Impact of Biologic Augmentation on Revision Surgery Rates After Meniscus Repair

A Matched-Cohort Analysis of 3420 Patients

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Background: Platelet-rich plasma (PRP) and bone marrow aspirate concentrate (BMAC) have gained popularity in recent years as biologic approaches to potentially augment healing after meniscus repair. There have been few studies comparing outcomes in patients undergoing meniscus repair with versus without biologic augmentation and, furthermore, little clarity on the role of biologic augmentation for meniscus repairs performed with concomitant anterior cruciate ligament reconstruction (ACLR).

Purpose: To determine the association of BMAC or PRP augmentation with revision surgery after both isolated meniscus repair and meniscus repair performed concomitantly with ACLR.

Study Design: Cohort study; Level of evidence, 3.

Methods: The PearlDiver Mariner dataset was queried to identify all patients who underwent primary meniscus repair, both with and without concomitant ACLR, and who received ipsilateral BMAC or PRP at the time of surgery. Patients who underwent similar surgery but without BMAC or PRP augmentation were then identified and matched in a 5:1 ratio according to age, sex, body mass index, and various comorbidities to 3 separate BMAC/PRP augmentation groups: overall cohort (with and without ACLR), repair with concomitant ACLR, and isolated repair. The primary outcome was revision meniscus surgery (meniscectomy or revision meniscus repair).

Results: Overall, 3420 patients (570 with BMAC/PRP augmentation; 2850 matched controls without augmentation) were included. There were no significant differences in the reported demographics or comorbidities between any of the BMAC/PRP groups and their respective matched controls ($P > .05$ for all comparisons). There was no difference in revision rate between BMAC/PRP-augmented isolated meniscus repairs and matched controls ($P = .235$). Patients who underwent BMAC/PRP-augmented meniscus repair with concomitant ACLR experienced a significantly lower incidence of revision surgery compared with matched controls without BMAC/PRP augmentation (5.2% vs 7.9% respectively; odds ratio, 0.41; 95% CI, 0.27-0.63; $P < .001$), but the number of revisions was relatively small.

Conclusion: There was no association between BMAC or PRP augmentation and the incidence of revision surgery after isolated primary meniscus repair. There was a statistically significant decrease in the rate of revision meniscus surgery when BMAC or PRP was used to augment meniscus repairs in the setting of concurrent ACLR; however, the overall revision rates were small.

Keywords: meniscus repair; meniscal tear; platelet-rich plasma; PRP; bone marrow aspirate concentrate; BMAC; knee arthroscopy; concomitant ACL reconstruction

Meniscus injuries are among the most common reasons for orthopaedic intervention, with an estimated 1 million knee arthroscopies being performed in the United States each year to address meniscus pathology.[10] The menisci are essential to preserving normal joint surface contact forces, and disruption to these structures via injury or surgical resection results in decreased shock absorptive capabilities within the knee, joint instability, mechanical symptoms, and predisposition to the early development of degenerative arthritis.[2,6,18,24,33,40] As the understanding of the sequelae of meniscus deficiency has grown, it has become increasingly clear that the menisci should be preserved when possible, and surgeons are more frequently electing to perform repairs of meniscal tears rather than meniscectomies when feasible.[1] However, meniscus repairs are not uniformly successful, with a recent study reporting failure rates as high 20% to 24% after meniscus repair in adults at intermediate follow-up.[36] In recent years, a great deal of effort has been made to identify potential risk factors for failure of meniscus repair[7,28] and to improve clinical outcomes.

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It is well established that meniscus repair performed concomitantly with anterior cruciate ligament (ACL) reconstruction (ACLR) has a lower risk of failure than isolated meniscus repair.[15,28] The prevailing thought behind this observation has been that bony bleeding that follows ACL tunnel drilling provides vital nutrients and growth factors into the joint space that augments the biologic milieu and healing environment for the repaired meniscus. Furthermore, intraoperative techniques such as incorporating autologous fibrin blood clots and bone marrow venting have been shown to benefit the healing of meniscus repairs, also presumably by supplementing the concentration of intra-articular growth factors.[§] From this premise, researchers have pondered whether providing other means of nonsurgical biologic augmentation alongside meniscus repair could provide similar results.

Platelet-rich plasma (PRP) is a product obtained from autologous blood that contains increased concentrations of platelets, cytokines, and growth factors. Bone marrow aspirate concentrate (BMAC) is obtained from aspirating autologous bone marrow, followed by centrifugation, yielding a product rich in mesenchymal stem cells, hematopoietic stem cells, growth factors, white blood cells, and platelets, serving to promote recovery in injured tissues.[14,29,30,34,42,44] PRP has been shown to positively affect fibrochondrocyte migration and extracellular matrix production, as well as enhance the activity and regeneration of meniscus cells in vitro.[4,5,25,26,35] Given the potential PRP and BMAC have demonstrated for healing, as well as the importance of meniscus repairs in preventing further joint degeneration, researchers have recently begun investigating whether augmenting meniscus repairs with BMAC or PRP intraoperatively and/or postoperatively can improve healing rates and clinical outcomes. However, shortcomings of past studies have included small sample sizes, lack of differentiation between meniscal tear type and/or repair technique, and vast differences in BMAC/PRP preparation.[12,17,29,32,37,39,42] As such, the role for these forms of biologic augmentation within meniscus repairs remains unclear in the literature.

