Management of Chondral Lesions of the Knee: Analysis of Trends and Short-Term Complications Using the National Surgical Quality Improvement Program Database

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Purpose: To provide updated surgical trends of cartilage procedures differentiated by the classic groups of palliative, repair, and restorative modalities. **Methods:** The American College of Surgeons National Surgical Quality Improvement Program database was queried from 2010-2016 for the following cartilage procedures: chondroplasty, microfracture, arthroscopic osteochondral autograft or allograft transplantation, open osteochondral autograft or allograft transplantation, and autologous chondrocyte implantation. Demographic variables and short-term (30-day) complications were analyzed with 1-way analysis of variance and post hoc analysis. Linear regression analysis was performed to analyze trends over time. **Results:** A total of 15,609 procedures performed between 2010 and 2016 were analyzed. On average, 342.2 ± 27.9 cartilage procedures were performed per 100,000 operations. There was a linear increase in the management of overall cartilage procedures per 100,000 operations ($P = .002$). There were also linear increases in arthroscopic osteochondral autograft transplantation, arthroscopic osteochondral allograft transplantation, open osteochondral autograft transplantation, open osteochondral allograft transplantation, and autologous chondrocyte implantation ($P < .001$, $P = .037$, $P = .001$, $P = .006$, and $P = .002$, respectively). Meniscectomy was the most frequently performed concomitant procedure (9.7%-64.2% of cases). Chondroplasty and microfracture showed no change in frequency over time ($P = .140$ and $P = .720$, respectively). The overall complication rate was 2.1% for chondroplasty, 1.4% for microfracture, 1.8% for arthroscopic osteochondral autograft transplantation, 1.0% for arthroscopic osteochondral allograft transplantation, 1.4% for open osteochondral autograft transplantation, 1.1% for open osteochondral allograft transplantation, and 0.75% for autologous chondrocyte implantation. Deep vein thrombosis was the most common complication, occurring in 0.4% to 1.0% of cases. No statistically significant difference was found in complication rates between procedures ($P = .105$). **Conclusions:** Cartilage restoration is becoming an increasingly popular modality to address chondral defects. Minimal complication rates suggest that these procedures may be safely performed concomitantly with other interventions. **Level of Evidence:** Level IV, retrospective database analysis.

See commentary on page 147

Isolated cartilage lesions are commonplace in young, athletic populations. Full-thickness cartilage defects may present in isolation or coexist with various other pathologies.[1] Once injured, cartilage is unable to fully regenerate because of poor vascularity and the limited presence of chondrocytes.[2] These lesions may be

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The authors report the following potential conflict of interest or source of funding: N.N.V. receives personal fees from Arthrex, Arthrosurface, Cymedica, DJ Orthopedics, Minivasive, Omeros, Orthospace, Ossur, Smith & Nephew, Athletico, ConMed Linvatec, Miomed, Mitek, and Vindico Medical-Orthopedics Hyperguide. A.B.Y. receives personal fees from Arthrex, JRF Ortho, and NuTech. B.J.C. receives personal fees from Aesculap/B. Braun, Aqua Boom, Arthrex, Athletico, Biomerix, DJ Orthopaedics, Elsevier Publishing, Flexion, Geistlich, Giteliscope, JRF Ortho, Medipost, Norvartis, Ossio, Regentis, Sanofi-Aventis, Saunders/Mosby-Elsevier, Smith & Nephew, Tornier, and Zimmer. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

Received March 26, 2018; accepted July 31, 2018.

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0749-8063/18373/$36.00
https://doi.org/10.1016/j.arthro.2018.07.049

subclinical at first but have the potential to degenerate further with time, resulting in chronic pain and reduced function.[3,4]

Available treatment modalities include palliative measures such as chondroplasty to reduce irritation and inflammation, reparative treatments aimed at increasing the presence of chondrocytes through stimulation of pluripotent cells, or restorative interventions involving the replacement of cartilage lesions with viable graft tissue.[3] Microfracture, a reparative treatment, has long since been the most common procedure in the treatment of focal lesions through filling of the defect with fibrocartilage.[5-7] The decision to treat these lesions is multifactorial and depends on patient demographic characteristics; functional status; concomitant pathology; rehabilitation goals; and defect size, number, and geometry.[8] Chondral lesions have been associated with inferior outcomes during procedures such as anterior cruciate ligament reconstruction and meniscectomy.[9-11]

Cartilage pathology is frequently associated with concomitant pathology and is therefore often addressed alongside meniscal tears, realignment procedures, or ligament reconstruction. The drawback of concomitantly addressing cartilage lesions during other procedures may be the risk of additional complications, expense, or longer rehabilitation. As the understanding of chondral knee biology increases, multicenter trends in operations provide valuable information in showing what procedures are being performed, as well as with which concomitant procedures.

