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Incidence of Displaced Posterolateral Tibial Plateau and Lateral Femoral Condyle Impaction Fractures in the Setting of Primary ACL Tear

Abstract

Background: Bone bruising of the posterolateral tibial plateau and the lateral femoral condyle sulcus terminalis have a well-established association with ACL tears. Impaction fractures of the femur and tibia may occur in these locations; however, there is a paucity of literature describing these fractures.

Purpose: The primary objective was to quantify the incidence, size, and location of impaction fractures of the posterolateral tibial plateau and lateral femoral condyle in patients with primary ACL tears. The secondary objective was to investigate the association between impaction fractures and concomitant meniscal and ligamentous injuries.

Study Design: Case Series; Level of evidence 4.

Methods: Patients with available MRI images who were treated for primary ACL tear by a single surgeon were identified. MRI images were reviewed with denotation of posterolateral tibial and femoral condylar contusions and displaced impaction fractures. Measurements of the lateral tibial plateau were taken in all patients with displaced lateral tibial plateau fractures and in a subset of control patients without tibial plateau fracture present in order to characterize the size and location of the bony lesion. Associations of impaction fractures with concomitant meniscal or ligamentous injuries were evaluated using chi-square testing.

Results: There were 825 knees identified with available MRI images. Displaced posterolateral tibial plateau impaction fractures were present in 407 knees (49.3%) and displaced lateral femoral condylar impaction fractures were present in 214 knees (25.9%). Patients with posterolateral tibial plateau impaction fractures were older than patients without these fractures (42.6 years vs 32.7, $p < .001$), while patients with lateral femoral condylar impaction fractures were younger (23.8 vs 32.7, $p < .001$). Seventy-one knees (8.6%) had a posterolateral tibial plateau impaction fracture with greater than 10% loss of lateral tibial plateau depth, and this group had an increased incidence of lateral meniscus posterior root tears (22.1% vs 12.0%, $p = .02$).

Conclusion: Displaced posterolateral tibial plateau impaction fractures occurred with a high incidence (49.3%) in patients with primary ACL tears and demonstrated an increased association with lateral meniscus posterior horn root tears as their size increased. Lateral femoral condylar impaction fractures occurred in 25.9% of patients with primary ACL tears and had an increased incidence of lateral meniscus tears and medial meniscal ramp lesions

Keywords: tibial plateau; impaction fracture; ACL tear

For Peer Review Only:

What is known about the subject: Bone bruising of the posterolateral tibial plateau and at the sulcus terminalis of the lateral femoral condyle have a well-established association with ACL injury, and impaction fractures in these locations have been previously described. However, the specific incidence of displaced posterolateral tibial plateau and lateral femoral condylar fractures and the size and location of these fractures has not been well described. Furthermore, associations with these fractures and meniscal injuries or other ligamentous injuries have not been well evaluated.

What this study adds to the existing literature: This study provides a description of the incidence of posterolateral tibial plateau and lateral femoral condyle impaction fractures in a large series of patients with primary ACL tears. Furthermore, it provides the first detailed description of the size and specific location of posterolateral tibial plateau impaction fractures and describes their association with lateral meniscus and posterior lateral meniscal root tears.

INTRODUCTION

Impaction fractures affecting the posterolateral aspect of the tibial plateau and the lateral femoral condyle have long been recognized as injuries associated with anterior cruciate ligament (ACL) injury[5,8,11,12,14]; however, most of the existing literature details occult fractures of the lateral tibial plateau and lateral femoral condyle. Occult fractures have been described as trabecular fractures, hemorrhage, and edema of the bone marrow without disruption of the cortex and cannot be detected with conventional radiography, synonymous with bone bruising or contusion.[5] Displaced impaction fractures, defined as a depression of the articular or cortical surface, and displaced osteochondral fractures, defined as a discrete fragment with an intact chondral surface, have been described occurring at either the anterior lateral femoral condyle or posterior lateral tibial plateau in association with an ACL tear.[5] There has been little investigation of these lesions in the literature in comparison to occult fractures or bone bruising.

There is increasing recognition of the contribution of the osseous geometry of the lateral tibial plateau to knee stability.[6,9,13] Musahl et. al reported an association with decreased medial to lateral tibial plateau size with a high grade pivot shift, although the effect of lateral tibial plateau depth was not assessed.[9] Studies have demonstrated higher pivot shift grades with increased anterior subluxation of the lateral tibial plateau[7], a change which would effectively decrease the amount of remaining lateral tibial plateau posterior to the weightbearing axis of the lateral femoral condyle. Despite this, there has been a paucity of investigation into the incidence, size and location, and risk factors for lateral tibial plateau impaction fractures in the setting of ACL injury. Thus, the primary objective of this study was to quantify the incidence of impaction fractures of the posterolateral tibial plateau and lateral femoral condyle in patients with primary ACL tears and to characterize the size and location of these fractures. The secondary objective of this study was to investigate the association between posterolateral tibial plateau and anterior or central lateral femoral condyle impaction fractures and concomitant meniscal and other ligament injuries in the setting of a primary ACL tear.

