Western Graduate&PostdoctoralStudies

Western University
Scholarship@Western

Electronic Thesis and Dissertation Repository

8-26-2013 12:00 AM

A Randomized Controlled Trial Comparing Arthroscopic Surgery to Conservative Management of Femoroacetabular Impingement

Heather C. Klaus
The University of Western Ontario

Supervisor
Dr. Dianne Bryant
The University of Western Ontario

Graduate Program in Kinesiology
A thesis submitted in partial fulfillment of the requirements for the degree in Master of Science
© Heather C. Klaus 2013

Follow this and additional works at: https://ir.lib.uwo.ca/etd

 Part of the Orthopedics Commons, Physiotherapy Commons, and the Sports Sciences Commons

Recommended Citation

Klaus, Heather C., "A Randomized Controlled Trial Comparing Arthroscopic Surgery to Conservative Management of Femoroacetabular Impingement" (2013). *Electronic Thesis and Dissertation Repository*. 1609.
https://ir.lib.uwo.ca/etd/1609

This Dissertation/Thesis is brought to you for free and open access by Scholarship@Western. It has been accepted for inclusion in Electronic Thesis and Dissertation Repository by an authorized administrator of Scholarship@Western. For more information, please contact wlswadmin@uwo.ca.

A RANDOMIZED CONTROLLED TRIAL COMPARING ARTHROSCOPIC SURGERY TO CONSERVATIVE MANAGEMENT OF FEMOROACETABULAR IMPINGEMENT

(Thesis format: Monograph)

by

Heather Cloe Klaus

Graduate Program in Kinesiology

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science

The School of Graduate and Postdoctoral Studies
The University of Western Ontario
London, Ontario, Canada

© H. Cloe Klaus 2013

Abstract

OBJECTIVE: To determine whether patients with femoroacetabular impingement (FAI) who undergo arthroscopic hip surgery experience similar outcomes at two years post-operative with respect to physical function, pain, and health related quality of life, compared to similar patients who receive conservative management, including medication and physiotherapy. This thesis is an interim analysis of ten participants who are six-months post-randomization.

METHODS: Participants were randomized to either operative treatment (6) or conservative treatment (4), and completed general and region specific quality of life questionnaires, including the Hip Outcome Score (HOS), Lower Extremity Functional Scale (LEFS), Modified Harris Hip Score (MHHS), Non-Arthritic Hip Score (NAHS), and SF-12.

RESULTS: This interim analysis did not find any statistical differences between groups for patient reported outcomes or range of motion at the six-month assessment.

CONCLUSIONS: These are the preliminary results of a larger study that lacks power; a larger sample is required to make definitive conclusions.

Keywords

femoroacetabular impingement, FAI, arthroscopy, non-operative treatment, conservative treatment, physical therapy, quality of life, hip, multi-centre, randomized controlled trial

Co-Authorship Statement

Dr. Douglas Naudie contributed to study design and revisions, general supervision of the study, and securing funding. Additionally, Dr. Naudie determined eligibility, provided participant consultations and follow-ups, and provided critical revision of the thesis.

Dr. Dianne Bryant contributed to study design and revisions, general supervision of the study, and completion of the Collaborative Clinical Study Agreement between London Health Sciences Centre and the Centre hospitalier universitaire de Quebec (CHUQ). Additionally, Dr. Bryant provided research assistant training, aided in data analysis and interpretation, and provided critical revision of the thesis.

Dr. Kevin Willits contributed to the general supervision of the study, while determining eligibility, and providing participant consultations and follow-ups.

Dr. Jackie Marsh contributed to study design and helped secure funding. Dr. Marsh also drafted and revised the Western University research ethics submission, and began participant recruitment and data collection.

Cloe Klaus contributed to completion of the Collaborative Clinical Study Agreement, study design revisions, participant recruitment and randomization, data acquisition, and supervision of participant assessments. Ms. Klaus assisted three centres (CHUQ, the Ottawa Hospital, and St. Michael's Hospital) to complete research ethics submissions, drafted and revised the study protocol submitted to all sites, and aided in troubleshooting for all sites. Ms. Klaus drafted and revised this thesis, and analyzed and interpreted the data.

Acknowledgments

We would like to acknowledge the Arthroscopy Association of North America and the Lawson Health Research Institute Internal Research Fund for their contribution and support of the study.

I would like to thank my supervisors, Drs. Dianne Bryant and Douglas Naudie, for their knowledge, patience, and guidance throughout this learning experience.

To the Fowler Kennedy Sport Medicine Clinic and Joint Replacement Clinic staff and fellows, your daily support and good conversation were always appreciated. Specifically, I'd like to thank Kathy Cuthbertson (RN), Marsha Yerema (RN), Anne McDougall, Jannine Jenken (RN), Brenda Hutton (RN), Fran Gauthier (RN), Fred Cook (RN), and Penny Campbell. Also, thank you to Melanie Werstine from FKSMC for creating the rehabilitation protocols and Cheryl Litchfield from LHRI for drafting the collaborative agreement.

Thank you, Stacey Wanlin, for your general support and kind smile, and for providing research assistant training, aiding in administrative duties assigned to the study, and completing Empower Health Research website training for all sites.

I could not have completed my studies without my peers in the "research crew." Thanks for the teamwork, as well as showing me the ropes, shooting the breeze, and keeping me sane.

Thank you to the participants who took part in our study, for your patience and assistance.

Finally, thank you to my family; I would not be here today without your unending love and constant encouragement. There is no limit to your awesomeness (kiddos included).

Dedication

To Allegra Lucia, for your love and support.

Cheers to our future (RALV).

Table of Contents

List of Tables

List of Figures

List of Appendices

List of Abbreviations

AAOS: American Academy of Orthopaedic Surgeons

ADL: activities of daily living

ANCOVA: analysis of covariance

AVN: avascular necrosis

CEA: lateral centre-edge angle

CI: confidence interval

DDH: developmental dysplasia of the hip

ER: external rotation

FABERs: flexion, abduction, and external rotation

FAI: femoroacetabular impingement

HOS: Hip Outcome Score

IR: internal rotation

LEFS: Lower Extremity Functional Scale

MCID: minimally clinically important difference

MCS: mental component summary scale (SF-12)

MD: mean difference

MHHS: Modified Harris Hip Score

MRA: magnetic resonance arthrography

MRI: magnetic resonance imaging

n: number of participants

NAHS: Non-Arthritic Hip Score

NSAIDs: non-steroid anti-inflammatory drugs

OA: osteoarthritis

PCS: physical component summary score (SF-12)

PT: physiotherapy

RCT: randomized controlled trial

REB: review ethics board

ROM: range of motion

SCFE: slipped capital femoral epiphysis

SD: standard deviation

SE: standard error

SF-12: Short Form 12

TFL: tensor fascia latae

WOMAC: Western Ontario and McMaster Universities OA Index

Chapter 1: Introduction

Femoroacetabular impingement (FAI) is a hip disorder described as impaired joint clearance between the femoral head-neck junction and acetabulum. Intra-articular injury and a gradual onset of pain and stiffness are normally associated with FAI. Two types of FAI exist: cam and pincer. Cam impingement is characterized by an increased anterolateral prominence of the femoral head-neck that impinges on the acetabulum during hip movement, namely flexion, adduction, and internal rotation. This insufficient femoral head-neck concavity, or offset, produces compressive and shear forces within the joint (Beck et al., 2004) and may lead to injury of the labrum and adjacent articular cartilage. The cause for cam impingement is not known, however, it may occur following Legg-Calvé-Perthes disease, slipped capital femoral epiphysis (SCFE), femoral neck retroversion, or malunited femoral neck fractures, all of which may create either femoral retroversion or a decreased head-neck offset.

Pincer impingement is an over coverage of the femoral head by the acetabulum, causing abutment of the two during hip movement. Labral and chondral damage at the anterior acetabular rim, as well as a contrecoup injury to the posterior inferior chondral surface are signs of pincer impingement. A retroverted acetabulum and coxa profunda are both predisposing factors for pincer impingement (Lavigne et al., 2004). In some patients, abnormalities of both the femur and acetabulum are present, resulting in what is known as mixed impingement.

The goals of conservative management for FAI are to reduce pain and stiffness, increase tolerance for exercise or activities of daily living (ADL), and prevent further

injury. Treatment may include physiotherapy (PT), behavior modification or rest, and medication. Currently, the gold standard treatment for FAI is hip surgery, despite a lack of scientific efficacy. Ganz et al. (2001) first described surgical treatment of FAI as an open hip dislocation procedure. Since then, other surgical procedures have been developed and implemented, and there has been an increasing trend towards hip arthroscopy (Bedi et al., 2011; Byrd & Jones, 2011; Gedouin et al., 2010; Guanche & Bare, 2006; Kemp et al., 2012; Philippon, Briggs, Yen, & Kuppersmith, 2009; Sampson, 2005; Weiland & Philippon, 2005). Regardless of the technique used the recommended surgical intervention includes the correction of bony anomalies through osteoplasty, as well as debridement or repair of chondral, labral, and soft tissue defects.

Short-term results of surgical treatment are encouraging. The resection of bone contributing to decreased joint clearance is believed to eliminate the impingement and prevent further injury or delay the progression of osteoarthritis (OA) (Lavigne et al., 2004). However, the degree of OA present prior to surgery may impact the success of treatment. Patients presenting with higher Tönnis OA grades (Tönnis, 1987) pre-surgery tend to experience worse outcomes compared to those with a lower grade of OA, and this may influence which procedure is performed. Additionally, although a correlation appears to exist between the presence of FAI and the early onset of OA (Beck, Kalhor, Leunig, & Ganz, 2005; Beck et al., 2004; Ganz et al., 2003; Lavigne et al., 2004), a cause-effect relationship has not been established. Continued degeneration of the joint is expected to follow surgery (Beck et al., 2004), and long-term studies determining the efficacy of surgical treatment of FAI have not been published.

Bedi, Chen, Robertson, & Kelly (2008) systematically reviewed the literature and

evaluated outcomes following surgical treatment of patients with a labral tear or FAI or both a labral tear and FAI. A search of the Medline, EMBASE, and Cochrane databases was conducted for articles published between 1980 and 2008 that described surgical intervention for labral tears or FAI. Investigators found that only short-term results were reported, with an average follow-up between two and three years, and that all articles had poor methodological quality (Bedi et al., 2008). Of the 19 studies included, one had a level three design (comparative design) while the remaining studies had level four designs (case series) (Bedi et al., 2008). They were unable to identify any randomized controlled trial (RCT) and only one study prospectively collected data (Bedi et al., 2008).

Clohisy, St John, & Schutz (2010) conducted a review with similar findings. Investigators searched electronically on PubMed, EMBASE, the Cumulative Index to Nursing and Allied Health, and the Cochrane Library for articles published between 1950 and 2009, as well as searching various journals by hand for articles published between December 2008 and April 2009, that described surgical intervention and outcomes for hip impingement. Studies included in the analysis had to be peer-reviewed, original studies, that reported outcomes following FAI surgery, with a minimum follow-up of two years, and written in English. Nine out of eleven articles were level four studies while the remaining two were level three studies (Clohisy et al., 2010). Each article reported improvement in hip function and reduction of pain, but the low levels of existing evidence prevents definitive conclusions from being made (Clohisy et al., 2010).

The current study randomized patients with FAI to arthroscopy and conservative management or conservative management alone and compared health related quality of life, physical function, range of motion, and pain between the two treatment groups. We

believe that participants with FAI who undergo appropriate physical therapy combined with appropriate analgesic and anti-inflammatory medication will show similar outcomes to patients who undergo surgery in addition to physical therapy. To our knowledge, no studies have been published that compare arthroscopy to conservative management of FAI.

Chapter 2: Literature Review

2.1 Anatomy of the Hip

The pelvic girdle is a bony ring that provides skeletal support to the spine and trunk, and transfers loads to the lower extremities. The two hipbones, known as the innominate bones, each consist of an ischium, ilium, and pubis (Figure 1) that fuse together following growth plate closure. The pelvis is attached to the spine posteriorly through the sacrum and serves as an attachment site for numerous muscles that act on the hip joint, lower extremities, and trunk. Three joints arise from the pelvis, including the pubis symphysis, sacroiliac joint, and the hip joint.

The hip joint, or acetabulofemoral joint, is a synovial ball and socket joint consisting of the femoral head and acetabulum. The acetabulum is a circular bony ridge on the lateral surface of the innominate bone that serves as the socket and is angled in an

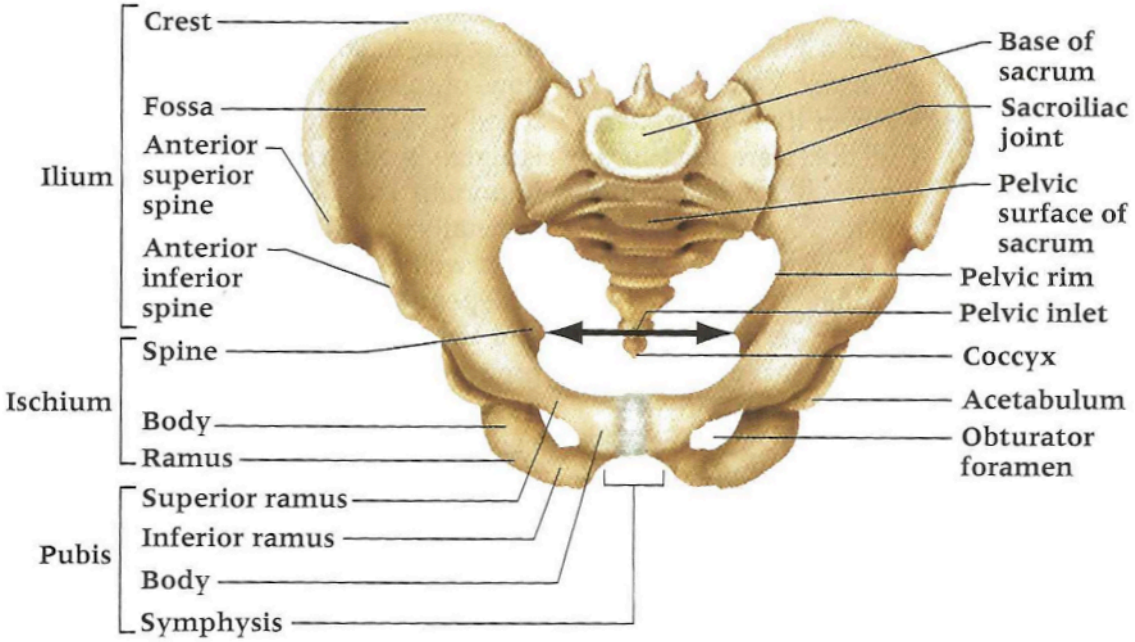


Figure 1 The pelvic girdle.
[Reprinted with permission by The McGraw-Hill Companies: Saladin, K. *Anatomy & Physiology: The Unity of Form and Function*. 5th ed. New York: McGraw Hill, 2010.]

anterior, inferior, and lateral direction. The anterior and inferior aspect of the acetabular ridge is incomplete and is known as the acetabular notch, and the roof of the acetabulum is called the acetabular sourcil. The femoral head arises proximally from the femur and is attached to the shaft through the femoral neck at an angle of about 125 degrees (Martini, 2006, p. 249). Two thirds of the femoral head is round and sits deep within the acetabulum providing bony support. Articular cartilage lines both the acetabulum and the femoral head.

Stability of the joint is increased through ligamentous support; the iliofemoral and pubofemoral ligaments support the capsule anteriorly, preventing hip hyperextension and limiting abduction, respectively, while the ischiofemoral ligament provides posterior stability to limit internal rotation (Floyd, 2007, p. 219). These three ligaments are regional thickenings of the capsule while a fourth ligament, the transverse acetabular ligament, seals the inferior border of the acetabular notch. The ligamentum teres is an intracapsular ligament that arises from the transverse acetabular ligament and directly attaches to the fovea capitis on the femoral head. The acetabulum is deepened by the labrum, a rim of fibrocartilage that aids in lubrication of the joint (Ferguson, Bryant, Ganz, & Ito, 2003), distribution of forces, and increased stability. Muscles around the hip help to further stabilize the joint and provide locomotion.

The hip is one of the most mobile joints in the body, second to the shoulder, and movement can occur in each of the transverse, sagittal, and coronal planes. Sagittal plane motion includes flexion and extension. The major hip flexors are the iliopsoas, rectus femoris, and pectineus, while the tensor fascia latae (TFL), sartorius, and adductor longus assist hip flexion. The hamstring group (biceps femoris, semimembranosus, and

semitendinosus) and gluteus maximus work together to achieve hip extension. Hip abduction and adduction occur within the coronal plane. Hip abductors play an essential role in pelvic stabilization during both single and double leg stance (Grimaldi, 2011), and include the TFL, gluteus medius, and gluteus minimus; they are assisted by the upper fibers of the gluteus maximus, sartorius, and piriformis. Hip adductors include the adductor brevis, adductor longus, adductor magnus, pectineus, and gracilis, and they are assisted by the lower fibers of the gluteus maximus. Finally, external rotation and internal rotation occur in the transverse plane. There are no true internal rotators of the hip, but certain muscles such as the adductor longus, adductor brevis, pectineus, and the posterior head of the adductor magnus contribute to the motion. They are assisted by the anterior fibers of the gluteus medius and gluteus minimus, and the TFL as the hip is flexed. Several small muscles contribute to femoral external rotation while stabilizing the head of the femur within the acetabulum (Prentice, 2011, p. 616). These muscles, along with the gluteus maximus, include the piriformis, gemellus superior and inferior, obturator internus and externus, and the quadratus femoris.

Blood supply to the hip stems from the internal and external iliac arteries. The deep medial femoral circumflex artery, arising from the external iliac artery, provides blood supply to the femoral head; it is vital to the health of the femoral head and must be avoided during surgical intervention as its disruption may lead to avascular necrosis (AVN) (Ganz et al., 2001). Important branches from the internal iliac artery include the gluteal, internal pudendal, obturator, and lateral sacral arteries. The femoral circumflex vein drains the region around the femoral head and neck then joins the femoral vein

before penetrating the pelvic cavity as the external iliac vein. The external and internal iliac veins combine caudally to create the common iliac vein.

Muscles of the hip and pelvis are all innervated from the lumbosacral plexus. Specifically, L2 through S1 provide the majority of nerves to the hip joint and are responsible for cutaneous sensation over the anterior and medial thigh. Relevant nerves include the femoral, obturator, gluteal (superior and inferior), and sciatic nerves; the pudendal nerve and lateral femoral cutaneous nerve of the thigh are also important as either may be injured during hip arthroscopy.

2.2 Epidemiology

The etiology of FAI is unknown, yet it has been associated with the development of OA. The overall prevalence of hip OA has been shown to be 10.9% (95% confidence intervals [CI], 10.6 to 11.2) (Pereira et al., 2011), while in the United States, symptomatic hip OA is purported to be 3% in those who are 30 years of age or older (Nho, Kymes, Callaghan, & Felson, 2013). Originally, OA was divided into primary, or idiopathic OA, and secondary OA, however, the likelihood of primary OA was shown to be small. Solomon (1976) claimed that over 90% of OA cases had a causative element and current research supports Solomon's findings. Ganz et al. (2003) stated that acetabular dysplasia and FAI are mostly accountable for these OA cases, while others have demonstrated that subclinical abnormalities such as FAI are present early in life in patients who go on to develop primary OA (Brand, 2009; Ito, Minka-II, Leunig, Werlen, & Ganz, 2001). The process may begin through chondral and labral lesions that lead to the degeneration of cartilage and exposure of subchondral bone (Ganz et al., 2003).

The prevalence of FAI is estimated at 10% to 15% within the general population (Leunig & Ganz, 2005), but it occurs in the asymptomatic population as well. Reichenbach et al. (2010) evaluated 244 asymptomatic male military recruits (mean age of 19.9 years) from Switzerland through MRI and reported an overall adjusted prevalence of cam impingement of 24% (95% CI, 19 to 30%). Another study by Laborie, Lehmann, Engesæter, Engesæter, & Rosendahl (2013) conducted within the general population reported prevalence of a positive anterior hip impingement test in asymptomatic 19-year-olds as 35 out of 480 men (7.3%) and 32 out of 672 women (1.2%) (Laborie et al., 2013).

Gosvig, Jacobsen, Sonne-Holm, & Gebuhr (2008) assessed 3202 hips for cam impingement through anterioposterior radiographs in a large cohort. A total of 1184 males (age range, 20 to 90 years) and 2018 females (23 to 89) were randomly selected and found to have prevalence of 17% and 4% for cam impingement, respectively. On the other hand, the prevalence of pincer impingement is not well known (Philippon, Maxwell, Johnston, Schenker, & Briggs, 2007).

Cam impingement is often seen in young athletic males with idiopathic origin, although it may be caused by various developmental factors. Legg-Calvé-Perthes disease is a childhood disease characterized by bone loss and flattening of the weight-bearing portion of the femoral head (Snow, David, Scarangella, & Bowen, 1993), which in turn, creates a reduced head-neck offset. Slipped capital femoral epiphysis presents in children and adolescents as a slip at the femoral epiphysis that can heal with an anterosuperior protuberance (Leunig et al., 2000). Femoral neck retrotorsion may also cause cam impingement following a malunited femoral neck fracture (Beck, Chegini, Ferguson, & Hosalkar, 2012). A predisposition to pincer impingement occurs in those with a

retroverted acetabulum indicating local over coverage, a previous periacetabular osteotomy (Siebenrock, Schoeniger, & Ganz, 2003), or coxa profunda, although most present with an unknown cause. Pincer morphology is typically seen in older active women.

2.3 Pathomechanics

Cam impingement (Figure 2B) is described as an abnormal joint clearance at the anterosuperior femoral head-neck junction that can cause repetitive collisions during hip motion. Historically, cam impingement was described as a pistol-grip deformity (Harris, 1986) and tilt deformity (Murray & Duncan, 1971), indicating its abnormal shape. The aspheric femoral head compresses the joint during flexion (Figure 3B), adduction and internal rotation causing the cartilage and labrum to be separated through outside-in shear forces at the acetabulum (Beck et al., 2004; Ito et al., 2001; Matheney et al., 2013). Initially, these forces create the abrasion and avulsion of acetabular cartilage from the subchondral bone and lead to the formation of anteriosuperior labrum pathology (Ganz et al., 2003). Osteophyte formation along the anterior femoral neck can occur as OA presents, (Sankar, Nevitt, et al., 2013) and the build up of bone subsequently creates an increased cam effect. The cam femoral head may display a reduced head-neck offset, potentially including a flattened head (Tibor & Leunig, 2012), or a wide or short neck (Ito et al., 2001; Leunig et al., 2000).

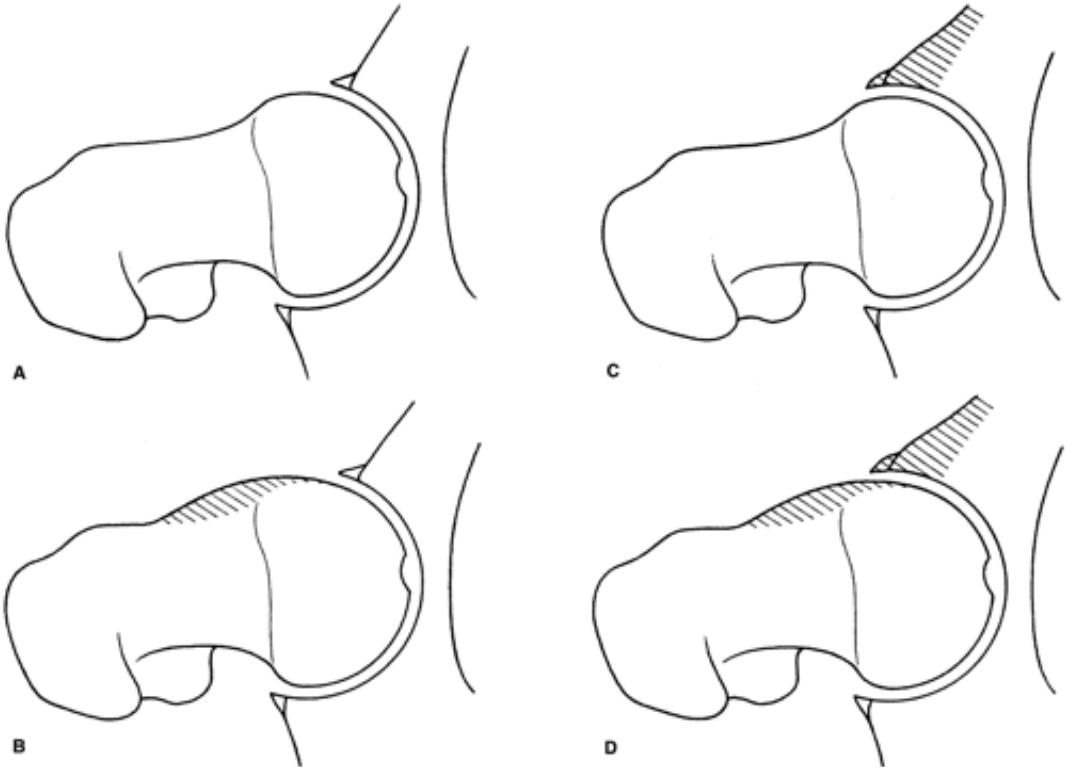


Figure 2 The factors causing FAI are shown. The reduced clearance during joint motion leads to repetitive abutment between the proximal femur and the anterior acetabular rim. (A) Normal clearance of the hip, (B) reduced femoral head and neck offset, (C) excessive over coverage of the femoral head by the acetabulum, and (D) combination of reduced head and neck offset and excessive anterior over coverage can be seen. [Reprinted with permission from Wolters Kluwer Health: Lavigne et al. (2004). Anterior femoroacetabular impingement: Part I. techniques of joint preserving surgery. Clinical Orthopaedics & Related Research, (418), 62.]

Pincer impingement (Figure 2C) is an acetabular over coverage of the joint that limits hip range of motion. The abutment between the femoral neck and acetabulum leverages the femur within the joint and creates a contrecoup chondral injury at the posteroinferior acetabular rim (Figure 4B) (Beck et al., 2004; Pfirrmann et al., 2006). A narrow band of cartilage and the labrum may be damaged, including hypertrophy and ossification of the labrum, on the anterior rim of the acetabulum at the site of impingement (Beck et al., 2005; Matheney et al., 2013).