Isolated cartilage defects are challenging conditions to treat, despite frequently occurring. Significant defects can cause debilitating symptoms of pain, crepitus, effusion, and joint locking. The inability of cartilage to regenerate on its own requires that patients be managed operatively for symptom relief. Unicompartmental knee arthroplasty and total knee arthroplasty are generally cost-inefficient options because of concerns regarding survivorship of implants in younger patients.[12] As a result, there is a high market demand for efficacious procedures to repair or restore the cartilage to delay the need for total knee arthroplasty.

The purpose of this study was to provide updated surgical trends of cartilage procedures differentiated by the classic groups of palliative, repair, and restorative modalities.[6] The hypothesis was that cartilage restoration procedures would be increasingly performed with a minimal complication risk.

Methods

Data Source

This study is a retrospective analysis of the American College of Surgeons (ACS) National Surgical Quality Improvement Program (NSQIP) database. The ACS NSQIP database between 2010 and 2016 was accessed for this study. This annually updated database provides 274 variables that are prospectively collected at 687 participating hospitals across the United States. Participation in the NSQIP database is voluntary and exclusive to the United States. Hospitals that wish to participate in this program must staff a surgical clinical reviewer with a medical background to oversee data collection. This is an additional quality measure of the database. Patients are monitored from the day of operation until 30 days after the operation for any adverse events, readmissions, and reoperations.[13] Participation in the NSQIP database has been shown not to affect outcomes or short-term complication rates.[14] Clinical reviewers at each participating institution are responsible for data collection after the operations. The ACS provides quality assurance from regular inter-rater reliability audits and reports a disagreement rate of less than 1.8%. This database has been established as a reliable source of data within orthopaedic surgery.[15]

Data Collection

This study received exemption from requiring institutional review board approval because all data collected were deidentified in the form of a publicly available database. Primary, secondary, tertiary, and quaternary billed Current Procedural Terminology (CPT) codes were queried for chondroplasty (29877), microfracture (29879), arthroscopic osteochondral allograft transplantation (29867), arthroscopic osteochondral autograft transplantation (29866), open osteochondral allograft transplantation (27415), open osteochondral autograft transplantation (27416), and autologous chondrocyte implantation (27412). Chondroplasty was considered palliative treatment, whereas microfracture was considered reparative. Osteochondral allograft or autograft transplantation and autologous chondrocyte implantation were considered restorative. Patients were excluded from analysis if any demographic information was missing, such as sex, age, weight, height, or functional status. Body mass index was calculated from weight in pounds and height in inches. Demographic information including age, sex, body mass index, American Society of Anesthesiologists class, current smoking status, and comorbidities was collected for all patients. Concomitant procedures were tabulated by CPT code.

Adverse Events

Adverse events included the following: anemia requiring transfusion, cardiac arrest requiring cardiopulmonary resuscitation, cerebrovascular accident, death, deep vein thrombosis, wound dehiscence, myocardial infarction, pneumonia, pulmonary embolism, renal insufficiency, sepsis, surgical-site infection, unplanned intubation, urinary tract infection, hospital readmission, and extended hospital stay ($\geq$4 days). Extended length of stay was defined as the nearest integer that was more than 1 standard deviation from the mean length of stay for the entire population (0.360 ± 4.018 days).[16] Readmission rates were only collected from 2011 onward. Data collected from 2010 were not included in the readmission analysis.

Statistical Analysis

Statistical analysis was performed using Stata software (version 11.2; StataCorp). One-way analysis of variance was used to determine statistically significant differences between demographic variables of patients undergoing each procedure. One-way analysis of variance with post hoc analysis was performed to determine differences in adverse events. Bonferroni correction was applied to account for the testing of multiple hypotheses. Trends over time were analyzed using linear regression models. To eliminate the influence of concomitant procedures, multivariate analysis was performed on only isolated cartilage procedures. The significance level was set at $P < .05$.

Results

Demographic Characteristics

In total, 15,609 procedures were included in this analysis. The average age was 46.4 ± 14.6 years (Fig 1). A summary of patient demographic characteristics and comorbidities is available in Table 1. Over time, the average age of patients undergoing cartilage procedures linearly decreased ($P < .001$) from 49.0 ± 14.2 years in 2010 to 44.0 ± 14.6 years in 2016.