METHODS

Study Design

This study was approved following review from an institutional review board (*institution and protocol number blinded for review*). Demographic information and data from surgical procedure charts were collected on all patients with primary ACL tears treated by a single board-certified orthopaedic surgeon (*initials blinded for review*) between April 2010 and March 2019. Patients without available MRI images were excluded from the study. For all patients meeting these criteria, pre-operative MRI images were reviewed to determine whether lateral tibial plateau and lateral femoral condyle bone bruising and/or impaction fractures were present. MRI signal change at the posterolateral tibial plateau was only classified as an impaction fracture if there was displacement of subchondral or cortical bone at the posterolateral tibial plateau rim visible on sagittal MRI T1 images. An impaction injury of the anterior or central aspect of the lateral femoral condyle was only considered an impaction fracture if there was greater than 1.5 mm depth at the sulcus terminalis based upon previously described criteria [4](Figure 1), or if there was a second area of concavity separate from the sulcus terminalis. For measurement of sulcus terminalis depth, a line tangential to the subchondral bone that intersects the anterior and posterior points where the concavity of the sulcus begins is drawn and the depth from the deepest portion of the sulcus is measured perpendicular to the tangential line. Nondisplaced fractures of either the tibial plateau or femoral condyle were not classified as fractures in this study.

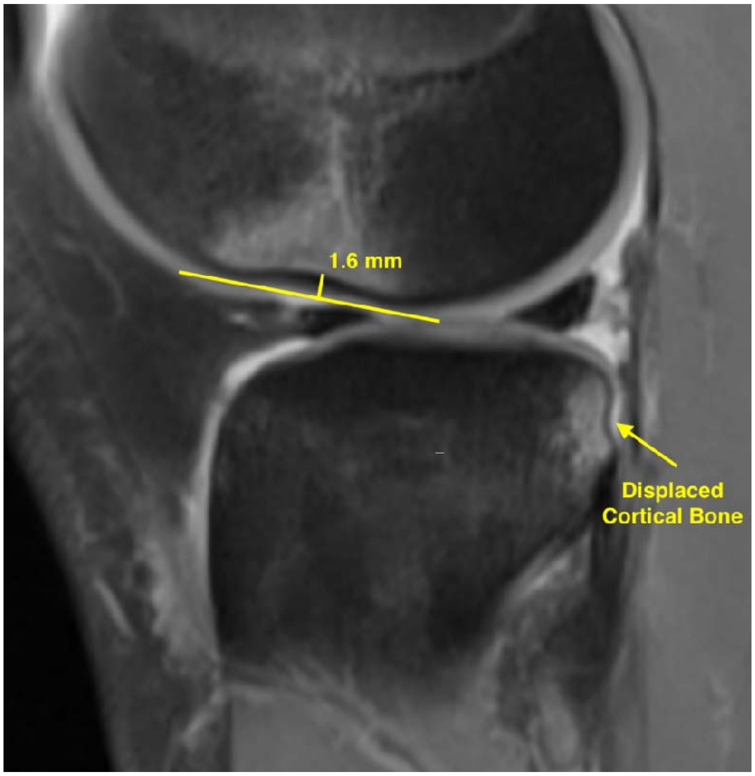

Figure 1. Sagittal image of MRI demonstrating classification of lateral femoral condyle (> 1.5 mm depth) and tibial plateau impaction fractures.

Measurement Technique

For all detected posterolateral tibial plateau impaction fractures, measurement of the bony lesion was performed with use of an OsiriX Lite PACS Viewer (Bernex, Switzerland). A standardized technique for measurement of the impaction fracture was developed. First, 3-dimensional multiplanar reconstruction (3D MPR) was used to ensure sagittal images were in the plane of the tibial plateau. Next, the sagittal slice at the 50th percentile of the lateral tibial plateau width was selected for measurement of lateral tibial plateau depth. A modified Amis and Jakob line was drawn along the lateral tibial plateau subchondral bone (as opposed to the medial tibial plateau parallel to the articular cortical line on lateral radiograph as originally described by Amis and Jakob), measuring the lateral tibial plateau articular distance from anterior to posterior. A line perpendicular to this line was then drawn vertically and placed as a tangent line along the posterior-most aspect of the proximal lateral tibia. The distance from the posterior endpoint of the lateral tibial plateau articular surface to this vertical line was then recorded, denoted as the posterior articular marginal distance (Figure 2).

