

Paper 1

Fresh Osteochondral Allograft Transplantation for Osteochondritis Dissecans of the Knee

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Objectives: Osteochondritis dissecans (OCD) of the knee can be difficult to treat. Cartilage restoration techniques are often indicated when the lesion or fragment cannot be salvaged. Fresh osteochondral allograft (OCA) transplantation can restore both bone and cartilage defect as a treatment modality. We hypothesize that osteochondral allografting is a successful method for treating osteochondritis dissecans of the knee.

Methods: Between 1983 and 2010, 164 patients (181 knees) underwent OCA for OCD of the femoral condyle(s) (type III or IV). Minimum two-year follow-up was available on 149 patients (165 knees). Median age was 25 years (range, 14 to 55) and 73% were male. Mean allograft size was 7.2 cm² (range, 2 to 23 cm²). Evaluation included frequency and type of reoperations, modified Merle d'Aubigné-Postel (18-point) scale, International Knee Documentation Committee (IKDC) pain and function scores, and Knee Society function (KS-F) score. Clinical failure was defined as revision OCA or conversion to arthroplasty. Graft survivorship was determined.

Results: Median follow-up time was 7.7 years (range, 2 to 28.4 years). 78% had more than 5-year follow-up. Fifty-one of 165 knees (31%) had reoperations, of which 21 (13%) were classified as allograft failures (13 OCA revisions, 5 UKA, and 3 TKA). OCA survivorship was 93% at 5 years, 87% at 10 years, and 77% at 20 years. Of the 144 knees whose grafts were still in situ, 91% were rated good/excellent, 8% were rated fair, and 1% was rated poor. Mean modified Merle d'Aubigné-Postel (18-point) scale was 17, mean IKDC pain and function scores were 2 and 8, and mean KS-F score was 93. 88% of patients reported satisfaction.

Conclusion: Osteochondral allograft transplantation was an effective treatment for osteochondritis dissecans of the knee, with significant improvement in pain and function scores and high patient satisfaction. Graft survivorship was 87% at 10 years.

Paper 2

Accelerated Return to Play Following Osteochondral Autograft Plug Transfer (OATS)

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Objectives: Chondral lesions about the knee are a challenging clinical entity particularly among high performance athletes whose return to play is dependant on the quality and durability of chondral repair. At our institution, we favor osteochondral autograft plug transfer (OATs) when lesion size and location allow, as we believe it results in the most durable cartilage repair currently available due to the transfer of autogenous hyaline cartilage into the area of injury. We further postulate that OATs may allow a more rapid return to play in the athlete population, as the release to full activity is predicated only on adequate time for bony healing and appropriate clinical progress. We investigated the time for return to play in a cohort of competitive athletes who had undergone OATs followed by an accelerated return to play protocol and compared this to previously published timelines for chondral repair procedures.

Methods: This was a retrospective chart review of an overall institutional cohort of 152 osteochondral autograft transfer surgeries performed by 4 fellowship trained orthopaedic surgeons over the past 12 years. We identified 20 competitive athletes (average age of 21.6 years) who had undergone isolated OATs procedures of the knee, followed by a physician-directed accelerated progression and return to sports. Athletes were evaluated for clinical outcomes, and time until full return to their prior level of athletic competition.

Results: In this cohort, osteochondral autograft transfer was carried out to address femoral condylar lesions in all 20 patients. The donor site was either the superolateral portion of the lateral condyle or the intercondylar notch. The average lesion size was 134mm² (36-280mm²). The average number of plugs per lesion was 2.15, with a maximum of 4 plugs and 6 patients receiving more than 2. Our bias is to use fewer, larger plugs when possible. All patients were kept partial weight bearing initially, and released to normal ambulation as early as 2 weeks for single plugs and by week 6 for multiple plugs and then advanced as tolerated. The average time until release to play in this cohort was 88.4 days (39-185), with successful resumption of sports in all patients. There were no clinical failures in this cohort and no patient required a revision surgery. Four patients did develop a joint effusion at one point along their recovery course and required aspiration and intra-articular injection.

Conclusion: Based on our findings, we assert that an accelerated return to play protocol following osteochondral autograft transfer will allow for a predictable and more rapid return to sports. This has resulted in a substantially reduced time to pre-injury activity levels in our elite athlete population when compared to the currently available literature. The majority of our patients in this cohort (80%) were cleared to resume athletics by 3 months post OATs procedure. When compared to the current literature on return to play after chondral surgery of the knee¹, this represents a greater than 50% more rapid return to full activities in these patients.

1. Mithoefer K, Hambly K, Della Villa S, Silvers H, Mandelbaum BR. Return to sports participation after articular cartilage repair in the knee: scientific evidence. *The American journal of sports medicine*. Nov 2009;37 Suppl 1:167S-176S.

Paper 3

Meniscal Allograft Transplantation Reoperation Rates, Operative Findings, and Survival Analysis: A Review of 200 Consecutive Transplants at Minimum Two-year Follow-up

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Objectives: Reoperation rates for meniscal allograft surgery (MAT) are high with a 70% survival rate at 10 years. The indications and findings for secondary surgery are not well characterized. The purpose of this study is to quantify the percentage of transplants requiring a re-operation, to characterize the operative findings, perform a survival analysis, and perform a case-control analysis if an early return to surgery is predictive of failure.

Methods: A retrospective review of prospectively collected data from a single-surgeon was performed. Inclusion period was 2003-2011. The number of patients returning to the OR and the findings at surgery were recorded. A meniscal transplant survival curve, the duration between transplantation and return to OR, and an odds-ratio of risk for failure for those requiring a re-operation in the perioperative period were calculated.

Results: Two hundred patients underwent a MAT during the study period. 38% were isolated; 62% had concomitant procedures. Sixty-four (32%) patients returned to the operating room, of which 38 (59%) were for a meniscal? debridement. The mean duration to secondary surgery was 21 months, with 73% within 2 years. One hundred seventy-two (86%) patients were evaluated at a mean 59 months (Range 24-118 months). Eight went on to require a revision MAT or total knee replacement (4.7%). Patients requiring secondary surgery within two years had an 8.4 odds-ratio for future failure (95% CI 1.6-43.4 p.007).

Conclusion: In the largest consecutive series reported in the literature, meniscal allograft transplantation (MAT) has a 95% success rate a mean of approximately five years. There is a 32% reoperation rate, with meniscal debridement the most common secondary surgical treatment.

Paper 4

Biomechanical Consequences of a Complete Radial Tear Adjacent to the Medial Meniscus Posterior Root Attachment Site

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Objectives: Complete radial tears near the medial meniscus posterior root attachment site disrupt the circumferential integrity of the meniscus (*similar to a posterior root avulsion*). These tears can compromise the circumferential integrity and have been reported in biomechanical studies to simulate the meniscectomized state. The purpose of the study was to quantify the tibiofemoral contact load and contact area changes that occur in cadaveric knees from complete posterior horn radial tears and subsequent repairs of the medial meniscus adjacent to the posterior root attachment site.

Methods: Six non-paired fresh-frozen human cadaveric knees each underwent 45 different testing conditions: 9 medial meniscus conditions (intact, root avulsion, root repair, serial radial tear and in-situ repair at 3, 6, and 9 mm from the root attachment site) at 5 flexion angles (0°, 30°, 45°, 60° and 90°); under a 1000-N axial load. Tekscan sensors were used to measure contact area and pressure in the medial and lateral compartments.

Results: The medial meniscus root avulsion and all radial tear conditions resulted in significantly decreased contact area and increased mean contact pressure compared with the intact state for knee flexion angles beyond 0° ($P < .05$). **Medial Compartment Contact Area** Individual comparisons of meniscus conditions for results at 30°, 45°, 60° and 90° of flexion demonstrated the following. At each angle, the root avulsion and 3, 6 and 9 mm radial tears resulted in a significant reduction (range 33%-45% decrease) in medial compartment contact area. **Medial Compartment Contact Pressure** Individual comparisons of meniscus conditions were performed at 30°, 45°, 60° and 90° of flexion. At each angle, the root avulsion and all radial tears resulted in a significant increase in average contact pressure (range 46%-110%) when compared to the intact meniscus. **Root Repair and In-situ Repairs** The root repair and in-situ repairs restored contact area and pressure to levels statistically indistinguishable from the intact meniscus, and increased contact area and decreased contact pressure when compared to the corresponding tear conditions (**Figure**).

Conclusion: Posterior horn radial tears adjacent to the medial meniscus root that extend to the meniscocapsular junction can lead to derangement of the loading profiles of the medial compartment that are similar to a root avulsion. Repair of these radial tears with an in-situ pullout technique restored joint mechanics to the intact state. **Clinical Relevance** Complete radial tears of the posterior horn of the medial meniscus, are biomechanically equivalent to root avulsions and could potentially lead to medial compartment arthrosis. An in-situ repair offers an alternative treatment to meniscectomy and can reestablish the posterior anchor point, thus improving load distribution in the medial compartment.

