INTRODUCTION
Large chondral lesions can be extremely debilitating because of the body's inability to repair this tissue. Treatment of such chondral defects can be challenging and various surgical techniques have been reported in the literature including drilling; marrow stimulation; internal fixation; fragment or loose body removal; and chondral resurfacing techniques. No consensus has been reached as to the best treatment option. The goal of both primary and salvage repair should be to re-establish the compromised subchondral bone, restore access to marrow in an injured or ischemic area, and to restore a protective cover of fibrocartilage and/or hyaline cartilage with good integration at the border zone. Should the primary effort at repair fail, an ideal salvage treatment would be minimally destructive thereby allowing for further efforts at repair. Paste grafting has been previously reported by the senior author for primary treatment of large Outerbridge Grade III and IV articular cartilage lesions. In this case series, we report the outcomes in nine patients undergoing articular cartilage paste grafting for primary and salvage treatment of massive articular cartilage defects with a minimum preoperative surface area and volume of 143 mm² and 572 mm³ respectively.

METHODS
Nine patients diagnosed with large, full-thickness articular cartilage lesions of the knee were treated by the senior author (KRS) at our institution using the articular cartilage paste graft technique. Prior to surgery, patients underwent an informed consent process as approved by an independent Institutional Review Board. Patients who had undergone articular cartilage paste grafting to a large, full-thickness chondral lesion of the femoral condyle and had a minimum of two years of follow-up were included. Mean follow-up was 84 ± 27 months (range 42 to 124 months). Patients were evaluated using MRI and validated subjective assessments of pain, activity, and function preoperatively and over the course of follow up. Lesion surface area and volume were estimated from MRI measurements. Lesion surface area was estimated from the product of anteroposterior and transverse dimensions. Lesion volume was estimated from the product of anteroposterior, transverse, and depth dimensions. Osteochondral lesions are not typically square; however, a square surface area and cubic volume are simple to compute and each offers a relative number to appreciate gross lesion size and offer subsequent analysis.

The subjective clinical outcome was determined from the analysis of International Knee Documentation Committee Subjective Knee Evaluation Form (IKDC) and Western Ontario and McMaster's Osteoarthritis (WOMAC) scores. IKDC scores were calculated using Anderson’s method to control for over- and under-estimation of missing values. Patients’ return to pre-injury sports and activities was measured using the Tegner score. A patient’s Tegner Index was calculated based on their pre-injury Tegner level at each follow up. This method captures a patient’s perceived percent recovery of activity over a diverse population despite any disagreement in pre-injury scores over time.

Variables were tested for normal distribution by the Kolmogorov-Smirnov test. Continuous variables are presented as mean ± standard deviation and non-normally distributed variables as median and interquartile [IQR] range. Preoperative and latest follow-up subjective test scores were compared by the Mann-Whitney test for non-parametric data. Significance level was set at \( p = 0.05 \).

RESULTS
Average age at time of surgery was 29.7 (range 17 – 50 yrs). Six patients were male, 3 were female. Six of nine patients underwent previous surgical intervention for treatment of a massive chondral defect on their femoral condyle. Average number of previous surgeries for these six patients was 3 (range 1 – 4). Previous surgical attempts lasted an average of 56 months (range 7 – 188 months) before articular cartilage paste grafting was performed. Average lesion surface area was estimated at 351.8 ± 162.3 mm² (range 143 – 600 mm²). Average lesion volume was estimated at an average of 2559.2 ± 2178 mm³ (range 572 – 7344 mm³). There was a significant improvement in mean lesion volume from baseline MRI measurement of 2599mm³ to 200mm³ \( (p = 0.015) \) at most recent follow up. Mean surface area MRI measurement improved from baseline of 352mm² to 71mm² \( (p = 0.001) \) at most recent follow. Figure 1 shows the treatment and healing response representative of the aggregate patient population. The filled lesion will often hypertrophy, and unfortunately sometimes requires further surgical intervention. Six of the nine (66.7%) cases in this study required an average of 1.8 (range 1 – 3) additional surgeries to treat hypertrophied repair tissue.

There was a significant improvement from median preoperative IKDC score of 39.1 points (IQR 28.5 – 52.3) to 83.9 points (IQR 57.5 – 96.0, \( p = 0.009 \)) at most recent follow up (Figure 2). Median WOMAC score improved significantly from a preoperative value of 22.0 points (IQR 12.0 – 57.0) to 1.0 points (IQR 0.0 – 18.0, \( p = 0.012 \)) at most recent follow up. Raw Tegner score improved as well from a preoperative median score of 2.0 (IQR: 0.3 – 5.3) to 6.0 (IQR: 4.8 - 9.0, \( p = 0.016 \)) at most recent follow up. Tegner Index Ratio improved significantly from a median preoperative value of 0.300 (IQR 0.031 – 0.857) to 0.857 (IQR 0.691 – 1.000, \( p = 0.033 \)) at most recent follow up.

CONCLUSIONS
Left untreated, large chondral lesions can lead to massive defects and present a formidable challenge to manage surgically. Furthermore, if primary repair fails, few options exist for salvage of the articular surface. This study supports the efficacy of articular cartilage paste grafting as a treatment for primary and salvage treatment of massive chondral lesions of the femoral condyle resulting in healed articular cartilage surface and subchondral bone.