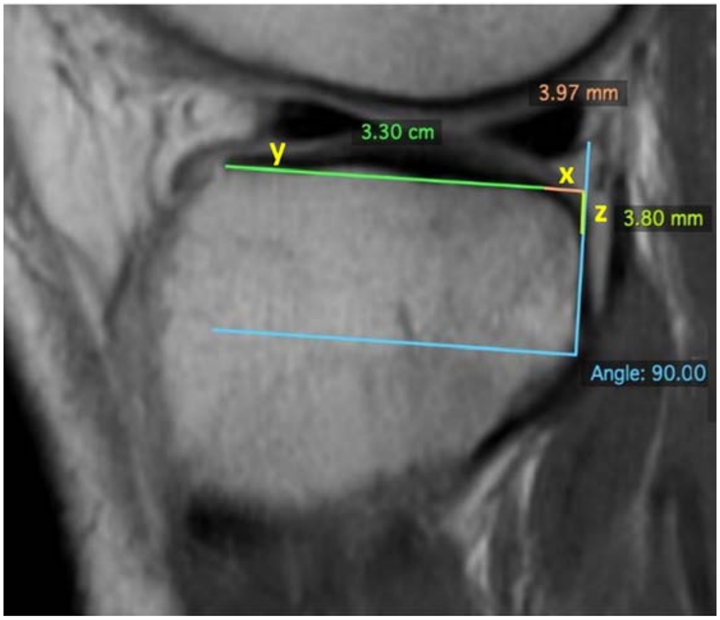

Figure 2. Tibial plateau impaction fracture measurement technique. Sagittal image on MRI demonstrating tibial plateau depth measurements in a control knee without an impaction fracture. Line y, is drawn first along the subchondral bone from the anterior to posterior aspect of the articular surface. Next, line x, the posterior articular marginal distance, is drawn extending from the posterior extent of the articular surface to a line perpendicular to line y and placed as a tangent line along the posterior-most aspect of the proximal lateral tibia. Line z, the posterior height, is measured from the level of the articular surface to the level where bone is first contacted along the posterior tangent line. Posterior articular marginal percentage is calculated as x/(x+y).

In order to use the posterior articular marginal distance as a proxy of articular surface loss, the above measurements were also made in a subset of 50 randomly selected control knees with ACL tear but without a lateral tibial impaction fracture. To allow for the assessment of possible differences between sexes, 25 male knees and 25 female knees were included in the control group. The posterior articular marginal percentage was calculated by dividing the posterior articular margin distance by the sum of the posterior articular margin distance and the lateral tibial plateau articular distance. This posterior articular marginal percentage calculated in control patients without impaction fracture was then averaged and subtracted from the posterior articular marginal percentages calculated for each knee with an impaction fracture to represent the percent of articular surface depth bone loss (Figure 3).

The same sagittal image located at 50% of the width of the lateral tibial plateau was also used to measure the height of the tibial plateau impaction fracture lesion at the anterior and posterior endpoints of the lesion, with measurement extending up to the modified Jakob and Amis line. The posterior height measurement was performed in the subset of control patients to allow for normalization as well. Finally, we also measured the width of the tibial plateau and the width of the bony impaction lesion using axial MRI slices (Figure 3B).

