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Proximal Femoral Nail Unlocked versus Locked (ProFNUL): a protocol for a multicentre, parallel-armed randomised controlled trial for the effect of femoral nail mode of lag screw locking and screw configuration in the treatment of intertrochanteric femur fractures

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ABSTRACT

Introduction Intertrochanteric fractures are common fragility injuries in the elderly. Surgical fixation using intramedullary devices are one of the widely used management options. To date, evidence demonstrating the effects of lag screw configuration and the mode of lag screw locking in these devices is lacking. The purpose of this study is to investigate whether the lag screw configuration (single vs integrated dual interlocking screw) and the mode of lag screw locking (static vs dynamic) of a femoral nail device result in differences in clinical and functional outcomes.

Methods and analysis A multicentre, pragmatic, single-blinded randomised controlled trial (RCT) with a three-arm parallel group design is proposed. Nine-hundred patients with intertrochanteric fractures (A1 and A2 AO/OTA) will be randomised to fracture treatment using a Gamma3 nail (Stryker; proximally dynamic) or a Trigen Intertan nail (Smith & Nephew) in a dynamic or static lag screw configuration. The primary outcome measure consists of radiological evidence of construct failure within 6 months following surgery, with failure being defined as breakage of the femoral nail or distal locking screw, a change in tip-apex distance of more than 10 mm or lag screw cut-out through the femoral head. Secondary outcomes include surgical data (operation time, fluoroscopy time), complications (surgical site infection, reoperation, patient death), return to mobility and home circumstances, functional independence, function and pain. Patients who are able to walk independently with or without a mobility aid and are able to answer simple questions and follow instructions will be asked to participate in three dimensional gait analysis at 6 weeks and 6 months to assess hip biomechanics from this cohort. Additional secondary measures of gait speed, hip range of motion, joint contact and muscle forces and gross activity monitoring patterns will be obtained in this subgroup.

Ethics and dissemination The Central Adelaide Local Health Network Human Research Ethics Committee has approved the protocol for this RCT (HREC/17/RAH/433). The results will be disseminated via peer-reviewed publications and presentations at relevant conferences.

Trial registration number ACTRN12618001431213.

Strengths and limitations of this study

- Multicentre, pragmatic, single-blinded randomised controlled trial.
- The first study to investigate the effects of femoral nail lag screw locking mode on clinical and functional outcomes.
- The first study to collect three-dimensional motion capture data from the patients postoperatively.
- Powered to detect differences in device failure between the three parallel arm groups in a large sample size (900).
- Limitations of the study include an unpredictable loss to follow-up from death or failure to attend.

INTRODUCTION

Background and rationale

Proximal femur fractures are a highly prevalent injury in the elderly,[1 2] with an estimated 1.31 million fractures occurring worldwide each year.[3 4] With a growing elderly population resulting from an increasing life expectancy,[5] there is an increasing global incidence of these fractures,[5–9] projected to reach 6.26 million by the year 2050.[10] Fractures within the intertrochanteric region represent approximately half of all proximal femur fractures.[11] Treatment typically consists of surgical fixation using either intramedullary (IM; eg, proximal femoral nail (Synthes)) or

extramedullary (eg, Dynamic Hip Screw, Synthes) fixation devices.

Since its introduction in the 1990s, IM fixation has become increasingly popular,[12] with increasing trends towards this device preference recorded in the USA[13] and Australia.[14] Numerous types of IM fixation devices are available for clinical use,[15] however the optimum implant choice remains unknown.[16] While there is evidence to support the use of these devices in the treatment of intertrochanteric fractures, the evidence demonstrating whether variations in design characteristics influence patient clinical outcomes is conflicting.[12 17–19] As no rationale behind implant selection can be drawn from the literature, there is considerable diversity regarding the choice of implant between clinicians.[20]

