



Factors associated with use of antibiotic prophylaxis following dental procedures in total joint replacement recipients

Jeffrey N. Katz^{*}, Zoey S. Song, Elizabeth E. Stanley, Nora K. Lenhard, Genevieve S. Silva, Angela Chen, Thomas S. Thornhill, Jeffrey Lange, Jamie E. Collins, Faith Selzer, Elena Losina

Orthopaedic and Arthritis Center for Outcomes Research, Department of Orthopedic Surgery and Division of Rheumatology, Immunity and Inflammation, Brigham and Women's Hospital, Harvard Medical School and the Department of Biostatistics, Boston University School of Public Health, United States

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ABSTRACT

Background: Total joint replacement recipients (TJR) are at risk for prosthetic joint infection (PJI), particularly those with comorbidities such as diabetes mellitus (DM) and rheumatoid arthritis (RA).

Methods: We mailed surveys to 1078 subjects undergoing primary TJR between 2011 and 2016 at an academic center. The survey asked about medical, dental, and orthopedic history and use of antibiotics prior to dental appointments. We generated adjusted relative risks (aRR) for using antibiotic prophylaxis less than always using Poisson regression, adjusting for demographic, clinical, and behavioral factors.

Results: We received surveys from 639 subjects; 597 were eligible and formed the analytical sample. 66 % reported always using antibiotic prophylaxis. DM and RA were not associated with prophylaxis use. Factors associated with less frequent use included: BMI ≥ 30 (aRR = 1.27, 95 % CI [1.01, 1.60]), dental cleanings < 2 times/year (aRR = 1.95, 95 % CI [1.56, 2.43]), and expressing little concern (compared to neutral) about getting PJI (aRR = 1.23, 95 % CI [0.97, 1.55]), though this association was not statistically significant. Greater antibiotic use was reported in subjects who had ≥ 3 TJRs, (aRR = 0.48, 95 % CI [0.29, 0.80]), underwent more invasive dental procedures (aRR = 0.74, 95 % CI [0.59, 0.93]), and were concerned (vs. neutral) about PJI (aRR = 0.53, 95 % CI [0.33, 0.84]).

Conclusions: Two-thirds of TJR recipients in an academic center reported always using antibiotic prophylaxis prior to dental visits. Usage rates varied by demographics, BMI, number of TJRs, type of dental procedure, and behavioral factors – but not by comorbidities associated with higher PJI risk.

1. Introduction

Over 7 million individuals in the US are currently living with a total hip or knee replacement [1], and at risk for prosthetic joint infection (PJI), a serious, costly complication of total joint replacement (TJR). PJI may result from local seeding perioperatively or post-operative hematogenous bacterial seeding. For decades, clinicians have prescribed antibiotics to TJR recipients prior to dental appointments to prevent dental-related bacteremia from causing PJI [2,3]. However, evidence to support this practice is limited. Recent studies have found little association between dental procedures and PJI [4,5]. Although invasive dental procedures create transient bacteremia, so do everyday activities, such as flossing [6,7]. Moreover, prophylactic antibiotic use is associated with adverse events [8], [9] has contributed to antibiotic resistance [10],

and is estimated to cost between \$11 and \$44 million annually in the US [11]. In light of this evidence, the American Dental Association (ADA) recommended against prophylactic antibiotic use by TJR recipients in 2014 [12]. In 2016, the American Academy of Orthopedic Surgeons recommended antibiotic prophylaxis only among patients at high risk of infection (due to poor glycemic control or immunocompromising comorbidities) when undergoing invasive dental procedures, defined as those involving manipulation of gingival or periapical tissue or perforation of oral mucosa [13].

Given decades of changing recommendations [12], [14–16] we envisioned there might be confusion among patients and providers about appropriate prophylaxis practices. Indeed, a 2015 survey of orthopedic surgeons and dentists in Nebraska found that while 81 % were aware of the ADA recommendations, 92 % of orthopedic surgeons and 75 % of

^{*} Corresponding author. Orthopaedic and Arthritis Center for Outcomes Research, Department of Orthopaedic Surgery, Brigham and Women's Hospital, 75 Francis Street, BTM 5016, Boston, MA, 02115, United States.

E-mail address: jnkatz@bwh.harvard.edu (J.N. Katz).

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general dentists reported they would continue to recommend antibiotic use prior to an invasive dental procedure [17]. Surveys of Australian and Canadian providers similarly found that a majority of surgeons prescribed antibiotics before dental procedures [18,19]. While these surveys focused on physician prescription patterns, there is a paucity of literature examining TJR recipients' reported use of pre-dental antibiotic utilization. Such data cannot be obtained from administrative data or from surveying physicians directly. Given these considerations, we sought to fill the gap by surveying TJR recipients to better understand patient practices with respect to prophylactic antibiotic use prior to dental procedures. Thus, we surveyed TJR recipients to determine utilization of antibiotics prior to dental visits; to identify factors associated with degree of antibiotic use; and to determine whether patients with diabetes mellitus (DM) and rheumatoid arthritis (RA), which elevate risk of PJI, are more likely to take antibiotics prior to dental visits.

2. Methods

2.1. Participants

We conducted a survey of TJR recipients at Brigham and Women's Hospital. We searched the institution's Research Patient Data Registry (RPDR) for patients who underwent primary total hip or knee replacement between 2011 and 2016, identified by ICD-10 codes OSRC, OSRD, OSR9 and OSRB or ICD-9 codes 81.51 and 81.54. Our sampling scheme was based on primary TJR and not revision surgeries to reduce the likelihood that subjects had prior experience with PJI.

Because DM and RA confer higher risk of PJI and are frequent comorbidities among TJR recipients, we oversampled TJR recipients with codes for these conditions (DM with ICD-10 codes E10 and E11; RA with ICD-10 codes M05 and M06). While 12 % of TJR recipients in the study period had codes for DM and 5 % had codes for RA, we over sampled to select 17 % with codes for DM, 17 % with codes for RA, and the remainder with neither condition. We confirmed in the electronic medical record that the surgery for each subject fell within the correct timeframe and that it was a primary surgery. We excluded patients that did not meet these criteria; there were no other exclusions.