Pair-wise post hoc comparison was performed to determine which procedures had significant differences between demographic variables. The chondroplasty (mean age, 46.4 ± 14.6 years) and microfracture (mean age, 48.3 ± 14.1 years) groups had significantly older populations than each restorative procedure ($P < .001$ for each). For patients undergoing microfracture, the average American Society of Anesthesiologists class was higher (2.0) in comparison with each cartilage restoration procedure ($P < .05$ for each).

Trends

On average, 342.2 ± 27.9 cartilage procedures were performed per 100,000 operations. The most commonly performed was chondroplasty (206.1 ± 27.9 per 100,000 operations), followed by microfracture (117.8 ± 9.7 per 100,000 operations). Open osteochondral allograft transplantation was the most frequently performed restoration technique (5.5 ± 2.5 per 100,000 procedures), followed by arthroscopic osteochondral allograft transplantation (4.4 ± 2.2 per 100,000 procedures), arthroscopic osteochondral autograft transplantation (3.9 ± 1.7 per 100,000 procedures), autologous chondrocyte implantation (2.6 ± 1.7 per 100,000 procedures), and open osteochondral autograft transplantation (1.9 ± 0.3 per 100,000 procedures). During the period of interest, there was a linear increase in overall cartilage procedures performed by 4.4% per year ($P = .002$). The number of arthroscopic osteochondral allograft transplantation procedures increased by 675.0% ($P < .001$); arthroscopic osteochondral autograft transplantation procedures by 132.5% ($P = .037$); open osteochondral allograft transplantation procedures by 160.4% ($P = .001$); open osteochondral autograft transplantation procedures by 45.3% ($P = .006$); and autologous chondrocyte implantation procedures by 626.6% ($P = .002$). There was no change in chondroplasty and microfracture procedures ($P = .140$ and $P = .720$, respectively). When grouped, cartilage restoration procedures increased by 206.0% overall ($P < .001$) (Fig 2).

Complications

The 30-day complication rates of all included cartilage procedures are displayed in Table 2. On the basis of post hoc analysis, patients who received microfracture had statistically reduced rates of sepsis, hospital readmission, and hospital length of stay compared with patients who received chondroplasty ($P = .003$, $P = .012$, and $P < .001$, respectively). There was no statistically significant difference between overall complication rates among procedures ($P = .105$). A type II error may still have been present despite the use of a large national database.

Concomitant Procedures

In total, 42.5% of cartilage procedures were performed without concomitant procedures. Meniscectomy was the most frequently performed concomitant procedure. Meniscectomies were performed along

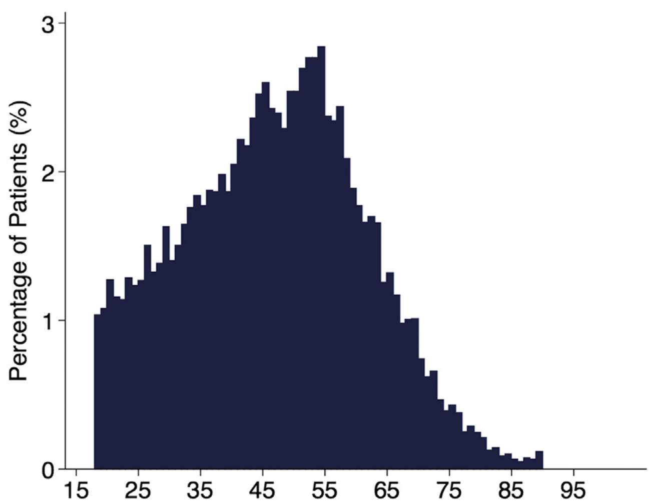

Fig 1. Age distribution of patients who received cartilage procedures.