The Gamma3 nail (Stryker) is a well-established and widely used current generation single lag screw IM device[12] which shows good clinical and radiographic outcomes.[21–23] However, complications still exist, with the most frequently reported complication being cut-out of the lag screw through the femoral head,[24–26] with an incidence rate ranging between 4% and 8%.[27–29] The Trigen Intertan nail (Smith & Nephew) is a similar current generation IM device, featuring a dual lag screw configuration comprised of a larger superior lag screw and a smaller screw integrated within the superior screw.[30] Together, this interlocking dual-oval shaped composite screw mechanism allows for linear compression of the fragments at the fracture site while providing high rotational stability.[31 32] Clinical studies evaluating the Intertan nail against other single screw devices have recorded a significant reduction in the occurrences of implant failure, fracture site non-union, mal-union, lag screw cut-out and uncontrolled varus fracture collapse.[30 31 33–35] Several authors have postulated the reduced complication rate being attributed to the design of this nail.[30] Moreover, ex vivo biomechanical studies have demonstrated superior biomechanical results with the Intertan nail.[36–39] However, despite the Gamma3 and Trigen Intertan nails, both being well-established implant choices used in the treatment of these fractures, very little direct comparative clinical evidence exists between these nails.

A meta-analysis by Ma *et al*[40] found only nine papers, four of which included the Gamma3 and the Intertan. Of these four, three were randomised controlled trials (RCTs) comparing the two devices, but with relatively small cohort sizes. From these studies, the Intertan nail was shown to result in a lower incidence of implant cut-out and femoral fractures which was of statistical significance. No statistically significant differences in time to union and postoperative complications were found between devices. Ma *et al* highlighted that a limitation of this statistical analysis was the relatively small sample size of the studies included, and indicated a need for more high-quality RCTs to yield a more convincing test power.[40] Hence, the literature reveals limited evidence of whether design characteristics of femoral nails affect clinical and patient outcomes in the treatment of trochanteric fractures.

In addition to the choice of the IM implants, other aspects of these devices used in the practical management of intertrochanteric fractures need further evaluation. This includes the mode of lag screw fixation (static or dynamic). Technically, both the Gamma3 and Intertan nails can be used in static or dynamic modes of the lag screw. In the dynamic mode, fracture collapse occurs under physiological loading, resulting in macro and micromotion of the fracture fragments as well as compression/apposition of fracture fragments,[41–43] desired to stimulate fracture healing. However, excessive sliding of the lag screw has been shown by some authors to lead to mechanical complications and negatively affect patient function.[44–46]

While there is evidence highlighting a reduced risk of lag screw cut-out when using a sliding lag screw in extramedullary devices,[45 47–50] there is a paucity of similar evidence relating to the use of IM devices. One study compared the static and dynamic modes of the proximal lag screw in the Gamma3 nail in 80 patients.[51] From this study, no statistically or clinically significant difference in Harris Hip Scores (HHS), time to fracture healing or length of hospital stay was found. No such comparative evidence exists for the Intertan nail. Moreover, no clinical studies to date, comparing one IM device to another has made any note of which mode of the lag screw was employed. Consequently, considerable variance in practice can be seen between clinicians.

For the Gamma3 nail, it is suggested by Stryker in their operative technique guide that the device has to be used in the dynamic mode, with the use of the nail in a static mode considered off label.[52] For the Intertan nail (Smith & Nephew), this decision is stated in their surgical technique guide as optional with both modes considered on label,[53] and left to the operating surgeons decision.

Considering the substantial costs attributed to the management of intertrochanteric fractures, we believe that more evidence is required to evaluate the effectiveness of a single or dual screw femoral nail, as well the use of these devices in the static and dynamic modes. Moreover, no previous studies have compared postoperative lower extremity biomechanics in patients with intertrochanteric fracture treated with these devices. This proposed multicentre, parallel, three-arm RCT has been designed to fill these gaps in knowledge, and will include a two-way comparison between the Gamma3 (dynamic) and Intertan (dynamic) nails, as well as the Intertan (dynamic) and Intertan (static) nails.

Objectives

Primary objective

The aim of this RCT is to investigate if there are differences in failure rates between the surgical management of intertrochanteric fractures using a single screw or dual screw femoral nail, as well as when using a femoral nail in either the static or dynamic modes of the lag screw.