Recruitment was conducted in waves between May 2018 and February 2020. We sent eligible participants letters that explained the rationale of the survey and offered the opportunity to opt out. Subjects who did not opt out were either mailed a copy of the survey or sent an online survey, according to their preference. We called those who did not respond to the survey up to three times. Participants received a blanket with the study logo or a \$15 gift card to thank them. The Partners HealthCare Human Subjects Committee approved the study protocol.

2.2. Data collection

We developed a 12-page survey that asked participants about history of joint replacements, diagnoses of DM and RA, dental history, use of antibiotics before dental appointments, and beliefs about antibiotics. The survey also contained the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) pain scale, the five-item Mental Health Inventory (MHI-5) [20], and questions about demographic information.

We completed a medical record review of all participants who returned the survey to capture additional demographic information and medical history documented prior to the TJR, including DM and RA.

2.3. Primary outcome

The study's primary analytic outcome was self-reported antibiotic prophylaxis prior to dental procedures and was derived from responses to the survey question: "How often have you used antibiotics before dental visits?" Responses were never, less than half of dental visits, more than half of dental visits, and always. We defined our primary outcome as "Not

Always" vs. "Always" and included "Ever" vs. "Never" as a secondary outcome.

2.4. Covariates

We categorized study participant characteristics into three domains: demographic, clinical, and behavioral. The demographic domain included participants' age at survey, sex, highest educational degree, self-reported race/ethnicity (Non-Hispanic White or Other), and year of receiving their first TJR procedure.

The clinical domain included whether participants had RA (with or without DM), DM only, or neither RA nor DM. We did not look separately at participants with both DM and RA because this category was sparsely populated. The clinical domain also included body mass index (BMI), type of TJR (e.g. total knee replacement (TKR) or total hip replacement (THR)), number of primary TJRs, whether they had revision TJR, and history of hospitalization for infection. We also asked what dental procedures patients had received since their TJR and classified the invasiveness of each procedure based on its bleeding risk ("high" if subjects reported one or more root canal, dental implant placement, or tooth extraction; "intermediate" if subjects reported one or more cavity filling, bridge placement, dental crown, or orthodontics but none of the "high" risk procedures; and "low" if subjects had none of the "high" or "intermediate" procedures. We had three sources of data on whether the respondent had RA or DM: questionnaires, the electronic medical record, and ICD-10 codes in the RPDR. We considered patients to have RA or DM if the condition was either listed as an ICD-10 code or noted in the medical record. We also included those who self-reported use of insulin as having DM even if DM was not explicitly noted in the medical record.

The behavioral domain included self-reported teeth cleaning frequency ("How often do you typically go to the dentist's office for routine teeth cleaning?"); concern about PJI ("How much do you agree with the following statement: I worry about getting an infection in my prosthetic knee or hip?"); and perception of antibiotic prophylaxis benefits ("Do you think taking antibiotics before dental procedures does more harm than good, or more good than harm?").

2.5. Statistical analysis

Descriptive statistics for the overall cohort were presented as numbers and percentages. We used χ^2 and Fisher's exact tests to compare categorical variables across prophylaxis groups. To provide further description of attitudes toward antibiotics, we compared features of respondents who reported they felt antibiotics did more harm than good and those who felt antibiotics did good than harm.

We used Poisson regression modeling with robust error variance to generate adjusted Relative Risk (aRR) estimates and confidence intervals (95 % CI) for the primary outcome: Not Always vs. Always use of antibiotic prophylaxis. We adjusted for covariates by (1) developing domain-specific models that included variables in the demographic, clinical, and behavioral domains; (2) creating a global (across each domain) model by combining variables that were associated with outcome at $\alpha = 0.15$ in each of the three domain-specific models; and (3) developing a parsimonious final analysis using a criterion of $\alpha = 0.15$ to stay in the model. We implemented the same analytical strategy for the secondary outcome (Ever vs. Never use of antibiotic prophylaxis). We included the RA and DM variables in the global model because we had hypothesized a priori that these variables would be associated with prophylaxis use. Because few subjects had both RA and DM, we included these subjects in the RA group.

2.6. Sample size

We sought a sample of 600 subjects, of whom 17 % had DM, 17 % RA (with or without DM), and the remainder neither comorbidity. This

sample size provided 80 % power to detect whether the anticipated 33 % of subjects with RA or DM were 33 % less likely (i.e. risk ratio of 0.67) to report lower use of prophylaxis than those without these conditions. We selected TJR recipients randomly from the RPDR database, stratifying by RA and DM so that each wave was comprised of 17 % with RA, 17 % with DM and the remainder with neither comorbidity. We sent waves of surveys iteratively until 600 eligible subjects returned questionnaires.

All analyses were performed using SAS 9.4 statistical software (SAS Institute Inc., Cary, NC).

3. Results

3.1. Analytical sample

Of 1462 subjects sampled (Fig. 1), 296 were excluded because the procedure they received was not a primary TKR or THR leaving 1166 letters sent to potential study subjects, of which 88 were never received or returned unopened. We sent surveys to 1078 subjects and received survey responses from 639 (59.3 %). The primary outcome variable was