Mixed impingement (Figure 2D) is the combination of the cam and pincer mechanisms, including the joint damage patterns seen in each abnormality (Ganz et al., 2003). Although there is controversy surrounding its existence, several studies have reported higher numbers of mixed impingement compared to cam and pincer alone. In one study, investigators radiographically evaluated 301 participants for FAI, diagnosing 100 (33.2%) with isolated cam impingement, 50 (16.6%) with isolated pincer impingement, and the majority with mixed (151, 50.2%) (Philippon et al., 2007). Similar

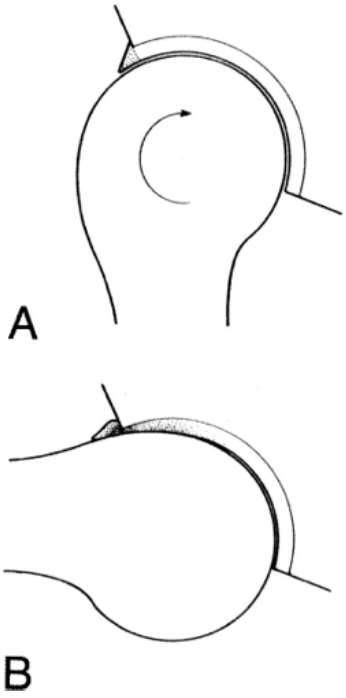


Figure 3 The mechanism of joint damage as caused by a cam impingement shows that (A) in extension, the asphericity of the femoral head does not interfere with the acetabular rim and that (B) in flexion of the hip, the acetabular labrum is lifted by the asphericity of the femoral head-neck contour and the acetabular cartilage is compressed.

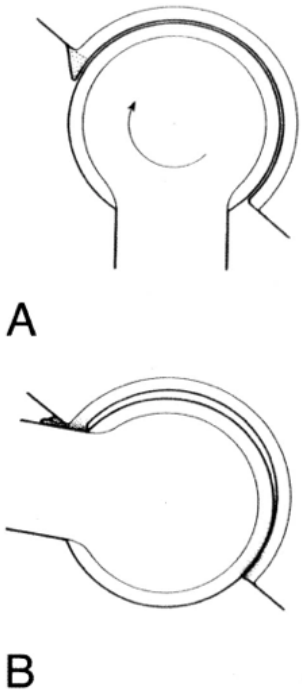


Figure 4 The mechanism of joint damage as caused by a pincer impingement shows (A) the hip is in extension and that (B) as the femoral neck approaches the acetabular rim in flex- ion, the labrum is crushed together with a narrow band of the acetabular cartilage. As the femoral head is levered out of the socket, a posteroinferior 'counter-coup' lesion occurs.

[Reprinted with permission from Wolters Kluwer Health: Beck et al. (2004). Anterior femoroacetabular impingement: Part II. midterm results of surgical treatment. Clinical Orthopaedics & Related Research, (418), 71.]

findings were present in a retrospective study of 96 asymptomatic hips where 17 (17.7%) were classified with cam impingement, 34 (35.4%) with pincer, and 45 (46.9%) with mixed (Hartofilakidis, Bardakos, Babis, & Georgiades, 2011).

A study by Cobb, Logishetty, Davda, & Iranpour (2010) warns against the classification of mixed impingement. Sixty individuals (male n = 33, female n = 27, mean age = 55 years ± 16), including normal healthy hips (20), cam hips (20), and pincer hips (20), were assessed for differing acetabular characteristics. After utilizing CT scans to create computer generated profiles of each acetabulum, comparisons showed that cam hips had a shallower acetabulum (84° ± 5°) than normal hips (87° ± 4°), which in turn were shallower than pincer acetabulum (96° ± 5°) (Cobb et al., 2010). No evidence of mixed impingement was found. The authors advised against resection of the acetabulum in "mixed impingement," or rather where cam lesions also existed as the surface area was already reduced compared to normal hips, and further reduction could lead to advanced OA (Cobb et al., 2010). Limitations to the study include a small sample size (20 participants per group) and the exclusion of hips with OA Tönnis grade ≥ 1 (Cobb et al., 2010). Evidence of differing acetabular depth was found in another study where the acetabulum was significantly ($p < .001$) deeper in pincer hips (mean, 4.8 mm), compared to cam hips (mean, 0.7mm) (Pfirrmann et al., 2006).

2.4 Association with Osteoarthritis

To date, there is no strong evidence to link FAI and the development of OA. Bardakos & Villar (2009) generated evidence that not all patients with cam lesions progress rapidly to end-stage osteoarthritis. They performed a longitudinal retrospective study to investigate which radiological parameters were associated with more rapid

progression to OA in participants with cam impingement. Patient medical records were scanned for participants aged < 50 years, who had a history of symptomatic primary arthritis, and were first seen prior to 1997. Participants were included if they had cam impingement and two sets of AP radiographs of adequate quality that were completed a minimum of ten years apart. Obturator foramina symmetry and the measured distance between the symphysis pubis and coccyx were used to assess radiographic quality. Excluded participants had Tönnis grade 3 OA, hip dysplasia, history of inflammatory arthritis, osteonecrosis of the femoral head or significant trauma, including fracture. A total of 43 participants (35 men), with a median age of 54 years (range, 28 to 55), and radiographs spaced apart by a mean of 127.1 months (range, 120 to 189) were included in the study. One observer (NVB) completed all radiological measurements twice, six weeks apart, evaluating the alpha angle, lateral centre edge-angle (CEA), medial proximal femoral angle, cross over sign, posterior wall sign, coxa profunda, protrusion acetabuli, and Tönnis Classification of OA. Intra-observer agreement was found to be very good ($\kappa \geq 0.81$) for all measurements, except when only moderate agreement was established for coxa profunda ($\kappa = 0.72$, CI (0.46 to 0.98)). Initially, 29 hips were assessed to have Tönnis grade 1 OA, and 14 hips to have Tönnis grade 2 OA, with a similar median age between groups (median, 54 years; range, 47.5 to 55; and median 54 years; range, 50 to 55, respectively). In the final radiographs, 28 hips (65%) had progression of OA while no significant relationship was seen between original OA grade and the progression of OA ($p = 0.31$). The results of this study suggest that some participants with mild to moderate hip OA may not progress in their severity at a follow-up of 10 years (Bardakos & Villar, 2009).

A study by Hartofilakidis, Bardakos, Babis, & Georgiades (2011) found similar evidence. They conducted a retrospective study to determine associations between FAI and degeneration of the hip joint. Investigators reviewed clinical records and plain radiographs of all patients who had surgical treatment of unilateral hip disease by the senior author (GH) between 1965 and 1994. Participants were ≤ 65 years of age, had no OA present on radiologic review, and had reported an asymptomatic contralateral hip that, through review for the study, showed evidence of FAI. A total of 96 participants were identified, including 31 males and 65 females, with a mean age of 49.3 years (range, 16 to 65) and had a range of FAI features including pistol grip deformity, anterior rim prominence, posterior wall sign, cross-over sign, alpha angle, CEA, and neck-shaft angle. The primary outcome for the study was the presence of early OA, as evident by joint space narrowing or the presence of osteophytes on the femoral head, assessed on radiographs from the participant's most recent follow-up.

Investigators reported that 79 hips (82.3%) remained free of OA for a mean of 18.5 years (range, 10 to 40) while only 17 hips (17.7%) developed OA within a mean of 12 years (range, 2 to 28). There were no statistically significant differences found between the rates of OA development between cam (5.9%), pincer (20.6%), and mixed impingement (20%). This case series has several limitations, including lack of controls, small sample size, and a retrospective analysis. However, results of this study suggest that a majority of hips with FAI will not proceed to hip degeneration through the OA process, and in the absence of symptomatic intra-articular injury, hip surgery may not be warranted in these individuals.

2.5 Diagnosis

Diagnosis of FAI requires a full examination including patient history, clinical examination, and imaging. Intra-articular diagnostic injection of the hip may add to the clinical picture.

2.5.1 Clinical Exam

During history, the patient may describe a gradual onset of intermittent groin or lateral hip pain, pain with prolonged sitting (Sankar, Nevitt, et al., 2013), limitations in physical activity and sport, and potentially catching or clicking within the joint (Nepple, Prather, Trousdale, Beaulé, et al., 2013). An area of lateral hip pain may be defined by cupping their hand just above the greater trochanter; with the thumb posterior and other fingers anterior, the hand creates a "C," thus this has been termed the C-sign (Byrd, 2013a, p. 15). Other pathologies can mimic FAI or radiate pain to the hip region, so it is important to rule out low back pain, lumbar disc ruptures, sacroiliac joint pain, and entrapment of the various lumbosacral nerves.

Following patient history, a clinical exam is warranted. Patient observation may show a reluctance to load the involved hip while standing and reduced hip flexion by leaning to the opposite side when seated (Byrd, 2013a, p. 8). Decreased abductor strength throughout gait and limited movements during range of motion (ROM) assessment should be noted, specifically flexion, internal rotation, and adduction. The impingement test is a combination of these three motions while the patient is supine. Starting with the involved leg on the table, the clinician dynamically flexes and internally rotates the hip and applies adduction at 90 degrees of flexion. This test is positive if the patient complains of a sharp increase in pain throughout this motion (Ganz et al., 2003). The test

can be altered to screen for posteroinferior impingement by extending the patient's hips off the distal edge of the table and applying external rotation and abduction to the joint (Leunig, Werlen, Ungersbock, Ito, & Ganz, 1997). The impingement test has been shown to be sensitive (78%) but poorly specific (10%) to intra-articular hip pathology (Martin, Irrgang, & Sekiya, 2008). Other clinical tests may include the log roll and FABERs (flexion, abduction, and external rotation of the hip) test, the straight leg raise test, and the McCarthy test to assess labral involvement. Finally, manual muscle testing, palpations, and neurovascular screening should be performed as needed.

2.5.2 Imaging

Imaging is vital in the diagnosis of FAI and several evaluation tools are useful. Imaging findings such as femoral head ossification, osteophytes, or herniation pits may indicate early degenerative disease or FAI (Sankar, Arden, et al., 2013). Classification of degenerative joint disease may be accomplished on plain radiographs or magnetic resonance imaging (MRI) using the Tönnis Classification system (Table 1) or by measuring joint space width. Joint space width is measured as the smallest distance between the acetabular roof and the femoral head, where a measurement ≤ 2 mm indicates OA (Gosvig, Jacobsen, Sonne-Holm, Palm, & Troelsen, 2010).

Anterior-posterior (AP) radiographs are routinely taken when a patient presents with hip pain indicative of FAI while cross-table lateral, frog-lateral, and 45° and 90° Dunn views may also be ordered. Cam impingement is evident when an anterosuperior prominence or reduced head-neck offset is present on plain radiographs. Lateral view radiographs allow good visualization of the cam defect while the 45° Dunn view may show the maximal cam lesion deformity (Meyer, Beck, Ellis, Ganz, & Leunig, 2006).

Table 1 Tönnis Classification System (Tönnis, 1987)

Grade	0	1	2	3
Conditions	▪ No signs of OA	▪ Increased sclerosis of the head and acetabulum ▪ Slight narrowing of joint space ▪ Slight lipping at joint margins	▪ Small cysts in the head/ acetabulum ▪ Increased narrowing of joint space ▪ Moderate loss of sphericity of the head	▪ Large cysts in the head or acetabulum ▪ Severe narrowing or obliteration of joint space ▪ Severe deformity of the head

Cam impingement may be quantified on radiographic films, MRI, or magnetic resonance arthrography (MRA) by using the alpha angle (Figure 5 and Figure 6). Calculation of the alpha angle begins by placing a best-fit circle around the femoral head. A line is drawn from the centre of the femoral neck, at its narrowest part, to the centre of the femoral head. Another line is drawn from the centre of the femoral head to the point where it extends outside the circle of best fit, and the subtended angle is measured (Nötzli et al., 2002). Different radiographic views of the same hip may create variability in this measurement.

Clohisy, Nunley, Otto, & Schoenecker (2007) performed a level three diagnostic study where radiographs of patients treated for cam impingement between January 1, 2003 and March 31, 2006 were retrospectively reviewed and matched to an asymptomatic control group. The study group contained 56 patients (61 hips) while the control group consisted of 24 patients (24 hips); both groups were similar in age (study group: mean, 32 years; range, 14-53 years; control group: mean, 35 years; range 18-49 years) and gender distribution (26% and 46% female, respectively) (Clohisy et al., 2007). Regardless of view, alpha angles were larger in hips with impingement when compared

to the control group. Average alpha angles, ranges, and significance were found respectively as listed: AP view of impingement (71.5°, 38°-132°) versus control (51.2°, 36°-94°, $p < 0.0001$); cross-table lateral view of impingement (58.8°, 31°-101°) versus control (47.2°, 30°-92°, $p < 0.05$); and frog lateral view of impingement (65.2°, 38°-114°) versus control (43.7°, 31°-76°, $p < 0.0001$) (Clohisy et al., 2007). This suggests that clinicians should be consistent when choosing a radiograph view to characterize the impingement. Controlling pelvic tilt and rotation during imaging sequences ensures consistent and accurate measurements (Nepple, Prather, Trousdale, Clohisy, et al., 2013).

For pincer impingement, the degree of acetabular retroversion, focal over coverage, and global over coverage should be assessed on AP radiographs (Nepple, Prather, Trousdale, Clohisy, et al., 2013). Retroversion is measured through the crossover, posterior wall, and ischial spine signs. A positive crossover sign is seen at the proximal acetabulum, where the anterior acetabular wall projects laterally to the posterior wall (Reynolds, Lucas, & Klaue, 1999). The posterior wall sign is positive for retroversion when the centre of the femoral head sits laterally to the posterior acetabular wall edge (Reynolds et al., 1999). True acetabular retroversion is present when both the posterior wall sign and cross-over sign are present, however, focal over coverage exists when only the cross-over sign is positive (Nepple, Prather, Trousdale, Clohisy, et al., 2013). A positive ischial spine sign occurs when the ischial spine projects medially into the pelvic inlet (Kalberer, Sierra, Madan, Ganz, & Leunig, 2008).

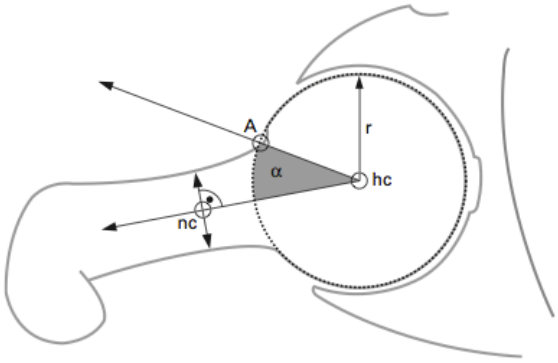


Figure 5a

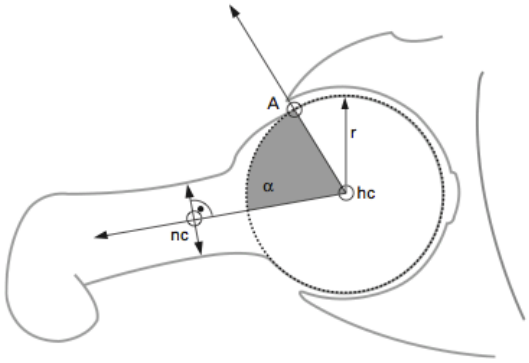


Figure 5b

Diagrams showing the construction of angle α. Point A is the anterior point where the distance from the centre of the head (hc) exceeds the radius (r) of the subchondral surface of the femoral head. α is then measured as the angle between A-hc and hc-nc, nc being the centre of the neck at the narrowest point. Figure 5a shows a hip in a normal subject and Figure 5b a typical deformation. Reproduced with permission and copyright © of the British Editorial Society of Bone and Joint Surgery [Nötzli HP, Wyss TF, Stoecklin CH, et al. The contour of the femoral head-neck junction as a predictor for the risk of anterior impingement. *J Bone Joint Surg [Br]* 2002;84-B:556-560. (Figures 2a, 2b, 4a and 4b)]

Global over coverage presents in the form of acetabular protrusion when the medial femoral head sits medially to the ilioischial line (Nepple, Prather, Trousdale, Clohisy, et al., 2013). Over coverage due to hip dysplasia is measured with the lateral centre-edge angle and acetabular inclination; both of these measurements utilize a horizontal line (HL) dissecting the inferior aspects of the ischial tuberosities. The lateral centre-edge angle is measured between two lines, one that is perpendicular to the HL and passes through the centre of the femoral head, and another line that joins the centre of the femoral head to the lateral acetabular sourcil (Nepple, Lehmann, Ross, Schoenecker, & Clohisy, 2013). Acetabular inclination is the angle between the HL and a line connecting the lateral and medial aspects of the acetabular sourcil (Nepple, Lehmann, Ross, Schoenecker, et al., 2013). A CEA of 25° to 35° is normal (Clohisy, Beaulé, O'Malley, Safran, & Schoenecker, 2008) while > 40° is considered abnormal (Tannast, Siebenrock, & Anderson, 2007).

MRI and MRA studies are used to evaluate extra-articular hip pathology, as well as intra-articular injuries, such as chondral and labral lesions. Either study may be used, but MRA can provide better visualization of lesions, specifically labral pathology, than MRI (Byrd, 2013a; Erb, 2013). The benefit of MRA is the gadolinium injection, a contrast dye that may be seen extending into the clefts and full-thickness tears of the labrum and aids diagnosis (Erb, 2013). Additionally, the clinician may observe bursitis, myotendinous pathology, joint effusions, articular cartilage damage, ligamentum teres injury, loose bodies, femoral head asphericity (Erb, 2013) and measure the alpha angle (Figure 6).

The presence of labral and cartilage damage within FAI is prevalent and can be evaluated through MRA. Kassarjian et al. (2005) retrospectively analyzed 42 hips on MRA from 40 patients (22 male) with a mean age of 36.5 years (17-67) and clinical presentation of FAI to determine common characteristics of cam impingement. They searched for patients undergoing MRA at Massachusetts General Hospital between 1999 and 2004 and excluded any patient with previous hip surgery, evidence of Legg-Calve-Perthes disease, osteonecrosis, SCFE, hip dysplasia, or acetabular retroversion (Kassarjian et al., 2005). They found that 40 out of 42 (95%) hips presented with anterosuperior cartilage damage while 100% had labral pathology in the same region (Kassarjian et al., 2005). Similar studies support these findings (Beck et al., 2005; Ganz et al., 2003; Nötzli et al., 2002), with one reporting damage to the anterosuperior cartilage and labrum in 84% and 94% of subjects, respectively (Pfirrmann et al., 2006). However, chondral damage evaluated through MRA can be missed, with one study reporting a

sensitivity of 22% and specificity of 100% for delamination (L. A. Anderson et al., 2009).

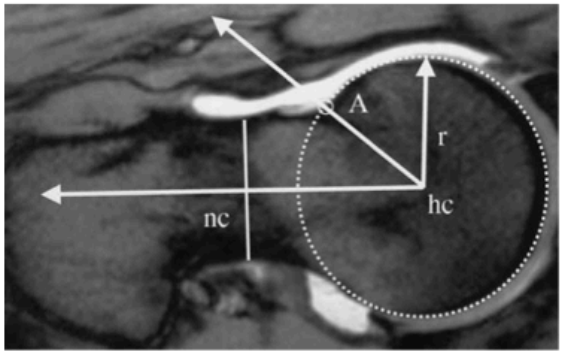


Figure 6a

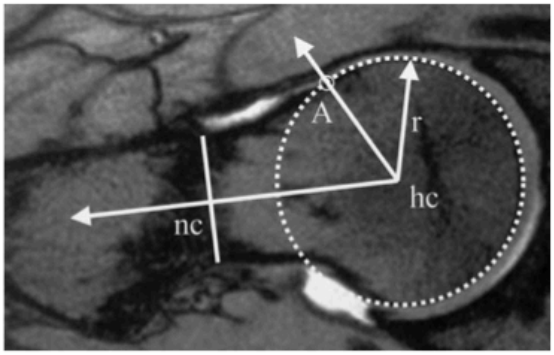


Figure 6b

MR scans showing the angle α in a) a normal and b) pathological hip.
Reproduced with permission and copyright © of the British Editorial Society of Bone and Joint Surgery [Nötzli HP, Wyss TF, Stoecklin CH, et al. The contour of the femoral head-neck junction as a predictor for the risk of anterior impingement. *J Bone Joint Surg [Br]* 2002;84-B:556-560. (Figures 2a, 2b, 4a and 4b)]

2.5.3 Other Assessment Techniques

Owing to the prevalence of asymptomatic FAI and labral pathology found on imaging intra-articular anesthetic injection may be used as a diagnostic tool to complete the clinical picture. The injection contains a local anesthetic agent, such as ropivacaine, and may be completed in conjunction with the MRA or when a fluoroscopy-guided injection is ordered separately. Intra-articular injections have been reported as specific (81%) and highly sensitive (100%) when differentiating between hip and lumbar spine pathology (Pateder & Hungerford, 2007), and as accurate predictors (90%) of intra-articular pathology (Byrd & Jones, 2004). The absence of pain relief following an injection suggests that either extra-articular pathology is the cause of hip pain or pain relief was masked due to the combination of MRA and injection (Martin et al., 2008).

Both an increase of fluid within the joint (Martin et al., 2008) and irritation from the gadolinium injection (Kuhlman & Domb, 2009) during MRA may cause the failed pain control.

2.5.4 Summary

Several imaging techniques exist to visualize the hip joint, but it is clear that further research is needed to establish standardized and widely accepted parameters for diagnosing FAI. There is a consensus that patients who are classified as having the condition must be symptomatic and have both clinical and radiologic presentation consistent with the diagnosis of FAI. Utilizing an alpha angle of ≥ 50 and a CEA of > 40 (Beck et al., 2012; Nepple, Prather, Trousdale, Beaulé, et al., 2013) may include those patients who are "near normal" to help establish a response to treatment for varying degrees of FAI.

2.6 Treatment Option

2.6.1 Surgery

Surgical intervention remains the gold standard for femoroacetabular treatment. The main goal of surgical treatment is to remove any bony impingement while simultaneously addressing associated articular pathology to prevent or delay OA progression (Clohisy et al., 2008). Several surgical approaches have been described, including hip dislocation through open surgery (Beck et al., 2004; Ganz et al., 2001), arthroscopy followed by a limited open procedure (Hartmann & Günther, 2009), and arthroscopy alone (Clohisy et al., 2008).

Open surgical hip dislocation is performed with the patient in the lateral decubitus position. A trochanteric osteotomy is performed to preserve the integrity of the piriformis and hip external rotators (Ganz et al., 2001). This technique protects the medial femoral circumflex artery through the intact obturator externus muscle, helping to prevent avascular necrosis of the femoral head (Ganz et al., 2001). The greater trochanteric fragment is retracted anterosuperiorly, and the hip dislocated, to expose the joint capsule and allow visualization of the entire acetabulum and most of the femoral head (Ganz et al., 2001). The femoral head-neck junction may be inspected for articular cartilage damage or a reduced head-neck offset, and debrided with a surgical rotating burr or chisel to correct the anomalies (Peters & Erickson, 2006). Resection of the femoral head-neck junction beyond 30% increases the risk of iatrogenic fractures and must be avoided (Mardones et al., 2005). Next, the acetabulum, articular cartilage, and labrum are examined for damage. If pincer impingement is present, the labrum is detached using a banana scalpel if it is to be repaired, otherwise debridement may occur. The pincer defect is corrected through resection arthroplasty, aiming to restore the CEA between 30° and 35° (Mardones & Nemtala, 2012). The hip may be relocated to ensure impingement-free ROM has been restored before the labrum is repaired with suture anchor fixation (Clohisy et al., 2008), and the greater trochanter is re-fixed to the femur with two or three 3.5 mm cortical screws (Ganz et al., 2001).

Hip arthroscopy is a minimally invasive procedure that can reduce recovery time in the treatment of FAI. With the patient in a supine or lateral decubitus position, the hip is distracted 8 to 10 mm to gain access to the central compartment (Clohisy et al., 2008). Three standard portals are utilized including the anterior, anterolateral, and posterolateral

portals, and an anterior capsulotomy allows visualization of intra-articular pathological changes (Byrd, 2013b; Clohisy et al., 2008). Any articular cartilage or labral damage is corrected using a shaver, and an osteotomy is used to correct a present pincer impingement. Traction is released, and the surgeon evaluates the peripheral compartment for a cam lesion, and if present, corrects it with bony resection. Following hip arthroscopy, patients are allowed to full weight bear as tolerated; however, if labral refixation occurred, patients should use crutches for up to four weeks to protect the labrum during healing (Byrd, 2013b). A return to sport following arthroscopic treatment of FAI can take four to six months (Byrd, 2013b).

Philippon, Briggs, Yen, & Kuppersmith (2009) conducted a prospective case series examining outcomes following arthroscopic treatment of FAI. One hundred and twelve participants (mean age, 40.6 years; 95% CI, 37.7 to 43.5), 50 of whom were men were included in the study following the screening of 209 consecutive patients between March 2005 and October 2005. Patients were excluded if they had bilateral hip arthroscopies, AVN, or previous surgery performed on the affected hip. Included participants were diagnosed with cam impingement using an alpha angle > 50° on cross-table lateral radiographs, pincer impingement as defined by acetabular retroversion or coxa profunda on AP radiographs, or mixed impingement when signs for both individual lesion were present. There were 12 participants lost to follow-up at the time of the two-year assessment (mean, 2.3 years; range, 2 to 2.9). Participants experienced an average improvement of 24 points (95% CI, 19 to 28, $p < 0.001$) on the primary outcome Modified Harris Hip Score (MHHS) from baseline to the final follow-up. Improvements on the Hip Outcome Score (HOS) ADL subscale (mean, 17 points; 95% CI, 12 to 22; $p <$

0.001), HOS sports subscale (mean, 24 points; 95% CI, 16 to 32; $p < 0.001$), and the Non-Arthritic Hip Score (NAHS) (mean, 14 points; 95% CI, 9 to 20; $p < 0.001$) were also observed. Results of this study show good short-term outcomes following arthroscopic management of FAI (Philippon et al., 2009).

A similar study conducted by Brunner, Horisberger, & Herzog (2009) focused on outcomes following hip arthroscopy regarding sport activity and exercise. Investigators prospectively recruited 53 participants (41 male) with a mean age of 42 years (range, 17 to 66) at the time of surgery and recorded their recreational activities. Included participants had an alpha angle > 50° and 22 of them were classified as having mixed impingement. Exclusion criteria included Tönnis OA grade 3, previous hip surgery, and musculoskeletal disorders or medical comorbidities that affected physical activity. Their primary outcome was the NAHS and the mean follow-up was 2.4 years (range, 2.0 to 3.2). Participants saw a mean improvement in the NAHS from 52 points (range, 27.5 to 73.75) preoperatively to 83.5 points (range, 60 to 97.5) at follow-up and a general increase in participants' hiking, jogging, biking, and aerobics/fitness. The investigators also noted a significant improvement ($p < 0.001$) in internal rotation and hip flexion from 6° (range, -20° to 45°) at baseline to 19° (range, -5° to 45°) at follow-up and from 107° (range, 60° to 130°) to 122° (range, 70° to 145°), respectively. They conclude that low-impact recreational activities are recommended following hip arthroscopic treatment of cam and mixed-impingement (Brunner et al., 2009).