It is hypothesised there will be no difference in failure rates between patients managed with a single screw or dual screw femoral nail device. It is also hypothesised that there will be no difference in failure rates between patients managed with a femoral nail in the static or dynamic mode of the lag screw.

Secondary objectives

Several secondary will also objectives will also be studied for this RCT to evaluate the effectiveness of the devices used by quantifying and drawing inferences from observed differences between treatment groups in the following:

1. Intraoperative surgical data (operation time, fluoroscopy time, blood loss, tip-apex distance (TAD)).
2. Pain within 6 months after surgery (visual analogue scale (VAS) Pain Score).
3. Patient function (Functional Independence Measure (FIM)) and hip function (HHS) within 6 months after surgery.
4. Postoperative hip biomechanics using objective measures from gait analysis up to 6 months after surgery.

Trial design

The Proximal Femoral Nail Unlocked versus Locked study is a multicentre, pragmatic (as defined by the Pragmatic-Explanatory Continuum Indicator Summary 2 Tool),[54] single-blinded RCT with a three-arm parallel group design.

METHODS AND ANALYSIS

Patients will be randomised using an online computerised sequence generation service to test if there is a difference in outcomes between the treatment interventions. Recruitment, medical and surgical data collection will take place at the Royal Adelaide Hospital and Queen Elizabeth Hospital with other sites added later as required for participant numbers. Radiographic images will be collected at a diagnostic imaging practice and three-dimensional (3D) motion capture data will be conducted at The University of Adelaide, South Australia.

This RCT has been registered with the Australian New Zealand Clinical Trials Registry. Trial registration data are shown in table 1.

This study protocol was developed in accordance with the Standard Protocol Items: Recommendations for Interventional Trials statement.

Patient and public involvement

Patients and public were not involved in the design, conduct or reporting of this study.

Eligibility

Patients over 60 years of age presenting to any of the participating hospitals with an isolated, closed intertrochanteric fracture will be recruited against the following eligibility criteria:

Inclusion criteria

1. Traumatic intertrochanteric femur fracture (A1 and A2 AO/OTA) where a decision has been made for surgical management using a femoral nail.
2. Closed injury.
3. Patients aged over 60 years.
4. Presentation to hospital within 14 days of injury.

Exclusion criteria

1. Patients with concomitant injuries affecting treatment and rehabilitation of the affected limb.
2. Patients with associated neurovascular injuries requiring immediate surgery.
3. Patients with limited English proficiency including family members.
4. Patients where consent is refused.

All eligible patients will be provided with a study information sheet and consent form by the hospital medical staff (online supplementary appendix). If eligible patients are not able to consent due to cognitive impairment, consent will be sought from the family, in the same manner that consent for surgery and anaesthesia occurs currently (online supplementary appendix). Randomisation will then occur once consent has been obtained.

Randomisation and blinding

Patients will be randomised via a computerised generation system managed by the Griffith University's Clinical Trial Unit (Griffith University, QLD, Australia), allocating patients to three study groups of equal weights using random block sizes of 6 and 9. Randomisation will be stratified by site (three categories), gender (two categories) and cognitive function via Abbreviated Mental Health Test Score (AMTS; two categories). Randomisation of the next subject will be computer-generated at the time of request by a medical research officer at the hospital via the online randomisation system.

Patients will be blinded to their allocation until the conclusion of the trial to reduce bias in patient-reported outcome measures. The statistician performing the analysis will also be blinded to the group allocation. Surgeons and researchers will not be blinded to allocation.

