11-4-2020 7:00 AM

Lateral Subvastus Lateralis Versus Medial Parapatellar Approach for Total Knee Arthroplasty

Sahil Prabhnoor S. Sidhu, *The University of Western Ontario*

Supervisor: Lanting, Brent A., *The University of Western Ontario*
Co-Supervisor: Teeter, Matthew G., *The University of Western Ontario*
Co-Supervisor: Willing, Ryan, *The University of Western Ontario*
A thesis submitted in partial fulfillment of the requirements for the Master of Science degree in Surgery

# Abstract

The current gold standard surgical approach for Total Knee Arthroplasty (TKA) is a medial parapatellar approach (MPA). We aimed to study a novel lateral subvastus lateralis approach (SLA) for TKA and compare patient outcomes and joint kinematics to the MPA.

Patients with neutral or varus alignment undergoing primary TKA were recruited to undergo the SLA. At one year postoperative, patient outcomes (WOMAC, SF-12, KSS) and joint kinematics (using radio stereometric analysis (RSA)) were analyzed. 7 LPA and 7 MPA patients were compared.

The SLA resulted in improved medial femoral rollback early in flexion, but less “regular” (external) rotation of the femur with respect to the tibia, as compared to the MPA. Patient outcomes were similar between groups.

The SLA may be a viable alternative to the MPA in TKA. Further studies are required to identify any benefits.

Keywords

Knee, arthroplasty, total knee arthroplasty, kinematics, approach

Summary for Lay Audience

Total knee arthroplasty (TKA), or joint replacement, is the gold standard treatment for osteoarthritis of the knee. In conventional TKA, the joint is entered medial to the patella, or "kneecap" (MPA). We aimed to study a novel lateral subvastus lateralis approach (SLA) which spares the medial soft tissues.

Seven patients underwent the SLA and seven patients underwent the MPA. At one year from surgery, the motion of the joint was analyzed using radio stereometric analysis (RSA) and patient outcomes were measured using validated scoring forms.

There was no significant difference in patient outcomes between the surgical approaches. The SLA resulted in perhaps more anatomic motion of the knee early in flexion with respect to the femur rolling back on the tibia, but also less anatomic rotation.

The SLA may be a viable alternative to the MPA in TKA. Further studies are required to identify any benefits.

Co-Authorship Statement

Dr. Brent Lanting: Supervised day-to-day activities, contributed to study design, reviewed and revised manuscript

Dr. Matthew Teeter: Contributed to study design, data analysis, reviewed and revised manuscript.

Dr. Ryan Willing: Contributed to study design, data analysis, reviewed and revised manuscript.

Jordan Broberg: Contributed to data collection and analysis for joint kinematics in chapter 4, reviewed and revised manuscript.

Dr. Lyndsay Somerville: Contributed to data collection and analysis for the systematic review in chapter 3.

Acknowledgments

This thesis would not have been possible without the help and support of several individuals. I would like to sincerely thank **Dr. Brent Lanting** for being so supportive and guiding me through this process. Even with your busy ORs and clinics, you always made time for me.

I would also like to thank **Dr. Ryan Willing** and **Dr. Matthew Teeter** for all their time and support. You were always available for testing and data analysis, and eager to help with any manuscript editing. I very much appreciate everything you did to make this thesis possible.

Furthermore, I would like to thank my parents, **Preet and Rupinder Sidhu**, and my family for supporting me throughout my entire academic career. Even when in the toughest times, your love and support helped me conquer any obstacle.

Finally, I would like to thank anyone who wasn't explicitly mentioned above yet supported me in my academic career.

Dedication

To Preet and Rupinder Sidhu

Thank you for teaching me the value of hard work and supporting me throughout everything.

Table of Contents

List of Abbreviations

TKA	Total knee arthroplasty
MPA	Medial parapatellar approach
SLA	Lateral subvastus lateralis approach
MV	Midvastus approach
SV	Medial subvastus approach
LPA	Lateral parapatellar approach
SF-12	Short form 12
PCS	Physical composite score
MCS	Mental composite score
WOMAC	Western Ontario and McMaster Universities Osteoarthritis Index
KSS	Knee society score
BMI	Body mass index
RSA	Radiostereometric analysis
PS	Posterior cruciate substituting/sacrificing
AAT	Anatomic axis of the tibia
MAT	Mechanical axis of the tibia

AAF	Anatomic axis of the femur
MAF	Mechanical axis of the femur

List of Tables

List of Figures

List of Appendices

Chapter 1

1 Introduction

This chapter provides background information on the knee, osteoarthritis, total knee arthroplasty, and thesis rationale.

1.1 The Knee: Anatomy and Biomechanics

1.1.1 Anatomy Overview

The knee is a complex articulation that dissipates forward momentum during gait and facilitates ambulation (Flandry & Hommel, 2011). It is the largest synovial joint in the body and consists of two separate articulations; the tibiofemoral joint and the patellofemoral joint (Fig 1.1). The tibiofemoral joint is the articulation between the tibia and femur and bears weight. The patellofemoral joint is the articulation between the patella and femur and facilitates knee extension. It provides a fulcrum for the extensor mechanism to function efficiently and keeps the pull of the quadriceps anterior to the femur (Flandry & Hommel, 2011) (Fig 1.2).

The lever arm of a system is defined as the distance from the fulcrum to the point at which a force acts. The patella helps to improve quadriceps efficiency by increasing the lever arm of the extensor mechanism. It does this by displacing the patellar tendon away from the contact point of the joint, which increases the moment arm (Aglietti & Menchetti, 1995).

The knee is commonly divided into three compartments in orthopaedics. These are the patellofemoral joint, or patellofemoral compartment, the medial tibiofemoral joint, or medial compartment, and the lateral tibiofemoral joint, or lateral compartment. As with any synovial joint, the articular portions of the knee are covered in cartilage.

1.1.2 Osteology

In terms of the osteology, the bones of the knee are the distal femur, patella, and proximal tibia. Each consists of cortical bone on the outside and cancellous bone within. The cancellous bone directly below the cartilage is referred to as the subchondral bone.

Both the distal femur and proximal tibia flare out as they approach the joint into condyles. The condyles of the proximal tibia are called the medial and lateral plateau. Between these are the tibial eminences where the cruciate ligaments and menisci attach. The medial tibial plateau has a concave articular surface while the lateral plateau is convex in the anteroposterior direction (Flandry & Hommel, 2011). The tibial tubercle/tuberosity is a bony prominence on the proximal anterior tibia where the patellar tendon attaches. The tibial shaft itself is triangular in the axial plane. Finally, the tibia articulates with the fibular head as shown in figure 1.1.

The distal femur becomes trapezoidal in the cross-sectional plane as it approaches the articular surface (Flandry & Hommel, 2011). The lateral cortex slopes at approximately 10 degrees and the medial cortex at 25 degrees in the axial plane. The medial femoral condyle is more elongated than the lateral, similar to the configuration of the tibial plateaus. Between these lies the intercondylar notch, which serves as the site of attachment for the cruciates.

The patella is the largest sesamoid bone in the human body and lies within the extensor mechanism, between the quadriceps and patellar tendons (Flandry & Hommel, 2011). The articular surface is divided by a vertical ridge into a broad lateral facet, a medial facet, and a smaller odd facet. The patella articulates with the anterior distal femur, or femoral sulcus.

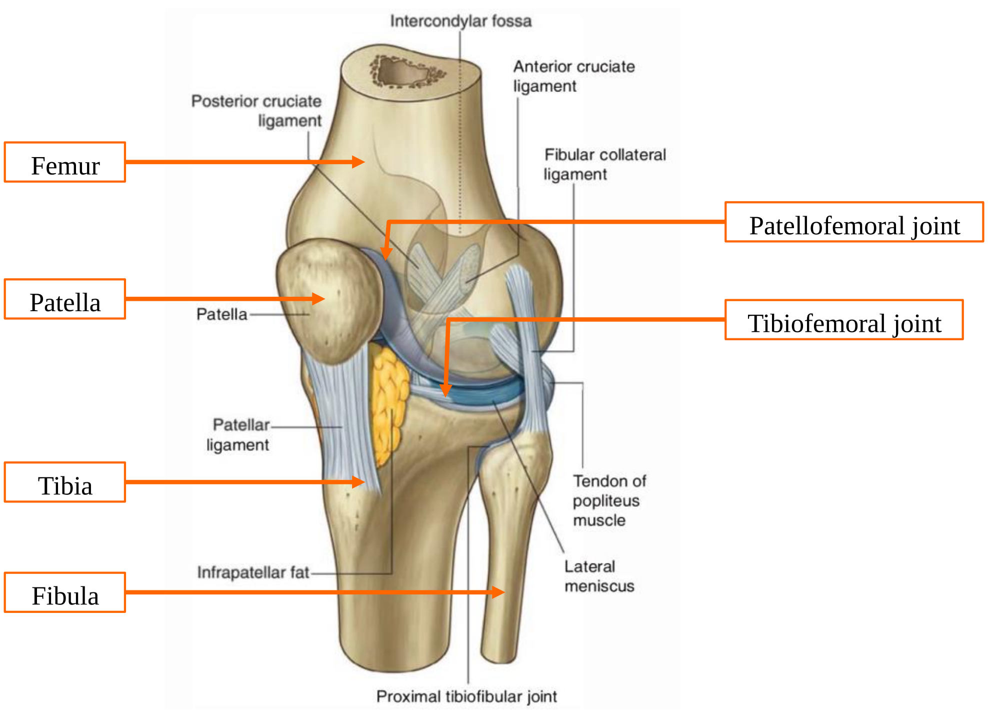

Figure 1.1. Knee anatomy. Image obtained from: Drake, R., Vogle, A., Mitchell, A. (2015). Gray’s Anatomy for Students, 3rd Edition. (Copyright approval license number: 4396780051808)

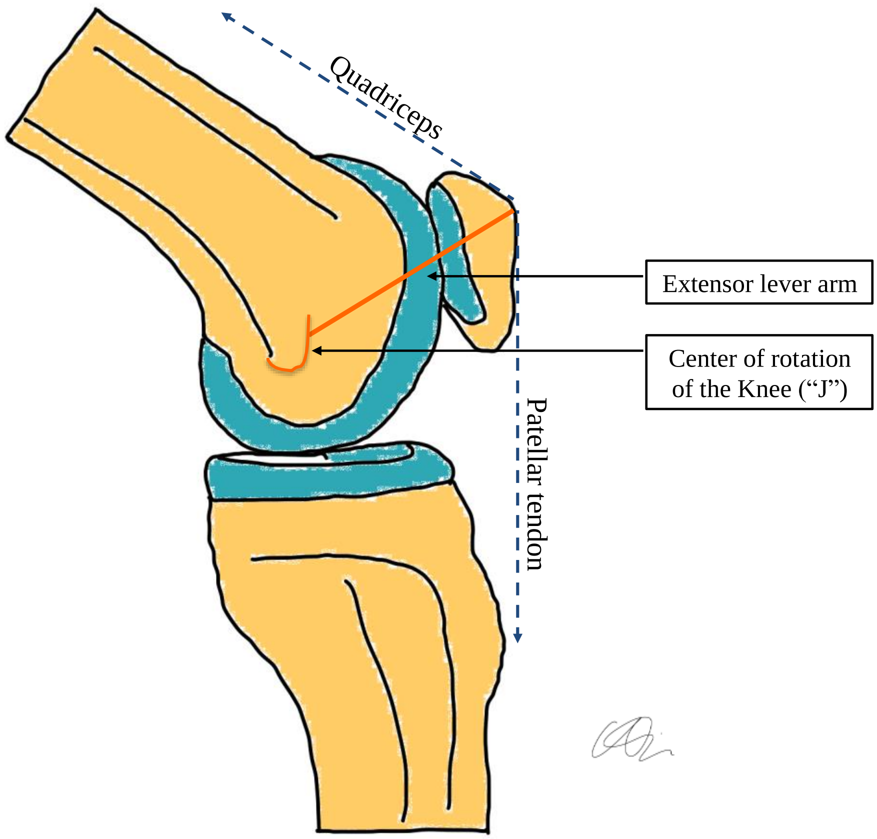

Figure 1.2. Extensor lever arm created by the extensor mechanism (patellar tendon, patellar and quadriceps tendon/muscle). Original drawing by Dr. Charles Dion, used with permission.

1.1.3 Soft Tissues of the Knee

The soft tissue structures of the knee are key in conferring and maintaining a stable joint. These consist of the menisci, ligaments, muscles, capsule and retinaculum (Flandry & Hommel, 2011; Masouros et al., 2010).

The menisci are two fibrocartilaginous structures within the medial and lateral compartments of the knee. They assist in load bearing by acting as shock absorbers, provide a contact area, and add to the stability of the joint. The medial meniscus is slightly broader than the lateral meniscus, which is more saucer shaped and more triangular in the cross-sectional plane. The anterior roots of the menisci are connected by the transverse ligament and both the anterior and posterior roots attach to the tibia. The menisci also join with the capsule peripherally. The medial meniscus, which is more stable than the lateral, is also anchored to the posterior oblique ligament and medial collateral ligament (Flandry & Hommel, 2011). Posteriorly, the lateral meniscus is anchored to the distal femur by the ligaments of Wrisberg and Humphrey.

The primary ligaments of the knee are the medial collateral ligament (MCL), lateral collateral ligament (LCL), anterior cruciate ligament (ACL), and posterior cruciate ligament (PCL). The cruciates originate in the intercondylar notch of the femur (Flandry & Hommel, 2011). The ACL originates at the lateral femoral condyle and attaches at the medial tibial eminence. It prevents anterior translation of the tibia as well as confers some rotational stability, particularly with internal rotation. Similarly, the PCL originates from the medial femoral condyle and inserts on the posterior surface of the proximal tibia. It prevents posterior translation of the tibia. Both cruciates are comprised of two bundles; the ACL consists of the anteromedial bundle (tight in flexion) and posterolateral bundle (tight in extension), and the PCL consists of the anterolateral bundle (tight in flexion) and posteromedial bundle (tight in extension). The LCL originates at the lateral femoral condyle and inserts at the fibular head. It resists varus stress. The MCL originates at the medial femoral condyle and inserts posterior to the pes anserinus on the tibia (Flandry & Hommel, 2011). Similarly, it helps resist valgus stress.

