidence in hip osteoarthritis and femoral neck fractures in women compared to men.(41, 115) On the other hand, (post)traumatic osteoarthritis of the hip is more common in men.(116, 117) Nevertheless, it would be interesting to investigate in future studies whether men and women respond differently to treatment and whether gender-specific factors influence postoperative rehabilitation or are not relevant.

4.1.2 BMI difference

Patients with (post)traumatic hip osteoarthritis and patients with primary hip osteoarthritis significantly differed in BMI. Patients with (post)traumatic hip osteoarthritis had a mean BMI of 22.3 ± 4.3, whereas patients with primary hip osteoarthritis had a mean BMI of 27.7 ± 2.9 ($p=0.002$). Differences in lifestyle, activity level and comorbidities may explain these discrepancies. In principle, a lower BMI in patients with (post)traumatic hip osteoarthritis may indicate a better overall physical condition, which could be beneficial for postoperative rehabilitation and long-term implant function. Being overweight leads to longer rehabilitation times and slower recovery.(118) Furthermore, obesity may limit mobility and the ability to participate in rehabilitation programmes. In addition, obesity has also been linked to an increased risk for surgical complications.(118-120)

4.1.3 ASA score

Analysis of the ASA scores within the two groups revealed no significant difference. There was a tendency towards patients with lower ASA scores in the (post)traumatic group, while patients in the primary hip osteoarthritis group presented with higher ASA scores. There is evidence in literature that a higher ASA score is associated with higher peri- and postoperative complication rates, and longer in-hospital stays.(121, 122)

4.1.4 Surgical duration

Mean surgical time for both groups was 42.0 ± 11.4 minutes. There was no significant difference between patients with primary hip osteoarthritis (39.8 ± 12.2 minutes) or (post)traumatic hip osteoarthritis (44.3 ± 10.5 minutes; p=0.335). Although the differences are not significant, it should be noted that patients with (post)traumatic osteoarthritis may have required longer operating times due to previous surgeries, as was the case in 5 patients, or due to a more complex anatomy as a result of trauma. In addition, it may have become necessary to remove plates, screws or nails from previous surgeries. These aspects have to be considered during surgical planning and patient counselling. The literature generally reports longer operation times and higher complication rates for THA in (post)traumatic hip osteoarthritis. This may be due to more complex surgical procedures owing to prior surgeries to the hip.(123)

4.1.5 Length of hospitalisation

The length of hospital stay was comparable between the two groups and showed no significant difference, with a mean of 6.3 ± 1.8 days for patients with (post)traumatic hip osteoarthritis and 7.3 ± 1.3 days for patients with primary hip osteoarthritis (p=0.101). This similarity suggests that postoperative care and recovery time are similar regardless of the underlying form of arthritis. The overall mean hospital stay of 6.8 ± 1.6 days, which is comparable to hospital stays across Austria, but longer than internationally reported.(124-126)

4.1.6 Weight bearing of patients

Postoperative weight bearing patterns differed between patient groups, with all patients undergoing primary THA being able to fully weight-bear after surgery. In the group of patients with (post)traumatic hip osteoarthrosis, only 3 patients were allowed to fully weight-bear, though. For the remaining patients, partial weight bearing with a maximum of half body weight was recommended: in 6 patients for 6 weeks, in 2 patients for 4 weeks, and in 1 patient for 2 weeks.

These different recommendations were based on the individual patient circumstances and the healing process of their (post)traumatic conditions. In addition, it is necessary to minimise stress on the healing structures in order to reduce the incidence of complications. On the other hand, there is a general consensus that the earliest possible postoperative mobilisation is an important treatment goal for older patients with trauma to reduce risk for secondary complications as deep vein thrombosis and pneumonia.(123, 127, 128)

4.1.7 Complications

No intraoperative or early postoperative complications were observed, which is an indication of the potential safety of the short stem THA, despite this observation being based on 12 cases with undefined selection criteria.