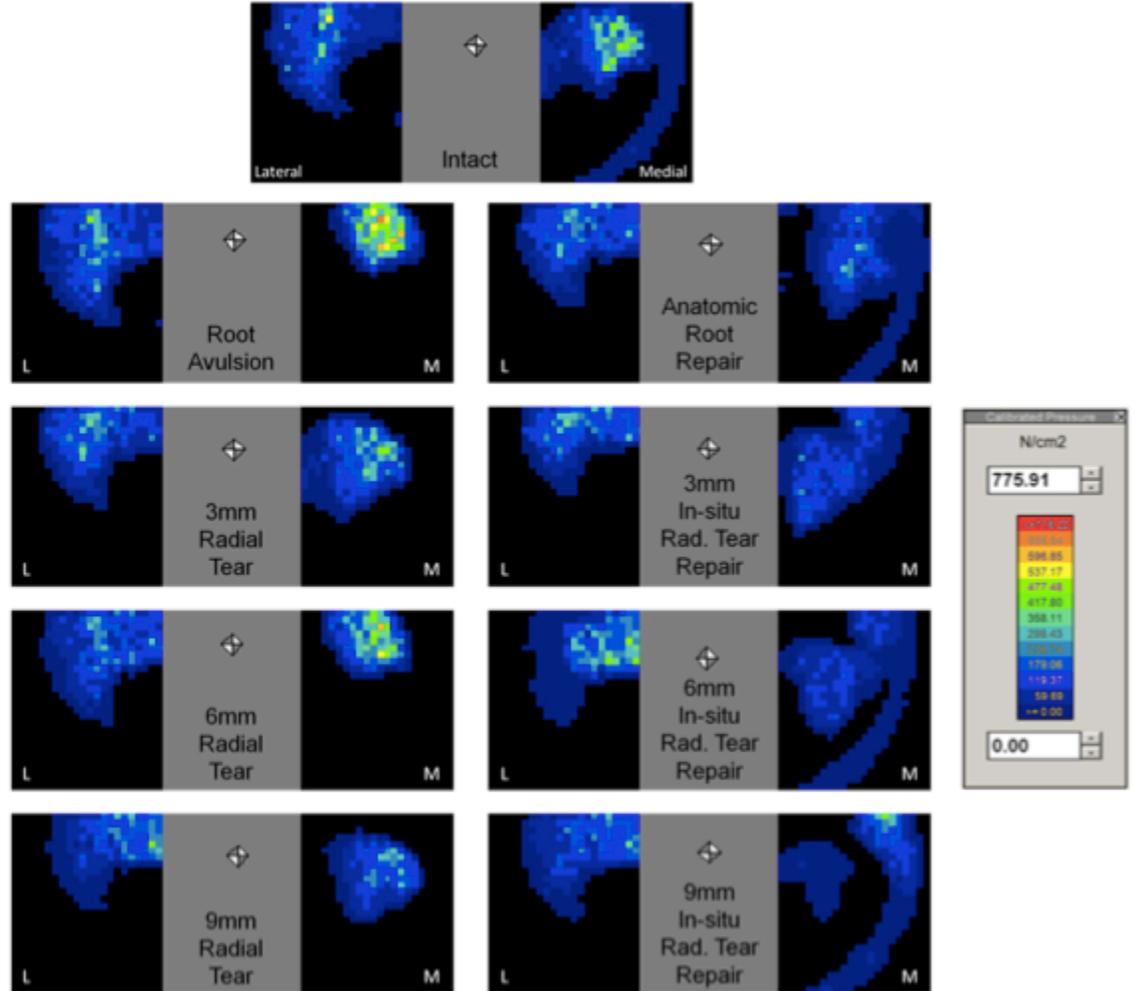


Figure. Representative Tekscan contact area and pressure maps of the medial and lateral compartments of a specimen at 30° of flexion undergoing the 9 medial meniscus conditions (right knee).

Paper 5

Pediatric ACL - Socioeconomic Factors That Contribute to a Delay in Presentation, and the Increase in Pathology that Correlates with Delayed Reconstruction

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Objectives: The pediatric anterior cruciate ligament (ACL) injury is being recognized as an increasingly important area of research interest. This study further investigates and augments the recently published data describing a delay in pediatric ACL reconstruction and concomitant pathology, which is limited in numbers and scope. Furthermore, this study is the first to investigate the socioeconomic factors that correlate with a delay to surgery.

Methods: All subjects that underwent primary anterior cruciate ligament reconstruction surgery at a single tertiary pediatric hospital between July 2005 and August 2009 were included. Demographic, clinical and socioeconomic variables were retrospectively collected from all patients less than nineteen years of age at the time of surgery.

The operative reports of all eligible subjects were reviewed. The treatment, location and severity of all chondral and meniscal injuries were recorded. The demographics and clinical characteristics of all subjects were summarized using descriptive statistics. Univariable logistic regression analyses were used to identify factors related to chondral and/or meniscal injuries that required additional operative treatment. Meniscal and chondral injuries were analyzed with Kaplan-Meier time to event models to compare time to surgery based on the severity of injury.

Results: A total of 133 subjects were included. (Figure 1) The average age at injury was 15 years old (range, 7.83 to 18.56) The median time to surgery among all subjects was 2.29 months [interquartile range 1.31 to 4.30]. A total of 26 subjects (19.55%) underwent ACL surgery greater than five months post injury.

A total of 59 chondral and 119 meniscal injuries were identified. The prevalence of chondral and/or meniscal injuries requiring operative treatment was 57.14% [95% CI: 48.73 to 65.55%].

A delay in surgery of greater than 5 months [$p = 0.0001$] and a return to activity prior to surgery [$p = 0.0007$] were significantly related to increased severity of concomitant pathology. The odds of a subject presenting with a chondral and/or meniscal injury that required additional operative treatment were 7.81 [95% CI: 2.21 to 27.58] times greater for a subject that underwent surgery greater than five months after their initial injury.

Demographic factors that were not significantly related include: gender [$p = 0.1601$], laterality [$p = 0.3940$], BMI percentage [$p = 0.2969$], ethnicity [$p = 0.5233$], bracing prior to surgery [$p = 0.6848$] and the subjective report of knee instability prior to surgery [$p = 0.3940$].

Age at injury [$p = 0.0004$], household income based on median income associated with zip code [$p = 0.0150$] and type of insurance (private vs. none/government assisted) [$p = 0.0491$] were significantly related to the timing of ACL surgery.

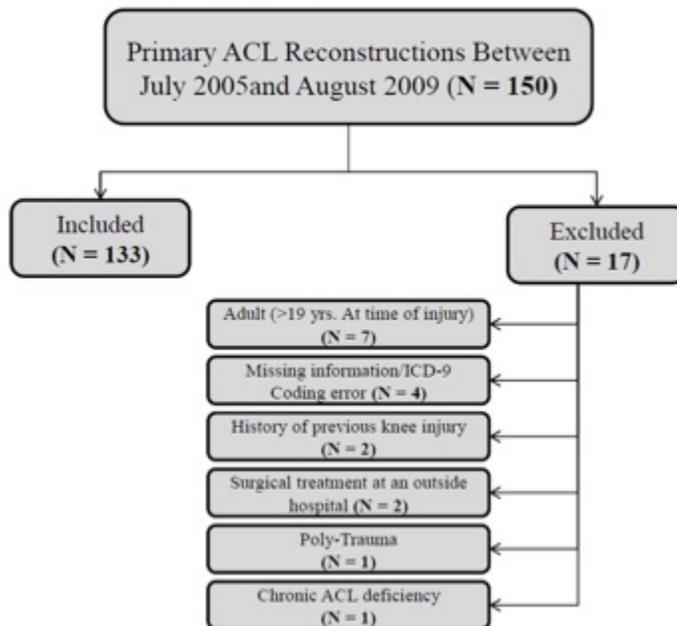
After controlling for household income, the rate at which surgery occurred was 1.19 times [95% CI: 1.09 to 1.30] greater for every one year increase in age at the time of injury. After controlling for age at

injury, the rate at which surgery occurred was 1.13 times [95% CI: 1.04 to 1.21] greater for every \$10,000 increase in household income.

Conclusion: This study shows that a delay in surgery greater than five months correlated with increased number and severity of chondral and/or meniscal injuries.

This is the first study of its kind to show that age at injury, insurance type and household income were significant, independent predictors of the rate at which ACL surgeries occurred.

Figure 1. Summary of Enrollment



Paper 6

Long-term Course in Adolescents after Anterior Cruciate Ligament Reconstruction (ACL)