Standard treatment pathway

The clinical pathway for recruited patients will be unchanged from the routine for each institution; surgery is typically carried out within 24–48 hours, and no changes will be necessary to any part of the surgical episode with the exception of the individual device used and mode of proximal locking as directed by the randomisation outcome. Training and observation will be provided to all surgeons throughout the duration of this study, from senior surgeons competent with the use of both devices; throughout the duration of the study it is anticipated that a large number of surgeons will carry out the procedures, using both devices at all sites. This adds to the pragmatic nature of the study. All fractures will be compressed proximally at the time of surgery, just prior to the nail

Table 1 Trial registration data

Data category	Information
Primary registry and trial identifying number	https://www.anzctr.org.au, ACTRN12618001431213
Date of registration in primary registry	27/08/2018
Secondary identifying numbers	None
Source of monetary or material support	Smith & Nephew Pty Ltd
Primary sponsor	Royal Adelaide Hospital, Department of Orthopaedics & Trauma Contact person: MR (mark.rickman@sa.gov.au) Smith & Nephew Inc Orthopaedic Division (SN)
Secondary sponsor	University of Adelaide, Centre for Orthopaedic & Trauma Research Contact person: AS (arjun.sivakumar@adelaide.edu.au) Contact person: DT (dominic.thewlis@adelaide.edu.au)
Contact for public queries	MR (mark.rickman@sa.gov.au)
Contact for scientific queries	DT (dominic.thewlis@adelaide.edu.au)
Public title	Evaluating the treatment methods of proximal femur fractures in elderly patients with trauma
Scientific title	A multicentre, single-blinded prospective RCT of the Gamma3 intramedullary nail to the unlocked and locked Intertan intramedullary nail for the treatment of proximal femur fractures
Countries of recruitment	Australia
Health problem studied	Proximal femur fracture
Interventions	Gamma3 trochanteric nail (unlocked proximally) Trigen Intertan Trochanteric nail (unlocked proximally) Trigen Intertan Trochanteric nail (locked proximally)
Key inclusion and exclusion criteria	Inclusion criteria: traumatic extracapsular hip fracture, closed injury, patient aged over 60 years, ability to be followed for up to 6 months, presentation to hospital within 14 days of injury Exclusion criteria: patients with concomitant injuries affecting treatment and rehabilitation of the affected limb, patients with associated neurovascular injuries requiring immediate surgery, patients where consent is refused, patients with limited English proficiency including family members
Study type	RCT
Date of first enrolment	05/09/2018
Target sample size	900
Recruitment status	Recruiting
Primary Outcome	Construct failure (time point: up to 6 months after intervention)
Key secondary outcomes	Incidence of Injury specific complications (time point: 6 months) Functional independence (time point: 6 months) Reoperation incidence (time point: 6 months) Return to mobility circumstances (time point: 6 months) Hip joint range of motion (time point: 6 months) Hip joint contact forces (time point: 6 months) Postoperative hip muscle function (abductors, flexors, extensors; time point: 6 months)

RCT, randomised controlled trial.

being either locked proximally or left unlocked. Similarly, postoperative management will remain unchanged from routine, including discharge timing and destination. All patients will be mobilised with full weight bearing as soon as possible after surgery.

Allocated interventions

1. A total of 900 patients with intertrochanteric fractures (31A1 and 31A2 AO/OTA) will be randomised to receive one of the three femoral nail interventions.
2. Gamma3 (Stryker; locked proximally).
3. Intertan (Smith & Nephew; unlocked proximally).
4. Intertan (Smith & Nephew; locked proximally).

Participant flow timeline

A succinct summary of the patient timeline is described by figure 1. Once a patient has been recruited and randomised, a baseline patient registration assessment will be completed through the use of an online form. Surgery will then proceed at the earliest available opportunity as per routine for the hospital. Nail diameters are all fixed at 11 mm for the Gamma3 nail, and 11.5 mm for the Intertan nail with the nail centrum collum diaphyseal