It has to be mentioned that in the group of patients with primary hip arthrosis, one patient developed pneumonia during hospitalisation. In the literature, the risk of pneumonia after any orthopaedic surgery can reach 14%. Following THA, though, the risk to develop pneumonia appears lower, ranging between 0.2% and 0.3%.(129, 130) Unsurprisingly, literature suggests that more complex procedures are associated with an increased complication rate.(131, 132) This could not be shown in our study due to a limited patient number, though. Nonetheless, there is a considerable amount of promising literature supporting the efficacy, applicability and safety of short stem THA.(133, 134)

4.1.8 Comparison of the HHS, WOMAC and Barthel index with the literature

As part of the study, the WOMAC, HHS and Barthel Index were investigated to evaluate the postoperative outcome and to compare them with the existing literature. The evaluation of pain reduction and joint function, mirrored by sections of the WOMAC and HHS, revealed results consistent with those reported in the literature. The first study included 30 patients with a follow-up of 5.6 years; the authors reported on a WOMAC score of 94 points and a Harris Hip Score of 90 points.(135) In the second study, 102 patients with short stem THAs had been investigated. At a mean follow-up of 5.2 years, patients achieved a mean score of 98 on the WOMAC and also on the HHS.(136)

The same was true for the Barthel Index, which assesses postoperative independence. In the first study, a Barthel Index of 87 points was reported for 156 patients on the day of discharge following a lower limb arthroplasty, of whom 80 had THA and 76 had total knee arthroplasty.(137) The second study included 49 patients who achieved an average Barthel Index of 79 points three months after surgery.(138)

The results of this study support the validity of the scores used to assess postoperative outcome and functional improvement following THA in general, and use of a short stem in (post)traumatic hip osteoarthritis. They are in accordance with existing findings.

4.1.9 Long-term outcomes and a comparison with existing literature

As all surgeries were conducted between March 2017 and September 2018, long-term results have yet to be obtained. Up to a median follow-up of 6 years and 3 months (until to June 2024), no complications associated with the used stems have been observed in the herein studied patient collective.

A comparison of the existing literature indicates that short stem THAs in young and old patients achieve similar short and long-term results to that of traditional straight stem THAs.(139, 140) Furthermore, it has been demonstrated that short stem THA allows for faster postoperative mobilisation.(141) In terms of patient satisfaction, postoperative function and pain relief are comparable to or even better than traditional straight-stem devices(140). There is evidence that short-stem THAs have a similar durability to conventional straight-stem implants. Although long-term data are still limited, the results so far, up to a maximum observation period of 14 years, are promising.(140, 142-144)

Furthermore, there is evidence in the literature that the reconstruction of hip offset and postoperative leg length difference is not adversely affected by the Dorr classification or the anatomical shape of the proximal femur in cementless THA with short stem and meta-diaphyseal fixation.(31)

It is important to note that when a THA is performed for fractures, the rates of dislocation have been unsatisfactorily high. Special attention should be given to the shape of the bone and the surgeon's expertise, especially in osteoporotic patients following a hip fracture.(29)

4.1.11 Age distribution comparison

A comparison of the absolute and percentage figures for all femoral neck fractures in 2016 with the implantation of short stem THA after post-traumatic hip osteoarthritis provides valuable information on which patient subgroups are particularly suitable for this treatment concept. The analysis shows that younger and more physically fit patients would potentially benefit from short stem THAs. This is also illustrated by the following graph, which shows that this treatment option was predominantly favoured among younger patients, as the comparison demonstrates.(22)

Age (years):	Femoral neck fracture Austria (n) total	Femoral neck fracture Austria (%)	(post)traumatic group (n) total	(post)traumatic group (%)
20-59	890	10	4	33.3
60-69	921	10.6	5	41.7
70-79	2.234	25.6	2	16.7
80-89	3.354	38.4	1	8.3
90 and older	1.337	15.4	0	0
Total:	8.736	100	12	100

Table 13: Age distribution comparison

4.1.12 Criticisms and limitation

The small number of only twelve patients herein studied represents a substantial limitation to this study. Consequently, the statistical power is impaired and the generalisability of findings is reduced. It would be beneficial to conduct future studies including larger patient groups in order to obtain more robust and generalisable results.