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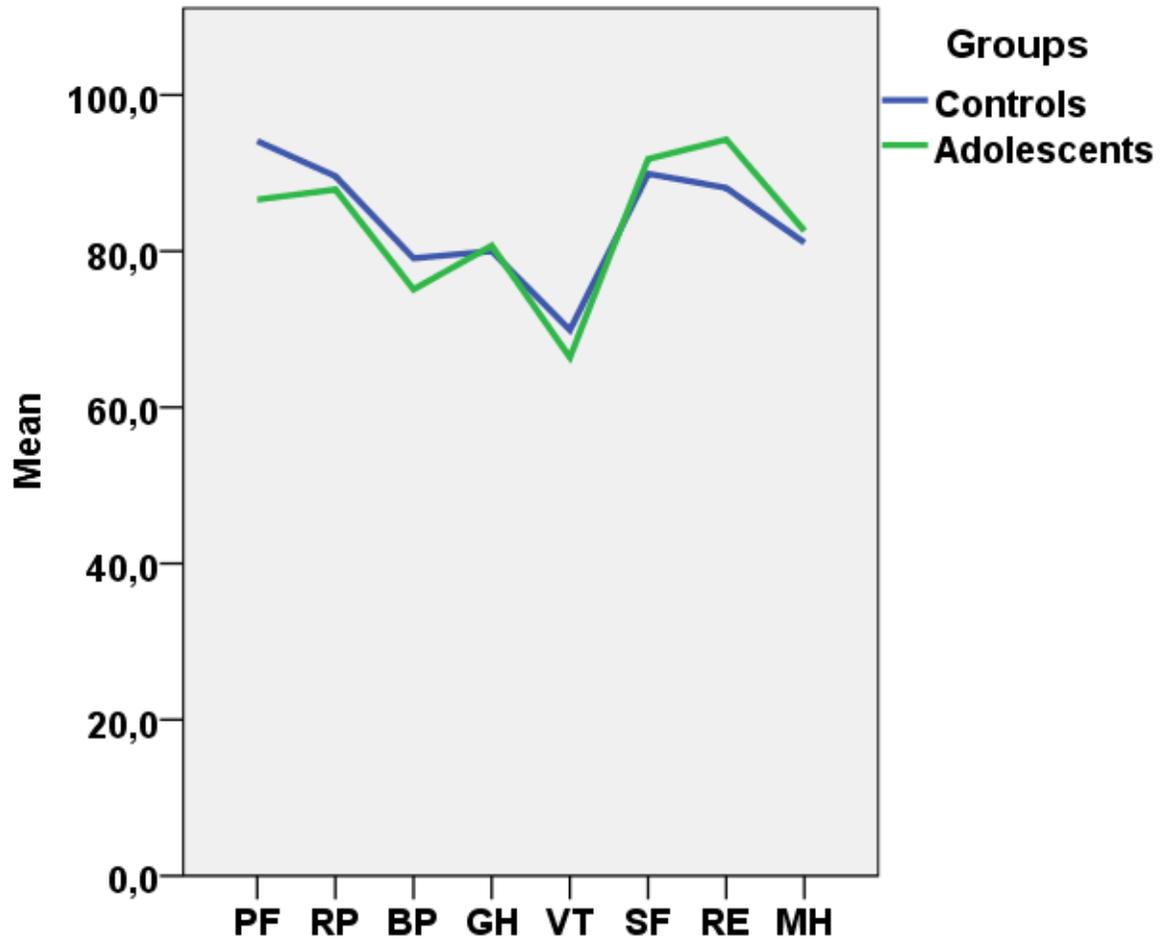
Objectives: The risk for further intra-articular damage associated with conservative treatment or delayed ACL reconstruction must be considered against the risk for growth disturbance with early reconstruction and trans-physeal drilling. Long-term follow-ups after surgical treatment of ACL injuries in children are rare. The aims of the present study were to evaluate the results 10-20 years after ACL reconstruction in terms of the presence of osteoarthritis, clinical assessments and health-related quality of life in patients who were adolescents at the time of surgery.

Methods: 32 children, aged 12-16 years (11 boys; 21 girls), with symptomatic unilateral ACL rupture, underwent reconstruction using bone-patellar bone-tendon (n=10) or hamstring tendon (n=22) autograft. Twenty-nine patients (91%) underwent clinical, radiographical and health-related quality of life assessments after 10-20 years (mean 175 months).

Results: The reconstructed knee had significantly more osteoarthritic changes compared to the non-involved contra lateral knee. Preoperatively the Tegner activity level was 4 (2-8) and the Lysholm knee score was 75 (50-90) points. At follow-up the corresponding values were 4 (1-7) and 84 (34-100) points, (p=n.s; preop v follow-up). The one-leg-hop test was 84% (0-105) preoperatively and 93% (53-126) at follow-up (p=0.003). At follow-up muscle strength measurements displayed more than 90 % of the non-involved leg in both extension and flexion. The knee laxity measurement was significantly less at follow-up than preoperatively (p=0.001). The SF-36 revealed scores comparable to healthy controls (fig. 1). The EQ 5D was 0.9. The KOOS values were lower in all dimensions compared to an aged matched healthy controls.

Conclusion: In the long term, patients who were adolescents at the time of ACL reconstruction reveal significantly more radiographically visible osteoarthritic changes in their operated knee than in their non-involved contralateral knee. Clinical outcomes and health-related quality of life are comparable to

healthy controls.



Paper 7

Rates and Determinants of Return to Play after Anterior Cruciate Ligament Reconstruction in Division 1 College Football Athletes: A Study of the ACC, SEC, and PAC-12

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Objectives: In competitive athletes, return to play (RTP) and return to pre-injury levels of performance are the main goals of anterior cruciate ligament (ACL) surgery. RTP has been studied in several athletic populations, such as the National Football League. However, to our knowledge, RTP has not been comprehensively evaluated in Division 1 college football. This study aimed to determine the rate of RTP amongst players in three major Division 1 college football conferences, and to investigate several athlete and surgery related variables that may affect RTP. We hypothesized that rates of RTP would be higher than those previously reported in the National Football League and that graft choice and history of concomitant meniscectomy would affect RTP. We also hypothesized that players with more experience, at higher depth chart positions, and/or on scholarship would RTP at higher rates than other players.

Methods: Head team orthopaedists and athletic trainers at institutions in the Atlantic Coast Conference, Southeastern Conference, and Pacific 12 Conference were contacted to request their participation in the study. Following IRB approval participating institutions were sent a standardized data collection spreadsheet that asked for RTP and other athlete- and surgery-specific information on all football players undergoing ACL reconstruction from 2004-2010. RTP was defined as an athlete participating in a full practice or official game after the date of his surgery. Athletes whose eligibility expired while injured were excluded from our analysis. Data from each institution was pooled and Chi-square and Fisher Exact tests were used to test the association between any categorical variables and RTP rates.

Results: Data from a total of 184 athletes was obtained. The overall rate of RTP was 82% amongst all athletes. 76% of athletes were able to return to a level of play equal or higher than before their injury. Player's depth chart position before injury did have a significant ($p = .0049$) association with RTP, with 73% of players who rarely played, 88% of utilized players, and 95% of starters returning to play after surgery. Athletes on scholarship returned to play at a higher rate (88%), than those not on scholarships (69%) ($p = .014$). Years of experience also had a significant ($p = .047$) effect on RTP, with freshman RTP at 83%, sophomores at 94%, juniors at 89%, seniors at 73%, and fifth year seniors at 75%. The use of autograft vs. allograft and the specific choice of autograft did not have a significant impact on RTP rates. Players who underwent a meniscectomy returned to play at a rate (79%) similar to those who did not have a concomitant meniscectomy (84%) ($p = .56$).

Conclusion: The overall rate of RTP in our Division 1 college football athlete cohort was higher than that previously reported in professional football players. Athletes at higher positions on the depth chart and those on scholarship returned to play at higher rates. Year in school also had a significant effect on RTP rates, while the type of ACL graft and the performance of meniscectomy did not.

Paper 8

The Direct Insertion of the ACL Carries More Load than the Indirect Insertion: An Important Consideration When Performing Anatomic ACLR

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Objectives: Recent histological studies have shown that the ACL consists of two different structures: the direct and indirect insertions. The direct insertion is located along the lateral intercondylar ridge and the indirect insertion is 'lower' in the notch, adjacent to the posterior articular cartilage. The 'lower' position has become more popular for locating the femoral tunnel, as surgeons switch to the anteromedial (AM) portal drilling technique in order to place the graft in the region of the native footprint. However, a recent registry-based outcomes study has reported a 1.5 times higher graft failure rate for AM portal versus traditional transtibial techniques. The objective of this study was to investigate the load characteristics of the native ACL in the regions of the direct and indirect insertions. We hypothesized that the direct insertion would carry more load than the indirect insertion.

Methods: Twelve cadaveric knees were mounted to a six degree of freedom robot equipped with a universal force-moment sensor. We simulated the Lachman and anterior drawer tests at 30° and 90° of flexion by applying a 134N anterior load, and the pivot shift test at 15° flexion by applying combined valgus (8Nm) and internal (4Nm) rotational moments. The kinematic pathway required to achieve these loading conditions was recorded for each intact knee. Using position control to repeat the loading paths, the robot recorded the loads for the ACL intact, ACL partially sectioned, and ACL completely sectioned states.

Sectioning Protocol: The lateral intercondylar ridge and posterior articular margin was identified in each case. The 50% mark between this two areas was used to delineate the regions of the direct and indirect insertions (Fig. 1). Sectioning order was alternated between each cadaver.

Footprint Digitization: The borders of the sectioned areas were digitized post-sectioning and mapped onto a computed tomography (CT) scan of each knee. The sectioning method was assessed under a blinded validation by experienced observers (TW, AP) who excluded two specimens that did not conform to the objective definitions of the sectioning method.

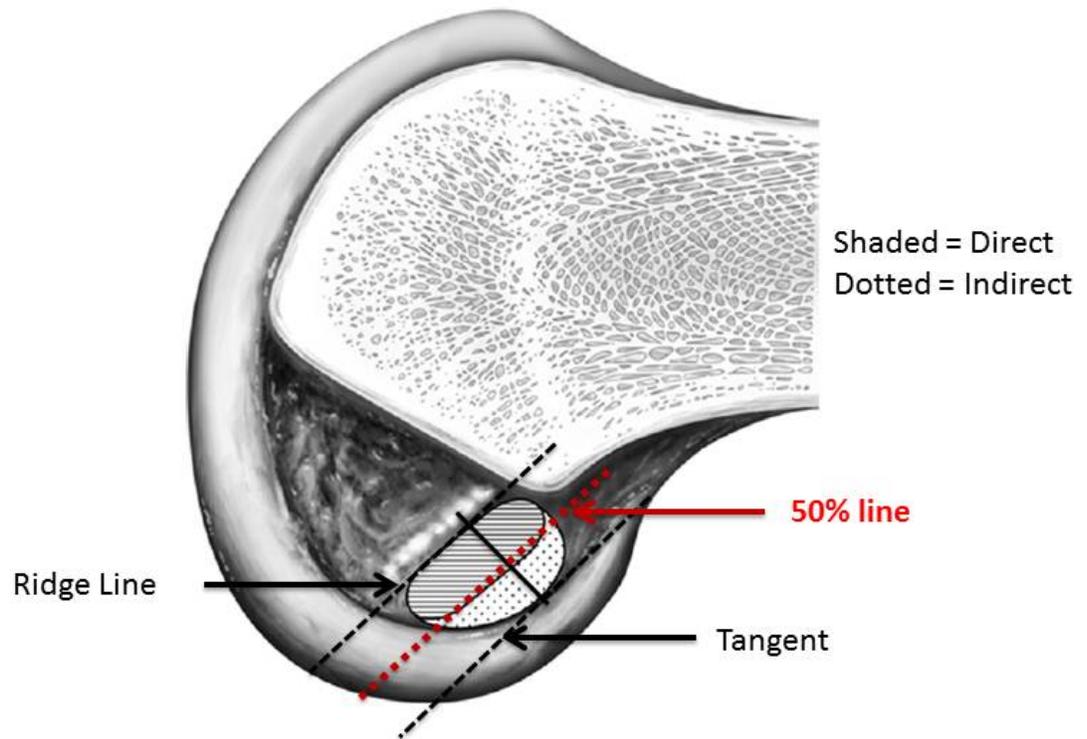
Statistics: Loads were compared between direct and indirect locations at different flexion angles by conducting two-way repeated measures ANOVA models.