There is currently a paucity of studies comparing outcomes between patients undergoing meniscus repairs with versus without BMAC or PRP augmentation, and thus definitive conclusions have been difficult to reach regarding the efficacy of these techniques.[3,16,19,20,23,34,43,44] Furthermore, there is even less clarity on the role of BMAC or PRP augmentation of meniscus repairs with concomitant ACLR, with a recent investigation by Everhart et al[16] suggesting that PRP augmentation in the context of concomitant ACLR offers no additional reduction in risk of meniscus repair failure.

The primary purpose of the present study was to further investigate the effect of BMAC or PRP augmentation after meniscus repairs, with or without concomitant ACLR, using a large patient cohort. More specifically, we sought to (1) investigate general demographics for patients receiving BMAC or PRP augmentation with meniscus repair in the United States, (2) determine the association of BMAC or PRP augmentation with revision surgery after isolated meniscus repair, and (3) investigate the association of BMAC or PRP augmentation with revision surgery after meniscus repair performed concomitantly with ACLR.

METHODS

PearlDiver Database

This study was determined to be exempt from institutional review board approval. A retrospective case-control study was performed using a national database of deidentified patient information (PearlDiver Patient Records Database, www.pearldiverinc.com). The study used the national all-payer Mariner knee arthroscopy dataset within PearlDiver, which contains all patients who underwent knee arthroscopy procedures. The Mariner dataset contains 122 million patients, with all information deidentified in compliance with the US Health Insurance Portability and Accountability Act. The dataset contains patient records from many private and government insurers—including 100% of Medicare and Medicaid patients—from all states and territories within the United States. The database provides patient demographic characteristics and procedural records for patients with International Classification of Diseases, 9th Revision (ICD-9) and International Classification of Diseases, 10th Revision (ICD-10) diagnoses and procedures or Current Procedural Terminology (CPT) codes. Provided a patient remained under the same insurance for each encounter, individual data were tracked along all locations of care.

[§]References 8, 9, 11, 13, 21, 22, 27, 38, 41.

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Ethical approval was not sought for the present study.

Study and Control Cohorts

The PearlDiver database was initially queried for all patients who underwent primary meniscus repair, both with and without concomitant ACLR, between 2010 and 2019. CPT codes 29882 and 29883 were used to identify patients who underwent meniscus repair, and patients who underwent concomitant ipsilateral ACLR at the time of surgery were identified using CPT code 29888. To identify patients who received ipsilateral BMAC or PRP at the time of surgery (study cohort), CPT codes 0232T and 38220 were used. For all procedures, laterality was confirmed by only including patients with an associated meniscal tear ICD-10 code with laterality specified. Patients with insufficient data regarding the laterality of the meniscus repair as determined by associated ICD-10 code, PRP injection, and/or ACLR were excluded. For patients who underwent bilateral procedures, each knee was considered a separate case. Patients who underwent concomitant posterior cruciate ligament reconstruction, extra-articular ligament reconstruction or repair, multiligamentous reconstruction, concomitant cartilage restoration procedures, or open meniscus repair or had a history of ipsilateral knee infection were likewise excluded.

Patients who underwent primary meniscus repair (both isolated and with concomitant ACLR) but without BMAC/PRP augmentation (control cohort) were then identified and matched in a 5:1 ratio according to age, sex, body mass index (BMI; obesity and morbid obesity), and the presence of various comorbidities (smoking status, alcohol abuse, diabetes mellitus, hyperlipidemia, hypertension, thyroid disease, and depression) to the study cohort.

Outcomes

The primary outcome studied was revision meniscus surgery (meniscectomy [CPT codes 29880 and 29881] or revision meniscus repair). Ipsilateral surgery was confirmed using associated ICD-10 codes with laterality. Differences in the rates of revision surgery were then compared between patients with and without BMAC/PRP augmentation (all meniscus repairs); in addition, outcomes were compared according to meniscus repair procedure (isolated or with concomitant ACLR).

Statistical Analysis

The demographic characteristics of the study and control cohorts were provided by the database or defined by their respective ICD-9 and ICD-10 codes, and they were subsequently matched and compared. Presence of comorbidities (smoking status, alcohol abuse, diabetes mellitus, hyperlipidemia, hypertension, thyroid disease, and depression) was compared using the chi-square test. Statistical comparisons of revision meniscus repair between cohorts were completed using multivariate binomial logistic regression analysis controlling for the aforementioned covariates. Odds ratios (ORs) with 95% confidence intervals were calculated for each comparison, and statistical significance was achieved when the P value was $<.05$. The statistical analysis was performed using BlueSky 7.4.0 software (BlueSky Statistics) and the embedded statistical software within PearlDiver, the open-source R program (R Foundation for Statistical Computing; www.r-project.org).