Finally, the muscles surrounding the knee confer dynamic stability and allow for motion. These are the quadriceps, hamstrings, adductors, gastrocnemius, and popliteus. The quadriceps consist of the vastus medialis, vastus intermedius, vastus lateralis, and rectus femoris. The hamstrings are comprised of the biceps femoris long and short heads, semimembranosus, and semitendinosus. The most important adductor for dynamic stability of the knee is gracilis (Hirschmann & Müller, 2015).

1.1.4 Kinematics of the Knee

Although the knee can be thought of as a hinged joint, it truly has 6 degrees of freedom; 3 planes of translation and 3 rotations (Fig 1.3).

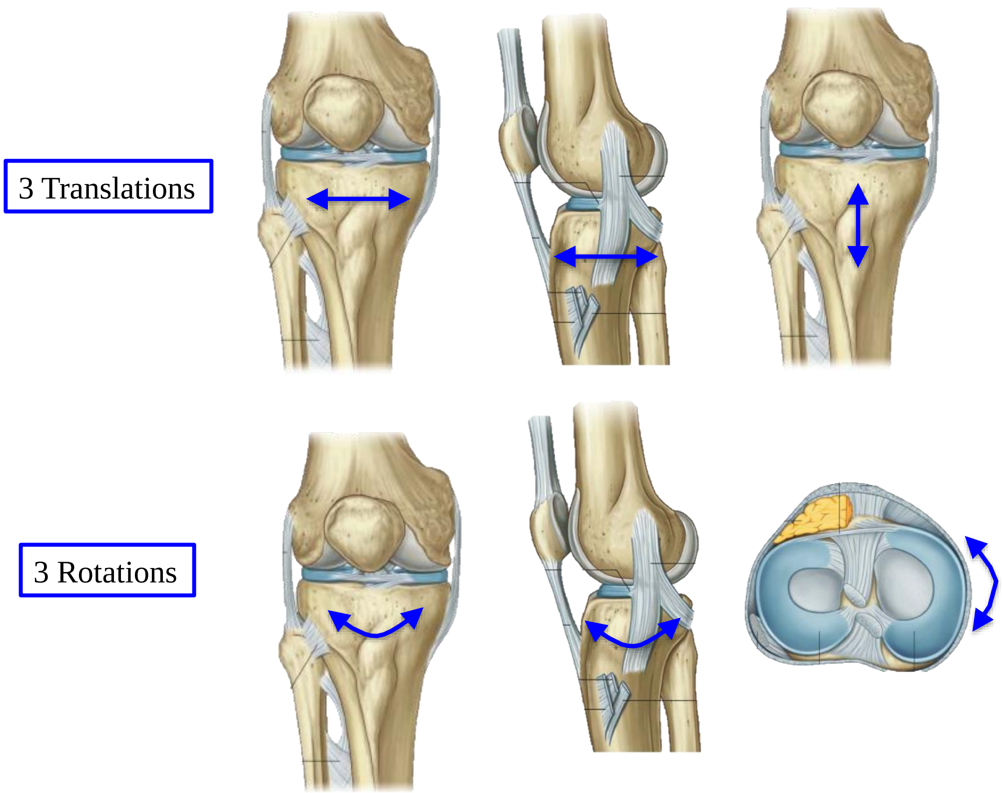

Figure 1.3. Degrees of freedom of the knee. Image modified from original obtained from: Drake, R., Vogle, A., Mitchell, A. (2015). Gray's Anatomy for Students, 3rd Edition. (Copyright approval license number: 4396780051808)

When it comes to describing the motion of the knee, either the femur or the tibia can be thought of as moving relative to the other. For our study and to more closely simulate a weight bearing scenario, we will refer to motion of the femur relative to the tibia. In its primary plane of motion, the knee moves between flexion and extension. As the knee flexes, the femoral condyles move posteriorly in a phenomenon called "femoral rollback". This translates the femoral center of rotation posteriorly and allows for the complete flexion in a native knee (Flandry & Hommel, 2011; Freeman & Pinskerova, 2005; Zingde & Slamin, 2017). The femoral center of rotation follows a "J" shaped path.

As the medial compartment is less mobile than the lateral, the femur also externally rotates with respect to the tibia during flexion. On average, lateral compartment rollback is 21 mm and medial compartment roll back is 1.9 mm, which leads to 21 degrees of rotation on average (Freeman & Pinskerova, 2005; Zingde & Slamin, 2017). As the knee extends fully, the femur internally rotates as part of the "screw home mechanism" which facilitates knee locking and efficient standing.

1.1.5 Knee Alignment

Understanding the alignment of the knee depends on 3 axes; the mechanical axis, vertical axis, and anatomic axis (Fig 1.4). The mechanical or weight bearing axis is a line drawn from the center of the femoral head to the center of the talus (Lording et al., 2016). Ideally, this passes through the center of the knee for neutral alignment. If it passes medial to the center of the knee, alignment is referred to as varus, and if it passes lateral to the knee centre, the alignment is in valgus. The medial compartment generally bears 60-70% of the load on the knee (Egloff et al., 2012). The vertical axis is simply a line drawn straight down from the pubic symphysis. The vertical and mechanical axes differ by 3 degrees. Similarly, the mechanical axis of the femur (MAF) is a line from the centre of the femoral head to the centre of the notch. The mechanical axis of the tibia (MAT) is a line from the centre of the tibial plateau to the centre of the talus. The anatomic axis of the femur and tibia are simply lines drawn down the centre of the intramedullary canals. The MAF and anatomic axis of the femur (AAF) differ by 5-7 degrees while the anatomic axis of the tibia (AAT) and MAT are typically the same. The hip-knee-ankle

(HKA) angle is the difference between the MAF and the MAT and is commonly used to describe the coronal alignment of the knee (Cooke et al., 1994; Hsu et al., 1990; Moser et al., 2019). A HKA of 180 degrees is considered as being “neutral” (Moser et al., 2019). A value larger than 180 means the knee is in valgus while a value lower than 180 is defined as varus. Although a neutral HKA was initially thought of as being physiologic, numerous studies have demonstrated that most native knees fall slightly outside this value. A recent systematic review of 15 studies by Moser et al. showed mean HKA ranged from 176.7-180.7 degrees (Moser et al., 2019). Bellemans et al. defined neutral alignment as 180 +/- 3 degrees, with constitutional varus being anything below that range and constitutional valgus being anything greater (Bellemans et al., 2012). They found 32% of male knees and 17.2% of female knees were in constitutional varus, while 2% of males and 2.8% of females were in constitutional valgus. A study by Vandekerckhove and Lanting showed that constitutional varus alignment also contributes significantly to varus osteoarthritis (Vandekerckhove et al., 2017).

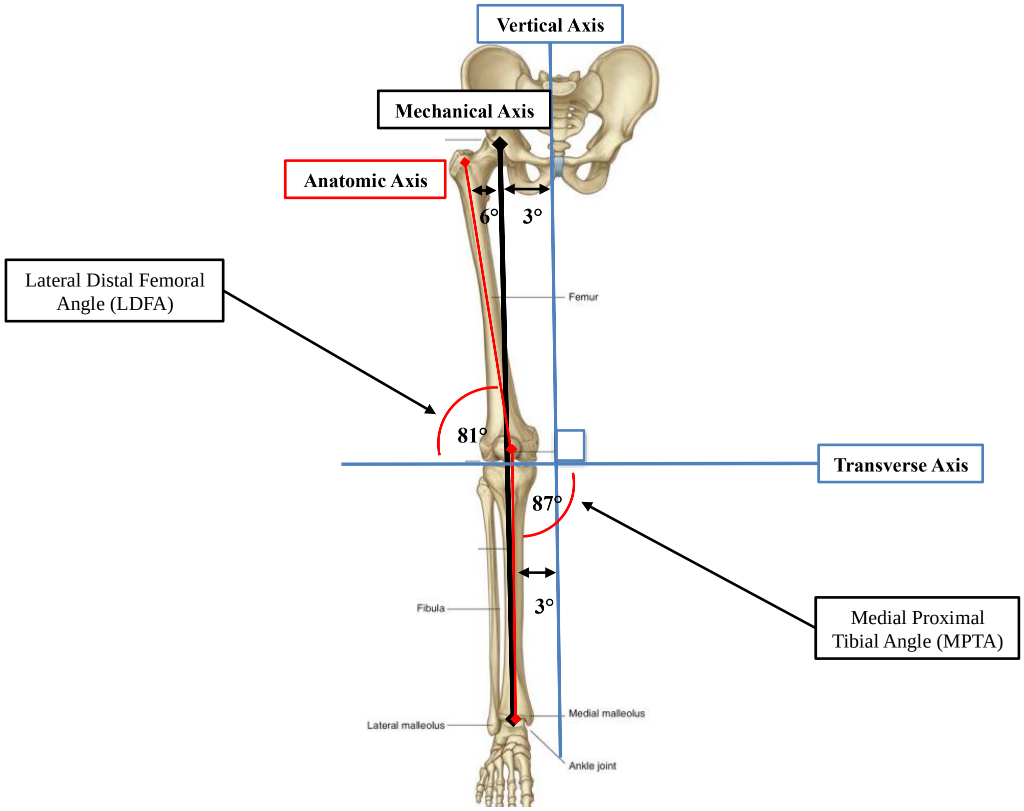

Figure 1.4. Alignment of the lower limb and knee. Image modified from original obtained from: Drake, R., Vogle, A., Mitchell, A. (2015). Gray's Anatomy for Students, 3rd Edition. (Copyright approval license number: 4396780051808)

The joint line orientation is another important aspect in coronal alignment. The joint line angle of the femur is measured between the MAF and a tangent line to the femoral condyles at the articular surface (Moser et al., 2019). Similarly, the joint line angle of the tibia is defined as the angle between the articular surface and the MAT. The joint line is normally in 3 degrees of varus, meaning the femoral joint line is in 3 degrees of valgus and the tibial joint line is in 3 degrees of varus, relative to their mechanical axes (Moser et al., 2019).

In terms of sagittal alignment, an important measurement is the posterior tibial slope (PTS), which is the angle between anatomic axis of the tibia and the articular surface. Values differ with ethnicity and sex. In a recent CT study of 378 patients, Pangaud et al. found the mean PTS to be 6.3 degrees with a range of -5.5 to 14.7 degrees (Pangaud et al., 2020).

1.2 Osteoarthritis and the Knee

Osteoarthritis is a condition characterized by progressive loss of cartilage in a synovial joint (McGrory et al., 2016). One of the most commonly affected joints is the knee and this condition can lead to significant pain, stiffness, and disability. With the increasing age of the North American population, as well as higher rates of obesity, the prevalence of osteoarthritis has also increased (McGrory et al., 2016). In fact, recent studies have quoted osteoarthritis as the leading cause of adult disability in the United States (Kurtz et al., 2007; Murphy & Helmick, 2012). Approximately ten percent of adults over the age of fifty five have painful, disabling knee osteoarthritis and as many as twenty five percent of these are severely disabled (Peat et al., 2001).

Treatment modalities for knee arthritis vary, ranging from nonoperative modalities to surgical management. Non operative management can include medications, such as anti-inflammatories and narcotics, intraarticular injections, and activity modification (McGrory et al., 2016). Many patients, however, fail non-operative management and approximately five percent of patients with knee osteoarthritis undergo surgical intervention (McGrory et al., 2016). Surgical management can take place in the form of an osteotomy or unicompartmental arthroplasty for select patients, but the gold standard remains a total knee arthroplasty (TKA). TKA is a common procedure. In fact, it is the most common reason for inpatient hospitalization in the United States (Maradit Kremers et al., 2015). Furthermore, the demand for total knee arthroplasty is dramatically increasing, with a projected increase of 143% in TKA procedures in the United States alone by 2050 (Inacio et al., 2017). Thus it remains a very relevant field to study.

1.3 Total Knee Arthroplasty

1.3.1 Overview of TKA

Total knee arthroplasty (TKA) is a procedure for the treatment of osteoarthritis where the articular portions of the joint are resected and replaced with a prosthetic joint. Figure 1.5 illustrates the bony cuts and potential components involved.

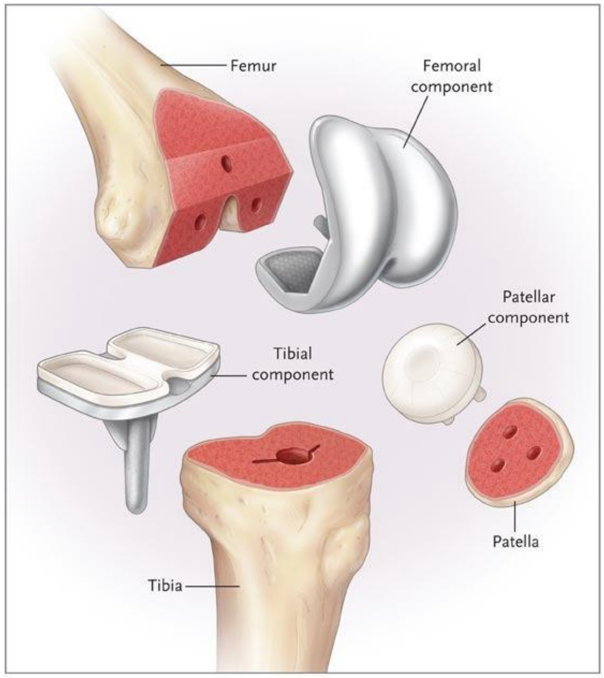

Figure 1.5. Bony resection and prosthetic components in total knee arthroplasty. Reproduced with permission from (Leopold, 2009), Copyright Massachusetts Medical Society.

1.3.2 Cruciate Retaining and Posterior Cruciate Substituting TKAs

Two common distinctions between different TKA designs is whether they are cruciate retaining (CR) or cruciate substituting (PS). In PS knees, the PCL is sacrificed and a cam and post mechanism prevents displacement and facilitates femoral rollback. In CR knees, the PCL is retained. The rationale for using CR knees is that it theoretically mimics the kinematics of a native knee more closely and is less constrained. Registry data has shown improved survivorship and lower revision rates in CR knees as compared to PS knees (Abdel et al., 2011; Comfort et al., 2014; Vertullo et al., 2017). RCTs, however, have shown only minor functional differences and no survivorship difference between the two (Bercik et al., 2013; Li et al., 2014; Scott & Smith, 2014; Vertullo et al., 2017); the concern with these is that they may be underpowered and lack the long-term follow-up that registry data can provide (Verra et al., 2015; Vertullo et al., 2017).

