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Rates of knee arthroplasty in patients with a history of arthroscopic chondroplasty: results from a retrospective cohort study utilising the National Hospital Episode Statistics for England

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Rates of knee arthroplasty in patients with a history of arthroscopic chondroplasty: results from a retrospective cohort study utilising the National Hospital Episode Statistics for England

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knee; arthroscopy; chondroplasty; knee replacement; arthroplasty; outcomes; osteoarthritis

Word count

ABSTRACT

OBJECTIVE

The purpose of this study was to analyse the rate of knee arthroplasty in the population of patients with a history of arthroscopic chondroplasty of the knee, in England, over ten years, with comparison to general population data for patients without a history of chondroplasty.

DESIGN

Retrospective cohort study

SETTING

English hospital episode statistics (HES) data

PARTICIPANTS AND INTERVENTIONS

Patients undergoing arthroscopic chondroplasty in England between 2007/08 and 2016/17 were identified.

Patients undergoing previous arthroscopic knee surgery or simultaneous cruciate ligament reconstruction or

microfracture in the same knee were excluded.

OUTCOMES

Patients subsequently undergoing a knee arthroplasty in the same knee were identified and mortalityadjusted survival analysis was performed (survival without undergoing knee arthroplasty). A cox proportional hazards model was used to identify factors associated with knee arthroplasty. Relative risk of knee arthroplasty (total or partial) in comparison to the general population was determined.

RESULTS

Through 2007-17, 157,730 eligible chondroplasty patients were identified. Within one-year, 5.91% (7984/135197; 95% CI 5.78 to 6.03) underwent knee arthroplasty and 14.22% (8145/57267; 95% CI 13.94 to 14.51) within five-years. Patients aged over 30 years with a history of chondroplasty were 17.32 times (risk ratio; 95% CI 16.81 to 17.84) more likely to undergo arthroplasty than the general population without a history of chondroplasty.

CONCLUSIONS

Patients with cartilage lesions of the knee, treated with arthroscopic chondroplasty, are at greater risk of
subsequent knee arthroplasty than the general population and for a proportion of patients, there is
insufficient benefit to prevent the need for knee arthroplasty within one- to five-years. These important new
data will inform patients of the anticipated outcomes following this procedure. The risk in comparison to
non-operative treatment remains unknown and there is an urgent need for a randomised clinical trial in this
population.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- Strengths of the data source analysed in this study include comprehensive, national, data collection and the ability to match treatment with outcomes, including by the laterality of intervention, over time.
- This is the largest cohort of patients undergoing arthroscopic chondroplasty that has been reported, with strict inclusion criteria excluding patients with a history of previous surgery to the same knee and those undergoing simultaneous ligament reconstruction or microfracture.
- All studies of this design rely on coding accuracy and some coding errors are inevitable and although outcomes were stratified by a range of patient factors, unmeasured potential confounders include body mass index, limb alignment, baseline radiographic status.
- Knee arthroplasty is an end-stage outcome and will underestimate the true burden and severity of symptomatic osteoarthritis in this population.
- The outcome had these patients not undergone arthroscopic chondroplasty remains unknown.



INTRODUCTION

Around 2 million knee arthroscopy procedures are performed worldwide each year.[1] Historically, knee washout and 'debridement' was shown to be ineffective for the treatment of advanced osteoarthritis.[2–4] For early osteoarthritis, however, a number of surgical and non-surgical treatments are available and treatment selection is challenging.[5] The aim of treatment in these cases is to improve symptoms and delay or prevent progressive osteoarthritis.[6]

Chondroplasty is a non-specific term that encompasses several techniques for the treatment of cartilage defects.[7] It includes debridement and abrasion using mechanical 'shavers' and, more recently, thermal or radiofrequency techniques have also emerged despite some concerns these techniques might risk inducing localised chondrocyte death.[7–11] Recent national guidance was cautiously supportive of radiofrequency chondroplasty for the treatment of "discrete chondral defects" based on a small number of clinical trials comparing the outcomes of mechanical and radiofrequency techniques.[12] It is not known which patients are most likely to benefit from chondroplasty procedures and when the procedure does not provide sustained benefit, knee arthroplasty is often indicated.

The purpose of this study was to determine the proportion of patients undergoing knee chondroplasty procedures that subsequently receive a knee arthroplasty in the same knee, with specific focus on the proportion of patients undergoing early arthroplasty with one-year or two-years of chondroplasty. Factors associated with the risk of subsequent arthroplasty are reported and the relative risk in comparison to the general population determined.

METHODS

Data source

National Hospital Episode Statistics (HES) data was obtained (application DARS-NIC-68703). HES contains a record of all patient attendances at National Health Service (NHS) hospitals in England.[13] The data is submitted by hospitals to claim payment for the services they provide and is also intended for secondary use, including research. HES includes episodes of care delivered in treatment centres (including those in the independent sector) funded by the NHS, episodes of care in England where patients are resident outside of England, and privately funded patients treated within NHS England hospitals. The information recorded in the HES database includes patient demographic and residence data, primary and secondary diagnoses including comorbidities, and all procedures undertaken.

Procedures

All HES records between 1 April 2007 and 31 March 2017 were extracted for patients undergoing arthroscopic chondroplasty. Patients undergoing previous arthroscopic knee surgery or simultaneous cruciate ligament reconstruction or microfracture in the same knee were excluded. Procedures were identified using the Classification of Surgical Operations and Procedures (OPCS-4) codes recorded within the HES data (see appendix 1 for OPCS-4 code list).[14] All knee arthroplasty (partial or total) procedures were also identified (appendix 2) for the whole population to enable the relative risk of knee arthroplasty with and without a history of chondroplasty to be determined.

Outcomes

The primary outcome was knee arthroplasty, matched to the side of any previous chondroplasty (using recorded OPCS-4 laterality codes).

Statistical analysis

Stata v15.1 (StataCorp, College Station, Texas, USA) was used to perform all analysis. In accordance with Office for National Statistics (ONS) and NHS Digital guidance, rates where the number of events was less than six were suppressed.[15] Procedures with date errors or missing laterality were excluded. The absolute rate of knee arthroplasty was determined at 1 year, 2 years, 5 years, and 8 years following arthroscopic chondroplasty as the proportion of the cohort with this minimum period of follow-up. Mortality adjusted Kaplan-Meier survival analysis (survival was defined as not undergoing knee arthroplasty) was also performed and stratified by patient age group and sex.

A Cox proportional-hazards model was used first to calculate the unadjusted hazard ratio of knee arthroplasty over time by age group, sex, index of multiple deprivation (quintile derived from regional factors in England including average income, employment, education, housing, and crime; 1=least deprived

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area, 5=most deprived), ethnicity, modified Charlson comorbidity index (derived with maximum 5-year diagnosis code lookback period),[16–18] year of treatment (chondroplasty), rurality, and ethnicity respectively.[16–19] The hazard ratios were then adjusted including all these variables in the model.

The relative risk (risk ratio) of knee arthroplasty in the population of patients with a history of chondroplasty in comparison to the general population (without a history of chondroplasty) was estimated for the year 2016-17. All patients undergoing knee arthroplasty in 2016-17 were identified and the number of these patients with a recorded previous chondroplasty (in the prior 10-years of HES data), versus those without, made up the numerator for each respective population. The chondroplasty population denominator was the number of patients with a history of chondroplasty that had not undergone a knee arthroplasty prior to 2016-17. The denominator for the non-chondroplasty population was the ONS mid-year population estimate less the chondroplasty population.

Patient and public involvement

There was no patient and public involvement in this study.

RESULTS

Over the study period, 157,830 chondroplasty patients were identified as eligible for analysis (Figure 1). The mean age of the chondroplasty cohort was 51.7 year (SD 13.8) and 48.1% were female (Table 1).

Overall, following chondroplasty, 5.91% (7984/135197; 95% confidence interval [CI] 5.78 to 6.03) patients underwent knee arthroplasty within 1 year, 9.41% (10787/114592; 95% CI 9.24 to 9.58) within 2 years, 14.22% (8145/57267; 95% CI 13.94 to 14.51) within 5 years, and 17.61% (2879/16347; 95% CI 17.03 to 18.20) within 8 years (Table 2). The risk of arthroplasty was greater in female patients (adjusted hazard ratio [HR] 1.38; 95% CI 1.34 to 1.42) and in older patients (adjusted HR 1.33 per five years; 95% CI 1.32 to 1.34) (Table 3, Figure 2; Figure 3). Patients with a greater comorbidity index were also at increased risk of subsequently undergoing arthroplasty (adjusted HR 1.03 per five units Charlson index; 95% CI 1.01 to 1.05).

The risk of knee arthroplasty after chondroplasty fell slightly over time, by year of chondroplasty treatment (adjusted HR 0.95 per five years; 95% CI 0.92 to 0.98). Patients in regions of increased deprivation and patients of white ethnicity were at greater risk of subsequent arthroplasty (Table 2). Patients undergoing concurrent meniscal surgery were also at greater risk of subsequent arthroplasty (adjusted HR 1.09; 95% CI 1.06 to 1.13).

In 2016-17, the rate of knee arthroplasty was 3.49% (95% CI 3.39 to 3.60) in patients (aged 30 or older) with a recorded history of chondroplasty and 0.20% (95% CI 0.19 to 0.20) in patients without a record of chondroplasty. This corresponded to an overall relative risk of knee arthroplasty for the chondroplasty cohort patients of 17.32 times (risk ratio [RR]; 95% CI 16.81 to 17.84) that of the general population (Table 3).

Although the absolute annual rate of knee arthroplasty was low, the relative risk of undergoing knee arthroplasty at a younger age was greatly elevated in comparison to arthroplasty at an older age, as shown in Table 3. Patients aged 30-39 with a history of a previous chondroplasty were 170.92 times (RR; 95% CI 116.72 to 250.30) more likely to undergo knee arthroplasty than the general population, per year, in comparison to 11.09 times (RR; 95% CI 10.42 to 11.80) more likely for the over 69 age group.

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DISCUSSION

Principal findings

Patients undergoing chondroplasty procedures of the knee have a 17 times increased risk of receiving a knee arthroplasty compared with the general population. Nearly 10% of patients will have received a knee arthroplasty within two years of the chondroplasty procedure. Young patients are at particularly elevated risk, reaching 171 times greater than the general population between 30 and 39 years of age. For a proportion of patients, the results indicate insufficient benefit to prevent the need for knee arthroplasty within one or two years.

Comparison to other studies

We previously reported trends in chondroplasty surgery in England, but data from other countries is not available.[20] The age-sex standardised rate of chondroplasty increased 191% from 17.6/100,000 (95% CI 17.2 to 18.0) in 2007/08 to 51.2/100,000 (95% CI 50.6 to 51.7) in 2016/17.[20] The rate of chondroplasty was greatest in patients aged 40-59 years (increasing 210% from 34.3/100,000 in 2007/08 to 106.4/100,000 in 2016/17.[20]

In England, although national guidance has been cautiously supportive of radiofrequency chondroplasty for specific indications. There is only limited evidence demonstrating the effectiveness of chondroplasty compared with alternative surgical or non-surgical treatments.[12] The only randomised studies have been limited to comparisons of different chondroplasty techniques.[10,12] Long-term outcomes following chondroplasty have yet to be reported.[12]

Older patients are much more likely to have generalised osteoarthritis, rather than "discrete chondral defects" for which the national guidance supports radiofrequency chondroplasty.[12,21] For more generalised osteoarthritis, chondroplasty is analogous to debridement and washout, where multiple clinical trials demonstrate no benefit.[2–4] The use of chondroplasty in the treatment of patients with more generalised chondral pathology is therefore unproven and not recommended.[22] In our study, there was considerable age-group variation in outcomes, with 18.8% of patients aged 60-79-years undergoing arthroplasty within two-years of chondroplasty, in comparison to 0.43% for patients undergoing chondroplasty aged 20-39-years. This observation is consistent with the presence of more established osteoarthritis in older age groups.

Our study represents a high-risk cohort of patients with cartilage damage. It is unknown from this observational data whether undergoing the chondroplasty procedure was beneficial to the symptoms or prognosis of these individuals over the full study period. Patients undergoing arthroplasty within 1-year of their arthroscopic chondroplasty, however, suggests sub-optimal treatment selection. These individuals are

highly unlikely to have had only localised or partial thickness lesions and our results may indicate that knee arthroplasty may have been a more appropriate treatment. It is unlikely that chondroplasty in these patients was a cost-effective choice of intervention, but whether chondroplasty can be cost-effective with optimal patient selection is unknown and requires evaluation in a high-quality randomised controlled trial.

Female patients were observed to be of greater risk of subsequent arthroplasty in our study. This has previously been observed following knee arthroscopy in the United States.[23] Patients of white ethnicity and greater deprivation were also at greater risk in our cohort. These findings may reflect differences in healthcare access including treatment thresholds for either the chondroplasty or knee arthroplasty, or differences in care seeking behaviour which has been shown to be influenced by socioeconomic, cultural, occupational, and psychological factors, or there could be biological factors underlying the observation.[24– 26] Patients with a greater comorbidity index were more likely to undergo subsequent arthroplasty, and the reason for this is unclear. One possible explanation might be an association between comorbidity and higher body mass index (BMI), which is not recorded in this dataset, with patients having a greater BMI being more likely to progress to end-stage osteoarthritis, or that these patients had more severe pathology at the time of their index chondroplasty.[27] Patients undergoing concurrent meniscal surgery were also likely to undergo subsequent arthroplasty, which is expected given the association between meniscal injury, osteoarthritis, and knee arthroplasty.[28]

Recently, there has been renewed focus on the importance of and requirements for individualised patient consent.[29] Our findings make an important contribution to the current evidence, and patients can now be appropriately counselled and consented with knowledge of anticipated long-term outcomes.

Strength and limitations

A key strength of our study is the identification of all knee chondroplasty procedures performed in the National Health Service over a 10-year period, creating the largest reported cohort of patients receiving this procedure. Patients with a history of prior arthroscopy in the same knee, simultaneous ligament reconstruction or microfracture were excluded to control for confounding factors. It should still be noted that patients undergoing non-NHS treatment, for example knee arthroplasty in the private sector after a previous knee arthroscopy under NHS care, would not be captured in this dataset. For all observational studies utilising large datasets there may be some concerns raised about coding accuracy. The data in our study was cleaned prior to analysis, excluding patients where procedures were missing the side of intervention, and cases where date coding errors were identified. Although some other data coding errors are inevitable, data errors in procedure coding would result in hospitals not receiving payment for surgery performed, and this provides a strong incentive for data accuracy with regards to the coding data analysed in this study.

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We were able to stratify risk of arthroplasty by a large number of patient factors, but certain procedure specific data is not recorded. Operative factors, such as the affected compartment of the knee and extent of initial cartilage damage before intervention, are not recorded in this database. These factors may be important in determining outcome, for example, there are likely to be differences in long-term outcomes between chondroplasty performed to the tibiofemoral joint in comparison to the patellofemoral joint.[30] Other unmeasured sources of potential confounding include BMI, leg alignment, and radiographic status at the time of intervention. These are important considerations when considering if a patient is suitable for chondral surgery intervention, but the specific impact of these factors on long-term outcomes in this population remains uncertain. Subjective, patient-reported, symptomatic outcome data is not yet available for this cohort and radiographic outcomes are not recorded in the HES database. Instead, our study focussed on the objective, measurable outcome of knee arthroplasty, matched to the same knee as the previous chondroplasty surgery intervention. Although knee arthroplasty represents the end-stage of symptomatic failure for patients with osteoarthritis, it is likely to considerably underestimate the overall health and symptom burden in this cohort. Patients, particularly younger patients, may not have been willing or suitable candidates for knee arthroplasty, and the threshold for arthroplasty may have been much higher for younger age groups or older patients with multiple comorbidities.

The outcome had patients in our study not undergone chondroplasty remains unknown and an answer to this question requires a randomised controlled trial with a non-operative treatment arm. It is important to note that, in general, chondroplasty is a non-specific term that encompasses several techniques for the debridement of cartilage defects.[7] The findings in this paper cannot be generalised to other types of arthroscopic and joint preservation surgery, cartilage repair and regeneration techniques, such as microfracture and autologous chondrocyte implantation.[6.30]

Our study reports the long-term outcomes following chondroplasty in a high-risk cohort of patients with cartilage damage for the first time. Our findings our stratified by a range of patient specific factors and will be important for informed consent and shared decision making between patients and clinicians. Further work is required to optimise treatment selection, however, and additional patient information may allow more accurate prediction of outcome and guide clinical management.

Conclusion

The risk of knee arthroplasty is 17 times greater in patients with a history of knee chondroplasty and in a proportion of patients, there is insufficient benefit to prevent the need for knee arthroplasty within one or two years. These important new data help inform patients and clinicians of the long-term outcomes following this procedure, at the population level, for the first time. Enhanced clinical guidance on the appropriate indications for chondroplasty are required and there is a need for high-quality randomised

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studies to determine the relative clinical and cost effectiveness of this intervention in comparison to

alternative, including non-surgical, treatments.

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Transparency declaration

The lead author (SA) affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and registered) have been explained.

Competing interests

Andrew Judge has received consultancy fees from Freshfields Bruckhaus Deringer (on behalf of Smith & Nephew Orthopaedics Limited), and is a member of the Data Safety and Monitoring Board (which involved receipt of fees) from Anthera Pharmaceuticals, Inc. All other authors declare no financial relationships with any organisations that might have an interest in the submitted work in the previous three years, no other relationships or activities that could appear to have influenced the submitted work.

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Ethical approval

Not required.