RESULTS

Overall, 570 patients who underwent BMAC/PRP augmentation during primary meniscus repair were identified. Of those, 397 underwent an isolated meniscus repair, and 173 had a concomitant ACLR at the time of the meniscus repair. These patients were compared to 2850 matched controls who underwent primary meniscus repair without BMAC/PRP augmentation (1985 as isolated meniscus repairs and 865 with concomitant ACLR). Overall, there were no significant differences in the reported patient characteristics or comorbidities between the BMAC/PRP group and their respective matched controls (Table 1). Similarly, there were no significant differences in the subgroups of patients who underwent isolated meniscus repair with versus without BMAC/PRP (Table 2) and patients who underwent meniscus repair plus ACLR with versus without BMAC/PRP augmentation (Table 3).

The results of multivariate analysis demonstrated no difference in the overall revision rate between BMAC/PRP-augmented meniscus repairs and matched controls who received no augmentation at the time of surgery ($P = .183$) (Table 4). There was likewise no difference in revision rate between the BMAC/PRP-augmented group and the matched control group for patients who underwent isolated meniscus repair specifically ($P = .235$) (Table 4). Compared to matched controls, patients who underwent BMAC/PRP augmentation at the time of meniscus repair with concomitant ACLR did experience a significantly lower incidence of revision surgery compared with those without BMAC/PRP augmentation (5.2% vs 7.9%, respectively; OR, 0.41; 95% CI, 0.27-0.63; $P < .001$), although the overall number of revisions was relatively small in both groups.

DISCUSSION

The current study adds to the growing body of literature surrounding the topic of biologic augmentation of meniscus repairs with BMAC or PRP. While many previous studies have been unable to demonstrate a clear benefit of biologic augmentation of meniscus repairs, they have been limited by relatively small sample sizes. Although this study provides an analysis of a relatively large cohort of patients with meniscus repair, there was still no difference in revision surgery rates for isolated meniscus repairs that were augmented with BMAC or PRP compared with those without augmentation. There was a slight, statistically significant decrease in the rates of revision surgery for concomitant ACLR and meniscus repair when augmented with BMAC or PRP, but the number of revisions was relatively small in both groups, making the clinical significance of this finding questionable.

TABLE 1
Group Characteristics for Overall Meniscus Repairs[a]

Characteristic	All Patients (N = 3420)	Meniscus Repair With BMAC/PRP (n = 570)	Matched Controls Without BMAC/PRP (n = 2850)	*P*
Age-group, y				.999
<20	882 (25.8)	147 (25.8)	735 (25.8)	
20-29	606 (17.7)	101 (17.7)	505 (17.7)	
30-39	540 (15.8)	90 (15.8)	450 (15.8)	
40-49	552 (16.1)	92 (16.1)	460 (16.1)	
≥50	840 (24.6)	140 (24.6)	700 (24.6)	
Male sex	1836 (53.7)	306 (53.7)	1530 (53.7)	.999
BMI group				.957
Obese (30-39.9 kg/m^2)	152 (4.4)	24 (4.2)	128 (4.5)	.767
Morbid obesity (≥40 kg/m^2)	155 (4.5)	26 (4.6)	129 (4.5)	.971
Comorbidities				
Smoking status	198 (5.8)	33 (5.8)	165 (5.8)	.999
Alcohol abuse	68 (2.0)	9 (1.6)	59 (2.1)	.443
Diabetes mellitus	102 (3.0)	19 (3.3)	83 (2.9)	.590
Type 1	16 (0.5)	3 (0.5)	13 (0.5)	.823
Type 2	86 (2.5)	16 (2.8)	70 (2.5)	.625
Hyperlipidemia	340 (9.9)	53 (9.3)	287 (10.1)	.574
Hypertension	327 (9.6)	48 (8.4)	279 (9.8)	.310
Thyroid disease	100 (2.9)	16 (2.8)	84 (2.9)	.856
Depression	266 (7.8)	41 (7.2)	225 (7.9)	.568

[a]Data are presented as number (%). BMAC, bone marrow aspirate concentrate; BMI, body mass index; PRP, platelet-rich plasma.