CR and PS knees may also differ in terms of kinematics (Victor et al., 2005). Results for CR knees vary, but several studies have demonstrated unphysiological roll forward motion of the medial femoral condyle during flexion (S. Banks et al., 2003; S. A. Banks et al., 1997; Dennis et al., 2003; Haas et al., 2002; Udomkiat et al., 2000). Lateral sided rollback during flexion is improved with PS knees, as is range of motion.

1.4 TKA Approaches

1.4.1 Surgical Approach Overview

Many approaches have been described for total knee arthroplasty (TKA), including the medial parapatellar (MPA), subvastus medialis, midvastus, trivector-retaining, and lateral parapatellar approach. The most commonly used of these is the medial parapatellar approach, which is considered the standard to which others are compared. In a standard medial parapatellar approach, a midline incision is used. Appropriate skin flaps are raised, and a medial parapatellar arthrotomy is used. The fat pad and menisci are resected along with the ACL. The exposure includes elevating the deep MCL, typically to the mid coronal plane off the tibia.

1.4.2 Medial Parapatellar Approach

Each approach has its advantages and disadvantages. The medial parapatellar allows for excellent exposure and is relatively straightforward to perform (Vaishya et al., 2016). The negative aspects of this approach include violating the extensor mechanism of the knee. In particular, the arthrotomy is performed by incising the quadriceps mechanism at its junction with the vastus medialis, which can theoretically destabilize the patella (Von Langenbeck, 1878). Patellar vascularity can also be compromised and the superior lateral genicular artery may be the only remaining source of blood supply after the medial parapatellar approach and fat pat excision (Stern et al., 1991). The infrapatellar branch of the saphenous nerve is also at risk medially, as it becomes subcutaneous after exiting the fascia between sartorius and gracilis. Injury to this may cause increased postoperative pain and painful neuroma (Stern et al., 1991). The prevalence of damage to the infrapatellar branch of the saphenous nerve as a postoperative complication varies greatly in the literature, with rates ranging from 0.5-53% (Xiang et al., 2019).

1.4.3 Subvastus Medialis Approach

The subvastus medialis approach was first popularized in 1991 by Hofmann, who sought out a more anatomic approach to the knee (Hofmann et al., 1991). This approach also involves a midline skin incision and development of flaps. From there, the border of the vastus medialis is visualized, its fascia is incised, and the vastus medialis is bluntly elevated from the medial intermuscular septum (Vaishya et al., 2016). Advantages of this approach include the fact that it does not violate the extensor mechanism. Additionally, it leaves the majority of vessels supplying the patella intact, if the dissection is carried out carefully (Vaishya et al., 2016). Unfortunately, the subvastus medialis approach is limited by difficulty with exposure and everting the patella (Matsueda & Gustilo, 2000; Roysam & Oakley, 2001). Currently, it is typically only used in thin patients with mobile tissues undergoing primary total knee arthroplasty. Randomized controlled trials comparing this approach to the medial parapatellar have provided mixed results. Some, such as that by Roysam et al. demonstrated earlier straight leg raise, reduced blood loss, lower opiate consumption, improved patellar tracking, and better knee flexion earlier in the recovery process (Roysam & Oakley, 2001). A recent high quality meta-analysis of randomized control trials showed that the medial subvastus approach resulted in improved range of motion at one week post operative ($p<0.05$), but no significant difference at six weeks or later (Liu et al., 2014) as compared to the medial parapatellar. The subvastus group also had earlier ability to straight leg raise. Otherwise, there were no significant differences in outcomes or complication rates.

1.4.4 Midvastus Approach

The midvastus approach for TKA is a modification of the subvastus first described by Engh et al. in 1997 (Engh et al., 1997). It also is a quadriceps sparing approach but allows for easier exposure as compared to the subvastus. This approach involves splitting the vastus medialis in line with the muscle fibers proximally (Engh et al., 1997; Keating et al., 1999). Distally, the arthrotomy is carried out similar to the medial parapatellar approach, ending medial to the tibial tubercle. Similar to the other quadriceps sparing approaches, the midvastus offers the theoretical benefits of improved patellar tracking, decreased postoperative pain, and quicker return of quadriceps strength (Keating et al., 1999). Results in the literature have been mixed. An early study by Keating et al. in 1999 comparing short term outcomes between the midvastus and medial parapatellar approach found no difference in range of motion, straight leg raise, extensor lag, or rehab at time of discharge (Keating et al., 1999). There was a higher rate of postoperative hematoma and manipulation in the midvastus patients, leading the group to conclude that they could not recommend this approach. Subsequent studies have been more promising. A recent meta-analysis of 32 randomized controlled trials demonstrated midvastus patients had significantly lower pain scores at 2 weeks postoperative as compared to medial parapatellar patients, but found no difference at other time points (Liu et al., 2014). Range of motion was also significantly greater at 1 week postoperatively for the midvastus group, but there was no difference at other time points. Midvastus approaches took significantly longer in terms of surgical time than medial parapatellar approaches. There was also no difference in Knee Society Score (KSS), time to straight leg raise, intraoperative blood loss, length of hospital stay, or postoperative complications (Liu et al., 2014).

1.4.5 Lateral Parapatellar Approach

Another previously described approach is the lateral parapatellar approach, which was first described in 1982 and later popularized by Keblish in 1991 (Cameron, 1991; P. A. Keblish, 1991). This approach involves a midline or slightly lateral skin incision, with a parapatellar arthrotomy made lateral to the patella. While also technically demanding

(P. A. Keblish, 1991), it allows for more direct access to lateral soft tissues in valgus knees (Vaishya et al., 2016). This is important as valgus knees tend to be tight laterally and lax medially. As such, soft tissue releases need to be carried out on the lateral side of the knee and any medial releases could further promote laxity on that side. Some proponents use this approach in valgus knees because they fear a standard medial parapatellar approach would further promote patellar maltracking (Peter A. Keblish, 2003). Additionally, the lateral parapatellar approach leaves the medial vasculature and nervous structures undisturbed (Vaishya et al., 2016). It does, however, violate the quadriceps and extensor mechanism. Studies on the lateral parapatellar approach unfortunately focus on valgus knees, with little data present analyzing this approach in varus or neutral knees. Furthermore, many studies incorporate use of a tibial tubercle osteotomy, which makes results difficult to interpret. Nonetheless, several studies have demonstrated promising outcomes with this approach in valgus knees. Sekiya et al. found improved postoperative flexion in the lateral parapatellar group ($p<0.001$), but employed extensive lateral releases, including the iliotibial band in many cases (Sekiya et al., 2014). They found no difference in surgical time, complications, blood loss, postoperative alignment, laxity, patient reported outcome scores, and Knee Society Scores (KSS). A recent Chinese meta-analysis of four randomized control trials also compared the lateral parapatellar approach to the medial parapatellar approach for valgus knees (Xu et al., 2020). This study found improved Knee Society Scores in the lateral group, but similar alignment, operative time, blood loss, Western Ontario and McMaster Universities Osteoarthritis Index, range of motion, postoperative pain, and range of motion.

1.5 Thesis Rationale

1.5.1 Rationale Overview

Despite numerous advances in modern TKA techniques, implants, and rehabilitation protocols, 10-30% of patients report some degree of dissatisfaction after undergoing TKA (Bourne et al., 2010; Van Onsem et al., 2019). Patient complaints include persistent pain, stiffness, and functional impairment. With this being such a common procedure with increasing prevalence, we sought to potentially improve total knee arthroplasty through a novel surgical approach, the lateral subvastus lateralis (Fig 1.7).

Our project aims to study an approach which may provide the benefits of the above approaches while minimizing their disadvantages. In particular, this study investigates a novel lateral subvastus lateralis approach (SLA) for total knee arthroplasty. This approach has the potential to allow for more “anatomic” lateral access; it offers the benefit of keeping the extensor mechanism and medial vasculature intact while allowing for direct access to lateral soft tissues. The SLA could also result in less cutaneous nerve damage and postoperative pain, as the subcutaneous nerve plexus on the lateral side of the knee is less developed than it is medially (Niki et al., 2011). Although the exact lateral innervation of the knee has not been well described and involves contributions from both the saphenous nerve and lateral cutaneous nerve of the thigh, damage to the infrapatellar branches of the saphenous nerve has been described as leading to anterior pain and an altered lateral area of sensation (Tennent et al., 1998). Thus, the SLA has the potential for improving postoperative pain scores, as well as functional outcome scores and range of motion due to its quadriceps sparing nature. To our knowledge, this approach has not been previously described in English literature other than preliminary studies done at our institution; a literature search conducted in PubMed and MEDLINE yielded no relevant results.

1.5.2 Prior Anatomic Work

Notably, we have performed cadaveric anatomic studies with good outcomes using this novel approach (Lanting et al., 2020). Lanting et al. described the details of performing this surgical approach. To review, in a standard medial parapatellar approach, a midline incision is used, skin flaps are raised, and a medial parapatellar arthrotomy is used. The fat pad and menisci are resected along with the ACL and the deep MCL is elevated/released to the mid coronal plane off the tibia. In a lateral subvastus lateralis approach however, the skin incision is slightly lateral to mid line; slightly more laterally proximally and ending just lateral to the tibial tubercle (Fig 1.7). After elevating appropriate skin flaps, the vastus lateralis is identified. The fascia is split lateral to the vastus lateralis, and extended to the patella, continuing distally along the lateral aspect of the patellar tendon to the tibial tubercle. As required, the exposure is extended laterally to gain an appropriate degree of exposure to allow entry for the saw blade for the proximal tibial cut.

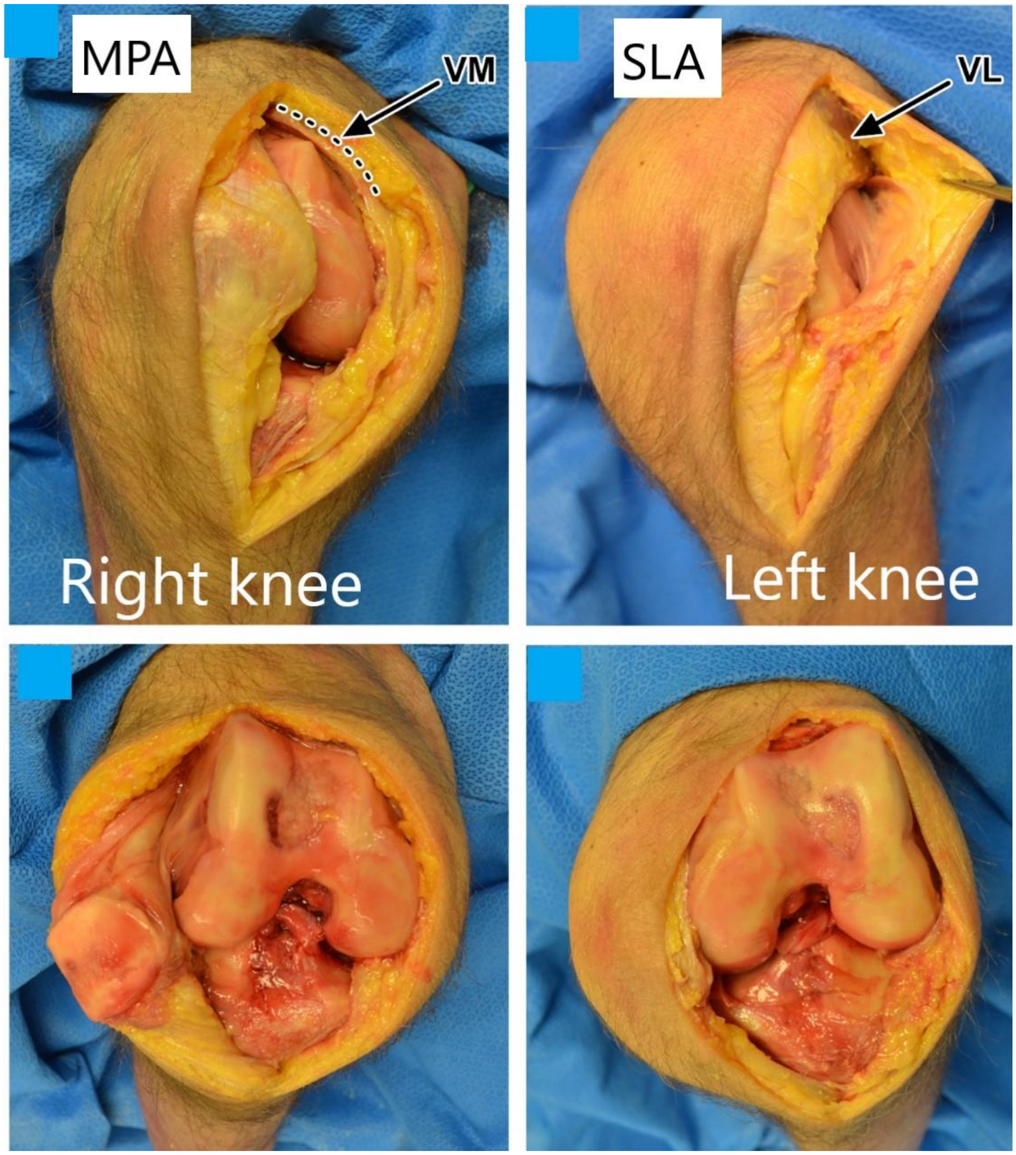

Figure 1.6. The lateral subvastus lateralis approach (SLA) and the conventional medial parapatellar approach (MPA). Image modified from original obtained from Dr. Brent Lanting, with permission.

Legault et al. investigated the length of incision required, visibility/adequacy of exposure provided, and patellar tracking in the subvastus lateralis approach (Josee A. Legault et al., 2018). To do this, they randomized twenty two cadavers to a medial parapatellar or lateral subvastus lateralis approach. They found no significant difference in incision length. Adequacy of exposure was also found to be comparable, with the subvastus lateralis approach giving increased visibility of the lateral femoral condyle and decreased visibility of the medial border or the tibial plateau, as compared to a medial parapatellar approach. This study also found the lateral subvastus approach to have improved patellar tracking and decreased damage to the quadriceps and extensor mechanism. Patellar tracking was measured quite subjectively, however. Of note, the subvastus lateralis approach did have increased incidence of disruption of the distal lateral fibres of the patellar tendon.