A small case series evaluated participants' improvements on the NAHS six-months post-operatively (Stähelin, Stähelin, Jolles, & Herzog, 2008). Patients presenting with symptomatic FAI between September 2004 and April 2005 who were undergoing

hip arthroscopy were included in the study while those with previous hip surgery, joint space narrowing by half as seen on radiographs, and Tönnis OA grade 3 were excluded. A total of 22 participants were recruited (15 men) with an average age of 42 years (range, 18 to 67) and an average preoperative alpha angle of 75.1° (range, 58° to 100°). At the six-month follow-up, there was a mean difference of 23.1 points (standard deviation (SD), ± 24.2; range, -13.8 to 76.3; $p < 0.05$) compared to baseline. Limitations of the study include a short follow-up period, small sample, poorly defined eligibility criteria, and lack of primary outcomes established a priori (Stähelin et al., 2008).

The most common complication of hip surgical treatment is heterotopic ossification while others include the breakdown of adhesions, inadequate debridement, persistent symptoms, failed trochanteric fixation, and neurapraxia of the sciatic, pudendal, and lateral femoral cutaneous nerves (Papalia et al., 2012). For all indications of hip arthroscopy, a complication rate of 1.5% has been reported (Ilizaliturri, 2009).

The focus of FAI treatment has been on surgical intervention and which procedure produces better results. Papalia et al. (2012) has shown that all procedures (open, arthroscopy, and arthroscopy followed by a mini-open procedure) are comparable in functional results, biomechanics, and return to sport, however, most research is heterogeneous and of low methodological quality (Aprato, Jayasekera, & Villar, 2012; Bedi et al., 2008; Ng, Arora, Best, Pan, & Ellis, 2010). Pain relief could be due to repair or resection of the labrum coupled with the enforced rest period following surgery, and long-term follow-up studies are required to determine the true efficacy of surgical treatment.

The advancement of arthroscopic surgery in FAI treatment resembles earlier attempts to treat OA within the shoulder and knee. Despite an original opinion that variations in the shape of the acromion could cause shoulder impingement and subsequent rotator cuff injury (Neer, 1972), studies have shown the opposite to be true (K. Anderson & Bowen, 1999; Gerber, Terrier, & Ganz, 1985; Liotard, Cochard, & Walch, 1998; Thompson et al., 1996; Wuelker, Plitz, Roetman, & Wirth, 1994). Also, arthroscopic management of knee OA has been shown to have no benefit when compared to conservative management (Kirkley et al., 2008) and sham surgery (Moseley et al., 2002). Similar findings in future research regarding FAI are plausible.

2.6.2 Conservative Treatment

FAI is prevalent in asymptomatic individuals, indicating that FAI may not be the cause of hip joint pathology, but instead faulty biomechanics and muscle weakness. Anterior hip forces increase when weak gluteal muscles and iliopsoas are present (Lewis, Sahrmann, & Moran, 2007) while poor general neuromuscular control can alter normal forces across the labrum and articular cartilage (Neumann, 2010) and lead to tears (Guanche & Sikka, 2005). Conservative treatment consisting of early pain management, lumbopelvic stabilization exercises, hip muscle strengthening, proprioception training, and functional training has been shown to decrease pain and improve functional performance in patients with labral tears (Yazbek, Ovanessian, Martin, & Fukuda, 2011).

Emara, Samir, Motasem, & Ghafar (2011) conducted a study on 37 athletic participants (27 male), with a mean age of 33 years (SD, ± 5; range, 23 to 47), completing conservative treatment for unilateral FAI with an alpha angle < 60°. There were four stages in the study: 1) activity modification and anti-inflammatory intake for

two to four weeks, 2) physiotherapy involving stretching to improve hip external rotation and abduction for two to three weeks, 3) assessment of their normal IR and flexion once acute pain diminished, and 4) adaptation of ADLs that predisposed them to FAI (i.e. the combination of hip flexion, IR, and adduction). After a follow-up of 25 to 28 months, only four participants (10.8%) were considered failures of conservative treatment and had subsequent hip arthroscopy. The remaining 33 participants had improvements in the Harris Hip Score (from 72 pre-treatment to 91 at six months, and 91 at two years follow-up, $p < 0.01$) and Non-Arthritic Hip Score (72 to 90, and 91, $p < 0.01$), where a higher score represents a higher level of function. These participants also had decreased pain as measured by the visual analogue scale (6 to 3, and 2, $p < 0.01$). Limitations of the study include the recruitment of participants with only mild FAI (alpha angle < 60°), a lack of definition for "failed conservative treatment," and the failure to report participant's physiotherapy compliance, however, most participants achieved early good results with ADL modification that suggests a role for conservative management in FAI (Emara et al., 2011).

A prospective observational study was performed by Hunt, Prather, Harris Hayes, & Clohisy (2012) on conservative treatment for pre-arthritic, intra-articular hip disorders, such as FAI, developmental dysplasia of the hip (DDH), and labral tears. Authors recruited 58 participants (9 men) between 18 and 50 years of age (mean ± SD, 35 ± 11) from a tertiary clinic who experienced any of the following: anterior or lateral hip pain; a history of worsening pain with activity, pivoting, hip flexion, or weight bearing; painful mechanical symptoms; pain at rest; positive hip impingement test, FABER test, log roll, or resisted straight leg-raise test; and physical examination findings consistent with hip

pathology (i.e.: pain differentiated from the spine and other lower extremity disorders). Patients who were outside the range of 18 to 50 years old, or who had previous hip surgery, inflammatory arthropathy, hip infection or tumor, lumbar radiculopathy, extra-articular hip disorders, major structural deformity of the hip, or Tönnis grade > 1 were excluded. Participants were classified as having no structural abnormalities (32), mild DDH (8), or mild FAI (18). Treatment was divided into three phases, including 1) conservative interventions (patient education, activity modification, PT protocol, and medications as needed), 2) fluoroscopically guided intra-articular hip injection, which, if positive for pain relief (≥ 50%), could lead to subsequent MRA imaging, and 3) surgical intervention. Participants would advance to the second stage if symptoms were still limiting function at the three-month follow-up. Progression to surgical treatment required a significant reduction in pain following injection as well as lesions found on MRA that were amenable to surgical repair. Outcomes measured included the Numeric Pain Scale (NPS), SF-12 Short Form Health Survey (SF-12), MHHS, Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), NAHS, and Baeck Questionnaire of Habitual Activity, completed at baseline, and 3, 6, and 12-months (Hunt et al., 2012).

Six participants were lost to follow-up prior to the three-month assessment. Physical therapy sessions were attended by 94% of participants (49/52), with an average of 6.4 (range, 1 to 19) sessions. At the three-month assessment, 14 participants (26.9%) were happy with their outcomes and did not progress to phase two. Ultimately, 29 participants (73%) progressed to phase two, 29 participants (56%) progressed to phase three, and by study completion, 56% of participants chose surgery. At the 12-month

follow-up assessment, there were no significant differences between groups on any outcomes. Participants limited to conservative treatment experienced changes from baseline to 12-month assessment as follows: NPS, 6 ± 3 to 3.3 ± 3; MHHS, 69.4 ± 11 to 78.9 ± 14; WOMAC, 25.1 ± 17 to 13.5 ± 14; Baeck questionnaire, 7.4 ± 1 to 6.9 ± 1; SF-12 physical composite subscore (PCS), 42.7 ± 9 to 47.6 ± 9; SF-12 mental health composite subscore (MCS), 38.3 ± to 45.1 ± 8; and NAHS, 70.4 ± 12 to 81.6 ± 12. Authors concluded that conservative management of these conditions should be attempted prior to surgical intervention. Unfortunately, their sample was too small to complete subgroup analysis to determine the benefits of treatment for each condition, such as FAI (Hunt et al., 2012).

A systematic review conducted by Wall, Fernandez, Griffin, & Foster, (2013) evaluated the current evidence on the conservative management for FAI. Investigators searched for any published studies on FAI before June 2012 in the following databases: PubMed, Ovid Medline, Excerpta Medica Database, Cumulative Index to Nursing and Allied Health, Allied and Complementary Medicine Database, and Cochrane Library databases. They also searched for ongoing and unpublished studies in the International Standard Randomised Controlled Trial Number Register and MetaRegister of Controlled Trials. Studies that only had abstracts or were single case series were excluded from review. A total of 53 studies met the inclusion criteria, the majority of which were review or discussion articles (48 studies, 65%). None of these 48 articles focused solely on the conservative treatment of FAI, but they had similar recommendations including activity modification, physiotherapy, or the use of non-steroidal anti-inflammatory drugs (NSAIDs). The articles that elaborated on physiotherapy details agreed that core

stabilization, hip strengthening, and avoidance of passive ROM were important (Wall et al., 2013). The eligible five articles consisted of four case series (3 prospective) and one descriptive epidemiologic study. Two of these, including the study by Emara et al. (2011) and the study by Hunt et al. (2012), were considered to have a GRADE evidence (Guyatt et al., 2008) of low quality, while the other three had very low quality. The authors conclude that non-operative treatment is a viable option for FAI, although insights from most articles should be drawn with caution as they appear to be opinions rather than evidence-based advice. They also conclude that higher-quality evidence is needed, such as the evaluation of physiotherapy against operative care to determine true clinical effectiveness (Wall et al., 2013).

Corticosteroid injection may be an effective pain relief modality during conservative management. A randomized, double-blind, placebo-controlled study evaluated corticosteroid injection of the hip versus a placebo (Lambert et al., 2007). Fifty-two participants with symptomatic OA for six months or greater were enrolled in the study, however, only 19 participants had complete data at the final follow-up (16 and 3, for the injection and placebo groups, respectively). The primary assessment was at two months post-injection, and the primary outcome measure was a 20% decrease on the WOMAC pain subscale. Participants were assessed at baseline, and one, two, three, and six months post-injection (Lambert et al., 2007). A significant difference in WOMAC pain scores was observed between the two groups ($p < 0.0001$). The corticosteroid group reported a reduction in the mean WOMAC pain scores from 310.1 mm at baseline to 157.4 mm (49.2% decrease) at the two-month follow-up. The placebo group had improvement from 314.3 mm at baseline to 306.5 mm at two-months (2.5% decrease).

The investigators did not report a sample size calculation and were required to discontinue the study due to the results of an interim analysis following recruitment of 52 participants. Given the early stopping and high rate of incomplete data, the study was likely underpowered and biased preventing a true evaluation of the treatment effect. The striking lost-to-follow-up rate within the placebo group is highlighted by the final number of participants in the steroid group (16 [51.6%] of 31) compared to the placebo group (3 [14.3%] of 21) at the final assessment (Lambert et al., 2007).

2.7 Summary

Variations in diagnosis and treatment of FAI and methods to measure outcomes following treatment for FAI are prevalent within the literature. The standardization of these elements is vital to align and compare future findings and provide definitive evidence regarding the treatment of FAI.

In May 2012, the American Academy of Orthopaedic Surgeons (AAOS) held a symposium to complete this objective; those present discussed disease definitions, clinical assessment, imaging, treatment, clinical outcome measures, and the future of FAI research. They published the consensus reached on these topics in the Journal of AAOS this year, but while this is a step in the right direction, higher-level research is required. To our knowledge, no RCTs have been published comparing surgery to conservative management of FAI, despite the urgent need of such trials (Clohisy & Kim, 2013).

Chapter 3: Objective

The primary objective of this study was to determine whether patients with FAI who receive conservative management, including medication and physiotherapy, experience similar outcomes at two years post-randomization compared to similar patients who undergo the standard treatment of arthroscopic hip surgery. Outcomes measured included health related quality of life, physical function, pain, and range of motion.

The null hypothesis states that the surgical group will have significantly improved scores while the alternative hypothesis states that there will be similar scores between the two groups.

For the purposes of this thesis, our objective was to compare the outcomes between treatment groups at the six-month assessment.

Chapter 4: Methodology

4.1 Study Design

This was a prospective multi-centre randomized controlled trial comparing arthroscopic surgical treatment to conservative treatment for patients diagnosed with FAI. Five centres across Canada were involved, including: the Fowler Kennedy Sport Medicine Clinic (FKSMC) and the London Health Sciences Centre University Hospital (LHSC UH), located in London, Ontario; St. Michael's Hospital in Toronto, Ontario; The Ottawa Hospital in Ottawa, Ontario; and Centre hospitalier universitaire de Quebec (CHUQ) in Quebec City, Quebec. Each institute's Research Ethics Board approved the study (Appendix A) and each site followed the same protocol.

The surgeon identified eligible participants during clinic. Participants presented with a symptomatic hip, evidence of physical limitations, and objective findings suspicious for FAI. Plain AP pelvis and lateral affected hip radiographs were reviewed to assess the femoral head and acetabulum for impingement, osteophytes, cysts, AVN, articular cartilage damage, joint space narrowing, loose bodies, and synovial disease. Findings were recorded on the X-Ray Assessment form. MRA was used to further assess the joint for impingement (alpha angle $\geq 50°$, CEA $> 40°$), cysts, osteophytes, femoral herniation pitt or collapse, os acetabuli, articular cartilage damage, labral tears, paralabral cysts, intra-articular bodies, joint effusion, soft tissue injury, incidental pelvic lesions, and pain reduction post-bupivacaine injection (if applicable). The MRI Arthrogram Assessment form recorded these findings. To confirm that FAI is the primary cause of the participant's pain the surgeon may order an intra-articular injection of a long acting local anaesthetic (i.e.: bupivacaine) if this was not done in combination with the MRA.

Once a participant was deemed eligible, the research assistant informed them of the study. Participants were made aware that study involvement was voluntary and that they could refuse to answer any question or withdraw at any time. Eligible consenting participants were randomly assigned with the use of a computer-generated system to receive either standard treatment of arthroscopic hip surgery combined with a standard physical therapy program, or to receive a course of conservative, non-operative treatment, including physical therapy and medications. Randomization was stratified by surgeon (D.N. and K.W.) and disease severity (Grade 1 versus Grade ≥ 2) as defined by the Tönnis classification grade to balance prognostic factors between groups. Following randomization, range of motion was collected, and participants completed their baseline forms. Participants then either booked surgery (surgical arm) or a follow-up appointment for three months following the start of treatment (rehabilitation arm). The Letter of Information and Consent form is available in Appendix B.

4.2 Eligibility Criteria

Patients 18 years of age or older, with an alpha angle greater than or equal to 50 degrees, who were diagnosed with FAI (cam, pincer, or mixed impingement), and had grade one, two, or three radiographic severity of osteoarthritis as defined by the Tönnis classification scale (Tönnis, 1987) were eligible to participate in this study.

Patients were excluded if they had an isolated labral tear detected by clinical examination or magnetic resonance imaging, Tönnis Grade Zero osteoarthritis, or inflammatory or post-infection arthritis. Patients with previous arthroscopic treatment for hip osteoarthritis, previous major hip trauma, a major neurologic deficit, or a major medical illness (where life expectancy was less than two years or they had a high intra-

operative risk) were also excluded. Lastly, patients who could not speak, understand, or read English (or French at the appropriate sites), who had a cognitive impairment or psychiatric illness that precluded informed consent or rendered the patient unable to complete questionnaires, or had no fixed address and no means of contact were excluded.

4.3 Outcome Measures

All outcome measures were entered into a web-based data management system (EmPower Health Research Inc, www.empowerhealthresearch.com) for this study. Each measure was completed at baseline, and at three, six, 12, 18, and 24 months following the start of treatment.

4.3.1 Primary Outcome Measure

The primary outcome measure was the Hip Outcome Score (HOS). The HOS is a disease-specific, self-administered questionnaire. The index consisted of three descriptive questions, plus another 28 questions divided into two subscales: Activities of Daily Living (19 items) and Sports (SP) (9 items). Subscale items were scored between four ("no difficulty") and zero ("unable to do"). Each item answered was added together, divided by the overall maximum total (four multiplied by the number of questions answered), and multiplied by 100 to get a percentage. Two items on the Activities of Daily Living subscale were not scored ("putting on socks and shoes" and "sitting for 15 minutes") which created a maximum total of 68 points for that section (Martin, Kelly, & Philippon, 2006). A higher score represents a higher level of physical function for both subscales. The minimal clinically important difference (MCID) was nine points for the Activities of Daily Living subscale, and six points for the Sports subscale (Lodhia, Slobogean, Noonan, & Gilbart, 2011). Lodhia et al. (2011) conducted a systematic

review on published patient reported outcome instruments for FAI and labral assessment and evaluated the content and clinimetric evidence of three instruments. The majority of evidence supported the use of HOS in this population as it was found to have the highest positive rating for internal consistency, construct validity, agreement, responsiveness, lack of floor and ceiling effect, and interpretability (Lodhia et al., 2011).

4.3.2 Secondary Outcome Measures

4.3.2.1 Global Health Questionnaires

The SF-12 Short Form Health Survey v.2 (SF-12) is a 12-item general health questionnaire that evaluated eight domains including physical health (physical functioning and role physical), mental health (role emotional and mental health), pain, vitality, social functioning, and general health (Ware, Kosinski, & Keller, 1996). The SF-12 has been shown to be valid, reliable, and responsive and was suggested for use in studies evaluating physical and mental health (Ware et al., 1996), such as patients with orthopedic conditions. It is generally accepted that the MCID for the SF-12 ranged from 3-5 points (Drummond, 2001).

4.3.2.2 Region Specific Questionnaires

The Lower Extremity Functional Scale (LEFS) is a 20-item, lower limb region-specific quality-of-life questionnaire. Items were scored from zero (“extreme difficulty/unable to perform activity”) to four (“no difficulty”) and added together for a maximum total of 80 points. The minimal clinically important difference is at least nine points (Binkley, Stratford, Lott, & Riddle, 1999). The LEFS is reliable and sensitive to change, and possesses both face and construct validity (Binkley et al., 1999; Watson et al., 2005).

The Modified Harris Hip Score (MHHS) is a nine-item, region-specific instrument modified from the Harris Hip Score, which was initially developed for use following acetabular fracture (Harris, 1969). The modified version excludes the domains of deformity and range of motion, to consist of the pain and function domains only. The pain domain has a maximum total of 44 points. The item rating pain in the unaffected hip was not scored. The function domain contained two sections scored as follows: 33 points for function: gait, and 14 points for functional activities. Item scores were added then multiplied by 1.1 to receive a total score out of 100 points (Bedi et al., 2008; Byrd & Jones, 2000), where a higher score indicated greater function and less pain.

The Non-Arthritic Hip Score (NAHS) is a 20-item, disease-specific questionnaire that consists of four domains: pain (five items), mechanical symptoms (four items), physical function (five items), and level of activity (six items) (Christensen, Althausen, Mittleman, Lee, & McCarthy, 2003). Items were scored between zero (“Extreme”) and four (“None”), added together, and multiplied by 1.25 for an overall total score maximum of 100. A higher score represents a higher level of physical function, and less pain and symptoms. The NAHS was shown to be reliable, and possess both high internal consistency and good validity (Christensen et al., 2003).

4.3.2.3 Range of Motion

The surgeon measured active hip flexion and passive hip flexion, internal rotation, external rotation, abduction, and adduction, bilaterally. The participant was supine for all measurements.

For active flexion, the participant flexed their hip as far as they were able. The surgeon then passively flexed the hip to end ROM for passive flexion. Internal and external rotation were both measured with the hip flexed to 90 degrees while abduction and adduction were both measured with the hip at neutral, or zero degrees flexion. The surgeon flexed the contralateral hip to measure adduction.

4.4 Procedures

All follow-up assessments occurred during the participants' regularly scheduled appointments with their surgeon at three, six, 12, 18, and 24 months. Questionnaires were completed in the paper-based form, or when accessing the web-based data management system. The online method was preferred as participants received email reminders with a link to the questionnaires when forms were due, and as the system operated in real-time, the research assistant could monitor the completion of due forms.

The prescription of medications, injections, and other treatments were not controlled by this study's protocol. Instead, the surgeon and participant decided which additional interventions were appropriate for managing any symptoms related to their condition; these were all recorded with the Co-Intervention and Medication forms. Co-existing conditions were recorded with the Self-Administered Comorbidity Questionnaire (Sangha, Stucki, Liang, Fossel, & Katz, 2003).

4.4.1 Control: Surgical Treatment

Following surgery, each participant's surgical details were collected with the Surgical Information form by accessing the operative report. Collected information included pre and post-operative diagnosis, procedure performed, visualized

compartments, anesthesia used, start and end time for surgery and traction (when available), deep vein thrombosis or antibiotic prophylaxis used, and any intra-operative complications.

Participants were encouraged to complete physical therapy as per standard care, and were given the FKSMC Hip Arthroscopy Protocol for Femoroacetabular Impingement (Appendix C). This protocol was shared with the participant's physical therapist (PT). The surgeon's instructions for the PT were to use the protocol as a guideline while their expertise and clinical judgment were to be used when determining the number of visits and exercise limits or progression. The PT was requested to complete reports at six weeks and three months for the study. The six-week physical therapy form recorded the date of the initial appointment, date of referral from the physician (if applicable), number of sessions completed, expected progression (yes or no), or stated that no physical therapy sessions had been completed. The three-month physical therapy form recorded the number of sessions completed since the six-week mark, expected progression (yes or no), or stated that no physical therapy sessions had been completed since the six-week mark.

Adverse events (AE) related or unrelated to the hip were recorded throughout the study using the Adverse Event form. The date of AE onset, treatment received, and the date of resolution (if applicable) were recorded. Cardiac, central nervous system, gastrointestinal, respiratory, or urinary complications, or participant death were recorded. Complications related to the hip could include infection, AVN, nerve injury, vascular injury, breakage of surgical instrument, intra-operative damage to articular cartilage, wound drainage, femoral neck fracture, haematoma and haemarthrosis, evidence of labral

re-tear, excessive stiffness, or pain worsening. There was an option under both sections to report other complications not listed. A follow-up form noted any additional actions taken (observation, PT, medication, hospital admission, surgical procedure, or none) since the last assessment and the date of resolution (if applicable).

Participants returned for their follow-up visits with the surgeon and completed all required forms.

4.4.2 Experimental: Conservative Treatment

Participants randomized to the conservative treatment arm were given the FKSMC Hip Conservative Management for Femoroacetabular Impingement (Appendix D). Similarly to those in the surgical arm, participants shared the protocol with their PT with identical instructions from the surgeon. The PT completed the same six-week and three-month physical therapy forms for the study. The AE form and follow-up form were completed as needed throughout the study.

4.5 Sample Size

A sample-size calculation was conducted with a statistical power of 80%, and 0.05 alpha error rate to detect a moderate effect size of 0.5 standard deviations, which has been shown to be equivalent to the minimally important difference (Norman, Sloan, & Wyrwich, 2013). Sixty-three participants per treatment group were required, and those numbers were inflated to 70 per group to account for an expected 10% loss to follow up rate (Chow, Shao, & Wang, 2003).

4.6 Statistical Analysis

The mean and standard deviation for the five questionnaires (HOS, NAHS, MHHS, LEFS, and SF-12 v2) for each group at baseline, three months, and six months, and the adjusted mean between-group difference with a 95% confidence interval (CI) at six months post-randomization were calculated. Independent samples t-tests were conducted to determine if significant differences between groups were present for age, OA grade, or alpha angle. Participants were analyzed using intention-to-treat (ITT).

An analysis of covariance (ANCOVA) was performed to analyze the primary outcome. The dependent variables were the ADL and SP subscale scores from the HOS at six months post-randomization, the independent variable was the treatment group, and the covariate was the baseline HOS scores. Identical analyses were used for the secondary outcomes. A set p-value of 0.05 was considered significant for all tests. All statistical analyses were completed using SPSS 21 statistic software (SPSS, Chicago, IL).

Chapter 5: Results

A total of 280 new patients visiting the tertiary clinics were screened for eligibility between April 2011 and April 2013 (Figure 7). Of these, 250 patients did not meet the eligibility requirements, 2 patients declined participation, and the surgeon recommended a specific treatment in 15 cases. Currently, 13 participants from two surgeons' clinics have been enrolled in the study: D.N. (8) and K.W. (5). Seven participants have been randomized to surgical treatment while six participants were randomized to conservative treatment. These analyses include the three and six-month data of 10 randomized participants, six in the surgical group and four in the conservative group. At this point, no participant has withdrawn from the study, nor have any participants from the conservative group crossed over to surgery due to unmanageable symptoms.

5.1 Baseline Demographics and Participant Characteristics

The baseline demographics and characteristics are similar between groups for gender, height, weight, body mass index (BMI), dominant side, previous health care providers seen, employment status, reduced hours of work, modified duties at work, third party compensation, and co-morbidities (Table 2). They were different in regards to: affected hip; symptoms present in the contralateral hip; use of painkillers, anti-inflammatories, and other treatments (massage therapy and active release therapy) prior to randomization and at baseline; duration of symptoms; and smoking history. The surgical group had a significantly higher average age compared to the conservative group, but there were no significant hip OA grade differences found between groups.

Nine of the ten participants had cam impingement, one in the surgical group had pincer impingement, and none displayed mixed impingement. There were no significant differences in alpha angle between groups (surgical: mean, 61.6 ± 5.3; conservative: mean, 62.8 ± 11.6), and the sole pincer lesion had a CEA of 48°. The HOS, NAHS, MHHS, LEFS, and SF-12 had similar baseline scores between groups (Table 3).

5.1.1 Surgical Procedure Characteristics

In the surgical group (n = 6), participants were postoperatively diagnosed with cam (83.3%) and pincer (16.7%) impingement. Of these participants, 83.3% had a labral tear and 33.3% had chondral damage. All six participants were treated with hip arthroscopy and osteoplasty, and 83% had labral and chondral debridement. Average traction time during surgery was 55.2 minutes (SD, ± 19.07). No intraoperative complications occurred.