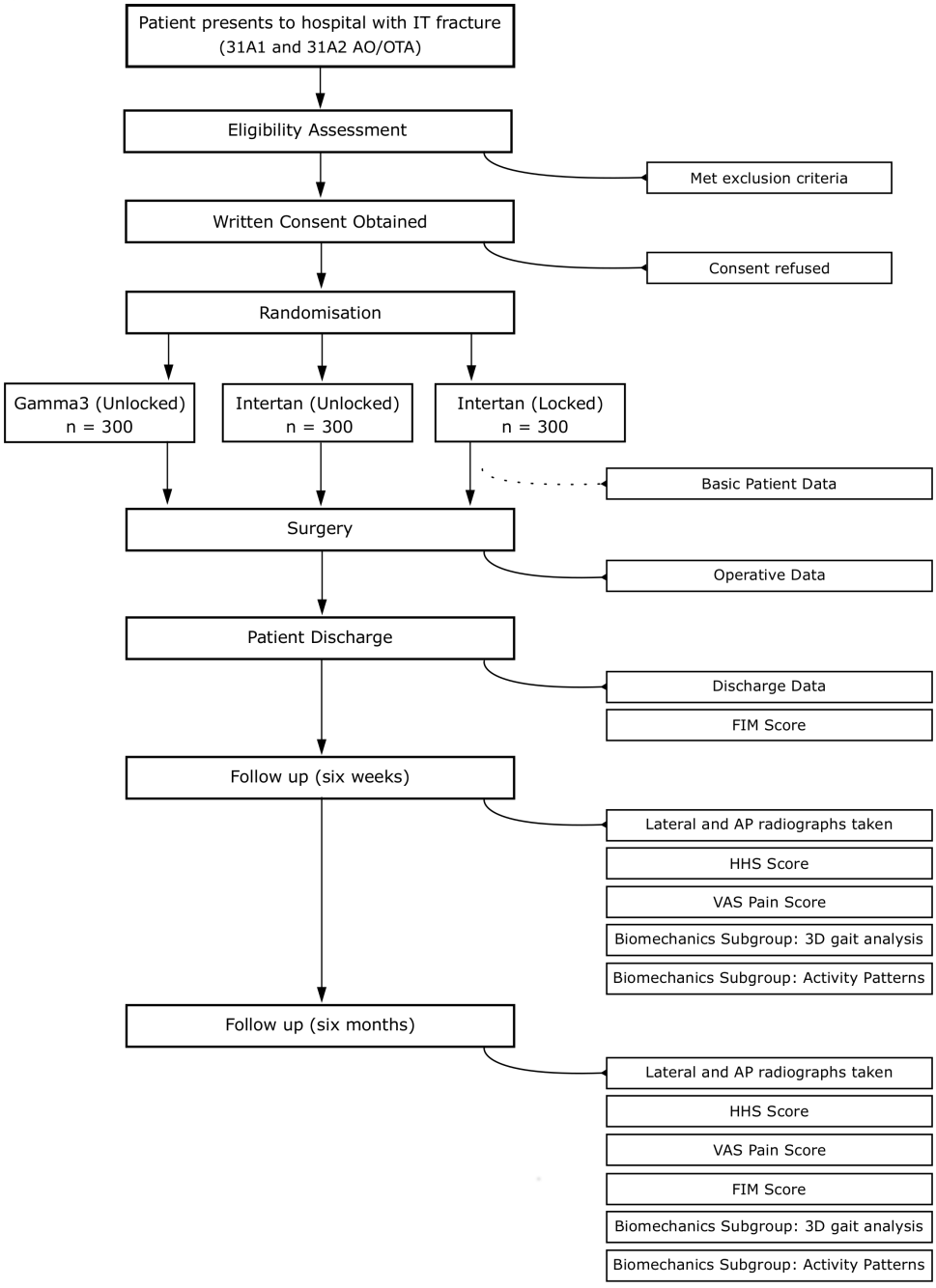

Figure 1 Patient flow diagram. 3D, three dimensional; AP, anteroposterior; FIM, functional independence measure; HHS, harris hip score; VAS, visual analogue scale.

angle at 125°. Following surgery, an operative information form will be completed by the operating surgeon using another online form. On patient discharge, medical staff will complete a patient discharge online form which includes a clinical assessment of FIM Score. Following discharge, follow-up appointments will be scheduled to coincide with 6 weeks and 6 months with appointment letters and X-ray referrals sent from the Royal Adelaide Hospital. A week prior to each patients appointment, patients will be called to confirm their appointments or reschedule, if required. Anteroposterior (AP) and lateral hip radiographs will be taken, followed by a clinical examination with an orthopaedic and trauma specialist, where measures of hip pain (VAS from 0 to 10) and hip function (HHS) will be recorded. At the 6 month follow-up, AP and lateral hip radiographs will be taken, followed by a similar clinical examination with an orthopaedic and trauma specialist. At this appointment, a FIM Score will be recorded in addition to VAS and HHSs.