Table 1. Demographic Information of Patients Undergoing Cartilage Procedures

	Chondroplasty	Microfracture	Arthroscopic OCAuto	Arthroscopic OCAllo	Open OCAllo	Open OCAuto	ACI	*P* Value*
Overall, n	9,317	5,308	277	199	279	92	137	
Age								<.001†
18-24 years	755 (8.1)	327 (6.2)	41 (14.8)	60 (30.2)	55 (19.7)	18 (19.6)	19 (13.9)	
25-34 years	1,393 (15.0)	669 (12.6)	67 (24.2)	60 (30.2)	91 (32.6)	22 (23.9)	68 (49.6)	
35-44 years	1,928 (20.7)	1,025 (19.3)	63 (22.7)	39 (19.6)	87 (31.2)	36 (39.1)	34 (24.8)	
45-54 years	2,430 (26.1)	1,475 (27.8)	39 (14.1)	23 (11.6)	32 (11.5)	6 (6.5)	14 (10.2)	
55-64 years	1,819 (19.5)	1,127 (21.2)	7 (2.5)	11 (5.5)	11 (3.9)	3 (3.3)	1 (0.7)	
65-74 years	746 (8.0)	536 (10.1)	7 (2.5)	4 (2.0)	0 (0)	4 (4.3)	1 (0.7)	
75-84 years	209 (2.2)	133 (2.5)	1 (0.4)	2 (1.0)	2 (0.7)	3 (3.3)	0 (0)	
≥85 years	37 (0.4)	1 (0)	2 (0.7)	0 (0)	1 (0.4)	0 (0)	0 (0)	
Sex								<.001†
Female	4,840 (51.9)	2,702 (50.9)	88 (31.8)	73 (36.7)	110 (39.4)	44 (47.8)	57 (41.6)	
Male	4,477 (48.1)	2,606 (49.1)	139 (50.2)	126 (63.3)	169 (60.6)	48 (52.2)	80 (58.4)	
BMI								<.001†
<25	1,807 (19.4)	843 (15.9)	60 (21.7)	59 (29.6)	68 (24.4)	20 (21.7)	32 (23.4)	
25-29.9	3,029 (32.5)	1,637 (30.8)	74 (26.7)	82 (41.2)	97 (34.8)	30 (32.6)	60 (43.8)	
30-34.9	2,266 (24.3)	1,363 (25.7)	56 (20.2)	36 (18.1)	62 (22.2)	31 (33.7)	33 (24.1)	
35-39.9	1,213 (13.0)	781 (14.7)	17 (6.1)	12 (6.0)	27 (9.7)	5 (5.4)	11 (8.0)	
≥40	1,002 (10.8)	684 (12.9)	20 (7.2)	10 (5.0)	25 (9.0)	6 (6.5)	1 (0.7)	
ASA class								<.001†
1	2,197 (23.6)	1,172 (22.1)	85 (30.7)	96 (48.2)	100 (35.8)	29 (31.5)	63 (46.0)	
2	5,266 (56.5)	2,956 (55.7)	117 (42.2)	92 (46.2)	151 (54.1)	55 (59.8)	65 (47.4)	
3	1,762 (18.9)	1,151 (21.7)	25 (9.0)	11 (5.5)	26 (9.3)	8 (8.7)	9 (6.6)	
4	92 (1.0)	29 (0.5)	0 (0)	0 (0)	2 (0.7)	0 (0)	0 (0)	
Current smoker								.018†
No	7,642 (82.0)	4,415 (83.2)	187 (67.5)	15 (7.5)	229 (82.1)	75 (81.5)	124 (90.5)	
Yes	1,675 (18.0)	893 (16.8)	40 (14.4)	48 (24.1)	50 (17.9)	17 (18.5)	13 (9.5)	
Diabetes mellitus								<.001†
No	8,449 (90.7)	4,793 (90.3)	221 (79.8)	193 (97.0)	274 (98.2)	89 (96.7)	137 (100)	
NIDDM	608 (6.5)	367 (6.9)	3 (1.1)	3 (1.5)	4 (1.4)	2 (2.2)	0 (0)	
IDDM	260 (2.8)	148 (2.8)	3 (1.1)	3 (1.5)	1 (0.4)	1 (1.1)	0 (0)	
Dyspnea on exertion								.129
No	9,105 (97.7)	5,165 (97.3)	224 (80.9)	196 (98.5)	276 (98.9)	90 (97.8)	137 (100)	
Yes	212 (2.3)	143 (2.7)	3 (1.1)	3 (1.5)	3 (1.1)	2 (2.2)	0 (0)	
Hypertension								<.001†
No	6,744 (72.4)	3,574 (67.3)	193 (69.7)	176 (88.4)	242 (86.7)	80 (87.0)	122 (89.1)	
Yes	2,573 (27.6)	1,734 (32.7)	34 (12.3)	23 (11.6)	37 (13.3)	12 (13.0)	15 (10.9)	
COPD								.173
No	9,162 (98.3)	5,225 (98.4)	225 (81.2)	198 (99.5)	278 (99.6)	92 (100)	137 (100)	
Yes	155 (1.7)	83 (1.6)	2 (0.7)	1 (0.5)	1 (0.4)	0 (0)	0 (0)	
Anemia								.191
No	8,753 (93.9)	5,021 (94.6)	217 (78.3)	191 (96.0)	260 (93.2)	88 (95.7)	134 (97.8)	
Yes	564 (6.1)	287 (5.4)	10 (3.6)	8 (4.0)	19 (6.8)	4 (4.3)	3 (2.2)	

NOTE. Data are presented as number of patients (percentage).