TABLE 2
Subgroup Characteristics for Isolated Meniscus Repair[a]

Characteristic	Isolated Meniscus Repair (N = 2382)	Meniscus Repair With BMAC/PRP (n = 397)	Matched Controls Without BMAC/PRP (n = 1985)	*P*
Age-group, y				.999
<20	552 (23.2)	92 (23.2)	460 (23.2)	
20-29	360 (15.1)	60 (15.1)	300 (15.1)	
30-39	342 (14.4)	57 (14.4)	285 (14.4)	
40-49	384 (16.1)	64 (16.1)	320 (16.1)	
≥50	744 (31.2)	124 (31.2)	620 (31.2)	
Male sex	1284 (53.9)	214 (53.9)	1070 (53.9)	.999
BMI group				.366
Obese (30-39.9 kg/m^2)	132 (5.5)	17 (4.3)	115 (5.8)	.230
Morbid obesity (≥40 kg/m^2)	102 (4.3)	20 (5.0)	82 (4.1)	.415
Comorbidities				
Smoking status	138 (5.8)	23 (5.8)	115 (5.8)	.999
Alcohol abuse	52 (2.2)	6 (1.5)	46 (2.3)	.316
Diabetes mellitus	76 (3.2)	15 (3.8)	61 (3.1)	.465
Type 1	11 (0.5)	2 (0.5)	9 (0.5)	.892
Type 2	65 (2.7)	13 (3.3)	52 (2.6)	.465
Hyperlipidemia	289 (12.1)	42 (10.6)	247 (12.4)	.299
Hypertension	282 (11.8)	38 (9.6)	244 (12.3)	.126
Thyroid disease	79 (3.3)	14 (3.5)	65 (3.3)	.798
Depression	221 (9.3)	32 (8.1)	189 (9.5)	.360

[a]Data are presented as number (%). BMAC, bone marrow aspirate concentrate; BMI, body mass index; PRP, platelet-rich plasma.

BMAC and PRP have gained immense popularity in recent years as a biologic approach to augment healing after meniscus repair due to their ability to facilitate fibrochondrocyte migration, stimulate meniscus cell regeneration in vitro, and assist in extracellular matrix production.[4,5,25,26,35] However, because of their relative novelty, the specific indications for their utilization in meniscus repair have yet to be fully elucidated. There has been considerable variation in the selection of patients receiving biologic injections among studies that have

TABLE 3
Subgroup Characteristics for Meniscus Repair With Concomitant ACLR[a]

Characteristic	Meniscus Repair With ACLR (N = 1038)	Meniscus Repair With BMAC/PRP (n = 173)	Matched Controls Without BMAC/PRP (n = 865)	*P*
Age-group, y				.999
<20	330 (31.8)	55 (31.8)	275 (31.8)	
20-29	246 (23.7)	41 (23.7)	205 (23.7)	
30-39	198 (19.1)	33 (19.1)	165 (19.1)	
40-49	168 (16.2)	28 (16.2)	140 (16.2)	
≥50	96 (9.2)	16 (9.2)	80 (9.2)	
Male sex	552 (53.2)	92 (53.2)	460 (53.2)	.999
BMI group				.335
Obese (30-39.9 kg/m^2)	43 (4.1)	7 (4.0)	36 (4.2)	.944
Morbid obesity (≥40 kg/m^2)	21 (2.0)	6 (3.5)	15 (1.7)	.139
Comorbidities				
Smoking status	60 (5.8)	10 (5.8)	50 (5.8)	.999
Alcohol abuse	21 (2.0)	3 (1.7)	18 (2.1)	.767
Diabetes mellitus	21 (2.0)	4 (2.3)	17 (2.0)	.767
Type 1	5 (0.5)	1 (0.6)	4 (0.5)	.841
Type 2	16 (1.5)	3 (1.7)	13 (1.5)	.822
Hyperlipidemia	70 (6.7)	11 (6.4)	59 (6.8)	.825
Hypertension	64 (6.2)	10 (5.8)	54 (6.2)	.817
Thyroid disease	13 (1.3)	2 (1.2)	11 (1.3)	.901
Depression	72 (6.9)	9 (5.2)	63 (7.3)	.325

[a]Data are presented as number (%). ACLR, anterior cruciate ligament reconstruction; BMAC, bone marrow aspirate concentrate; BMI, body mass index; PRP, platelet-rich plasma.

TABLE 4
Revision Rates for PRP-Augmented and Nonaugmented Meniscus Repairs[a]

Revision Type	All Patients, No.	Patients Undergoing Revision, No.	Revision Rate, %	Multivariate Analysis	
				OR (95% CI)	*P*
All meniscus repair				0.85 (0.70-1.02)	.183
With BMAC/PRP	570	41	7.2		
Control	2850	216	7.6		
Isolated meniscus repair				0.87 (0.70-1.09)	.235
With BMAC/PRP	397	32	8.1		
Control	1985	163	8.2		
Meniscus repair with concomitant ACLR				0.41 (0.27-0.63)	**<.001**
With BMAC/PRP	173	9	5.2		
Control	865	68	7.9		

[a]Boldface *P* value indicates statistical significance ($P < .05$). ACLR, anterior cruciate ligament reconstruction; BMAC, bone marrow aspirate concentrate; BMI, body mass index; OR, odds ratio; PRP, platelet-rich plasma.