The follow-up period of the present study can be considered another limitation, as no definitive statements can be made regarding the long-term durability and functionality of the herein investigated short-stem THA. An extended follow-up period would be desirable in order to reliably confirm the sustainability of the positive results.

Due to differing recommendations for postoperative weight-bearing, the comparability of outcomes between patient groups may be affected. It would therefore be advisable to employ more standardised loading protocols in future studies, or usage of a stem type that rather addresses poor bone quality to allow full weight bearing.

4.2 Conclusion

This retrospective study, conducted at the Department of Orthopaedics and Trauma, Medical University of Graz, analysed 12 patients treated with the ANA NOVA Proxy® Short-Stem THA. The results of this study suggest that the treatment of (post)traumatic hip osteoarthritis with a short-stem implant is a promising alternative for certain patient groups and offers potential advantages over conventional straight-stem THAs.

The results of this study were compared with those of 12 patients with primary hip osteoarthritis receiving the same stem. The only significant difference between the two groups was found regarding BMI, whilst groups were comparable regarding duration of surgery, in-hospital stay, ASA score, as well as pre- and postoperative Hb and CRP levels.

In addition, specific scores such as the WOMAC, HHS and Barthel Index were used to measure patients' functionality, pain and activities of daily living. Excellent results were achieved in all areas, and again the results were consistent with previous studies on this topic.

Short stem THA offers a number of advantages, particularly in young and active patients. These include a less traumatic approach to the hip, better reconstruction of the hip geometry, and less use of foreign material. All these factors favour this form of treatment for hip osteoarthritis and are particularly important in a young patient population. The use of short-stem THAs potentially leads to improvements in postoperative recovery and functionality, and may offer a tailored approach for young, active patients with specific anatomical conditions. However, it should be noted that further studies with larger samples are needed to confirm the findings herein made.

5 Annex

5.1 Western Ontario and McMaster Universities Osteoarthritis Index(106, 145)

WOMAC Fragebogen

Symptome – Diese Fragen beziehen sich auf Beschwerden von Seiten Ihres Hüftgelenks während der **vergangenen Woche.**

S1. Fühlen Sie manchmal ein Mahlen, hören Sie manchmal ein Klicken oder irgendein Geräusch in Ihrer Hüfte?

○ Nie ○ selten ○ manchmal ○ Oft ○ immer

S2. Schwierigkeiten beim ausstrecken des Beines

○ keine ○ schwach ○ mäßig ○ stark ○ Sehr stark

S3. Schwierigkeiten beim Gehen

○ keine ○ schwach ○ mäßig ○ stark ○ Sehr stark

Steifigkeit – Die nachfolgenden Fragen betreffen die Steifigkeit Ihres Hüftgelenks während der **letzten Woche.** Unter Steifigkeit versteht man ein Gefühl der Einschränkung oder Verlangsamung der Fähigkeit Ihr Hüftgelenk zu bewegen.

S4. Wie stark ist Ihre Hüftsteifigkeit morgens nach dem Aufstehen?

○ keine ○ schwach ○ mäßig ○ stark ○ Sehr stark

S7. Wie stark ist ihre Hüftsteifigkeit nachdem Sie saßen, lagen oder sich ausruhten im **Verlauf des Tages?**

○ keine ○ Schwach ○ mäßig ○ stark ○ Sehr stark

Schmerz

P1. Wie oft schmerzt Ihre Hüfte?

○ Nie ○ monatlich ○ wöchentlich ○ täglich ○ immer

Wie ausgeprägt waren Ihre Schmerzen in der **vergangenen Woche** als Sie zB.

P2. Ihre Hüfte ganz austreckten?

○ keine ○ schwach ○ mäßig ○ stark ○ Sehr stark

P3. Ihre Hüfte ganz beugten?

○ keine ○ schwach ○ mäßig ○ stark ○ Sehr stark

P4. auf ebenem Boden gingen?

○ keine ○ schwach ○ mäßig ○ stark ○ Sehr stark

P5. Treppen herauf oder herunter gingen?

○ keine ○ schwach ○ mäßig ○ stark ○ Sehr stark

P6. nachts im Bett lagen?

○ keine ○ schwach ○ mäßig ○ stark ○ Sehr stark

1

P7. saßen oder lagen zB. auf der Couch?