Patients who are able to walk independently with or without a mobility aid and are able to answer simple questions and follow instructions will be included in a 'biomechanics subgroup' where 3D gait analysis will be performed at the 6 weeks and 6 month follow-ups immediately following the clinical examination. After the gait analysis, patients will be provided with a wrist worn activity monitor

(GeneActiv Original, Activinsights Ltd, Kimbolton, UK, 100 Hz) to wear for 7 days at a time, providing information on 24 hours gross physical activity patterns of these patients. Patients will be asked to complete a sleep log during this period to better distinguish sedentary time from sleep. After 7 days, patients will post the monitors back via prepaid return envelopes. Patients living rurally and unable to attend follow-up appointments will have X-ray appointments organised at locations convenient to them collected over the phone by an orthopaedics and trauma specialist. Patients presenting to clinics reporting complications, will be reviewed by a clinician and radiographs taken, as per standard procedure. In these events, the occurrence of these complications is recorded against the patient's hospital number.

Outcomes

Primary outcome measure

The primary outcome measure is radiological evidence of device–bone construct failure at any point up to 6 months following surgery and will be assessed via AP and lateral radiographs. Failure will be defined as the occurrence of any of the following:

1. Breakage (mechanical fracture) of the femoral nail.[55]
2. Breakage (mechanical fracture) of the distal locking screw.
3. Protrusion of lag screw through the cortex of the femoral head (cut-out).[56]
4. A change in TAD of more than 10 mm.

The TAD,[57] measured from the tip of the lag screw to the apex of the femoral cortex in lateral and AP radiographs, is generally used in clinical practice and is desirable for this measurement to be under 25 mm. TADs larger than 25 mm have been shown to serve as an accurate indicator of future protrusion of a lag screw through the femoral head (cut-out).[58] The TAD has been shown to be reproducible to within 2–3 mm between measurements[57 59] and highlighted to change by 2–3 mm over time.[60] A change in TAD of more than 10 mm has therefore been selected as a reference level which represents failure of the IM device to maintain fracture stability.

Secondary outcome measures

Secondary outcomes will also assess differences in the effectiveness between the interventions using several measures, including the following.

Femoral neck shortening

Femoral neck shortening will be measured from the AP radiograph along the long axis of the femur. This is a frequently used measure after surgical treatment of hip fractures[61 62] and is regarded a reliable measure.[63]

Functional independence: FIM Score

The FIM Score is a widely used instrument for measuring the severity of patient disability and dependence in rehabilitation medicine.[64] It has been demonstrated as a validated and reliable measure[65] with good interrater reliability of the total score (Intraclass correlation coefficient of 0.96).[66]

Pain: VAS

Pain will be assessed using a VAS[67] of categorical values from 0 to 10, with 0 indicating no pain and 10 indicating excruciating pain. The VAS pain score is a commonly used and validated measurement for patient-reported acute pain.[68]

Hip function: HHS

Hip function will be assessed by a clinician using the HHS to evaluate hip function and disability across domains of pain, function, absence of deformity and range of motion.[69] The HHS is a well performing[70] and frequently used clinician-based outcome measure that has shown high reliability and validity in evaluating hip function.[71 72]

Perioperative data

Perioperative data recorded in this trial will include surgery time, fluoroscopy time, intraoperative TAD, length of hospital stay, union time and intraoperative complications, all of which are commonly reported as valid measures across a number of RCTs evaluating femoral nail devices.[40 73–77] Intraoperative blood loss will also be recorded, however the reliability of this measure is unclear due to its underestimation during hip fracture surgery.[78]