investigated the effects on meniscus repair. In the study by Griffin et al[19] investigating the efficacy of PRP augmentation on isolated meniscus repairs performed by 3 surgeons within 35 patients, those who received PRP augmentation were on average younger (mean age, 26 vs 35 years; $P = .045$) and had a lower BMI (24 vs 28 kg/m^2; $P = .035$) than those who underwent nonaugmented repair; otherwise, there were no statistically significant differences in sex, smoking status, or meniscal tear type distribution (laterality, location, repair technique) between the groups. The authors also conceded that it was uncertain as to whether PRP was used on more difficult tears. Yang et al[43] evaluated clinical outcomes in 61 patients who underwent multiple intra-articular PRP injections after both isolated meniscus repairs and those with concomitant ACL reconstruction under a single surgeon and found that there were no statistically significant differences in patient demographic factors, smoking status, tear pattern, ACL status, suture technique, or knee joint alignment between those who received PRP augmentation and those who did not. There was, however, a larger mean suture number used (3.9 vs 2.2; $P < .001$) in the repair of meniscal tears in the PRP group than in the non-PRP group, which aligned with the surgeon's criteria that patients with larger, more complex, and less vascularized tears were indicated for PRP injection. Everhart et al[16] investigated the effects of PRP

augmentation on meniscus repairs—in the setting of isolated meniscus repair and concomitant ACLR—within 550 patients under a single surgeon. Patients were selected for PRP augmentation based on year of surgery, as the surgeon began incorporating PRP from 2010 to 2015 and did not use the product before this time. Those authors found no differences in sex, age, or BMI between those undergoing augmented versus nonaugmented surgeries; however, there was a larger proportion of vertically oriented tears in the non-PRP group compared with the PRP group (96% vs 73%; $P < .001$) and a larger percentage of avascular extension (extension beyond the red zone of the meniscus periphery) in the PRP-augmented group than in the nonaugmented group (52% vs 39%; $P = .007$).

In the current study, patients who underwent meniscus repair with BMAC or PRP augmentation were matched 5:1 to controls who underwent nonaugmented repair, and as such, there were no significant differences between the demographic factors and comorbidities among the 2 groups. Similar to some previous studies, meniscal tear type and characteristics were not able to be analyzed and directly compared. With respect to age and sex, those who underwent meniscus repair with BMAC or PRP augmentation were well stratified across all age ranges, as 25.8% of patients were <20 years old, and 24.6% of patients were >50 years old. When looking at patients who underwent biologic-augmented meniscus repair with concomitant ACLR specifically, there was an inverse relationship between patient age and the proportion of the cohort they represented, with patients >50 years old making up only 9.2% versus 31.8% of patients being <20 years old. This trend was not observed in the biologic-augmented isolated meniscus repair group, and hence it can likely be explained by a decreased tendency for older patients to undergo ACLR in general than biologic augmentation at the time of surgery. There was likewise a roughly equal distribution among the sexes within the biologic-augmented meniscus repair group overall, with 53.7% males and 46.3% females. With regard to BMI and the other comorbidities that were analyzed, there were no specific trends identified within the biologic-augmented meniscus repair group.

Recent studies investigating whether biologic augmentation improves outcomes within isolated meniscus repair have reached varying conclusions. In their 2019 investigation, Everhart et al[16] reported on isolated meniscus repair in 151 patients. Researchers found that meniscus repair failure (as defined by subsequent meniscectomy, no evidence of healing on repeat arthroscopy, revision meniscus repair, or subsequent total knee arthroplasty) occurred in 20.3% of isolated meniscus repairs, but Kaplan-Meier analysis of meniscus repair survival with stratification by PRP augmentation demonstrated that the use of PRP augmentation significantly improved survival of these repairs ($P = .008$) over a 3-year follow-up period. Furthermore, Kaminski et al[28] conducted a double-blind, placebo-controlled study in which 37 patients underwent either PRP-augmented or nonaugmented repair of a vertical meniscal tear under a single surgeon and found that after 18 weeks, upon either second-look arthroscopy or magnetic resonance imaging (MRI), the PRP-augmented repair group had a significantly higher meniscus healing rate than the nonaugmented repair group (85% vs 47%; $P = .048$). These findings are contrasted by the aforementioned investigation by Griffin et al,[19] who used PRP in the setting of isolated inside-out meniscus repair for 15 (43%) of their study participants, whereas 20 (57%) underwent nonaugmented repair. Researchers found no difference in reoperation rate between PRP-augmented and nonaugmented repairs (27% vs 25%; $P = .89$), as well as no difference in functional outcomes as measured by mean International Knee Documentation Committee score (69 vs 76; $P < .288$) and Lysholm Knee Scoring Scale (66 vs 89; $P = .065$), after a mean follow-up of 4 years. The present investigation found there was no significant difference in the revision rate of isolated meniscus repairs with BMAC or PRP augmentation (8.1% vs 8.2%; $P = .235$). These results were from an analysis of 2382 patients (397 PRP augmented and 1985 nonaugmented) across multiple surgeons and institutions, representing the largest and most diverse study of its type to date.