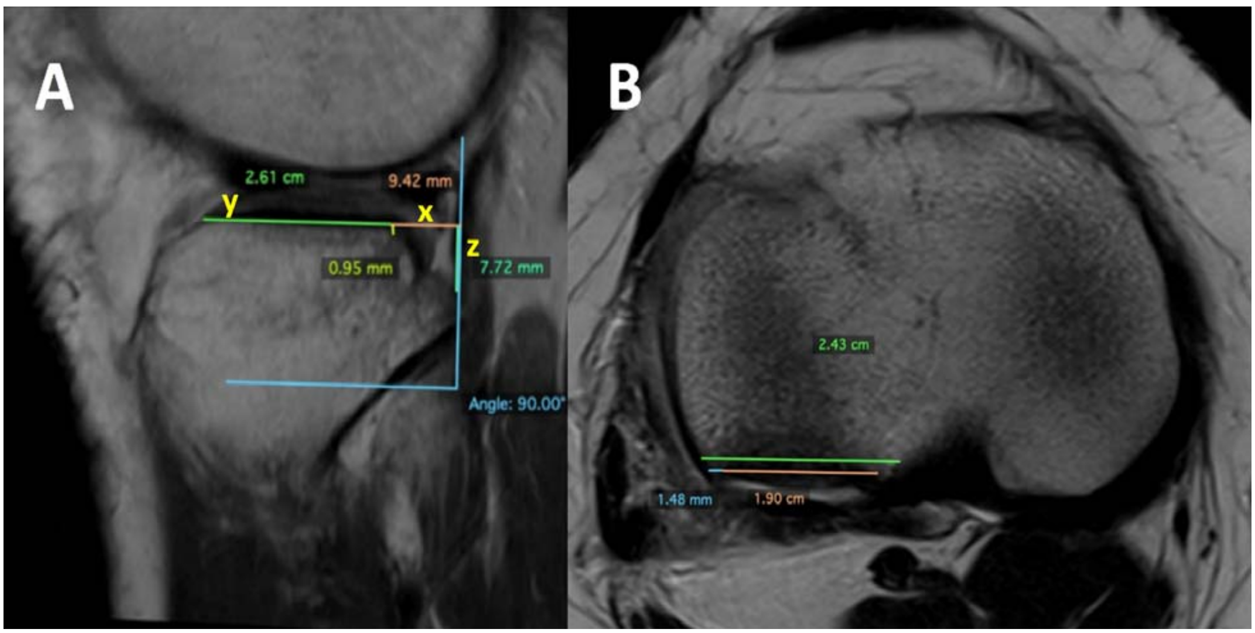

Figure 3. Sagittal (A) and axial (B) magnetic resonance imaging slices demonstrating tibial plateau depth (A) and impaction lesion width (B) measurements in a knee with an impaction fracture. Percent of articular surface depth bone loss is calculated as: x/(x+y) – .099 (control posterior articular marginal percentage).

Statistical Analysis

Descriptive statistics were used to evaluate the incidence of posterolateral tibial plateau and anterior or central lateral femoral condylar impaction fractures and bone bruising. In the subset of knees with a posterolateral tibial plateau fracture, additional descriptive statistics were used to describe the size and location of these lesions. Clinical characteristics for patients with posterolateral tibial plateau and anterior or central lateral femoral condylar impaction fractures and contusions were analyzed to assess for correlations with other knee structural injuries using chi-square testing for categorical variables and the Mann-Whitney U test for continuous variables with non-normal distributions. All statistical analysis was performed using IBM SPSS Statistical Suite, version 25, and the alpha level was set for statistical significance at 0.05.

RESULTS

There were 912 knees with primary ACL tears identified, with 825 knees (814 patients) having available MRI images. Displaced posterolateral tibial plateau impaction fractures were present in 407 knees (49.3%), and displaced anterior or central lateral femoral condylar impaction fractures were present in 214 knees (25.9%). A total of 512 knees (62.1%) had either an impaction fracture of the tibial plateau or the femoral condyle, while 109 knees (13.2%) had bipolar (both lateral femoral condyle and lateral tibial plateau) impaction fractures. Lateral tibial plateau bone bruising was present in 634 knees (76.8%) and lateral femoral condyle bone bruising was present in 407 knees (49.3%). A total of 654 (79.3%) knees had bruising of either the tibial plateau, femoral condyle or both, with only 385 of these knees having bipolar bruising (36.7%).

Patients with posterolateral tibial plateau impaction fractures were significantly older than patients without these fractures (40.4 years versus 30.4, $p < .001$), however, lateral femoral condylar impaction fractures occurred in significantly younger patients (29.2 years versus 37.5, $p < .001$). These age differences become even more substantial when segregating isolated tibial plateau and femoral condyle impaction fractures from bipolar fractures (Table 1). Posterolateral tibial plateau impaction fractures occurred significantly more in females (54.2%) compared to males (44.8%)(Chi-square value

7.3, p = .007), while there was no difference in rates of lateral femoral condylar or bipolar impaction fractures between sexes (*p* = 0.38, 0.44). There was no association between body mass index (BMI) and the occurrence of a posterolateral tibial plateau or lateral femoral condylar impaction fracture (p = 0.67). Both tibial and femoral impaction fractures occurred more frequently as a result of a noncontact injury mechanism (86.8% and 80.0% respectively).

	N	Age (years)	STD	Min	Max
No fracture	313	32.7	13.4	12.0	72.9
Tibial Impaction	297	42.6	12.8	12.9	73.6
Femoral Impaction	105	23.8	7.9	13.6	46.2
Bipolar Impaction	110	34.6	14.2	14.2	65.4
>10% TP Depth Loss	71	50.6	11.9	18.3	73.6
Total	825	35.4	14.2	11.2	73.6

Table 1. Mean age of patients with different types of impaction fractures. STD; standard deviation. Min; minimum. Max; maximum. TP; tibial plateau.

Descriptive statistics of measurements of the lateral tibial plateau posterior articular margin distance and percentage and posterior height measured in the subset of control patients with an ACL tear but no impaction fracture are shown in Table 2. There was no difference between posterior articular margin percentage calculated in control males compared to control females (p = 0.79), thus justifying the use a single correction factor for both male and female knees. The mean value for posterior articular marginal percentage measure from the controls was 9.9%, which was subsequently used as a correction factor when determining lateral tibial plateau bone loss in knees with impaction fractures.