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60		Research Datalink (CPRD). Br J Sports Med 2018;:bjsports-2017-097762. doi:10.1136/bjsports-							
		2017-097762							

- Chan SW, Tulloch E, Cooper ES, *et al.* Montgomery and informed consent: where are we now? *BMJ* 2017;2224:j2224. doi:10.1136/bmj.j2224
- Kraeutler MJ, Belk JW, Purcell JM, *et al.* Microfracture Versus Autologous Chondrocyte
 Implantation for Articular Cartilage Lesions in the Knee: A Systematic Review of 5-Year Outcomes.
 Am J Sports Med 2017;:036354651770191. doi:10.1177/0363546517701912

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TABLES

TABLE 1: Demographics and	descriptive statistics of chondroplasty cohort
TIDLE 1. Demographics and	descriptive statistics of chondroplasty conort

	n	%
Total	157730	100.00
Sex		1
Male	81884	51.91
Female	75846	48.09
Age group (years)		
<20	2868	1.82
20-39	24648	15.63
40-59	83258	52.79
60-79	45191	28.65
80+	1765	1.12
Charlson comorbid	lity index	
0	121605	77.10
1 - 15	34719	22.01
16 - 30	1296	0.82
31 - 50	110	0.07
Index of multiple d	eprivation	(quintiles)
1 = least deprived	36043	23.21
2	35189	22.66
3	32493	20.92
4	27312	17.59
5 = most deprived	24266	15.62
Missing	2427	
Rurality		1
Urban	119766	76.42
Rural	36953	23.58
Missing	1011	
Ethnicity		
White	141928	94.43
Asian	953	0.63
Black	4511	3.00
Mixed	2122	1.41
Other	792	0.53
Missing	7424	0.82 0.07 (quintiles) 23.21 22.66 20.92 17.59 15.62 76.42 23.58 94.43 0.63 3.00 1.41 0.53 41.84 58.16
Concurrent proced		1
None	65987	41.84
	91743	58.16
Meniscal		

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	1-year ou	itcome		2-year ou	tcome		5-year of	utcome		8-year ou	itcome	
	n	n TKA	% (95% CI)	n	n TKA	% (95% CI)	n	n TKA	6/bmjopen-2019-030609 % (95% CI) 9	n	n TKA	% (95% CI)
Total	135,197	7984	5.91% (5.78, 6.03)	114,592	10787	9.41% (9.24, 9.58)	57,267	8145	<u>9</u> 14.22% (13.94, 14.51)	16,347	2879	17.61% (17.03, 18.20
Sex									↓			
Male	69,787	3160	4.53% (4.37, 4.68)	59,101	4261	7.21% (7.00, 7.42)	29,688	3315	11.17% (10.81, 11.53)	8,514	1208	14.19% (13.45, 14.9)
Female	65,410	4824	7.38% (7.18, 7.58)	55,491	6526	11.76% (11.49, 12.03)	27,579	4830	17.51% (17.07, 17.93)	7,833	1671	21.33% (20.43, 22.2)
Sex	00,110	1021	1.5676 (1.16, 1.56)	00,191	0020	11.7070 (11.19, 12.05)	27,377	1050		1,000	10/1	21.3370 (20.13, 22.2)
< 20	_	-	-		-	-	-	-	- 0	-	-	_
20 - 39	21,548	48	0.22% (0.16, 0.30)	18,583	79	0.43% (0.34, 0.53)	10,004	95	0.95% (0.77, 1.16)	3,094	53	1.71% (1.29, 2.23)
40 - 59	72,345	2654	3.67% (3.53, 3.81)	60,974	4049	6.64% (6.44, 6.84)	29,844	3327	11.15% (10.79, 11.57)	8,552	1287	15.05% (14.30, 15.82
60 - 79	39,741	4994	12.57% (12.24, 12.90)	33,680	6343	18.83% (18.42, 19.25)	16,716	4522	27.05% (26.38, 27.72)	4,508	1479	32.81% (31.44, 34.2
$\frac{80 + 1}{80 + 1}$	1,563	288	18.43% (16.53, 20.44)	1,355	316	23.32% (21.09, 25.67)	703	201	28.59% (25.28, 32.0 2)	193	60	31.09% (24.64, 38.1)
	comorbidity			-,			,		<u></u> 7			
0	104,530	5369	5.14% (5.00, 5.27)	89,081	7366	8.27% (8.09, 8.45)	45,505	5837	12.83% (12.52, 13.4)	13,362	2148	16.08% (15.46, 16.7
1 - 15	29,475	2467	8.37% (8.06, 8.69)	24,540	3228	13.15% (12.73, 13.58)	11,371	2207	19.41% (18.69, 20.5)	2,884	701	24.31% (22.75, 25.9
16 - 30	1,102	138	12.52% (10.63, 14.62)	898	180	20.04% (17.47, 22.82)	391	101	25.83% (21.56, 30.47)	101	30	29.70% (21.02, 39.6
31 - 50	90	10	11.11% (5.46, 19.49)	73	13	17.81% (9.84, 28.53)	-	-		-	-	-
	nultiple dep				-		1	1		1	1	1
1	31,054	1846	5.94% (5.68, 6.21)	26,546	2405	9.06% (8.72, 9.41)	13,422	1835	13.67% (13.09, 14.28)	3,878	629	16.22% (15.07, 17.42
2	30,218	1799	5.95% (5.69, 6.23)	25,638	2409	9.40% (9.04, 9.76)	12,819	1779	13.88% (13.28, 14.49)	3,474	617	17.76% (16.50, 19.0
3	27,974	1737	6.21% (5.93, 6.50)	23,721	2324	9.80% (9.42, 10.18)	11,833	1772	14.98% (14.34, 15.65)	3,374	635	18.82% (17.51, 20.18
4	23,312	1387	5.95% (5.65, 6.26)	19,702	1913	9.71% (9.30, 10.13)	9,771	1420	14.53% (13.84, 15.23)	2,762	496	17.96% (16.54, 19.44
5	20,591	1104	5.36% (5.06, 5.68)	17,194	1588	9.24% (8.81, 9.68)	8,420	1197	14.22% (13.48, 14.98)	2,451	444	18.12% (16.61, 19.70
Rurality		1							n n			
Urban	102,665	6004	5.85% (5.71, 5.99)	86,807	8135	9.37% (9.18, 9.57)	43,287	6148	14.20% (13.88, 14.)	2,154	12,242	17.60% (16.92, 18.28
Rural	31,760	1944	6.12% (5.86, 6.39)	27,127	2613	9.63% (9.28, 9.99)	13,739	1980	14.41% (13.83, 15.0)	713	3,987	17.88% (16.70, 19.1)
Ethnicity								•	NO.			
White	122,261	7672	6.28% (6.14, 6.41)	103,979	10366	9.97% (9.79, 10.15)	52,267	7834	14.99% (14.68, 15.39)	14,908	2,750	18.45% (17.83, 19.08
Mixed	750	21	2.80% (1.74, 4.25)	609	32	5.25% (3.62, 7.34)	278	22	7.91% (5.03, 11.74)	76	8	10.53% (4.66, 19.69)
Asian	3,722	130	3.49% (2.93, 4.13)	3,088	186	6.02% (5.21, 6.92)	1,465	167	11.40% (9.82, 13.14)	362	75	20.72% (16.66, 25.20
Black	1,770	27	1.53% (1.01, 2.21)	1,466	53	3.62% (2.72, 4.70)	677	38	5.61% (4.00, 7.62) 0	171	15	8.77% (4.99, 14.06)
Other	645	15	2.33% (1.31, 3.81)	518	18	3.47% (2.07, 5.44)	250	21	8.40% (5.27, 12.55)	75	9	12.00% (5.64, 21.56)
Concurren	nt procedur	es							st.			
None	57,208	2686	4.70% (4.52, 4.87)	50,256	3754	7.47% (7.24, 7.70)	28,578	3252	11.38% (11.01, 11.75)	9,370	1,389	14.82% (14.11, 15.5)
Meniscal	77,989	5298	6.79% (6.62, 6.97)	64,336	7033	10.93% (10.69, 11.18)	28,689	4893	17.06% (16.62, 17.55)	6,977	1,490	21.36% (20.40, 22.34

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Table 3: Unadjusted and adjusted* risk of knee arthroplasty following arthroscopic chondroplasty

	Unadj	justed Risk Subsequent TKA	Ad	Adjusted Risk Subsequent TK			
	HR	95% CI	HR	95% CI			
Sex							
Male	1.00	1.00	1.00	1.00			
Female	1.61	1.57, 1.66	1.38	1.34, 1.42			
Age (per five years) ‡			I			
Per year	1.35	1.35, 1.36	1.33	1.32, 1.34			
Year of treatment	(per five years	5)		I			
Year	0.99	0.96, 1.03	0.95	0.92, 0.98			
Charlson comorbio	lity index (pe	r five units)	I	1			
Charlson index	1.29	1.27, 1.31	1.03	1.01, 1.05			
Index of multiple d	leprivation (q	uintile)					
1 = least	1.00	1.00	1.00	1.00			
2	1.03	0.99, 1.08	1.07	1.03, 1.12			
3	1.08	1.04, 1.13	1.17	1.12, 1.22			
4	1.03	0.99, 1.08	1.20	1.15, 1.26			
5 = most	1.01	0.96, 1.06	1.29	1.23, 1.36			
Rurality							
Urban	1.00	1.00	1.00	1.00			
Rural	1.03	1.00, 1.07	0.99	0.95, 1.02			
Ethnicity			0				
White	1.00	1.00	1.00	1.00			
Mixed	0.50	0.38, 0.65	0.66	0.51, 0.86			
Asian	0.65	0.59, 0.72	0.73	0.66, 0.81			
Black	0.35	0.28, 0.42	0.44	0.36, 0.54			
Other	0.34	0.24, 0.48	0.45	0.32, 0.64			
Concurrent proced	lures	1					
None	1.00	1.00	1.00	1.00			
Meniscal surgery	1.52	1.48, 1.57	1.09	1.06, 1.13			

* adjusted by all variables in the table; \ddagger age <20 years suppressed due to small numbers; HR = hazard ratio; CI = confidence interval; TKA = total or partial knee arthroplasty

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Table 4: Rates and relative risk of undergoing TKA with previous chondroplasty by age at TKA in 2016-17

$\begin{array}{c ccccccccccccccccccccccccccccccccccc$		Prior chondrop	lasty	Without prior c	chondroplasty	Relative Risk		
(years)TKA /100kTKA /100kTKA /100kTKA /100k $30 - 39$ 274.48190.16, 383.351.601.32, 1.92170.92116.72, 250.3 (0.27%) $(0.19\%, 0.38\%)$ (0.00%) $(0.00\%, 0.00\%)$ $(0.00\%, 0.00\%)$ 116.72, 250.3 $40 - 49$ 1454.021318.04, 1600.0619.7918.79, 20.8272.4565.00, 80.76 (1.45%) $(1.32\%, 1.60\%)$ (0.02%) $(0.02\%, 0.02\%)$ 72.4565.00, 80.76 $50 - 59$ 3626.623448.20, 3811.60130.68128.05, 133.3526.8225.41, 28.30 (3.63%) $(3.45\%, 3.81\%)$ (0.13%) $(0.13\%, 0.13\%)$ 26.8225.41, 28.30 $60 - 69$ 5179.174933.67, 5433.20386.68381.64, 391.7712.7812.16, 13.44 $70 +$ 6090.505721.53, 6475.82520.46514.89, 526.0711.0910.42, 11.80 00 verall3494.613394.82, 3596.52195.38193.90, 196.8717.3216.81, 17.84 $(30 +)$ (3.49%) $(3.39\%, 3.60\%)$ (0.20%) $(0.19\%, 0.20\%)$ 17.3216.81, 17.84	Age at TKA	A Annual Rate		Annual Rate				
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	(years)	TKA /100k	95% CI	TKA /100k	95% CI	KK	95% CI	
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	20 20	274.48	190.16, 383.35	1.60	1.32, 1.92	170.02	116 72 250 20	
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	30 - 39	(0.27%)	(0.19%, 0.38%)	(0.00%)	(0.00%, 0.00%)	170.92	110.72, 250.50	
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	40 40	1454.02	1318.04, 1600.06	19.79	18.79, 20.82	72.45	65 00 80 76	
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	40 - 49	(1.45%)	(1.32%, 1.60%)	(0.02%)	(0.02%, 0.02%)	/2.45	03.00, 80.70	
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	50 50	3626.62	3448.20, 3811.60	130.68	128.05, 133.35	26.92	25 41 28 20	
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	50 - 59	(3.63%)	(3.45%, 3.81%)	(0.13%)	(0.13%, 0.13%)	20.82	25.41, 28.50	
(5.18%) $(4.93%, 5.43%)$ $(0.39%)$ $(0.38%, 0.39%)$ $(0.38%, 0.39%)$ $70 +$ 6090.50 $(6.09%)$ $5721.53, 6475.82$ $(5.72%, 6.48%)$ 520.46 $(0.52%)$ $514.89, 526.07$ $(0.51%, 0.53%)$ 11.09 $10.42, 11.80$ Overall $(30 +)$ 3494.61 $(3.49%)$ $3394.82, 3596.52$ $(3.39%, 3.60%)$ 195.38 $(0.20%)$ $193.90, 196.87$ $(0.19%, 0.20%)$ 17.32 $16.81, 17.84$	(0, (0)	5179.17	4933.67, 5433.20	386.68	381.64, 391.77	10.70	10.16.10.44	
70 + (6.09%) (5.72%, 6.48%) (0.52%) (0.51%, 0.53%) 11.09 10.42, 11.80 Overall 3494.61 3394.82, 3596.52 195.38 193.90, 196.87 17.32 16.81, 17.84 (30 +) (3.49%) (3.39%, 3.60%) (0.20%) (0.19%, 0.20%) 17.32 16.81, 17.84	60 - 69	(5.18%)	(4.93%, 5.43%)	(0.39%)	(0.38%, 0.39%)	12.78	12.16, 13.44	
(6.09%) (5.72%, 6.48%) (0.52%) (0.51%, 0.53%) Overall 3494.61 3394.82, 3596.52 195.38 193.90, 196.87 (30 +) (3.49%) (3.39%, 3.60%) (0.20%) (0.19%, 0.20%) 17.32	7 0 .	6090.50	5721.53, 6475.82	520.46	514.89, 526.07	11.00	10.42, 11.80	
(30 +) (3.49%) (3.39%, 3.60%) (0.20%) (0.19%, 0.20%) 17.32 16.81, 17.84	/0+	(6.09%)	(5.72%, 6.48%)	(0.52%)	(0.51%, 0.53%)	11.09		
(30+) (3.49%) (3.39%, 3.60%) (0.20%) (0.19%, 0.20%)	Overall	3494.61	3394.82, 3596.52	195.38	193.90, 196.87	17.22	16.01.17.04	
KA = total or partial knee arthroplasty; RR = risk ratio	(30+)	(3.49%)	(3.39%, 3.60%)	(0.20%)	(0.19%, 0.20%)	17.32	16.81, 17.84	

FIGURES

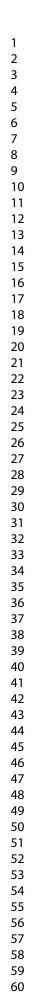
Figure 2: Survival curve (not undergoing knee arthroplasty) following chondroplasty by age†

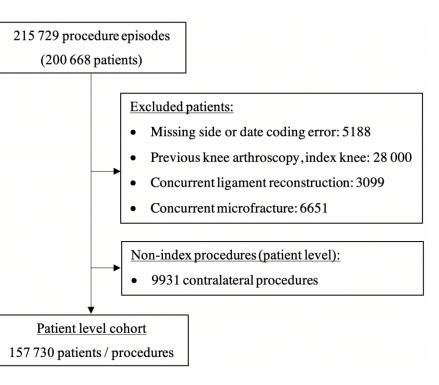
• umbers *†* Age groups < 20 years and 80+ years suppressed due to small numbers

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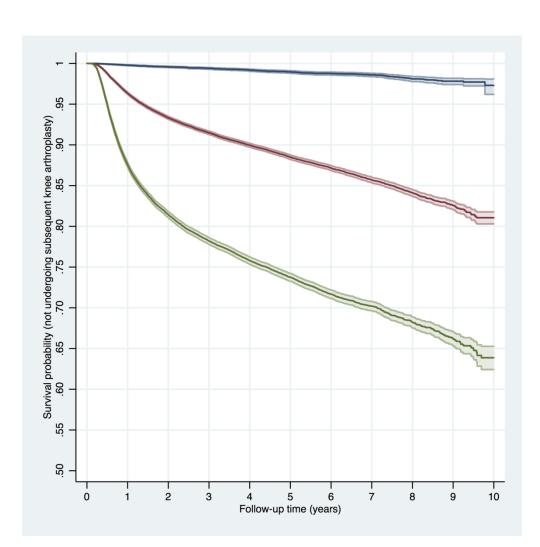
Figure 3: Survival curve (not undergoing knee arthroplasty) following chondroplasty by sex*

* Age groups < 20 years and 80+ years suppressed due to small numbers



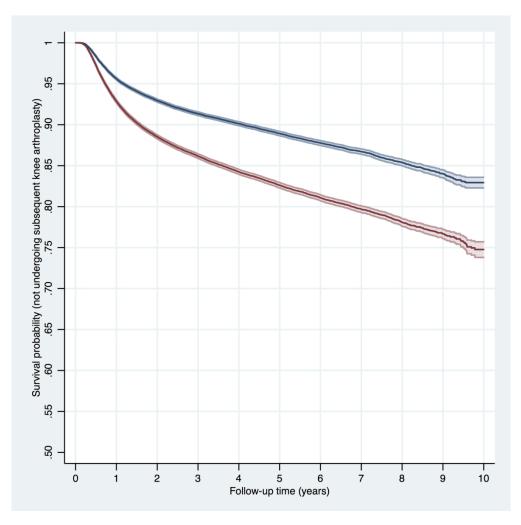


Flow chart illustrating extraction of patient level cohort



Survival curve (not undergoing knee arthroplasty) following chondroplasty by age





Survival curve (not undergoing knee arthroplasty) following chondroplasty by sex

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Appendix 1: OPCS procedure code list