5.1.2 Physical Therapy Characteristics

Nine of ten participants completed physiotherapy sessions during the first six months (four conservative, five surgical). The six-week physiotherapy details of one participant in the surgical group were unavailable because the clinic went out of business. In the conservative treatment group, participants attended an average of 6.25 PT appointments (range, 2 to 10) in the first six weeks while only one participant continued PT beyond that point, completing an additional three sessions. Surgical group participants attended an average of three PT sessions (range, 0 to 8) by the six-week appointment (averaged across the five participants who had six-week data). Only two participants continued their PT treatment to the three-month assessment, one attending

seven sessions and the other attending four. One surgical group participant did not attend any physiotherapy.

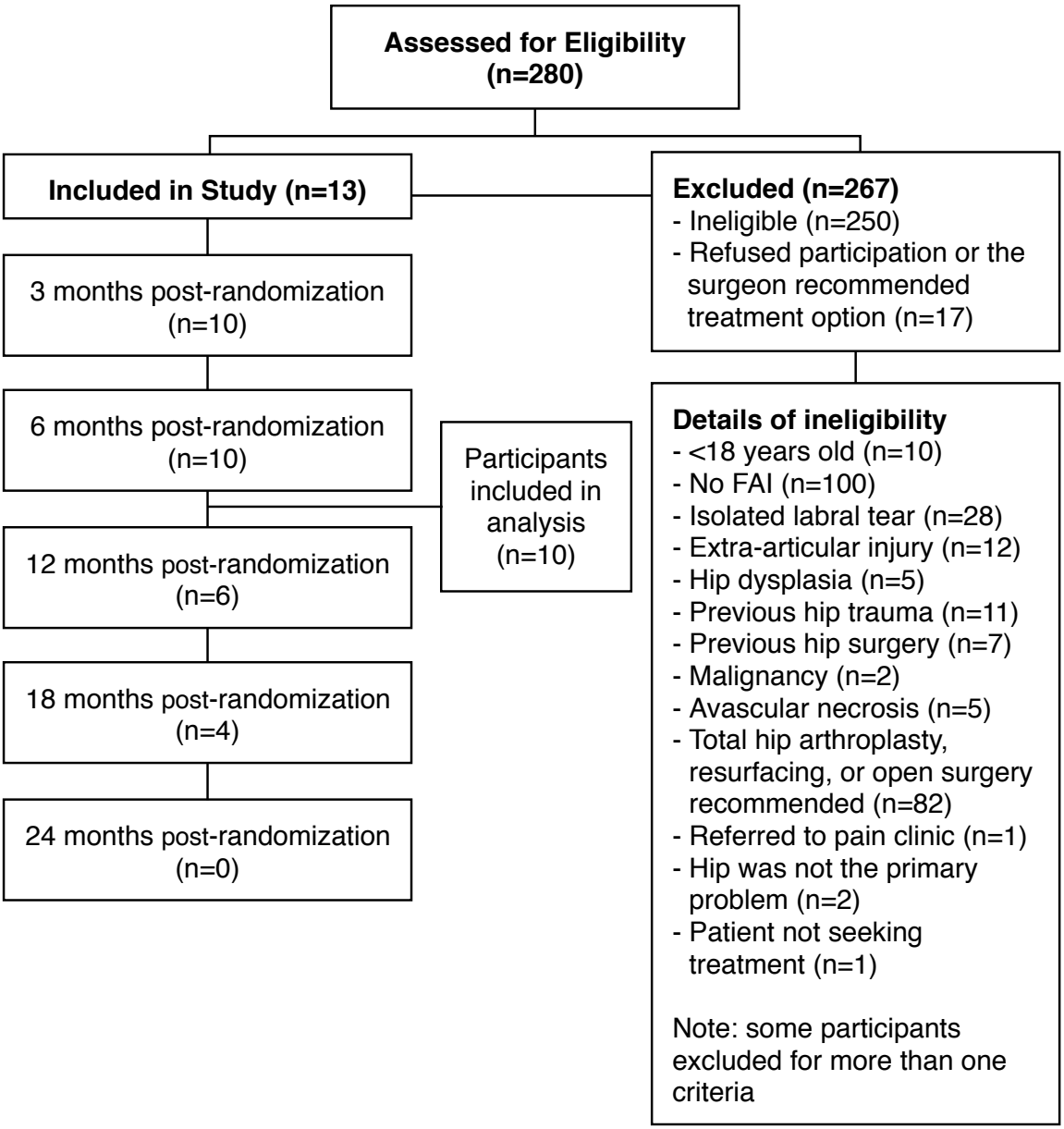


Figure 7 Participant flow chart

Table 2 Participant Demographics and Baseline Characteristics

Characteristic	Surgical (n = 6)	Conservative (n = 4)
Sex, n (%)		
Male	6 (100%)	4 (100%)
Age, mean ± SD (years)	43.7 ± 7.0	33.5 ± 6.5
Height, mean ± SD (centimeters)	185.0 ± 7.1	186.1 ± 4.8
Weight, mean ± SD (lbs)	214.5 ± 20.6	215 ± 37.6
BMI, mean ± SD	27.0 ± 3.7	28.2 ± 5.1
Affected hip, n (%)		
Right	4 (66.7)	2 (50.0)
Symptoms in Opposite Hip	3 (50.0)	1 (25.0)
Dominant side, n (%)		
Right	5 (83.3)	3 (75.0)
Previous Treatment, n (%)[a]		
Pain Killers	5 (83.3)	1 (25.0)
Anti-inflammatories	5 (83.3)	2 (50.0)
Corticosteroid injection	2 (33.3)	0 (0.0)
Non-steroid injection	0 (0.0)	1 (25.0)
Physical Therapy	3 (50.0)	2 (50.0)
0-6 weeks	1 (16.7)	0 (0.0)
6-12 weeks	0 (0.0)	1 (25.0)
> 12 weeks	2 (33.3)	1 (25.0)
Surgery	0 (0.0)	0 (0.0)
Other	2 (33.3)	0 (0.0)
Previous health care providers, median (range)	2 (1 – 4)	2.5 (1 – 6)
Duration of symptoms, median (range) (years)	5.5 (3 – 30)	1 (0.5 – 4)
Activity at Injury, n (%)		
Activities of daily living	0 (0.0)	1 (25.0)
Traffic accident	1 (16.7)	0 (0.0)
Work	0 (0.0)	0 (0.0)
Sport	2 (33.3)	2 (50.0)
No specific injury recalled	3 (50.0)	1 (25.0)
Smoking history, n (%)		

Characteristic	Surgical (n = 6)	Conservative (n = 4)
No	4 (66.7)	3 (75.0)
Yes, quit	2 (33.3)	0 (0.0)
Duration, median (range) (years)	4 (3 – 5)	0 (0.0)
Packs/day, median (range)	0.18 (0.1 - 0.3)	0 (0.0)
Yes	0 (0.0)	1 (25.0)
Duration, median (range) (years)	0 (0.0)	15 (N/A)
Packs/day, median (range)	0 (0.0)	1 (N/A)
Employment Status, n (%)		
Full-time	4 (66.7)	4 (100.0)
Part-time	0 (0.0)	0 (0.0)
Retired	1 (16.7)	0 (0.0)
Student	0 (0.0)	0 (0.0)
Stay-at-home parent/spouse	0 (0.0)	0 (0.0)
Social assistance	0 (0.0)	0 (0.0)
Volunteer	0 (0.0)	0 (0.0)
Other	1 (16.7)	0 (0.0)
Employment Type		
Repetitive activity involving walking	4 (66.7)	1 (25.0)
Desk job	2 (33.3)	1 (25.0)
Other	0 (0.0)	2 (50.0)
N/A	0 (0.0)	0 (0.0)
Reduced Hours of Work Due to Hip	3 (50.0)	2 (50.0)
Modified Duties at Work Due to Hip	3 (50.0)	2 (50.0)
Off-Work Unrelated to Hip	0 (0.0)	0 (0.0)

Abbreviations: SD = standard deviation, NSAIDs = non-steroid anti-inflammatory agents

[a] Participants were able to select more than one previous treatment, baseline medication, and baseline co-morbidity. Percentages are not required to sum to 100.

Table 3 Surgical Procedure Characteristics

Characteristic	Surgical (n = 6)
Postoperative Diagnosis, n (%)	
FAI	6 (100.0)
Cam	5 (83.3)
Pincer	1 (16.7)
Mixed	0 (0.0)
Labral tear	5 (83.3)
Chondral damage	2 (33.3)
Loose body	0 (0.0)
Snapping iliopsoas	0 (0.0)
Procedure Performed, n (%)	
Arthroscopy	6 (100.0)
Labral debridement	5 (83.3)
Labral repair	0 (0.0)
Chondral debridement	5 (83.3)
Osteoplasty	6 (100.0)
Removal of loose bodies	0 (0.0)
Traction Time, mean ± SD (minutes)[a]	55.2 ± 19.1
Intraoperative Complications, n (%)	
Yes	0 (0.0)

Abbreviations: FAI = femoroacetabular impingement; SD = standard deviation
[a] Traction time only available for one surgeon (D.N.) (n=5)

5.2 Data Analysis

Baseline, three-month, and six-month outcome scores are presented in Table 4. Last outcome carried forward (LOCF) was used to complete the missing six-month follow-up assessment for one participant in the conservative group who was unable to take time off from work for the assessment. All other participants completed each questionnaire.

5.3 Primary Outcome

A repeated measures ANCOVA with a modified Bonferroni correction was performed to analyze 10 participants' six-month HOS scores while controlling for baseline scores. The dependent variables were the ADL and SP subscale scores from the HOS at six months post-randomization, the independent variable was the treatment group, and the covariates were the baseline HOS scores and age. Age was included as a covariate in the ANCOVA as it was a significant factor ($t_{(8)} = 2.33$, $p < 0.05$) between groups.

For the HOS ADL subscale, the adjusted means 86.7 ± 6.9 at three months and 88.7 ± 6.2 at six months for the surgical group were used to calculate between group differences. In the conservative group, the adjusted means 63.6 ± 9.1 at three months and 64.1 ± 8.2 at six months were used to calculate between group differences. For the HOS SP subscale, the surgical group had adjusted means of 72.6 ± 8.1 at three months and 81.0 ± 10.4 at six months. The conservative group had adjusted means of 39.1 ± 10.6 at three months and 32.0 ± 13.6 at six months. The mean between-groups difference was not statistically significant between treatment groups at any time point ($p < 0.05$) (Table 5).

5.4 Secondary Outcomes

Each secondary outcome, including the LEFS, MHHS, NAHS, SF-12 PCS, SF-12 MCS, and ROM, were analyzed at six-months post-randomization using an ANCOVA while controlling for the baseline scores and age (Table 5). A modified Bonferroni

correction was applied to adjust for Type I error. There were no statistically significant differences found between treatment groups for any outcome.

5.4.1 Range of Motion

Range of motion was not complete for all participants. Some participants did not see the surgeon in person for their appointments, including one conservative group participant at three-months and another conservative group participant at six-months, while one participant from the surgical group did not show up for their six-month clinic appointment. One participant from the surgical group had only baseline ROM complete; they did not come to the clinic for their three-month appointment, and ROM was missed at the six-month appointment due to the research assistant being ill. LOCF was used to impute the missing data at the six-month appointment, but the two participants with missing three-month ROM were excluded pair-wise from the ROM analysis. The adjusted means and between-group differences for range of motion are presented in Table 6.

5.5 Adverse Events

One participant experienced a minor infection of their stitches post-operatively, but following stitch removal and the use of an antibiotic (cephalex) the infection cleared up within a day. Other adverse events reported from the surgical group include one reporting vision problems and two participants reporting a slip and fall (recommended treatment for one was eight weeks of PT while recommended treatment for the other was 14 weeks of PT, in addition to active release therapy). In the conservative group, one

participant reported bilateral knee stiffness eight months following randomization that for now is under observation. No other AE's have been reported.

Table 4 Unadjusted Outcomes by Group Over Time

	n	Baseline	3 months	6 months
HOS ADL *(unadjusted mean ± SD)*				
Surgical	6	51.0 ± 18.9	77.4 ± 22.2	79.7 ± 17.7
Conservative	4	77.6 ± 8.4	77.6 ± 10.2	77.7 ± 15.6
HOS SP *(unadjusted mean ± SD)*				
Surgical	6	27.6 ± 21.0	59.3 ± 31.2	66.4 ± 30.0
Conservative	4	51.8 ± 27.2	59.0 ± 24.5	53.5 ± 35.6
LEFS *(unadjusted mean ± SD)*				
Surgical	6	30.3 ± 19.0	57.8 ± 23.1	60.5 ± 21.5
Conservative	4	52.5 ± 16.3	56.0 ± 17.6	57.0 ± 17.2
MHHS *(unadjusted mean ± SD)*				
Surgical	6	54.6 ± 15.4	75.7 ± 17.9	79.0 ± 19.3
Conservative	4	61.9 ± 13.6	70.1 ± 12.0	72.1 ± 17.8
NAHS *(unadjusted mean ± SD)*				
Surgical	6	46.7 ± 20.5	82.3 ± 8.9	86.3 ± 10.8
Conservative	4	67.5 ± 12.0	75.3 ± 18.6	77.8 ± 23.5
SF-12 PCS *(unadjusted mean ± SD)*				
Surgical	6	34.1 ± 10.0	46.7 ± 7.7	48.1 ± 12.4
Conservative	4	40.6 ± 10.4	42.0 ± 11.9	43.4 ± 13.0
SF-12 MCS *(unadjusted mean ± SD)*				
Surgical	6	53.3 ± 14.4	53.9 ± 11.4	52.4 ± 8.8
Conservative	4	54.1 ± 10.1	55.4 ± 9.6	53.4 ± 10.1
Physiotherapy Sessions Attended *(unadjusted mean, (range))*				
Surgical	6	N/A	3 (0-8)	1.8 (0-7) [a]
Conservative	4	N/A	6.3 (2-10)	0.8 (0-3) [b]

[a] Only two participants completed physiotherapy past the 6 week follow-up
[b] Only one participant completed physiotherapy past the 6 week follow-up
Abbreviations: HOS ADL = Hip Outcome Score Activities of Daily Living subscale; HOS SP = Hip Outcome Score Sports subscale; LEFS = Lower Extremity Functional Scale; MHHS = Modified Harris Hip Score; NAHS = Non-Arthritic Hip Score; SF-12 PCS = SF-12 Health Survey Physical Component Summary Scale; SF-12 MCS = SF-12 Health Survey Mental Component Summary Scale; N/A = not applicable.

Table 5 Adjusted Means and Between-Group Differences for Outcome Measures

Outcome Measure	Baseline			
	Surg. (n=6)[a]	Cons. (n=4)[a]	Difference (95% CI)	P value
HOS ADL	54.5 ± 7.2	72.2 ± 9.3	-17.5 (-48.4, 13.3)	*p*=0.22
HOS SP	27.3 ± 11.6	51.5 ± 14.9	-23.7 (-73.4, 26.0)	*p*=0.23
LEFS	33.6 ± 8.5	47.7 ± 10.9	-14.1 (-50.4, 22.3)	*p*=0.39
MHHS	59.0 ± 6.3	55.4 ± 8.2	3.6 (-23.6, 30.8)	*p*=0.77
NAHS	51.1 ± 8.0	60.9 ± 10.3	-9.9 (-144.2, 24.5)	*p*=0.52
SF-12 PCS	37.6 ± 4.1	35.3 ± 5.2	2.4 (-15.0, 19.8)	*p*=0.76
SF-12 MCS	49.4 ± 5.6	59.9 ± 7.2	-10.5 (-34.3, 13.4)	*p*=0.33
	3 Months Post-Randomization			
	Surg. (n=6)[a]	Cons. (n=4)[a]	Difference (95% CI)	P value
HOS ADL	86.7 ± 6.9	63.7 ± 9.1	23.1 (-9.3, 55.5)	*p*=0.13
HOS SP	72.6 ± 8.1	39.1 ± 10.6	33.5 (-3.8, 70.8)	*p*=0.07
LEFS	64.5 ± 7.7	46.1 ± 10.0	18.4 (-16.7, 53.5)	*p*=0.25
MHHS	74.4 ± 4.4	72.2 ± 5.6	2.2 (-17.3, 21.7)	*p*=0.79
NAHS	85.7 ± 6.4	70.2 ± 8.3	15.6 (-13.3, 44.4)	*p*=0.23
SF-12 PCS	48.0 ± 3.4	40.1 ± 4.4	8.00 (-7.1, 23.1)	*p*=0.24
SF-12 MCS	55.1 ± 4.0	53.6 ± 5.2	1.5 (-16.9, 19.8)	*p*=0.85
	6 Months Post-Randomization			
	Surg. (n=6)[a]	Cons. (n=4)[a]	Difference (95% CI)	P value
HOS ADL	88.7 ± 6.2	64.1 ± 8.2	24.6 (-4.4, 53.7)	*p*=0.08
HOS SP	81.0 ± 10.4	32.0 ± 13.6	49.4 (1.3,97.5)	*p*=0.05
LEFS	68.1 ± 8.1	45.6 ± 10.5	22.5 (-14.4, 59.4)	*p*=0.19
MHHS	79.1 ± 5.0	71.9 ± 6.5	7.2 (-15.2, 29.5)	*p*=0.46
NAHS	90.9 ± 8.1	70.8 ± 10.5	20.1 (-16.5, 56.7)	*p*=0.23
SF-12 PCS	48.1 ± 4.7	43.4 ± 6.0	4.8 (-16.0, 25.6)	*p*=0.59
SF-12 MCS	51.8 ± 4.3	54.4 ± 5.6	-2.6 (-22.4, 17.3)	*p*=0.76

*Denotes statistical significance, $p < 0.05$

[a]Adjusted means ± standard error, mean differences (95% CI), P values presented for comparisons at baseline, 3 months, and 6 months post-randomization

Abbreviations: CI = confidence interval; Surg. = surgical group; Cons. = conservative group; HOS ADL = Hip Outcome Score Activities of Daily Living subscale; HOS SP = Hip Outcome Score Sports subscale; LEFS = Lower Extremity Functional Scale; MHHS = Modified Harris Hip Score; NAHS = Non-Arthritic Hip Score; SF-12 PCS = SF-12 Health Survey Physical Component Summary Scale; SF-12 MCS = SF-12 Health Survey Mental Component Summary Scale.

Table 6 Adjusted Means and Between-Group Differences for Range of Motion

Range of Motion	Surg. (n=6)[a†]	Cons. (n=4)[a†]	Difference (95% CI)	P value
	Baseline			
Flexion (a)	-11.7 ± 14.4	-21.3 ± 17.0	14.5 (-17.4, 46.3)	*p*=0.32
Flexion (p)	-13.3 ± 9.3	-15.0 ± 16.8	5.9 (-20.2, 32.0)	*p*=0.61
IR	-10.8 ± 8.6	-8.8 ± 16.5	7.8 (-14.0, 29.5)	*p*=0.43
ER	-0.8 ± 3.8	1.3 ± 2.5	-2.4 (-9.4, 4.7)	*p*=0.45
Abduction	-0.8 ± 9.2	0.0 ± 0.0	-5.0 (-19.1, 9.2)	*p*=0.44
Adduction	-0.8 ± 5.9	1.3 ± 2.5	-3.5 (-13.6, 6.6)	*p*=0.44
	3 Months Post-Randomization			
	Surg. (n=5)[a]	Cons. (n=3)[a]	Difference (95% CI)	P value
Flexion (a)	1.0 ± 6.5	-10.0 ± 10.0	14.0 (-8.1, 36.0)	*p*=0.15
Flexion (p)	0.0 ± 12.8	-8.3 ± 7.6	4.5 (-24.5, 33.5)	*p*=0.69
IR	7.0 ± 8.4	-6.7 ± 7.6	16.7 (-2.4, 35.8)	*p*=0.07
ER	-4.0 ± 15.6	0.0 ± 0.0	-5.7 (-43.0, 31.6)	*p*=0.69
Abduction	-1.0 ± 7.4	-1.7 ± 2.9	6.0 (-3.9, 15.9)	*p*=0.17
Adduction	0.2 ± 3.6	0.0 ± 0.0	1.5 (-6.3, 9.3)	*p*=0.62
	6 Months Post-Randomization			
	Surg. (n=5)[a]	Cons. (n=3)[a]	Difference (95% CI)	P value
Flexion (a)	0.0 ± 7.9	-10.0 ± 10.0	5.1 (-8.9, 19.1)	*p*=0.37
Flexion (p)	-8.0 ± 11.0	-10.0 ± 10.0	8.4 (-14.9, 31.7)	*p*=0.37
IR	8.0 ± 11.5	-5.0 ± 5.0	9.3 (-18.9, 37.5)	*p*=0.41
ER	7.5 ± 18.9	0.0 ± 0.0	23.1 (-6.5, 52.7)	*p*=0.10
Abduction	-1.0 ± 6.5	-5.0 ± 5.0	9.0 (-3.6, 21.5)	*p*=0.12
Adduction	12.0 ± 16.1	-5.0 ± 8.7	24.2 (-13.5, 61.9)	*p*=0.15

*Denotes statistical significance, $p < 0.05$

[†] A positive value indicates ROM of the affected limb was greater while a negative value indicates ROM of the unaffected limb was greater.

[a]Adjusted means ± standard error, mean differences (95% CI), P values presented for comparisons at baseline, 3 months, and 6 months post-randomization

Abbreviations: CI = confidence interval; Surg. = surgical group; Cons. = conservative group; (a) = active range of motion; (p) = passive range of motion; IR = internal rotation; ER = external rotation.

Table 7 Participant's Scores for the Hip Outcome Score

	Baseline		3M Post-Randomization		6M Post-Randomization	
Group	HOS ADL	HOS SP	HOS ADL	HOS SP	HOS ADL	HOS SP
Surgical						
1	57.35	32.14	95.59	91.67	91.18	77.78
2	76.47	47.22	89.71	80.56	94.12	84.38
3	36.76	2.78	83.82	44.44	88.24	80.56
4	64.71	44.44	85.94	58.33	82.35	75.00
5	45.59	38.89	75.00	75.00	76.47	75.00
6	25.00	0.00	34.38	5.56	45.59	5.56
Ad. Avg.	**54.5 ± 7.2**	**27.3 ± 11.6**	**86.7 ± 6.9**	**72.6 ± 8.1**	**88.7 ± 6.2**	**81.0 ± 10.4**
Conservative						
7	70.59	66.67	79.41	72.22	77.94	58.33
8	73.53	47.22	72.06	58.33	72.06	58.33
9	76.56	15.63	67.86	25.00	64.06	5.56
10	89.71	77.78	91.18	80.56	96.88	91.67
Ad. Avg.	**72.2 ± 9.3**	**51.5 ± 14.9**	**63.7 ± 9.1**	**39.1± 10.6**	**64.1 ± 8.2**	**32.0 ± 13.6**

Abbreviations: HOS ADL = Hip Outcome Score Activities of Daily Living subscale; HOS SP = Hip Outcome Score Sports subscale; Ad. Avg. = Adjusted group mean.

Chapter 6: Discussion

The purpose of this thesis was to analyze the preliminary results at six months post-randomization for participants with FAI who were randomized to either surgical treatment or conservative treatment. Despite non-statistically significant differences between groups at all time points, at baseline the surgical group tended to have worse outcome scores than the conservative group, except for the MHHS and SF-12 PCS that were almost identical between groups. By the three-month assessment, the surgical group tended to have better scores on all outcomes, and at the six-month assessment the difference in mean-scores further increased in favour of the surgical group except for the two SF-12 subscales (Table 5).

It is worth noting that all participants in the surgical group saw improvements in both of their HOS subscale scores between baseline and the three-month assessment, and these scores were maintained or further improved by the six-month assessment (Table 7). Comparatively, HOS scores for the conservative group participants either remained similar or got worse (Table 7).

Our findings are consistent with a case series study by Stähelin, Stähelin, Jolles, & Herzog (2008) where participants undergoing arthroscopic treatment for cam impingement saw a significant improvement of approximately 23 points on the NAHS between baseline and a six-month follow-up. In our study, surgical group participants experienced an improvement in NAHS scores that exceeded 23 points at the six-month follow-up. Additionally, our six-month results resemble the outcomes from Philippon, Briggs, Yen, & Kuppersmith (2009) with respect to MHHS, HOS ADL, HOS SP, and

NAHS scores at the 24-month follow-up. The growth of our study's sample size and subsequent increase in power will allow for more in depth comparisons of these two studies with ours.

The conservative group saw a general decrease in HOS, LEFS, and SF-12 MCS scores over time, but an increase in MHHS, NAHS, and SF-12 PCS scores. One participant had received one corticosteroid injection at the three-month assessment while another participant self-reported taking ibuprofen (800 mg, 4x/day) and Tylenol extra strength (500 mg, 6x/day) as needed at the three and six-month assessments. Considering that only one out of the four participants from the conservative group continued physiotherapy following the six-week mark, it is difficult to draw any insight from the varying outcome scores. However, the average number of PT sessions attended by participants in our study is similar to the average 6.4 sessions (range, 1 to 19) attended by participants in Hunt et al.'s (2012) study at the three-month assessment.

In the case series study by Emara, Samir, Motasem, & Ghafar (2011) participants undergoing conservative treatment of FAI exhibited greater improvements on the NAHS at the six-month follow-up when compared to our interim analysis. Unlike our study, Emara et al. only included participants with mild FAI (alpha angle < 60°) who exhibited no signs of OA, while all participants from the conservative group had OA and an average alpha angle of 62.8 in our study.

No surgical group participants experienced commonly reported complications such as neurapraxia, nerve palsies, or heterotopic ossification following surgery (Papalia et al., 2012); however, one did experience a minor infection following surgery that

cleared up within a day following stitch removal and the use of an antibiotic (cephalex). One participant in the conservative group reported bilateral knee stiffness eight months into treatment that has not required specific treatment. No other AE's have been reported that are directly related to the study.

This study has several limitations. Surgeon bias may have affected recruitment. For example, some surgeons did not offer study participation to patients who had already completed a course of physiotherapy. We did take steps to reduce the biasing effect of surgeon bias by insisting that eligibility was determined prior to randomization. Additionally, the surgeon could affect participant attitude regarding entering the study, either by not equally explaining both treatment options or by suggesting a specific treatment to the patient prior to informing them of the study.

Another limitation was our failure to standardize the ROM measurement. Assessors infrequently used a goniometer when measuring ROM, and it was rare for the same clinician to assess a participant at each follow-up. It would have been beneficial to have one assessor at each site completing ROM measurements who was blinded to group allocation. Ideally, we would have trained one assessor at each site and demonstrated their intra-rater reliability, and inter-rater reliability with assessors at different sites. However, this study was underfunded, which did not allow for in-person meetings.

As this is an interim analysis, the results presented here were based on only 10 out of 140 participants required to properly power this study. The small sample used in this analysis means that the confidence intervals around the between-groups difference are wide and therefore do not allow for definitive conclusions to be made at this time.