Regarding the treatment of combined meniscus and ACL injuries, previous studies have suggested ACLR performed at the time of meniscus repair confers a protective effect against subsequent repair failure.[15,31] It has been postulated that that bony bleeding from tunnels drilled during ACLR facilitates an optimal healing environment for the repaired meniscus via the delivery of growth factors such as vascular endothelial growth factor and platelet-derived growth factor. As both BMAC and PRP have likewise been shown to contain growth factors, influence cellular activity, and modulate the extracellular environment,[4,5,25,26,29,35,42] researchers have questioned whether it could provide even further benefit to meniscus repairs performed alongside ACL repairs. Everhart et al[16] investigated the effects of PRP administration in meniscus repairs with concomitant ACLR, with 241 patients undergoing PRP-augmented surgery and 158 undergoing nonaugmented surgery. After a 3-year follow-up period, Kaplan-Meier analysis found that PRP augmentation had no effect on meniscus repair survival when administered in the setting of concomitant ACLR ($P = .28$), with an overall meniscus repair failure rate of 14.1%. In comparison, the current study analyzed 1038 patients who underwent meniscus repair with concomitant ACLR, 173 of whom received BMAC or PRP augmentation at the time of surgery and 865 of whom underwent nonaugmented repair. BMAC or PRP augmentation at the time of meniscus repair and concomitant ACLR did confer a small reduction in subsequent revision rates compared with patients who did not receive BMAC or PRP (5.2% vs 7.9%; $P < .001$). While this did achieve statistical significance, this relatively small reduction in failure rate may not represent a meaningful clinical difference.

Limitations

The results of the current study must be considered within the context of its limitations, many of which are inherent to administrative database research. Like much of the research on this topic, specific details regarding the preparation of the BMAC or PRP, the manner in which it was

administered, and the concentration used in each patient were not available within the utilized database. Furthermore, the potentially differing effects of PRP and BMAC administration were not individually accounted for (rather, they were analyzed in a combined fashion), and details regarding meniscal tear type, location, characteristics, and repair technique were not available. Thus, conclusions could not be drawn regarding the manner in which various BMAC or PRP preparations affect meniscus repair outcomes, we could not account for the possibility that surgeons chose to use biologic augmentation variably depending on the specific qualities of each meniscal tear or repair, and we could not investigate relationships between how different meniscal tear or repair types respond to these treatments.

A second limitation was that database entry relies on accurate coding of all procedures, surgeries, and diagnoses; should providers miscode or not code, it would introduce potential sources of error into our study and thus affect the strength of our analysis and the reliability of our results. Third, many surgeons routinely use other techniques intraoperatively outside of BMAC or PRP to biologically augment their meniscus repairs. Notable examples include marrow venting and the incorporation of autologous fibrin blood clots, both of which have demonstrated effectiveness in the context of meniscal injury and repair.[‖] Given there are no CPT codes specific to these procedures, the present investigation does not account for the possibility that they were used intraoperatively or for their potential effects on meniscus repair outcomes both with or without additional biologic augmentation. Last, utilization of an administrative database necessitated that we also rely on CPT and ICD coding to identify our desired endpoints (namely, revision surgery as a representation of meniscus repair failure); hence, we were unable to identify structural or clinical failures, as could be determined by MRI, second-look arthroscopy, or functional outcome scores. Despite these limitations, we believe that the administrative database still allows for useful conclusions to be drawn, as the large number of patients enabled us to examine outcomes associated with BMAC or PRP augmentation in meniscus repair across a representative population.

CONCLUSION

In this large, matched cohort study, the overall rate of revision surgery after meniscus repair was approximately 7%. There was no association between BMAC or PRP augmentation and the incidence of revision surgery after isolated primary meniscus repair. There was a statistically significant decrease in the rates of revision meniscus surgery when BMAC or PRP was used to augment meniscus repairs in the setting of concurrent ACLR; however, this slight reduction is of limited clinical significance.

[‖] References 8, 9, 11, 13, 21, 22, 27, 38, 41.