7 of 28					BMJ Open <u>3</u> .
Appendix 1: OPCS proc	edure code li	st			BMJ Open BMJ
PROCEDURE	OPCS 4.4	OPCS 4.5	OPCS 4.6	OPCS 4.7	Description 0
Chondroplasty*	W83.3*	W83.3*	W83.3*	W83.3*	Endoscopic shaving of articular cartilage
Chondroplasty*	W83.4*	W83.4*	W83.4*	W83.4*	Endoscopic articular abrasion chondroplasty
Chondroplasty*	W83.5*	W83.5*	W83.5*	W83.5*	Endoscopic articular thermal chondroplasty
Chondroplasty*	W83.6*	W83.6*	W83.6*	W83.6*	Endoscopic excision of articular cartilage NEC
Chondroplasty*	W89.1*	W89.1*	W89.1*	W89.1*	Endoscopic excision of articular cartilage NEC > Endoscopic chondroplasty NEC =:
Microfracture*	W83.1*	W83.1*	W83.1*	W83.1*	Endoscopic drilling of lesion of articular cartilage
Microfracture*	W84.5*	W84.5*	W84.5*	W84.5*	Endoscopic drilling of epiphysis for repair of articular cartilage
Meniscal surgery	W82.2	W82.2	W82.2	W82.2	Endoscopic resection of semilunar cartilage NEC §
Meniscal surgery	W82.3	W82.3	W82.3	W82.3	Endoscopic repair of semilunar cartilage
Meniscal surgery	W82.1	W82.1	W82.1	W82.1	Endoscopic total excision of semilunar cartilage
Ligament reconstruction (exclusion)*	W74.2	W74.2	W74.2	W74.2	Reconstruction of intra-articular ligament NEC
Ligament reconstruction (exclusion)*	W84.1	W84.1	W84.1	W84.1	Endoscopic repair of intra-articular ligament
Ligament reconstruction (exclusion)*	W84.2	W84.2	W84.2	W84.2	Endoscopic reattachment of intra-articular ligament
Ligament reconstruction (exclusion)*	W72.3	W72.3	W72.3	W72.3	Primary prosthetic replacement of intra-articular lig
Ligament reconstruction (exclusion)*	W72.4	W72.4	W72.4	W72.4	Prosthetic replacement of intra-articular ligament NEC
Arthroplasty*	W43.1	W43.1	W43.1	W43.1	Primary total prosthetic replacement of joint using Rement NEC
Arthroplasty*	W44.1	W44.1	W44.1	W44.1	Primary total prosthetic replacement of joint not using cement NEC
Arthroplasty*	W44.8	W44.8	W44.8	W44.8	Other specified total prosthetic replacement of other
Arthroplasty*	W44.9	W44.9	W44.9	W44.9	Unspecified total prosthetic replacement of other joint not using cement
Arthroplasty*	W45.1	W45.1	W45.1	W45.1	Primary total prosthetic replacement of joint NEC
Arthroplasty*	W45.8	W45.8	W45.8	W45.8	Other specified other total prosthetic replacement of other joint
Arthroplasty*	W45.9	W45.9	W45.9	W45.9	Unspecified other total prosthetic replacement of other joint
Arthroplasty*	W53.8	W53.8	W53.8	W53.8	Other specified prosthetic replacement of articulation of other bone not using cement
Arthroplasty	W40.1	O18.1	O18.1	O18.1	Primary hybrid prosthetic replacement of knee joint Using cement
Arthroplasty	W40.8	O18.8	O18.8	O18.8	Other specified hybrid prosthetic replacement of knee joint using cement
Arthroplasty	W40.9	O18.9	O18.9	O18.9	Unspecified hybrid prosthetic replacement of knee joint using cement
Arthroplasty	W40.1	W40.1	W40.1	W40.1	Primary total prosthetic replacement of knee joint using cement
Arthroplasty	W40.8	W40.8	W40.8	W40.8	Other specified total prosthetic replacement of knee joint using cement

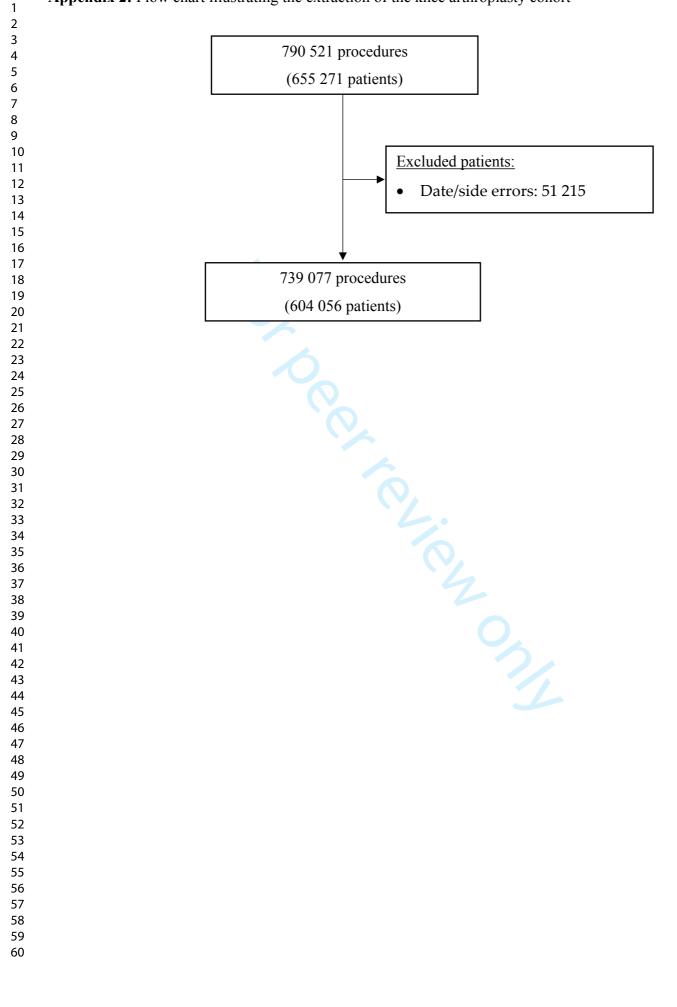
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					Φ
Arthroplasty	W40.9	W40.9	W40.9	W40.9	Unspecified total prosthetic replacement of knee joi $\vec{\mathfrak{gt}}$ using cement
Arthroplasty	W41.1	W41.1	W41.1	W41.1	Primary total prosthetic replacement of knee joint not using cement
Arthroplasty	W41.8	W41.8	W41.8	W41.8	Other specified total prosthetic replacement of kneegoint not using cement
Arthroplasty	W41.9	W41.9	W41.9	W41.9	Unspecified total prosthetic replacement of knee joi $\mathbf{\hat{g}}$ not using cement
Arthroplasty	W42.1	W42.1	W42.1	W42.1	Primary total prosthetic replacement of knee joint NEC
Arthroplasty	W42.8	W42.8	W42.8	W42.8	Other specified other total prosthetic replacement of knee joint
Arthroplasty	W42.9	W42.9	W42.9	W42.9	Unspecified other total prosthetic replacement of knee joint
Arthroplasty*	W58.1	W58.1	W58.1	W58.1	Primary resurfacing arthroplasty of joint

rquired (2846, 2765, 2845, 2844, 2777, 5727) *: Additional site-specific knee code required (Z846, Z765, Z845, Z844, Z774, or Z787)

Appendix 2: Flow chart illustrating the extraction of the knee arthroplasty cohort



Rates of knee arthroplasty in patients with a history of arthroscopic chondroplasty: results from a retrospective cohort study utilising the National Hospital Episode Statistics for England

Journal:	BMJ Open
Manuscript ID	bmjopen-2019-030609.R1
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review only

Rates of knee arthroplasty in patients with a history of arthroscopic chondroplasty: results from a retrospective cohort study utilising the National Hospital Episode Statistics for England

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Word count

ABSTRACT

OBJECTIVE

The purpose of this study was to analyse the rate of knee arthroplasty in the population of patients with a history of arthroscopic chondroplasty of the knee, in England, over ten years, with comparison to general population data for patients without a history of chondroplasty.

DESIGN

Retrospective cohort study

SETTING

English hospital episode statistics (HES) data

PARTICIPANTS AND INTERVENTIONS

Patients undergoing arthroscopic chondroplasty in England between 2007/08 and 2016/17 were identified.

Patients undergoing previous arthroscopic knee surgery or simultaneous cruciate ligament reconstruction or

microfracture in the same knee were excluded.

OUTCOMES

Patients subsequently undergoing a knee arthroplasty in the same knee were identified and mortalityadjusted survival analysis was performed (survival without undergoing knee arthroplasty). A Cox proportional hazards model was used to identify factors associated with knee arthroplasty. Relative risk of knee arthroplasty (total or partial) in comparison to the general population was determined.

RESULTS

Through 2007-17, 157,730 eligible chondroplasty patients were identified. Within one-year, 5.91% (7984/135197; 95% CI 5.78 to 6.03) underwent knee arthroplasty and 14.22% (8145/57267; 95% CI 13.94 to 14.51) within five-years. Patients aged over 30 years with a history of chondroplasty were 17.32 times (risk ratio; 95% CI 16.81 to 17.84) more likely to undergo arthroplasty than the general population without a history of chondroplasty.

CONCLUSIONS

Patients with cartilage lesions of the knee, treated with arthroscopic chondroplasty, are at greater risk of
subsequent knee arthroplasty than the general population and for a proportion of patients, there is
insufficient benefit to prevent the need for knee arthroplasty within one- to five-years. These important new
data will inform patients of the anticipated outcomes following this procedure. The risk in comparison to
non-operative treatment remains unknown and there is an urgent need for a randomised clinical trial in this
population.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- Strengths of the data source analysed in this study include comprehensive, national, data collection and the ability to match treatment with outcomes, including by the laterality of intervention, over time.
- This is the largest cohort of patients undergoing arthroscopic chondroplasty that has been reported, with strict inclusion criteria, excluding patients with a history of previous surgery to the same knee and those undergoing simultaneous ligament reconstruction or microfracture.
- All studies of this design rely on coding accuracy and some coding errors are inevitable; although outcomes were stratified by a range of patient factors, unmeasured potential confounders include body mass index, limb alignment, baseline radiographic status.
- Knee arthroplasty is an end-stage outcome and will underestimate the true burden and severity of symptomatic osteoarthritis in this population.

• The outcome had these patients not undergone arthroscopic chondroplasty remains unknown.

INTRODUCTION

Around 2 million knee arthroscopy procedures are performed worldwide each year.[1] Historically, knee washout and 'debridement' was shown to be ineffective for the treatment of advanced osteoarthritis.[2–4] For early osteoarthritis, however, a number of surgical and non-surgical treatments are available and treatment selection is challenging.[5] The aim of treatment in these cases is to improve symptoms and delay or prevent progressive osteoarthritis.[6]

Chondroplasty is a non-specific term that encompasses several techniques for the treatment of cartilage defects.[7] It includes debridement and abrasion using mechanical 'shavers' and, more recently, thermal or radiofrequency techniques have also emerged despite some concerns these techniques might risk inducing localised chondrocyte death.[7–11] Recent national guidance was cautiously supportive of radiofrequency chondroplasty for the treatment of "discrete chondral defects" based on a small number of clinical trials comparing the outcomes of mechanical and radiofrequency techniques.[12] It is not known which patients are most likely to benefit from chondroplasty procedures and when the procedure does not provide sustained benefit, knee arthroplasty is often indicated. The success rate of chondroplasty is, however, poorly understood and the proportion of patients undergoing subsequent knee arthroplasty after this intervention has been unknown.

The purpose of this study was to determine the proportion of patients undergoing knee chondroplasty procedures that subsequently receive a knee arthroplasty in the same knee, with specific focus on the proportion of patients undergoing early arthroplasty with one-year or two-years of chondroplasty. Factors associated with the risk of subsequent arthroplasty are reported and the relative risk in comparison to the general population determined.

METHODS

Data source

National Hospital Episode Statistics (HES) data was obtained (application DARS-NIC-68703). HES contains a record of all patient attendances at National Health Service (NHS) hospitals in England.[13] The data is submitted by hospitals to claim payment for the services they provide and is also intended for secondary use, including research. HES includes episodes of care delivered in treatment centres (including those in the independent sector) funded by the NHS, episodes of care in England where patients are resident outside of England, and privately funded patients treated within NHS England hospitals. The information recorded in the HES database includes patient demographic and residence data, primary and secondary diagnoses including comorbidities, and all procedures undertaken.

Procedures

All HES records between 1 April 2007 and 31 March 2017 were extracted for patients undergoing arthroscopic chondroplasty. Patients undergoing previous arthroscopic knee surgery or simultaneous cruciate ligament reconstruction or microfracture in the same knee were excluded. Procedures were identified using the Classification of Surgical Operations and Procedures (OPCS-4) codes recorded within the HES data (see appendix 1 for OPCS-4 code list).[14] All knee arthroplasty (partial or total) procedures were also identified (appendix 2) for the whole population to enable the relative risk of knee arthroplasty with and without a history of chondroplasty to be determined.

Outcomes

The primary outcome was knee arthroplasty, matched to the side of any previous chondroplasty (using recorded OPCS-4 laterality codes).

Statistical analysis

Stata v15.1 (StataCorp, College Station, Texas, USA) was used to perform all analysis. In accordance with Office for National Statistics (ONS) and NHS Digital guidance, rates where the number of events was less than six were suppressed.[15] Procedures with date errors or missing laterality were excluded. The absolute rate of knee arthroplasty was determined at 1 year, 2 years, 5 years, and 8 years following arthroscopic chondroplasty as the proportion of the cohort with this minimum period of follow-up. Mortality adjusted Kaplan-Meier survival analysis (survival was defined as not undergoing knee arthroplasty) was also performed and stratified by patient age group and sex.

A Cox proportional-hazards model was used first to calculate the unadjusted hazard ratio of knee arthroplasty over time by age group, sex, index of multiple deprivation (quintile derived from regional factors in England including average income, employment, education, housing, and crime; 1=least deprived

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area, 5=most deprived), ethnicity, modified Charlson comorbidity index (derived with maximum 5-year diagnosis code lookback period),[16–18] year of treatment (chondroplasty), rurality, and ethnicity respectively.[16–19] The hazard ratios were then adjusted including all these variables in the model.

The relative risk (risk ratio) of knee arthroplasty in the population of patients with a history of chondroplasty in comparison to the general population (without a history of chondroplasty) was estimated for the year 2016-17. All patients undergoing knee arthroplasty in 2016-17 were identified and the number of these patients with a recorded previous chondroplasty (in the prior 10-years of HES data), versus those without, made up the numerator for each respective population. The chondroplasty population denominator was the number of patients with a history of chondroplasty that had not undergone a knee arthroplasty prior to 2016-17. The denominator for the non-chondroplasty population was the ONS mid-year population estimate less the chondroplasty population.

Patient and public involvement

There was no patient and public involvement in this study.

RESULTS

Over the study period, 157,730 chondroplasty patients were identified as eligible for analysis (Figure 1). The mean age of the chondroplasty cohort was 51.7 year (SD 13.8) and 48.1% were female (Table 1). Over the same period, 604,056 patients underwent knee arthroplasty, of which 35,916 (5.95%) had a record of a previous chondroplasty (Table 1).

Overall, following chondroplasty, 5.91% (7984/135197; 95% confidence interval [CI] 5.78 to 6.03) patients underwent knee arthroplasty within 1 year, 9.41% (10787/114592; 95% CI 9.24 to 9.58) within 2 years, 14.22% (8145/57267; 95% CI 13.94 to 14.51) within 5 years, and 17.61% (2879/16347; 95% CI 17.03 to 18.20) within 8 years (Table 2). The risk of arthroplasty was greater in female patients (adjusted hazard ratio [HR] 1.38; 95% CI 1.34 to 1.42) and in older patients (adjusted HR 1.33 per five years; 95% CI 1.32 to 1.34) (Table 3, Figure 2; Figure 3). Patients with a greater comorbidity index were also at increased risk of subsequently undergoing arthroplasty (adjusted HR 1.03 per five units Charlson index; 95% CI 1.01 to 1.05).

The risk of knee arthroplasty after chondroplasty fell slightly over time, by year of chondroplasty treatment (adjusted HR 0.95 per five years; 95% CI 0.92 to 0.98). Patients in regions of increased deprivation and patients of white ethnicity were at greater risk of subsequent arthroplasty (Table 2). Patients undergoing concurrent meniscal surgery were also at greater risk of subsequent arthroplasty (adjusted HR 1.09; 95% CI 1.06 to 1.13).

In 2016-17, the rate of knee arthroplasty was 3.49% (95% CI 3.39 to 3.60) in patients (aged 30 or older) with a recorded history of chondroplasty and 0.20% (95% CI 0.19 to 0.20) in patients without a record of chondroplasty. This corresponded to an overall relative risk of knee arthroplasty for the chondroplasty cohort patients of 17.32 times (risk ratio [RR]; 95% CI 16.81 to 17.84) that of the general population (Table 4).

Although the absolute annual rate of knee arthroplasty was low, the relative risk of undergoing knee arthroplasty at a younger age was greatly elevated in comparison to arthroplasty at an older age, as shown in Table 4. Patients aged 30-39 with a history of a previous chondroplasty were 170.92 times (RR; 95% CI 116.72 to 250.30) more likely to undergo knee arthroplasty than the general population, per year, in comparison to 11.09 times (RR; 95% CI 10.42 to 11.80) more likely for the over 69 age group.

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DISCUSSION

Principal findings

Patients undergoing chondroplasty procedures of the knee have a 17 times increased risk of receiving a knee arthroplasty compared with the general population. Nearly 10% of patients will have received a knee arthroplasty within two years of the chondroplasty procedure. The relative risk of undergoing arthroplasty at a young age is particularly elevated, reaching 171 times the general population rate for arthroplasty between the ages of 30 and 39 years of age. For a proportion of patients, the results indicate insufficient benefit to prevent the need for knee arthroplasty within one or two years, but the risk had these patients not undergone chondroplasty remains unknown.

Comparison to other studies

We previously reported trends in chondroplasty surgery in England, but data from other countries is not available.[20] The age-sex standardised rate of chondroplasty increased 191% from 17.6/100,000 (95% CI 17.2 to 18.0) in 2007/08 to 51.2/100,000 (95% CI 50.6 to 51.7) in 2016/17.[20] The rate of chondroplasty was greatest in patients aged 40-59 years (increasing 210% from 34.3/100,000 in 2007/08 to 106.4/100,000 in 2016/17.[20]

In England, although national guidance has been cautiously supportive of radiofrequency chondroplasty for specific indications, there is only limited evidence demonstrating the effectiveness of chondroplasty compared with alternative surgical or non-surgical treatments.[12] The only randomised studies have been limited to comparisons of different chondroplasty techniques.[10,12] Long-term outcomes following chondroplasty have yet to be reported.[12]

Older patients are much more likely to have generalised osteoarthritis, rather than "discrete chondral defects" for which the national guidance supports radiofrequency chondroplasty.[12,21] For more generalised osteoarthritis, chondroplasty is analogous to debridement and washout, where multiple clinical trials demonstrate no benefit.[2–4] The use of chondroplasty in the treatment of patients with more generalised chondral pathology is therefore unproven and not recommended.[22] In our study, there was considerable age-group variation in outcomes, with 18.8% of patients aged 60-79-years undergoing arthroplasty within two-years of chondroplasty, in comparison to 0.43% for patients undergoing chondroplasty aged 20-39-years. This observation is consistent with the presence of more established osteoarthritis in older age groups.