We also experienced some barriers to recruitment. Five different sites are participating in this trial that required approval from each of their individual research ethics board (REB). According to the Tri-Council Policy Statement, each institute is held accountable for any research being carried out under its name or when using its resources, and a member of that institution engaging in research must gain approval from their own REB. The ethics applications vary between institutes; it can take considerable time to navigate the REB process and gain approval from all sites. Getting each centre recruiting was further hindered by a lack of consensus between all surgeons on study protocol, such as inclusion criteria for Tönnis OA grade (inclusion or exclusion of grades zero and three), and follow-up assessment time points (the study originally called for a two and six week follow-up). At the time of this analysis, of the five centres with REB approval, only two centres (FKSMC and LHSC UH) have recruited participants.

Strengths of the study include participant randomization, which reduces selection bias and balances prognostic factors between groups, the intention to treat principal that preserved the randomized groupings, and completeness of follow-up. Only one participant had missed a follow-up assessment that was corrected for using LOCF as it is a conservative approach to replacing missing end-point data that prevents inflation of the Type I error rate. Recording co-interventions helps to evaluate the benefit of either surgery or conservative treatment while taking into account the additional strategies participants undertook to control their pain. The external validity of this study is primarily pragmatic, allowing for the evaluation of conservative treatment of FAI under normal health-care setting circumstances and application of the results to the general population. Finally, our sample appears to be representative of the population compared

to studies with similar populations (Brunner et al., 2009; Emara et al., 2011; Philippon et al., 2009).

To our knowledge, this is the first RCT to evaluate the outcomes of surgical treatment compared to conservative treatment of FAI. At this time, results are inconclusive, and the efficacy of either treatment cannot be determined. Moving forward, this study could strengthen its methodological design by standardizing ROM assessment, gathering more detailed information about participants' physiotherapy (including when and why participants discontinue PT services), and potentially increasing the efficacy of participant compliance for physiotherapy.

Future studies should continue to focus on methodologically sound RCTs evaluating the effectiveness of conservative treatment and arthroscopic treatment of FAI; observational cohorts may be undertaken to determine the predictors of improved outcomes, as well as participant expectations of treatment (Clohisy et al., 2013). Other related areas that require further research are advanced imaging techniques to better predict intra-articular pathology (i.e.: evaluating cartilage damage and changes over time), and the use of new outcome measures designed specifically for arthroscopic treatment of FAI. New questionnaires have been developed, such as the Copenhagen Hip and Groin Outcome Score (HAGOS), 33-item International Hip Outcome Tool (iHOT-33), and the iHOT-12 that have not yet been widely used within the literature or validated (Harris-Hayes et al., 2013). Future studies could utilize these instruments as they were designed employing input from patients representative of the FAI condition, and the instruments are more suited for patients undergoing hip arthroscopy (Harris-Hayes et al., 2013).

Chapter 7: Summary

The presented results are the preliminary findings of an ongoing RCT, and definitive conclusions cannot be made regarding the effectiveness of conservative treatment compared to surgical treatment of FAI. At this time, only one participant experienced an adverse event (infection) following surgery. Participants appear to have similar outcomes between groups. This study will continue to gather data from the five centres.

References

Anderson, K., & Bowen, M. K. (1999). Spur reformation after arthroscopic acromioplasty. *Arthroscopy: The Journal of Arthroscopic and Related Surgery*, *15*(7), 788–791.

Anderson, L. A., Peters, C. L., Park, B. B., Stoddard, G. J., Erickson, J. A., & Crim, J. R. (2009). Acetabular cartilage delamination in femoroacetabular impingement. Risk factors and magnetic resonance imaging diagnosis. *The Journal of bone and joint surgery. American volume*, *91*(2), 305–13. doi:10.2106/JBJS.G.01198

Aprato, A., Jayasekera, N., & Villar, R. N. (2012). Does the modified Harris hip score reflect patient satisfaction after hip arthroscopy? *The American journal of sports medicine*, *40*(11), 2557–60. doi:10.1177/0363546512460650

Bardakos, N. V, & Villar, R. N. (2009). Predictors of progression of osteoarthritis in femoroacetabular impingement: a radiological study with a minimum of ten years follow-up. *The Journal of bone and joint surgery. British volume*, *91*(2), 162–9. doi:10.1302/0301-620X.91B2.21137

Beck, M., Chegini, S., Ferguson, S., & Hosalkar, H. (2012). Mechanism of femoroacetabular impingement. In Ó. Marín-Peña (Ed.), *Femoroacetabular Impingement* (pp. 9–22). Berlin, Heidelberg: Springer Berlin Heidelberg. doi:10.1007/978-3-642-22769-1

Beck, M., Kalhor, M., Leunig, M., & Ganz, R. (2005). Hip morphology influences the pattern of damage to the acetabular cartilage: femoroacetabular impingement as a cause of early osteoarthritis of the hip. *The Journal of bone and joint surgery British volume*, *87*(7), 1012–8. doi:10.1302/0301-620X.87B7.15203

Beck, M., Leunig, M., Parvizi, J., Boutier, V., Wyss, D., & Ganz, R. (2004). Anterior femoroacetabular impingement: part II. midterm results of surgical treatment. *Clinical orthopaedics and related research*, (418), 67–73.

Bedi, A., Chen, N., Robertson, W., & Kelly, B. T. (2008). The management of labral tears and femoroacetabular impingement of the hip in the young, active patient. *Arthroscopy : the journal of arthroscopic & related surgery*, *24*(10), 1135–45. doi:10.1016/j.arthro.2008.06.001

Bedi, A., Dolan, M., Hetsroni, I., Magennis, E., Lipman, J., Buly, R., & Kelly, B. T. (2011). Surgical treatment of femoroacetabular impingement improves hip kinematics: a computer-assisted model. *The American journal of sports medicine*, *39 Suppl*, 43S–9S. doi:10.1177/0363546511414635

Binkley, J. M., Stratford, P. W., Lott, S. A., & Riddle, D. L. (1999). The lower extrenity functional scale (LEFS): Scale development, measurement properties, and clinical application. *Physical Therapy*, *79*(4), 371–383.

Brand, R. (2009). 50 years ago in CORR: Slipping of the upper femoral epiphysis. Beckett Howorth MD. CORR 1957;10:148-173. *Clinical orthopaedics and related research*, *467*(3), 859–60. doi:10.1007/s11999-008-0681-x

Brunner, A., Horisberger, M., & Herzog, R. F. (2009). Sports and recreation activity of patients with femoroacetabular impingement before and after arthroscopic osteoplasty. *The American journal of sports medicine*, *37*(5), 917–22. doi:10.1177/0363546508330144

Byrd, J. W. T. (2013a). Patient Selection and Physical Examination. In J.W. Thomas Byrd (Ed.), *Operative Hip Arthroscopy* (pp. 7–32). New York, NY: Springer New York. doi:10.1007/978-1-4419-7925-4

Byrd, J W Thomas. (2013b). My Approach to Femoroacetabular Impingement. In J.W. Thomas Byrd (Ed.), *Operative Hip Arthroscopy* (pp. 215–235). New York, NY: Springer New York. doi:10.1007/978-1-4419-7925-4

Byrd, J W Thomas, & Jones, K. S. (2000). Prospective analysis of hip arthroscopy with 2-year follow-up. *Arthroscopy : the journal of arthroscopic & related surgery*, *16*(6), 578–87. doi:10.1053/jars.2000.7683

Byrd, J W Thomas, & Jones, K. S. (2004). Diagnostic Accuracy of Clinical Assessment, Magnetic Resonance Imaging, Magnetic Resonance Arthrography, and Intra-articular Injection in Hip Arthroscopy Patients. *American Journal of Sports Medicine*, *32*(7), 1668–1674. doi:10.1177/0363546504266480

Byrd, J W Thomas, & Jones, K. S. (2011). Arthroscopic management of femoroacetabular impingement in athletes. *The American journal of sports medicine*, *39 Suppl*, 7S–13S. doi:10.1177/0363546511404144

Christensen, C. P., Althausen, P. L., Mittleman, M. A., Lee, J.-A., & McCarthy, J. C. (2003). The nonarthritic hip score: reliable and validated. *Clinical orthopaedics and related research*, (406), 75–83. doi:10.1097/01.blo.0000043047.84315.4b

Clohisy, J. C., Beaulé, P. E., O'Malley, A., Safran, M. R., & Schoenecker, P. (2008). AOA symposium. Hip disease in the young adult: current concepts of etiology and surgical treatment. *The Journal of bone and joint surgery. American volume*, *90*(10), 2267–81. doi:10.2106/JBJS.G.01267

Clohisy, J. C., & Kim, Y.-J. (2013). Femoroacetabular Impingement Research Symposium. *Journal of the American Academy of Orthopaedic Surgeons*, *21*(Supplement 1), vi – viii.

Clohisy, J. C., Kim, Y.-J., Lurie, J., Glyn-Jones, S., Wall, P., Wright, R., … Lohmander, S. (2013). Clinical trials in orthopaedics and the future direction of clinical investigations for femoroacetabular impingement. *Journal of the American Academy of Orthopaedic Surgeons*, *21*(Supplement 1), S47–52.

Clohisy, J. C., Nunley, R. M., Otto, R. J., & Schoenecker, P. L. (2007). The frog-leg lateral radiograph accurately visualized hip cam impingement abnormalities. *Clinical orthopaedics and related research*, *462*, 115–21. doi:10.1097/BLO.0b013e3180f60b53

Clohisy, J. C., St John, L. C., & Schutz, A. L. (2010). Surgical treatment of femoroacetabular impingement: a systematic review of the literature. *Clinical orthopaedics and related research*, *468*(2), 555–64. doi:10.1007/s11999-009-1138-6

Cobb, J., Logishetty, K., Davda, K., & Iranpour, F. (2010). Cams and pincer impingement are distinct, not mixed: the acetabular pathomorphology of femoroacetabular impingement. *Clinical orthopaedics and related research*, *468*(8), 2143–51. doi:10.1007/s11999-010-1347-z

Drummond, M. (2001). Introducing economic and quality of life measurements into clinical studies. *Ann Med*, *33*, 344–349.

Emara, K., Samir, W., Motasem, E. H., & Ghafar, K. A. El. (2011). Conservative treatment for mild femoroacetabular impingement. *Journal of orthopaedic surgery (Hong Kong)*, *19*(1), 41–5. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/21519074

Erb, R. E. (2013). Adult Hip Imaging for the Arthroscopist. In J.W. Thomas Byrd (Ed.), *Operative Hip Arthroscopy* (pp. 33–54). New York, NY: Springer New York. doi:10.1007/978-1-4419-7925-4

Ferguson, S. J., Bryant, J. T., Ganz, R., & Ito, K. (2003). An in vitro investigation of the acetabular labral seal in hip joint mechanics. *Journal of Biomechanics*, *36*(2), 171–178. doi:10.1016/S0021-9290(02)00365-2

Floyd, R. T. (2007). The Hip Joint and Pelvic Girdle. In E. Barrosse, C. Johnson, L. Huenefeld, J. D. Ersery, J. Gordon, & M. R (Eds.), *Manual of Structural Kinesiology* (16th ed., pp. 216–257). New York, NY: McGraw-Hill.

Ganz, R., Gill, T. J., Gautier, E., Ganz, K., Krügel, N., & Berlemann, U. (2001). Surgical dislocation of the adult hip: A technique with full access to the femoral head and acetabulum without the risk of avascular necrosis. *The Journal of bone and joint surgery British volume*, *83-B*(8), 1119–1124.

Ganz, R., Parvizi, J., Beck, M., Leunig, M., Nötzli, H., & Siebenrock, K. A. (2003). Femoroacetabular impingement: a cause for osteoarthritis of the hip. *Clinical orthopaedics and related research*, (417), 112–20. doi:10.1097/01.blo.0000096804.78689.c2

Gedouin, J.-E., May, O., Bonin, N., Nogier, A., Boyer, T., Sadri, H., … Laude, F. (2010). Assessment of arthroscopic management of femoroacetabular impingement. A prospective multicenter study. *Orthopaedics traumatology surgery research OTSR*, *96*(8 Suppl), S59–67. doi:10.1016/j.otsr.2010.08.002

Gerber, C., Terrier, F., & Ganz, R. (1985). The role of the coracoid process in the chronic impingement syndrome. *British Editorial Society of Bone and Joint Surgery*, *67-B*(5), 703–708.

Gosvig, K. K., Jacobsen, S., Sonne-Holm, S., & Gebuhr, P. (2008). The prevalence of cam-type deformity of the hip joint: a survey of 4151 subjects of the Copenhagen Osteoarthritis Study. *Acta radiologica*, (4), 436–41. doi:10.1080/02841850801935567

Gosvig, K. K., Jacobsen, S., Sonne-Holm, S., Palm, H., & Troelsen, A. (2010). Prevalence of malformations of the hip joint and their relationship to sex, groin pain, and risk of osteoarthritis: a population-based survey. *The Journal of bone and joint surgery. American volume*, *92*(5), 1162–9. doi:10.2106/JBJS.H.01674

Grimaldi, A. (2011). Assessing lateral stability of the hip and pelvis. *Manual therapy*, *16*(1), 26–32. doi:10.1016/j.math.2010.08.005

Guanche, C. A., & Bare, A. A. (2006). Arthroscopic treatment of femoroacetabular impingement. *Arthroscopy : the journal of arthroscopic & related surgery*, *22*(1), 95–106. doi:10.1016/j.arthro.2005.10.018

Guanche, C. A., & Sikka, R. S. (2005). Acetabular labral tears with underlying chondromalacia: a possible association with high-level running. *Arthroscopy : the journal of arthroscopic & related surgery : official publication of the Arthroscopy*

Association of North America and the International Arthroscopy Association, *21*(5), 580–5. doi:10.1016/j.arthro.2005.02.016

Guyatt, G. H., Oxman, A. D., Vist, G. E., Kunz, R., Falck-Ytler, Y., Alonso-Coello, P., & Schünemann, H. J. (2008). GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. *British Medical Journal*, *336*(7650), 924–926.

Harris, W. H. (1969). Traumatic arthritis of the hip after dislocation and acetabular fractures: treatment by mold arthroplasty. *The Journal of Bone and Joint Surgery*, *51-A*(4), 737–755.

Harris, W. H. (1986). Etiology of osteoarthritis of the hip. *Clinical orthopaedics and related research*, (213), 20–33.

Harris-Hayes, M., McDonough, C. M., Leunig, M., Lee, C. B., Callaghan, J. J., & Roos, E. M. (2013). Clinical outcomes assessment in clinical trials to assess treatment of femoroacetabular impingement: use of patient-reported outcome measures. *Journal of the American Academy of Orthopaedic Surgeons*, *21*(Supplement 1), S39–46.

Hartmann, A., & Günther, K.-P. (2009). Arthroscopically assisted anterior decompression for femoroacetabular impingement: technique and early clinical results. *Archives of orthopaedic and trauma surgery*, *129*(8), 1001–9. doi:10.1007/s00402-008-0806-4

Hartofilakidis, G., Bardakos, N. V, Babis, G. C., & Georgiades, G. (2011). An examination of the association between different morphotypes of femoroacetabular impingement in asymptomatic subjects and the development of osteoarthritis of the hip. *The Journal of bone and joint surgery. British volume*, *93-B*(5), 580–6. doi:10.1302/0301-620X.93B5.25236

Hunt, D., Prather, H., Harris Hayes, M., & Clohisy, J. C. (2012). Clinical outcomes analysis of conservative and surgical treatment of patients with clinical indications of prearthritic, intra-articular hip disorders. *PM & R : the journal of injury, function, and rehabilitation*, *4*(7), 479–87. doi:10.1016/j.pmrj.2012.03.012

Ilizaliturri, V. M. (2009). Complications of arthroscopic femoroacetabular impingement treatment: a review. *Clinical orthopaedics and related research*, *467*(3), 760–8. doi:10.1007/s11999-008-0618-4

Ito, K., Minka-II, M., Leunig, M., Werlen, S., & Ganz, R. (2001). Femoroacetabular impingement and the cam-effect: a MRI-based quantitative anatomical study of the femoral head-neck offset. *The Journal of bone and joint surgery British volume*, *83-B*, 171–176.

Kalberer, F., Sierra, R. J., Madan, S. S., Ganz, R., & Leunig, M. (2008). Ischial spine projection into the pelvis: a new sign for acetabular retroversion. *Clinical orthopaedics and related research*, *466*(3), 677–83. doi:10.1007/s11999-007-0058-6

Kassarjian, A., Yoon, L. S., Belzile, E., Connolly, S. A., Millis, M. B., & Palmer, W. E. (2005). Triad of MR arthrographic findings in patients with cam-type femoroacetabular impingement. *Radiology*, *236*(2), 588–592.

Kemp, J. L., Collins, N. J., Makdissi, M., Schache, A. G., Machotka, Z., & Crossley, K. (2012). Hip arthroscopy for intra-articular pathology: a systematic review of outcomes with and without femoral osteoplasty. *British journal of sports medicine*, *46*(9), 632–43. doi:10.1136/bjsports-2011-090428

Kirkley, A., Birmingham, T. B., Litchfield, R. B., Giffin, J. R., Willits, K. R., Wong, C. J., … Fowler, P. J. (2008). A randomized trial of arthroscopic surgery for osteoarthritis of the knee. *The New England journal of medicine*, *359*(11), 1097–1107.

Kuhlman, G. S., & Domb, B. G. (2009). Hip impingement: identifying and treating a common cause of hip pain. *Am Fam Physician*, *80*(12), 1429–1434.

Laborie, L. B., Lehmann, T. G., Engesæter, I. O., Engesæter, L. B., & Rosendahl, K. (2013). Is a positive femoroacetabular impingement test a common finding in healthy young adults? *Clinical orthopaedics and related research*, *471*(7), 2267–77. doi:10.1007/s11999-013-2850-9

Lambert, R. G. W., Hutchings, E. J., Grace, M. G. A., Jhangri, G. S., Conner-Spady, B., & Maksymowych, W. P. (2007). Steroid injection for osteoarthritis of the hip: a randomized, double-blind, placebo-controlled trial. *Arthritis and rheumatism*, *56*(7), 2278–87. doi:10.1002/art.22739

Lavigne, M., Parvizi, J., Beck, M., Siebenrock, K. A., Ganz, R., & Leunig, M. (2004). Anterior femoroacetabular impingement: Part I . Techniques of joint preserving surgery. *Clinical orthopaedics and related research*, (418), 61–66.

Leunig, M., Casillas, M. M., Hamlet, M., Hersche, O., Nötzli, H., Slongo, T., & Ganz, R. (2000). Slipped capital femoral epiphysis. *Acta Orthop Scand*, *71*(4), 370–375.

Leunig, M., & Ganz, R. (2005). [Femoroacetabular impingement. A common cause of hip complaints leading to arthrosis]. *Der Unfallchirurg*, *108*(1), 9–10, 12–7. doi:10.1007/s00113-004-0902-z

Leunig, M., Werlen, S., Ungersbock, A., Ito, K., & Ganz, R. (1997). Evaluation of the acetabular labrum by MR arthrography. *The Journal of bone and joint surgery British volume*, (79-B), 230–234.

Lewis, C. L., Sahrmann, S. A., & Moran, D. W. (2007). Anterior hip joint force increases with hip extension, decreased gluteal force, or decreased iliopsoas force. *Journal of biomechanics*, *40*(16), 3725–31. doi:10.1016/j.jbiomech.2007.06.024

Liotard, J.-P., Cochard, P., & Walch, G. (1998). Critical analysis of the supraspinatus outlet view: rationale for a standard scapular Y-view. *J Shoulder Elbow Surg*, *7*, 134–139.

Lodhia, P., Slobogean, G. P., Noonan, V. K., & Gilbart, M. K. (2011). Patient-reported outcome instruments for femoroacetabular impingement and hip labral pathology: a systematic review of the clinimetric evidence. *Arthroscopy : the journal of arthroscopic & related surgery*, *27*(2), 279–86. doi:10.1016/j.arthro.2010.08.002

Mardones, R., Gonzalez, C., Chen, Q., Zobitz, M., Kaufman, K. R., & Trousdale, R. T. (2005). Surgical treatment of femoroacetabular impingement: evaluation of the

effect of the size of the resection. *The Journal of bone and joint surgery. American volume*, *87*(2), 273–279.

Mardones, R., & Nemtala, F. (2012). Bone Resection: First Step for Treatment, How Much is Too Much? In Ó. Marín-Peña (Ed.), *Femoroacetabular Impingement* (pp. 73–76). Berlin, Heidelberg: Springer Berlin Heidelberg. doi:10.1007/978-3-642-22769-1

Martin, R. L., Irrgang, J. J., & Sekiya, J. K. (2008). The diagnostic accuracy of a clinical examination in determining intra-articular hip pain for potential hip arthroscopy candidates. *Arthroscopy : the journal of arthroscopic & related surgery*, *24*(9), 1013–8. doi:10.1016/j.arthro.2008.04.075

Martin, R. L., Kelly, B. T., & Philippon, M. J. (2006). Evidence of validity for the hip outcome score. *Arthroscopy : the journal of arthroscopic & related surgery*, *22*(12), 1304–11. doi:10.1016/j.arthro.2006.07.027

Martini, F. H. (2006). The Appendicular Skeleton. In N. George, M. Roney, K. Neumann, & D. Cogan (Eds.), *Fundamentals of Anatomy & Physiology* (7th ed., pp. 238–257). San Francisco, CA: Pearson/Benjamin Cummings.

Matheney, T., Sandell, L., Foucher, K., Lamontagne, M., Grodzinsky, A. J., & Peters, C. L. (2013). Motion analysis, cartilage mechanics, and bilogy in femoroacetabular impingement: current understanding and areas of future research. *Journal of the American Academy of Orthopaedic Surgeons*, *21*(Supplement 1), S27–32.

Meyer, D. C., Beck, M., Ellis, T., Ganz, R., & Leunig, M. (2006). Comparison of six radiographic projections to assess femoral head/neck asphericity. *Clinical orthopaedics and related research*, *445*, 181–5. doi:10.1097/01.blo.0000201168.72388.24

Moseley, J., O'Malley, K., Petersen, N., Menke, T., Brody, B., Kiykendall, D., … Wray, N. (2002). A controlled trial of arthroscopic surgery for osteoarthritis of the knee. *The New England journal of medicine*, *347*(2), 81–88.

Murray, R. O., & Duncan, C. (1971). Athletic activity in adolescence as an etiological factor in degenerative hip disease. *The Journal of bone and joint surgery British volume*, *53B*(3), 406–419.

Neer, C. S. (1972). Anterior acromioplasty for the chronic impingement syndrome in the shoulder. *The Journal of Bone and Joint Surgery*, *54-A*(1), 41–50.

Nepple, J. J., Lehmann, C. L., Ross, J. R., Schoenecker, P. L., & Clohisy, J. C. (2013). Coxa Profunda Is Not a Useful Radiographic parameter for diagnosing pincer-type femoroacetabular impingement. *The Journal of Bone and Joint Surgery*, *95*(5), 417–423.

Nepple, J. J., Prather, H., Trousdale, R. T., Beaulé, P. E., Glyn-Jones, S., & Kim, Y.-J. (2013). Clinical diagnosis of femoroacetabular impingement. *Journal of the American Academy of Orthopaedic Surgeons*, *21*(Supplement 1), S16–19.

Nepple, J. J., Prather, H., Trousdale, R. T., Clohisy, J. C., Beaulé, P. E., Glyn-Jones, S., … Kim, Y.-J. (2013). Diagnostic imaging of femoroacetabular impingement. *Journal of the American Academy of Orthopaedic Surgeons*, *21*(Supplement 1), S20–26.

Neumann, D. A. (2010). Kinesiology of the hip: a focus on muscular actions. *The Journal of orthopaedic and sports physical therapy*, *40*(2), 82–94. doi:10.2519/jospt.2010.3025

Ng, V., Arora, N., Best, T., Pan, X., & Ellis, T. (2010). Efficacy of surgery for femoroacetabular impingement: a systematic review. *The American journal of sports medicine*, *38*(11), 2337–45. doi:10.1177/0363546510365530

Nho, S. J., Kymes, S. M., Callaghan, J. J., & Felson, D. T. (2013). The burden of hip osteoarthritis in the United States: epidemiologic and economic considerations. *Journal of the American Academy of Orthopaedic Surgeons*, *21*(Supplement 1), S1–S6.

Norman, G. R., Sloan, J. A., & Wyrwich, K. W. (2013). Interpretation of changes in health-related quality of life: the remarkable universality of half a standard deviation. *Medical Care*, *41*(5), 582–592.

Nötzli, H. P., Wyss, T. F., Stoecklin, C. H., Schmid, M. R., Treiber, K., & Hodler, J. (2002). The contour of the femoral head-neck junction as a predictor for the risk of anterior impingement. *The Journal of bone and joint surgery British volume*, *84-B*(4), 556–560. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12043778

Papalia, R., Del Buono, A., Franceschi, F., Marinozzi, A., Maffulli, N., & Denaro, V. (2012). Femoroacetabular impingement syndrome management: arthroscopy or open surgery? *International orthopaedics*, *36*(5), 903–14. doi:10.1007/s00264-011-1443-z

Pateder, D. B., & Hungerford, M. W. (2007). Use of fluoroscopically guided intra-articular hip injection in differentiating the pain source in concomitant hip and lumbar spine arthritis. *American Journal of Orthopedics*, *36*(11), 591–593.

Pereira, D., Peleteiro, B., Araújo, J., Branco, J., Santos, R. A., & Ramos, E. (2011). The effect of osteoarthritis definition on prevalence and incidence estimates: a systematic review. *Osteoarthritis and cartilage / OARS, Osteoarthritis Research Society*, *19*(11), 1270–85. doi:10.1016/j.joca.2011.08.009

Peters, C. L., & Erickson, J. A. (2006). Treatment of femoro-acetabular impingement with surgical dislocation and débridement in young adults. *The Journal of Bone and Joint Surgery*, *88-A*(8), 1735–1741.