Results: Under an anterior tibial load at 30° flexion, the direct insertion carried 83.9% ($\pm 7.2\%$) of the total ACL load compared to 16.1% ($\pm 7.2\%$) in the indirect insertion ($p < 0.001$). The direct insertion also carried more load at 90° flexion (95.2% vs 4.8%; $p < 0.001$). Under a combined rotatory load at 15° flexion, the direct insertion carried 84.2% ($\pm 4.2\%$) of the total ACL load compared to 15.8% ($\pm 4.2\%$) in the indirect insertion ($p < 0.001$).

Conclusion: The fibres in the direct insertion of the ACL carry more load than fibres in the indirect insertion. Previous studies have suggested that the direct insertion plays a major role in the mechanical

link between the ACL and bone. With the current shift in emphasis towards anatomic ACL reconstruction, it may be beneficial to create the femoral tunnel within the direct insertion rather than 'lower' in the notch. Although further work is required in determining graft behaviour at the new insertions sites described in this study, our findings suggest that placing a graft in the region of the direct insertion may be an important consideration when adhering to the principles of anatomic ACL reconstruction.

Figure 1: Sagittal Section of Lateral wall Intercondylar Notch of Femur



Paper 9

The Effect of an Acetabular Labral Tear, Repair, Resection, and Reconstruction on the Hip Fluid Seal

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Objectives: The acetabular labrum is theorized to have an important role in the normal function of the hip through the hip fluid seal. The hip fluid seal functions to create intra-articular fluid pressurization and stability to distractive forces. Yet, the effect of a labral tear or partial labral resection, and interventions including labral repair and labral reconstruction, on the hip fluid seal remain to be defined. The purpose of the current study was to characterize the hip fluid seal, including intra-articular fluid pressurization and stability to distraction, in six different labral conditions: (1) intact, (2) labral tear, (3) labral repair, (4) partial resection, (5) labral reconstruction with iliotibial band, and (6) complete resection. Additionally, the current study investigates the effect of looped (3a) and through (3b) type labral suture repairs on the hip fluid seal.

Methods: Eight cadaveric hips with a mean age of 47 (range 41-51) years were included in the study. Hips were compressed using an Instron testing device with a force of 2.7 times body weight (2118 N), simulating the single leg stance phase of gait, while intra-articular pressure was continuously measured with three miniature 1.0 x 0.3 mm pressure transducers. Additionally, the distractive strength of the hip fluid seal was recorded after each loading cycle. Three loading trials were performed for each labral condition. Specimens were randomized to looped or through type labral suture repairs within matched hips. Peak intra-articular pressures and distractive strength measurements for each condition were normalized relative to the intact state of each hip (percentage of intact state). Statistical analyses were performed utilizing a general linear model with repeated measures analysis for several predetermined comparisons of labral conditions.

Results: Intra-articular fluid pressurization of the intact state varied from 78 to 422 kPa, while the distractive strength of the hip fluid seal ranged from 124 to 150 N. Labral tear, partial resection, and complete resection resulted in average decreases in pressurization of 25%, 47%, and 76%, and decreases in distractive strength of 24%, 71%, and 73% respectively, compared to the intact state. Through type labral suture repair resulted in significantly greater improvement in fluid pressurization, compared to the labral tear state, than the looped type repair (+66.4% vs. -12.5%, $p=0.029$). Labral reconstruction resulted in a mean normalized pressurization of 110% and distraction of 66%, with an improvement in pressurization of 53% and distraction of 37% compared to a partial labral resection ($p=0.012$ and $p=0.021$, respectively). A moderate positive correlation between peak fluid pressurization and distractive strength was present (Pearson correlation coefficient 0.435, $p=0.016$).

Conclusion: The presence of a labral tear or partial labral resection results in decreases in intra-articular fluid pressurization and stability to a distractive force. Through type labral suture repair restores the hip fluid seal significantly better than a looped type repair at time zero. Labral reconstruction with an iliotibial band graft significantly improves pressurization (to levels similar to the intact state) and stability to distractive force, compared to a partial labral resection.

Figure 1. Experimental testing setup including (A) Instron, (B) potted femoral specimen, (C) potted

acetabular specimen, and (D) heated saline bath.

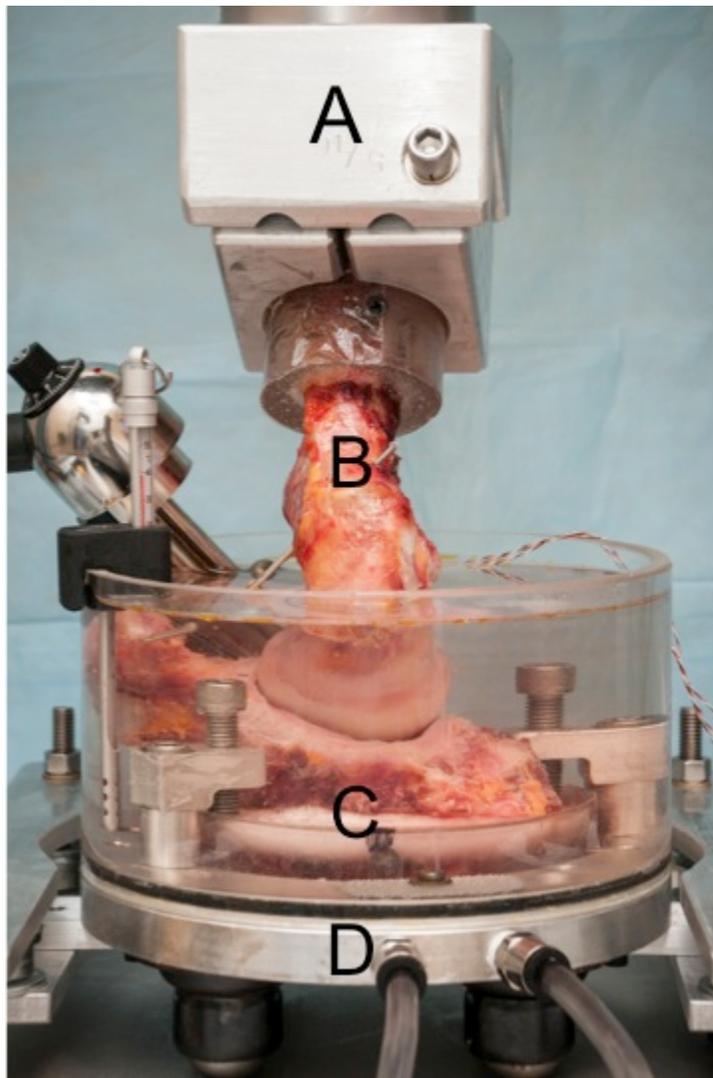


Table 1. Fluid Pressurization and Maximal Distractive Strength of Hip Seal for Each Labral Condition

	Fluid Pressurization		Maximal Distractive Strength	
	Mean (SD)	Mean Change from Intact	Mean (SD)	Mean Change from Intact
Intact	100%		100%	
Labral Tear	75.1% (32.8)	-24.9%	75.6% (34.4)	-24.4%
Labral Repair	102.1% (68.7)	+2.1%	84.0% (19.8)	-16.0%

-Looped repair	69.8% (39.0)	-30.2%	75.2% (24.0)	-24.8%
-Through repair	134.3% (82.0)	+34.3%	92.1% (12.1)	-7.9%
Partial Resection	53.2% (37.4)	-46.8%	29.2% (26.4)	-70.8%
Labral Reconstruction	109.5% (37.8)	+9.5%	66.0% (35.1)	-34.0%
Complete Resection	24.1% (17.7)	-75.9%	26.9% (22.0)	-73.1%

Paper 10

Results of Non-operative and Operative Management Of Apophyseal Avulsion Fractures of the Hip and Pelvis in Adolescent Athletes

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Objectives: Apophyseal avulsion fractures of the hip and pelvis occur almost exclusively in the adolescent population, with greater numbers being seen recently as the popularity and intensity of youth sports increases. Limited evidence exists detailing the demographics or distribution of these fractures by injury site. The goal of the current study was to present a comprehensive perspective on 437 of these fractures, including the indications and clinical course of 25 cases that underwent surgical intervention.

Methods: All cases of an apophyseal avulsion fracture of the hip or pelvis between the years of 1981-2012 at a tertiary care pediatric center underwent radiographic and chart review, including operative details for that sub-population. Demographic data was analyzed, along with radiographic displacement, healing times, and return to sports for both groups.