ACI, autologous chondrocyte implantation; ASA, American Society of Anesthesiologists; BMI, body mass index; COPD, chronic obstructive pulmonary disease; IDDM, insulin-dependent diabetes mellitus; NIDDM, non–insulin-dependent diabetes mellitus; OCAllo, osteochondral allograft; OCAuto, osteochondral autograft.

*One-way analysis of variance showing differences in demographic variables between procedures.

†Statistically significant.

with 21.2% of chondroplasties, 64.2% of microfractures, 28.5% of arthroscopic osteochondral autograft transplantations, 19.6% of arthroscopic osteochondral allograft transplantations, 15.2% of open osteochondral autograft transplantations, and 9.7% of open osteochondral allograft transplantations. There were no meniscectomies performed with autologous chondrocyte implantation. Anterior cruciate ligament reconstruction was performed in 2.8% of chondroplasties, 6.7% of microfractures, 21.7% of arthroscopic osteochondral autograft transplantations, 31.7% of arthroscopic osteochondral allograft transplantations, 10.9% of open osteochondral autograft transplantations, 3.9% of open osteochondral allograft transplantations, and 2.2% of autologous chondrocyte implantations. Meniscal allograft transplantation and osteotomy were exclusively performed with cartilage restoration procedures (Table 3).

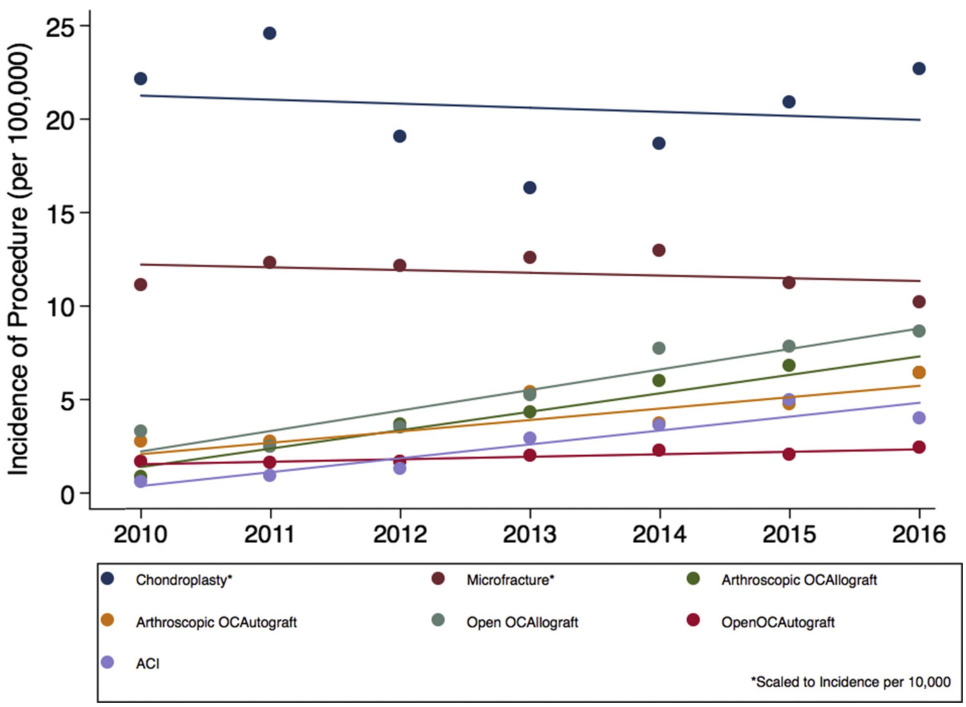

Fig 2. Trends in management of cartilage lesions between 2010 and 2016. (ACI, autologous chondrocyte implantation; OC, osteochondral.)

Multivariate Analysis

In isolated cartilage procedures (n = 6,639), the incidence of adverse events was 1.7%. After accounting for demographic variables, there was no association between procedure performed and incidence of adverse events ($P = .593$). Age greater than 75 years, insulin-dependent diabetes mellitus, and preoperative anemia were associated with an increased risk of adverse events ($P = .048$, $P = .044$, and $P = .001$, respectively).

Discussion

The principal findings of this study indicate that the incidence of restorative procedures is growing in comparison with palliative and reparative procedures.