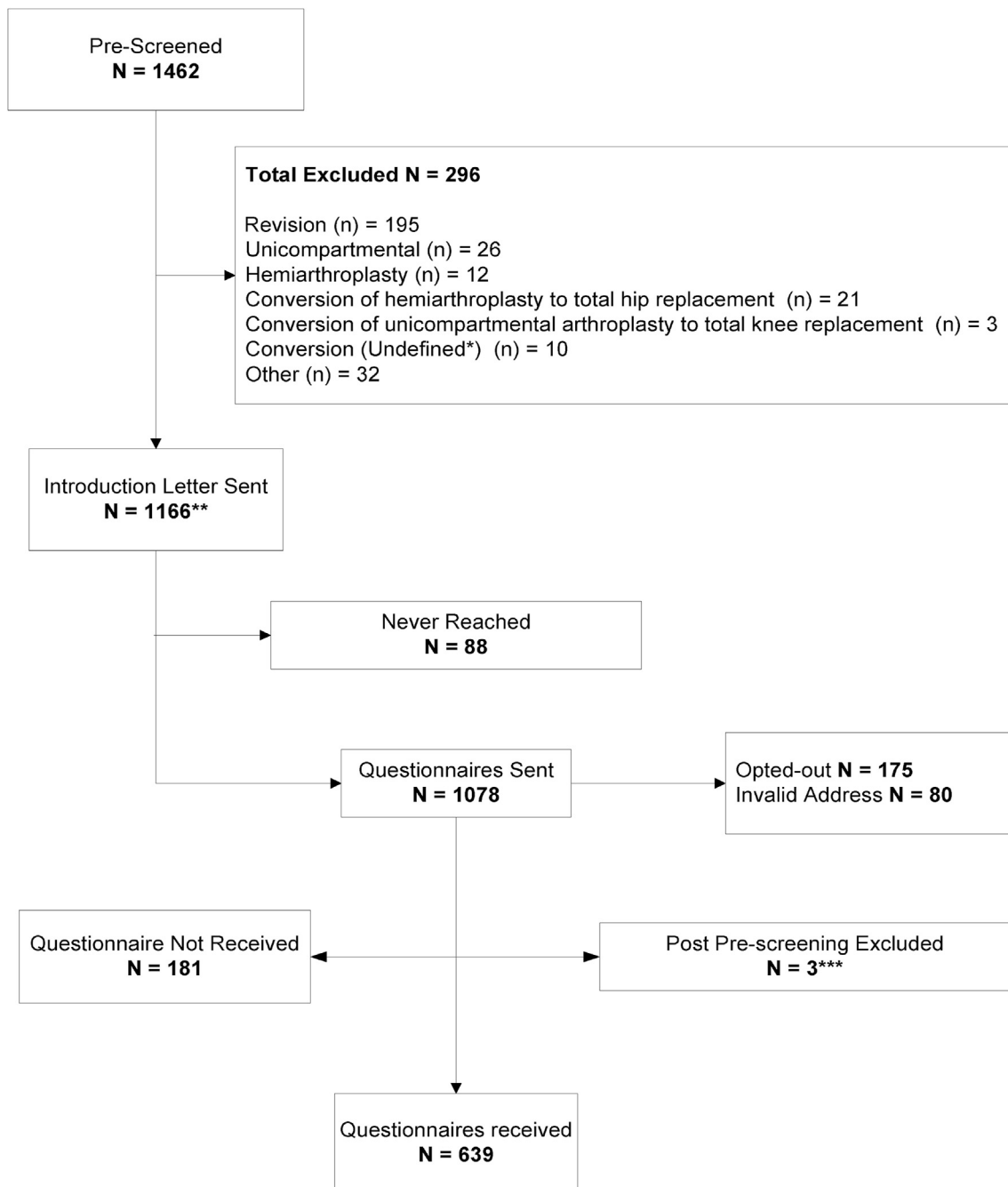


Fig. 1. Legend: Diagram showing the flow of subjects. *: Undefined means either conversion of hemiarthroplasty to total hip replacement or conversion of unicompartmental arthroplasty to total knee replacement. **: Including N = 2 people not receiving introduction letters until questionnaires sent due to protocol deviation. ***: N = 3 people excluded for having revision rather than primary joint replacement surgery. Note: We included N = 597 patients in the final analytical sample from whose questionnaire responses contains complete information regarding dental antibiotic prophylaxis use.

not reported by 42 respondents, leaving 597 subjects (55.4 % of surveys sent) eligible for the final analysis. We did not include subjects with missing covariate data in the multivariate analyses, leaving 540 subjects in these models. The prevalence of RA and DM were similar between responders and non-responders to the survey. Among responders, those that qualified for the final analytic sample were similar in age and BMI to those that did not.

The sample included 283 (47 %) primary THR recipients and 314 (53 %) primary TKR recipients (Table 1). 51 % underwent their primary TJR procedure during the 2011–2013 timeframe while 49 % participants received their primary TJR between 2014 and 2016. Our sample included 396 (66 %) subjects with neither RA nor DM, 97 (16 %) with RA (with or without DM), and 104 (17 %) with DM only. The mean (SD) age of our study sample was 71 (10), and the mean BMI at time of surgery was 31 (7) kg/m². 60 % of subjects were female and 88 % non-Hispanic White. Many participants had other primary or revision TJRs in addition to the procedure that resulted in their being selected. Seventy-five subjects (13 %) had three or more primary or revision TJRs and 66 (11 %) had at least one revision TJR. Most participants (N = 438, 73 %) in our study reported they routinely undergo dental cleanings at least twice a year.

3.2. Dental antibiotic prophylaxis utilization among TJR recipients

The majority of participants (n = 393, 66 %) reported always using antibiotic prophylaxis for dental procedures (Table 1). Sixty participants (10 %) reporting using prophylaxis more than half the time, but not always; 74 (12 %) reported less than half the time; and 70 (12 %) reported never using prophylactic antibiotics for dental procedures. We dichotomized the 4-level survey responses to Not Always vs. Always for the primary analysis. Table 1 provides descriptive data on Not Always vs. Always use of prophylactic antibiotics according to demographic, clinical, and behavioral characteristics. Patients with RA, DM or both conditions did not report a higher use of prophylactic antibiotics in our sample, with 63 % of those with RA (with or without DM), 63 % of those with DM only, and 67 % of those with neither condition reporting Always using antibiotics.

Those self-reported as Non-Hispanic White, and with college education, BMI < 30, and TJR in the later sampling period (2014–2016) were more likely to report Always using antibiotic prophylaxis (Table 1). Similarly, participants undergoing at least 3 primary TKR/THR surgeries and those without a history of hospitalization for an infection in the past 6 years were more likely to report Always using antibiotic prophylaxis. Participants who reported undergoing dental procedures with intermediate or high bleeding risk, or receiving dental cleanings more than twice a year, were also more likely to Always use antibiotic prophylaxis. Finally, participants who expressed worry about getting PJI after their TJR surgery and those who perceived prophylactic antibiotics as doing more good than harm were more likely to endorse Always use antibiotic prophylaxis.