○ keine ○ schwach ○ mäßig ○ stark ○ Sehr stark

P8. aufrecht standen?

○ keine ○ schwach ○ mäßig ○ stark ○ Sehr stark

P9. auf hartem Boden gingen (zB Asphalt)

○ keine ○ schwach ○ mäßig ○ stark ○ Sehr stark

P10. auf unebenen Boden gingen?

○ keine ○ schwach ○ mäßig ○ stark ○ Sehr stark

Aktivitäten des täglichen Lebens – Die nachfolgenden Fragen beziehen sich auf Ihre körperliche Leistungsfähigkeit. Hierunter verstehen wir Ihre Fähigkeiten sich selbstständig zu bewegen bzw. sich selbst zu versorgen. Für jede der nachfolgenden Aktivitäten sollen Sie das Ausmaß der Schwierigkeiten angeben, welche Sie durch Ihr Hüftgelenk innerhalb der **letzten Woche** erfahren haben.

AI. Treppen herunterstiegen?

○ keine ○ schwach ○ mäßig ○ stark ○ Sehr stark

A2. Treppen heraufstiegen?

○ keine ○ schwach ○ mäßig ○ stark ○ Sehr stark

A3. vom Sitzen aufstanden?

○ keine ○ schwach ○ mäßig ○ stark ○ Sehr stark

A4. standen?

○ keine ○ schwach ○ mäßig ○ stark ○ Sehr stark

A5. sich bückten um zB. etwas vom Boden aufzuheben?

○ keine ○ schwach ○ mäßig ○ stark ○ Sehr stark

A6. auf ebenen Boden gingen

○ keine ○ schwach ○ mäßig ○ stark ○ Sehr stark

A7. ins Auto ein- oder ausstiegen?

○ keine ○ schwach ○ mäßig ○ stark ○ Sehr stark

A8. einkaufen gingen?

○ keine ○ schwach ○ mäßig ○ stark ○ Sehr stark

A9. Strümpfe/Socken anzogen?

○ keine ○ schwach ○ mäßig ○ stark ○ Sehr stark

A10. vom Bett aufstanden?

○ keine ○ schwach ○ mäßig ○ stark ○ Sehr stark

A11. Strümpfe/Socken auszogen?

○ keine ○ schwach ○ mäßig ○ stark ○ Sehr stark

A12. im Bett lagen und sich drehten, ohne die Hüfte dabei zu beugen?

○ keine ○ schwach ○ mäßig ○ stark ○ Sehr stark

A13. in oder aus der Badewanne kamen?

○ keine ○ schwach ○ mäßig ○ stark ○ Sehr stark

A14. saßen?

○ keine ○ schwach ○ mäßig ○ stark ○ Sehr stark

A15. sich auf die Toilette setzten oder aufstanden?

○ keine ○ schwach ○ mäßig ○ stark ○ Sehr stark

A16. schwere Hausarbeit verrichteten (schrubben, Garten umgraben..)?

○ keine ○ schwach ○ mäßig ○ stark ○ Sehr stark

A17. Leichte Hausarbeit verrichteten (Staub wischen, kochen..)?

○ keine ○ schwach ○ mäßig ○ stark ○ Sehr stark

5.2 Harris-Hip-Score (107)

FOMT
Fortbildungen für orthopädische Medizin und manuelle Therapie

Harris Hip Score
–
deutsche Version

Der folgende Fragebogen dient der Erfassung von Beschwerden und Problemen bei alltäglichen Aktivitäten, die durch Ihr Hüftgelenk verursacht werden.

Bitte beantworten Sie alle Fragen gemäß Ihrem aktuellen Zustand. Sollten Sie momentan keine Beschwerden haben, dann bewerten Sie die Fragen entsprechend Ihrem Zustand in der vergangenen Woche.