Pfirrmann, C. W., Mengiardi, B., Dora, C., Kalberer, F., Zanetti, M., & Hodler, J. (2006). Cam and pincer femoroacetabular impingement : characteristic MR arthrographic findings in 50 patients. *Radiology*, *240*(3), 778. Retrieved from http://radiology.rsna.org/content/240/3/778.full

Philippon, M. J., Briggs, K. K., Yen, Y.-M., & Kuppersmith, D. A. (2009). Outcomes following hip arthroscopy for femoroacetabular impingement with associated

chondrolabral dysfunction: minimum two-year follow-up. *The Journal of bone and joint surgery. British volume*, *91-B*, 16–23. doi:10.1302/0301-620X.91B1.21329

Philippon, M. J., Maxwell, R. B., Johnston, T. L., Schenker, M., & Briggs, K. K. (2007). Clinical presentation of femoroacetabular impingement. *Knee surgery, sports traumatology, arthroscopy*, *15*(8), 1041–7. doi:10.1007/s00167-007-0348-2

Prentice, W. E. (2011). The Thigh, Hip, Groin, and Pelvis. In *Principles of Athletic Training* (14th ed., pp. 605–638). New York, NY: McGraw-Hill.

Reichenbach, S., Jüni, P., Werlen, S., Nüesch, E., Pfirrmann, C. W., Trelle, S., … Leunig, M. (2010). Prevalence of cam-type deformity on hip magnetic resonance imaging in young males: a cross-sectional study. *Arthritis care & research*, *62*(9), 1319–27. doi:10.1002/acr.20198

Reynolds, D., Lucas, J., & Klaue, K. (1999). Retroversion of the acetabulum: a cause of hip pain. *The Journal of bone and joint surgery British volume*, *81-B*(2), 281–288.

Sampson, T. G. (2005). Arthroscopic treatment of femoroacetabular impingement. *Techniques in Orthopaedics*, *20*(1), 56–62.

Sangha, O., Stucki, G., Liang, M. H., Fossel, A. H., & Katz, J. N. (2003). The Self-Administered Comorbidity Questionnaire: a new method to assess comorbidity for clinical and health services research. *Arthritis and rheumatism*, *49*(2), 156–63. doi:10.1002/art.10993

Sankar, W. N., Arden, N., Kim, Y.-J., Grodzinsky, A. J., Sandell, L., Scanzello, C., & Siebenrock, K. A. (2013). Staging of hip osteoarthritis for clinical trials on femoroacetabular impingement. *Journal of the American Academy of Orthopaedic Surgeons*, *21*(Supplement 1), S33–38.

Sankar, W. N., Nevitt, M., Parvizi, J., Felson, D. T., Agricola, R., & Leunig, M. (2013). Femoroacetabular impingement: defining the conidtion and its role in the pathophysiology of osteoarthritis. *Journal of the American Academy of Orthopaedic Surgeons*, *21*(Supplement 1), S7–15.

Siebenrock, K. A., Schoeniger, R., & Ganz, R. Anterior femoro-acetabular impingement due to acetabular retroversion: treatment with periacetabular osteotomy. , 85 The Journal of Bone and Joint Surgery 278–286 (2003).

Snow, S. W., David, K., Scarangella, S., & Bowen, J. R. (1993). Anterior impingement of femoral head: A late phenomenon of leggc calve perthes disease. *Journal of Pediatric Orthopaedics*, *13*, 286–89.

Solomon, L. (1976). Patterns of osteoarthritis of the hip. *The Journal of bone and joint surgery British volume*, *58*(2), 176–183.

Stähelin, L., Stähelin, T., Jolles, B. M., & Herzog, R. F. (2008). Arthroscopic offset restoration in femoroacetabular cam impingement: accuracy and early clinical outcome. *Arthroscopy : the journal of arthroscopic & related surgery : official publication of the Arthroscopy Association of North America and the International Arthroscopy Association*, *24*(1), 51–57.e1. doi:10.1016/j.arthro.2007.08.010

Tannast, M., Siebenrock, K. a, & Anderson, S. E. (2007). Femoroacetabular impingement: radiographic diagnosis--what the radiologist should know. *AJR. American journal of roentgenology*, *188*(6), 1540–52. doi:10.2214/AJR.06.0921

Thompson, W. O., Debski, R. E., Boardman, N. D., Taskiran, E., Warner, J. J., Fu, F. H., & Woo, S. L. (1996). A biomechanical analysis of rotator cuff deficiency in a cadaveric model. *The American Journal of Sports Medicine*, *24*(3), 286–292. Retrieved from http://ajs.sagepub.com/content/24/3/286.abstract

Tibor, L. M., & Leunig, M. (2012). The pathoanatomy and arthroscopic management of femoroacetabular impingement. *Bone Joint Res*, *1*(10), 245–257.

Tönnis, D. (1987). *Congenital Dysplasia and Dislocation of the Hip in Children and Adults*. New York, NY: Springer New York.

Wall, P. D., Fernandez, M., Griffin, D. R., & Foster, N. E. (2013). Nonoperative treatment for femoroacetabular impingement: a systematic review of the literature.

PM & R : the journal of injury, function, and rehabilitation, *5*(5), 418–26. doi:10.1016/j.pmrj.2013.02.005

Ware, J. E., Kosinski, M., & Keller, S. D. (1996). A 12-item short-form health survey: construction of scales and preliminary tests of reliability and validity. *Medical Care*, *34*(3), 220–233.

Watson, C. J., Propps, M., Ratner, J., Zeigler, D. L., Horton, P., & Smith, S. S. (2005). Reliability and responsiveness of the lower extremity functional scale and the anterior knee pain scale in patients with anterior knee pain. *Journal of Orthopaedic & Sports Physical Therapy*, *35*(3), 136–146.

Weiland, D. E., & Philippon, M. J. (2005). Arthroscopic technique of femoroacetabular impingement. *Operative Techniques in Orthopaedics*, *15*(3), 256–260. doi:10.1053/j.oto.2005.07.002

Wuelker, N., Plitz, W., Roetman, B., & Wirth, C. J. (1994). Function of the supraspinatus muscle: Abduction of the humerus studied in cadavers. *Acta Orthop Scand*, *65*(4), 442–446.

Yazbek, P. M., Ovanessian, V., Martin, R. L., & Fukuda, T. Y. (2011). Nonsurgical treatment of acetabular labrum tears: a case series. *The Journal of orthopaedic and sports physical therapy*, *41*(5), 346–53. doi:10.2519/jospt.2011.3225

Appendices

Appendix A: Ethics Approval Notices

Use of Human Participants - Ethics Approval Notice

Principal Investigator: Dr. Douglas Naudie
Review Number: 17805
Review Level: Full Board
Approved Local Adult Participants: 30
Approved Local Minor Participants: 0
Protocol Title: A Randomized Controlled Trial Comparing ARthroscopic Surgery to Conservative Management of Femoroacetabular Impingement
Department & Institution: Surgery, London Health Sciences Centre
Sponsor: Physician Services Incorporated (PSI)

Ethics Approval Date: April 12, 2011 **Expiry Date:** May 31, 2014

Documents Reviewed & Approved & Documents Received for Information:

Document Name	Comments	Version Date
UWO Protocol		
Letter of Information & Consent		

This is to notify you that the University of Western Ontario Health Sciences Research Ethics Board (HSREB) which is organized and operates according to the Tri-Council Policy Statement: Ethical Conduct of Research Involving Humans and the Health Canada/ICH Good Clinical Practice Practices: Consolidated Guidelines; and the applicable laws and regulations of Ontario has reviewed and granted approval to the above referenced study on the approval date noted above. The membership of this HSREB also complies with the membership requirements for REB's as defined in Division 5 of the Food and Drug Regulations.

The ethics approval for this study shall remain valid until the expiry date noted above assuming timely and acceptable responses to the HSREB's periodic requests for surveillance and monitoring information. If you require an updated approval notice prior to that time you must request it using the UWO Updated Approval Request form.

Member of the HSREB that are named as investigators in research studies, or declare a conflict of interest, do not participate in discussions related to, nor vote on, such studies when they are presented to the HSREB.

The Chair of the HSREB is Dr. Joseph Gilbert. The UWO HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

Signature

Ethics Officer to Contact for Further Information

___ Janice Sutherland	✓ Elizabeth Wambolt	___ Grace Kelly

This is an official document. Please retain the original in your files.

Research Western

Use of Human Participants - Ethics Approval Notice

Principal Investigator: Dr. Douglas Naudie
Review Number: 17805
Review Level: Delegated
Approved Local Adult Participants: 30
Approved Local Minor Participants: 0
Protocol Title: A Randomized Controlled Trial Comparing ARthroscopic Surgery to Conservative Management of Femoroacetabular Impingement
Department & Institution: Surgery, London Health Sciences Centre
Sponsor: Physician Services Incorporated (PSI)

Ethics Approval Date: January 10, 2012 **Expiry Date:** May 31, 2014
Documents Reviewed & Approved & Documents Received for Information:

Document Name	Comments	Version Date
Change in Study Personnel	Cloe Klaus has been added to the study team.	
Revised UWO Protocol	Revised eligibility criteria	
Revised Letter of Information & Consent		2011/11/04

This is to notify you that The University of Western Ontario Research Ethics Board for Health Sciences Research Involving Human Subjects (HSREB) which is organized and operates according to the Tri-Council Policy Statement: Ethical Conduct of Research Involving Humans and the Health Canada/ICH Good Clinical Practice Practices: Consolidated Guidelines; and the applicable laws and regulations of Ontario has reviewed and granted approval to the above referenced revision(s) or amendment(s) on the approval date noted above. The membership of this REB also complies with the membership requirements for REB's as defined in Division 5 of the Food and Drug Regulations.

The ethics approval for this study shall remain valid until the expiry date noted above assuming timely and acceptable responses to the HSREB's periodic requests for surveillance and monitoring information. If you require an updated approval notice prior to that time you must request it using the UWO Updated Approval Request Form.

Members of the HSREB who are named as investigators in research studies, or declare a conflict of interest, do not participate in discussion related to, nor vote on, such studies when they are presented to the HSREB.

The Chair of the HSREB is Dr. Joseph Gilbert. The UWO HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

Signature

Ethics Officer to Contact for Further Information

Janice Sutherland	Grace Kelly	Shantel Walcott

This is an official document. Please retain the original in your files.

The **University *of* Western Ontario**
Office of Research Ethics
Support Services Building Room 5150 • London, Ontario • CANADA - N6G 1G9
PH: 519-661-3036 • F: 519-850-2466 • ethics@uwo.ca • www.uwo.ca/research/ethics

CHUQ
CENTRE HOSPITALIER
UNIVERSITAIRE DE QUÉBEC

Québec, le 13 juillet 2012

Docteur Étienne Belzile
a/s de Madame Sylvie Turmel, Inf.
Orthopédie
CHUQ-L'HDQ, Local 3431

Objet : Projet A12-06-961 / Approbation finale
Étude clinique randomisée comparant la chirurgie arthroscopique versus le traitement conservateur des troubles fémoro-acétabulaires

Docteur,

La présente fait suite à l'étude du projet en titre lors de la réunion plénière (Full Board) du Comité d'éthique de la recherche du CHUQ du 12 juin 2012. Les membres du Comité ont pris connaissance de votre envoi reçu le 9 juillet 2012 en réponse aux recommandations lors de la rencontre en comité restreint, tenue le 13 juillet 2012.

Le Comité a examiné les documents et constate que les modifications apportées répondent aux exigences. Le Comité prend donc acte et approuve le contenu éthique du projet ainsi que les documents suivants :

- ✓ Le formulaire de présentation d'un projet de recherche au CHUQ, daté du 18 mai 2012;
- ✓ Le protocole de recherche pour le traitement conservateur, daté de septembre 2011;
- ✓ Le protocole de recherche pour le traitement arthroscopique, daté de septembre 2011;
- ✓ Le feuillet d'information et formulaire de consentement, modifié et daté du 29 juin 2012;
- ✓ Le questionnaire HOS, modifié et daté du 29 juin 2012;
- ✓ Le questionnaire NAHS, non daté et reçu le 29 mai 2012;
- ✓ L'échelle fonctionnelle du membre inférieur, non datée et reçue le 29 mai 2012;
- ✓ Le questionnaire Sf-12 v2, daté du 15 mai 2012;
- ✓ Les lettres d'approbation éthique de l'étude par le Comité d'éthique de la recherche de l'University of Western Ontario Health Sciences, datées des 12 avril 2011 et 10 janvier 2012;
- ✓ Le document *Off Site Procedures For Securing and Storing Written Records, Videotapes, Computer Discs, Recording and Questionnaires, Data and Specimens*, non daté et reçu le 29 mai 2012.

Cette approbation éthique est valable pour une période de un an. Le Comité vous informe qu'il est de votre responsabilité de faire une demande de renouvellement, si nécessaire, pour le 13 juillet 2013 en complétant le formulaire de renouvellement annuel et en indiquant le numéro de SIRUL, si applicable.

De plus, durant cette période de un an, il est très important de noter que vous devez faire parvenir au Comité toute modification apportée au projet en titre, afin que celui-ci l'étudie et émette une lettre d'approbation ou un accusé de réception.

Cette décision sera entérinée lors d'une prochaine réunion plénière.

Je vous prie d'agréer, Docteur, l'expression de mes sentiments les meilleurs.

Pierre Douville, M.D.
Président du sous-comité A
Comité d'éthique de la recherche du CHUQ

YC/FN/mnl
(5.AP.1 juin, 5.BD août 2012)

UNIVERSITY OF OTTAWA HEART INSTITUTE
INSTITUT DE CARDIOLOGIE DE L'UNIVERSITÉ D'OTTAWA

THE OTTAWA HOSPITAL
L'HÔPITAL D'OTTAWA

uOttawa

Ottawa Hospital Research Ethics Boards / Conseils d'éthique en recherches

725 Parkdale Avenue, Box 411, Ottawa, Ontario K1Y 4E9 613-798-5555 ext. 14902 Fax: 613-761-4311
http://www.ohri.ca/ohreb

May 28, 2012

Dr. Paul Beaulé
c/o Anna Fazekas
Ottawa Hospital - General Campus
Division of Orthopaedic Surgery
501 Smyth Road, Box 502, Room 6229
Ottawa, Ontario K1H 8L6

Dear Dr. Beaulé:

Re: Protocol # 20120048-01H **A Randomized Controlled Trial Comparing Arthroscopic Surgery to Conservative Management of Femoroacetabular Impingement**

Protocol approval valid until - March 18, 2013

Thank you for the letter from Mr. K. Kemp dated May 16, 2012. This protocol was reviewed by the full Board of the Ottawa Hospital Research Ethics Board (OHREB) at the meeting held on February 21, 2012 and re-submitted to the Full Board at the meeting held on March 19, 2012. You have met the requirements of the OHREB and your protocol has been granted approval by the OHREB. No changes, amendments or addenda may be made to the protocol or the consent form without the OHREB's review and approval.

PLEASE NOTE: THE APPROVAL OF THIS PROTOCOL IS CONDITIONAL UPON A FULLY-SIGNED STUDY CONTRACT/AGREEMENT BETWEEN THE OTTAWA HOSPITAL RESEARCH INSTITUTE, THE PRINCIPAL INVESTIGATOR AND THE SPONSOR (OR AS OTHERWISE REQUIRED). YOU CANNOT START THE STUDY, OR BEGIN TO RECRUIT RESEARCH PARTICIPANTS INTO THE STUDY UNTIL THE STUDY CONTRACT/AGREEMENT HAS BEEN SIGNED BY ALL PARTIES, AND HAS BEEN RECEIVED BY THE OTTAWA HOSPITAL RESEARCH INSTITUTE'S CONTRACTS OFFICE. FOR FURTHER DETAILS, PLEASE CONTACT ALISON IRWIN, CONTRACTS ADMINISTRATOR AT AIRWIN@OHRI.CA OR AT 613-798-5555 EXT. 19690.

Approval is for the following documentation:
- Protocol dated March 2, 2012
- Revised OHREB application, received March 9, 2012
- English Hip Outcome Score (HOS), received January 17, 2012
- English Non-Arthritic Hip Score, received January 17, 2012
- English and French Modified Harris Hip Score
- English and French SF-12 Health Survey
- English Information Sheet and Consent Form dated March 22, 2012
- French Information Sheet and Consent Form dated April 18, 2012
- English Physical Therapy 6 Week Report document received March 9, 2012

The validation date should be indicated on the bottom of all consent forms and information sheets (see copy attached). If the study is to continue beyond the expiry date noted above, a Renewal Form should be submitted to the OHREB approximately six weeks prior to the current expiry date. If the study has been completed by this date, a Termination Report should be submitted.

The Ottawa Hospital Research Ethics Board is constituted in accordance with, and operates in compliance with the requirements of the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans; Health

.../2

Canada Good Clinical Practice: Consolidated Guideline; Part C Division 5 of the Food and Drug Regulations of Health Canada; and the provisions of the Ontario Health Information Protection Act 2004 and its applicable Regulations.

Yours sincerely,

Raphael Saginur, M.D.
Chairman
Ottawa Hospital Research Ethics Board

Encl.

/cb

Research Ethics Office
Telephone: (416) 864-6060 Ext. 2557
Facsimile: (416) 864-6043
E-mail: pateld@smh.toronto.on.ca

St. Michael's
Inspired Care.
Inspiring Science.

February 12, 2013

Dr. Daniel Whelan,
Division of Orthopaedic Surgery,
St Michael's Hospital

Dear Dr. Whelan,

Re: REB# 12-066 - A randomized controlled trial comparing Arthroscopic surgery to Conservative Management of Femoroacetabular Impingement

REB APPROVAL:	**Original Approval Date**	**February 12, 2013**
	Annual/Interval Review Date	**February 12, 2014**

Thank you for your application submitted on **March 6, 2012**. At the St Michael's Hospital (SMH) Research Ethics Board (REB) meeting held on March 21, 2012, the above referenced study was discussed and subsequently the views derived from this discussion have been documented and resolved.

The REB approves the study as it is found to comply with relevant research ethics guidelines, as well as the Ontario Personal Health Information Protection Act (PHIPA), 2004. The REB hereby issues approval for the above named study for a period of 12 months from the date of this letter. Continuation beyond that date will require further review of REB approval. In addition, the following are appropriate and hereby approved:

1. Protocol version dated January 13, 2012
2. Consent Form version dated February 12, 2013

Furthermore, the following documents have been received and are acknowledged:

1. Co-Intervention Form
2. Co-Morbidity Questionnaire
3. Demographics Questionnaire
4. Medication Form
5. Hip Outcome Score
6. Lower Extremity Functional Scale
7. Modified Harris Hip Score
8. Non-arthritic Hip Score
9. Adverse Event Form
10. MRI Arthrogram Assessment
11. Pre-Op Tests
12. Range of Motion
13. Contact Information Form

During the course of this investigation, any significant deviations from the approved protocol and/or unanticipated developments or significant adverse events should immediately be brought to the attention of the REB.

Please note that if a Clinical Trial Agreement is required, it must be submitted to the Office of Research Administration for review and approval. Any additional institutional approvals **must be** coordinated and approved through the Office of Research Administration prior to initiation of this research. All drug dispensing must be coordinated through the Research Pharmacy at 416-864-5413.

The St. Michael's Hospital (SMH) Research Ethics Board (REB) operates in compliance with the Tri-Council Policy Statement Ethical Conduct for Research Involving Humans, the Ontario Personal Health Information Protection Act, 2004, and ICH Good Clinical Practice Consolidated Guideline E6, Health Canada Part C Division 5 of the Food and Drug Regulations, Part 4 of the Natural Health Product Regulations, and the Medical Devices regulations. Furthermore, all investigational drug trials at SMH are conducted by Qualified Investigators (as defined in the latter document).

With best wishes

☐ Dr. Bob Hyland
Chair, Research Ethics Board

☐ Dr. Brenda McDowell
Vice Chair, Research Ethics Board

BH/BJM/mis

Appendix B: Letter of Information and Consent

Letter of Information

Study Title: A Randomized Controlled Trial Comparing Arthroscopic Surgery to Conservative Management of Femoroacetabular Impingement

Principal Investigators: Douglas Naudie MD FRCSC
London Health Sciences Centre
University Hospital
London, ON

Kevin Willits, MD FRCSC
Fowler Kennedy Sports Medicine Clinic
3M Centre,University of Western Ontario
London, On

Purpose:
Hip arthroscopy has gained popularity over the past 5 years despite a lack of evidence for its effectiveness. Prior to hip arthroscopy, physiotherapy and other conservative management was the usual treatment for femoroacetabular impingement (FAI).

You are being invited to participate in a study to determine whether patients with FAI who undergo arthroscopic surgery of the hip experience similar outcomes compared to similar patients who receive conservative management, including medication and physiotherapy. Specifically we are interested in comparing physical function, pain, and health related quality of life.

Research Activity:
If you agree to participate, you will be assigned to one of two groups (arthroscopy or conservative management). A random selection process (like flipping a coin) will determine which group you will be assigned to. You will have an equal chance of being assigned to either group. One hundred and forty (140) patients will take part in this study at 5 centres across Canada; 70 will undergo arthroscopic surgery, and 70 will undergo conservative management; approximately 30 patients from London will participate.

If you are assigned to the arthroscopy group, you will undergo arthroscopic hip surgery that will take place within 6 weeks of being enrolled in the study. After your surgery you will begin a standardized physical therapy program. If you are assigned to the conservative group, you will immediately begin a physical therapy program developed especially for patients with FAI to stabilize and strengthen the structures around the hip joint.

You will be asked to complete five questionnaires to measure quality of life and functional ability at 2 weeks, 6 weeks, 3 months, 6 months, 12 months, and 24 months following the start of your treatment. You will also be asked to record all medications or other treatments that you are taking for your hip pain. We will also measure your range of motion at each visit. Completing these questionnaires will take approximately 15-20 minutes of your time and collection of range of motion measurements will take approximately 5 minutes. If you prefer, you may complete the questionnaires online from your home or work prior to your follow up appointments with your surgeon. If you wish to do this, we will provide you with a username and password to access the online database where you will answer your questions.

Risks:

Much like any surgical procedure, hip arthroscopy involves similar elements of risk, however the rate of complication following hip arthroscopy is extremely low. Complications following hip arthroscopy are rare and the majority are temporary. There are, however, risks which include the standard risks of undergoing general anaesthesia and specific risks associated with hip arthroscopy.

Complications have been reported to occur in up to 5% of patients and are most often related to temporary numbness/altered feeling in the groin and genitalia. This is due to a combination of distraction of the hip joint and pressure on the nerves in the groin at the time of surgery. This is uncommon and although there is a theoretical risk that this numbness could be permanent, in the majority the numbness recovers fully, usually within a few days.

The risks involved with physiotherapy for treatment of FAI are low. There is a chance that you could fall, injure or re-injure yourself when performing the exercises, however the risks are no greater than those encountered with typical postoperative rehabilitation protocols.

Benefits:

There are no direct benefits to you for participating in this study; however your participation will help inform surgeons and physiotherapists as to which treatment program offers patients with FAI the best outcome.

Cost/Compensation:
You will not be compensated for your participation in this study. The assessments for this study will coincide with your routine follow-ups with your surgeon. This study has no additional requirements as to the number of physiotherapy sessions you attend. Therefore, you should plan to pay for your physiotherapy costs as you would have done without study participation.

Voluntary Participation:
Your participation in this study is voluntary. You may refuse to participate, refuse to answer any questions or withdraw from the study at any time with no effect on your future care. Should you choose to withdraw from this study, we will keep all data obtained up to the point that you chose to withdraw.

Participation in this study does not prevent you from participating in any other research studies at the present time or future. If you are participating in another research study, we ask that you please inform of us of your participation. You do not waive any legal rights by signing the consent form.

Request for Study Results:
Should you decide to participate and want to receive a copy of the study results, please provide your contact information on a separate piece of paper. Once the study has been published, a copy will be mailed to you. Please note that the results of this study are not expected for at least 5 years. Should your mailing information change, please let us know.

Confidentiality:
Any personal health information collected or other information related to you will be coded by study numbers to ensure that persons outside of the study will not be able to identify you. In any publication, presentation or report, your name will not be used and any information that discloses your identity will not be released or published unless required by law. It is important to understand that despite these protections being in place, there continues to be the risk of unintentional release of information. The study personnel will protect your records and keep all the information in your study file confidential to the greatest extent possible. The chance that this information will be accidentally released is small.

The data that is collected from you is protected by a username and password. It travels in a scrambled format to a server (storage computer) that is located in Toronto, Ontario. The company that houses the database is a professional company with extremely high standards of physical and virtual security (VPSville). We want to let you know however, that even with this high level of security, there is always a remote chance that your information

could be accessed or "hacked" by someone who is not supposed to have your information. If we became aware that this had happened, we would inform you immediately.

Representatives of The University of Western Ontario Health Sciences Research Ethics Board may contact you or require access to your study-related records to monitor the conduct of the research.

Contacts:
If you have any questions regarding this study, please contact the study coordinator, Cloe Klaus at or your orthopaedic surgeon. If you have any questions about your right as a research participant or the conduct of the study you may contact Dr. David Hill, Scientific Director, Lawson Health Research Institute at

This letter is yours to keep for future reference. Thank you for considering participation in this study. We appreciate your time and interest.

Consent

Study Title: A Randomized Controlled Trial Comparing Arthroscopic Surgery to Conservative Management of Femoroacetabular Impingement

I have read the Letter of Information, have had the nature of the study explained to me and I agree to participate. All questions have been answered to my satisfaction. I will receive a copy of the Letter of Information and this signed consent form.

_____	_____	_____
Printed Name of Participant	Signature of Participant	Date
_____	_____	_____
Printed Name of Person Obtaining Consent	Signature of Person Obtaining Consent	Date

Appendix C: FKSMC Hip Arthroscopy Protocol for Femoroacetabular Impingement

HIP ARTHROSCOPY PROTOCOL FOR FEMOROACETABULAR IMPINGEMENT (FAI)

This protocol is intended to provide the clinician with instruction, direction, rehabilitative guidelines and functional goals for hip arthroscopy for femoroacetabular impingement (FAI) with or without a labral tear. It is not intended to be a substitute for clinical decision-making regarding the progression of a patient's post-operative course based on physical exam/findings and individual progress. The physiotherapist must exercise their best professional judgment to determine how to integrate this protocol into an appropriate treatment plan. The general treatment for a variety of hip procedures involves post operative protection for healing, stretching/mobilizing tight or restricted structures, strengthening the hip musculature and most importantly ensuring that there is adequately lumbo-pelvic stability (i.e. core strength).

This protocol divided into 4 phases. Actual progress may be faster or slower depending on the individual. Decisions to advance patients through the phases of rehabilitation should be based on achieving the appropriate level of tissue healing, as well as clinical presentation and response to treatment. As an individual's progress is variable and each will possess various pre-operative deficiencies and possible pathologies, this protocol must be individualized for optimal return to activity. Some exercises may be adapted depending on the equipment availability at each facility. There may be slight variations in this protocol or additional restrictions placed by the surgeon post-operatively depending on findings at the time of the surgery. If a clinician requires assistance in treatment progression please contact the referring physician or the physiotherapy department.