Our study represents a high-risk cohort of patients with cartilage damage. It is unknown from this observational data whether undergoing the chondroplasty procedure was beneficial to the symptoms or prognosis of these individuals over the full study period. Patients undergoing arthroplasty within 1-year of

their arthroscopic chondroplasty, however, suggests sub-optimal treatment selection. These individuals are highly unlikely to have had only localised or partial thickness lesions and our results may indicate that knee arthroplasty may have been a more appropriate treatment. It is unlikely that chondroplasty in these patients was a cost-effective choice of intervention, but whether chondroplasty can be cost-effective with optimal patient selection is unknown and requires evaluation in a high-quality randomised controlled trial.

Female patients were observed to be of greater risk of subsequent arthroplasty in our study. This has previously been observed following knee arthroscopy in the United States.[23] Patients of white ethnicity and greater deprivation were also at greater risk in our cohort. These findings may reflect differences in healthcare access including treatment thresholds for either the chondroplasty or knee arthroplasty, or differences in care seeking behaviour which has been shown to be influenced by socioeconomic, cultural, occupational, and psychological factors, or there could be biological factors underlying the observation.[24– 26] Patients with a greater comorbidity index were more likely to undergo subsequent arthroplasty, and the reason for this is unclear. One possible explanation might be an association between comorbidity and higher body mass index (BMI), which is not recorded in this dataset, with patients having a greater BMI being more likely to progress to end-stage osteoarthritis, or that these patients had more severe pathology at the time of their index chondroplasty.[27] Patients undergoing concurrent meniscal surgery were also more likely to undergo subsequent arthroplasty, which is expected given the association between meniscal injury, osteoarthritis, and knee arthroplasty.[28]

Recently, there has been renewed focus on the importance of and requirements for individualised patient consent.[29] Our findings make an important contribution to the current evidence, and patients can now be appropriately counselled and consented with knowledge of anticipated long-term outcomes.

Strength and limitations

A key strength of our study is the identification of all knee chondroplasty procedures performed in the National Health Service over a 10-year period, creating the largest reported cohort of patients receiving this procedure. Patients with a history of prior arthroscopy in the same knee, simultaneous ligament reconstruction or microfracture were excluded as potential confounding factors. It should still be noted that patients undergoing non-NHS treatment, for example knee arthroplasty in the private sector after a previous knee arthroscopy under NHS care, would not be captured in this dataset and the number of these procedures performed in the private sector is currently unknown. National data does indicate, however, that private healthcare expenditure as a proportion of total healthcare expenditure has remained relatively stable at around 17-18% of total health expenditure between 2005 and 2015.[30] For all observational studies utilising large datasets there may be some concerns raised about coding accuracy. The data in our study was cleaned prior to analysis, excluding patients where procedures were missing the side of intervention, and cases where date coding errors were identified. Although some other data coding errors are inevitable, data

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errors in procedure coding would result in hospitals not receiving payment for surgery performed, and this provides a strong incentive for data accuracy with regards to the coding data analysed in this study.

We were able to stratify risk of arthroplasty by a large number of patient factors, but certain procedure specific data is not recorded. Operative factors, such as the affected compartment of the knee and extent of initial cartilage damage before intervention, are not recorded in this database. These factors may be important in determining outcome, for example, there are likely to be differences in long-term outcomes between chondroplasty performed to the tibiofemoral joint in comparison to the patellofemoral joint.[31] Other unmeasured sources of potential confounding include BMI, leg alignment, and radiographic status at the time of intervention. These are important considerations when considering if a patient is suitable for chondral surgery intervention, but the specific impact of these factors on long-term outcomes in this population remains uncertain. Subjective, patient-reported, symptomatic outcome data is not yet available for this cohort and radiographic outcomes are not recorded in the HES database. Instead, our study focussed on the objective, measurable outcome of knee arthroplasty, matched to the same knee as the previous chondroplasty surgery intervention. Although knee arthroplasty represents the end-stage of symptomatic failure for patients with osteoarthritis, it is likely to considerably underestimate the overall health and symptom burden in this cohort. Patients, particularly younger patients, may not have been willing or suitable candidates for knee arthroplasty, and the threshold for arthroplasty may have been much higher for younger age groups or older patients with multiple comorbidities.

The outcome had patients in our study not undergone chondroplasty remains unknown and an answer to this question requires a randomised controlled trial with a non-operative treatment arm. It is important to note that, in general, chondroplasty is a non-specific term that encompasses several techniques for the debridement of cartilage defects.[7] The findings in this paper cannot be generalised to other types of arthroscopic and joint preservation surgery, cartilage repair and regeneration techniques, such as microfracture and autologous chondrocyte implantation.[6,31]

Our study reports the long-term outcomes following chondroplasty in a high-risk cohort of patients with cartilage damage for the first time. Our findings our stratified by a range of patient specific factors and will be important for informed consent and shared decision making between patients and clinicians. Further work is required to optimise treatment selection, however, and additional patient information may allow more accurate prediction of outcome and guide clinical management.

Conclusion

The risk of knee arthroplasty is 17 times greater in patients with a history of knee chondroplasty and in a proportion of patients, there is insufficient benefit to prevent the need for knee arthroplasty within one or two years. These important new data help inform patients and clinicians of the long-term outcomes

following this procedure, at the population level, for the first time. Enhanced clinical guidance on the appropriate indications for chondroplasty are required and there is a need for high-quality randomised studies to determine the relative clinical and cost effectiveness of this intervention in comparison to alternative, including non-surgical, treatments.

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Data availability

No additional data available.

3 **Details of contributors** 4

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14 **Transparency declaration** 15

The lead author (SA) affirms that the manuscript is an honest, accurate, and transparent account of the study 16 17 being reported; that no important aspects of the study have been omitted; and that any discrepancies from 18 19 the study as planned (and registered) have been explained. 20

Competing interests 21 22

Andrew Judge has received consultancy fees from Freshfields Bruckhaus Deringer (on behalf of Smith & Nephew Orthopaedics Limited), and is a member of the Data Safety and Monitoring Board (which involved 26 receipt of fees) from Anthera Pharmaceuticals, Inc. All other authors declare no financial relationships with any organisations that might have an interest in the submitted work in the previous three years, no other 28 relationships or activities that could appear to have influenced the submitted work. 30

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Ethical approval

Not required.

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5 6		https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/healthcaresystem/bullet
7		ins/ukhealthaccounts/2016 (accessed 5 Jun 2018).
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10 11 12 13		Implantation for Articular Cartilage Lesions in the Knee: A Systematic Review of 5-Year Outcomes.
		Am J Sports Med 2017;:036354651770191. doi:10.1177/0363546517701912
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TABLES

TABLE 1: Demographics and descriptive statistics of cohort

	Chondr	oplasty Cohort	Knee Arthroplasty Cohort					
	A	III Cases	No Previous	Chondroplasty	Previous Chondroplasty			
	n	%	n	%	n	%		
Total	157730	100.00	568,140	94.05	35,916	5.95		
Sex								
Male	81884	51.91	244,684	43.07	15,512	43.19		
Female	75846	48.09	323,456	56.93	20,404	56.81		
Age group								
(years)								
<20	2868	1.82	1,179	0.21	1	< 0.01		
20-39	24648	15.63	1,568	0.28	353	0.98		
40-59	83258	52.79	85,797	15.1	14,023	39.04		
60-79	45191	28.65	400,541	70.5	20,361	56.69		
80+	1765	1.12	79,055	13.91	1,178	3.28		
Charlson								
comorbidity								
index								
0	121605	77.10	534,399	94.06	27,331	76.1		
1 - 15	34719	22.01	31,683	5.58	8,175	22.76		
16 - 30	1296	0.82	1,879 0.33		393	1.09		
31 - 50	110	0.07	179	0.03	17	0.05		
Index of multiple								
deprivation								
(quintiles)								
1 = least deprived	36043	23.21	121,813	21.44	7,921	22.05		
2	35189	22.66	127,672	22.47	7,938	22.1		
3	32493	20.92	123,160	21.68	7,806	21.73		
4	27312	17.59	103,236	18.17	6,372	17.74		
5 = most deprived	24266	15.62	85,283	15.01	5,416	15.08		
Missing	2427		6,976		463			
Rurality								
Urban	119766	76.42	423,895	74.61	27,157	75.61		
Rural	36953	23.58	141,271	24.87	8,634	24.04		
Missing	1011		2,974		125			
Ethnicity								
White	141928	94.43	525,934	92.57	34,349	95.64		
Mixed	953	0.63	1,844	0.32	115	0.32		
Asian	4511	3.00	19,203	3.38	804	2.24		
Black	2122	1.41	5,840	1.03	193	0.54		
Other	792	0.53	1,367	0.24	68	0.19		
Missing	7424		13,952		387			
Concurrent								
procedures								
None	65987	41.84	-	-	-	-		
Meniscal	91743	58.16	-	-	-	-		

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Table 2: Cohort demographics and adjusted odds of arthroplasty

of 28						ВМЈ Ор	en		,/bmj			
able 2: (Cohort de	mograp	ohics and adjusted of	lds of art	hroplast	y			6/bmjopen-2019-030609 % (95% CI)			
	1 year ou	1-year outcome* 2-year outcome* 5-year outcome*							9-03	8-year o	utcomo*	
	n	n	% (95% CI)	n 2-year ou	n TKA	% (95% CI)	n n	n TKA	% (95% CI)	n	n TKA	% (95% CI)
		TKA										,
Fotal	135,197	7984	5.91% (5.78, 6.03)	114,592	10787	9.41% (9.24, 9.58)	57,267	8145	14.22% (13.94, 14.51)	16,347	2879	17.61% (17.03, 18.2
Sex									₽			
Male	69,787	3160	4.53% (4.37, 4.68)	59,101	4261	7.21% (7.00, 7.42)	29,688	3315	11.17% (10.81, 11.5)	8,514	1208	14.19% (13.45, 14.9
Female	65,410	4824	7.38% (7.18, 7.58)	55,491	6526	11.76% (11.49, 12.03)	27,579	4830	17.51% (17.07, 17.9)	7,833	1671	21.33% (20.43, 22.2
Sex	,		,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,						<u>.</u>	.,		
< 20	-	-	-	-	-	-	-	-	- 2	-	-	-
20 - 39	21,548	48	0.22% (0.16, 0.30)	18,583	79	0.43% (0.34, 0.53)	10,004	95	0.95% (0.77, 1.16)	3,094	53	1.71% (1.29, 2.23)
40 - 59	72,345	2654	3.67% (3.53, 3.81)	60,974	4049	6.64% (6.44, 6.84)	29,844	3327	11.15% (10.79, 11.5 g)	8,552	1287	15.05% (14.30, 15.
50 - 79	39,741	4994	12.57% (12.24, 12.90)	33,680	6343	18.83% (18.42, 19.25)	16,716	4522	27.05% (26.38, 27.7)	4,508	1479	32.81% (31.44, 34.
$\frac{30}{30}$ +	1,563	288	18.43% (16.53, 20.44)	1,355	316	23.32% (21.09, 25.67)	703	201	28.59% (25.28, 32.0 2)	193	60	31.09% (24.64, 38.
	comorbidity		10.1570 (10.55, 20.11)	1,000	1010		100	-01	<u> 10:00000000000000000000000000000000000</u>	170	00	
)	104,530	5369	5.14% (5.00, 5.27)	89,081	7366	8.27% (8.09, 8.45)	45,505	5837	12.83% (12.52, 13.14)	13,362	2148	16.08% (15.46, 16.
1 - 15	29,475	2467	8.37% (8.06, 8.69)	24,540	3228	13.15% (12.73, 13.58)	11,371	2207	19.41% (18.69, 20.5)	2,884	701	24.31% (22.75, 25.
16 - 30	1,102	138	12.52% (10.63, 14.62)	898	180	20.04% (17.47, 22.82)	391	101	25.83% (21.56, 30.42)	101	30	29.70% (21.02, 39.
31 - 50	90	10	11.11% (5.46, 19.49)	73	13	17.81% (9.84, 28.53)	-	-	- 3	-	-	-
	ultiple depr			,,,	10	1110170 (2101, 20102)	I			1		
1	31,054	1846	5.94% (5.68, 6.21)	26,546	2405	9.06% (8.72, 9.41)	13,422	1835	13.67% (13.09, 14.2)	3,878	629	16.22% (15.07, 17.
2	30,218	1799	5.95% (5.69, 6.23)	25,638	2409	9.40% (9.04, 9.76)	12,819	1779	13.88% (13.28, 14.49)	3,474	617	17.76% (16.50, 19.
3	27,974	1737	6.21% (5.93, 6.50)	23,721	2324	9.80% (9.42, 10.18)	11,833	1772	14.98% (14.34, 15.65)	3,374	635	18.82% (17.51, 20.
4	23,312	1387	5.95% (5.65, 6.26)	19,702	1913	9.71% (9.30, 10.13)	9,771	1420	14.53% (13.84, 15.23)	2,762	496	17.96% (16.54, 19.
5	20,591	1104	5.36% (5.06, 5.68)	17,194	1588	9.24% (8.81, 9.68)	8,420	1197	14.22% (13.48, 14.98)	2,451	444	18.12% (16.61, 19.
Rurality	20,071	110.	0.0070 (0.000, 0.000)	17,1271	1000	(0.01,).00)	0,120	11.27	<u> </u>	2,.01	1	10.12/0 (10.01, 1).
Urban	102,665	6004	5.85% (5.71, 5.99)	86,807	8135	9.37% (9.18, 9.57)	43,287	6148	14.20% (13.88, 14.3)	2,154	12,242	17.60% (16.92, 18.
Rural	31,760	1944	6.12% (5.86, 6.39)	27,127	2613	9.63% (9.28, 9.99)	13,739	1980	14.41% (13.83, 15.0 1)	713	3,987	17.88% (16.70, 19.
Ethnicity	01,700	1711	0.12/0 (0.000, 0.000)	_,,,_,	2010	, , , , , , , , , , , , , , , , , , , ,	10,707	1,00		, 10	5,507	11.0070 (10.70, 17.
White	122,261	7672	6.28% (6.14, 6.41)	103,979	10366	9.97% (9.79, 10.15)	52,267	7834	14.99% (14.68, 15.39)	14,908	2,750	18.45% (17.83, 19.
Mixed	750	21	2.80% (1.74, 4.25)	609	32	5.25% (3.62, 7.34)	278	22	7.91% (5.03, 11.74)	76	8	10.53% (4.66, 19.6
Asian	3,722	130	3.49% (2.93, 4.13)	3,088	186	6.02% (5.21, 6.92)	1,465	167	11.40% (9.82, 13.14)	362	75	20.72% (16.66, 25.
Black	1,770	27	1.53% (1.01, 2.21)	1,466	53	3.62% (2.72, 4.70)	677	38	5.61% (4.00, 7.62) g	171	15	8.77% (4.99, 14.06
Other	645	15	2.33% (1.31, 3.81)	518	18	3.47% (2.07, 5.44)	250	21	8.40% (5.27, 12.55)	75	9	12.00% (5.64, 21.5
	t procedure				1.5				<u> </u>			
None	57,208	2686	4.70% (4.52, 4.87)	50,256	3754	7.47% (7.24, 7.70)	28,578	3252	11.38% (11.01, 11.75)	9,370	1,389	14.82% (14.11, 15.
Meniscal	77,989	5298	6.79% (6.62, 6.97)	64,336	7033	10.93% (10.69, 11.18)	28.689	4893	17.06% (16.62, 17.56)	6,977	1,490	21.36% (20.40, 22.3

* = excluding those patients where the date of their procedure was less than this number of years from the end of the observation period in the dataset; - $\frac{d}{\sqrt{2}}$ uppressed due to small numbers; CI = confidence interval; TKA = total or partial knee arthroplasty

HR

1.00

1.38

1.33

0.95

1.03

1.00

1.07

1.17

1.20

1.29

1.00

0.99

1.00

0.66

0.73

0.44

0.45

1.00

1.09

Adjusted Risk Subsequent TKA

95% CI

1.00

1.34, 1.42

1.32, 1.34

0.92, 0.98

1.01, 1.05

1.03, 1.12

1.12, 1.22

1.15, 1.26

1.23, 1.36

0.95, 1.02

0.51, 0.86

0.66, 0.81

0.36, 0.54

0.32, 0.64

1.06, 1.13

<20 years suppressed due to small numbers; HR = hazard ratio; CI = confidence

1.00

1.00

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1.00

Table 3: Unadjusted and adjusted* risk of knee arthroplasty following arthroscopic chondroplasty

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	Unad	justed Risk Subsequ
	HR	95% CI
Sex		
Male	1.00	1.00
Female	1.61	1.57, 1.66
Age (per five years	s) ‡	·
Per year	1.35	1.35, 1.36
Year of treatment	(per five year	s)
Year	0.99	0.96, 1.03
Charlson comorbi	dity index (pe	r five units)
Charlson index	1.29	1.27, 1.31
Index of multiple of	leprivation (q	uintile)
1 = least	1.00	1.00
2	1.03	0.99, 1.08
3	1.08	1.04, 1.13
4	1.03	0.99, 1.08
5 = most	1.01	0.96, 1.06
Rurality		
Urban	1.00	1.00
Rural	1.03	1.00, 1.07
Ethnicity		
White	1.00	1.00
Mixed	0.50	0.38, 0.65
Asian	0.65	0.59, 0.72
Black	0.35	0.28, 0.42
Other	0.34	0.24, 0.48
Concurrent procee	lures	I
None	1.00	1.00
Meniscal surgery	1.52	1.48, 1.57

BMJ Open

Table 4: Rates and relative risk of undergoing TKA with previous chondroplasty by age at TKA in 2016-17