1.5.3 Kinematics and Stability

Other than patient outcome measures and postoperative outcome scores, our study also aims to investigate knee kinematics using the lateral subvastus lateralis approach. Kinematics refers to the motion of the femur or femoral component relative to the tibia or tibial component. In a native knee, there is femoral rollback relative to the tibia, meaning the center of rotation on the femur moves posteriorly with knee flexion (Victor et al., 2005). This is necessary to increase flexion range of motion and avoid impingement. Biomechanically, the goal of total knee arthroplasty is to mimic the kinematics of a native knee as closely as possible. However it is well known that the kinematics of a knee after arthroplasty do not exactly match that of a native knee, using conventional implants or surgical approaches (Victor et al., 2005). Common differences demonstrated in prior studies include decreased posterolateral femoral rollback, abnormal axial rotation between the femur and the tibia throughout the range of movement, a different centre of rotation of the knee in the horizontal plane, and condylar lift-off (Victor et al., 2005).

Our rationale for studying postoperative kinematics is that it directly relates to the stability of the knee. Stability largely depends on balancing, which is a key step in total knee arthroplasty. This is relevant, as a major cause of dissatisfaction after total knee arthroplasty is instability, with several studies listing instability as the third leading cause of revision in TKA (Daems et al., 2016; Kannan et al., 2015; Toutoungi et al., 2000). Thus, the importance of properly balancing the knee cannot be overemphasized. The other top two reasons for revision are stiffness and infection. Of these three, all but infection could be secondary to surgical technique. Therefore, an approach that will maximize medial stability (by better preserving the deep MCL) may allow for maintenance of a medial pivot and more physiological motion in the lateral compartment.

Recent literature has shown that certain kinematic patterns may be associated with poor patient outcomes in TKA (Van Onsem et al., 2019). Specifically in closed chain exercises, more pronounced anterior femoral motion on the medial side, mid-flexion instability, and decreased posterior femoral translation in the lateral compartment with deep flexion has been associated with lower patient reported outcome scores (Van Onsem et al., 2019). Furthermore, increased anterior translation can also decrease the lever arm for knee extension and lead to impaired quadriceps efficiency, which can also cause patient dissatisfaction (Furu et al., 2016).

1.5.4 Prior Biomechanical Work

We have demonstrated promising biomechanical outcomes with the lateral subvastus lateralis approach as well. Cadaveric trials were conducted prior to proceeding with patient trials to ensure that this approach provides a stable knee. Our group sought to conduct a cadaveric biomechanical study comparing kinematics and laxity of a lateral subvastus lateralis approach to a medial parapatellar approach. This project used 14 fresh frozen cadaveric knees randomized to a medial parapatellar approach or a lateral subvastus lateralis approach. Specimens were cycled in a Vivo joint simulator and kinematics and laxity tested. Overall, there was no significant difference between approaches. This helped justify that prospective patient trials were a feasible next step in studying this approach.

1.5.5 Pseudo Dynamic Fluoroscopy

Pseudo dynamic fluoroscopy, or radiostereometric analysis (RSA), is a technique used to measure joint kinematics. It involves using a biplane calibration cage and RSA software to match x-rays to 2D/3D CAD models of femoral and tibial components (Teeter et al., 2017). This allows for the tracking of femoral and tibial component positions relative to each other at various degrees of flexion, using weightbearing AP and lateral images. This approach has been demonstrated as having excellent accuracy, with an error of 0.19 mm for translation and 0.52 degrees for rotation (Teeter et al., 2017).

Use of RSA analysis could help justify that the lateral subvastus approach provides a stable joint with motion similar to that of a conventional total knee arthroplasty or native joint. As discussed earlier, very little literature exists correlating certain kinematic patterns to patient satisfaction. Ultimately, a joint motion path similar to that of medial parapatellar approach knees would theoretically suggest the subvastus lateralis approach provides comparable long term outcomes.

Overall, there is no literature investigating the lateral subvastus lateralis approach other than recent biomechanical and cadaveric studies conducted at our institution. There is no patient data available yet on this approach. This project aims to bridge that gap and provide more insight into an approach that has the potential to improve a common high volume surgical procedure.

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Chapter 2

2 Thesis Purpose, Objectives, and Hypotheses

This chapter provides an overview of the purpose.

2.1 Purpose

The purpose of this thesis is to understand the effect of surgical approach on patient outcomes when performing a total knee arthroplasty (TKA), with a focus on the novel subvastus lateralis approach. As a first step, we will retrospectively review one of the author's TKA patients to compare outcomes between other surgical approaches (medial parapatellar, midvastus, medial subvastus, and lateral parapatellar). We will then compare a novel lateral subvastus lateralis approach (SLA) to the conventional medial parapatellar approach (MPA) for total knee arthroplasty in consenting patients. In this prospective study, patients who undergo the subvastus lateralis approach will be followed postoperatively with patient reported outcome measures (Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), Short Form 12 (SF-12), Knee Society Score (KSS)) and quasi-static stereo radiography (pseudo dynamic fluoroscopy) to assess joint kinematics. Outcomes will be compared to a group undergoing a standard medial parapatellar approach. Intraoperative and postoperative complications will also be recorded.

2.2 Objectives

1. To retrospectively review and compare patient reported outcome measures (WOMAC, SF-12, KSS) between patients undergoing TKA via medial parapatellar, midvastus, medial subvastus, or lateral parapatellar approach.

2. To compare patient reported outcome measures (WOMAC, SF-12, KSS) between patients undergoing TKA via a SLA versus a MPA.

3. To compare joint kinematics using pseudo dynamic fluoroscopy between patients undergoing TKA via SLA versus MPA.

4. To report on and compare intraoperative and postoperative complications between the SLA group versus MPA group.

2.3 Hypotheses

We hypothesize that patients undergoing the SLA will have lower postoperative pain scores as compared to MPA patients, as the subcutaneous nerve supply is less developed laterally on the knee (Niki et al., 2011). Otherwise we expect there will be no significant difference in patient reported outcome measures between the two groups. We anticipate the intraoperative complication rate in SLA patients may be higher, as any novel surgical approach can have a learning curve.

With regards to joint kinematics, we hypothesize the SLA knees will have a lateral pivot point and not significantly differ from MPA knees. This is consistent with joint motion patterns in prior pseudo dynamic fluoroscopy studies, which have also demonstrated that joint kinematics depend largely on implant design (Morcos et al., 2019; Teeter et al., 2017).

2.4 References

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Chapter 3

3 Does Surgical Approach Affect Patient Outcomes in Total Knee Arthroplasty?

This chapter presents a retrospective review of patient outcomes at our institution based on surgical approach used. This review was done to add context and for better understanding of the thesis topic.

3.1 Introduction

Many approaches have been described for total knee arthroplasty (TKA), including the medial parapatellar (MPA), subvastus medialis, midvastus, and lateral parapatellar approach. The most commonly used of these is the medial parapatellar approach, which is considered the standard to which others are compared.

In a standard medial parapatellar approach, a midline incision is used and a medial parapatellar arthrotomy is made. It allows for excellent exposure and is relatively straightforward to perform (Vaishya et al., 2016). A subvastus medialis approach typically also involves a midline skin incision, but the incision may be positioned more oblique and medially. From there, the border of the vastus medialis is visualized, its fascia is incised, and the vastus medialis is bluntly elevated from the medial intermuscular septum (Hofmann et al., 1991; Vaishya et al., 2016). Engh et al. described a modification to the subvastus approach in which the vastus medialis is split in line with its muscle fibers proximally; this was named the midvastus approach (Engh et al., 1997). Finally, the lateral parapatellar approach also involves a midline incision, but may be positioned lateral to the tibial tubercle. The arthrotomy is made lateral to the patella (P.

A. Keblish, 1991) and extends into the quadriceps tendon, leaving a small lateral margin to enable repair.

Each approach has its advantages and disadvantages. For example, although the medial parapatellar approach provides an excellent view of the joint, it involves violating the extensor mechanism and medial structures (Vaishya et al., 2016). The subvastus medialis and midvastus approaches are “quadriceps sparing”, but are more technically difficult to perform and often saved for thinner patients (Engh et al., 1997; Hofmann et al., 1991; Keating et al., 1999; Matsueda & Gustilo, 2000; Roysam & Oakley, 2001; Vaishya et al., 2016). They may also result in decreased accuracy of implant positioning (Yuan et al., 2017). The lateral parapatellar approach provides direct access to lateral structures in valgus knees and spares medial soft tissues, but also can be technically challenging (P. A. Keblish, 1991; Vaishya et al., 2016). It has also been described in conjunction with a tibial tubercle osteotomy (TTO), which is a procedure that carries its own inherent risks, such as nonunion.

Although several randomized control trials exist comparing the subvastus medialis and midvastus approaches to the medial parapatellar approach, sample sizes are small and the results are mixed. For example, Cho et al. found results favouring the midvastus approach in terms of early quadriceps strength, Varnell et al. found results favouring the medial parapatellar approach in terms of functional ability measured by the ability to negotiate stairs, Varela-Egocheaga et al. found results favoring the subvastus medialis approach in terms of range of motion and Knee Society Score, and Heekin et al. found no significant difference between these approaches in terms of Knee Society Score, range of motion, surgical time, and blood loss (Cho et al., 2014; Heekin & Fokin, 2014; Pan et al., 2010; Varela-Egocheaga et al., 2010; Varnell et al., 2011).

Similarly, RCTs comparing the lateral and medial parapatellar approaches also tend to have small sample size and showed mixed results. Many studies also incorporate use of a tibial tubercle osteotomy, which makes results difficult to interpret. Nonetheless, several studies have demonstrated promising outcomes, such as improved range of motion and Knee Society Scores, with this approach in valgus knees (Sekiya et al., 2014; Xu et al., 2020).

Given the small sample size and mixed results of existing studies, we aimed to add to the body of literature by retrospectively reviewing patients at our institution and comparing outcomes of the subvastus, midvastus, and lateral parapatellar approaches to the standard medial parapatellar approach.

3.2 Materials and Methods

After obtaining approval by our institutional ethics board, the institutional database was queried to identify patients having undergone primary total knee arthroplasty between 2015 and 2019. Patients were included if they were over the age of 30 and underwent primary total knee arthroplasty for osteoarthritis. Revision cases were excluded, as were patients that underwent arthroplasty for a reason other than osteoarthritis. All total knee arthroplasties were performed by a single surgeon at our institution with the vast majority of cases using a Stryker Triathlon implant.

Patient demographics were recorded. Short Form 12 (SF-12), Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), Knee Society Total Score (KSS), Knee Society function scores, and range of motion (ROM) were recorded at yearly intervals from the initial surgical date. Any instance of revision, as well as the reason for revision, were also recorded.

Charts were retrospectively reviewed by the lead author to categorize patients by surgical approach utilized. Patient groups were matched using propensity score matching for age, BMI, and sex. Propensity score matching is a common technique used in medical research (Luo et al., 2010). A propensity score was generated for age, BMI, and sex for each patient and patients were manually matched by the lead author. Statistical analysis between groups was done using SPSS (IBM SPSS Statistics 23). The student's t-test was used to compare the cohorts; Welch's t-test was used where there was inability to assume similar variance.

3.3 Results

Medial Parapatellar versus Midvastus Approach

After matching for age, BMI, and sex, sixty-eight patients met inclusion criteria for the medial parapatellar group with a mean age of 66.7 +/- 9.6 and a mean BMI of 30.5 +/-4.8. Sixty-eight patients were included in the midvastus group with a mean age of 68.0 +/- 9.2 and mean BMI of 30.8 +/- 4.7. There was no significant difference in age (p=0.426) or BMI (p=0.776) between these groups. There was a significant difference in sex between groups (p=0.001). Of the patients that underwent a medial parapatellar approach, 68 had follow-up up and outcome data to 1 year post-op and 39 had follow-up and outcome data up to 2 years post-op. In the midvastus group, 68 patients had follow-up and outcome data up to 1 year post-op and 19 had follow-up and outcome data up to 2 years post-op. Sixty (88.2%) of the medial parapatellar patients and 59 (86.8%) of the midvastus patients had preoperative varus alignment. Patient demographics, follow-up, and alignment are summarized in Tables 3.1-3.3.

Approach	N	Mean Age	BMI	Male	Female
Medial parapatellar	68	66.7+/-9.6	30.5+/-4.8	48 (70.6%)	20 (29.4%)
Midvastus	68	68.0+/-9.2	30.8+/-4.7	29 (42.7%)	39 (57.4%)

Table 3.1. Patient demographics and characteristics for the medial parapatellar and midvastus groups.

Approach	Follow-up up to 1 year	Follow-up up to 2 years
Medial parapatellar	68	39
Midvastus	68	19

Table 3.2. Duration of followup in the medial parapatellar and midvastus groups.

Approach	Varus	Valgus
Medial parapatellar	60 (88.2%)	8 (11.8%)
Midvastus	59 (86.8%)	9 (13.2%)

Table 3.3. Preoperative alignment in the medial parapatellar and midvastus groups.

Outcome scores of the medial parapatellar and midvastus groups are summarized in Table 3.4. There were no significant differences up to two years between the two groups.

Of the medial parapatellar patients, 2 (2.9%) required revision; one patient underwent revision for lateral patellar subluxation and the other had patellar resurfacing for anterior knee pain. Three (4.4%) patients in midvastus group required revision; one patient was revised for aseptic loosening of the tibial component and two patients underwent patellar resurfacing for anterior knee pain.