REFERENCES

1. Abrams GD, Frank RM, Gupta AK, Harris JD, McCormick FM, Cole BJ. Trends in meniscus repair and meniscectomy in the United States, 2005-2011. *Am J Sports Med*. 2013;41(10):2333-2339.
2. Baratz ME, Fu FH, Mengato R. Meniscal tears: the effect of meniscectomy and of repair on intraarticular contact areas and stress in the human knee. A preliminary report. *Am J Sports Med*. 1986;14(4): 270-275.
3. Belk JW, Kraeutler MJ, Thon SG, Littlefield CP, Smith JH, McCarty EC. Augmentation of meniscal repair with platelet-rich plasma: a systematic review of comparative studies. *Orthop J Sports Med*. 2020; 8(6):2325967120926145.
4. Bhargava MM, Attia ET, Murrell GA, Dolan MM, Warren RF, Hannafin JA. The effect of cytokines on the proliferation and migration of bovine meniscal cells. *Am J Sports Med*. 1999;27(5):636-643.
5. Bhargava MM, Hidaka C, Hannafin JA, Doty S, Warren RF. Effects of hepatocyte growth factor and platelet-derived growth factor on the repair of meniscal defects in vitro. *In Vitro Cell Dev Biol Anim*. 2005; 41(8–9):305-310.
6. Bhatia S, LaPrade CM, Ellman MB, LaPrade RF. Meniscal root tears: significance, diagnosis, and treatment. *Am J Sports Med*. 2014; 42(12):3016-3030.
7. Blackwell R, Schmitt LC, Flanigan DC, Magnussen RA. Smoking increases the risk of early meniscus repair failure. *Knee Surg Sports Traumatol Arthrosc*. 2016;24(5):1540-1543.
8. Chahla J, Kennedy NI, Geeslin AG, et al. Meniscal repair with fibrin clot augmentation. *Arthrosc Tech*. 2017;6(6):e2065-e2069.
9. Chrysanthou C, Laliotis N, Galanis N, et al. Meniscal repair using fibrin clot from autologous blood: description of the surgical technique. *JRPMS*. 2018;2(3):89-94.
10. Cook JL. The current status of treatment for large meniscal defects. *Clin Orthop Relat Res*. 2005;(435):88-95.
11. Dean CS, Chahla J, Matheny LM, Mitchell JJ, LaPrade RF. Outcomes after biologically augmented isolated meniscal repair with marrow venting are comparable with those after meniscal repair with concomitant anterior cruciate ligament reconstruction. *Am J Sports Med*. 2017;45(6):1341-1348.
12. Degen RM, Conti MS, Camp CL, Altchek DW, Dines JS, Werner BC. Epidemiology and disease burden of lateral epicondylitis in the USA: analysis of 85,318 patients. *HSS J*. 2018;14(1):9-14.
13. Desai T, Babu SS, Lal JV, et al. Fibrin clot augmented repair of longitudinal tear of medial meniscus. *Arthrosc Tech*. 2021;10(11): e2449-e2455.
14. Desando G, Giavaresi G, Cavallo C, et al. Autologous bone marrow concentrate in a sheep model of osteoarthritis: new perspectives for cartilage and meniscus repair. *Tissue Eng Part C Methods*. 2016; 22(6):608-619.
15. Espejo-Reina A, Serrano-Fernández JM, Martín-Castilla B, Estades-Rubio FJ, Briggs KK, Espejo-Baena A. Outcomes after repair of chronic bucket-handle tears of medial meniscus. *Arthroscopy*. 2014;30(4):492-496.
16. Everhart JS, Cavendish PA, Eikenberry A, Magnussen RA, Kaeding CC, Flanigan DC. Platelet-rich plasma reduces failure risk for isolated meniscal repairs but provides no benefit for meniscal repairs with anterior cruciate ligament reconstruction. *Am J Sports Med*. 2019; 47(8):1789-1796.
17. Fitzpatrick J, Bulsara MK, McCrory PR, Richardson MD, Zheng MH. Analysis of platelet-rich plasma extraction: variations in platelet and blood components between 4 common commercial kits. *Orthop J Sports Med*. 2017;5(1):2325967116675272.
18. Greis PE, Bardana DD, Holmstrom MC, Burks RT. Meniscal injury: I. Basic science and evaluation. *J Am Acad Orthop Surg*. 2002;10(3): 168-176.
19. Griffin JW, Hadeed MM, Werner BC, Diduch DR, Carson EW, Miller MD. Platelet-rich plasma in meniscal repair: does augmentation improve surgical outcomes? *Clin Orthop Relat Res*. 2015;473(5): 1665-1672.