Results: 413 patients underwent definitive non-operative treatment, 72% of which were male. The mean age was 14.5 years. The anatomic site of injury was well-distributed: AIIS 29%, ASIS 27%, ischial tuberosity 17%, lesser trochanter 15%, and iliac crest 11%. Half of all injuries occurred during one of three different athletic activities (soccer 26%, track 13%, baseball/softball 11%), with a wide range of sports in the overall cohort. In the 287 nonop cases with adequate follow up data to confirm mean radiographic union and time of return to sports (RTS), healing occurred at 2.7 months and RTS at 2.8 months respectively. The mean age of the cohort of 25 patients who ultimately required operative treatment was 15.7 years, with 72% of cases being initially treated with nonoperative measures. The ischial tuberosity was the most common (64%) anatomic site with others including AIIS 16%, iliac crest 16%, and ASIS 4%. Excision of the apophyseal fragment was the intervention pursued for 48% of cases, with the mean time to union of 4.8 months in 11 cases which underwent fixation and had adequate follow up data.

Conclusion: In over 400 cases of apophyseal avulsion fractures in an adolescent population, 94% were successfully treated nonoperatively, with mean times of healing and return to sports under 3 months. Most cases requiring surgery failed primary conservative care, many of which underwent fragment excision, rather than fixation, due to the chronic nature of their preoperative period. Better understanding of the rare indications for early fixation and functional outcome measures of both nonoperative and operative management of these injuries is warranted, particularly given their increasing frequency paralleling a rise in overuse and youth sports injuries.

Paper 11

Arthroscopic Hip Revision Surgery for Residual FAI: Surgical Outcomes

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Objectives: There is a steep surgical learning curve when managing femoroacetabular impingement (FAI) and residual FAI can lead to continued pain and disability. There is very limited data reporting outcomes after revision arthroscopy for residual FAI.

Methods: The records of patients that underwent arthroscopic hip revision surgery for residual FAI based on plain radiographs and 3D CT scans were reviewed. Pre and post-operative structural pathomorphology, intra-operative findings, and pre and post-operative outcomes measures using Modified Harris Hip Scoring (MHHS), SF-12 scoring, and pain on a visual analogue scale (VAS) were evaluated. Outcomes after revision arthroscopic FAI correction were compared to a cohort that underwent primary arthroscopic FAI correction.

Results: 59 patients (85 hips) underwent arthroscopic revision FAI correction (mean 20.8 months follow-up). There were 98 previous arthroscopic surgeries and 4 previous surgical dislocations. There were 39 males and 46 females with a mean age of 29.5 years (range 16 - 59). 80 hips had residual cam-type FAI, and 64 hips had residual pincer-type FAI and underwent femoral and rim resections, respectively. The labrum was debrided in 27 hips, repaired in 48 hips and reconstructed with allograft in 8 hips. Adhesions were excised for 54 hips. The results of revision arthroscopic FAI correction were compared to 154 patients (169 hips) that underwent primary arthroscopic FAI correction (mean 25.2 months follow-up). The mean improvement for outcomes scores after revision FAI correction was 18.9 points (MHHS, $p < .01$), 13.4 points (SF-12, $p < .01$), and 2.2 points (VAS, $p < .01$) compared to 23.7 points (MHHS, $p < .01$), 22.3 points (SF-12, $p < .01$), and 4.6 points (VAS, $p < .01$) after primary arthroscopic FAI correction. Most recent outcomes scores and mean improvement in outcome scores were significantly better after primary (81.1% good/ excellent results) compared to revision (69.8% good/excellent results) FAI correction (MHS ($p > .05$), SF-12 ($p < .01$), VAS ($p < .01$)).

Conclusion: With appropriate indications and expectations, arthroscopic hip revision surgery for residual FAI led to significantly improved outcome measures. Outcomes, however, were inferior to those after primary arthroscopic FAI corrective surgery.

Paper 12

Outcomes of Endoscopic Treatment for Greater Trochanteric Pain Syndrome: Minimum of Two-Year Follow-Up

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Objectives: Greater trochanteric pain syndrome (GTPS) is a common complaint with an estimated incidence of 1.8/1,000 persons. GTPS usually responds well to conservative treatment. In refractory cases, endoscopy offers a less invasive approach than open surgery, and offers the advantage of evaluating and treating coexistent intraarticular disorders. The purpose of this study is to report the clinical outcomes of endoscopic treatment for GTPS at a minimum of two years follow-up and to report the incidence and outcomes of hip abductor tears.

Methods: During the study period, patients who presented with lateral hip pain, pain on palpation over the greater trochanter or hip abductor weakness and were treated with an endoscopic trochanteric bursectomy were included. Exclusion criteria were previous hip conditions and Tonnis grade ≥ 2 . Patient reported outcome (PRO) scores used include the modified Harris Hip Score (mHHS), the Non-Arthritic Hip Score (NAHS), the Hip Outcome Score-Activities of Daily Living (HOS-ADL), and the Hip Outcome Score-Sport Specific Subscale (HOS-SSS). PRO scores were collected pre-operatively and two-years postoperatively. Visual analog scale (VAS) scores and patient satisfaction ratings were also collected. Any revision surgeries, complications, or conversions to total hip arthroplasty (THA) were noted.

Results: A total of 59 cases met the inclusion/exclusion criteria, of which 50 patients (85%) were available for follow-up at minimum two years. Forty-six patients reported two-year follow up PRO scores and four patients needed total hip replacement surgery. All patients had endoscopic trochanteric bursectomy. Thirteen patients (26%) had a gluteus medius tear treated during surgery. Average follow up was 31 months (range 24-50). Average age was 50 years (range 23-75). Patients demonstrated significant improvement ($p < 0.01$) from pre-operative to last follow-up in all PROs. Patients who underwent gluteus medius (GM) repair demonstrated higher improvement in all PROs compared to patients without GM pathology (Table 1). Four patients (8%) went on to have THA, three patients (6%) required revision arthroscopy. Nine patients (18%) had a complication; however, all were transient and none required further surgical intervention.

Conclusion: Patients experienced a statistically significant clinical improvement in PROs, and pain scores, and reported high satisfaction after endoscopic trochanteric bursectomy with or without gluteus medius repair. We conclude that peritrochanteric endoscopy is a safe and efficient treatment option for recalcitrant GTPS.

Comparison of Patients With and Without Gluteus Medius Pathology

	Pre-operative	Pre-operative	Last Follow-up	Last Follow-up	Improvement	Improvement
	No GM Tear	GM Repair	No GM Tear	GM Repair	No GM tear	GM Repaire
mHHS	55.25	48.55	80.75	86.39	25.5	37.84
HOS-ADL	61.59	46.93	80.62	88.45	19.04	41.53
HOS-SSS	37.84	30.82	62.92	78.58	25.08	47.76
NAHS	53.92	46.46	78.05	80.58	24.13	34.12
VAS	6.45	6.62	3.24	2.31	3.21	4.31

Paper 13

A Prospective Outcome Evaluation of Humeral Avulsions of the Glenohumeral ligament (HAGL) Tears Repairs in an Active Population

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Objectives: Humeral Avulsions of the Glenohumeral ligament (HAGL) are an infrequent and underappreciated cause of shoulder instability and dysfunction. The purposes of this study are to prospectively evaluate the presentation, clinical history and surgical outcomes of patients with HAGL tears.

Methods: Over an eight-year period, patients with failed non-operative shoulder dysfunction with a confirmed HAGL tear on MR Arthrogram, who elected to undergo surgical treatment were prospectively investigated. Independent variables were patient demographics, clinical presentation, physical examination findings, and arthroscopic findings. The dependent variables assessed included return to work and activity rates, pre-operative and post-operative patient reported outcomes (ASES, SANE, WOSI scores) and independent physical examinations. Statistical analysis was via Student's t-test and significance set at $p < .05$.

Results: A total of 23 of 24 patients (96%) were evaluated at a mean of 32.1 months (Range 24-68 months). There were 11 females (48%) and 12 males (52%) at a mean age of 24.2 years (Range 18-33). Mechanism of injury was core training (cross-fit or equivalent) in 48%, pull-ups in 22%, and unknown in 30%. The primary complaint was pain in 82%; 20% of patients complained of instability symptoms. There were 12 patients with anterior HAGLs, 8 patients with reverse HAGLs and 3 with combined anterior and posterior lesions. 10 patients had both HAGL and labral tears, 13 with isolated HAGL. 9 patients underwent arthroscopic surgical repair and 14 underwent an open surgical repair. There was a clinically and statistically significant improvement in patient reported outcomes (WOSI=54%, SANE=50%) improved (WOSI=83%, SANE=87%, $p < 0.01$). 21 of 23 (91%) patients returned demonstrated patient satisfaction and a return to full activity.

Conclusion: This study demonstrates patients with symptomatic HAGL tears present with pain and shoulder dysfunction, that anterior and reverse HAGL tears are nearly distributed equally. After surgery, patients demonstrated statistically and clinically significant improved outcomes, a predictable return to activity and patient satisfaction. Additional work is necessary to determine optimal treatments, especially with combined HAGL and labral tears.

Paper 14

Results of Latarjet Coracoid Transfer to Revise Failed Arthroscopic Instability Repairs

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Objectives: Arthroscopic instability repair has supplanted open techniques to anatomically reconstruct anteroinferior instability pathology. Arthroscopic technique can fail for a variety of reasons. We have utilized the Latarjet as a revision option in failed arthroscopic instability repairs when there is altered surgical anatomy, capsular deficiency and/or glenoid bone compromise and recurrent glenohumeral instability.