3.3. Multivariate analysis

Domain-specific models (Table 2) revealed that among demographic factors, self-reported race/ethnicity and year of receiving the first primary TJR were associated with antibiotic prophylactic use. BMI, number of TJRs received, and bleeding risk of dental procedure were related to antibiotic use in the clinical model. Routine teeth cleaning frequency and concerns about infection of prosthetic joints were associated with antibiotic use in the behavioral model. These variables were then entered into the global model. The question about whether prophylactic antibiotics do more harm than good is somewhat tautologous to the primary outcome; therefore, we examined this variable descriptively (see below) but did not enter it into the models. A variable combining RA and DM (one or the other vs. neither) was entered in the global model to test our hypothesis that participants with these conditions would be more likely

Table 1

Patient characteristics by dental antibiotic prophylaxis use (always/not always).

	All N = 597	Always use antibiotics N = 393	Not always use antibiotics N = 204
	N	N (%)	N (%)
Age at Survey	80	50 (62.50)	30 (37.50)
≤ 60			
60–65	67	43 (64.18)	24 (35.82)
65–70	122	84 (68.85)	38 (31.15)
70–75	146	99 (67.81)	47 (32.19)
> 75	181	116 (64.09)	65 (35.91)
Unknown	1	1 (100.00)	0 (0)
Sex			
Female	360	239 (66.39)	121 (33.61)
Male	228	149 (65.35)	79 (34.65)
Unknown	9	5 (55.56)	4 (44.44)
Education			
High School or Less	94	53 (56.38)	41 (43.62)
Some College/Associates	179	114 (63.69)	65 (36.31)
Degree			
Collegiate Degrees	317	223 (70.35)	94 (29.65)
Unknown	7	3 (42.86)	4 (57.14)
Non-Hispanic White			
No	53	24 (45.28)	29 (54.72)
Yes	528	359 (67.99)	169 (32.01)
Unknown	16	10 (62.50)	6 (37.50)
Year Category	304	187 (61.51)	117 (38.49)
2011–2013			
2014–2016	293	206 (70.31)	87 (29.69)
Number of TKR/THR Procedures	522	331 (63.41)	191 (36.59)
1–2 TKR/THR			
≥ 3 TKR/THR	75	62 (82.67)	13 (17.33)
TKR/THR Revision	531	347 (65.35)	184 (34.65)
No Knee/Hip Revision			
Had Knee/Hip Revision	66	46 (69.70)	20 (30.30)
BMI (kg/m ²)	110	80 (72.73)	30 (27.27)
< 25			
25–30	194	132 (68.04)	62 (31.96)
30–35	150	91 (60.67)	59 (39.33)
35–40	72	46 (63.89)	26 (36.11)
≥ 40	67	41 (61.19)	26 (38.81)
Unknown	4	3 (75.00)	1 (25.00)
Comorbidities	396	267 (67.42)	129 (32.58)
Neither RA nor DM			
RA (w/or w/o DM)	97	61 (62.89)	36 (37.11)
DM only	104	65 (62.50)	39 (37.50)
TJR Surgery Type	283	192 (67.84)	91 (32.16)
THR			
TKR	314	201 (64.01)	113 (35.99)
Infection in the last 6 years that required hospitalization?	518	348 (67.18)	170 (32.82)
No			
Yes	79	45 (56.96)	34 (43.04)
Bleeding level of Dental Procedure			
Low	192	104 (54.17)	88 (45.83)
Intermediate	151	108 (71.52)	43 (28.48)
High	243	172 (70.78)	71 (29.22)
Unknown	11	9 (81.82)	2 (18.18)
Routine teeth cleaning frequency			
Never or < 2 times/year	152	66 (43.42)	86 (56.58)
≥ 2 times/year	331	238 (71.90)	93 (28.10)
> 2 times/year	107	85 (79.44)	22 (20.56)
Unknown	7	4 (57.14)	3 (42.86)
Do you think taking antibiotics before dental procedures does more harm than good, or more good than harm?			
More harm than good	28	13 (46.43)	15 (53.57)
More good than harm	288	231 (80.21)	57 (19.79)
I don't know	263	143 (54.37)	120 (45.63)
Unknown	18	6 (33.33)	12 (66.67)
Worry about getting infection in prosthetic knee or hip			

(continued on next page)

Table 1 (continued)

	All N = 597	Always use antibiotics N = 393	Not always use antibiotics N = 204
Strongly/Agree	100	82 (82.00)	18 (18.00)
Neutral	165	110 (66.67)	55 (33.33)
Disagree	148	97 (65.54)	51 (34.46)
Strongly disagree	167	98 (58.68)	69 (41.32)
Unknown	17	6 (35.29)	11 (64.71)

RA = rheumatoid arthritis; DM = diabetes mellitus; TKR = total knee replacement; THR = total hip replacement.

*: Bleeding level of dental procedure is **Intermediate** if patients have had one or more of the less bloody procedures (Cavity filling, Bridge placement, Dental crown, Orthodontics) but none of the more bloody procedures (Root canal, Dental implant placement, Tooth extraction); **High** if patients have had one or more of the bloody procedures (Root canal, Dental implant placement, Tooth extraction); **None** if they have had none of these procedures.

to use prophylactic antibiotics. The adjusted relative risk for the combined RA or DM variable was 1.09 (95 % CI 0.86, 1.38), indicating that these conditions did not have a clinically meaningful or statistically significant association with prophylactic antibiotic use.

In the final parsimonious model, we found that patients who underwent a primary TJR during 2011–2013 (aRR = 1.44, 95 % CI [1.15, 1.81]), had a BMI ≥ 30 kg/m² (aRR = 1.27, 95 % CI [1.01, 1.60]), underwent teeth cleanings < 2 times per year (aRR = 1.95, 95 % CI [1.56, 2.43]), and did not worry about PJI (aRR = 1.23, 95 % CI [0.97, 1.55]) were more likely to report Not Always using antibiotic prophylaxis for dental procedures (though the effect of ‘did not worry’ was not statistically significant; Table 2). Furthermore, compared to patients who identified as non-Hispanic White, other race/ethnicity groups in our study sample were more likely to report Not Always using antibiotic prophylaxis, although this difference was not statistically significant (aRR = 1.34, 95 % CI [0.99, 1.81]). Several features were associated with a lower likelihood of participants’ reporting Not Always using antibiotics,

Table 2

Adjusted Relative Risk (aRR) of Not Always vs. Always use of Dental Antibiotic Prophylaxis (DAP).