Age at TKA (years)Annu TKA $30 - 39$ 274.48 (0.279 $40 - 49$ 1454.0 (1.459) $40 - 49$ 1454.0 (1.459) $50 - 59$ 3626.0 (3.639) $60 - 69$ 5179.1 (5.189) $70 +$ 6090.2 (6.099)Overall3494.0 (3.499) $(30 +)$ (3.499)	100k 19 5) (0. 2 13 5) (1. 2 34 5) (3. 7 49 5) (4. 0 57 5) (5. 1 33 5) (3.	5% CI 00.16, 383.35 0.19%, 0.38%) 318.04, 1600.06 .32%, 1.60%) 448.20, 3811.60 .45%, 3.81%) 033.67, 5433.20 .93%, 5.43%) 721.53, 6475.82 .72%, 6.48%) 394.82, 3596.52 .39%, 3.60%) asty; RR = risk p	Annual Rate TKA /100k 1.60 (0.00%) 19.79 (0.02%) 130.68 (0.13%) 386.68 (0.39%) 520.46 (0.52%) 195.38 (0.20%)	95% CI 1.32, 1.92 (0.00%, 0.00%) 18.79, 20.82 (0.02%, 0.02%) 128.05, 133.35 (0.13%, 0.13%) 381.64, 391.77 (0.38%, 0.39%) 514.89, 526.07 (0.51%, 0.53%) 193.90, 196.87 (0.19%, 0.20%)	RR 170.92 72.45 26.82 12.78 11.09 17.32	95% CI 116.72, 250.30 65.00, 80.76 25.41, 28.30 12.16, 13.44 10.42, 11.80 16.81, 17.84
$\begin{array}{c} 274.43\\ (0.279\\ 40 - 49\\ (1.459\\ 50 - 59\\ \hline 60 - 69\\ \hline 70 +\\ \hline 6090.3\\ (3.639\\ \hline 70 +\\ \hline 6090.3\\ (5.189\\ \hline 70 +\\ \hline 6090.3\\ (3.499\\ \hline 0 \ verall\\ \hline 3494.6\\ (3.499\\ \hline \end{array}$	100k 19 5) (0. 2 13 5) (1. 2 34 5) (3. 7 49 5) (4. 0 57 5) (5. 1 33 5) (3.	00.16, 383.35 0.19%, 0.38%) 318.04, 1600.06 .32%, 1.60%) 148.20, 3811.60 .45%, 3.81%) 033.67, 5433.20 .93%, 5.43%) 721.53, 6475.82 .72%, 6.48%) 394.82, 3596.52 .39%, 3.60%)	1.60 (0.00%) 19.79 (0.02%) 130.68 (0.13%) 386.68 (0.39%) 520.46 (0.52%) 195.38 (0.20%)	1.32, 1.92 (0.00%, 0.00%) 18.79, 20.82 (0.02%, 0.02%) 128.05, 133.35 (0.13%, 0.13%) 381.64, 391.77 (0.38%, 0.39%) 514.89, 526.07 (0.51%, 0.53%) 193.90, 196.87 (0.19%, 0.20%)	170.92 72.45 26.82 12.78 11.09	116.72, 250.34 65.00, 80.76 25.41, 28.30 12.16, 13.44 10.42, 11.80
$\begin{array}{c} 30 - 39 \\ (0.27) \\ 40 - 49 \\ (1.45) \\ 50 - 59 \\ (3.63) \\ 60 - 69 \\ (5.18) \\ 70 + \\ (6.09) \\ 0 \\ 0 \\ (30 +) \\ (3.49) \end{array}$	5) (0. 2 13 5) (1. 2 34 5) (3. 7 49 5) (4. 0 57 5) (5. 1 33 5) (3.	0.19%, 0.38%) 318.04, 1600.06 .32%, 1.60%) 448.20, 3811.60 .45%, 3.81%) 933.67, 5433.20 .93%, 5.43%) 721.53, 6475.82 .72%, 6.48%) 394.82, 3596.52 .39%, 3.60%)	(0.00%) 19.79 (0.02%) 130.68 (0.13%) 386.68 (0.39%) 520.46 (0.52%) 195.38 (0.20%)	(0.00%, 0.00%) 18.79, 20.82 (0.02%, 0.02%) 128.05, 133.35 (0.13%, 0.13%) 381.64, 391.77 (0.38%, 0.39%) 514.89, 526.07 (0.51%, 0.53%) 193.90, 196.87 (0.19%, 0.20%)	72.45 26.82 12.78 11.09	65.00, 80.76 25.41, 28.30 12.16, 13.44 10.42, 11.80
(0.279) $40 - 49$ (1.459) (1.459) (3.639) (3.639) (5.189) $70 +$ (6.099) (5.189) $70 +$ (6.099) (3.499)	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	318.04, 1600.06 .32%, 1.60%) 148.20, 3811.60 .45%, 3.81%) 933.67, 5433.20 .93%, 5.43%) 721.53, 6475.82 .72%, 6.48%) 394.82, 3596.52 .39%, 3.60%)	19.79 (0.02%) 130.68 (0.13%) 386.68 (0.39%) 520.46 (0.52%) 195.38 (0.20%)	18.79, 20.82 (0.02%, 0.02%) 128.05, 133.35 (0.13%, 0.13%) 381.64, 391.77 (0.38%, 0.39%) 514.89, 526.07 (0.51%, 0.53%) 193.90, 196.87 (0.19%, 0.20%)	72.45 26.82 12.78 11.09	65.00, 80.76 25.41, 28.30 12.16, 13.44 10.42, 11.80
$\begin{array}{c} 40 - 49 \\ (1.45) \\ 50 - 59 \\ (3.63) \\ \hline \\ 60 - 69 \\ (5.18) \\ \hline \\ 70 + \\ \hline \\ (6.09) \\ \hline \\ Overall \\ (30 +) \\ \end{array}$	5) (1. 2 34 5) (3. 7 49 5) (4. 0 57 5) (5. 1 33 5) (3.	.32%, 1.60%) 448.20, 3811.60 .45%, 3.81%) 933.67, 5433.20 .93%, 5.43%) 721.53, 6475.82 .72%, 6.48%) 394.82, 3596.52 .39%, 3.60%)	(0.02%) 130.68 (0.13%) 386.68 (0.39%) 520.46 (0.52%) 195.38 (0.20%)	(0.02%, 0.02%) 128.05, 133.35 (0.13%, 0.13%) 381.64, 391.77 (0.38%, 0.39%) 514.89, 526.07 (0.51%, 0.53%) 193.90, 196.87 (0.19%, 0.20%)	26.82 12.78 11.09	25.41, 28.30 12.16, 13.44 10.42, 11.80
(1.459) $50 - 59$ (3.639) $60 - 69$ (5.189) $70 +$ (6.099) $Overall$ $(30 +)$ (3.499)	2 34 5) (3. 7 49 5) (4. 0 57 5) (5. 1 33 5) (3.	448.20, 3811.60 .45%, 3.81%) 933.67, 5433.20 .93%, 5.43%) 721.53, 6475.82 .72%, 6.48%) 394.82, 3596.52 .39%, 3.60%)	130.68 (0.13%) 386.68 (0.39%) 520.46 (0.52%) 195.38 (0.20%)	128.05, 133.35 (0.13%, 0.13%) 381.64, 391.77 (0.38%, 0.39%) 514.89, 526.07 (0.51%, 0.53%) 193.90, 196.87 (0.19%, 0.20%)	26.82 12.78 11.09	25.41, 28.30 12.16, 13.44 10.42, 11.80
$50 - 59 \qquad (3.63)$ $60 - 69 \qquad (5.18)$ $70 + \qquad (6.09)$ $Overall \qquad 3494.0$ $(30 +) \qquad (3.49)$	5) (3. 7 49 6) (4. 0 57 6) (5. 1 33 5) (3.	.45%, 3.81%) 933.67, 5433.20 .93%, 5.43%) 721.53, 6475.82 .72%, 6.48%) 394.82, 3596.52 .39%, 3.60%)	(0.13%) 386.68 (0.39%) 520.46 (0.52%) 195.38 (0.20%)	(0.13%, 0.13%) 381.64, 391.77 (0.38%, 0.39%) 514.89, 526.07 (0.51%, 0.53%) 193.90, 196.87 (0.19%, 0.20%)	12.78	12.16, 13.44
$\begin{array}{c} (3.63)\\ \hline 60 - 69 \\ \hline (5.18)\\ \hline 70 + \\ \hline (6.09)\\ \hline Overall \\ (30 +) \\ \hline (3.49)\\ \hline \end{array}$	7 49 5) (4 0 57 5) (5 1 33 5) (3	033.67, 5433.20 93%, 5.43%) 721.53, 6475.82 72%, 6.48%) 394.82, 3596.52 39%, 3.60%)	386.68 (0.39%) 520.46 (0.52%) 195.38 (0.20%)	381.64, 391.77 (0.38%, 0.39%) 514.89, 526.07 (0.51%, 0.53%) 193.90, 196.87 (0.19%, 0.20%)	12.78	12.16, 13.44
$ \begin{array}{c} 60 - 69 \\ \hline 70 + \\ \hline (6.099) \\ \hline (3.499) \\ \hline (3.499) \end{array} $	5) (4. 0 57 5) (5. 1 33 5) (3.	.93%, 5.43%) 721.53, 6475.82 .72%, 6.48%) 394.82, 3596.52 .39%, 3.60%)	(0.39%) 520.46 (0.52%) 195.38 (0.20%)	(0.38%, 0.39%) 514.89, 526.07 (0.51%, 0.53%) 193.90, 196.87 (0.19%, 0.20%)	11.09	10.42, 11.80
$\begin{array}{c} (5.189) \\ \hline 70 + \\ (6.099) \\ \hline 0 \\ 0 \\ (30 +) \\ \end{array}$	0 57 5) (5) 1 33 5) (3)	721.53, 6475.82 .72%, 6.48%) 394.82, 3596.52 .39%, 3.60%)	520.46 (0.52%) 195.38 (0.20%)	514.89, 526.07 (0.51%, 0.53%) 193.90, 196.87 (0.19%, 0.20%)	11.09	10.42, 11.80
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(30+) (3.49%	b) (3.		(0.20%)	(0.19%, 0.20%)	17.32	16.81, 17.84
	· .				17.32	16.81, 17.84
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			rano			

FIGURES

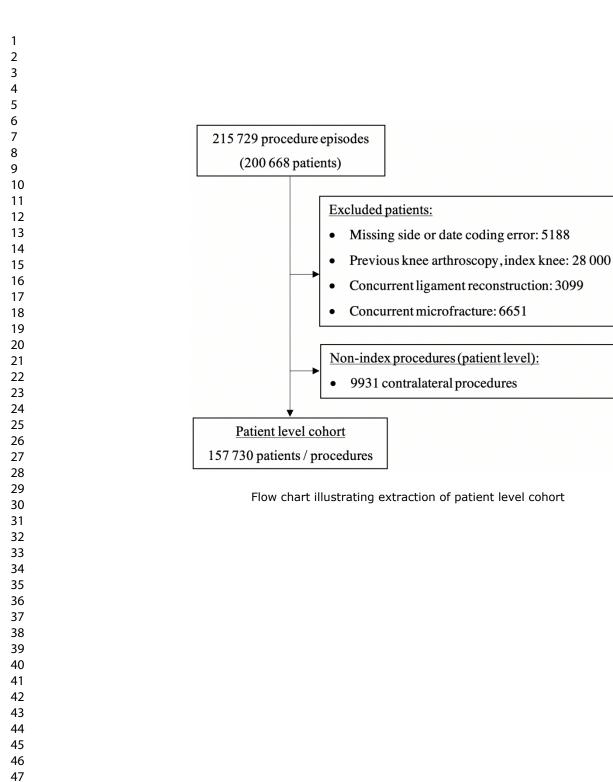
Figure 1: Flow chart illustrating extraction of patient level cohort

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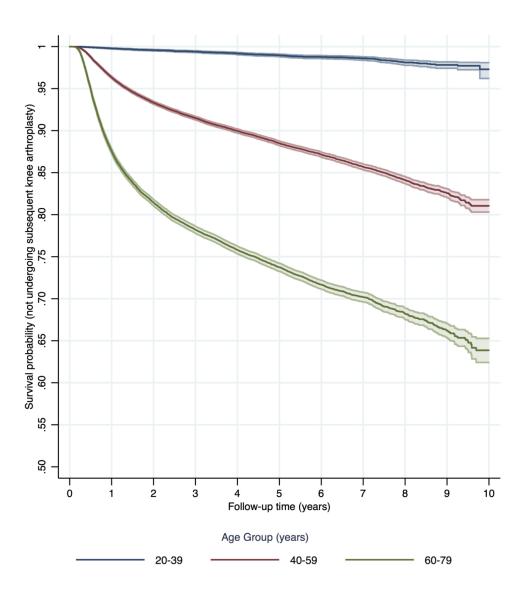
Figure 2: Survival curve (not undergoing knee arthroplasty) following chondroplasty by aget

Figure 3: Survival curve (not undergoing knee arthroplasty) following chondroplasty by sex*

For peer teriew only * Age groups < 20 years and 80+ years suppressed due to small numbers







[†] Age groups < 20 years and 80+ years suppressed due to small numbers

Figure 2: Survival curve (not undergoing knee arthroplasty) following chondroplasty by age⁺

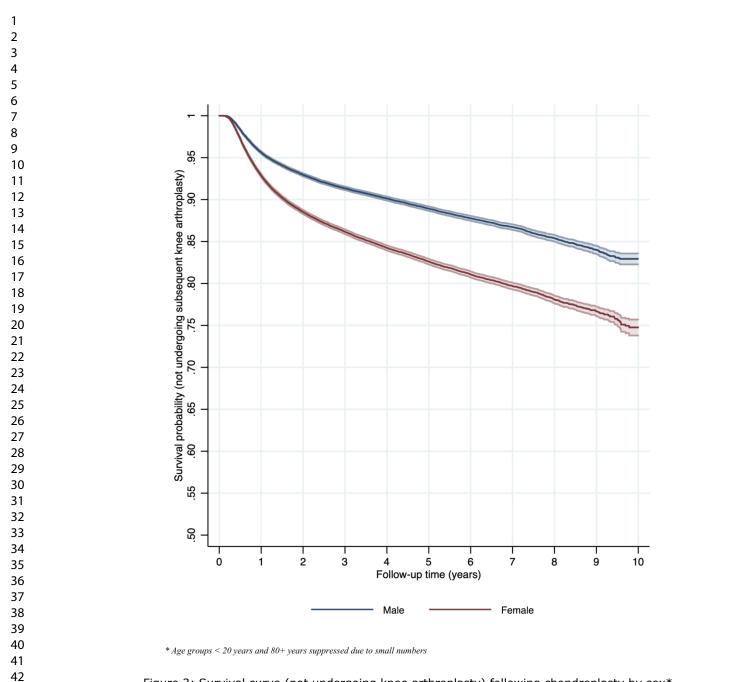


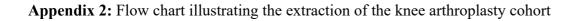
Figure 3: Survival curve (not undergoing knee arthroplasty) following chondroplasty by sex*

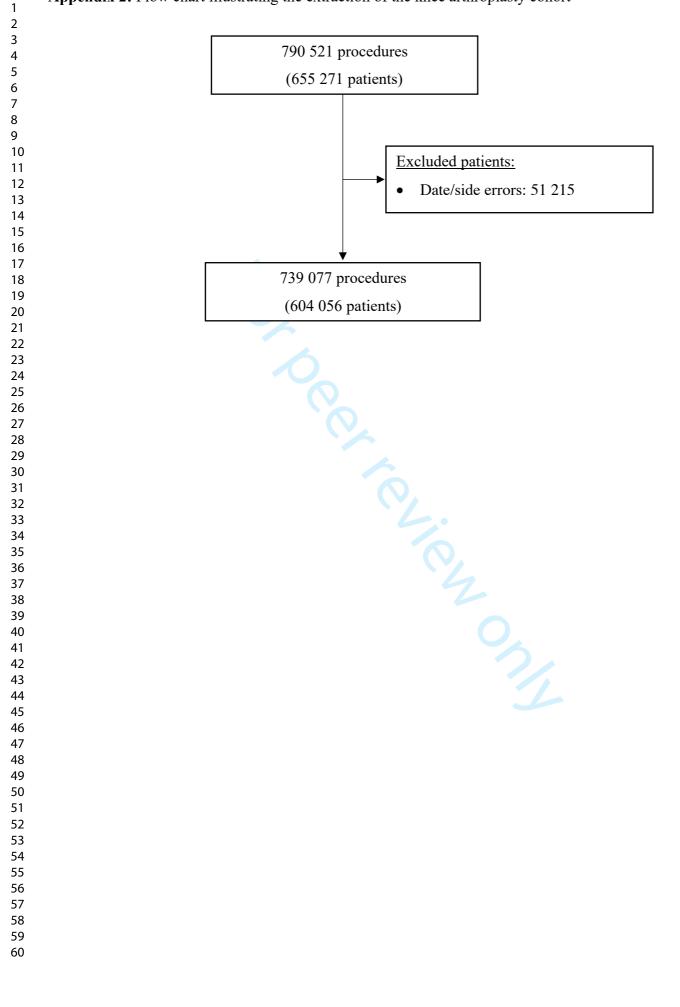
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Appendix 1: OPCS procedure code list