Table 2. Thirty-Day Complication Rates of Cartilage Procedures

	Chondroplasty	Microfracture	Arthroscopic OCAuto	Arthroscopic OCAllo	Open OCAuto	Open OCAllo	ACI	*P* Value*
Adverse event	198 (2.1)	78 (1.4)	5 (1.8)	2 (1.0)	4 (1.4)	1 (1.1)	1 (0.7)	.105
Anemia requiring transfusion	19 (0.2)	5 (0.1)	0	0	2 (0.7)	1 (1.1)	0	.500
Cardiac arrest requiring CPR	1 (0)	0	0	0	0	0	0	.995
Cerebrovascular accident	0	1 (0)	0	0	0	0	0	.926
Death	3 (0)	0	0	0	0	0	0	.919
Deep vein thrombosis	44 (0.4)	38 (0.5)	2 (0.7)	2 (1.0)	1 (0.4)	1 (1.1)	0	.412
Dehiscence	2 (0)	2 (0)	1 (0.4)	0	0	0	0	.054
Myocardial infarction	6 (0.1)	1 (0)	0	0	0	0	0	.919
Pneumonia	16 (0.2)	4 (0.1)	0	0	0	0	0	.714
Pulmonary embolism	14 (0.2)	7 (0.1)	0	0	0	0	1 (0.7)	.599
Renal insufficiency	6 (0.1)	0	0	0	0	0	0	.674
Sepsis	46 (0.4)	5 (0.1)	0	0	0	0	0	.003†
Surgical-site infection	66 (0.7)	24 (0.5)	1 (0.4)	0	2 (0.7)	0	0	.365
Unplanned intubation	0	1 (0)	0	0	0	0	0	.926
Urinary tract infection	20 (0.2)	4 (0.1)	1 (0.4)	0	1 (0.4)	0	0	.392
Adverse hospital metric								
Hospital readmission	114 (1.2)	37 (0.7)	5 (1.8)	0	4 (1.4)	0	1 (0.7)	.012†
Extended hospital stay (≥4 d)	268 (2.9)	29 (0.5)	3 (1.1)	4 (2.0)	9 (3.2)	1 (1.1)	1 (0.7)	<.001†

NOTE. Data are presented as number of patients (percentage).

ACI, autologous chondrocyte implantation; CPR, cardiopulmonary resuscitation; OCAllo, osteochondral allograft; OCAuto, osteochondral autograft.

*One-way analysis of variance showing differences in demographic variables between procedures.

†Microfracture had a reduced rate of sepsis ($P = .001$), readmission ($P = .022$), and extended hospital stay ($P < .001$) in comparison with chondroplasty by post hoc analysis.

Table 3. Concomitant Procedures Associated With Cartilage Palliation, Repair, and Restoration

Procedure	Chondroplasty	Microfracture	Arthroscopic OCAuto	Arthroscopic OCAllo	Open OCAuto	Open OCAllo	ACI
Realignment							
Tibial osteotomy	0	0	0	0	0	0	11 (8.0)
Tibial tubercle osteotomy	0	0	0	0	0	10 (3.6)	15 (10.9)
Distal femoral osteotomy	0	0	0	0	2 (2.2)	0	2 (1.5)
High tibial osteotomy	0	0	2 (0.7)	0	0	14 (5.0)	3 (2.2)
Meniscus							
Meniscal allograft transplant	0	0	3 (1.1)	1 (0.5)	1 (1.1)	10 (3.6)	3 (2.2)
Meniscectomy							
Medial and lateral	516 (5.5)	1,117 (21.0)	22 (7.9)	2 (1.0)	0	0	0
Medial or lateral	1,464 (15.7)	2,292 (43.2)	57 (20.6)	37 (18.6)	14 (15.2)	27 (9.7)	0
Meniscus repair	110 (1.2)	121 (2.3)	16 (5.8)	13 (6.5)	0	3 (1.1)	0
Ligamentous stability							
MPFL reconstruction	0	0	0	0	0	0	4 (2.9)
Open ACL reconstruction	0	0	0	0	0	7 (2.5)	0
Arthroscopic ACL reconstruction	262 (2.8)	356 (6.7)	60 (21.7)	63 (31.7)	10 (10.9)	11 (3.9)	3 (2.2)
Knee arthroscopy							
Diagnostic knee arthroscopy	113 (1.2)	0	0	5 (2.5)	3 (3.3)	14 (5.0)	6 (4.4)
Knee arthroscopy + lateral release	190 (2.0)	320 (6.0)	7 (2.5)	0	2 (2.2)	0	1 (0.7)
Knee arthroscopy + loose body removal	354 (3.8)	157 (3.0)	5 (1.8)	1 (0.5)	3 (3.3)	12 (4.3)	2 (1.5)
Knee arthroscopy + synovectomy	500 (5.4)	307 (5.8)	0	0	1 (1.1)	4 (1.4)	0
Knee arthroscopy + synovectomy major	343 (3.7)	666 (12.5)	27 (9.7)	2 (1.0)	4 (4.3)	2 (0.7)	0
Lysis of adhesions	9 (0.1)	0	0	0	0	0	0
Stand-alone procedure	5,212 (55.9)	1,086 (20.5)	67 (24.2)	77 (38.7)	28 (30.4)	96 (34.4)	73 (53.3)