Outcomes	Medial Parapatellar Mean	Midvastus Mean	p value **Significant if p<0.05**
SF-12 MCS- 1 year post-op	52.3+/-10.4	52.3+/-10.9	0.785
SF-12 PCS – 1 year post-op	41.0+/-10.1	44.0+/-10.4	0.122
SF-12 MCS- 2 years post-op	53.6+/-9.2	54.9+/-9.7	0.694
SF-12 PCS- 2 years post-op	32.4+/-10.5	42.5+/-10.3	0.952
WOMAC pain score- 1 year post-op	80.0+/-20.7	81.4+/-18.2	0.712
WOMAC stiffness score- 1 year post-op	70.4+/-24.1	72.1+/-19.4	0.677

WOMAC function score- 1 year post-op	78.5+/-20.2	78.9+/-18.3	0.916
WOMAC total score- 1 year post-op	77.8+/-19.7	78.9+/-16.6	0.778
WOMAC pain score- 2 years post-op	82.9+/-16.8	81.1+/-32.9	0.862
WOMAC stiffness score- 2 years post-op	79.1+/-18.8	71.1+/-26.8	0.275
WOMAC function score- 2 years post-op	82.6+/-18.1	83.2+/-21.9	0.929
WOMAC total score- 2 years post-op	81.8+/-15.6	83.3+/-21.3	0.806
Extension (degrees)- 1 year post-op	0.2+/-1.4	0.5+/-1.8	0.312
Flexion (degrees)- 1 year post-op	119.4+/-10.3	114.7+/-19.3	0.131
KSS Function- 1 year post-op	83.2+/-21.2	85.2+/-18.9	0.613
KSS Knee- 1 year post-op	91.5+/-11.6	93.0+/-9.8	0.503
KSS Total- 1 year post-op	173.5+/-28.9	176.3+/-25.6	0.626
Extension (degrees)- 2 years postop	0.7+/-1.8	0.8+/-1.9	0.818

Flexion (degrees)- 2 years post-op	120.2+/-9.6	114.6+/-11.2	0.131
KSS Function- 2 years post-op	85.0+/-19.8	90.9+/-12.2	0.289
KSS Knee- 2 years post-op	91.4+/-13.7	90.6+/-12.8	0.866
KSS Total- 2 years post-op	174.4+/-31.6	184.4+/-19.0	0.282

Table 3.4. Outcome scores in medial parapatellar and midvastus approach patients up to 2 years post-op. SF-12 Physical Composite Score (PCS), SF-12 Mental Health Composite Score (MCS), WOMAC scores, ROM, and KSS scores were compared between the two groups.

Medial Parapatellar versus Subvastus Medialis Approach

After matching for age, BMI, and sex, eight patients met inclusion criteria for the medial parapatellar group, with a mean age of 68.2 +/- 8.8 and mean BMI of 28.4 +/- 1.9. Eight patients were included in the medial subvastus group with a mean age of 70.4 +/- 6.5 and mean BMI of 28.5 +/- 2.3. There was no significant difference in age (p=0.575), BMI (p=0.914), or sex (p=0.248) between these groups. In the medial parapatellar group, all 8 patients had follow-up and outcome data up to 2 years post-op. In the subvastus group, 8 patients had follow-up and outcome data up to 1 year post-op and 6 patients had follow-up and outcome data up to 2 years. All patients had preoperative varus alignment in both groups. Patient demographics, follow-up, and alignment are summarized in Tables 3.5-3.7.

Approach	N	Mean Age	BMI	Male	Female
Medial parapatellar	8	68.2+/-8.8	28.4+/-1.9	1 (12.5%)	7 (87.5%)
Medial subvastus	8	70.4+/-6.5	28.5+/-2.3	3 (37.5%)	5 (62.5%)

Table 3.5. Patient demographics and characteristics for the medial parapatellar and subvastus groups.

Approach	Follow-up up to 1 year	Follow-up up to 2 years
Medial parapatellar	8	8
Medial subvastus	8	6

Table 3.6. Duration of follow-up in the medial parapatellar and subvastus groups.

Approach	Varus	Valgus
Medial parapatellar	8 (100%)	0 (0%)
Midvastus	8 (100%)	0 (0%)

Table 3.7. Preoperative alignment in the medial parapatellar and subvastus groups.

Outcome scores between the two groups are listed in Table 3.8. There was a significant difference in SF-12 Physical Composite Score (PCS) at 2 years post-op (p=0.036) and WOMAC stiffness score at 2 years post-op (p=0.014), both favouring the subvastus approach. The medial parapatellar group had significantly higher flexion at 1 year post-op (p=0.022). There were no other significant difference between the two approaches at other time points, as summarized in Table 3.8.

One patient (12.5%) in the medial parapatellar group required revision in the form of patellar resurfacing for anterior knee pain. No patients in the subvastus group underwent revision.

Outcomes	Medial Parapatellar Mean	Subvastus Mean	p value **Significant if p<0.05**
SF-12 MCS- 1 year post-op	56.7+/-11.5	58.0+/-2.3	0.816
SF-12 PCS – 1 year post-op	45.4+/-13.2	43.1+/-13.1	0.773
SF-12 MCS- 2 years post-op	53.7+/-10.3	52.2+/-8.8	0.816
SF-12 PCS- 2 years post-op	38.6+/-11.5	53.2+/-5.1	**0.036**
WOMAC pain score- 1 year post-op	71.4+/-26.3	86.4+/-19.3	0.247
WOMAC stiffness score- 1 year post-op	62.5+/-29.8	75.0+/-21.6	0.386

WOMAC function score- 1 year post-op	74.1+/-25.2	84.6+/-18.7	0.408
WOMAC total score- 1 year post-op	72.5+/-27.0	83.3+/-18.5	0.411
WOMAC pain score- 2 years post-op	72.5+/-20.6	98.0+/-2.7	0.089
WOMAC stiffness score- 2 years post-op	56.3+/-12.5	85.0+/-13.7	**0.014**
WOMAC function score- 2 years post-op	65.9+/-26.2	94.4+/-6.9	0.115
WOMAC total score- 2 years post-op	66.7+/-19.8	94.0+/-5.8	0.066
Extension (degrees)- 1 year post-op	0.8+/-2.0	0+/-0	0.389
Flexion (degrees)- 1 year post-op	126.7+/-4.1	114.0+/-8.2	**0.022**
KSS Function- 1 year post-op	90.7+/-14.3	85.0+/-28.1	0.645
KSS Knee- 1 year post-op	97.3+/-2.58	94.8+/-2.9	0.163
KSS Total- 1 year post-op	186.5+/-16.8	176.8+/-31.5	0.559
Extension (degrees)- 2 years postop	1.7+/-2.9	0+/-0	0.423

Flexion (degrees)- 2 years post-op	110.0+/-21.8	121.0+/-2.2	0.474
KSS Function- 2 years post-op	66.7+/-28.9	98.0+/-4.5	0.199
KSS Knee- 2 years post-op	72.7+/-25.7	97.8+/-2.5	0.232
KSS Total- 2 years post-op	139.3+/-53.5	195.3+/-4.8	0.211

Table 3.8. Outcome scores in medial parapatellar and subvastus approach patients up to 2 years post-op. SF-12 Physical Composite Score (PCS), SF-12 Mental Health Composite Score (MCS), WOMAC scores, ROM, and KSS scores were compared between the two groups.

Medial Parapatellar versus Lateral Parapatellar Approach

As the lateral parapatellar approach is generally reserved for valgus knees, only knees with valgus preoperative alignment in each group were compared. Patient demographics for the valgus patients are listed in Table 3.9. The matched valgus medial parapatellar group had a mean age of 69.0 +/- 12.3 and mean BMI of 30.5 +/- 0.4. The valgus lateral parapatellar group had a mean age of 69.6 +/- 21.1 and mean BMI of 31.4 +/- 6.9. There was no significant difference in age (p=0.962) or BMI (p=0.834) between the groups. All patients had follow-up and outcome data up to 1 year. The mean preoperative valgus angle in the lateral parapatellar group was 17.4 +/- 5.1 degrees, which was significantly higher than the mean valgus angle of 7.0 +/- 4.7 degrees in the medial parapatellar group (p=0.024).

Approach	N	Mean Age	BMI	Male	Female
Medial parapatellar	4	69.0+/-12.3	30.5+/-0.4	0 (0%)	4 (100%)
Lateral Parapatellar	4	69.6+/-21.1	31.4+/-6.9	0 (0%)	4 (100%)

Table 3.9. Patient demographics for the medial and lateral parapatellar groups when including only patients with valgus preoperative alignment.

Outcome scores for each group are listed in Table 3.10. There was a significant difference in SF-12 PCS at 1 year post-op (p=0.011) and WOMAC function score at 1 year post-op (p=0.022), both interestingly favouring the medial parapatellar approach. There was no significant difference in SF-12 MCS, WOMAC pain, stiffness, and total scores, ROM, or KSS at 1 year post-op.

No patients in either group required revision.

Outcomes	Medial Parapatellar Mean	Lateral Parapatellar Mean	p value **Significant if p<0.05**
SF-12 MCS- 1 year post-op	46.5+/-17.7	43.0+/-7.1	0.727

SF-12 PCS – 1 year post-op	53.0+/-7.1	34.5+/-3.7	**0.011**
WOMAC pain score- 1 year post-op	92.5+/-3.5	71.7+/-10.4	0.080
WOMAC stiffness score- 1 year post-op	62.5+/-17.7	66.3+/-7.5	0.813
WOMAC function score- 1 year post-op	89.0+/-9.9	61.7+/-4.5	**0.022**
WOMAC total score- 1 year post-op	85.0+/-5.7	67.0+/-6.6	0.052
Extension (degrees)- 1 year post-op	1.7+/-2.9	2.5+/-2.9	0.721
Flexion (degrees)- 1 year post-op	123.3+/-5.8	110.0+/-11.5	0.107
KSS Function- 1 year post-op	93.3+/-11.5	43.8+/-54.4	0.165
KSS Knee- 1 year post-op	98.3+/-2.1	95.3+/-2.5	0.145
KSS Total- 1 year post-op	191.7+/-10.2	139.0+/-56.1	0.156

Table 3.10. Outcome scores in medial parapatellar and lateral parapatellar approach patients with valgus preoperative alignment up to 1 year post-op. SF-12 Physical Composite Score (PCS), SF-12 Mental Health Composite Score (MCS), WOMAC scores, ROM, and KSS scores

3.4 Discussion

Although there are several RCTs comparing the medial parapatellar, midvastus, medial subvastus, and lateral parapatellar approaches, many are small in sample size, show mixed results, and have short followup (Liu et al., 2014; Xu et al., 2020). We aimed to add to this body of literature by reporting outcomes of a single surgeon, expertise-based study.

The midvastus approach for TKA was first described as a modification of the subvastus approach to allow for easier exposure (Engh et al., 1997). Similar to the other quadriceps sparing approaches, it offers the theoretical benefits of improved patellar tracking, decreased postoperative pain, and quicker return of quadriceps strength (Keating et al., 1999). Results in the literature, however, have been mixed. Quadriceps sparing approaches may have a higher risk of malalignment and component malposition (Yuan et al., 2017). An early study by Keating et al. in 1999 comparing short term outcomes between the midvastus and medial parapatellar approach found no difference in range of motion, straight leg raise, extensor lag, or rehab at time of discharge (Keating et al., 1999). There was a higher rate of postoperative hematoma and manipulation in the midvastus patients, leading the group to conclude that they could not recommend this approach. Subsequent studies have been more promising. A recent meta-analysis of 32 randomized controlled trials demonstrated midvastus patients had significantly lower pain scores at 2 weeks postoperative as compared to medial parapatellar patients, but found no difference at other time points (Liu et al., 2014). Range of motion was also significantly greater at 1 week postoperatively for the midvastus group, but there was no difference at other time points. Midvastus approaches took significantly longer in terms of surgical time than medial parapatellar approaches. There was also no difference in KSS, time to straight leg raise, intraoperative blood loss, length of hospital stay, or postoperative complications (Liu et al., 2014).

In our cohort of midvastus patients, we found no significant difference in SF-12, WOMAC scores, range of motion, or KSS scores at 1 and 2 years post-op. This was consistent with prior studies, which tend to show short term benefits of quadriceps sparing approaches, but no difference in long-term outcomes (Engh et al., 1997; Liu et al., 2014). Of note, there was a significant difference in the number of males and females in the MPA and MV groups. It is unclear if this may have influenced results, as some prior studies have shown worse outcomes in females as compared to males, while others have shown no difference (Lim et al., 2015; MacDonald et al., 2008; Perez et al., 2018).

Another quadriceps sparing approach, the subvastus medialis was first popularized in 1991 by Hofmann, who sought out a more anatomic approach to the knee (Hofmann et al., 1991). Advantages of this approach include the fact that it also does not violate the extensor mechanism. Additionally, it leaves the majority of vessels supplying the patella intact, if the dissection is carried out carefully (Vaishya et al., 2016). Unfortunately, the subvastus medialis approach is limited by difficulty with exposure and everting the patella (Matsueda & Gustilo, 2000; Roysam & Oakley, 2001). Currently, it is typically only used in thin patients with mobile tissues undergoing primary total knee arthroplasty. Randomized controlled trials comparing this approach to the medial parapatellar have provided mixed results. Some, such as that by Roysam et al. demonstrated earlier straight leg raise, reduced blood loss, lower opiate consumption, improved patellar tracking, and better knee flexion earlier in the recovery process

(Roysam & Oakley, 2001). Liu et al.'s meta-analysis showed that the medial subvastus approach resulted in improved range of motion at one week post operative ($p<0.05$), but no significant difference at six weeks or later (Liu et al., 2014). The subvastus group also had earlier ability to straight leg raise. Otherwise, there were no significant differences in outcomes or complication rates.

Although our sample size was small, our subvastus patients showed some promising results. The subvastus group had higher SF-12 PCS ($p=0.036$) and WOMAC stiffness scores ($p=0.014$) at 2 years post-op. Both of these were greater than the minimal clinically important difference (N. D. Clement et al., 2019; Nicholas D. Clement et al., 2018). Interestingly our study showed long term benefits with this quadriceps sparing approach, unlike most of the existing literature (Liu et al., 2014). The medial parapatellar group did, however, have significantly higher flexion at 1 year post-op ($p=0.022$). This was quite surprising given prior RCTs have found no difference in long-term range of motion between the two approaches, or in the case of Varela-Egocheaga et al.'s work improved range of motion in subvastus patients at one year (Liu et al., 2014; Varela-Egocheaga et al., 2010).