PROCEDURE	OPCS 4.4	OPCS 4.5	OPCS 4.6	OPCS 4.7	Description 0
Chondroplasty*	W83.3*	W83.3*	W83.3*	W83.3*	Endoscopic shaving of articular cartilage
Chondroplasty*	W83.4*	W83.4*	W83.4*	W83.4*	Endoscopic shaving of articular cartilage S Endoscopic articular abrasion chondroplasty S
Chondroplasty*	W83.5*	W83.5*	W83.5*	W83.5*	Endoscopic articular thermal chondroplasty
Chondroplasty*	W83.6*	W83.6*	W83.6*	W83.6*	Endoscopic excision of articular cartilage NEC
Chondroplasty*	W89.1*	W89.1*	W89.1*	W89.1*	
Microfracture*	W83.1*	W83.1*	W83.1*	W83.1*	Endoscopic chondroplasty NEC Endoscopic drilling of lesion of articular cartilage
Microfracture*	W84.5*	W84.5*	W84.5*	W84.5*	Endoscopic drilling of epiphysis for repair of articular ca
Meniscal surgery	W82.2	W82.2	W82.2	W82.2	Endoscopic resection of semilunar cartilage NEC
Meniscal surgery	W82.3	W82.3	W82.3	W82.3	Endoscopic repair of semilunar cartilage
Meniscal surgery	W82.1	W82.1	W82.1	W82.1	Endoscopic total excision of semilunar cartilage
Ligament reconstruction (exclusion)*	W74.2	W74.2	W74.2	W74.2	Reconstruction of intra-articular ligament NEC D Endoscopic repair of intra-articular ligament D
Ligament reconstruction (exclusion)*	W84.1	W84.1	W84.1	W84.1	Endoscopic repair of intra-articular ligament
Ligament reconstruction (exclusion)*	W84.2	W84.2	W84.2	W84.2	Endoscopic reattachment of intra-articular ligament
Ligament reconstruction (exclusion)*	W72.3	W72.3	W72.3	W72.3	Primary prosthetic replacement of intra-articular ligamen
Ligament reconstruction (exclusion)*	W72.4	W72.4	W72.4	W72.4	Prosthetic replacement of intra-articular ligament NEC
Arthroplasty*	W43.1	W43.1	W43.1	W43.1	Primary total prosthetic replacement of joint using cement NEC
Arthroplasty*	W44.1	W44.1	W44.1	W44.1	Primary total prosthetic replacement of joint not using cement NEC
Arthroplasty*	W44.8	W44.8	W44.8	W44.8	Other specified total prosthetic replacement of other joint using cement
Arthroplasty*	W44.9	W44.9	W44.9	W44.9	Unspecified total prosthetic replacement of other joint noPusing cement
Arthroplasty*	W45.1	W45.1	W45.1	W45.1	Primary total prosthetic replacement of joint NEC
Arthroplasty*	W45.8	W45.8	W45.8	W45.8	Other specified other total prosthetic replacement of othe gioint
Arthroplasty*	W45.9	W45.9	W45.9	W45.9	Unspecified other total prosthetic replacement of other joint
Arthroplasty*	W53.8	W53.8	W53.8	W53.8	Other specified prosthetic replacement of articulation of the bone not using ceme
Arthroplasty	W40.1	O18.1	O18.1	018.1	Primary hybrid prosthetic replacement of knee joint using cement
Arthroplasty	W40.8	018.8	018.8	018.8	Other specified hybrid prosthetic replacement of knee joint using cement
Arthroplasty	W40.9	O18.9	O18.9	018.9	Unspecified hybrid prosthetic replacement of knee joint using cement
Arthroplasty	W40.1	W40.1	W40.1	W40.1	Primary total prosthetic replacement of knee joint using coment
Arthroplasty	W40.8	W40.8	W40.8	W40.8	Other specified total prosthetic replacement of knee joint Lising cement
Arthroplasty	W40.9	W40.9	W40.9	W40.9	Unspecified total prosthetic replacement of knee joint using cement
Arthroplasty	W41.1	W41.1	W41.1	W41.1	Primary total prosthetic replacement of knee joint not using cement
Arthroplasty	W41.8	W41.8	W41.8	W41.8	Other specified total prosthetic replacement of knee joint not using cement
Arthroplasty	W41.9	W41.9	W41.9	W41.9	Unspecified total prosthetic replacement of knee joint no dising cement
Arthroplasty	W42.1	W42.1	W42.1	W42.1	Primary total prosthetic replacement of knee joint NEC
Arthroplasty	W42.8	W42.8	W42.8	W42.8	Other specified other total prosthetic replacement of kneedoint
Arthroplasty	W42.9	W42.9	W42.9	W42.9	Unspecified other total prosthetic replacement of knee jowat
Arthroplasty*	W58.1	W58.1	W58.1	W58.1	Primary resurfacing arthroplasty of joint 8

*: Additional site-specific knee code required (Z846, Z765, Z845, Z844, Z774, or Z787)





Rates of knee arthroplasty in patients with a history of arthroscopic chondroplasty: results from a retrospective cohort study utilising the National Hospital Episode Statistics for England

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Rates of knee arthroplasty in patients with a history of arthroscopic chondroplasty: results from a retrospective cohort study utilising the National Hospital Episode Statistics for England

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Keywords

knee; arthroscopy; chondroplasty; knee replacement; arthroplasty; outcomes; osteoarthritis

Word count

ABSTRACT

OBJECTIVE

The purpose of this study was to analyse the rate of knee arthroplasty in the population of patients with a history of arthroscopic chondroplasty of the knee, in England, over ten years, with comparison to general population data for patients without a history of chondroplasty.

DESIGN

Retrospective cohort study

SETTING

English hospital episode statistics (HES) data

PARTICIPANTS AND INTERVENTIONS

Patients undergoing arthroscopic chondroplasty in England between 2007/08 and 2016/17 were identified.

Patients undergoing previous arthroscopic knee surgery or simultaneous cruciate ligament reconstruction or

microfracture in the same knee were excluded.

OUTCOMES

Patients subsequently undergoing a knee arthroplasty in the same knee were identified and mortalityadjusted survival analysis was performed (survival without undergoing knee arthroplasty). A Cox proportional hazards model was used to identify factors associated with knee arthroplasty. Relative risk of knee arthroplasty (total or partial) in comparison to the general population was determined.

RESULTS

Through 2007-17, 157,730 eligible chondroplasty patients were identified. Within one-year, 5.91% (7984/135197; 95% CI 5.78 to 6.03) underwent knee arthroplasty and 14.22% (8145/57267; 95% CI 13.94 to 14.51) within five-years. Patients aged over 30 years with a history of chondroplasty were 17.32 times (risk ratio; 95% CI 16.81 to 17.84) more likely to undergo arthroplasty than the general population without a history of chondroplasty.

CONCLUSIONS

Patients with cartilage lesions of the knee, treated with arthroscopic chondroplasty, are at greater risk of
subsequent knee arthroplasty than the general population and for a proportion of patients, there is
insufficient benefit to prevent the need for knee arthroplasty within one- to five-years. These important new
data will inform patients of the anticipated outcomes following this procedure. The risk in comparison to
non-operative treatment remains unknown and there is an urgent need for a randomised clinical trial in this
population.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- Strengths of the data source analysed in this study include comprehensive, national, data collection and the ability to match treatment with outcomes, including by the laterality of intervention, over time.
- This is the largest cohort of patients undergoing arthroscopic chondroplasty that has been reported, with strict inclusion criteria, excluding patients with a history of previous surgery to the same knee and those undergoing simultaneous ligament reconstruction or microfracture.
- All studies of this design rely on coding accuracy and some coding errors are inevitable; although outcomes were stratified by a range of patient factors, unmeasured potential confounders include body mass index, limb alignment, baseline radiographic status.
- Knee arthroplasty is an end-stage outcome and will underestimate the true burden and severity of symptomatic osteoarthritis in this population.

• The outcome had these patients not undergone arthroscopic chondroplasty remains unknown.

INTRODUCTION

Around 2 million knee arthroscopy procedures are performed worldwide each year.[1] Historically, knee washout and 'debridement' was shown to be ineffective for the treatment of advanced osteoarthritis.[2–4] For early osteoarthritis, however, a number of surgical and non-surgical treatments are available and treatment selection is challenging.[5] The aim of treatment in these cases is to improve symptoms and delay or prevent progressive osteoarthritis.[6]

Chondroplasty is a non-specific term that encompasses several techniques for the treatment of cartilage defects.[7] It includes debridement and abrasion using mechanical 'shavers' and, more recently, thermal or radiofrequency techniques have also emerged despite some concerns these techniques might risk inducing localised chondrocyte death.[7–11] Recent national guidance was cautiously supportive of radiofrequency chondroplasty for the treatment of "discrete chondral defects" based on a small number of clinical trials comparing the outcomes of mechanical and radiofrequency techniques.[12] It is not known which patients are most likely to benefit from chondroplasty procedures and when the procedure does not provide sustained benefit, knee arthroplasty is often indicated. The success rate of chondroplasty is, however, poorly understood and the proportion of patients undergoing subsequent knee arthroplasty after this intervention has been unknown.

The purpose of this study was to determine the proportion of patients undergoing knee chondroplasty procedures that subsequently receive a knee arthroplasty in the same knee, with specific focus on the proportion of patients undergoing early arthroplasty with one-year or two-years of chondroplasty. Factors associated with the risk of subsequent arthroplasty are reported and the relative risk in comparison to the general population determined.

METHODS

Data source

National Hospital Episode Statistics (HES) data was obtained (application DARS-NIC-68703) in a deidentified (pseudo-anonymised) format from NHS Digital.[13] HES contains a record of deidentified patient attendances at National Health Service (NHS) hospitals in England.[13] The data is submitted by hospitals to claim payment for the services they provide and is also intended for secondary use, including research. HES includes episodes of care delivered in treatment centres (including those in the independent sector) funded by the NHS, episodes of care in England where patients are resident outside of England, and privately funded patients treated within NHS England hospitals. The information recorded in the HES database includes patient demographic and residence data, primary and secondary diagnoses including comorbidities, and all procedures undertaken.

Procedures

All HES records between 1 April 2007 and 31 March 2017 were extracted for patients undergoing arthroscopic chondroplasty. Patients undergoing previous arthroscopic knee surgery or simultaneous cruciate ligament reconstruction or microfracture in the same knee were excluded. Procedures were identified using the Classification of Surgical Operations and Procedures (OPCS-4) codes recorded within the HES data (see appendix 1 for OPCS-4 code list).[14] All knee arthroplasty (partial or total) procedures were also identified (appendix 2) for the whole population to enable the relative risk of knee arthroplasty with and without a history of chondroplasty to be determined.

Outcomes

The primary outcome was knee arthroplasty, matched to the side of any previous chondroplasty (using recorded OPCS-4 laterality codes).

Statistical analysis

Stata v15.1 (StataCorp, College Station, Texas, USA) was used to perform all analysis. In accordance with Office for National Statistics (ONS) and NHS Digital guidance, rates where the number of events was less than six were suppressed.[15] Procedures with date errors or missing laterality were excluded. The absolute rate of knee arthroplasty was determined at 1 year, 2 years, 5 years, and 8 years following arthroscopic chondroplasty as the proportion of the cohort with this minimum period of follow-up. Mortality adjusted Kaplan-Meier survival analysis (survival was defined as not undergoing knee arthroplasty) was also performed and stratified by patient age group and sex.

A Cox proportional-hazards model was used first to calculate the unadjusted hazard ratio of knee arthroplasty over time by age group, sex, index of multiple deprivation (quintile derived from regional

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factors in England including average income, employment, education, housing, and crime; 1=least deprived area, 5=most deprived), ethnicity, modified Charlson comorbidity index (derived with maximum 5-year diagnosis code lookback period),[16–18] year of treatment (chondroplasty), rurality, and ethnicity respectively.[16–19] The hazard ratios were then adjusted including all these variables in the model.

The relative risk (risk ratio) of knee arthroplasty in the population of patients with a history of chondroplasty in comparison to the general population (without a history of chondroplasty) was estimated for the year 2016-17. All patients undergoing knee arthroplasty in 2016-17 were identified and the number of these patients with a recorded previous chondroplasty (in the prior 10-years of HES data), versus those without, made up the numerator for each respective population. The chondroplasty population denominator was the number of patients with a history of chondroplasty that had not undergone a knee arthroplasty prior to 2016-17. The denominator for the non-chondroplasty population was the ONS mid-year population estimate less the chondroplasty population.

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Patient and public involvement

There was no patient and public involvement in this study.

RESULTS

Over the study period, 157,730 chondroplasty patients were identified as eligible for analysis (Figure 1). The mean age of the chondroplasty cohort was 51.7 year (SD 13.8) and 48.1% were female (Table 1). Over the same period, 604,056 patients underwent knee arthroplasty, of which 35,916 (5.95%) had a record of a previous chondroplasty (Table 1).

Overall, following chondroplasty, 5.91% (7984/135197; 95% confidence interval [CI] 5.78 to 6.03) patients underwent knee arthroplasty within 1 year, 9.41% (10787/114592; 95% CI 9.24 to 9.58) within 2 years, 14.22% (8145/57267; 95% CI 13.94 to 14.51) within 5 years, and 17.61% (2879/16347; 95% CI 17.03 to 18.20) within 8 years (Table 2). The risk of arthroplasty was greater in female patients (adjusted hazard ratio [HR] 1.38; 95% CI 1.34 to 1.42) and in older patients (adjusted HR 1.33 per five years; 95% CI 1.32 to 1.34) (Table 3, Figure 2; Figure 3). Patients with a greater comorbidity index were also at increased risk of subsequently undergoing arthroplasty (adjusted HR 1.03 per five units Charlson index; 95% CI 1.01 to 1.05).

The risk of knee arthroplasty after chondroplasty fell slightly over time, by year of chondroplasty treatment (adjusted HR 0.95 per five years; 95% CI 0.92 to 0.98). Patients in regions of increased deprivation and patients of white ethnicity were at greater risk of subsequent arthroplasty (Table 2). Patients undergoing concurrent meniscal surgery were also at greater risk of subsequent arthroplasty (adjusted HR 1.09; 95% CI 1.06 to 1.13).

In 2016-17, the rate of knee arthroplasty was 3.49% (95% CI 3.39 to 3.60) in patients (aged 30 or older) with a recorded history of chondroplasty and 0.20% (95% CI 0.19 to 0.20) in patients without a record of chondroplasty. This corresponded to an overall relative risk of knee arthroplasty for the chondroplasty cohort patients of 17.32 times (risk ratio [RR]; 95% CI 16.81 to 17.84) that of the general population (Table 4).

Although the absolute annual rate of knee arthroplasty was low, the relative risk of undergoing knee arthroplasty at a younger age was greatly elevated in comparison to arthroplasty at an older age, as shown in Table 4. Patients aged 30-39 with a history of a previous chondroplasty were 170.92 times (RR; 95% CI 116.72 to 250.30) more likely to undergo knee arthroplasty than the general population, per year, in comparison to 11.09 times (RR; 95% CI 10.42 to 11.80) more likely for the over 69 age group.

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DISCUSSION

Principal findings

Patients undergoing chondroplasty procedures of the knee have a 17 times increased risk of receiving a knee arthroplasty compared with the general population. Nearly 10% of patients will have received a knee arthroplasty within two years of the chondroplasty procedure. The relative risk of undergoing arthroplasty at a young age is particularly elevated, reaching 171 times the general population rate for arthroplasty between the ages of 30 and 39 years of age. For a proportion of patients, the results indicate insufficient benefit to prevent the need for knee arthroplasty within one or two years, but the risk had these patients not undergone chondroplasty remains unknown.

Comparison to other studies

We previously reported trends in chondroplasty surgery in England, but data from other countries is not available.[20] The age-sex standardised rate of chondroplasty increased 191% from 17.6/100,000 (95% CI 17.2 to 18.0) in 2007/08 to 51.2/100,000 (95% CI 50.6 to 51.7) in 2016/17.[20] The rate of chondroplasty was greatest in patients aged 40-59 years (increasing 210% from 34.3/100,000 in 2007/08 to 106.4/100,000 in 2016/17.[20]

In England, although national guidance has been cautiously supportive of radiofrequency chondroplasty for specific indications, there is only limited evidence demonstrating the effectiveness of chondroplasty compared with alternative surgical or non-surgical treatments.[12] The only randomised studies have been limited to comparisons of different chondroplasty techniques.[10,12] Long-term outcomes following chondroplasty have yet to be reported.[12]

Older patients are much more likely to have generalised osteoarthritis, rather than "discrete chondral defects" for which the national guidance supports radiofrequency chondroplasty.[12,21] For more generalised osteoarthritis, chondroplasty is analogous to debridement and washout, where multiple clinical trials demonstrate no benefit.[2–4] The use of chondroplasty in the treatment of patients with more generalised chondral pathology is therefore unproven and not recommended.[22] In our study, there was considerable age-group variation in outcomes, with 18.8% of patients aged 60-79-years undergoing arthroplasty within two-years of chondroplasty, in comparison to 0.43% for patients undergoing chondroplasty aged 20-39-years. This observation is consistent with the presence of more established osteoarthritis in older age groups.

Female patients were observed to be of greater risk of subsequent arthroplasty in our study. This has previously been observed following knee arthroscopy in the United States.[23] Patients of white ethnicity and greater deprivation were also at greater risk in our cohort. These findings may reflect differences in

healthcare access including treatment thresholds for either the chondroplasty or knee arthroplasty, or differences in care seeking behaviour which has been shown to be influenced by socioeconomic, cultural, occupational, and psychological factors, or there could be biological factors underlying the observation.[24–26] Patients with a greater comorbidity index were more likely to undergo subsequent arthroplasty, and the reason for this is unclear. One possible explanation might be an association between comorbidity and higher body mass index (BMI), which is not recorded in this dataset, with patients having a greater BMI being more likely to progress to end-stage osteoarthritis, or that these patients had more severe pathology at the time of their index chondroplasty.[27] Patients undergoing concurrent meniscal surgery were also more likely to undergo subsequent arthroplasty, which is expected given the association between meniscal injury, osteoarthritis, and knee arthroplasty.[28]

Recently, there has been renewed focus on the importance of and requirements for individualised patient consent.[29] Our findings make an important contribution to the current evidence, and patients can now be appropriately counselled and consented with knowledge of anticipated long-term outcomes.

Strength and limitations

A key strength of our study is the identification of all knee chondroplasty procedures performed in the National Health Service over a 10-year period, creating the largest reported cohort of patients receiving this procedure. Patients with a history of prior arthroscopy in the same knee, simultaneous ligament reconstruction or microfracture were excluded as potential confounding factors. It should still be noted that patients undergoing non-NHS treatment, for example knee arthroplasty in the private sector after a previous knee arthroscopy under NHS care, would not be captured in this dataset and the number of these procedures performed in the private sector is currently unknown. National data does indicate, however, that private healthcare expenditure as a proportion of total healthcare expenditure has remained relatively stable at around 17-18% of total health expenditure between 2005 and 2015.[30] For all observational studies utilising large datasets there may be some concerns raised about coding accuracy. The data in our study was cleaned prior to analysis, excluding patients where procedures were missing the side of intervention, and cases where date coding errors were identified. Although some other data coding errors are inevitable, data errors in procedure coding would result in hospitals not receiving payment for surgery performed, and this provides a strong incentive for data accuracy with regards to the coding data analysed in this study.