	N	Mean	STD
Posterior height (mm)	50	4.0	0.9
Posterior articular margin (mm)	50	3.6	0.7
Posterior articular marginal percentage (%)	50	9.9	1.8
Posterior articular marginal percentage (%) - Male	25	10.0	2.0
Posterior articular marginal percentage (%) - Female	25	9.8	1.6

Table 2. Posterolateral tibial plateau measurements in control patient group. STD; standard deviation.

Descriptive statistics of measurements of the lateral tibial plateau impaction lesions measured in this study are reported in Table 3. Seventy-one knees (8.6%) had a posterolateral tibial plateau impaction fracture with greater than 10% loss of lateral tibial plateau depth. Patients with greater than 10% loss of tibial plateau depth were significantly older than those without (50.6 years vs 34.0, $p < .001$). There was a resultant subchondral bone step-off at the anterior aspect of the impaction fracture of 2 mm or greater in 30.0% of knees with impaction fractures. In the axial plane, the lesion was centered in the middle third of the lateral tibial plateau in 93.1% of all impaction lesions of the tibial plateau, with only 4.2% and 2.7% centered in the medial third and lateral third, respectively.

	Mean	Minimum	Maximum	Std. Deviation
Lateral tibial plateau depth bone loss percentage (%)	5.2	0	24.1	5.1
Posterior height (mm)	7.0	2.1	15.3	2.2
Lesion articular step-off (mm)	1.7	0	9.0	2.3
Lesion width (mm)	14.5	3.2	30.1	5.0
Lesion axial midpoint (%) (Referenced from lateral-most aspect of posterior tibial plateau)	49.9	13.6	80.6	8.8

Table 3. Posterolateral tibial plateau impaction fracture lesion measurements.

Associations between the presence of posterolateral tibial plateau and lateral femoral condyle impaction fractures or bone bruising and various meniscal injuries are shown in Table 4. Medial meniscus ramp lesions occurred more frequently in knees with tibial, femoral, and bipolar impaction fractures, as well as in knees with tibial or femoral contusions compared to patients without impaction fractures or bruising. The strongest significant association for ramp lesions occurred with femoral condyle impaction fractures as ramp lesions were present in 27.1% of knees with femoral condyle impaction fractures compared to 15.6% of knees without (odds ratio: 2.0 (1.4 -2.9), p = .001). Similarly, femoral condyle impaction fractures showed the strongest association with the incidence of lateral meniscal tears (66.7% vs. 53.9%, odds ratio: 1.7 (1.2 – 2.4), p = .001), while bipolar impaction fractures and femoral contusions also had significant associations with lateral meniscal tears. Femoral impaction fractures and contusions also showed significant correlations with lateral meniscus posterior root tears, but the largest differential in incidence percentage occurred in patients with greater than 10% lateral tibial plateau depth bone loss percentage (22.1% vs. 12.0%, odds ratio: 2.1 (1.1 – 3.9), p = .02). When comparing the bony morphology of the lateral tibial plateau impaction fracture lesion in patients with and without lateral meniscus posterior root tears, there was a significantly greater bone loss percentage in patients with root tears (7.2% vs. 4.9%, *p* = .003); however, there was no difference in height or width of the lesion (p = 0.50 and 0.33 respectively).

		Lateral meniscus tear		Lateral meniscus posterior root tear		Medial meniscus tear		Medial meniscus ramp lesion		Medial meniscus posterior root tear	
		Incidence	*p*	Incidence	*p*	Incidence	*p*	Incidence	*p*	Incidence	*p*
Tibial impaction	0	221/409 (54.0%)	0.06	51/406 (12.6%)	0.82	191/411 (46.5%)	0.28	**66/410 (16.1%)**	**0.05**	16/411 (3.9%)	0.65
	1	240/396 (60.6%)		52/397 (13.1%)		199/396 (50.3%)		**85/396 (21.5%)**		13/395 (3.3%)	
Femoral impaction	0	**320/594 (53.9%)**	**0.001**	**66/592 (11.1%)**	**0.03**	287/595 (48.2%)	0.98	**93/595 (15.6%)**	**0.001**	24/595 (4.0%)	0.27
	1	**140/210 (66.7%)**		**36/210 (17.1%)**		102/211 (48.3%)		**57/210 (27.1%)**		5/210 (2.4%)	
Tibial contusion	0	97/188 (51.6%)	0.08	16/186 (8.6%)	0.06	98/189 (51.9%)	0.27	**23/189 (12.2%)**	**0.01**	9/189 (4.8%)	0.33
	1	362/615 (58.9%)		85/615 (13.8%)		291/616 (47.2%)		**126/615 (20.5%)**		20/615 (3.3%)	
Femoral contusion	0	**215/406 (53.0%)**	**0.02**	**37/405 (9.1%)**	**0.003**	208/407 (51.1%)	0.11	**63/407 (15.5%)**	**0.02**	19/407 (4.7%)	0.10
	1	**244/397 (61.5%)**		**64/396 (16.2%)**		181/398 (45.5%)		**86/397 (21.7%)**		10/397 (2.5%)	