KEY POINTS

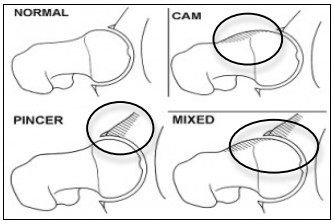
FEMOROACETABULAR IMPINGEMENT

Femoroacetabular impingement is characterized by decreased joint clearance between the femoral head / neck and acetabulum (ball & socket). There are two described types:[9]

- 'Cam' impingement is defined as an abnormality of the anterolateral femoral head/neck junction
- 'Pincer' impingement is described as over coverage of the acetabulum over the femoral head causing increased compressive forces between the rim of the acetabulum and the femoral head/neck.

In the majority of cases (86%)[11], cam and pincer forms exist together i.e. 'mixed impingement'.

With arthroscopic surgery, the anterior capsule is excised, an *osteoplasty* is perform for the cam impingement at the femoral head/neck junction to shave down the bony abnormality and re-create a more normal shaped femoral head. *Rim trimming* is the procedure used with a pincer impingement to address the bony abnormality of the acetabulum.



WEIGHT BEARING AND GAIT RETRAINING

Weight bearing status must be adhered to based on the surgeon's orders. Most patients will be protected weight-bearing (PWB) as tolerated with crutches post-operatively. If there are additional considerations, found at the time of surgery, partial weight-bearing may be ordered based on the extent of the surgery as well as the healing properties/timelines for the involved tissue (i.e. bone, cartilage, labral tissue, capsuloligamentous structures). Patients should follow the suggested weight bearing guidelines and be instructed to progress slowly, using pain as a guide.

RANGE OF MOTION (ROM)

Gentle passive ROM within patient tolerance can be commenced immediately post-operatively for flexion. Extension to neutral and passive internal rotation may also be initiated early post operatively with the goal of preventing joint capsule adhesions. Around the 2-week mark, abduction and external rotation can be added. Generally, a 4-6 week timeline is required to recover from the aspects of surgical intervention including intra-articular swelling. As a result, DO NOT push end ROM during this phase of healing and encourage hip ROM only to tolerance. Rehabilitative exercises should not be painful within the hip joint.

STRENGTHENING EXERCISES

To optimize post-operative recovery, it is important to assess and address any pre-disposing factors that may have contributed to hip pathology prior to surgery.[10] Altered motor control strategies around the lumbar-pelvic-hip region, hip weakness and postural mal-alignment contribute to various hip pathologies. A thorough assessment of the lumbar-pelvic region, hip and lower extremity is necessary and will need to be continually monitored throughout the rehab process. Generally, motor control retraining is more important than strength or power of individual muscles.

Most weight bearing strengthening exercises have been show to produce significantly higher gluteal muscle activity vs. non-weight bearing exercises as there is a need for greater external torque forces on the pelvic-hip complex.[4] These findings relate to the weight of the leg and lever arm over coming the effect of gravity; three factors that are very important to consider with exercise progression. Post-operatively exercises will commence as ROM and non weight-bearing strengthening exercises (supine and standing). Logical progression is from 2-legged weight bearing (i.e. squats, lunges…) to single limb (i.e. step-ups, step-downs, single leg squat…). An EMG summary sheet is provided for gluteal muscle activation (GMax and GMed) levels for a variety of common therapeutic exercises given in rehabilitation from numerous articles in the literature.[1-8]

QUALITY VS. COMPENSATION

Physiotherapists often feel compelled to progress patients by giving them new exercises each time they are in for therapy. It cannot be stressed enough that it is ***not*** beneficial to give patients exercises they are not neuromuscularly ready for. It is very important to observe the *quality* of the exercises that are being performed. Weaknesses in specific muscle groups lead to compensations, which produce faulty movement patterns. These faulty patterns are then integrated into unconscious motor programs, which perpetuate the original weakness. If these are allowed to occur and are not corrected, any joint or structure along the kinetic chain may be exposed to injury.

RETURN TO ACTIVITY/SPORT

Return to sport will depend on the individual's pre-operative level of activity/function and their ability to control the lumbar-pelvic-hip complex with dynamic single leg transfers. Returning to activities that require change of direction or speed work should be assessed on an individual basis. Gradual resumption of pain-free activities over a 3-6 month period is expected; however, actual progress may be faster or slower depending on the individual. Patients may continue to see gradual improvement in symptoms for up to one-year postoperatively.[10]

PHASE I: 0-2 WEEKS

- ***GOALS***
  - Protect the surgical repair
  - Patient education re: gait
    - Protected weight-bearing (PWB): weight bearing as tolerated with crutches
    - Ensure heel-toe patterning and pelvic alignment
  - Minimise post-operative pain and swelling
  - ROM goals: within tolerance

- ***EXERCISE SUGGESTIONS***

ROM & Flexibility
- Active assist supine heel slides with towel/belt +/– slider board
- Therapist assist or active assisted flexion, extension (to neutral), IR log/leg rolling

Muscle Strength & Endurance

Lumbo-Pelvic (core stability):
- Supine Transverse abdominis (TA) and Pelvic floor setting
  **cueing should be specific to lifting pelvic floor and indrawing lower abdominal
  (effort scale for pelvic floor/abdominal contraction should be 2-4 out of 10 with normal breathing)

Hip/Gluteals/Quadriceps:
- Isometric gluteal squeezes supine or standing
- Isometric abd/add supine (bent knees)
- Isometric quadriceps

Calves:
- Ankle pumping and toe crunches +/– with leg elevation
- Gastroc/soleus stretches if needed

Modalities
- Ice 15-25 minutes
- Interferential current therapy (pain relief)
- Game Ready

PHASE II: 2-6 WEEKS

➢ *GOALS*

- Patient education re: gait
  - Wean off crutches 2→1→none (i.e. can be discharged from crutches when gait pattern is normalized)
  - Ensure heel-toe patterning and pelvic alignment
- ROM goals: 90° flexion and full extension by end of 6 weeks
- Stretching structures abound hip complex i.e. muscles, capsule
- Address motor control deficits around lumbo-pelvic-hip complex and transition from non-weight bearing hip ROM and strengthening to more functional closed chain exercises
- Baseline proprioception

➢ *EXERCISE SUGGESTIONS*

ROM & Flexibility

- PROM stretches:
  - Hip extension / anterior capsule (Thomas stretch), prone heel to bum (Quadriceps)
  - IR at 0° (straight leg), 70° (supine bent knee) and prone knee bent IR
  - Adductors
  - Hip circles / circumduction
- Continue as needed with slider board – progress to FABER heel slides as tolerated
- Quadruped rocking for hip flexion (pain free, ensure neutral spine)
- Scar / soft tissue massage: typically around TFL, ITB, GMed, Hip Flexor/upper Quadriceps
- Stationary bike high seat (to avoid pinching)[10]

Muscle Strength & Endurance

Lumbo-Pelvic (core stability):

- Standing and sitting posture with TA and pelvic floor
- Basic supine TA and pelvic floor:
  - Inner range bent knee fall outs→ full range
    **Requires activation of TA and pelvic floor to maintain centralization of the femoral head with lower extremity exercise

Hip/Gluteals/Hamstrings/Quadriceps:

- Prone terminal hip/knee extension (pillow / foam roller under anterior ankle)
- Prone hip extension off edge of bed
- Clam shells→ isometric side lying hip abduction→isotonic hip abduction
- Supine bridging: double, single, on ball
- Standing hip extension, abduction →progress to pulleys or ankle weights (do not allow trunk shift)
- Quads: Isometrics, quads over roll +/– muscle stimulation or biofeedback
- Shuttle™ 2 → 1 leg as tolerated
- Sit-to-stand: high plinth, lower as tolerated
- Squats: wall, mini, progress to deeper squats as able

Pool program (optional):

- Deep-water pool program if incisions are healed for: cardiovascular fitness, ROM, and hip muscle activation (i.e. buoyancy belt in deep water: walking, cycling, hip exercises, knee/ankle ROM…)

Proprioception:
- Weight scales: weight shifting, equal weight bearing: forward/backward and side-to-side→progress to single leg weight shift with core activation and hip/pelvic control
- Wobble boards with support: side-to-side, forward/backward
- Standing on ½ foam roller: balance→rocking forward/backward

Modalities
- Ice/IFC/Game Ready

PHASE III: 6-12 WEEKS

➢ ***GOALS***
- Continue stretches as needed
- Progress exercises to include more challenges to lumbo-pelvic-hip control (core stability)
- Progress proprioception

➢ ***EXERCISE SUGGESTIONS***

ROM & Flexibility
- Quadruped rocking with IR/ER bias
- Stool rotations IR/ER (stand with hip extended-one knee bent with shin on stool, rotate hip in /out)
- Distraction: manual/belt assist in restricted ROM
  **only indicted if loss of motion in a particular range
- Stationary bike→Elliptical forward (with TA/pelvic floor setting)→backward
- Treadmill walking forward →backward (for hip extension)

Muscle Strength & Endurance

Lumbo-Pelvic (core stability):
- Progression of TA and pelvic floor and functional activation with exercise:
  - heel march→march (active hip flexion)
  - heel slides→heel slides + hip flexion (assisted with belt under femur →active)
  - single leg heel taps as tolerated
    **Still requires activation of TA and pelvic fool to maintain centralization of the femoral head with lower extremity exercise
- Walking and WB postures with TA and pelvic floor

Gluteals/Hamstrings/Quadriceps:
- Continue hip strengthening with increased weights/tubing resistance
- Quadruped – alternate arm & leg
- Shuttle™work on strength & endurance, 2 → 1 leg (increase resistance)
- Shuttle™ side lying leg press (top leg)
- Sit to stand: high seat, low seat, 2 legs
- Single leg stance (affected side), hip abduction/extension (unaffected side)
- Single leg stance with hip hike
- Sahrman single leg wall glut med (both sides)
- Tubing kickbacks/mule kicks (both sides)
- Side stepping with theraband (thigh/ankle)
- Profitter: abduction, extension, side-to-side
- Forward and lateral step-ups 4-6-8" (push body weight up through weight bearing heel slow and with control, also watch for hip hiking or excessive ankle dorsiflexion)
- Lunge: static ¼ - ½ range→full range

Proprioception
2 legs→1 leg:
- Wobble boards: without support: side-to-side, forward/backward
- Standing on ½ foam roller: balance→rocking forward/backward
- Single leg stance 5→30→60 seconds (when full WB without trendelenberg or pelvic rotation)

Modalities
- Ice/IFC/Game Ready

PHASE IV: Return to Activity
3-6+ Months

- ***GOALS***
  - Lower chain concentric/eccentric strengthening of quadriceps & hamstrings
  - Functional movement patterns
  - Progress proprioception
  - Continue flexibility exercises

- ***EXERCISE SUGGESTIONS***

Muscle Strength & Endurance

Lumbo-Pelvic (core stability) +Gluteals/Hamstrings/Quadriceps:
- Advanced core: side plank (on elbows/feet), prone plank (on elbows/toes)
- Continue hip strengthening with increased weights/tubing resistance
  - Hip IR/ER with pulleys→theraband in flexed, neutral, extended positions
  - Hamstring curls, eccentrics, deadlifts 2→1 leg
- Progress resistance of Shuttle™working on strength & endurance, 2→1 leg
- Shuttle™ standing kick backs (hip/knee extension)
- Lunge walking, forwards/backwards, hand weights
- Sit to stand: high seat, low seat, single leg
- Single leg: wall squat→mini squat→dead lift
- Sahrman single leg wall glut med with single leg mini squat (both sides)
- Side shuffling/hopping with theraband (thighs/ankles)
- Eccentric lateral step down on 2-4-6" step with control (watch for hip hiking or excessive ankle dorsiflexion)
- Hopping: 2-1 leg (if required)
- Activities challenging all planes of motion: 2-1 leg

Proprioception
- Wobble boards: vision, vision removed, 2 legs, single leg: side to side, forward, backward
- Single leg stance 5→30→60 seconds on unstable surface i.e. pillow, mini-tramp, BOSU™, Airex™, Dynadisc™ with/without support – progress to no vision
- Single leg stance performing higher end upper body skills specific to patient goal(s)

Cardiovascular Fitness
- Stationary bike, Elliptical→Stairmaster with TA/pelvic floor setting and adequate pelvic/hip control (i.e. absent trendelenberg, pelvic rotation)
- Treadmill: walk, side stepping, interval jog→jog, interval run→run as tolerated (if required)

Hip Arthroscopy for FAI: Guidelines for Manual Therapy and Exercise

EXERCISES	Phase I Week 0-2	Phase II Week 2- 6	Phase III Week 6-12	Phase IV Week 12 +
General				
Crutches	●	●		
Gait retraining	●	●		
Hip ROM to tolerance	●	●		
Scar/soft tissue massage	●	●		
Quadruped (neutral spine) rocking, IR/ER bias		●	●	
Stretches (if required):				
Hip Flexors (to neutral), Gastrocs	●			
Quads, Hamstrings, Adductors		●		
TA/Pelvic floor				
Supine activation, progressions, sitting	●	●		
Standing, walking, weight-bearing, functional exs.		●	●	●
Advanced core: quad alternate lifts, plank, side plank			●	●
Functional Exercises: *Performed with accurate core activation*				
Supine bridging: double, single, ball		●		
S/L: clam shells, long lever hip abduction		●		
Weight transfer		●		
Standing hip abduction, extension		●	●	
Squats: wall, mini, 60°-90°		●	●	
Shuttle: 2 legs, 1leg, ↑resistance/reps		●	●	
Sit to stand: high seat, low seat, 2 legs, single leg			●	
Side-step ankle band, shuffling, hopping			●	●
Lunges: ¼-½-full, forward, backward, walking, hand weights			●	●
Single Leg stance, + hip hike			●	●
Pro-fitter (abduction, extension, side-to-side)			●	●
Tubing kickbacks (mule kicks)			●	●
Step ups 4-6-8": forward, lateral			●	●
Single leg: wall squat, mini-squat, dead lift			●	●
Sahrman single leg wall glut med, + mini squat			●	●
Shuttle standing kick backs (hip/knee extension)				●
Step Downs 4-6-8"				●
Hopping: forward, backward, side-side				●
Proprioception				
Wobble boards, ½ foam roller, double, single leg		●	●	
Squats, Lunges on Dynadisc, Airex, Bosu…			●	●
Single leg balance, ↑time, complexity of skill			●	●
Cardiovascular Fitness				
Bike	●	●	●	●
Pool		●	●	●
Elliptical		●	●	●
Stairmaster			●	●
Treadmill: forward, backward, jog, run			●	●

Highest % MVIC EMG Exercises for Glut Med and Glut Max Muscles

Exercise	Glut Med ranges	Glut Max ranges
Clam Shell	38-40[1]	34-39[1]
Side-lying Hip Abduction	81[1], 39[2], 42[4]	39[1], 21[2]
Plank (on elbows/toes)	27[2]	9[2]
Quadruped Opp Arm & Leg	42[2]	56[2]
Bridge	28[2]	25[2]
1 Legged Bridge	47[2]	40[2]
Side bridge (on elbows/feet)	74[2]	21[2]
Standing Hip Abduction (NWB side)	28-33[4]	
Standing Hip abduction (WB leg)	42-46[4]	
Side lunge	39[1]	41[1]
Forward Lunge	42[1], 29[2], 18[6]	44[1] / 36[2] / 22[6]
Forward Hop	45[1]	35[1]
Sideways Hop	57[1]	30[1]
Side Step with Ankle Band	61[1]	27[1]
Lateral Step Up	43[2], 38[3]	29[2], 56[3]
Forward Step Up	44[3]	74[3]
1 Leg Wall squat	52[3], 13/25/35[5] (Ant,Mid,Post GMED)	86[3]
Single Leg Squat	64[1], 36[3], 30[6]	59[1], 57[3], 35[6]
Single Limb Dead Lift	58[1]	59[1]
Pelvic Drop	57[4], 21/28/38[5] (Ant,Mid,Post GMED)	
Sarhmann Wall Glut Med	28/39/76[5] (Ant/Mid/Post GMED)	
Walking	16[8]	13[8]
Elliptical	18-20[8]	18-20[8]
ProFitter: Trunk upright ½ way side-to-side Trunk upright slide end-to-end Hips flexed slide end-to-end	 17[7] 30[7] 36[7]	 14[7] 15[7] 25[7]

1. Distefano LJ et al. *Gluteal muscle activation during common therapeutic exercises.* JOSPT. 2009;39(7):532-540.
2. Ekstrom RA et al. *Electromyographic analysis of core trunk, hip, and thigh muscles during 9 rehabilitation exercises*. JOSPT. 2007;37(12):754-762.
3. Ayotte NW et al. *Electromyographical analysis of selected lower extremity muscles during 5 unilateral weight-bearing exercises.* JOSPT. 2007;37(2):48-55.
4. Bolga LA & Uhl TL. *Electromyographic analysis of hip rehabilitation exercises in a group of healthy subjects*. JOSPT. 2005;35(8):487-494.
5. O'Sullivan K et al. *Electromyographic analysis of the three subdivisions of gluteus medius during weight-bearing exercises***.** Sports Medicine, Arthroscopy, Rehabilitation, Therapy & Technology. 2010;2:17-25.
6. Boudreau SN et al**.** *Hip-muscle activation during the lunge, single-leg squat, and step-up-and-over exercises***.** Journal of Sport Rehabilitation. 2009;18:91-103.
7. Banerjee P et al. *Torso and hip muscle activity and resulting spine load and stability while using the Profitter 3-D cross trainer*. Journal of Applied Biomechanics. 2009;25:73-84.
8. Burnfield JM et al. *Similarity of joint kinematics and muscle demands between elliptical training and walking: Implication for practice*. Physical Therapy. 2010; 90(2):289-305.
9. Lavigne M et al. *Anterior femoroacetabular impingement, part I: Techniques of joint preserving surgery*. Clin Orthop Related Research. 2004; 418:61-66.
10. Shindle M et al. *Arthroscopic management of labral tears in the hip.* JBJS. 2008;90:2-19.
11. Beck M et al. *Hip morphology influences the pattern of damage to the articular cartilage: femoroacetabular impingement as a cause of early osteoarthritis of the hip*. JBJS Br. 2005;87:1012-18.

Appendix D: FKSMC Conservative Management for Femoroacetabular Impingement

FOWLER KENNEDY
SPORT MEDICINE CLINIC

CONSERVATIVE MANAGEMENT FOR FEMOROACETABULAR IMPINGEMENT (FAI)

This protocol is intended to provide the clinician with instruction, direction, rehabilitative guidelines and functional goals for the conservative treatment of femoroacetabular impingement (FAI). It is not intended to be a substitute for clinical decision-making regarding the patient progression based on physical exam/findings and individual progress. The physiotherapist must exercise their best professional judgment to determine how to integrate this protocol into an appropriate treatment plan. The general treatment guideline involves stretching/mobilizing any tight or restricted structures, strengthening the hip musculature and most importantly ensuring that there is adequately lumbo-pelvic stability (i.e. core strength).

This protocol divided into 2 phases. Actual progress may be faster or slower depending on the individual. Decisions to advance patients through the phases of rehabilitation should be based on the clinical presentation and response to treatment (this includes the use of outcome measures such as hip range of motion (ROM), Hip Outcome Score (HOS), Harris Hip Score, P4, Lower Extremity Functional Scale (LEFS) etc...). As an individual's progress is variable, this protocol must be individualized for optimal return to activity. Some exercises may be adapted depending on the equipment availability at each facility. There may be slight variations in this protocol depending on findings at the time of assessment (i.e. hip hypo or hyper mobility). If a clinician requires assistance in treatment progression please contact the referring physician or the physiotherapy department.

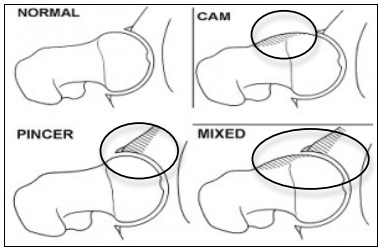
KEY POINTS

FEMOROACETABULAR IMPINGEMENT

Femoroacetabular impingement is characterized by decreased joint clearance between the femoral head/neck and acetabulum (ball & socket). There are two described types:[9]

- '**Cam**' impingement is defined as an abnormality of the anterolateral femoral head/neck junction
- '**Pincer**' impingement is described as over coverage of the acetabulum over the femoral head causing increased compressive forces between the rim of the acetabulum and the femoral head/neck.

In the majority of cases (86%)[11], cam and pincer forms exist together i.e. '**mixed impingement**'.



HIP BIOMECHANICS, ELECTROMYOGRAPHY (EMG) AND ASSESSMENT GUIDELINES

It is important to note that FAI is prevalent in those who are asymptomatic as well.[10] This indicates that FAI may not be the cause of hip joint pathology/degeneration or soft tissue injury. Faulty biomechanics such as joint hypo or hyper-mobility (including generalized ligament laxity), altered motor control strategies around the lumbar-pelvic-hip region, hip weakness/muscle imbalances and postural mal-alignment are some of many causative factors for hip pain. Our ability to assess these deficits and to tailor a management program is essential for optimal pelvic/hip control and more important function.

Surface EMG from normal lateral hip muscles have shown reciprocal phasic low level activity during standing.[12] This means that left and right musculature alternate their activity normally in an on-off (load/unload) strategy. With lumbo-pelvic-hip dysfunction, the pattern shifts more toward tonic activity with a loss of phasic (Type II) muscle fibres in the superficial hip abductors and an abnormal co-contraction strategy of both GMed muscles.[12-14] During routine activities such as walking, going up/down stairs, standing up/sitting down and weight shifting onto one leg, the hip joint averages contact forces between 1.5-2.5 times body-weight.[15] The abductorial forces required to maintain a level pelvis during single leg weight bearing, are comprised of 70% from the gluteal muscle forces and 30% from muscles that influence tension in the iliotibial band (i.e. tensor fascia lata and the upper portion of glueus maximus).[16] As a result, these muscles groups are fundamental when addressing lumbo-pelvic-hip dysfunction and pain.

POSTURAL HABITS

Common postural habits include sitting cross-legged in hip adduction, sleeping in side-lying with the hip in flexion/adduction but the most common negative standing postural habit for hip stability is 'hanging on one hip' where the trunk and body weight is shifted towards one leg with the weight bearing hip/pelvis in a position of adduction. In this position of hip adduction (i.e. trendelenberg), many negative biomechanical consequences have been shown to occur:

1. increased hip joint forces (i.e. joint compression).[16,17]
2. increased compressive loading of the ITB over the greater trochanter into which the Gluteus Medius (GMED) tendon inserts.[18]
3. the requirement for hip muscle activity is decreased (because the ITB is taut) and the forces to overcome gravity are mostly resisted by ITB tension alone.[19]

This poor postural habit (i.e. excessive hip adduction in weight bearing) can lead to additional negative consequences such as structural muscle lengthening changes over time (i.e. additional sarcomeres).[20] This shifts the optimal function of the muscle such that the greatest isometric tension is now generated in a new lengthened position. This may be evident with manual muscle testing of hip abductors (i.e. the shortened or neutral position tests weak and the lengthened position, such as 10° adduction, tests strong). If this postural patterning is not addressed and corrected, it can lead decreased force production with the hip in a neutral position. This can lead to painful pathomechanics such as increased compressive loads in the hip joint with resultant joint dysfunction/degeneration and/or muscular tendonopathies. Assessing and retraining poor postural habits is a crucial consideration for achieving positive long term results.[21]

STRENGTHENING EXERCISES

Most weight bearing strengthening exercises have been show to produce significantly higher gluteal muscle activity vs. non-weight bearing exercises as there is a need for greater external torque forces on the pelvic-hip complex.[4] These findings relate to the weight of the leg and lever arm over coming the effect of gravity; three factors that are very important to consider with exercise progression. Post-operatively exercises will commence as ROM and non weight-bearing strengthening exercises (supine and standing). Logical progression is from 2-legged weight bearing (i.e. squats, lunges…) to single limb (i.e. step-ups, step-downs, single leg squat…). An EMG summary sheet is provided for gluteal muscle activation (GMax and GMed) levels for a variety of common therapeutic exercises given in rehabilitation from numerous articles in the literature.[1-8]

ACUTE PHASE I: 0-4 WEEKS

- ***GOALS***
  - Patient education re: rest, NSAIDs, activity/ADL modification to adapt to hip morphology, decrease compression and painful movements, cessation of sports or other aggravating factors
  - Address hip ROM deficits if any
  - Stretching structures abound hip complex i.e. muscles, capsule (if needed and if pain free)
  - Address motor control deficits around lumbo-pelvic-hip complex
  - Strengthening weak key muscle groups
  - Baseline proprioception and effective weight transfer without compensatory movement patterns

- ***EXERCISE SUGGESTIONS***

ROM & Flexibility

- Stretches/ROM:
  - Hip extension / anterior capsule,
  - Hip flexion, Add/Abductors
  - IR at 0° and in flexion positions, ER
- Quadruped rocking for hip flexion (pain free, ensure neutral spine)
- Stationary bike high seat avoid deep hip flexion (pain)
- Distraction: manual/belt assist in restricted ROM
  **only indicted if loss of motion in a particular range

Muscle Strength & Endurance

Lumbo-Pelvic (core stability):

- Supine Transverse abdominis (TA) and Pelvic floor setting
  **cueing should be specific to lifting pelvic floor and indrawing lower abdominal
  (effort scale for pelvic floor/abdominal contraction should be 2-4 out of 10 with normal breathing)
- Basic supine TA and pelvic floor:
  - Inner range bent knee fall outs→full range
  - heel march→march (active hip flexion)
  - heel slides→heel slides + hip flexion (assisted with belt under femur→active)
  - single leg heel taps as tolerated
  **Requires activation of TA and pelvic floor to maintain centralization of the femoral head with lower extremity exercise
- Standing, sitting, walking, and weight-bearing postures with TA and pelvic floor

Hip/Gluteals/Hamstrins/Quadriceps:

- Prone hip extension off edge of bed
- Clam shells→isometric side lying hip abduction→isotonic hip abduction
- Supine bridging: double, single, on ball
- Standing hip extension, abduction→progress to pulleys or ankle weights (do not allow trunk shift)
- Shuttle™ 2→1 leg as tolerated
- Squats: wall, mini, progress to deeper squats as able

Proprioception:

2 legs:

- Equal weight bearing: forward/backward and side-to-side→progress to single leg weight shift with core activation and hip/pelvic control
- Wobble boards with support: side-to-side, forward/backward
- Standing on ½ foam roller: balance→rocking forward/backward