Methods: We reviewed 51 shoulders (40 ♂, 11♀) that underwent Latarjet coracoid transfer for the revision of failed previous arthroscopic instability repair. The avg. age was 32.6 yrs (16-58). All patients had recurrent symptomatic anterior instability after previous arthroscopic surgery, and avg. time from arthroscopic repair to Latarjet was 13 months (4-40 mn). All had either CT or MRI that revealed suture anchor material in the glenoid, labral and capsular stripping, and anteroinferior glenoid bone loss or erosion. Advanced bone loss percentage analysis was not performed for this study. We excluded all patients that had a previous open repair, a seizure disorder, or if the Latarjet was a primary procedure. Outcome scores pre-operatively avg: SST: 6.7 (1-12); VAS: 3 (0-8); ASES: 63 (32-89).

Coracoid transfer was performed thru a subscapularis split in 38, and with tendon takedown in 13. The coracoid was osteotomized along its long axis parallel to the undersurface of the lateral aspect. This provided at least 2.5 to 3.5 cm of graft with the conjoined tendon attached. The coracoacromial (CA) ligament was incised leaving a 1 cm. stump. The transfer was affixed flush with the articular surface but not lateral to it, with two 3.5 mm cortical screws in lag fashion overdrilling the coracoid with the CA ligament directed laterally. The capsule was then repaired to the CA ligament to make the transfer extra-articular.

Results: At avg. 4 yr (2-7 yrs) follow-up stability had been maintained in 51 (100%).without further instability surgery. There were no hardware, neurologic, or infection complications. No graft resorption or non-unions occurred. DJD developed in 3 patients and required eventual resurfacing hemiarthroplasty in 2, and TSA in 1 at an avg of 3 years post-Latarjet (2-5 yrs). Outcome scores post-operatively avg: SST:9.3 (6-12); VAS: 2 (0-6); ASES: 84 (64-92).

Conclusion: A consecutive series of Latarjet coracoids transfers utilized for the revision of previous failed arthroscopic anteroinferior instability repairs achieved consistent stability. Progressive DJD was not due to hardware, but was encountered in 5%.

Paper 15

Clinical Outcomes Following the Latarjet Procedure in Contact and Collision Athletes

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Objectives: Although there are several reports of clinical outcomes after the Latarjet procedure for recurrent anterior glenohumeral instability, the literature is sparse for these Latarjet outcomes in the strictly contact or collision-type sport athletes who have significant glenoid deficiency and/or failed previous stabilization surgery.

The purpose of this study was to evaluate the clinical and functional results of these contact or collision athletes who underwent a Latarjet for symptomatic instability with glenoid bone loss or failed stabilization surgery, using modern instability outcome measures.

Study Design: Case series, Level of evidence, 4

Methods: Sixty-one consecutive contact and/or collision athletes (64 shoulders) treated with an open Latarjet procedure for recurrent anterior glenohumeral instability with significant glenoid bony deficiency and/or failed prior stabilization were retrospectively identified from two surgeons' practices. Thirty-nine patients and 42 shoulders (66%) were evaluated at a mean follow-up of 46 months (range: 24-95), whose an average age of surgery of 25.9 years (range: 16-47). Primary outcome measures were the Western Ontario Shoulder Instability Index (WOSI), American Shoulder and Elbow Society Questionnaire (ASES), Visual Analogue Scale, and return to sporting activity. IRB approval was granted for this study.

Results: Thirty-seven of forty-two shoulders (88%) were perceived as stable to these athletes. Two patients experienced subluxation events at 18 and 24 months after their Latarjet procedures. These 2 patients underwent further surgery including an arthroscopic debridement with biceps tenodesis and the other a revision stabilization Eden-Hybinette procedure, performed at 22 and 29 months after their Latarjets, respectively. One additional patient underwent surgery for hardware removal with arthroscopic debridement, with no reports of concomitant instability. Average WOSI and ASES scores for 42 shoulders were 76.5% (range: 6.4-100%, +/- 24.4) and 89.9 (range: 21.7-100, +/- 17.3). The average VAS score was 1.1. Fifty-four percent (21/39) of the athletes returned to their preoperative sports level, 18% (7/39) decreased their activity level in the same sport, 13% (5/39) changed sports and 15% (6/39) decreased level and changed sport, or stopped sports altogether.

Conclusion: At a minimum of 2 year follow-up, 72 % of contact/collision athletes returned to their original sport, whereas 28% had to change their sport type after their Latarjet, or stop sporting activities altogether. Failure by subluxation occurred in 4.8% of shoulders (at an average of 21 months); 88% reported their shoulder as feeling stable with average WOSI and ASES scores of 76.5% and 89.9 respectively. In this challenging group of patients, the Latarjet procedure successfully restores stability in 88% of cases; 72% return to their pre-operative sport type.

Paper 16

Primary Versus Revision Arthroscopic Rotator Cuff Repair - An Analysis In 350 Consecutive Patients

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Objectives: The aim of this study was to evaluate the outcome of revision arthroscopic rotator cuff surgery when compared with primary arthroscopic rotator cuff surgery in a large cohort of patients.

Methods: A consecutive series of 350 (300 primary and 50 revision) arthroscopic rotator cuff repairs performed by a single surgeon with a minimum of two years follow-up were retrospectively reviewed using prospectively collected data. With the 50 revision cases as a reference, three primary repair cases were chosen immediately before and three after each revision case. Standardized, patient-ranked outcomes, examiner determined assessments, and ultrasound determined rotator cuff integrity was assessed pre-operatively at six months and two years after surgery.

Results: The revision group had a significantly larger pre-operative tear size ($4.1 \text{ cm}^2 \pm 0.5 \text{ cm}^2$) (mean \pm SEM) compared to the primary group ($3.0 \text{ cm}^2 \pm 0.2 \text{ cm}^2$) ($p < 0.05$). The mean age of the revision group (63years, range 43-80) was older compared to the primary group (60years, range 18-88) ($p < 0.05$). The re-tear rate for primary rotator cuff repair was 16% at 6 months and 21% at two years; while the re-tear rate for revision repair was 28% at six months and deteriorated to 40% at two years ($p < 0.05$). Two years after surgery the primary group reported less pain at rest ($p < 0.02$), during sleep ($p < 0.03$) and with overhead activity ($p < 0.01$) compared to the revision group. The primary group had better forward flexion (+13 Degrees, $p < 0.03$), abduction (+18 Degrees, $p < 0.01$) and internal rotation (+2 vertebral levels, $p < 0.001$) compared to the revision group at two years after surgery. The primary group also had significantly greater strength (+15 N, $p < 0.0004$), lift-off strength (+9.3 N, $p < 0.02$) and adduction strength (+22 N, $p < 0.003$) compared to the revision group at two years.

Conclusion: The short term clinical outcomes of patients undergoing revision rotator cuff repair were similar to primary rotator cuff repair. However, these results did not persist and by two years patients who had revision rotator cuff repair were twice as likely to have re-torn compared to those undergoing primary repair. The increase re-tear rate in the revision group at two years was associated with increased pain and impaired overhead function.

Paper 17

The Critical Shoulder Angle is Predictive of Rotator Cuff Tears and Shoulder Osteoarthritis and is Better Assessed with Radiographs over MRI

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Objectives: The critical shoulder angle (CSA) (Moor et al., Annual Meeting AAOS 2013) is measured as the angle between glenoid and lateral border of the acromion and has been associated with glenohumeral osteoarthritis (OA) as well as rotator cuff tears (RTC). The purpose of this study was to determine the reproducibility of the CSA for the detection of patients with RTC or OA by x-ray and to determine whether the CSA can also be measured with magnetic resonance imaging (MRI).

Methods: In this IRB approved study, a pre-hoc power analysis was performed to determine sample size. The CSA was measured by x-ray and MRI in 3 age-matched groups of 10 patients each, consisting of a non-traumatic full-thickness RCT group, a non-traumatic and non-inflammatory OA group, and a non-RCT/non-OA-pathology group. All patients underwent routine x-rays with a standardized technique and had standard shoulder MRI's in a 3.0T magnet. All pathologies were determined from pre-op imaging studies and were confirmed at surgery. Subjects were retrieved from a prospectively collected data registry. Three independent observers, one radiologist and 2 orthopedic surgeons, performed the measurements. CSA angles were measured using Stryker OfficePACS Power 4.1 Express Edition (Kalamozoo, MI).

Results: The inter-observer correlation coefficients of the measurements done by x ray and MRI were 0.95 and 0.83, respectively. There were differences in the mean CSA's among the three groups, measured by x-ray (ANOVA between RCT, OA, non-RCT/non-OA: $p < 0.001$). MRI showed greater variability in the CSA measurements among observers and across pathologies. Radiographs were more predictive of pathology than MRI. For example, patients with CSAs greater than 35° had a 79.3% chance to be part of the RCT group when measured by x-ray, whereas the chance was only 69.0% using MRI. Those with angles less than 30° by x-ray had an 82.6% probability to be part of the OA group, whereas the probability dropped to 47.3% when the measurement was done by MRI. When the study groups were compared, no significant differences were seen in the mean CSAs by x-ray and MRI in the RCT and non-RCT/non-OA pathology group, $37.3 \pm 2.6^\circ$ versus $36.4 \pm 1.9^\circ$ ($p = 0.24$) and $32.7 \pm 2.5^\circ$ versus $31.8 \pm 2.7^\circ$ ($p = 0.20$), respectively. Whereas a significant difference was observed the OA group by x-ray $28.7 \pm 2.2^\circ$ versus $31.3 \pm 4.4^\circ$ by MRI ($p = 0.01$), although the trend remained for a lower CSA in OA.