20. Haunschild ED, Huddleston HP, Chahla J, Gilat R, Cole BJ, Yanke AB. Platelet-rich plasma augmentation in meniscal repair surgery: a systematic review of comparative studies. *Arthroscopy*. 2020;36(6):1765-1774.
21. Henning CE, Lynch MA, Yearout KM, Vequist SW, Stallbaumer RJ, Decker KA. Arthroscopic meniscal repair using an exogenous fibrin clot. *Clin Orthop Relat Res*. 1990;(252):64-72.
22. Howarth WR, Brochard K, Campbell SE, Grogan BF. Effect of microfracture on meniscal tear healing in a goat (*Capra hircus*) model. *Orthopedics*. 2016;39(2):105-110.
23. Hutchinson I, Perrone G, Murray M, Rodeo S. Can platelet-rich plasma enhance anterior cruciate ligament and meniscal repair? *J Knee Surg*. 2015;28(1):19-28.
24. Hutchinson ID, Moran CJ, Potter HG, Warren RF, Rodeo SA. Restoration of the meniscus: form and function. *Am J Sports Med*. 2014;42(4):987-998.
25. Ionescu LC, Lee GC, Huang KL, Mauck RL. Growth factor supplementation improves native and engineered meniscus repair in vitro. *Acta Biomater*. 2012;8(10):3687-3694.
26. Ishida K, Kuroda R, Miwa M, et al. The regenerative effects of platelet-rich plasma on meniscal cells in vitro and its in vivo application with biodegradable gelatin hydrogel. *Tissue Eng*. 2007;13(5):1103-1112.
27. Jang SH, Ha JK, Lee DW, Kim JG. Fibrin clot delivery system for meniscal repair. *Knee Surg Relat Res*. 2011;23(3):180-183.
28. Kaminski R, Kulinski K, Kozar-Kaminska K, et al. A prospective, randomized, double-blind, parallel-group, placebo-controlled study evaluating meniscal healing, clinical outcomes, and safety in patients undergoing meniscal repair of unstable, complete vertical meniscal tears (bucket handle) augmented with platelet-rich plasma. *Biomed Res Int*. 2018;2018:9315815.
29. Kim GB, Seo MS, Park WT, Lee GW. Bone marrow aspirate concentrate: its uses in osteoarthritis. *Int J Mol Sci*. 2020;21(9):3224.
30. Longo UG, Campi S, Romeo G, Spiezia F, Maffulli N, Denaro V. Biological strategies to enhance healing of the avascular area of the meniscus. *Stem Cells Int*. 2012;2012:528359.
31. Lyman S, Hidaka C, Valdez AS, et al. Risk factors for meniscectomy after meniscal repair. *Am J Sports Med*. 2013;41(12):2772-2778.
32. Magalon J, Bausset O, Serratrice N, et al. Characterization and comparison of 5 platelet-rich plasma preparations in a single-donor model. *Arthroscopy*. 2014;30(5):629-638.
33. Markolf KL, Mensch JS, Amstutz HC. Stiffness and laxity of the knee—the contributions of the supporting structures. A quantitative in vitro study. *J Bone Joint Surg Am*. 1976;58(5):583-594.
34. Massey PA, Zhang A, Stairs CB, Hoge S, Carroll T, Hamby AM. Meniscus repair outcomes with and without bone marrow aspiration concentrate. *Orthop J Sports Med*. 2019;7(7)(suppl 5):2325967119S00283.
35. McNulty AL, Guilak F. Integrative repair of the meniscus: lessons from in vitro studies. *Biorheology*. 2008;45(3-4):487-500.
36. Nepple JJ, Dunn WR, Wright RW. Meniscal repair outcomes at greater than five years: a systematic literature review and meta-analysis. *J Bone Joint Surg Am*. 2012;94(24):2222-2227.
37. Oh JH, Kim W, Park KU, Roh YH. Comparison of the cellular composition and cytokine-release kinetics of various platelet-rich plasma preparations. *Am J Sports Med*. 2015;43(12):3062-3070.
38. Ra HJ, Ha JK, Jang SH, Lee DW, Kim JG. Arthroscopic inside-out repair of complete radial tears of the meniscus with a fibrin clot. *Knee Surg Sports Traumatol Arthrosc*. 2013;21(9):2126-2130.
39. Sundman EA, Cole BJ, Fortier LA. Growth factor and catabolic cytokine concentrations are influenced by the cellular composition of platelet-rich plasma. *Am J Sports Med*. 2011;39(10):2135-2140.
40. Voloshin AS, Wosk J. Shock absorption of meniscectomized and painful knees: a comparative in vivo study. *J Biomed Eng*. 1983;5(2):157-161.
41. Woodmass JM, LaPrade RF, Sgaglione NA, Nakamura N, Krych AJ. Meniscal repair: reconsidering indications, techniques, and biologic augmentation. *J Bone Joint Surg Am*. 2017;99(14):1222-1231.
42. Yamaguchi FSM, Shams S, Silva EA, Stilhano RS. PRP and BMAC for musculoskeletal conditions via biomaterial carriers. *Int J Mol Sci*. 2019;20(21):5328.
43. Yang CP, Hung KT, Weng CJ, Chen ACY, Hsu KY, Chan YS. Clinical outcomes of meniscus repair with or without multiple intra-articular injections of platelet rich plasma after surgery. *J Clin Med*. 2021;10(12):2546.
44. Zaffagnini S, Poggi A, Reale D, Andriolo L, Flanigan DC, Filardo G. Biologic augmentation reduces the failure rate of meniscal repair: a systematic review and meta-analysis. *Orthop J Sports Med*. 2021;9(2):2325967120981627.