We were able to stratify risk of arthroplasty by a large number of patient factors, but certain procedure specific data is not recorded. Operative factors, such as the affected compartment of the knee and extent of initial cartilage damage before intervention, are not recorded in this database. These factors may be important in determining outcome, for example, there are likely to be differences in long-term outcomes between chondroplasty performed to the tibiofemoral joint in comparison to the patellofemoral joint.[31] Other unmeasured sources of potential confounding include BMI, leg alignment, and radiographic status at

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the time of intervention. These are important considerations when considering if a patient is suitable for chondral surgery intervention, but the specific impact of these factors on long-term outcomes in this population remains uncertain. Subjective, patient-reported, symptomatic outcome data is not yet available for this cohort and radiographic outcomes are not recorded in the HES database. Instead, our study focussed on the objective, measurable outcome of knee arthroplasty, matched to the same knee as the previous chondroplasty surgery intervention. Although knee arthroplasty represents the end-stage of symptomatic failure for patients with osteoarthritis, it is likely to considerably underestimate the overall health and symptom burden in this cohort. Patients, particularly younger patients, may not have been willing or suitable candidates for knee arthroplasty, and the threshold for arthroplasty may have been much higher for younger age groups or older patients with multiple comorbidities. It is also important to note that, in general, "chondroplasty" is a non-specific term that encompasses several techniques for the debridement of cartilage defects.[7] The findings in this paper cannot be generalised to other types of arthroscopic and joint preservation surgery, cartilage repair and regeneration techniques, such as microfracture and autologous chondrocyte implantation.[6,31]

Our study represents a high-risk cohort of patients with cartilage damage. It is unknown from this observational data whether undergoing the chondroplasty procedure was beneficial to the symptoms or prognosis of these individuals over the full study period. That is, it is not known whether the chondroplasty procedure delayed or prevented arthroplasty in those patients that did not undergo arthroplasty (approximately 86% by 5-years), in which case delivery of the intervention may have been cost-effective, or the converse interpretation is that the procedure may have been over-used and that the natural history of symptomatic osteoarthritis in this population was unaltered. For example, the observed proportion of patients undergoing arthroplasty within 1-year of their arthroscopic chondroplasty (6%) is suggestive of suboptimal treatment selection. These individuals are highly unlikely to have had only localised or partial thickness lesions and our results may indicate that knee arthroplasty may have been a more appropriate treatment. Nevertheless, the symptomatic outcome in the patients that did not undergo arthroplasty is not known and the answer to whether the procedure is cost-effective with optimal patient selection is unknown and requires evaluation in a high-quality randomised controlled trial with a non-operative treatment arm. Such a trial should help to evaluate the optimal indications for chondroplasty, assess the relative rate of progression of treated chondral damage with versus without chondroplasty, and ultimately determine whether appropriate use of chondroplasty is beneficial to patient outcome including, potentially, the longterm demand for knee arthroplasty.

Our study reports the long-term outcomes following chondroplasty in a high-risk cohort of patients with cartilage damage for the first time. Our findings our stratified by a range of patient specific factors however further work is required to optimise treatment selection and additional patient information may allow more accurate prediction of outcome and guide clinical management.

Conclusion

The risk of knee arthroplasty is 17 times greater in patients with a history of knee chondroplasty and in a proportion of patients, there is insufficient benefit to prevent the need for knee arthroplasty within one or two years. These important new data help inform patients and clinicians of the long-term outcomes following this procedure, at the population level, for the first time. Enhanced clinical guidance on the appropriate indications for chondroplasty are required and there is a need for high-quality randomised studies to determine the relative clinical and cost effectiveness of this intervention in comparison to alternative, including non-surgical, treatments.

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Data availability

No additional data available.

3 **Details of contributors** 4

SGFA: concept, methodology, analysis, writing and editing paper, guarantor.

- 7 AJRP: writing and editing paper.
- 8 AJ: methodology, analysis, editing paper. 9
- 10 DJB: concept, editing paper. 11
- 12 AJP: concept, methodology, editing paper. 13

14 **Transparency declaration** 15

The lead author (SA) affirms that the manuscript is an honest, accurate, and transparent account of the study 16 17 being reported; that no important aspects of the study have been omitted; and that any discrepancies from 18 19 the study as planned (and registered) have been explained. 20

Competing interests 21 22

Andrew Judge has received consultancy fees from Freshfields Bruckhaus Deringer (on behalf of Smith & Nephew Orthopaedics Limited), and is a member of the Data Safety and Monitoring Board (which involved 26 receipt of fees) from Anthera Pharmaceuticals, Inc. All other authors declare no financial relationships with any organisations that might have an interest in the submitted work in the previous three years, no other 28 relationships or activities that could appear to have influenced the submitted work. 30

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Ethical approval

Not required.

for peer review only

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TABLES

TABLE 1: Demographics and descriptive statistics of cohort

	Chondr	oplasty Cohort	Knee Arthroplasty Cohort						
	A	III Cases	No Previous	Chondroplasty	Previous Chondroplasty				
	n	%	n	%	n	%			
Total	157730	100.00	568,140	94.05	35,916	5.95			
Sex									
Male	81884	51.91	244,684	43.07	15,512	43.19			
Female	75846	48.09	323,456	56.93	20,404	56.81			
Age group									
(years)									
<20	2868	1.82	1,179	0.21	1	< 0.01			
20-39	24648	15.63	1,568	0.28	353	0.98			
40-59	83258	52.79	85,797	15.1	14,023	39.04			
60-79	45191	28.65	400,541	70.5	20,361	56.69			
80+	1765	1.12	79,055	13.91	1,178	3.28			
Charlson									
comorbidity									
index									
0	121605	77.10	534,399	94.06	27,331	76.1			
1 - 15	34719	22.01	31,683	5.58	8,175	22.76			
16 - 30	1296	0.82	1,879	0.33	393	1.09			
31 - 50	110	0.07	179	0.03	17	0.05			
Index of multiple									
deprivation									
(quintiles)									
1 = least deprived	36043	23.21	121,813	21.44	7,921	22.05			
2	35189	22.66	127,672	22.47	7,938	22.1			
3	32493	20.92	123,160	21.68	7,806	21.73			
4	27312	17.59	103,236	18.17	6,372	17.74			
5 = most deprived	24266	15.62	85,283	15.01	5,416	15.08			
Missing	2427		6,976		463				
Rurality									
Urban	119766	76.42	423,895	74.61	27,157	75.61			
Rural	36953	23.58	141,271	24.87	8,634	24.04			
Missing	1011		2,974		125				
Ethnicity									
White	141928	94.43	525,934	92.57	34,349	95.64			
Mixed	953	0.63	1,844	0.32	115	0.32			
Asian	4511	3.00	19,203	3.38	804	2.24			
Black	2122	1.41	5,840	1.03	193	0.54			
Other	792	0.53	1,367	0.24	68	0.19			
Missing	7424		13,952		387				
Concurrent									
procedures									
None	65987	41.84	-	-	-	-			
Meniscal	91743	58.16	-	-	-	-			

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Table 2: Cohort demographics and adjusted odds of arthroplasty

of 28						ВМЈ Ор	en		6/bmjopen-2019-030609 % (95% CI)				
able 2: (Cohort demographics and adjusted odds of arthroplasty												
	1-year ou	teomo*		2-year outcome* 5-year outcome*							2 8-year outcome*		
	n	n	% (95% CI)	n 2-year ou	n TKA	% (95% CI)	n n	n TKA	% (95% CI)	n	n TKA	% (95% CI)	
		TKA											
Fotal	135,197	7984	5.91% (5.78, 6.03)	114,592	10787	9.41% (9.24, 9.58)	57,267	8145	14.22% (13.94, 14.51)	16,347	2879	17.61% (17.03, 18.2	
Sex									₽				
Male	69,787	3160	4.53% (4.37, 4.68)	59,101	4261	7.21% (7.00, 7.42)	29,688	3315	11.17% (10.81, 11.5)	8,514	1208	14.19% (13.45, 14.9	
Female	65,410	4824	7.38% (7.18, 7.58)	55,491	6526	11.76% (11.49, 12.03)	27,579	4830	17.51% (17.07, 17.9)	7,833	1671	21.33% (20.43, 22.2	
Sex	,		,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,						<u>.</u>	.,			
< 20	-	-	-	-	-	-	-	-	- 2	-	-	-	
20 - 39	21,548	48	0.22% (0.16, 0.30)	18,583	79	0.43% (0.34, 0.53)	10,004	95	0.95% (0.77, 1.16)	3,094	53	1.71% (1.29, 2.23)	
40 - 59	72,345	2654	3.67% (3.53, 3.81)	60,974	4049	6.64% (6.44, 6.84)	29,844	3327	11.15% (10.79, 11.5 g)	8,552	1287	15.05% (14.30, 15.	
50 - 79	39,741	4994	12.57% (12.24, 12.90)	33,680	6343	18.83% (18.42, 19.25)	16,716	4522	27.05% (26.38, 27.7)	4,508	1479	32.81% (31.44, 34.	
$\frac{30}{30}$ +	1,563	288	18.43% (16.53, 20.44)	1,355	316	23.32% (21.09, 25.67)	703	201	28.59% (25.28, 32.0 2)	193	60	31.09% (24.64, 38.	
	comorbidity		10.1570 (10.55, 20.11)	1,000	1010		100	-01	<u> 10:00000 (10:10;01:00)</u> 7	170	00		
)	104,530	5369	5.14% (5.00, 5.27)	89,081	7366	8.27% (8.09, 8.45)	45,505	5837	12.83% (12.52, 13.14)	13,362	2148	16.08% (15.46, 16.	
1 - 15	29,475	2467	8.37% (8.06, 8.69)	24,540	3228	13.15% (12.73, 13.58)	11,371	2207	19.41% (18.69, 20.5)	2,884	701	24.31% (22.75, 25.	
16 - 30	1,102	138	12.52% (10.63, 14.62)	898	180	20.04% (17.47, 22.82)	391	101	25.83% (21.56, 30.42)	101	30	29.70% (21.02, 39.	
31 - 50	90	10	11.11% (5.46, 19.49)	73	13	17.81% (9.84, 28.53)	-	-	- 3	-	-	-	
	ultiple depr			,,,	10	1110170 (2101, 20102)	I			1			
1	31,054	1846	5.94% (5.68, 6.21)	26,546	2405	9.06% (8.72, 9.41)	13,422	1835	13.67% (13.09, 14.2)	3,878	629	16.22% (15.07, 17.	
2	30,218	1799	5.95% (5.69, 6.23)	25,638	2409	9.40% (9.04, 9.76)	12,819	1779	13.88% (13.28, 14.49)	3,474	617	17.76% (16.50, 19.	
3	27,974	1737	6.21% (5.93, 6.50)	23,721	2324	9.80% (9.42, 10.18)	11,833	1772	14.98% (14.34, 15.65)	3,374	635	18.82% (17.51, 20.	
4	23,312	1387	5.95% (5.65, 6.26)	19,702	1913	9.71% (9.30, 10.13)	9,771	1420	14.53% (13.84, 15.23)	2,762	496	17.96% (16.54, 19.	
5	20,591	1104	5.36% (5.06, 5.68)	17,194	1588	9.24% (8.81, 9.68)	8,420	1197	14.22% (13.48, 14.98)	2,451	444	18.12% (16.61, 19.	
Rurality	20,071	110.	0.0070 (0.000, 0.000)	17,1271	1000	(0.01,).00)	0,120	11.27	<u> </u>	2,.01	1	10.12/0 (10.01, 1).	
Urban	102,665	6004	5.85% (5.71, 5.99)	86,807	8135	9.37% (9.18, 9.57)	43,287	6148	14.20% (13.88, 14.3)	2,154	12,242	17.60% (16.92, 18.	
Rural	31,760	1944	6.12% (5.86, 6.39)	27,127	2613	9.63% (9.28, 9.99)	13,739	1980	14.41% (13.83, 15.0 1)	713	3,987	17.88% (16.70, 19.	
Ethnicity	01,700	1711	0.12/0 (0.000, 0.000)	_,,,_,	2010	, , , , , , , , , , , , , , , , , , , ,	10,707	1,00		, 10	5,507	11.0070 (10.70, 17.	
White	122,261	7672	6.28% (6.14, 6.41)	103,979	10366	9.97% (9.79, 10.15)	52,267	7834	14.99% (14.68, 15.39)	14,908	2,750	18.45% (17.83, 19.	
Mixed	750	21	2.80% (1.74, 4.25)	609	32	5.25% (3.62, 7.34)	278	22	7.91% (5.03, 11.74)	76	8	10.53% (4.66, 19.6	
Asian	3,722	130	3.49% (2.93, 4.13)	3,088	186	6.02% (5.21, 6.92)	1,465	167	11.40% (9.82, 13.14)	362	75	20.72% (16.66, 25.	
Black	1,770	27	1.53% (1.01, 2.21)	1,466	53	3.62% (2.72, 4.70)	677	38	5.61% (4.00, 7.62) g	171	15	8.77% (4.99, 14.06	
Other	645	15	2.33% (1.31, 3.81)	518	18	3.47% (2.07, 5.44)	250	21	8.40% (5.27, 12.55)	75	9	12.00% (5.64, 21.5	
	t procedure				1.5				<u> </u>				
None	57,208	2686	4.70% (4.52, 4.87)	50,256	3754	7.47% (7.24, 7.70)	28,578	3252	11.38% (11.01, 11.75)	9,370	1,389	14.82% (14.11, 15.	
Meniscal	77,989	5298	6.79% (6.62, 6.97)	64,336	7033	10.93% (10.69, 11.18)	28.689	4893	17.06% (16.62, 17.56)	6,977	1,490	21.36% (20.40, 22.3	

* = excluding those patients where the date of their procedure was less than this number of years from the end of the observation period in the dataset; - $\frac{d}{\sqrt{2}}$ uppressed due to small numbers; CI = confidence interval; TKA = total or partial knee arthroplasty

HR

1.00

1.38

1.33

0.95

1.03

1.00

1.07

1.17

1.20

1.29

1.00

0.99

1.00

0.66

0.73

0.44

0.45

1.00

1.09

Adjusted Risk Subsequent TKA

95% CI

1.00

1.34, 1.42

1.32, 1.34

0.92, 0.98

1.01, 1.05

1.03, 1.12

1.12, 1.22

1.15, 1.26

1.23, 1.36

0.95, 1.02

0.51, 0.86

0.66, 0.81

0.36, 0.54

0.32, 0.64

1.06, 1.13

<20 years suppressed due to small numbers; HR = hazard ratio; CI = confidence

1.00

1.00

1.00

1.00

Table 3: Unadjusted and adjusted* risk of knee arthroplasty following arthroscopic chondroplasty

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	Unad	justed Risk Subsequ
	HR	95% CI
Sex		
Male	1.00	1.00
Female	1.61	1.57, 1.66
Age (per five years	s) ‡	·
Per year	1.35	1.35, 1.36
Year of treatment	(per five year	s)
Year	0.99	0.96, 1.03
Charlson comorbi	dity index (pe	r five units)
Charlson index	1.29	1.27, 1.31
Index of multiple of	leprivation (q	uintile)
1 = least	1.00	1.00
2	1.03	0.99, 1.08
3	1.08	1.04, 1.13
4	1.03	0.99, 1.08
5 = most	1.01	0.96, 1.06
Rurality		
Urban	1.00	1.00
Rural	1.03	1.00, 1.07
Ethnicity		
White	1.00	1.00
Mixed	0.50	0.38, 0.65
Asian	0.65	0.59, 0.72
Black	0.35	0.28, 0.42
Other	0.34	0.24, 0.48
Concurrent procee	lures	I
None	1.00	1.00
Meniscal surgery	1.52	1.48, 1.57

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Table 4: Rates and relative risk of undergoing TKA with previous chondroplasty by age at TKA in 2016-17