Bipolar impaction	0	**388/696 (55.7%)**	**0.03**	85/694 (12.2%)	0.22	336/698 (48.1%)	0.79	**120/697 (17.2%)**	**.005**	26/698 (3.7%)	0.62
	1	**73/107 (68.2%)**		18/109 (16.5%)		54/109 (49.5%)		**31/109 (28.4%)**		3/108 (2.8%)	
Tibial Impaction >10%	0	415/736 (56.4%)	0.07	**88/735 (12.0%)**	**0.02**	353/739 (47.8%)	0.29	136/738 (18.4%)	0.46	26/739 (3.5%)	0.69
	1	46/68 (67.6%)		**15/68 (22.1%)**		37/68 (54.4%)		15/68 (22.1%)		3/67 (4.5%)	

Table 4. Chi-Square associations between posterolateral tibial plateau and lateral femoral condylar impaction fractures and contusions with various meniscal pathologies. 0 = not present, 1 = present

Associations between the presence of posterolateral tibial plateau and lateral femoral condyle impaction fractures or bone bruising and associated ligament injuries are reported in Table 5. Combined ACL and posterolateral corner injuries had a very strong association with decreased incidence with tibial, femoral and bipolar impaction fractures, as well as with femoral and tibial contusions ($p < .02$). Combined ACL and PCL tears also showed a decreased incidence in the setting of either tibial impaction fractures or contusions ($p < .001$). However, combined ACL and MCL tears had higher incidences in knees with lateral femoral contusions ($p < .02$).

		MCL injury		FCL injury		PLC injury		PCL injury	
		Incidence	*p*	Incidence	*p*	Incidence	*p*	Incidence	*p*
Tibial impaction	0	86/418 (20.6%)	0.31	**135/418 (32.3%)**	**0.02**	**37/418 (8.9%)**	**0.001**	**37/418 (8.6%)**	**0.001**
	1	93/395 (23.5%)		**98/395 (24.8%)**		**8/395 (2.0%)**		**12/395 (3.0%)**	
Femoral impaction	0	131/598 (21.9%)	0.87	166/598 (27.8%)	0.33	**43/598 (7.2%)**	**0.001**	40/598 (6.7%)	0.19
	1	48/214 (22.4%)		67/214 (31.3%)		**2/214 (0.9%)**		9/214 (4.2%)	
Tibial contusion	0	37/190 (19.5%)	0.32	63/190 (33.2%)	0.13	**32/190 (16.8%)**	**0.001**	**25/190 (13.2%)**	**0.001**
	1	142/621 (22.9%)		170/621 (27.4%)		**13/621 (2.1%)**		**24/621 (3.9%)**	
Femoral contusion	0	**74/409 (18.1%)**	**0.006**	117/409 (28.6%)	0.94	**35/409 (8.6%)**	**0.001**	24/409 (5.9%)	0.83
	1	**105/402 (26.1%)**		116/402 (28.9%)		**10/402 (2.5%)**		25/402 (6.2%)	
Bipolar impaction	0	157/704 (22.3%)	0.62	202/704 (28.7%)	0.96	**44/704 (6.3%)**	**.02**	46/704 (6.5%)	0.12
	1	22/109 (20.2%)		31/109 (28.4%)		**1/109 (0.9%)**		3/109 (2.8%)	

Tibial Impaction >10%	0	162/745 (21.7%)	0.54	**223/745 (29.9%)**	**0.008**	42/745 (5.6%)	0.67	46/745 (6.2%)	0.56
	1	17/68 (25.0%)		**10/68 (14.7%)**		3/68 (4.4%)		3/68 (4.4%)	

MCL- medial collateral ligament; FCL- fibular collateral ligament; PLC- posterolateral corner; PCL- posterior cruciate ligament

Table 5. Chi-Square associations between posterolateral tibial plateau and lateral femoral condylar impaction fractures and contusions with various ligamentous injuries. 0 = not present, 1 = present

DISCUSSION

The main finding of this study was that there were high rates of displaced impaction fractures of the posterolateral tibial plateau (49.3%) and the lateral femoral condyle (25.9%) in patients with primary ACL tears. Posterolateral tibial plateau impaction fractures were more likely to occur in older patients, while lateral femoral condylar impaction fractures occurred more often in younger patients. While the clinical significance of these fractures is not yet known, this study demonstrated an association between these lesions and certain types of meniscal tears. Tibial, femoral, and bipolar impaction fractures were all associated with an increased risk of medial meniscal ramp tears, and femoral impaction fractures were associated with increased incidence of lateral meniscus tears and lateral meniscus posterior root tears ($p < .05$). Tibial impaction fractures resulting in greater than 10% loss of tibial plateau depth were also associated with an increased incidence of lateral meniscus posterior root tears, with an incidence of 22.1% in this group.