Injury/surgery-specific complications

Surgical complications not only affect clinical outcome parameter, but appear to be a significant and often long-term predictor of patient postoperative psychosocial outcomes.[79 80] Complications recorded will include the number and type of injury and surgery-specific events and complications including, technical complications, surgical site infection, unplanned surgery and death up to 1 year following surgery. This has been reliably collected in previous studies.[81 82]

Reoperation

The number of patients presenting to the clinic requiring reoperation will be recorded in this trial. The rate of reoperation is a reliable measure in assessing quality of medical treatment.[83]

General medical complications

In this study, the number of patients suffering from general medical complications will be recorded. This has been collected and reported as a valid measure in the literature.[80]

Secondary outcome measures: biomechanics subgroup

Physical mobility: Timed up and go

Physical mobility will be assessed using the timed up and go (TUG) test which has been widely used in the literature[84] and noted to be a practical and reliable performance indicator of physical mobility.[85] The validity of the TUG has been highlighted with its correlation with

a number of mobility and performance measures such as the BBS[86] and gait speed[85 87] with normative reference values available.[88]

Hip biomechanics and function: 3D motion analysis

Using a 10 camera motion capture system (Vicon Motion Systems Ltd, Oxford, UK, 100 Hz), 3D kinematic data will be collected as patients are asked to walk short distances between two marked points at their own comfortable pace. A set of 49 retroreflective markers will be placed on anatomical landmarks of each patient to identify positions of joints, in line with standardised position and coordinate system protocols established by the International Society of Biomechanics.[89] In addition to the recorded 3D marker trajectories using the above motion capture setup, ground reaction forces will be measured via two force platforms (AMTI Optima, Watertown, Massachusetts, USA, 2000 Hz) as well as superficial muscle activity (ie, activation, timing and amplitude) using passive surface electromyography electrodes (Delsys, Boston, Massachusetts, USA, 2000 Hz, contact material 99.99% silver, interbar spacing 10 mm, common mode rejection ratio >80 dB). These electrodes will be placed on the hamstring (biceps femoris), gluteal muscles (gluteus maximus and gluteus medius), quadriceps (rectus femoris and vastus medialis) and hip adductor (adductor longus) of each leg, in line with 'Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscles' (SENIAM) guidelines. This standardisation ensures reliability in using 3D motion capture for the measurement gait parameters.[90]

An OpenSim[91] model will be scaled using the 3D motion data alongside the Musculoskeletal Atlas Programme software to produce patient-tailored musculoskeletal models.[92] Dynamic simulations will be run on the musculoskeletal models using OpenSim to calculate objective outcome measures from gait analysis including (but not limited to):

1. Hip range of motion.
2. Hip joint contact forces.
3. Hip muscle force (simulated).

Gait speed

Gait speed will be calculated from the motion capture trials as a valid and reliable measure of physical performance during gait, commonly reported in the literature.[93]

24-Hour activity patterns

Twenty-four hours activity monitoring data over a 7-day period will be collected at the 6 week and 6 month time points, using wearable accelerometers at the wrist (GeneActiv Original, Activinsights Ltd, Kimbolton, UK, 100 Hz). Patients will be asked to wear these activity monitors, at all times besides bathing. To better distinguish sedentary time from sleep time, patients will also be asked to fill in sleep logs. Physical activity measured using wrist-worn accelerometers has been strongly correlated to gross motor activity patterns measured using waist-worn monitors.[94] Wrist-worn accelerometers will be used as opposed to waist-worn or ankle-worn accelerometers for better compliance.

Data management

Outcome data will be entered electronically and stored in a password-protected shared drive and backed up weekly to a password-protected folder on the University of Adelaide's network. Only investigators will have access to the data.

Sample size

Gamma3 nail failure rates in the literature have been reported to vary from 2% to 15%.[95 96] We opted for a conservative failure estimate of 7.5% as it represents the mid-range of reported data.[97] A clinically significant difference between the two groups would be a difference of 5% between the two intervention groups. Therefore using a significance level of 0.05 and power of 80%, allowing for 30% loss to follow-up at 6 months (including 10% mortality) and a 1.5 variance inflation factor to allow for repeated measurements over time, results in a requirement for 300 patients in each of the three groups (control group—unlocked Gamma3 nail, and each of the intervention groups—unlocked and locked Intertan nail).