Conclusion: The CSA measured by x-ray showed excellent inter-observer agreement and less variability than measurements done by MRI, especially in patients with OA. The CSA was also highly diagnostic for predicting RCT's and OA of the shoulder. This study furthermore confirms the work of Moor and Gerber and suggests that there may be biomechanical and anthropomorphic components that underlie these shoulder disorders. CSA may also have effects on clinical outcome after surgical treatment. Furthermore, novel surgical procedures might be able to affect the CSA to hasten or prevent progression of RCT's or OA.

Paper 18

Increased Post-Operative Stiffness after Arthroscopic Suprapectoral Biceps Tenodesis

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Objectives: Biceps tenodesis can be performed open or arthroscopically and can be positioned in a suprapectoral or subpectoral position. Suprapectoral tenodesis can be carried out arthroscopically, whereas the subpectoral tenodesis is performed as an open procedure. The goal of this study is to compare the incidence of postoperative stiffness between arthroscopic suprapectoral and open subpectoral biceps tenodesis and evaluate risk factors for its occurrence.

Methods: *Study Design:* The charts of all patients who underwent arthroscopic or open biceps tenodesis who were a minimum of two years post-procedure were reviewed. Patients with preoperative frozen shoulder, prior shoulder surgery, or massive rotator cuff tears which required longer post-operative immobilization were excluded. Post-operative stiffness was defined as persistent range of motion deficit ($<100^{\circ}$ of forward flexion and abduction; $<40^{\circ}$ of internal or external rotation) and pain resulting in a diagnosis of post-operative frozen shoulder and requiring either an injection, lysis of adhesions/manipulation, or both.

Analysis: Means were calculated for continuous variables and compared using Student's t test. Frequencies for categorical variables were compared using chi square tests.

Results: We identified 249 consecutive biceps tenodeses from 2008-11 (106 arthroscopic, 143 open) that met inclusion and exclusion criteria. A significantly increased incidence of post-operative stiffness was found in the arthroscopic tenodesis cohort as compared to the open cohort (17.9% vs. 5.6%, $p=0.002$). The groups were otherwise well matched. (*Table I*).

Further analysis was performed comparing patients with and without post-operative stiffness within the arthroscopic cohort. (*Table II*) Female gender (63.2% vs 33.3%, $p = 0.016$) and smoking (36.8% vs 16.1%, $p = 0.040$) were independent risk factors for post-operative stiffness after arthroscopic tenodesis. Location of the tenodesis from the top of the humeral head as measured on x-ray was 32.4 mm (stiff cohort) versus 50.3 mm (non-stiff cohort) ($p < 0.0001$). BMI, workmans compensation status and concomitant procedures did not significantly increase the risk of post-operative stiffness. Auto-immune diagnoses such as diabetes mellitus and thyroid disease were also not significant predictors for post-operative stiffness. Of the 19 arthroscopic tenodesis patients who developed post-operative stiffness, 18 had normal range of motion and were pain free by final follow up. In 16 patients, symptoms resolved with one or more injections; two patients did require reoperation, undergoing arthroscopic lysis of adhesions and manipulation.

	Arthroscopic Tenodesis	Open Subpectoral Tenodesis	p
n	106	143	
Age (SD)	51.5 (9.5)	53.5 (11.2)	0.191
BMI (SD)	29.1 (6.2)	30.3 (6.8)	0.142
Gender female # (%)	41 (38.7%)	40 (28.0%)	0.075
Workman's Comp # (%)	5 (4.7%)	11 (7.7%)	0.344
Diabetes # (%)	9 (8.5%)	18 (12.6%)	0.304
Thyroid Disease # (%)	10 (9.4%)	12 (8.4%)	0.774
Depression # (%)	14 (13.2%)	11 (7.7%)	0.152
Concomitant Procedures			
Rotator cuff repair # (%)	61 (57.5%)	74 (51.7%)	0.364
Acromioplasty # (%)	95 (89.6%)	120 (83.9%)	0.195
Distal clavicle excision # (%)	23 (21.7%)	29 (20.3%)	0.785
Post-op Stiffness	19 (17.9%)	8 (5.6%)	0.002

	No post op stiffness	Post op stiffness	p
n	87	19	
Age (SD)	52.2 (9.8)	50.6 (13.7)	0.446
BMI (SD)	29.5 (5.6)	26.9 (3.8)	0.060
Gender female # (%)	29 (33.3%)	12 (63.2%)	0.016
Workman's Comp # (%)	4 (4.6%)	1 (5.3%)	0.901
Diabetes # (%)	8 (9.2%)	1 (5.3%)	0.577
Thyroid Disease # (%)	7 (8.0%)	2 (10.5%)	0.725
Depression # (%)	12 (13.8%)	2 (10.5%)	0.703
Smoker # (%)	14 (16.1%)	7 (36.8%)	0.040
Concomitant Procedures			
Rotator cuff repair # (%)	50 (57.5%)	11 (57.9%)	0.973
Acromioplasty # (%)	78 (89.7%)	17 (89.5%)	0.981
Distal clavicle excision # (%)	20 (23.0%)	3 (15.8%)	0.490

Conclusion: Our results demonstrate a notable incidence of post-operative stiffness after arthroscopic suprapectoral tenodesis. This occurs more commonly in females and smokers. A more proximal location of the tenodesis is noted in patients who develop post-operative stiffness. The relationship between this issue and the arthroscopic suprapectoral tenodesis technique may be multifactorial, with potential etiologies including increased soft-tissue manipulation, fluid extravasation, bursal resection in the sub-deltoid space, increased risk of bleeding in the region of the bicipital sheath, or possibly an effect related

to over-tensioning of the biceps with a presentation mimicking post-operative capsulitis, that improves over time and with symptom-based management.

Paper 19

Outcomes of Primary Biceps Sub-pectoral Tenodesis in an Active Population: A prospective Evaluation of 101 Patients

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Objectives: SLAP tears and tendonitis disorders of the long head of the biceps tendon (LHBT) remain a challenge to treat in an active population. The purpose of this study is to prospectively compare the surgical outcomes of a primary biceps tenodesis for SLAP tears and biceps tenosynovitis in a young active population.

Methods: Over a 6-year period, 125 patients with mean age of 42.6 (range, 26.3 to 56.5) with a diagnosis of LHBT were prospectively evaluated. Inclusion criteria included patients with a clinical diagnosis of a type II SLAP or anterior shoulder pain who failed conservative management and underwent a diagnostic shoulder arthroscopy. Patients were excluded for full-thickness rotator cuff tears, AC joint pathology, and labral pathology outside of the SLAP lesion. Patients with an arthroscopically confirmed labral tear or biceps tendonopathy underwent a mini-open subpectoral tenodesis with interference screw and were independently evaluated with patient reported outcome measurements (SANE, WORC), and a biceps position examination. Statistical analysis was via Student's t-test and significance set at $p < .05$.

Results: 101 of 125 patients (81%) completed the study requirements at a mean of 2.75 years (range 1.5 to 5.7 years). 50 Patients were diagnosed with SLAP II tears (40%) and 75 patients with biceps tendonitis (60%), 28 (22%) underwent a rotator cuff debridement for a concomitant low-grade partial rotator cuff tear and LHBT instability. There was a clinically and statistical improvement in patient outcomes scores: (WORC=54%, SANE=58) improved to (WORC=89%, SANE=89.5, $p < 0.01$). 82% of patients returned to work and full activity at a mean of 4.1 months. The biceps muscle measured relative to the antecubital fossa of operative (mean 3.20 cm) versus non-operative (3.11 cm) was not clinically different ($p = 0.57$), except in the 3 that failed tenodesis fixation. There was an 8% complication rate: 3 patients sustained failure of the LHBT tenodesis requiring revision; 2 superficial infections treated with antibiotics; and 3 transient musculoskeletal neuropathias.

Conclusion: A primary biceps tenodesis for pathology of the LHBT provides a clinical and statistically significant improvement in shoulder outcomes with a reliable and efficient return to previous activity level and low risk for surgical complications. However, additional work is necessary to define optimal primary treatment of LHB disorders.

Paper 20

Biomechanical Comparison of the Interval Throwing Progression and Baseball Pitching: Upper Extremity Stresses in Training and Rehabilitation

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Objectives: The interval throwing progression is a hallmark of the rehabilitation program designed for baseball pitchers or position players returning from shoulder or elbow injury. It typically begins with flat-ground throws at a short distance and progressively increases to 180 feet or more. For pitchers, this phase is then followed by throwing off the mound, progressing from partial-effort to full-effort pitches. Theoretically, the progression of throwing phases allows an injured athlete to gradually recover his flexibility, arm strength, and mechanics while moving from less stressful activities to more stressful activities. While this throwing program has been a part of baseball rehabilitation and conditioning for decades, little is known about the biomechanical stresses generated during flat-ground throwing or variable effort pitching off the mound.

Methods: Twenty-nine healthy, college baseball pitchers were analyzed using a quantitative motion analysis system. The participants threw from flat ground at distances of 60-ft, 90-ft, 120-ft, and 180-ft, being instructed to throw “hard, on a horizontal line”. The pitchers then threw fastballs from a mound at 3 different efforts: 60% effort, 80% effort, and full-effort. Biomechanical parameters of position, velocity, and kinetic values were recorded. Mean values were calculated for humeral internal rotation torque (HIRT) and elbow valgus load (EVL) for each throw type. This data was then used to compare shoulder and elbow stresses between the various throws. The differences among mean values were analyzed with a repeated-measures analysis of variance (ANOVA). Post hoc paired t tests were performed when the ANOVA revealed a significant difference.