	Adjusted Relative Risk (aRR) [95 % CI] Not Always Use DAP vs. Always Use DAP Demographic Model	P-value	Adjusted Relative Risk (aRR) [95 % CI] Not Always Use DAP vs. Always Use DAP Global Model	P-value	Adjusted Relative Risk (aRR) [95 % CI] Not Always Use DAP vs. Always Use DAP Parsimonious Model	P-value
Year	1.38 [1.08, 1.76]	0.0095	1.44 [1.14, 1.80]	0.0019	1.44 [1.15, 1.81]	0.0017
2011–2013	Ref		Ref		Ref	
2014–2016						
Race & Ethnicity	1.49 [1.06, 2.10]	0.0538	1.34 [0.99, 1.82]	0.0935	1.34 [0.99, 1.81]	0.0965
Other	Ref		Ref		Ref	
Non- Hispanic White						
Age	Ref	0.8457				
≤ 70	1.02 [0.80, 1.31]					
> 70						
Sex	Ref	0.5404				
Female	1.08 [0.85, 1.38]					
Male						
Education	Ref	0.3867				
High School or less	1.01 [0.72, 1.44]					
Some college/Associate	0.85 [0.61, 1.19]					
Collegiate Degree						
Clinical model						
Comorbidity	Ref	0.4066	Ref	0.4308		
Neither RA nor DM	1.11 [0.87, 1.43]		1.10 [0.87, 1.38]			
RA/DM or Both						
Number of TJRs	Ref	0.0012	Ref	0.0003	Ref	0.0003
≤ 2	0.48 [0.27, 0.83]		0.48 [0.29, 0.80]		0.48 [0.29, 0.80]	
≥ 3						
BMI (kg/m ²)	Ref	0.0368	Ref	0.0529	Ref	0.0378
< 30	1.29 [1.02, 1.65]		1.26 [1.00, 1.58]		1.27 [1.01, 1.60]	
≥ 30						
History of Hospitalization for Infection	Ref	0.2412				
No	1.22 [0.89, 1.67]					
Yes						
Bleeding level of Dental Procedure*	Ref	0.0012	Ref	0.0105	Ref	0.0114
Low	0.66 [0.53, 0.84]		0.74 [0.59, 0.93]		0.74 [0.59, 0.93]	
Intermediate or high						
Surgery type	1.04 [0.82, 1.32]	0.7566				
Total knee replacement	Ref					
Total hip replacement						
Revision of Procedure	0.87 [0.56, 1.34]	0.4919				
Yes	Ref					
No						
Behavioral model						
Routine Teeth Cleaning Frequency	2.14 [1.72, 2.67]	$< .0001$	1.95 [1.56, 2.43]	$< .0001$	1.95 [1.56, 2.43]	$< .0001$
Never or < 2 times/yr	Ref		Ref		Ref	
≥ 2 times/yr						
Worry about getting infection in prosthetic knee or hip	0.53 [0.33, 0.85]	0.0003	0.53 [0.34, 0.85]	0.0003	0.53 [0.33, 0.84]	0.0003
Strongly/Agree	Ref		Ref		Ref	
Neutral/Disagree	1.24 [0.98, 1.57]		1.23 [0.97, 1.55]		1.23 [0.97, 1.55]	
Strongly Disagree						

DAP: Dental Antibiotic Prophylaxis. RA = rheumatoid arthritis; DM = diabetes mellitus; TKR = total knee replacement; THR = total hip replacement.

including receiving ≥ 3 TJR procedures (aRR = 0.48, 95 % CI [0.29, 0.80]), undergoing invasive dental procedures with moderate or high risk of bleeding (aRR = 0.74, 95 % CI [0.59, 0.93]), and being concerned about getting a PJI (aRR = 0.53, 95 % CI [0.33, 0.84]).

3.4. Secondary analysis

A total of 527 (88 %) participants reported Ever using antibiotic prophylaxis prior to dental visits (Appendix Table 1). We did not observe an association between having RA/DM or both conditions and Never using prophylactic antibiotics. We found that subjects who did not worry about getting a PJI (aRR = 1.49, 95 % CI [0.89, 2.50]) were more likely to report Never using antibiotic prophylaxis for dental visits, (though 'did not worry' was not statistically significant) as were subjects with BMI ≥ 40 kg/m² (aRR = 1.95 [1.17, 3.24]). Further, subjects who never or infrequently had teeth cleanings had a 4-fold higher probability of reporting Never using antibiotic prophylaxis than patients who reported ≥ 2 teeth cleanings annually (aRR = 4.11, 95 % CI [2.41, 7.04]). College education level vs. high school or less (aRR = 0.57, 95 % CI [0.34, 0.96]), receiving ≥ 3 TJR procedures (aRR = 0.12, 95 % CI [0.02, 0.90]), having dental procedures with intermediate or high bleeding risk (aRR = 0.41, 95 % CI [0.24, 0.70]), and worrying about getting a PJI (aRR = 0.33, 95 % CI [0.08, 1.36]) were associated with a lower likelihood of Never using antibiotic prophylaxis (Appendix Table 2).

In relation to dental care, only 5 % of subjects reported they thought prophylactic antibiotics did more harm than good, 49 % thought they did more good than harm, and 48 % indicated they did not know if antibiotics did more good than harm (Appendix Table 3). Those with a college education were more likely to report that antibiotics did more good than harm compared to those with high school education or less (52 % vs. 41 %; Appendix Table 2). Similarly, those who underwent \geq three TJRs were more likely to report that prophylactic antibiotics did more good than harm, compared to those with $<$ three TJRs (61 % vs. 46 %). Those who underwent \geq two teeth cleanings on an annual basis and those who worried more about PJI were also more likely to report that prophylactic antibiotics did more good than harm. Finally, TJR recipients with RA were somewhat more likely to report that antibiotics did more good than harm.