Finally, the lateral parapatellar approach is another alternative to the medial parapatellar which was first described in 1982 and later popularized by Keblish in 1991 (Cameron, 1991; P. A. Keblish, 1991). While also technically demanding (P. A. Keblish, 1991), it allows for more direct access to lateral soft tissues in valgus knees (Vaishya et al., 2016). Some proponents use this approach in valgus knees because they fear a standard medial parapatellar approach would further promote patellar maltracking (Peter A. Keblish, 2003). Additionally, the lateral parapatellar approach leaves the medial vasculature and nervous structures undisturbed (Vaishya et al., 2016). Studies on the lateral parapatellar approach unfortunately focus on valgus knees, with little data present analyzing this approach in varus or neutral knees. Furthermore, many studies incorporate use of a tibial tubercle osteotomy, which makes results difficult to interpret. Nonetheless, several studies have demonstrated promising outcomes with this approach in valgus knees. Sekiya et al. found improved postoperative flexion in the lateral parapatellar group ($p<0.001$), but employed extensive lateral releases, including the iliotibial band in many cases (Sekiya et al., 2014). They found no difference in surgical time, complications, blood loss, postoperative alignment, laxity, patient reported outcome scores, and Knee Society Scores (KSS). A recent meta-analysis also compared the lateral parapatellar approach to the medial parapatellar approach for valgus knees and found improved Knee Society Scores in the lateral group, but similar alignment, operative time, blood loss, WOMAC scores, postoperative pain, and range of motion (Xu et al., 2020).

As the lateral parapatellar approach is commonly described for valgus knees, allowing for direct access to the tight lateral structures, our analysis for this group involved only knees with valgus preoperative alignment. Our comparison of the medial and lateral parapatellar approach in valgus knees actually found significantly lower SF-12 PCS ($p=0.011$) and WOMAC function scores ($p=0.022$) at 1 year post-op for the lateral parapatellar group. Both of these were greater than the minimal clinically important difference (N. D. Clement et al., 2019; Nicholas D. Clement et al., 2018). There was no significant difference in other components of the SF-12, WOMAC, ROM, or KSS however. This is also unlike findings from prior RCTs which tend to show no significant difference or an advantage with the lateral parapatellar approach (Xu et al., 2020). It is important to note however that our lateral parapatellar patients tended to have a more severe preoperative valgus deformity than the medial parapatellar group (p=0.024).

Our study did have notable limitations. Alternative TKA approaches are not typically performed by surgeons at our institution, and as such this was a single surgeon study with small sample size. The study was also retrospective in nature and patient outcome data was not collected earlier than 1 year post-op, which prevented us from analyzing any early benefits of quadriceps sparing approaches. Furthermore, we used propensity scores to match groups, which requires manually selecting patients with similar propensity scores; thus, this can introduce bias (Luo et al., 2010). Statistical analysis also utilized multiple t-tests, which meant error could have been higher with each subsequent test. Finally, we did not compare preoperative outcome scores between groups, which may have differed. A large, high quality RCT with extended follow-up is required to compare surgical approaches for TKA.

3.5 Conclusion

Compared to a standard medial parapatellar approach, the midvastus approach shows no significant difference in outcomes up to 2 years. The subvastus approach shows superior SF-12 and WOMAC scores at 2 years post-op, but worse flexion at 1 year. The lateral parapatellar approach for valgus knees had inferior SF-12 and WOMAC scores when compared to the medial parapatellar, but selected for a more severe preoperative valgus deformity. Ultimately, a large RCT with extensive follow-up is recommended to verify the benefits of quadriceps sparing approaches.

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Chapter 4

4 Patient Outcomes and Joint Kinematics in a Novel Lateral Subvastus Lateralis Approach for Total Knee Arthroplasty

This chapter presents a prospective analysis of joint kinematics and patient outcomes with the SLA versus MPA.

4.1 Introduction

Despite numerous advances in modern Total Knee Arthroplasty (TKA) techniques, implants, and rehabilitation protocols, 10-30% of patients report some degree of dissatisfaction after undergoing TKA (Bourne et al., 2010; Van Onsem et al., 2019). Thus, there remains room for improvement.

One potential route for optimizing outcomes is through surgical approach. Currently, the gold standard approach for TKA is the medial parapatellar approach (MPA). In a standard MPA, a midline incision is used. Appropriate skin flaps are raised, and a medial parapatellar arthrotomy is used. The fat pad and menisci are resected along with the ACL. The exposure includes releasing the deep MCL, typically to the mid coronal plane off the tibia (Vaishya et al., 2016). Disadvantages of this approach include violating the extensor mechanism of the knee, potentially destabilizing the patella, compromising the medial blood supply, and possibly injuring the infrapatellar branch of the saphenous nerve (Stern et al., 1991; Von Langenbeck, 1878).

We propose a lateral subvastus lateralis approach (SLA). This approach utilizes a skin incision that is lateral to mid line; slightly more laterally proximally and ending just lateral to the tibial tubercle (Fig 4.1). After elevating appropriate skin flaps, the vastus lateralis is identified. The fascia is split lateral to the vastus lateralis, and extended to the patella, continuing distally along the lateral aspect of the patellar tendon to the tibial tubercle. As required, the exposure is extended laterally to gain an appropriate degree of exposure to allow entry for the saw blade for the proximal tibial cut. The SLA offers the benefit of keeping the extensor mechanism and medial blood supply intact, while allowing for direct access to lateral soft tissues.

The SLA may theoretically lead to decreased postoperative pain scores as compared to the MPA, due to the nervous supply of the knee originating medially. Range of motion and functional outcome scores may also be improved at earlier time points, as a result of sparing the quadriceps mechanism.

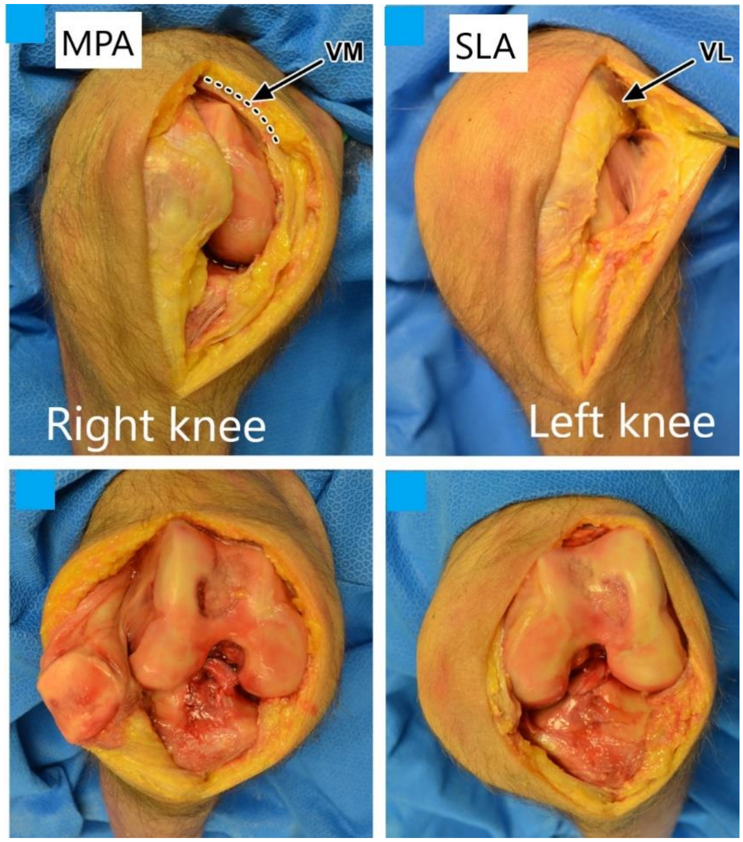

Figure 4.1. The lateral subvastus lateralis approach (SLA) and the conventional medial parapatellar approach (MPA). Image modified from original obtained from Dr. Brent Lanting, with permission.

To our knowledge, the SLA has not previously been described or studied other than at our institution. In particular, we have performed cadaveric anatomic studies demonstrating good outcomes and adequate exposure with this novel approach (Lanting et al., 2020). We have also performed a cadaveric biomechanics study showing no difference in TKA kinematics or laxity between the SLA and MPA; the results of this have been submitted for publication.

In this study, we aimed to prospectively compare patient reported outcome measures (Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), Short Form 12 (SF-12), Knee Society Score (KSS)) and joint kinematics (using pseudo dynamic fluoroscopy/quasi-static stereo radiography) between the standard MPA and novel SLA.

4.2 Materials and Methods

This was a prospective cohort study. After receiving Health Science Research Ethics Board approval (Appendix A), 15 patients were appropriately consented and recruited to undergo the SLA. The consent process involved a thorough discussion of the approach and potential risks. Inclusion criteria included patients undergoing primary TKA for osteoarthritis with varus or neutral alignment. Exclusion criteria were patients undergoing revision, TKA for any reason other than osteoarthritis, and valgus alignment. This group was matched for age, BMI, and alignment as closely as possible with a group of MPA patients. The data for the MPA group was previously collected as part of another study and taken from our institutional database. All patients underwent TKA by a fellowship trained Orthopaedic Surgeon using cruciate retaining (CR) Stryker Triathlon implants (Triathlon, Stryker, Mahwah, NJ). The Triathlon femoral component has a single radius of curvature in the sagittal plane from 10 degrees to 110 degrees of flexion. The posterior condyles are designed to enable deep flexion up to 150 degrees, with up to 20 degrees of rotation (Teeter et al., 2017). For the MPA group, a standard midline incision was used, skin flaps raised, and medial parapatellar arthrotomy made. The deep MCL was released to the mid coronal plane. For the SLA group, the skin incision was made just lateral to mid line, skin flaps raised, vastus lateralis elevated, and patella subluxated to expose the joint. Any intraoperative complications were recorded.

Joint Kinematics

Kinematics refers to motion, in this case between the femur and the tibia. Joint kinematics were compared between the two approach groups using pseudo-dynamic fluoroscopy, or quasi-static stereo radiography at approximately 12 months postoperative (mean follow-up 12.9 +/- 2.9 months). Baseline or preoperative kinematics were not analyzed. These radiostereometric analysis (RSA) images were obtained using a uniplanar calibration cage (RSA Biomedical) while patients had weight bearing images taken throughout various degrees of flexion (Broberg et al., 2020; Morcos et al., 2019). RSA images were captured at 20 degree increments from 0-120 degrees. Model based RSA software (MBRSA, RSAcore, Leiden, Netherlands) was used to match the manufacturer's CAD models to the arthroplasty components for each RSA image. This method involved static images, unlike true dynamic fluoroscopy; however, this technique has been shown to be reliable in prior studies (Angerame et al., 2019; Broberg et al., 2020; Morcos et al., 2019; Teeter et al., 2017). This method has been demonstrated as having excellent accuracy, with an error of 0.19 mm for translation and 0.52 degrees for rotation (Broberg et al., 2020; Teeter et al., 2017). This technique allows for tracking of the relative motion between the tibial and femoral components. A model polyethylene liner with appropriate thickness (matching the implanted poly insert) was fixed to the baseplate model (for the tibial baseplate). The point of shortest distance between the femoral and tibial components was found in the medial and lateral compartments and its magnitude measured. This was defined to be the contact point. The contact region was defined to be the area where the tibial/femoral distance was within 0.5 mm of the shortest distance. A size 4 right medium-sized tibial model was used to normalize the contact location. Anterior-posterior (AP) contact point, excursion, and magnitude of anterior motion were all measured in the medial and lateral compartments. Axial rotation was also measured. Paradoxical anterior motion was tracked and compared using a 3mm threshold, which has been used in prior studies (Angerame et al., 2019; Broberg et al., 2020). Condylar liftoff or separation was tracked using a threshold of 1.0mm for the shortest tibial/femoral distance; any distance greater than this qualified as an instance of liftoff (Broberg et al., 2020; Prins et al., 2014; Teeter et al., 2017). The amount of normal or “regular” rotation was also measured and was defined to be continuous external rotation of the femur with respect to the tibia with flexion. Similarly, “irregular” motion was defined to be continuous internal rotation of the femur with respect to the tibia with progressive flexion.

Statistical analysis was done using Prism 8 (GraphPad Software, San Diego, CA). The Shapiro-Wilk test was used to assess for normality. Kinematics were compared between the SLA and MPA groups using independent sample t-tests or the Mann-Whitney test (for continuous data). Values were considered to be significant if $p<0.05$.

Patient Outcomes

Patients in both groups were administered the WOMAC, SF-12, and KSS to measure outcomes approximately 1 year from surgery (mean follow-up 12.9 +/- 2.9 months).

Statistical analysis between groups was done using SPSS (IBM SPSS Statistics 23). The student's t-test was used to compare outcome scores between the MPA and SLA cohorts.

4.3 Results

Data collection for this study was significantly affected by the COVID pandemic and related restrictions. We were able to collect outcome scores and kinematics data for 7 of the SLA patients. This was matched to a group of MPA patients as closely as possible for age, BMI, sex, and alignment. Patient demographics are listed in Table 4.1. There was no significant difference in BMI between groups (p=0.996), but there was a significant difference in age (p=0.015). We were limited in matching by the demographics of the MPA patients available in the institutional database.

Table 4.1. Demographics data for the lateral subvastus lateralis (SLA) and medial parapatellar (MPA) groups.

Approach	N	Mean Age	Mean BMI	Male	Female
Lateral Subvastus Lateralis	7	72.6+/-9.7	29.69+/-5.60	5/7 (71.4%)	2/7 (28.6%)
Medial Parapatellar	7	60.7+/-5.2	29.67+/-5.62	5/7 (71.4%)	2/7 (28.6%)

Joint Kinematics

With regards to the AP contact point in the medial compartment, significant differences were found between the SLA and MPA groups at 20 and 40 degrees of flexion. At both 20 and 40 degrees, the medial AP contact point was more posterior in the SLA knees (p=0.018 and p=0.035 for 20 and 40 degrees, respectively). There were no significant differences in medial AP contact point at 0 degrees (p=0.065), 60 degrees (p=0.34), 80 degrees (p=0.20), 100 degrees (p=0.54), and 120 degrees (p=0.80). Medial AP contact point values are listed in table 4.2 and plotted in figure 4.2. Contact regions are also visually represented in Figure 4.5. The medial AP contact point in the SLA group moved from anterior to posterior from 0-20 degrees, posterior to anterior from 20-100 degrees, and anterior to posterior from 100-120 degrees. In the MPA group, medial AP contact point moved from anterior to posterior from 0-20 degrees, posterior to anterior from 20-80 degrees, and anterior to posterior from 80-120 degrees.