Age at TKA (years)Annu TKA $30 - 39$ 274.48 (0.279 $40 - 49$ 1454.0 (1.459) $40 - 49$ 1454.0 (1.459) $50 - 59$ 3626.0 (3.639) $60 - 69$ 5179.1 (5.189) $70 +$ 6090.2 (6.099)Overall3494.0 (3.499) $(30 +)$ (3.499)	100k 19 5) (0. 2 13 5) (1. 2 34 5) (3. 7 49 5) (4. 0 57 5) (5. 1 33 5) (3.	5% CI 00.16, 383.35 0.19%, 0.38%) 318.04, 1600.06 .32%, 1.60%) 448.20, 3811.60 .45%, 3.81%) 033.67, 5433.20 .93%, 5.43%) 721.53, 6475.82 .72%, 6.48%) 394.82, 3596.52 .39%, 3.60%) asty; RR = risk p	Annual Rate TKA /100k 1.60 (0.00%) 19.79 (0.02%) 130.68 (0.13%) 386.68 (0.39%) 520.46 (0.52%) 195.38 (0.20%)	95% CI 1.32, 1.92 (0.00%, 0.00%) 18.79, 20.82 (0.02%, 0.02%) 128.05, 133.35 (0.13%, 0.13%) 381.64, 391.77 (0.38%, 0.39%) 514.89, 526.07 (0.51%, 0.53%) 193.90, 196.87 (0.19%, 0.20%)	RR 170.92 72.45 26.82 12.78 11.09 17.32	95% CI 116.72, 250.30 65.00, 80.76 25.41, 28.30 12.16, 13.44 10.42, 11.80 16.81, 17.84
$\begin{array}{c} 274.43\\ (0.279\\ 40 - 49\\ (1.459\\ 50 - 59\\ \hline 60 - 69\\ \hline 70 +\\ \hline 6090.3\\ (3.639\\ \hline 70 +\\ \hline 6090.3\\ (5.189\\ \hline 70 +\\ \hline 6090.3\\ (3.499\\ \hline 0 \ verall\\ \hline 3494.6\\ (3.499\\ \hline \end{array}$	100k 19 5) (0. 2 13 5) (1. 2 34 5) (3. 7 49 5) (4. 0 57 5) (5. 1 33 5) (3.	00.16, 383.35 0.19%, 0.38%) 318.04, 1600.06 .32%, 1.60%) 148.20, 3811.60 .45%, 3.81%) 033.67, 5433.20 .93%, 5.43%) 721.53, 6475.82 .72%, 6.48%) 394.82, 3596.52 .39%, 3.60%)	1.60 (0.00%) 19.79 (0.02%) 130.68 (0.13%) 386.68 (0.39%) 520.46 (0.52%) 195.38 (0.20%)	1.32, 1.92 (0.00%, 0.00%) 18.79, 20.82 (0.02%, 0.02%) 128.05, 133.35 (0.13%, 0.13%) 381.64, 391.77 (0.38%, 0.39%) 514.89, 526.07 (0.51%, 0.53%) 193.90, 196.87 (0.19%, 0.20%)	170.92 72.45 26.82 12.78 11.09	116.72, 250.34 65.00, 80.76 25.41, 28.30 12.16, 13.44 10.42, 11.80
$\begin{array}{c} 30 - 39 \\ (0.27) \\ 40 - 49 \\ (1.45) \\ 50 - 59 \\ (3.63) \\ 60 - 69 \\ (5.18) \\ 70 + \\ (6.09) \\ 0 \\ 0 \\ (30 +) \\ (3.49) \end{array}$	5) (0. 2 13 5) (1. 2 34 5) (3. 7 49 5) (4. 0 57 5) (5. 1 33 5) (3.	0.19%, 0.38%) 318.04, 1600.06 .32%, 1.60%) 448.20, 3811.60 .45%, 3.81%) 933.67, 5433.20 .93%, 5.43%) 721.53, 6475.82 .72%, 6.48%) 394.82, 3596.52 .39%, 3.60%)	(0.00%) 19.79 (0.02%) 130.68 (0.13%) 386.68 (0.39%) 520.46 (0.52%) 195.38 (0.20%)	(0.00%, 0.00%) 18.79, 20.82 (0.02%, 0.02%) 128.05, 133.35 (0.13%, 0.13%) 381.64, 391.77 (0.38%, 0.39%) 514.89, 526.07 (0.51%, 0.53%) 193.90, 196.87 (0.19%, 0.20%)	72.45 26.82 12.78 11.09	65.00, 80.76 25.41, 28.30 12.16, 13.44 10.42, 11.80
(0.279) $40 - 49$ (1.459) (1.459) (3.639) (3.639) (5.189) $70 +$ (6.099) (5.189) $70 +$ (6.099) (3.499)	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	318.04, 1600.06 .32%, 1.60%) 148.20, 3811.60 .45%, 3.81%) 933.67, 5433.20 .93%, 5.43%) 721.53, 6475.82 .72%, 6.48%) 394.82, 3596.52 .39%, 3.60%)	19.79 (0.02%) 130.68 (0.13%) 386.68 (0.39%) 520.46 (0.52%) 195.38 (0.20%)	18.79, 20.82 (0.02%, 0.02%) 128.05, 133.35 (0.13%, 0.13%) 381.64, 391.77 (0.38%, 0.39%) 514.89, 526.07 (0.51%, 0.53%) 193.90, 196.87 (0.19%, 0.20%)	72.45 26.82 12.78 11.09	65.00, 80.76 25.41, 28.30 12.16, 13.44 10.42, 11.80
$\begin{array}{c} 40 - 49 \\ (1.45) \\ 50 - 59 \\ (3.63) \\ \hline \\ 60 - 69 \\ (5.18) \\ \hline \\ 70 + \\ \hline \\ (6.09) \\ \hline \\ Overall \\ (30 +) \\ \end{array}$	5) (1. 2 34 5) (3. 7 49 5) (4. 0 57 5) (5. 1 33 5) (3.	.32%, 1.60%) 448.20, 3811.60 .45%, 3.81%) 933.67, 5433.20 .93%, 5.43%) 721.53, 6475.82 .72%, 6.48%) 394.82, 3596.52 .39%, 3.60%)	(0.02%) 130.68 (0.13%) 386.68 (0.39%) 520.46 (0.52%) 195.38 (0.20%)	(0.02%, 0.02%) 128.05, 133.35 (0.13%, 0.13%) 381.64, 391.77 (0.38%, 0.39%) 514.89, 526.07 (0.51%, 0.53%) 193.90, 196.87 (0.19%, 0.20%)	26.82 12.78 11.09	25.41, 28.30 12.16, 13.44 10.42, 11.80
(1.459) $50 - 59$ (3.639) $60 - 69$ (5.189) $70 +$ (6.099) $Overall$ $(30 +)$ (3.499)	2 34 5) (3. 7 49 5) (4. 0 57 5) (5. 1 33 5) (3.	448.20, 3811.60 .45%, 3.81%) 933.67, 5433.20 .93%, 5.43%) 721.53, 6475.82 .72%, 6.48%) 394.82, 3596.52 .39%, 3.60%)	130.68 (0.13%) 386.68 (0.39%) 520.46 (0.52%) 195.38 (0.20%)	128.05, 133.35 (0.13%, 0.13%) 381.64, 391.77 (0.38%, 0.39%) 514.89, 526.07 (0.51%, 0.53%) 193.90, 196.87 (0.19%, 0.20%)	26.82 12.78 11.09	25.41, 28.30 12.16, 13.44 10.42, 11.80
$50 - 59 \qquad (3.63)$ $60 - 69 \qquad (5.18)$ $70 + \qquad (6.09)$ $Overall \qquad 3494.0$ $(30 +) \qquad (3.49)$	5) (3. 7 49 6) (4. 0 57 6) (5. 1 33 5) (3.	.45%, 3.81%) 933.67, 5433.20 .93%, 5.43%) 721.53, 6475.82 .72%, 6.48%) 394.82, 3596.52 .39%, 3.60%)	(0.13%) 386.68 (0.39%) 520.46 (0.52%) 195.38 (0.20%)	(0.13%, 0.13%) 381.64, 391.77 (0.38%, 0.39%) 514.89, 526.07 (0.51%, 0.53%) 193.90, 196.87 (0.19%, 0.20%)	12.78	12.16, 13.44
$\begin{array}{c} (3.63)\\ \hline 60 - 69 \\ \hline (5.18)\\ \hline 70 + \\ \hline (6.09)\\ \hline Overall \\ (30 +) \\ \hline (3.49)\\ \hline \end{array}$	7 49 5) (4 0 57 5) (5 1 33 5) (3	033.67, 5433.20 93%, 5.43%) 721.53, 6475.82 72%, 6.48%) 394.82, 3596.52 39%, 3.60%)	386.68 (0.39%) 520.46 (0.52%) 195.38 (0.20%)	381.64, 391.77 (0.38%, 0.39%) 514.89, 526.07 (0.51%, 0.53%) 193.90, 196.87 (0.19%, 0.20%)	12.78	12.16, 13.44
$ \begin{array}{c} 60 - 69 \\ \hline 70 + \\ \hline (6.099) \\ \hline (3.499) \\ \hline (3.499) \end{array} $	5) (4. 0 57 5) (5. 1 33 5) (3.	.93%, 5.43%) 721.53, 6475.82 .72%, 6.48%) 394.82, 3596.52 .39%, 3.60%)	(0.39%) 520.46 (0.52%) 195.38 (0.20%)	(0.38%, 0.39%) 514.89, 526.07 (0.51%, 0.53%) 193.90, 196.87 (0.19%, 0.20%)	11.09	10.42, 11.80
$\begin{array}{c} (5.189) \\ \hline 70 + \\ (6.099) \\ \hline 0 \\ 0 \\ (30 +) \\ \end{array}$	0 57 5) (5) 1 33 5) (3)	721.53, 6475.82 .72%, 6.48%) 394.82, 3596.52 .39%, 3.60%)	520.46 (0.52%) 195.38 (0.20%)	514.89, 526.07 (0.51%, 0.53%) 193.90, 196.87 (0.19%, 0.20%)	11.09	10.42, 11.80
70 + (6.09% Overall 3494.0 (30 +) (3.49%)	5) (5. 1 33 5) (3.	.72%, 6.48%) 394.82, 3596.52 .39%, 3.60%)	(0.52%) 195.38 (0.20%)	(0.51%, 0.53%) 193.90, 196.87 (0.19%, 0.20%)		
(6.09% Overall 3494.0 (30 +) (3.49%)	1 33 5) (3.	394.82, 3596.52 .39%, 3.60%)	195.38 (0.20%)	193.90, 196.87 (0.19%, 0.20%)		
(30+) (3.49%	b) (3.		(0.20%)	(0.19%, 0.20%)	17.32	16.81, 17.84
	· .				17.32	16.81, 17.84
	nee arthropla	asty; RR = risk r	ratio			
			rano			

FIGURES

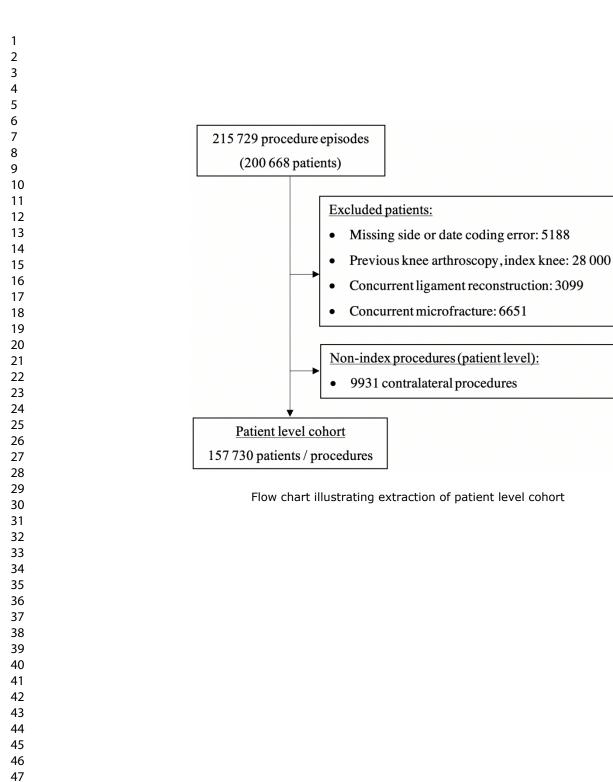
Figure 1: Flow chart illustrating extraction of patient level cohort

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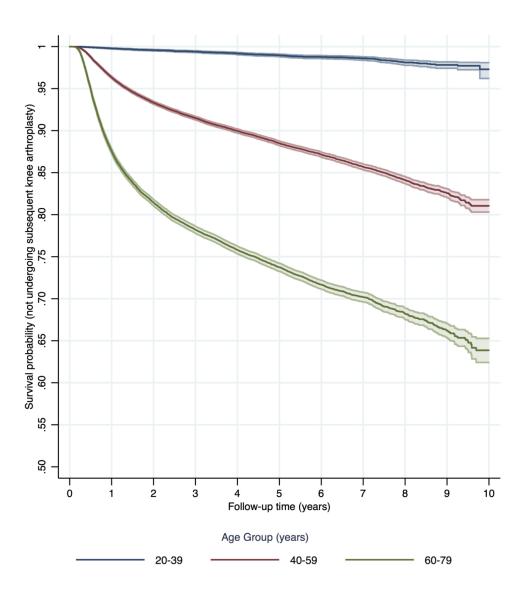
Figure 2: Survival curve (not undergoing knee arthroplasty) following chondroplasty by aget

Figure 3: Survival curve (not undergoing knee arthroplasty) following chondroplasty by sex*

For peer teriew only * Age groups < 20 years and 80+ years suppressed due to small numbers







[†] Age groups < 20 years and 80+ years suppressed due to small numbers

Figure 2: Survival curve (not undergoing knee arthroplasty) following chondroplasty by age⁺

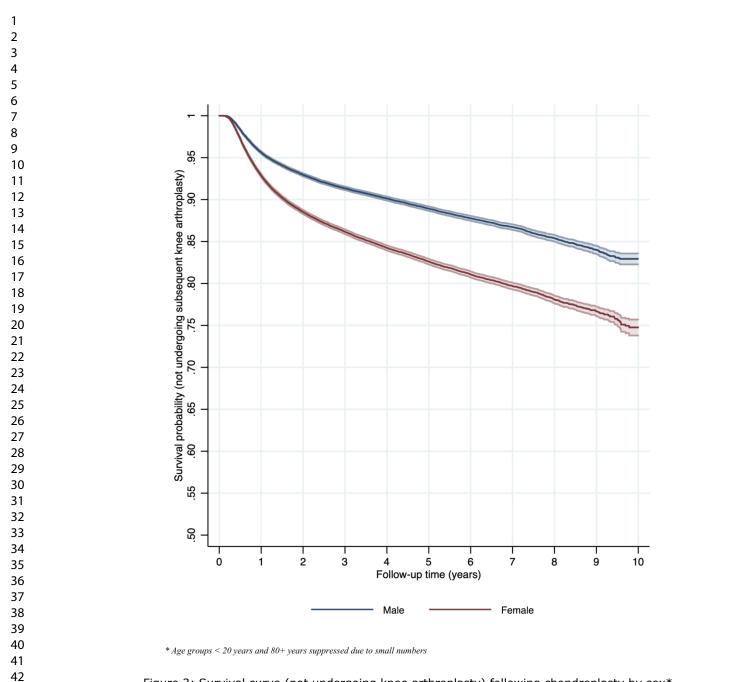


Figure 3: Survival curve (not undergoing knee arthroplasty) following chondroplasty by sex*

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Appendix 1: OPCS procedure code list

PROCEDURE	OPCS 4.4	OPCS 4.5	OPCS 4.6	OPCS 4.7	Description 0
Chondroplasty*	W83.3*	W83.3*	W83.3*	W83.3*	Endoscopic shaving of articular cartilage
Chondroplasty*	W83.4*	W83.4*	W83.4*	W83.4*	Endoscopic shaving of articular cartilage S Endoscopic articular abrasion chondroplasty S
Chondroplasty*	W83.5*	W83.5*	W83.5*	W83.5*	Endoscopic articular thermal chondroplasty
Chondroplasty*	W83.6*	W83.6*	W83.6*	W83.6*	Endoscopic excision of articular cartilage NEC
Chondroplasty*	W89.1*	W89.1*	W89.1*	W89.1*	
Microfracture*	W83.1*	W83.1*	W83.1*	W83.1*	Endoscopic chondroplasty NEC Endoscopic drilling of lesion of articular cartilage
Microfracture*	W84.5*	W84.5*	W84.5*	W84.5*	Endoscopic drilling of epiphysis for repair of articular ca
Meniscal surgery	W82.2	W82.2	W82.2	W82.2	Endoscopic resection of semilunar cartilage NEC
Meniscal surgery	W82.3	W82.3	W82.3	W82.3	Endoscopic repair of semilunar cartilage
Meniscal surgery	W82.1	W82.1	W82.1	W82.1	Endoscopic total excision of semilunar cartilage
Ligament reconstruction (exclusion)*	W74.2	W74.2	W74.2	W74.2	Reconstruction of intra-articular ligament NEC D Endoscopic repair of intra-articular ligament D
Ligament reconstruction (exclusion)*	W84.1	W84.1	W84.1	W84.1	Endoscopic repair of intra-articular ligament
Ligament reconstruction (exclusion)*	W84.2	W84.2	W84.2	W84.2	Endoscopic reattachment of intra-articular ligament
Ligament reconstruction (exclusion)*	W72.3	W72.3	W72.3	W72.3	Primary prosthetic replacement of intra-articular ligamen
Ligament reconstruction (exclusion)*	W72.4	W72.4	W72.4	W72.4	Prosthetic replacement of intra-articular ligament NEC
Arthroplasty*	W43.1	W43.1	W43.1	W43.1	Primary total prosthetic replacement of joint using cement NEC
Arthroplasty*	W44.1	W44.1	W44.1	W44.1	Primary total prosthetic replacement of joint not using cement NEC
Arthroplasty*	W44.8	W44.8	W44.8	W44.8	Other specified total prosthetic replacement of other joint using cement
Arthroplasty*	W44.9	W44.9	W44.9	W44.9	Unspecified total prosthetic replacement of other joint noPusing cement
Arthroplasty*	W45.1	W45.1	W45.1	W45.1	Primary total prosthetic replacement of joint NEC
Arthroplasty*	W45.8	W45.8	W45.8	W45.8	Other specified other total prosthetic replacement of othe gioint
Arthroplasty*	W45.9	W45.9	W45.9	W45.9	Unspecified other total prosthetic replacement of other joint
Arthroplasty*	W53.8	W53.8	W53.8	W53.8	Other specified prosthetic replacement of articulation of the bone not using ceme
Arthroplasty	W40.1	O18.1	O18.1	018.1	Primary hybrid prosthetic replacement of knee joint using cement
Arthroplasty	W40.8	018.8	018.8	018.8	Other specified hybrid prosthetic replacement of knee joint using cement
Arthroplasty	W40.9	O18.9	O18.9	018.9	Unspecified hybrid prosthetic replacement of knee joint using cement
Arthroplasty	W40.1	W40.1	W40.1	W40.1	Primary total prosthetic replacement of knee joint using coment
Arthroplasty	W40.8	W40.8	W40.8	W40.8	Other specified total prosthetic replacement of knee joint Lising cement
Arthroplasty	W40.9	W40.9	W40.9	W40.9	Unspecified total prosthetic replacement of knee joint using cement
Arthroplasty	W41.1	W41.1	W41.1	W41.1	Primary total prosthetic replacement of knee joint not using cement
Arthroplasty	W41.8	W41.8	W41.8	W41.8	Other specified total prosthetic replacement of knee joint not using cement
Arthroplasty	W41.9	W41.9	W41.9	W41.9	Unspecified total prosthetic replacement of knee joint no dising cement
Arthroplasty	W42.1	W42.1	W42.1	W42.1	Primary total prosthetic replacement of knee joint NEC
Arthroplasty	W42.8	W42.8	W42.8	W42.8	Other specified other total prosthetic replacement of kneedoint
Arthroplasty	W42.9	W42.9	W42.9	W42.9	Unspecified other total prosthetic replacement of knee jowat
Arthroplasty*	W58.1	W58.1	W58.1	W58.1	Primary resurfacing arthroplasty of joint 8

*: Additional site-specific knee code required (Z846, Z765, Z845, Z844, Z774, or Z787)