Statistical analysis

The primary outcome measure of device failure is considered a binary outcome (device failed/did not fail). A binary logistic regression model will be performed to assess the association between the outcome of device failure and the predictor of device type (Gamma3 unlocked, Intertan unlocked and Intertan locked). Confounders of AMTS and gender will also be included in the model as covariates as they were stratification factors in the randomisation. Post-hoc comparisons will result in ORs, 95% CIs, comparison p values and a global p value.

Some secondary outcomes are measured over two time periods. The FIM Score is measured at patient discharge and at 6 months. Therefore, a linear mixed-effects model will be used for the outcome of FIM Score and the interaction of time and device type, adjusting for repeated measurements over time as a random effect. A logarithmic transformation of the outcome may be necessary. Similarly, as pain (VAS) and HHS are measured at 6 weeks and 6 months, linear mixed-effects models will be used for these outcomes. For perioperative continuous outcomes, including surgery time, fluoroscopy time, intraoperative TAD, length of hospital stay and fracture union time, the association with device type will be investigated using a linear regression. For dichotomous secondary outcomes, including intraoperative complications, injury-specific complication rates, reoperation rates and general medical complication rates, the association with device type will be investigated using binary logistic regression. Stratification variables AMTS and gender will be included as covariates in all secondary regression models.

For the biomechanics subgroup, secondary measures of gait speed, hip range of motion, hip muscle forces and joint contact forces will be measured at 6 weeks and 6 months. Three linear mixed-effects models will be used with the device type (Gamma3 unlocked, Intertan unlocked and Intertan locked) as a fixed factor with timepoint as a repeated measure and the interaction of time and device type. Post-hoc pairwise comparisons will then be used to identify the differences in the outcomes between the timepoints of 6 weeks and 6 months.

An intention-to-treat analysis will be performed (and as randomised analysis to deal with protocol non-adherence). Missing data will be handled on the basis of each outcome—if a patient is missing outcome data for a particular regression, they will be excluded from that regression. However, if they are not missing data for the remaining outcomes, they will be included in those analyses. The use of linear mixed-effects models also retains patient data when there is missing data from only one time period. Evidence for a statistically significant difference will be accepted as $p<0.05$. The statistical software that will be used is SAS V.9.4 (SAS Institute Inc, Cary, North Carolina, USA).

Trial oversight

The overall oversight of the trial will be under the responsibility of the head of the Department for Orthopaedics and Trauma at the Royal Adelaide Hospital and supported by the University of Adelaide's Centre for Orthopaedic & Trauma Research. A Trial Steering Committee (TSC) and Data Safety and Monitoring Committee (DSMC) will be set up. The TSC will comprise of the chief investigator and associate investigator and will provide overall supervision. the DSMC will comprise of an associate investigator, clinicians and database management staff at the Royal Adelaide Hospital. The DSMC and TSC will meet prior to commencing the trial with further meetings arranged depending on the trial requirements.

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Contributors MR, DT and AS contributed to the design and implementation of the study. AL will contribute to data collection and SE will contribute to the statistical analysis of the data. AS will be responsible for data collection, processing and analysis of the biomechanics subgroup. AS, AL, MR, DT and SE contributed to the writing of this manuscript. All investigators will communicate any protocol modifications such that amendments can be made to the relevant parties (ethics committee, trial registry).

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Competing interests IP is owned by the Royal Adelaide Hospital/University of Adelaide.

Patient consent for publication Not required.

Ethics approval This protocol has received ethics approval by the Central Adelaide Local Health Network Human Research Ethics Committee and will be conducted in accordance to the NHMRC National Statement of Ethical Conduct in Human Research. This clinical trial has been registered on the Australia New Zealand Clinical Trials Registry (ANZCTR): ACTRN12618001431213.

Provenance and peer review Not commissioned; externally peer reviewed.

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