4. Discussion

We assessed prophylactic antibiotic use for dental visits among 597 recipients of primary TKR or THR at a major medical center. Two-thirds indicated they always use prophylactic antibiotics prior to dental visits. We found that subjects who received multiple TJR surgeries, underwent invasive dental procedure(s), and who had greater worry about getting PJI versus those who were neutral were more likely to always use antibiotic prophylaxis consistently while subjects who did not regularly receive routine dental cleanings were less likely to always use antibiotic prophylaxis. We also found less frequent antibiotic prophylaxis use among subjects who received their primary TJR in the earlier study period (2011–2013) and among patients who were obese (BMI ≥ 30) at the time of surgery. We did not detect a meaningful relationship between either RA or DM use of antibiotic prophylaxis.

The interpretation of these findings is complex because the ADA and the AAOS provided conflicting and changing guidelines in the last decade. The AAOS changed its recommendation in the last decade from recommending routine prophylaxis among TJR recipients to recommending it only in the setting of factors that raise the risk of PJI, while the ADA changed its recommendation from recommending prophylaxis in the setting of increased infection risk to not recommending prophylaxis at all. To place these findings in an international perspective, authoritative bodies in Canada, New Zealand, Australia and the Netherlands do not recommend prophylactic antibiotics prior to dental procedures in persons with prosthetic joint infections [21–25]. These recommendations are based on the paucity of data demonstrating the dental

procedures are important risk factors for PJI.

Surveys of orthopedic surgeons and dentists suggest these professionals use prophylaxis selectively, including for subjects perceived to be at higher risk of PJI because of comorbid conditions. We are not certain which provider types (orthopedist, dentist, primary care provider, other) prescribed the antibiotics in subjects who used prophylaxis. Further, economic analyses suggest that antibiotic prophylaxis prior to dental procedures among TJR recipients may be cost-effective for those at higher risk of infection, such as those with DM and other conditions that predispose to infection [26,27].

In the context of these changing recommendations, we did not anticipate uniformity in use of prophylaxis. Indeed, use varied with two thirds always using prophylaxis.

We did anticipate that antibiotic prophylaxis would be more frequent in subjects with either RA or DM, but found that these comorbidities were not associated with use of prophylaxis. Clinicians who wish to encourage potentially at-risk individuals to use prophylactic antibiotics might further focus their efforts on those with characteristics found in this analysis to be associated with lower use of prophylactic antibiotics, including obesity, non-Hispanic White race/ethnicity, less frequent dental cleanings, a single TJR, and less worry about the risk of PJI. The finding that half of participants did not know whether prophylactic antibiotics do more harm than good may reflect the uncertainty in the professional community around this problem as well as lack of education of TJR recipients about this important question.

We acknowledge several limitations. The validity of self-reported use of prophylactic antibiotics is uncertain. With a 59.3 % survey response rate, it is conceivable that our estimates of prophylactic antibiotic use are not representative of the full sample. The study was performed in a single academic center, and we acknowledge that recommendations for prophylactic antibiotics may be different from those treated in the community. The subjects had surgery between 2011 and 2016. We deliberately sampled subjects who would be several years out from their surgeries at the time of the survey to permit insight into whether patients who had more recent TJR were more likely to use antibiotic prophylaxis than those with more remote surgery. But we acknowledge that clinicians' practice preferences regarding prophylaxis may also have changed over the intervening years, especially as the ADA and AAOS recommendations were published in 2014 and 2016 respectively. We did not adjust the overall estimate of prophylaxis use to account for oversampling of subjects with RA or DM because these conditions were not associated with use.

We conclude that about two-thirds of TJR recipients always use prophylactic antibiotics prior to dental procedures and 88 % use them some of the time. Recipients at higher risk of TJR, including those with RA and DM, do not use prophylaxis any more than those without these comorbidities. Targeting factors associated with less frequent use may help to increase use of prophylactic antibiotics in patients at increased risk of PJI following invasive dental procedures.

Authorship

All authors should have made substantial contributions to all of the following: (1) the conception and design of the study, or acquisition of data, or analysis and interpretation of data, (2) drafting the article or revising it critically for important intellectual content, (3) final approval of the version to be submitted. By signing below each author also verifies that he (she) confirms that neither this manuscript, nor one with substantially similar content, has been submitted, accepted or published elsewhere (except as an abstract). Each manuscript must be accompanied by a declaration of contributions relating to sections (1), (2) and (3) above. This declaration should also name one or more authors who take responsibility for the integrity of the work as a whole, from inception to finished article. These declarations will be included in the published manuscript.

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Declaration of competing interest

At the end of the text, under a subheading “Conflict of interest statement” all authors must disclose any financial and personal relationships with other people or organisations that could inappropriately influence (bias) their work. Examples of potential conflicts of interest include employment, consultancies, stock ownership, honoraria, paid expert testimony, patent applications/registrations, and research grants or other funding.

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Role of the funding source

Authors should declare the role of study sponsors, if any, in the study design, in the collection, analysis and interpretation of data; in the writing of the manuscript; and in the decision to submit the manuscript for publication. If the study sponsors had no such involvement, the authors should state this.

Studies involving humans or animals

Clinical trials or other experimentation on humans must be in accordance with the ethical standards of the responsible committee on

human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000. Randomized controlled trials should follow the Consolidated Standards of Reporting Trials (CONSORT) guidelines and be registered in a public trials registry.

Studies involving experiments with animals were in accordance with institution guidelines.

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Author contributions

Conception and design: Katz, Collins, Selzer, Losina • Analysis and interpretation of the data: Song, Katz, Collins, Selzer, Losina • Drafting of the article: Katz • Critical revision of the article for important intellectual content: all authors • Final approval of the article: all authors • Provision of study materials or patients: Thornhill • Statistical expertise: Collins, Losina • Obtaining of funding: Katz, Thornhill, Losina • Administrative, technical, or logistic support: Stanley, Lenhard, Silva, Chen, Selzer • Collection and assembly of data: Stanley, Lenhard, Silva, Chen, Song.