Schmerzen		
kein Schmerz		44
leichter Schmerz	gelegentliche Beschwerden oder geringgradige Schmerzwahrnehmung, die Aktivität ist nicht behindert.	40
geringe Schmerzen	keine Auswirkung auf die durchschnittliche Aktivität, selten mäßige Schmerzen nach ungewohnten Tätigkeiten, gelegentlich z.B. Aspirin.	30
mäßige Schmerzen	Schmerz erträglich, regelmäßige Arbeit möglich, jedoch Behinderung bei gewöhnlicher Aktivität, gelegentlich stärkere Analgetika erforderlich	20
deutliche Schmerzen	starke gelegentlich auftretende und wieder vergehende Schmerzen, ernsthafte Einschränkung des Aktivitätsniveaus, stärkere Schmerzmittel	10
schwere Schmerzen	starker Schmerz auch im Bett, der Schmerz zwingt den Patienten überwiegend im Bett zu bleiben, schwerste Beeinträchtigung	0
Ergebnis		

ADL		
Treppen steigen	eine Stufe nach der anderen ohne Nachziehen des Beines und ohne den Gebrauch eines Geländers	4
	Stufe nach Stufe ohne Nachziehen eines Beines, aber mit Geländer	2
	Treppengehen ist noch möglich mit beliebigen Hilfsmitteln	1
	Patient ist nicht in der Lage Treppen zu steigen	0
Öffentliche Verkehrs-mittel	Patient ist in der Lage, öffentliche Verkehrsmittel zu benutzen	1
Sitzen	Patient kann bequem auf jedem Stuhl für 1 Stunde sitzen	5
	Patient kann bequem auf einem hohen Stuhl für eine halbe Stunde sitzen	3
	Patient ist nicht in der Lage, auf irgend einem Stuhl bequem zu sitzen	0
Schuhe und Strümpfe anziehen	Patient kann ohne weiteres Strümpfe anziehen und Schuhe binden	4
	Patient kann unter Schwierigkeiten Strümpfe anziehen und Schuhe binden	2
	Patient ist nicht in der Lage, Schuhe oder Strümpfe anzuziehen	0
Ergebnis		

Gehfähigkeit		
Hinken	kein Hinken	11
	leichtes Hinken	8
	mäßiges Hinken	5
	schweres Hinken	0
Gehhilfen	keine	11
	einzelner Stock für längere Strecken	7
	einzelner Stock für die meiste Zeit	5
	eine Unterarm-Gehstütze	3
	zwei Stöcke	2
	zwei Unterarm-Gehstützen oder Gehunfähigkeit	0
Entfernungen	unbegrenzt	11
	zwei Kilometer	8
	200 bis 500 Meter	5
	nur in der Wohnung	2
	Bett oder Stuhl	0
Ergebnis		

Deformitäten		
Adduktions-kontraktur	weniger als 10 Grad 10 Grad oder mehr	1 0
Innenrotations-kontraktur	weniger als 10 Grad 10 Grad oder mehr	1 0
Beuge-kontraktur	weniger als 15 Grad 15 Grad oder mehr	1 0
Beinlängen-differenz	weniger als 3 cm 3 cm oder mehr	1 0
Ergebnis		

Mobilität (in allen Ebenen)		
Mobilität	300-210°	5
Mobilität	209-160°	4
Mobilität	159-100	3
Mobilität	99-60°	2
Mobilität	59-30°	1
Mobilität	29-0°	0
Ergebnis		

Gesamtergebnis	

Auswertung

- Der Harris Hip Score (HHS) ist ein Fragebogen der bei annähernd allen Hüftpathologien unabhängig vom Leistungsniveau verwendet werden kann. Er evaluiert hauptsächlich Beschwerden im alltäglichen Leben (ca. 90%). Des Weiteren werden Symptome aus dem Bereich Körperfunktion (z.B. Gelenkmobilität und Deformität ca. 10%) abgefragt . Es ist allerdings zu bedenken, dass jüngere und insbesondere sportlich sehr ambitionierte Patienten nicht voll evaluiert werden können. Dies ist dadurch begründet, dass sehr basale Aktivitäten abgeprüft werden und dementsprechend ADL´s, welche größere Kraftleistungen beinhalten, weniger Beachtung finden. Hierfür müssten andere Assessmenttools hinzugefügt werden.