Contusion of the lateral femoral condyle has been reported to occur in 20-60% of ACL tears[4], with this series reporting an incidence of 49.3%. Similarly, posterolateral tibial plateau impaction contusions have been reported to occur in 60-85% of ACL tears[1–3,10,16], with this series reporting an incidence of 76.8%. While the presence of overt posterolateral tibial plateau fractures visible on lateral radiographs associated with ACL tears have been previously reported[5], there is no prior descriptive epidemiology of these fractures. This study provides detailed characterization of the incidence, size, and location of these impaction fractures. A more detailed characterization of the size and location of femoral condylar impaction fractures and corresponding lateral notch sign has been previously reported by Hoffelner et. al.[4] While defining and characterizing these lesions is an important initial step, more information is necessary to determine the effect of these lesions on patient outcomes, both subjectively and objectively.

The potential effect of these impaction fractures on patient outcomes in the setting of ACL injury remains unknown. Wahl et al. demonstrated that the tibial plateau articular depth was shorter in patients with ACL tears in a recent case-control study analyzing MRI measurements[15], which we theorize could mean that patients with bone loss resulting from impaction fracture could be at increased risk for ACL re-rupture. Musahl et. al has also demonstrated that tibial plateau geometry can affect clinically detectable stability of the knee, with a decreased medial to lateral diameter of the lateral tibial plateau being associated with higher pivot shift grade.[9] Given that we observed a lateral tibial plateau depth bone loss percentage of greater than 10% in 8.6% of all patients in our primary ACL tear cohort, we found that altered lateral tibial plateau geometry is not that uncommon following a primary ACL tear. Whether the tibial and femoral impaction fractures observed in the current case series have a clinically significant effect on postoperative knee stability and whether the presence of these lesions affects patient-reported outcomes requires further investigation.

One of the key findings of this study which may have clinical utility is the association between tibial and femoral impaction fractures and contusions with associated meniscal and ligament pathology. The associated increases in meniscal pathology, specifically with medial ramp lesions and lateral root tears, can serve to heighten clinical suspicion for these meniscal injuries if the corresponding impaction fractures are found on imaging. Specifically, the presence of a femoral impaction fracture should increase concern for lateral meniscal tears, lateral meniscal posterior root tears, and medial meniscal ramp lesions, while a tibial impaction fracture affecting greater than 10% of lateral tibial plateau depth should increase concern for a tear of the lateral meniscus posterior root. We did observe associations with concomitant ligament tears with impaction fractures as well, with posterolateral tibial and lateral femoral impaction fractures and contusions showing a decreased incidence of PLC tears and posterolateral tibial impaction fractures, and contusions showing a decreased incidence of PCL tears. We also found that lateral femoral condylar contusions should increase clinical suspicion for an MCL tear.

This study is not without limitations. First, because pre-injury MRIs for the patients in this study were not available, the size of the tibial impaction fracture lesions in this study were not measured by direct comparison of pre- and post-injury MRIs. Instead, measurements were performed with the use of a correction factor based on the normal anatomy of the lateral tibial plateau on MRIs in a series of control patients. While this methodology is reproducible, it provides an estimation of the actual impaction fracture lesion size rather than a direct measurement. A second limitation was using MRI images rather than CT images to quantify bone injury. CT images would potentially provide more accurate diagnosis and measurement of impaction fractures since they better depict bone compared to MRI scans. However, MRIs are more readily available to clinicians because they are usually part of the work up of ACL injuries making the study more applicable. In order to provide more consistency despite the inherent differences in the images we used for measurement, we used a PACS viewer which allowed for multiplanar reconstruction to ensure measurements were made in the desired plane.

CONCLUSION

Displaced posterolateral tibial plateau impaction fractures occurred with a high incidence (49.3%) in patients with primary ACL tears and demonstrated an increased association with lateral meniscus posterior horn root tears as their size increased. Lateral femoral condylar impaction fractures occurred in 25.9% of patients with primary ACL tears and had an increased incidence of lateral meniscus tears and medial meniscal ramp lesions.