NOTE. Data are presented as number of patients (percentage).

ACI, autologous chondrocyte implantation; ACL, anterior cruciate ligament; MPFL, medial patellofemoral ligament; OCAllo, osteochondral allograft; OCAuto, osteochondral autograft.

Chondroplasty and microfracture are performed over 20 times as frequently as restorative procedures (>100 per 100,000 operations). However, the popularity of restorative procedures is increasing, whereas that of palliative and reparative options has become stagnant. As indications for cartilage restoration are becoming better defined, there is a growing trend toward cartilage restoration techniques in the United States. This is reasonable because these techniques have been shown to have successful, durable long-term outcomes[17-20] whereas the outcomes of palliative and reparative treatments are more variable. The complication rates of all included procedures are under 3%, and any minor differences between complication rates may be attributable to the heterogeneity of the patient population. Most of these procedures were performed along with adjunctive procedures, with meniscectomy being the most frequently reported.

Trends obtained within this study are comparable with those in studies previously conducted through insurance databases from years prior.[21-23] These findings suggest the equivalent of 342 cartilage procedures per 100,000 cases, whereas a previous study found 900 per 100,000 cases.[21] The discrepancy may be justified by the fact that only private insurers were queried in establishing the previous frequency of cartilage procedures. Because the NSQIP database draws directly from patient medical records, payer bias is not present within this study. However, institutions that are understaffed to participate in the ACS NSQIP will not be reflected in the database. For this reason, the NSQIP database over the 7 included years contains data from 4.6 million patients, whereas the PearlDiver database contains approximately 172 million patients within the same time span.[21] The PearlDiver database, although massive and capable of allowing large-scale conclusions to be drawn, has some limitations by the fact that data are organized by billing and diagnosis codes that do not have any quality-assurance checks. The advantages of performing this study with the ACS NSQIP database are greater granularity, more thorough data on short-term complications, and increased quality-assurance protocols in place. In comparison with the previous study, the growth rate of palliative procedures was not found to be linearly increasing whereas that of restorative procedures still is. This finding suggests a trend toward more restoration techniques as indications for these procedures are becoming better established. It is interesting to note that a decreasing trend was reported from the American Board of Orthopaedic Surgery database, although this may be a result of reporting bias because only cases that are submitted for case-based examination will be represented by this database.[23] There exist multiple reasons for the incidence of chondroplasty performed remaining stagnant, although these trends cannot be explained with full accuracy. Variability in billing for chondroplasty exists between practices because Medicare and private insurance payers have differences in coding rules. Beginning in 2012, as part of the bundled-payment program, when chondroplasty was performed with meniscectomy, it was not billed using separate CPT codes. For this reason, chondroplasty procedures may be undercounted and appear stagnant. Despite this, there remains an undeniable increase in the incidence of restorative procedures performed during the included time frame.

Generally, the senior authors (N.N.V, A.B.Y., B.J.C.) refrain from performing cartilage procedures on incidental cartilage defects.[24,25] The size of the lesion is the next important consideration because small lesions under 2 cm^2 may be treated with debridement or microfracture whereas lesions greater than 4 cm^2 may be more suitable for autologous chondrocyte implantation or osteochondral allograft/autograft transplantation.[7] The patient profile must be evaluated to determine the optimal treatment modality because younger patients may benefit more from restorative treatment with autograft or allograft transplantation and chondrocyte implantation at the cost of longer rehabilitation protocols whereas older patients may benefit more from palliative measures to alleviate symptoms.[26,27] Lesion size is not captured by these trends, but a significantly older demographic received chondroplasty and microfracture whereas a younger demographic received restoration. Additional scientific literature have specified indications for use of cartilage restoration procedures over recent years, which corroborate the increase in restoration techniques.[10]