SUB-ACUTE PHASE II: 4-12+ WEEKS

- ***GOALS***
  - Continue flexibility exercises in pain free ranges if required
  - Progress exercises to include more challenges to lumbo-pelvic-hip control (core stability)
  - Strengthen weak key muscle groups with functional closed chain exercises
  - Progress proprioception to single leg without compensatory movement patterns

- ***EXERCISE SUGGESTIONS***

ROM & Flexibility

- Quadruped rocking with IR/ER bias
- Stationary bike→Elliptical forward (with TA/pelvic floor setting)/backward→Stairmaster with TA/pelvic floor setting and adequate pelvic/hip control (i.e. absent trendelenberg, pelvic rotation)
- Treadmill: walk forward→backward (for hip extension), side stepping, interval jog→jog, interval run→run (if tolerated)

Muscle Strength & Endurance

Lumbo-Pelvic (core stability) +Gluteals/Hamstrings/Quadriceps:

- Advanced core: side plank (on elbows/feet), prone plank (on elbows/toes)
- Continue hip strengthening with increased weights/tubing resistance
  - Hip IR/ER with pulleys→theraband in flexed, neutral, extended positions
  - Hamstring curls, eccentrics, deadlifts 2→1 leg
- Quadruped – alternate arm & leg lift
- Shuttle™work on strength & endurance, 2→1 leg (progress with increased resistance)
- Shuttle™ side lying leg press (top leg)
- Shuttle™ standing kick backs (hip/knee extension)
- Sit to stand: high seat, low seat, 2 legs, single leg
- Single leg stance (affected side), hip abduction/extension (unaffected side)
- Single leg stance with hip hike
- Sahrman single leg wall glut med (both sides)→+ mini squat
- Tubing kickbacks/mule kicks (both sides)
- Lunge: static ¼ - ½ range→full range
- Lunge walking, forwards/backwards, hand weights
- Side stepping→shuffling→hopping +/- theraband (thigh/ankle)
- Profitter: abduction, extension, side-to-side
- Single leg: wall squat→mini squat→dead lift
- Forward and lateral step-ups 4-6-8" (push body weight up through weight bearing heel slow and with control, also watch for hip hiking or excessive ankle dorsiflexion)
- Eccentric lateral step down on 2-4-6" step with control (watch for hip hiking or excessive ankle dorsiflexion)

Proprioception

2 legs→1 leg:

- Wobble boards: without support: side-to-side, forward/backward vision, vision removed, 2 legs,
- Wobble boards: single leg: side to side, forward/backward
- Standing on ½ foam roller: balance→rocking forward/backward
- Single leg stance 5→30→60 seconds (when full WB without trendelenberg or pelvic rotation)
- Single leg stance 5→30→60 seconds on unstable surface i.e. pillow, mini-tramp, BOSU™, Airex™, Dynadisc™ with/without support – progress to no vision
- Single leg stance performing higher end upper body skills specific to patient goal(s)

Conservative Management for FAI: Guidelines for Manual Therapy & Exercise

EXERCISES	Phase I Week 0-4	Phase II Week 4-12+
General		
Hip ROM to tolerance	●	●
Stretches (if required):		
Hip Flexors, Quads, Hamstrings, Add/Abductors, Int/Ext Rotators	●	●
TA/Pelvic floor		
Supine activation, progressions, sitting	●	●
Standing, walking, weight-bearing, functional exercises	●	●
Advanced core: quadruped alternate arm/leg lifts, plank, side plank		●
Functional Exercises: *Performed with accurate core activation*		
Supine bridging: double, single, ball	●	
S/L: clam shells, long lever hip abduction	●	
Quadruped (neutral spine) rocking, IR/ER bias	●	●
Standing hip abduction, extension	●	●
Squats: wall, mini, 60°-90°	●	●
Shuttle: 2 legs, 1leg, ↑resistance/reps	●	●
Sit to stand: high seat, low seat, 2 legs, single leg	●	●
Sahrman single leg wall glut med (both sides)		●
Side-step ankle band, shuffling, hopping		●
Lunges: ¼-½-full, forward, backward, walking, hand weights		●
Single Leg stance, + hip hike		●
Pro-fitter (abduction, extension, side-to-side)		●
Tubing kickbacks (mule kicks)		●
Step ups 4-6-8": forward, lateral		●
Single leg: wall squat, mini-squat, dead lift		●
Sahrman single leg wall glut med, + mini squat		●
Shuttle standing kick backs (hip/knee extension)		●
Step Downs 4-6-8"		●
Hopping: forward, backward, side-side		●
Proprioception		
Wobble boards, ½ foam roller, double, single leg	●	●
Squats, Lunges on Dynadisc, Airex, Bosu…		●
Single leg balance, ↑time, complexity of skill		●
Cardiovascular Fitness		
Bike	●	●
Elliptical	●	●
Stairmaster		●
Treadmill: forward, backward, jog, run		●

Highest % MVIC EMG Exercises for Glut Med and Glut Max Muscles

Exercise	Glut Med ranges	Glut Max ranges
Clam Shell	38-40[1]	34-39[1]
Side-lying Hip Abduction	81[1], 39[2], 42[4]	39[1], 21[2]
Plank (on elbows/toes)	27[2]	9[2]
Quadruped Opp Arm & Leg	42[2]	56[2]
Bridge	28[2]	25[2]
1 Legged Bridge	47[2]	40[2]
Side bridge (on elbows/feet)	74[2]	21[2]
Standing Hip Abduction (NWB side)	28-33[4]	
Standing Hip abduction (WB leg)	42-46[4]	
Side lunge	39[1]	41[1]
Forward Lunge	42[1], 29[2], 18[6]	44[1] / 36[2] / 22[6]
Forward Hop	45[1]	35[1]
Sideways Hop	57[1]	30[1]
Side Step with Ankle Band	61[1]	27[1]
Lateral Step Up	43[2], 38[3]	29[2], 56[3]
Forward Step Up	44[3]	74[3]
1 Leg Wall squat	52[3], 13/25/35[5] (Ant,Mid,Post GMED)	86[3]
Single Leg Squat	64[1], 36[3], 30[6]	59[1], 57[3], 35[6]
Single Limb Dead Lift	58[1]	59[1]
Pelvic Drop	57[4], 21/28/38[5] (Ant,Mid,Post GMED)	
Sarhmann Wall Glut Med	28/39/76[5] (Ant/Mid/Post GMED)	
Walking	16[8]	13[8]
Elliptical	18-20[8]	18-20[8]
ProFitter:		
Trunk upright ½ way side-to-side	17[7]	14[7]
Trunk upright slide end-to-end	30[7]	15[7]
Hips flexed slide end-to-end	36[7]	25[7]

1. Distefano LJ et al. *Gluteal muscle activation during common therapeutic exercises.* JOSPT. 2009;39(7):532-540.
2. Ekstrom RA et al. *Electromyographic analysis of core trunk, hip, and thigh muscles during 9 rehabilitation exercises*. JOSPT. 2007;37(12):754-762.
3. Ayotte NW et al. *Electromyographical analysis of selected lower extremity muscles during 5 unilateral weight-bearing exercises.* JOSPT. 2007;37(2):48-55.
4. Bolga LA & Uhl TL. *Electromyographic analysis of hip rehabilitation exercises in a group of healthy subjects*. JOSPT. 2005;35(8):487-494.
5. O'Sullivan K et al. *Electromyographic analysis of the three subdivisions of gluteus medius during weight-bearing exercises.* Sports Medicine, Arthroscopy, Rehabilitation, Therapy & Technology. 2010;2:17-25.
6. Boudreau SN et al**.** *Hip-muscle activation during the lunge, single-leg squat, and step-up-and-over exercises.* Journal of Sport Rehabilitation. 2009;18:91-103.
7. Banerjee P et al. *Torso and hip muscle activity and resulting spine load and stability while using the Profitter 3-D cross trainer.* Journal of Applied Biomechanics. 2009;25:73-84.
8. Burnfield JM et al. *Similarity of joint kinematics and muscle demands between elliptical training and walking: Implication for practice*. Physical Therapy. 2010; 90(2):289-305.
9. Lavigne M et al. *Anterior femoroacetabular impingement, part I: Techniques of joint preserving surgery*. Clin Orthop Related Research. 2004; 418:61-66.
10. Abellan J et al. *Radiological evidence of femoroacetabular impingement in asymptomatic athletes*. Br J Sports Med. 2011;45(4):333
11. Beck M et al. *Hip morphology influences the pattern of damage to the articular cartilage: femoroacetabular impingement as a cause of early osteoarthritis of the hip*. JBJS Br. 2005;87:1012-18.
12. Nelson-Wong E et al. *Gluteus medius muscle activation patterns as a predictor of low back pain during standing*. Clinical Biomechanics. 2008;23:545-53.
13. Long W et al. *Functional recovery of noncemented total hip arthroplasty*. Clnical Orthopaedics & Related Research. 1993;288:73-7.
14. Sirca A & Susec-Michieli M. *Selective type II fibre muscular atrophy in patients with osteoarthritis of the hip*. Journal of the Neurological Sciences. 1980;44:149-59.
15. Bergmann G et al. *Hip contact forces and gait patterns form routine activities.* Journal of Biomechanics. 2001;34:859-871.
16. Kummer B. *Is the pauwels theory of hip biomechanics still valid? A critical analysis based on modern methods*. Annals of Anatomy. 1993;175:203-10.
17. McLeish R & Charnley J. *Abduction forces in the one-legged stance.* Journal of Biomechanics. 1970;3:191-209.
18. Birmbaum K et al. *Anatomical and biomechanical investigations of the iliotibial tract.* Surgical and Radiological Anatomy. 2004;26:433-46.
19. Inman V. *Functional aspects of the abductor muscles of the hip*. JBJS. 1947;29:607-19.
20. Goldspink DF. *The influence of immobilization and stretch on protein turnover of rat skeletal muscle.* Journal of Physiology. 1977;264:267-82.
21. Grimaldi A. *Assessing lateral stability of the hip and pelvis.* Manual Therapy. 2011;16:26-32.

Appendix E: Copyrighted Material Permissions

Figure 1

Permissions Department
Contracts, Copyrights and Permissions
Segment Administration

PERMISSION LICENSE: PRINT REPUBLICATION

Request ID/Invoice Number: CHL54328

Date: June 21, 2013

To: Chloe Klaus
Fowler Kennedy Sport Medicine Clinic
Western University
3M Centre, 1151 Richmond St.
London ON N6A 3K7
CANADA
"Licensee"

McGraw-Hill Material

Author: Saladin, Kenneth
Title: Anatomy & Physiology: The Unity of Form and Function, 5/e © 2010
ISBN: 0071312838
Description of material: Figure 21-9, pg. 614 (ONLY)

Fee: WAIVED [Master's Thesis]

Licensee Work:

Author: Klaus, C.
Title: A Randomized Control Trial Comparing Arthroscopic Surgery to Conservative Management of Femoroacetabular Impingement
Publisher: Western University
Publication Date: 2013
Print Run: 1
Distribution Territory: Canada
Languages: English

Permission for the use described above is granted under the following conditions:

1. The permission fee is waived.

2. No adaptations, deletions, or changes will be made in the material without the prior written consent of The McGraw-Hill Companies.

Request ID/Invoice Number: CHL54328

2 Penn Plaza, 10th Floor | New York, NY 10121-2298 | phone: (212) 904.2574 | mhe-permissions@mheducation.com

3. This permission is non-exclusive, non-transferable, and limited to the use specified herein. The McGraw-Hill Companies expressly reserves all rights in this material.

4. A credit line must be printed on the first page on which the material appears. This credit must include the author, title, copyright date, and publisher, and indicate that the material is reproduced with permission of The McGraw-Hill Companies.

5. This permission does not allow the use of any material, including but not limited to photographs, charts, and other illustrations, which appears in a McGraw-Hill Companies' work copyrighted in or credited to the name of any person or entity other than The McGraw-Hill Companies. Should you desire permission to use such material, you must seek permission directly from the owner of that material, and if you use such material you agree to indemnify The McGraw-Hill Companies against any claim from the owners of that material.

Please sign both copies and return one to the McGraw-Hill Permissions Department, 2 Penn Plaza, 10th Floor, New York, NY 10121.

For McGraw-Hill:

Ebony Lane
Permissions Department
McGraw-Hill Education

For Licensee:

Name _____

Title MSc (c) Kinesiology - Sport Medicine

Request ID/Invoice Number: CHL54328

Figure 2

WOLTERS KLUWER HEALTH LICENSE TERMS AND CONDITIONS

Jun 15, 2013

This is a License Agreement between Cloe Klaus ("You") and Wolters Kluwer Health ("Wolters Kluwer Health") provided by Copyright Clearance Center ("CCC"). The license consists of your order details, the terms and conditions provided by Wolters Kluwer Health, and the payment terms and conditions.

All payments must be made in full to CCC. For payment instructions, please see information listed at the bottom of this form.

License Number	3170430189472
License date	Jun 15, 2013
Licensed content publisher	Wolters Kluwer Health
Licensed content publication	Current Orthopaedic Practice
Licensed content title	Anterior Femoroacetabular Impingement: Part I. Techniques of Joint Preserving Surgery
Licensed content author	Martin Lavigne, Javad Parvizi, Martin Beck, et al
Licensed content date	Jan 1, 2004
Volume Number	418
Type of Use	Dissertation/Thesis
Requestor type	Individual
Author of this Wolters Kluwer article	No
Title of your thesis / dissertation	A Randomized Control Trial Comparing Arthroscopic Surgery to Conservative Management of Femoroacetabular Impingement
Expected completion date	Aug 2013
Estimated size(pages)	80
Billing Type	Invoice
Billing address	1151 Richmond St 3M Centre FKSMC London, ON N6A 3K7 Canada
Total	0.00 USD
Terms and Conditions	

Terms and Conditions

1. A credit line will be prominently placed and include: for books - the author(s), title of book, editor, copyright holder, year of publication; For journals - the author(s), title of

2. The requestor warrants that the material shall not be used in any manner which may be considered derogatory to the title, content, or authors of the material, or to Wolters Kluwer.
3. Permission is granted for a one time use only within 12 months from the date of this invoice. Rights herein do not apply to future reproductions, editions, revisions, or other derivative works. Once the 12-month term has expired, permission to renew must be submitted in writing.
4. Permission granted is non-exclusive, and is valid throughout the world in the English language and the languages specified in your original request.
5. Wolters Kluwer cannot supply the requestor with the original artwork or a "clean copy."
6. The requestor agrees to secure written permission from the author (for book material only).
7. Permission is valid if the borrowed material is original to a Wolters Kluwer imprint (Lippincott-Raven Publishers, Williams & Wilkins, Lea & Febiger, Harwal, Igaku-Shoin, Rapid Science, Little Brown & Company, Harper & Row Medical, American Journal of Nursing Co, and Urban & Schwarzenberg - English Language).
8. If you opt not to use the material requested above, please notify Rightslink within 90 days of the original invoice date.
9. Please note that articles in the ahead-of-print stage of publication can be cited and the content may be re-used by including the date of access and the unique DOI number. Any final changes in manuscripts will be made at the time of print publication and will be reflected in the final electronic version of the issue.
   Disclaimer: Articles appearing in the Published Ahead-of-Print section have been peer-reviewed and accepted for publication in the relevant journal and posted online before print publication. Articles appearing as publish ahead-of-print may contain statements, opinions, and information that have errors in facts, figures, or interpretation. Accordingly, Lippincott Williams & Wilkins, the editors and authors and their respective employees are not responsible or liable for the use of any such inaccurate or misleading data, opinion or information contained in the articles in this section.
10. This permission does not apply to images that are credited to publications other than Wolters Kluwer journals. For images credited to non-Wolters Kluwer journal publications, you will need to obtain permission from the journal referenced in the figure or table legend or credit line before making any use of the image(s) or table(s).
11. The following statement needs to be added when reprinting the material in Open Access publications: 'promotional and commercial use of the material in print, digital or mobile device format is prohibited without the permission from the publisher Lippincott Williams & Wilkins. Please contact journalpermissions@lww.com for further information.
12. In case of **Disease Colon Rectum, Plastic Reconstructive Surgery, The Green Journal, Critical Care Medicine, Pediatric Critical Care Medicine, the American Heart Publications, the American Academy of Neurology** the following guideline applies: no drug brand/trade name or logo can be included in the same page as the material re-used
13. When requesting a permission to translate a full text article, Wolters Kluwer/Lippincott Williams & Wilkins requests to receive the pdf of the translated document
14. Other Terms and Conditions:

If you would like to pay for this license now, please remit this license along with your payment made payable to "COPYRIGHT CLEARANCE CENTER" otherwise you will be invoiced within 48 hours of the license date. Payment should be in the form of a check or money order referencing your account number and this invoice number RLNK501043987.
Once you receive your invoice for this order, you may pay your invoice by credit card. Please follow instructions provided at that time.

Make Payment To:
Copyright Clearance Center
Dept 001
P.O. Box 843006
Boston, MA 02284-3006

For suggestions or comments regarding this order, contact RightsLink Customer Support: customercare@copyright.com or +1-877-622-5543 (toll free in the US) or +1-978-646-2777.

Gratis licenses (referencing $0 in the Total field) are free. Please retain this printable license for your reference. No payment is required.

Figures 3 and 4

WOLTERS KLUWER HEALTH LICENSE TERMS AND CONDITIONS

Jun 20, 2013

This is a License Agreement between Cloe Klaus ("You") and Wolters Kluwer Health ("Wolters Kluwer Health") provided by Copyright Clearance Center ("CCC"). The license consists of your order details, the terms and conditions provided by Wolters Kluwer Health, and the payment terms and conditions.

All payments must be made in full to CCC. For payment instructions, please see information listed at the bottom of this form.

License Number	3173240038075
License date	Jun 20, 2013
Licensed content publisher	Wolters Kluwer Health
Licensed content publication	Current Orthopaedic Practice
Licensed content title	Anterior Femoroacetabular Impingement: Part II. Midterm Results of Surgical Treatment
Licensed content author	Martin Beck, Michael Leunig, Javad Parvizi, et al
Licensed content date	Jan 1, 2004
Volume Number	418
Type of Use	Dissertation/Thesis
Requestor type	Individual
Author of this Wolters Kluwer article	No
Title of your thesis / dissertation	A Randomized Control Trial Comparing Arthroscopic Surgery to Conservative Management of Femoroacetabular Impingement
Expected completion date	Aug 2013
Estimated size(pages)	80
Billing Type	Invoice
Billing address	1151 Richmond St 3M Centre FKSMC London, ON N6A 3K7 Canada
Total	0.00 USD
Terms and Conditions	

Terms and Conditions

1. A credit line will be prominently placed and include: for books - the author(s), title of book, editor, copyright holder, year of publication; For journals - the author(s), title of

2. The requestor warrants that the material shall not be used in any manner which may be considered derogatory to the title, content, or authors of the material, or to Wolters Kluwer.
3. Permission is granted for a one time use only within 12 months from the date of this invoice. Rights herein do not apply to future reproductions, editions, revisions, or other derivative works. Once the 12-month term has expired, permission to renew must be submitted in writing.
4. Permission granted is non-exclusive, and is valid throughout the world in the English language and the languages specified in your original request.
5. Wolters Kluwer cannot supply the requestor with the original artwork or a "clean copy."
6. The requestor agrees to secure written permission from the author (for book material only).
7. Permission is valid if the borrowed material is original to a Wolters Kluwer imprint (Lippincott-Raven Publishers, Williams & Wilkins, Lea & Febiger, Harwal, Igaku-Shoin, Rapid Science, Little Brown & Company, Harper & Row Medical, American Journal of Nursing Co, and Urban & Schwarzenberg - English Language).
8. If you opt not to use the material requested above, please notify Rightslink within 90 days of the original invoice date.
9. Please note that articles in the ahead-of-print stage of publication can be cited and the content may be re-used by including the date of access and the unique DOI number. Any final changes in manuscripts will be made at the time of print publication and will be reflected in the final electronic version of the issue.
   Disclaimer: Articles appearing in the Published Ahead-of-Print section have been peer-reviewed and accepted for publication in the relevant journal and posted online before print publication. Articles appearing as publish ahead-of-print may contain statements, opinions, and information that have errors in facts, figures, or interpretation. Accordingly, Lippincott Williams & Wilkins, the editors and authors and their respective employees are not responsible or liable for the use of any such inaccurate or misleading data, opinion or information contained in the articles in this section.
10. This permission does not apply to images that are credited to publications other than Wolters Kluwer journals. For images credited to non-Wolters Kluwer journal publications, you will need to obtain permission from the journal referenced in the figure or table legend or credit line before making any use of the image(s) or table(s).
11. The following statement needs to be added when reprinting the material in Open Access publications: 'promotional and commercial use of the material in print, digital or mobile device format is prohibited without the permission from the publisher Lippincott Williams & Wilkins. Please contact journalpermissions@lww.com for further information.
12. In case of **Disease Colon Rectum, Plastic Reconstructive Surgery, The Green Journal, Critical Care Medicine, Pediatric Critical Care Medicine, the American Heart Publications, the American Academy of Neurology** the following guideline applies: no drug brand/trade name or logo can be included in the same page as the material re-used
13. When requesting a permission to translate a full text article, Wolters Kluwer/Lippincott Williams & Wilkins requests to receive the pdf of the translated document
14. Other Terms and Conditions:

If you would like to pay for this license now, please remit this license along with your payment made payable to "COPYRIGHT CLEARANCE CENTER" otherwise you will be invoiced within 48 hours of the license date. Payment should be in the form of a check or money order referencing your account number and this invoice number RLNK501048019.
Once you receive your invoice for this order, you may pay your invoice by credit card. Please follow instructions provided at that time.

Make Payment To:
Copyright Clearance Center
Dept 001
P.O. Box 843006
Boston, MA 02284-3006

For suggestions or comments regarding this order, contact RightsLink Customer Support: customercare@copyright.com or +1-877-622-5543 (toll free in the US) or +1-978-646-2777.

Gratis licenses (referencing $0 in the Total field) are free. Please retain this printable license for your reference. No payment is required.

Figures 5 and 6

Gmail by Google

Image Reprint Permission for Master's Thesis

Deborah Gray Mon, Jun 17, 2013 at 4:30 AM
To: Cloe Klaus

Dear Cloe Klaus

Thank you for your inquiry. Please find below our permission statement:

Nötzli HP, Wyss TF, Stoecklin CH, et al. The contour of the femoral head-neck junction as a predictor for the risk of anterior impingement. *J Bone Joint Surg [Br]* 2002;84-B:556-560. (Figures 2a, 2b, 4a and 4b)

Thank you for your permission request. We are pleased to grant permission for you to reproduce figures 2a, 2b, 4a and 4b from this 2002 article, *provided full and correct acknowledgement of source is given*. On this occasion the permission is granted *free of charge* as the material is to be used in your thesis and therefore falls under the category of academic purposes, and is not for widespread or commercial publication or distribution, but *please note that our fees are usually £550 for a complete article, £110 per page or £55 per table or figure (meaning this request would normally total £220 GBP).*

Our standard acknowledgement is as follows (**please ensure you cite the paper as shown above**):

'Reproduced with permission and copyright © of the British Editorial Society of Bone and Joint Surgery [citation].'

Please note that as a courtesy it is necessary to seek, or make all reasonable attempts to seek, the author's permission in each case. The most recent address can be found on the front page of the article. The current email address we have for corresponding author Prof Dr Nötzli is:

If you have any further questions, please do not hesitate to contact me.

Kind regards,

Deborah

==========
Deborah Gray (Miss)
Production Management Assistant
The British Editorial Society of Bone and Joint Surgery
22 Buckingham Street, London,

www.bjj.boneandjoint.org.uk
==========

Our title has changed to *The Bone & Joint Journal*, formerly known as *JBJS (Br)*

Gmail by Google

Image Reprint Permission for Master's Thesis

Noetzli Hubert Mon, Jul 8, 2013 at 1:03 PM
To: Cloe Klaus

Dear Cloe

You are very welcome to use the Images from our article "The contour of the femoral head-neck junction as a predictor for the risk of anterior impingement," from 2002.

Good luck with your master's thesis, which I find very interesting. Especially your results would also be of high interest for me.
Please let me know if I can be of further help.

Kind regards

Hubert Nötzli

Prof. Dr. med. Hubert P. Nötzli

Hüft- und Beckenchirurgie

Orthopädie Sonnenhof

Buchserstrasse 30

CH-3006 Bern

Von: Cloe Klaus
Gesendet: Sonntag, 7. Juli 2013 23:10
An: Noetzli Hubert
Betreff: Fwd: Image Reprint Permission for Master's Thesis

Dr Nötzli,

I am hoping to use images from your article "The contour of the femoral head-neck junction as a predictor for the risk of anterior impingement," from 2002. I have received permission from The Bone and Joint Journal (below), but they requested I seek your permission as well.

I plan to use figures 2a and 2b, as well as 4a and 4b, within my master's thesis titled "A randomized control trial comparing arthroscopic surgery to conservative management of femoroacetabular impingement," which should be completed August 2013.

Kind regards,
Cloe

---------- Forwarded message ----------
From: **Deborah Gray**
Date: Mon, Jun 17, 2013 at 4:30 AM
Subject: RE: Image Reprint Permission for Master's Thesis
To: Cloe Klaus

Dear Cloe Klaus

Curriculum Vitae

Name: Heather Cloe Klaus

Post-secondary Education and Degrees:

Western University
London, Ontario, Canada
2011 - Present
MSc. (c) Kinesiology – Sport Medicine

Lees-McRae College
Banner Elk, North Carolina, USA
2003 - 2008
B.S. Athletic Training, B.S. Psychology

Research Experience

Hip Arthroscopy Registry
Western University & Fowler Kennedy Sport Medicine Clinic
Status: In Progress
Role: Research Assistant responsible for screening, recruitment, and follow-up of participants from Sept. 2011 – July 2013

Honours and Awards:

Graduate Student Teaching Award Recipient '13 & Nominee '12
Western University, 2011 - 2013

Three-Minute Thesis Finalist
Western University, Spring 2013

Western Graduate Research Scholarship (WGRS)
Western University, 2011 - 2013

Senior Symposium Presenter
Division of Science & Mathematics
Lees-McRae College, 2008

Related Work Experience

Teaching Assistant
Introduction to the Practical Aspects of Athletic Injuries KIN 3336
Western University
2012 - present

Research Assistant
Fowler Kennedy Sport Medicine Clinic
2012 - present

Guest Lecturer presenting The Hip and Groin: Special Topics
Introduction to Athletic Injuries KIN 2236
Western University, Spring 2012 & 2013