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Appendix Table 1 Patient Characteristics by Dental Antibiotic Prophylaxis Use (Ever/ Never)

	All (N = 597)		Ever Used Antibiotics N = 527		Never used antibiotics (N = 70)
	N		(%)	N	(%)
Age at Survey	80	69	(86.25)	11	(13.75)
≤ 60					
60–65	67	59	(88.06)	8	(11.94)
65–70	122	110	(90.16)	12	(9.84)
70–75	146	134	(91.78)	12	(8.22)
> 75	181	154	(85.08)	27	(14.92)
Unknown	1	1	(100.00)	0	(0)
Sex					
Female	360	310	(86.11)	50	(13.89)
Male	228	210	(92.11)	18	(7.89)
Unknown	9	7	(77.78)	2	(22.22)
Education					
High School or less	94	70	(74.47)	24	(25.53)
Some College/Associates degree	179	157	(87.71)	22	(12.29)
Collegiate Degrees	317	295	(93.06)	22	(6.94)
Unknown	7	5	(71.43)	2	(28.57)
Non-Hispanic White					
No	53	40	(75.47)	13	(24.53)
Yes	528	473	(89.58)	55	(10.42)
Unknown	16	14	(87.50)	2	(12.50)
Year Category					
2011–2013	304	273	(89.80)	31	(10.20)
2014–2016	293	254	(86.69)	39	(13.31)
Number of TKR/THR Procedures					

(continued on next page)

Appendix Table 1 (continued)

	All (N = 597)		Ever Used Antibiotics N = 527		Never used antibiotics (N = 70)
	N	N	(%)	N	(%)
1–2 TKR/THR	522	454	(86.97)	68	(13.03)
≥3 TKR/THR	75	73	(97.33)	2	(2.67)
TKR/THR Revision					
No Knee/Hip Revision	531	471	(88.70)	60	(11.30)
Had Knee/Hip Revision	66	56	(84.85)	10	(15.15)
BMI (kg/m ²)					
< 25	110	102	(92.73)	8	(7.27)
25–30	194	171	(88.14)	23	(11.86)
30–35	150	137	(91.33)	13	(8.67)
35–40	72	63	(87.50)	9	(12.50)
≥40	67	51	(76.12)	16	(23.88)
Unknown	4	3	(75.00)	1	(25.00)
Comorbidities					
Neither RA nor DM	396	357	(90.15)	39	(9.85)
RA (w/or w/o DM)	97	83	(85.57)	14	(14.43)
DM only	104	87	(83.65)	17	(16.35)
TJR Surgery Type					
THR	283	251	(88.69)	32	(11.31)
TKR	314	276	(87.90)	38	(12.10)
Infection in the last 6 years that required hospitalization?					
No	518	458	(88.42)	60	(11.58)
Yes	79	69	(87.34)	10	(12.66)
Bleeding level of Dental Procedure					
Low	192	147	(76.56)	45	(23.44)
Intermediate	151	142	(94.04)	9	(5.96)
High	243	229	(94.24)	14	(5.76)
Unknown	11	9	(81.82)	2	(18.18)
Routine teeth cleaning Frequency					
Never or < 2 times/year	152	108	(71.05)	44	(28.95)
= 2 times/year	331	311	(93.96)	20	(6.04)
> 2 times/year	107	103	(96.26)	4	(3.74)
Unknown	7	5	(71.43)	2	(28.57)
Do you think taking antibiotics before dental procedures does more harm than good, or more good than harm?					
More harm than good	28	25	(89.29)	3	(10.71)
More good than harm	288	281	(97.57)	7	(2.43)
I don't know	263	210	(79.85)	53	(20.15)
Unknown	18	11	(61.11)	7	(38.89)
Worry about getting infection in prosthetic knee or hip					
Strongly/Agree	100	97	(97.00)	3	(3.00)
Neutral	165	149	(90.30)	16	(9.70)
Disagree	148	128	(86.49)	20	(13.51)
Strongly disagree	167	143	(85.63)	24	(14.37)
Unknown	17	10	(58.82)	7	(41.18)

*: Bleeding level of dental procedure is **Intermediate** if patients have had one or more of the less bloody procedures (Cavity filling, Bridge placement, Dental crown, Orthodontics) but none of the more bloody procedures (Root canal, Dental implant placement, Tooth extraction); **High** if patients have had one or more of the bloody procedures (Root canal, Dental implant placement, Tooth extraction); **Low** if they have had none of these procedures.

Appendix Table 2
Adjusted Relative Risk (aRR) of Never vs. Ever used Dental Antibiotic Prophylaxis (DAP)

	Adjusted Relative Risk (aRR) [95 % CI] Never Use DAP vs. Used DAP Demographic Model	P-value	Adjusted Relative Risk (aRR) [95 %CI] Never Use DAP vs. Used DAP Global Model	P-value	Adjusted Relative Risk (aRR) [95 %CI] Never Use DAP vs. Used DAP Most Parsimonious model	P-value
Year	0.78 [0.47, 1.31]	0.3507				
2011–2013	Ref					
2014–2016						
Race & Ethnicity	0.91 [0.39, 2.10]	0.8214				
Other	Ref					
Non- Hispanic White						
Age	Ref	0.5250				
≤ 70	0.85 [0.50, 1.41]					
> 70		0.0809		0.1473		

(continued on next page)

Appendix Table 2 (continued)