Major categories of concomitant procedures addressed with chondral defects include meniscal insufficiency, ligamentous instability, and malalignment.[7] Several studies have shown negative outcomes in patients undergoing meniscectomies with untreated large chondral defects among both athletes and non-athletes.[28,29] The recent Chondral Lesions and Meniscus Procedures (ChAMP) trial showed no statistically significant differences in patient-reported outcomes (Western Ontario and McMaster Universities Osteoarthritis Index, Knee Injury and Osteoarthritis Outcome Score, Short Form 36) between patients with meniscal tears and chondral lesions receiving chondroplasty concomitant with meniscectomy and those receiving meniscectomy alone.[30] However, chondroplasty has shown clinical improvement in cases without concomitant pathology and may be ideal particularly when long rehabilitation processes are undesirable.[31-33] Similar findings exist for microfracture,[34] which may suggest these modalities do not sufficiently address large chondral defects. Malalignment procedures and meniscal allograft transplantation were exclusive to cartilage restoration procedures. This trend is expected because malalignment and meniscal deficiency have been established to predict chondral damage.[35] Addressing concomitant pathology while performing a restorative procedure provides patients with maximum chances of a successful outcome.[36,37]

Short-term complication rates were found to be under 3% in cartilage restoration procedures, which corroborates findings of previous meta-analyses.[38-40] Complications were not affected by the decision to use autograft versus allograft transplantation (1.8% vs 1.0% for arthroscopic and 1.4% vs 1.1% for open). Fresh allograft must be used for transplantation because frozen tissue lacks the number of chondrocytes needed for viable restoration.[41] The requirements for preservation and management of allograft tissue before surgery limit availability because donor tissue must be implanted between 15 and 28 days after harvest to allow for sufficient serologic testing and minimal chondrocyte loss.[42] Autograft allocation from non—weight-bearing surfaces would potentially allow for increased transplant procedures in areas with limited access to harvest allografts. Rates of complications and donor-site morbidity under 3%[43] and 9% in MegaOATS transfer (large osteochondral autogenous transplantation system) from the posterior femoral condyle[44] have been reported. Despite recent findings that microfracture achieves similar improvements in patient-reported outcomes to autograft transplantation and chondrocyte implantation at short-term follow-up,[45] we find that restoration techniques remain on the rise. This trend may reflect the perception that restorative procedures provide greater durability over time, although long-term outcomes have yet to show this.[46,47] In addition, autologous chondrocyte implantation was reported to have increased failure when performed after prior microfracture, which suggests these procedures should not be used subsequently.[48] It is of note that procedural complication rates were reflective of all procedures in a particular case and do not necessarily reflect the risk of performing the chondral procedures. Patients who underwent chondroplasty had marginally greater rates of complications than other procedures, although this is likely an effect of concomitant procedures and demographic differences that were unable to be controlled for.

The NSQIP database was chosen over others because data are directly collected from patient medical records rather than payer information, which reduces recording bias. Furthermore, only the NSQIP database is able to accurately capture all short-term complications within 30 days.

Limitations

There are several limitations to this study. The ACS NSQIP database only contains information from the United States; therefore, these data are limited in their generalizability. Although the NSQIP database contains data associated with multiple cartilage procedures, it does not report information regarding specific characteristics of the chondral lesions. In particular, there is no way to know the associated lesion size or location; this will impact the treatment plan. This database also lacks the granularity to determine specific indications for cartilage treatment. Studies from large, multicenter databases do not provide all variables associated with procedural complication or incidence rates; therefore, statistical conclusions may be limited in accounting for confounding. Rates of failure are unavailable because this does not necessarily necessitate a readmission or reoperation within the 30-day window. In addition, comparison of complication rates between the included cartilage restoration techniques is limited by differences in concomitant procedures. Furthermore, patients are not followed up past 30 days, so outcomes are restricted to the short-term postoperative period. This study is unable to comment on the durability and survivorship of these treatment modalities. The data are also limited to the institutions that participate in the ACS NSQIP, although this number continues to increase. Smaller surgical sites such as outpatient ambulatory surgical centers or community hospitals are unlikely to participate in data collection but may be performing the procedures analyzed in this study. Despite this, the NSQIP database provides multicenter data that are well powered to glean overall trends over time and generalized complication rates with high quality assurance.

Conclusions

Cartilage restoration is becoming an increasingly popular modality to address chondral defects. Minimal complication rates suggest that these procedures may be safely performed concomitantly with other interventions.

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