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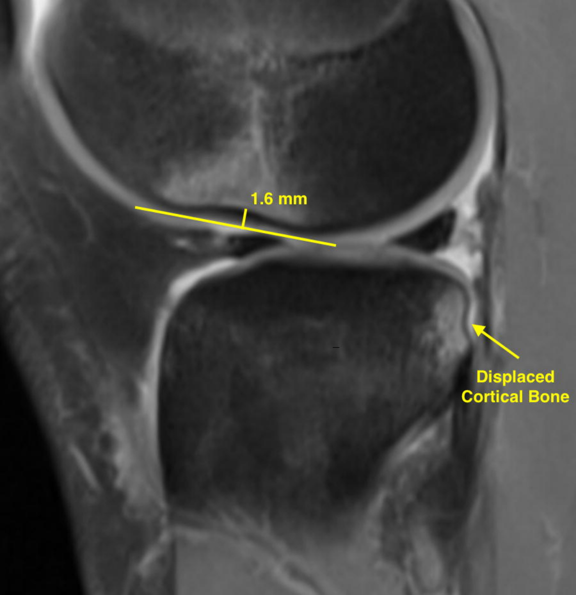
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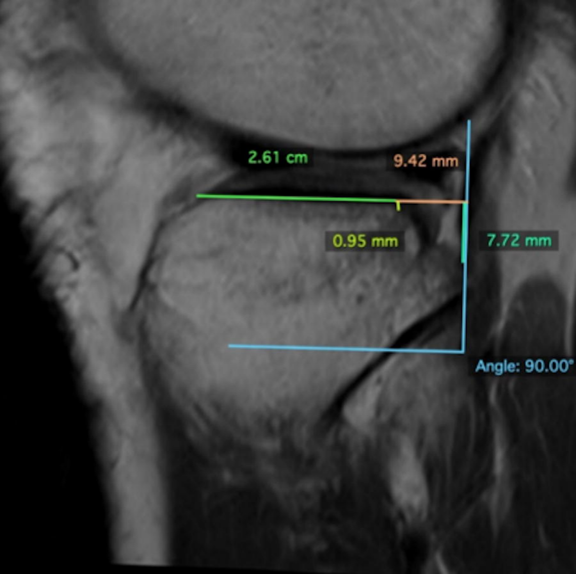
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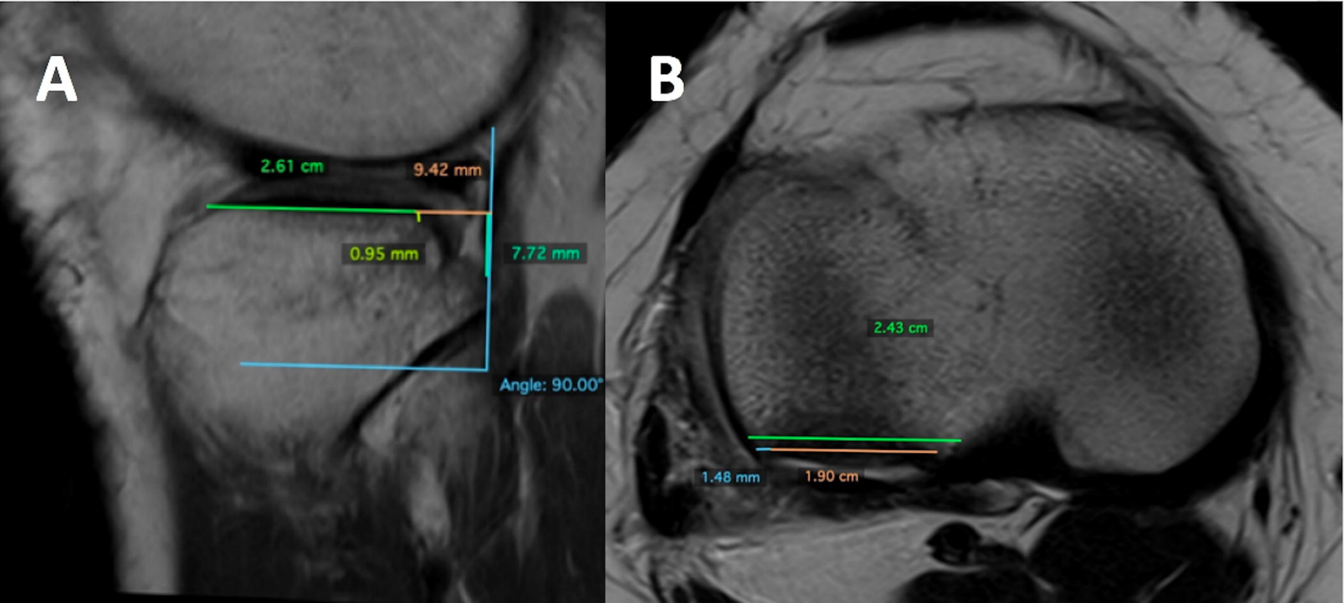
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