Results: Statistically significant differences exist across all mound intensities (60%, 80%, and 100% effort) for nHIRT ($p=0.03$) and nEVL ($p=0.04$), as both parameters increased with percentage throwing effort. No statistically significant differences were found across all flat ground distances in either nHIRT or nEVL ($p>0.05$). No statistically significant difference in peak HIRT or peak EVL were found when comparing full effort pitching to flat ground throws at any distance ($p>0.10$). The longer flat ground throws at 180 feet did show significantly different kinematics and biomechanical patterns when compared with pitching from the mound, while shorter flat ground throws had patterns similar to those of pitching.

Conclusion: Variable effort pitching off the mound demonstrates significantly lower stresses on the shoulder and elbow during partial-effort throws, illustrating the importance of these throws during the recovery and rehabilitation process. Flat ground throwing at distances as short as 60 feet had similar biomechanical stresses on the upper extremity when compared with pitching full-effort from the mound. Despite lower velocity, this similar stress illustrates the mechanical disadvantage of throwing from the flat ground in a stationary position. No increase in shoulder or elbow stress was seen with

increasing distances from the flat ground, likely because the pitchers began using a “crow-hop” for the longer distances, facilitating the throw with their lower extremity. The mechanical advantage of throwing from a mound or using the crow-hop may be protective during rehabilitation and training throws, generating lower humeral internal rotational torque, lower elbow valgus load, and more throwing efficiency.

Comparison of Joint Torques Among Various Efforts From Mound				
	60% Effort	80% Effort	100% Effort	P-Value
Humeral internal rotational torque (HIRT), mean, Nm	34.5	37.4	45.2	0.05
nHIRT (HIRT/ BW x H), mean	0.23	0.25	0.30	0.03
Elbow valgus load (EVL), mean, Nm	38.4	46.3	49.6	0.06
nEVL (EVL/ BW x H), mean	0.25	0.30	0.33	0.04

Comparison of Joint Torques Among Throws						
	Mound Fastball (60.5-ft)	60-ft Throw	90-ft Throw	120-ft Throw	180-ft Throw	P- Value
Humeral internal rotational torque (HIRT), mean, Nm	45.2	41.0	43.1	37.2	40.5	0.22
nHIRT (HIRT/ BW x H), mean	0.30	0.26	0.28	0.24	0.26	0.14
Elbow valgus load (EVL), mean, Nm	49.6	50.0	47.6	40.1	43.1	0.16
nEVL (EVL/ BW x H), mean	0.33	0.32	0.30	0.26	0.28	0.12



Paper 21

Return to Play after Nonsurgical Treatment of Elbow Ulnar Collateral Ligament Injuries in Professional Baseball Players

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Objectives: Injury to the elbow ulnar collateral ligament (UCL) is relatively common in pitchers. In the 70's reconstructive surgery was developed as a viable option to a potentially career ending injury. Multiple studies have demonstrated return to play (RTP) rates of 74-83% after reconstruction. Studies of RTP after nonoperative treatment in throwing athletes are limited, reporting 42%. There are no studies reporting RTP rates with nonoperative treatment of professional baseball players. The purpose of this study was to identify professional baseball players' ability to return to play after UCL injuries based on nonoperative vs. operative treatment, MRI grade, and player position.

Methods: A retrospective review of a single professional baseball organization (6 minor league teams and 1 Major league team) between 2006 & 2011 revealed 72 medial elbow injuries. MRI was performed on all players. UCL injuries were diagnosed in 45 players by physical exam & MRI. Players were treated with rehabilitation, surgery or both. Success was RTP for >1 season. Rates of RTP and return to the same level of play or higher (RTSP) were calculated and correlated with MRI grade, location, and player position. MRI grading used was: 1 intact ligament +/- edema, 2 partial tearing, 3 complete tear, and 4 chronic healed injury.

Results: Overall 91% of 45 players had RTP, and 87% had RTSP. Fifteen were treated surgically and 30 nonoperatively with rehab. Of players treated surgically, 73% had RTSP, whereas 93% of nonoperatively treated players had RTSP (p-value 0.07). All players with grade III tears had surgery. Of surgically treated players, none had grade I injuries, 13% had grade II injuries, 53% had grade III injuries, and 33% had grade IV injuries. Of nonoperatively treated players, 13% had grade I injuries, 23% had grade II injuries, none had grade III injuries, and 60% had grade IV injuries. Of all grade II and grade IV injuries, 78% were treated nonoperatively and all but 1 player in each group (treated nonoperatively) had successful RTSP. Of the players treated for grade III tears, 50% had RTSP, whereas 92% of players treated for incomplete (grades I, II and IV) injuries had RTSP (p-value 0.01), regardless of treatment. When considering RTP rather than RTSP for complete vs. incomplete injuries, the rates improved to 75% and 95% (p-value 0.13) respectively. All grade I injuries, 86% of grade II injuries and 91% of grade IV injuries had RTSP. Of the 45 players with UCL injuries, 33 were pitchers. Among pitchers treated surgically RTP was 86% and RTSP was 71%. Nonoperatively treated pitcher's RTP and RTSP was the same, 95%. Among the pitchers, 24% had grade III injuries whereas none of the positional players had grade III injuries. Ten of 11 positional players treated nonoperatively had RTSP. One positional player was treated operatively and had RTSP.

Conclusion: Professional baseball players treated nonoperatively for UCL injuries have a much higher RTP rate than previously published among throwing athletes. Pitchers are more likely to develop UCL injuries than positional players and are more likely to have complete tears leading to surgical treatment.

Incomplete UCL injuries are more likely to lead to nonoperative treatment and a higher RTSP than complete tears. RTP and RTSP occurs at a higher rates for non-pitchers than pitchers. MRI grade of UCL injuries can help predict the potential for RTP and need for surgery.

Paper 22

Performance and Return-to-Sport after Tommy John Surgery in Major League Baseball Pitchers

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Objectives: Ulnar collateral ligament reconstruction (UCLR) is a common procedure performed in Major League Baseball (MLB) pitchers with symptomatic UCL deficiencies. The purpose of this study was to determine: 1) the rate of return to pitching in the MLB following UCLR, 2) performance after return to pitching, and 3) the difference in return to pitching and performance between pitchers who underwent UCLR and matched controls who did not.

Methods: MLB pitchers with symptomatic UCL deficiency that underwent UCLR between 1986 and 2012 were evaluated. Players' data was extracted from MLB team websites, injury reports, player profiles/biographies, press releases and cross-referenced with the MLB injury database (MLB411). All player, elbow, and surgical demographic data were analyzed. Age, body mass index (BMI), position, handedness, and MLB experience-matched controls were selected from the MLB during the same years as those undergoing UCLR. An "index year" was designated for controls, analogous to UCLR year in cases. Return to pitching and performance measures in MLB was compared between cases and controls. Student's t-tests were performed for analysis of within-group and between-group variables, respectively.

Results: One hundred forty-eight pitchers (83%) were able to return to pitching in MLB. Length of career in MLB following UCLR was 3.9 +/- 2.84 years. Revision rate was 3.9%. In the year prior to UCLR (or index year in controls), cases were significantly ($p < 0.05$) worse than controls with regard to number of innings pitched, games played, wins, and winning percentage and were not significantly different than controls in all remaining parameters. Pitchers undergoing UCLR had significantly ($p < 0.05$) fewer losses, a lower losing percentage, and lower earned run average (ERA) following surgery (versus pre-surgery). In addition, cases threw significantly ($p < 0.05$) fewer walks and allowed fewer hits, runs, and home runs following surgery. Comparisons between cases and controls for the timeframe following UCLR (cases) or index year (controls) demonstrated that cases had significantly ($p < 0.05$) fewer losses per season and a lower losing percentage. In addition, cases had a significantly lower ERA and fewer walks and hits allowed per inning pitched (WHIP) (Table 1).

Conclusion:

There is a high rate of return to pitching in the MLB following UCLR. Performance declined prior to surgery and improved following surgery. When comparing to demographic-matched controls, UCLR had better results in multiple performance measures. Ulnar collateral ligament reconstruction allows for a predictable and successful return to professional-level baseball.

Pre-and post- UCLR outcome data vs. Demographic-matched controls

Before and after UCLR		P Value
ERA	5.7 (pre) vs 4.2 (post)	<.001
WHIP	1.6 (pre) vs 1.4 (post)	<.001
Losses/season	4.4 (pre) vs 3.1 (post)	<.001
Losing percentage	19% (pre) vs 14% (post)	.001
Hits given up/season	77 (pre) vs 58 (post)	.001
Runs given up/season	39 (pre) vs 30 (post)	.002
Home runs given up/season	8.7 (pre) vs 6.7 (post)	.002
Walks thrown/season	30 (pre) vs 22 (post)	<.001
Year one prior to UCLR (or index year)		
Innings pitched	54 (cases) vs 90 (controls);	<.001
Games played	21 (cases) vs 30 (controls);	<.001
Number of wins	2.7 (cases) vs 5.4 (controls);	<.001
Winning percentage	14% (cases) vs 21% (controls)	.003
After UCLR (or index year)		
ERA	4.2 (cases) vs 6.4 (controls);	<.001
WHIP	1.4 (cases) vs 1.7 (controls);	<.001
Losses/season	3.1 (cases) vs 4.3 (controls);	.003
Losing percentage	14% (cases) vs 23% (controls);	<.001
Hits given up/IP	1.01 (cases) vs 1.17 (controls)	<.001