- Der HHS kann nicht vom Patienten alleine ausgefüllt werden. Die Anteile Mobilität und Deformität werden vom Behandler gemessen und hinzugefügt. Die Unterpunkte Schmerz, ADL und Gehfähigkeit dagegen können vom Patient selbst evaluiert werden. Die komplette Durchführung benötigt daher ca. 15 Minuten. Für die Auswertung müssen ca. 5 Minuten veranschlagt werden.

- Die einzelnen Kategorien ergeben bei einem optimalen Ergebnis für den Schmerz 44 Punkte, die Funktion 44 Punkte, die Unterpunkte Deformität und Mobilität steuern 4 respektive 5 Punkte bei. Das maximal erreichbare Ergebnis beträgt also 100 Punkte. Grundsätzlich können die erreichten Werte wie folgt eingeordnet werden:
  - Exzellentes Ergebnis (oder Funktionsstatus): 90-100 Punkte
  - Gutes Ergebnis (oder Funktionsstatus): 80-89 Punkte
  - Durchschnittliches Ergebnis (oder Funktionsstatus): 70-79 Punkte
  - Schlechtes Ergebnis (oder Funktionsstatus): <70 Punkte

- Wird der Fragebogen nach einer Endoprothesenversorgung eingesetzt, so wird eine postoperative Verbesserung von 20 Punkten mit einem stabilen Implantat ohne weitere Eingriffe mit einem guten bis sehr guten Ergebnis gleichgesetzt. Die minimal klinisch relevante Veränderung wird zwischen 10%-20% angegeben.

- Da dieser Fragebogen nicht selten auch telefonisch eingesetzt wird kommt manchmal der modifizierte HHS zum Einsatz. Dabei werden die vom Therapeut erhobenen Daten (Beweglichkeit und Deformität) entfernt. Die maximale Punktzahl kann so auf 95 bzw. 91 sinken. Die Bewertung erfolgt dann ebenfalls in 10 Schritten ausgehend von einer geringeren Gesamtpunktzahl (siehe oben).

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5.3 Barthel-Index(108)

Patientendaten

Aktivitäten des täglichen Lebens (ADL), Barthel-Index

Datum:

1. Essen	Punkte	
Unabhängig, benutzt Geschirr und Besteck	10	
Braucht Hilfe, z.B. beim Schneiden	5	
Total hilfsbedürftig	0	
2. Baden		
Badet oder duscht ohne Hilfe	5	
Badet oder duscht mit Hilfe	0	
3. Waschen		
Wäscht Gesicht, kämmt, rasiert bzw. schminkt sich, putzt Zähne	5	
Braucht Hilfe	0	
4. An- und Auskleiden		
Unabhängig, inkl. Schuhe anziehen	10	
Hilfsbedürftig, kleidet sich teilweise selbst an/aus	5	
Total hilfsbedürftig	0	
5. Stuhlkontrolle		
Kontinent	10	
Teilweise inkontinent	5	
Inkontinent	0	
6. Urinkontrolle		
Kontinent	10	
Teilweise inkontinent	5	
Inkontinent	0	
7. Toilettenbenutzung		
Unabhängig bei Benutzung der Toilette/des Nachtstuhls	10	
Braucht Hilfe für z.B. Gleichgewicht, Kleidung aus-/anziehen, Toilettenpapier	5	
Kann nicht auf Toilette/Nachtstuhl	0	
8. Bett-/(Roll-)Stuhltransfer		
Unabhängig (gilt auch für Rollstuhlfahrer)	15	
Minimale Assistenz oder Supervision	10	
Kann sitzen, braucht für den Transfer jedoch Hilfe	5	
Bettlägerig	0	
9. Bewegung		
Unabhängiges Gehen (auch mit Gehhilfe) für mindestens 50 m	15	
Mindestens 50 m Gehen, jedoch mit Unterstützung	10	
Für Rollstuhlfahrer: unabhängig für mindestens 50 m	5	
Kann sich nicht mindestens 50 m fortbewegen	0	
10. Treppensteigen		
Unabhängig (auch mit Gehhilfe)	10	
Braucht Hilfe oder Supervision	5	
Kann nicht Treppensteigen	0	
Gesamtpunktzahl (max. 100)		

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