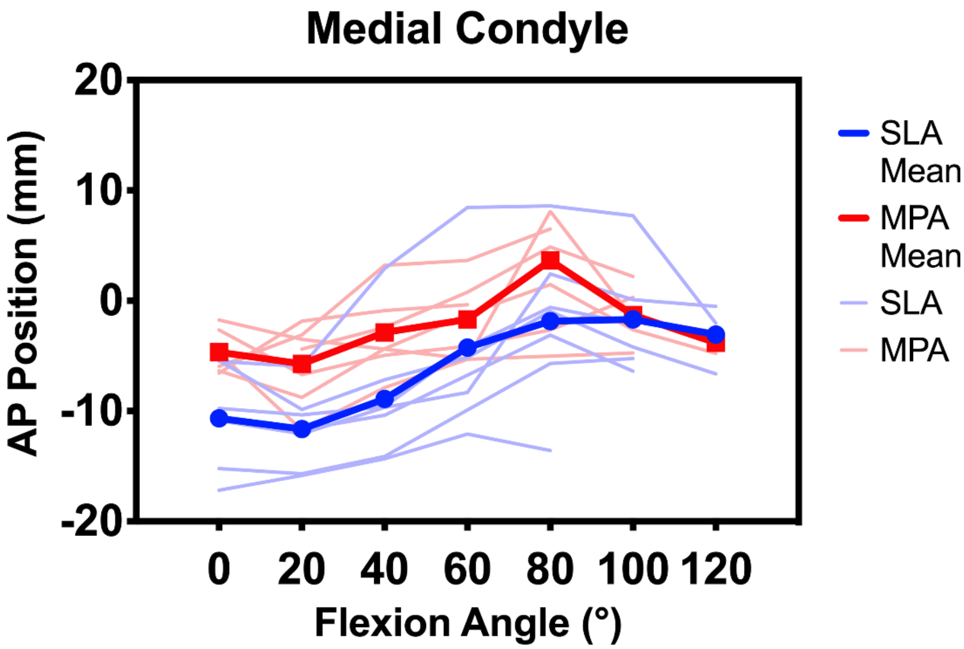

Figure 4.2. Medial compartment AP contact point for each approach. There was a significant difference at 20 (p=0.018) and 40 (p=0.035) degrees.

There were no significant differences in AP contact point in the lateral compartment between the SLA and MPA. No significant differences existed at 0 degrees (p=0.065), 20 degrees (p=0.13), 40 degrees (p=0.29), 60 degrees (p=0.76), 80 degrees (p=0.53), 100 degrees (p>0.99), or 120 degrees (p=0.80). Lateral compartment AP contact point values are listed in table 4.2 and contact regions are illustrated in Figure 4.5. These values are also plotted in Figure 4.3. In the SLA knees, lateral AP contact point moved from anterior to posterior from 0-20 degrees, posterior to anterior from 20-60 degrees, and anterior to posterior from 60-120 degrees. In the MPA group, lateral contact point moved from anterior to posterior from 0-20 degrees, posterior to anterior from 20-40 degrees, anterior to posterior from 40-60 degrees, posterior to anterior from 60-80 degrees, and anterior to posterior from 80-120 degrees.

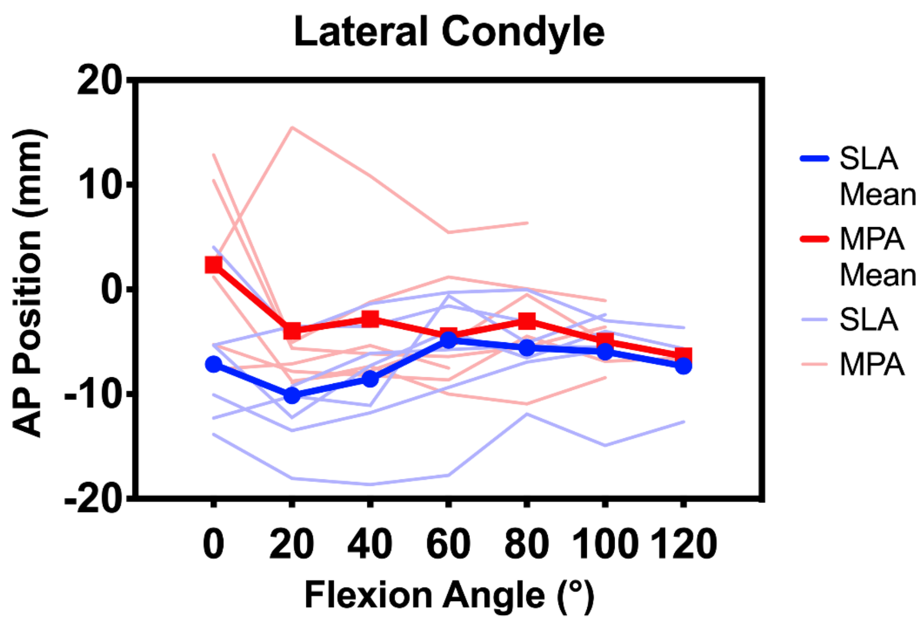

Figure 4.3. Lateral compartment AP contact point for each approach. There was no significant difference at any degree of flexion.

There were no significant differences in excursion in either the medial (p=0.84) or lateral (p=0.29) compartments between approaches. There was also no significant difference in the incidence of paradoxical motion in the medial (p>0.99) and lateral (p=0.19) compartments, or the magnitude of anterior motion in the medial (p=0.84) and lateral (p=0.73) compartments between approaches. Similarly, there were no significant differences in the incidence of medial (p>0.99) and lateral (p=0.73) condylar separation. Excursion, anterior motion, and condylar separation is listed for each approach in table 4.2.

With respect to the axial rotation, there were no significant differences at any degree of flexion between the SLA and MPA. There was no difference at 0 degrees (p=0.59), 20 degrees (p=0.80), 40 degrees (p=0.90), 60 degrees (p=0.54), 80 degrees (p>0.99), 100 degrees (p=0.93), or 120 degrees (p>0.99). Axial rotation values are listed in table 4.2 and plotted in Figure 4.4.

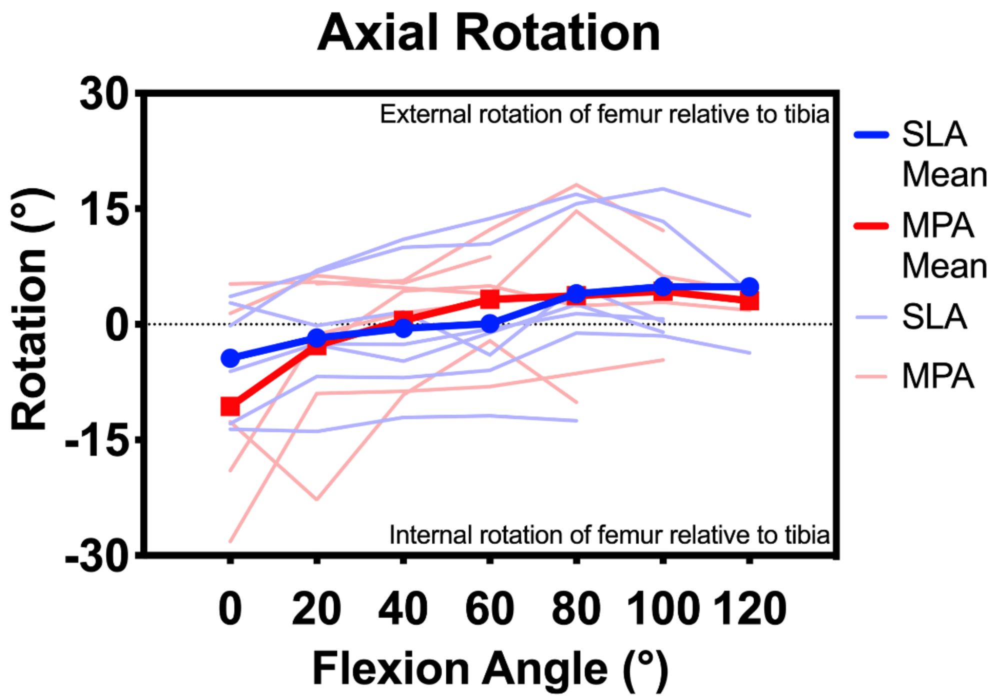

Figure 4.4. Axial rotation for each approach. There was no significant difference at any degree of flexion.

There was, however, a significant difference in the magnitude of continuous axial rotation between the SLA and MPA. SLA knees had significantly less “regular” (external) rotation of the femur with respect to the tibia throughout flexion, as compared to the MPA (p=0.022). There was no significant difference between approaches with regards to the magnitude of continuous “irregular” (internal) rotation (p=0.84). Continuous axial rotation values are listed in table 4.2.

Table 4.2. Kinematics data for the lateral subvastus lateralis (SLA) and medial parapatellar (MPA) groups. P<0.05 was considered to be significant.

Variable	Subvastus Lateralis	Medial Parapatellar	p-Value
Medial AP Contact Point (mm)			
0°	-10.6 (4.86)	-4.66 (2.04)	0.065
20°	-11.6 (3.45)	-5.72 (3.53)	**0.018**
40°	-8.91 (5.81)	-2.88 (3.81)	**0.035**
60°	-4.26 (7.74)	-1.70 (3.38)	0.34
80°	-1.85 (6.88)	3.66 (4.30)	0.20
100°	-1.69 (5.15)	-1.29 (2.67)	0.54
120°	-3.06 (3.18)	-3.82 (1.35)	0.80
Lateral AP Contact Point (mm)			
0°	-7.14 (6.51)	2.35 (8.18)	0.065
20°	-10.1 (5.14)	-3.97 (8.71)	0.13
40°	-8.55 (5.82)	-2.83 (7.10)	0.29
60°	-4.84 (7.37)	-4.45 (5.66)	0.76
80°	-5.57 (3.66)	-3.01 (6.42)	0.53
100°	-5.95 (4.60)	-4.98 (2.86)	>0.99
120°	-7.32 (4.73)	-6.38 (0.25)	0.80
Excursion (mm)			
Medial	10.3 (3.36)	9.89 (2.68)	0.84
Lateral	7.17 (2.77)	10.9 (6.13)	0.29
Incidence of Paradoxical Anterior Motion (%)			
Medial	100	100	>0.99
Lateral	100	66.7	0.19
Magnitude of Anterior Motion (mm)			
Medial	10.3 (3.36)	9.89 (2.68)	0.84
Lateral	6.59 (2.93)	6.00 (4.15)	0.73

Incidence of Condylar Separation (%)			
Medial	14.3	0.00	>0.99
Lateral	28.6	0.00	0.46
Axial Rotation (°)			
0°	-4.40 (7.66)	-10.6 (12.5)	0.59
20°	-1.76 (7.37)	-2.74 (10.5)	0.80
40°	-0.53 (8.62)	0.52 (6.60)	0.90
60°	0.10 (9.05)	3.23 (6.75)	0.54
80°	3.98 (10.1)	3.71 (11.2)	>0.99
100°	4.91 (8.33)	4.30 (6.09)	0.93
120°	4.87 (8.90)	3.07 (1.74)	>0.99
Magnitude of Continuous Axial Rotation (°)			
Regular (External)	8.50 (5.36)	17.9 (5.53)	**0.022**
Irregular (Internal)	-3.68 (4.42)	-4.84 (4.73)	0.84

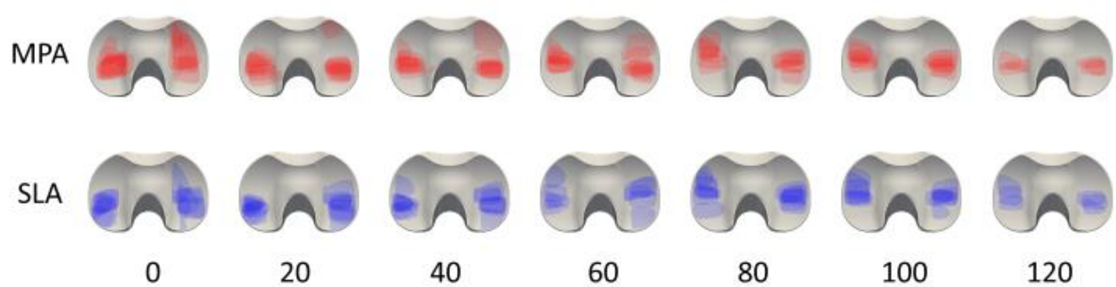

Figure 4.5. Contact region maps for the lateral subvastus lateralis (SLA) and medial parapatellar approach (MPA) knees. Overlaid maps show the contact region at the various degrees of flexion (0-120 degrees).

Patient Outcomes

Postoperative outcome scores for each group are listed in Table 4.3. There was no significant difference in WOMAC pain (p=0.886), WOMAC stiffness (p=0.792), WOMAC function (p=0.510), WOMAC total (p=0.250), SF-12 Physical Composite Score (PCS) (p=0.712), SF-12 Mental Composite Score (MCS) (p=0.855), Knee Society function score (p=0.107), or Knee Society Knee score (p=0.471) between the SLA and MPA groups.

Table 4.3. Postoperative outcome scores for the SLA and MPA groups. Outcome scores were collected approximately one year from surgery.

	Lateral Subvastus Lateralis Mean	Medial Parapatellar Mean	p value (significant if p<0.05)
Postop WOMAC Pain	76.43+/-19.52	78.57+/-26.57	0.866
Postop WOMAC Stiffness	66.07+/-18.70	69.64+/-29.63	0.792
Postop WOMAC Function	70.38+/-16.97	79.20+/-29.89	0.510
Postop WOMAC Total	90.00+/-6.06	76.93+/-27.93	0.250

Postop SF-12 PCS	43.72+/-7.87	42.14+/-7.79	0.712
Postop SF-12 MCS	54.33+/-8.31	53.54+/-7.42	0.855
Postop KSS Function	75.71+/-17.90	92.86+/-18.90	0.107
Postop KSS Knee	90.71+/-7.34	94.14+/-9.69	0.471

Revisions/Complications

No patient in either group underwent revision surgery. In terms of complications, one patient in the SLA group sustained an intraoperative tibia fracture requiring insertion of a stemmed tibial component and screws.

4.4 Discussion

Considering 10-30% of TKA patients are dissatisfied in some form with their joint, there remains room for improvement (Bourne et al., 2010; Van Onsem et al., 2019). We aimed to study a novel lateral subvastus lateralis approach (SLA) for TKA which spares the medial soft tissues of the knee and therefore could avoid destabilizing the patella, improve patellar tracking, and avoid compromising the medial blood supply

(Stern et al., 1991; Von Langenbeck, 1878). The subcutaneous nerve plexus is also less developed on the lateral side of the knee, which could potentially result in less postoperative pain (Niki et al., 2011). Additionally, a lateral approach would allow for direct access to lateral soft tissues.

With regards to the kinematics analysis, the SLA resulted in a significantly more posterior medial contact point at 20 and 40 degrees of flexion (p=0.018 and p=0.035 respectively) as compared to the MPA. There were no significant differences in medial contact point at all other degrees of flexion and no significant differences in lateral contact point at any degree of flexion between the groups. It is unclear exactly what the significance of a more posterior medial contact point at 20 and 40 degrees of flexion means, but it could indicate increased early femoral rollback in the SLA group. Femoral rollback is a phenomenon present in the native knee that is sought after in TKA designs, as posterior femoral translation during flexion can improve quadriceps function and range of motion by preventing impingement (Flandry & Hommel, 2011; Freeman & Pinskerova, 2005; Most et al., 2003; Zingde & Slamin, 2017). Additionally, Van Onsem et al demonstrated in their kinematic study that increased anterior translation medially early in flexion could be linked to poorer patient outcomes (Van Onsem et al., 2019); thus more initial posterior motion in the SLA group may potentially be beneficial. Intuitively, however, increased medial compartment motion in the SLA group was surprising. Considering that the releases in the SLA are done on the lateral side, violating the lateral fascia and capsule, one would have expected decreased medial and perhaps increased lateral motion. The MPA on the other hand, which involves dissecting through the medial soft tissues and releasing the deep MCL to the mid coronal plane, would have intuitively resulted in a more mobile medial compartment. It is possible that the limited medial release and intact medial capsule in the SLA allowed for more anatomic medial motion and thus increased medial femoral rollback. Perhaps violating the medial soft tissues in the MPA resulted in the implant design itself dictating more of the medial contact point, which would have translated into minimal motion in a single radius TKA like the Stryker Triathlon (Broberg et al., 2020; Teeter et al., 2017).

There were no significant differences between approaches for the lateral AP contact point, excursion, incidence of paradoxical anterior motion, magnitude of anterior motion, or incidence of condylar separation. This indicates that the SLA resulted in similar kinematics to the MPA with respect these parameters.

Although there was no significant difference in axial rotation at specific degrees of flexion between the SLA and MPA, there was a significant difference in the magnitude of continuous axial rotation. The SLA knees had significantly less “regular” (external) rotation throughout flexion than the MPA group (p=0.022). This meant that the SLA knees had slightly less anatomic continuous rotation, as the femur normally externally rotates with respect to the tibia in flexion in the native knee (Flandry & Hommel, 2011; Freeman & Pinskerova, 2005; Zingde & Slamin, 2017). There was however no significant difference in “irregular” (internal) rotation between groups (p=0.84). Less femoral external rotation with flexion in the SLA group was somewhat unexpected; with increased lateral releases in the SLA, one would have anticipated a more mobile lateral compartment. It is possible that a more extensive medial release in the MPA group facilitated more anatomic external rotation.

Although techniques have been described for measuring patellar tracking using computer models and RSA, we did not assess patellar tracking in this study (Bey et al., 2008). This would be worth pursuing in future studies. There were no significant differences in patient outcome scores at one year postoperative. There was no significant difference in the total WOMAC score (p=0.250), SF-12 PCS (p=0.712), SF-12 MCS (p=0.855), KSS function score (p=0.107), or KSS knee score (p=0.471) between approaches. One patient in the SLA group sustained an intraoperative tibia fracture requiring a stemmed component. No patients in either group underwent a revision. The tibia fracture occurred in the first patient in which the SLA was attempted. This may indicate the presence of a learning curve, similar to the direct anterior approach for total hips (Torres et al., 2019). Although sample size was small, the ease and familiarity of the approach did improve with experience. Future studies may consider adding operative time as a means of quantifying the learning curve.

Although we did not find any improvements in postoperative pain or function scores with the SLA as originally hypothesized, the fact that there was no significant difference in one-year outcomes was still promising. This indicates that the SLA is a safe approach to continue to study. Perhaps any potential benefits in pain and function are only present in the early postoperative period and outcome scores converge as time progresses, much like the direct anterior approach for total hip arthroplasty (Maldonado et al., 2019). We intend to continue to gather kinematics and outcome data on the remaining patients in our cohort, which we were not able to test due to the COVID pandemic. Further studies on the SLA should also investigate early outcomes to determine if there is any accelerated recovery benefit with the SLA.

It is important to note that this approach may not be suitable for obese patients or those with severe deformity. Although exposure was similar to the MPA for the patients in our cohort, the patella was still not able to be everted and instead required subluxation. At this stage, we would not advise others adopt this approach until further testing is done. Our study did have some notable limitations. We were not able to complete testing on our entire recruited cohort due to the COVID pandemic and related restrictions. Sample size was small as a result. Furthermore, images used for kinematic analysis were static; however, prior studies have shown this RSA technique to be reliable (Angerame et al., 2019; Broberg et al., 2020; Morcos et al., 2019; Teeter et al., 2017). Another significant limitation of our study was that we did not have preoperative outcome scores available for the entire cohort and thus baseline scores could have differed between groups. There is data to suggest that preoperative outcome scores affect postoperative scores (Lingard et al., 2004). Finally, we did not collect outcome scores at time points earlier than one year postoperative, and as such, could not identify any early benefits. We also did not explicitly test quadriceps function, measure patellar tracking, or objectively track altered sensation, which would be useful in subsequent studies. Ultimately, further studies with large sample size are required to analyze any potential advantages of the SLA.

4.5 Conclusion

The SLA resulted in improved medial femoral rollback early in flexion as compared to the MPA, but less “regular” (external) rotation of the femur with respect to the tibia. There were no significant differences in patient outcomes at one year postoperative. The SLA may be a viable alternative to the MPA in TKA; further studies are required to identify any benefits.

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Chapter 5

5 Summary and Conclusions

This chapter summarizes and concludes the thesis.

5.1 Summary and Conclusions

To summarize, our initial retrospective review investigated the effect of surgical approach on patient outcomes in TKA. Patients having undergone TKA at our institution were organized based on whether they had a MPA, MV, SV, or LPA approach and WOMAC, KSS, SF-12, and ROM were compared up to 2 years postoperative. This review found that there were no significant differences in outcomes between the MPA and MV up to 2 years. The SV group had significantly higher SF-12 PCS (p=0.036) and WOMAC stiffness score (p=0.014) at 2 years, but significantly lower flexion at 1 year (p=0.022) as compared to the MPA. The LPA, which was only analyzed for valgus knees, had significantly lower SF-12 PCS (p=0.011) and WOMAC function scores (p=0.022) at 1 year as compared to the MPA group. However, the LPA group had more severe valgus preoperative deformity (p=0.024), which likely influenced results.

From this initial retrospective review, we concluded that there was no significant difference between the MPA and MV approach. The SV approach did offer some improved long-term outcomes over the MPA (SF-12 and WOMAC), but also had significantly less flexion at 1 year. The LPA outcomes were inferior but likely influenced by more severe preoperative deformity. Further studies are required to investigate the potential benefit of existing quadriceps sparing approaches.

In the prospective arm of our study, we aimed to study patient outcomes and joint kinematics (using RSA) in a novel SLA versus conventional MPA. With regards to the kinematics analysis, the SLA resulted in a more posterior medial AP contact point at 20 and 40 degrees of flexion (p=0.018 and p=0.035, respectively) as compared to the MPA. There was no significant difference in medial AP contact point at other degrees of flexion, lateral AP contact point at any degree of flexion, excursion, incidence of paradoxical anterior motion, incidence of condylar separation, or axial rotation at any degree of flexion. The SLA did result in less "regular" (external) continuous axial rotation throughout flexion than the MPA (p=0.022). However, there was no difference in the "irregular" (internal) continuous axial rotation through flexion (p=0.84). There were no significant differences in patient outcome scores at one year postoperative between approaches.

Thus, we concluded that the SLA resulted in improved medial femoral rollback early in flexion, but less anatomic "regular" (external) rotation of the femur with respect to the tibia. The SLA and MPA both resulted in similar patient outcomes. Further studies are required to identify any benefits with this novel surgical approach.

5.2 Future Directions

We were not able to complete testing on our entire cohort due to the COVID pandemic and related restrictions. As such, we intend to continue collecting kinematics and outcome data on these patients when able. Ultimately, further studies with large sample size and data collection in the early postoperative period are required to identify any benefits that the SLA may offer.

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Appendices

Appendix A: Research Ethics Board (REB) approval

Western Research

Date: 12 February 2019

To: Dr. Brent Lanting

Project ID: 113090

Study Title: Lateral subvastus lateralis approach for total knee arthroplasty

Application Type: HSREB Initial Application

Review Type: Full Board

Date Approval Issued: 12/Feb/2019

REB Approval Expiry Date: 12/Feb/2020

Curriculum Vitae

Name: Sahil Prabhnoor Sidhu

Education:
Western University
London, Ontario, Canada
2017-2022 Orthopaedic Surgery Residency (in progress)

Cumming School of Medicine, University of Calgary
Calgary, Alberta, Canada
2014-2017 MD

University of British Columbia, Okanagan
Kelowna, British Columbia, Canada
2011-2014 BSc

Academic Highlights and Achievements:
Western Graduate Research Scholarship- University of Western Ontario 2019-2020
Licentiate of the Medical Council of Canada- 2019
UBC Dean's List Distinction- University of British Columbia Okanagan 2012, 2013, 2014
UBC Deputy Vice Chancellor Scholarship for Continuing Students – University of British Columbia Okanagan 2012, 2013
Southern Interior Development Initiative Trust Scholarship – University of British Columbia Okanagan 2013
UBC Major Entrance Scholarship –University of British Columbia Okanagan 2011
UBC President's Entrance Scholarship –University of British Columbia Okanagan 2011
Governor General's Academic Medal – 2011
Skills Canada Provincial Bronze and Regional Gold Medals for Mechanical CAD – Mechanical drafting competition in the Okanagan/BC 2009, 2010.

Work Experience:
Orthopaedic Surgery Resident, 2017-present.
Western University, London, ON.

Farming, 2008-2017.
GWS Orchards, Brewster, WA.

Publications:
Atwan Y, Charron BP, Sidhu SP, Cavanagh J, Degen R. Publication Productivity Among Academic Orthopaedic Surgeons in Canada. Cureus. 2020 Jun;12(6): e8441. doi:10.7759/cureus.8441

Sidhu SP, White NJ. Antibiotic Impregnated Cement Dowel in a Tibial Stump to Salvage Infected Below-Knee Amputation in a Diabetic. JAAOS Global Research & Reviews. 2019 Oct;3(10).

Sidhu SP, Iablokov V, Hisey B, Byford-Richardson L, Coderre S. Diverticulosis vs. Diverticulitis: Distinguishing Features. Slide for The Calgary To Understanding Disease. Published online Oct 2016. https://calgaryguide.ucalgary.ca/diverticulosis-vs-diverticulitis-distinguishing-features/

Research Projects in Progress:
Sidhu SP, Moslemian A, Yamomo G, Vakili S, Kelly P, Lanting B, Willing R. Lateral Subvastus Lateralis versus Medial Parapatellar Approach for Total Knee Arthroplasty: A Cadaveric Biomechanical Study.
Manuscript submitted to The Knee.

Sidhu SP, Teeter M, Willing R, Somerville L, Lanting B. Does Surgical Approach Affect Patient Outcomes in Total Knee Arthroplasty?
Manuscript submitted to the Canadian Journal of Surgery.

Sidhu SP, Lanting B, Kelly P, Vasarhelyi E, Willing R. Trial Tibial Inserts May Result in Different Knee Kinematics from Final Poly Inserts in Total Knee Arthroplasty.
Manuscript submitted to The Knee.

Sidhu SP, Atwan Y, Cavanagh J, Lawendy AR. High Energy Transsyndesmotic Ankle Fracture Dislocation- Injury Characteristics, Radiographic Outcomes, and Factors Affecting the Rate of Post-traumatic Arthritis in Logsplitter Injuries.
Manuscript being edited for journal submission.

Sidhu SP, Vasarhelyi E. Two-Stage Revision Total Knee Arthroplasty with an Articulating Spacer: Minimum Five-year Review.
Manuscript being edited for journal submission.

Sidhu SP, Bailey C, Rasoulinejad P. Clinical, Radiographic, and MRI Outcomes in Non-Operative Type II Odontoid Fractures in the Elderly: A Retrospective Study.
Presented at Resident Research Day 2019.

Presentations
Podium Presentation. Oct 2019.
Resident Research Day, London, ON

Sidhu SP, Bailey C, Rasoulinejad P. Clinical, Radiographic, and MRI Outcomes in Non-Operative Type II Odontoid Fractures in the Elderly: A Retrospective Study

Poster Presentation. Oct 2018.
Resident Research Day, London, ON
Sidhu SP, Moslemian A, Yamomo G, Vakili S, Kelly P, Lanting B, Willing R. Lateral Subvastus Lateralis versus Medial Parapatellar Approach for Total Knee Arthroplasty: A Cadaveric Biomechanical Study.

Professional Development and Additional Training:
American Association of Hip and Knee Surgeons (AAHKS) Annual Meeting and Resident Course, Nov 2019, Dallas, TX.
Licentiate of the Medical Council of Canada, 2019.
Surgical Foundations/Principles of Surgery, 2019, London, ON.
AO Basic Principles of Fracture Management, Sept 2018, San Diego, CA.
Advanced Trauma Life Support, 2017, London, ON.
Advanced Cardiac Life Support, 2017, London, ON.
Clinical Leadership Seminar Series, Jan/Feb 2016, Calgary, AB.
Canadian Society of Orthopaedic Technologists "Mad Skills" Conference, 2015, Calgary, AB.

Community Involvement and Contributions to Faculty
Orthopaedic Resident "Boot Camp" Teacher, 2020
Western University, London, ON.
Surgical Anatomy Teacher (for 4th year medical students), 2020.
Western University, London, ON.
T-OSCE Examiner for medical students, 2019.
Western University, London, ON.
Impact Program Mock Trauma Educator (for high school students), 2018.
London Health Sciences Centre, London, ON.
Volunteer, 2010-2013.
Harmony House Health Care Center, Brewster, WA.
Volunteer, 2008-2013.
Penticton Regional Hospital, Penticton, BC.
Volunteer, 2010-2012.
Ironman Canada Triathlon, Penticton, BC.
Volunteer, 2008-2011.
Amnesty International Group, Penticton, BC.

Languages:
English and Punjabi