Sex	Ref		Ref			
Female	0.62 [0.35, 1.10]		0.69 [0.41, 1.17]			
Male						
Education	Ref	0.0187	Ref	0.1349	Ref	0.0706
High School or less	0.53 [0.29, 0.99]		0.59 [0.34, 1.03]		0.57 [0.34, 0.96]	
Some college/Associate	0.34 [0.18, 0.64]		0.53 [0.30, 0.96]		0.48 [0.27, 0.85]	
Collegiate Degree						
Clinical Model						
Comorbidity	Ref	0.1526	Ref	0.1176		
Neither RA nor DM	1.46 [0.90, 2.38]		1.49 [0.93, 2.37]			
RA/DM or Both						
Number of TJR	Ref	0.0002	Ref	0.0004	Ref	0.0006
≤ 2	0.14 [0.02, 0.97]		0.12 [0.02, 0.87]		0.12 [0.02, 0.90]	
≥ 3						
BMI (kg/m ²)	Ref	0.0088	Ref	0.0383	Ref	0.0331
< 40	2.84 [1.68, 4.78]		1.93 [1.15, 3.23]		1.95 [1.17, 3.24]	
≥ 40						
History of Hospitalized Infection	Ref	0.8044				
No	0.92 [0.46, 1.82]					
Yes						
Bleeding level of Dental Procedure*	Ref	<.0001	Ref	0.0013	Ref	0.0011
Low	0.25 [0.15, 0.43]		0.42 [0.24, 0.70]		0.41 [0.24, 0.70]	
Intermediate or high						
Surgery type	0.92 [0.57, 1.48]	0.7301				
TKR	Ref					
THR						
Revision of Procedure	1.44 [0.74, 2.81]	0.3547				
Yes	Ref					
No						
Behavioral model						
Routine Teeth Cleaning Frequency	5.70 [3.35, 9.68]	<.0001	4.21 [2.46, 7.22]	<.0001	4.11 [2.40, 7.04]	<.0001
Never or < 2 times/yr	Ref		Ref		Ref	
≥ 2 times/yr						
Worry about getting infection in prosthetic knee or hip	Ref	0.0004	Ref	0.0038	Ref	0.0042
Neutral	0.25 [0.06, 1.03]		0.37 [0.09, 1.50]		0.33 [0.08, 1.36]	
Strongly/Agree	1.37 [0.79, 2.38]		1.56 [0.93, 2.62]		1.49 [0.89, 2.50]	
Strongly/Disagree						

Note.

*DAP: Dental Antibiotic Prophylaxis.

**For interpreting purpose, we didn't include behavior/attitude variables in the Global Model.

Appendix Table 3
Factors associated with report of whether antibiotics did more good than harm

	All N = 597		More harm than good N = 28		More good than harm N = 295		I don't know N = 278	
	N	N	(%)	N	(%)	N	(%)	
<hr/>								
Age at Survey								
≤ 60	80	3	(3.75)	35	(43.75)	40	(50.00)	
60–65	67	2	(2.99)	31	(46.27)	33	(49.25)	
65–70	122	6	(4.92)	60	(49.18)	53	(43.44)	
70–75	146	8	(5.48)	82	(56.16)	50	(34.25)	
> 75	181	9	(4.97)	80	(44.20)	86	(47.51)	
Unknown	1	0	(0)	0	(0)	1	(100.00)	
Sex								
Female	360	12	(3.33)	182	(50.56)	154	(42.78)	
Male	228	15	(6.58)	105	(46.05)	105	(46.05)	
Unknown	9	1	(11.11)	1	(11.11)	4	(44.44)	
Education								
High School or less	94	1	(1.06)	39	(41.49)	50	(53.19)	
Some College/Associates degree	179	8	(4.47)	83	(46.37)	84	(46.93)	
Collegiate Degree	317	19	(5.99)	165	(52.05)	125	(39.43)	
Unknown	7	0	0	1	(14.29)	4	(57.14)	
Non-Hispanic White								
No	53	3	(5.66)	18	(33.96)	30	(56.60)	
Yes	528	24	(4.55)	264	(50.00)	227	(42.99)	
Unknown	16	1	(6.25)	6	(37.50)	6	(37.50)	
Year Category:								

(continued on next page)

Appendix Table 3 (continued)

	All N = 597		More harm than good N = 28		More good than harm N = 295		I don't know N = 278	
	N	N	(%)	N	(%)	N	(%)	
2011–2013	304	17	(5.59)	136	(44.74)	139	(45.72)	
2014–2016	293	11	(3.75)	152	(51.88)	124	(42.32)	
Number of TKR/THR Procedures								
1–2 TKR/THR	522	28	(5.36)	242	(46.36)	237	(45.40)	
≥ 3 TKR/THR	75	0	0	46	(61.33)	26	(34.67)	
TKR/THR Revision								
No Knee/Hip Revision	531	26	(4.90)	251	(47.27)	240	(45.20)	
Had Knee/Hip Revision	66	2	(3.03)	37	(56.06)	23	(34.85)	
BMI (kg/m ²)								
< 25	110	9	(8.18)	45	(40.91)	51	(46.36)	
25–30	194	6	(3.09)	98	(50.52)	87	(44.85)	
30–35	150	8	(5.33)	74	(49.33)	64	(42.67)	
35–40	72	1	(1.39)	40	(55.56)	30	(41.67)	
≥ 40	67	4	(5.97)	29	(43.28)	30	(44.78)	
Unknown	4	0	0	2	(50.00)	1	(25.00)	
Comorbidities	396	22	(5.56)	191	(48.23)	175	(44.19)	
Neither RA nor DM								
RA (w/or w/o DM)	97	4	(4.12)	53	(54.64)	36	(37.11)	
DM only	104	2	(1.92)	44	(42.31)	52	(50.00)	
Surgery Type:								
THR	283	11	(3.89)	130	(45.94)	134	(47.35)	
TKR	314	17	(5.41)	158	(50.32)	129	(41.08)	
Infection in the last 6 years that required hospitalization?								
No	518	23	(4.44)	256	(49.42)	224	(43.24)	
Yes	79	5	(6.33)	32	(40.51)	39	(49.37)	
Bleeding level of Dental Procedure								
Low	192	9	(4.69)	82	(42.71)	95	(49.48)	
Intermediate	151	6	(3.97)	81	(53.64)	61	(40.40)	
High	243	13	(5.35)	120	(49.38)	102	(41.98)	
Unknown	11	0	0	5	(45.45)	5	(45.45)	
Routine teeth cleaning Frequency								
Never or < 2 times/year	152	9	(5.92)	56	(36.84)	83	(54.61)	
= 2 times/year	331	13	(3.93)	175	(52.87)	135	(40.79)	
> 2 times/year	107	6	(5.61)	55	(51.40)	43	(40.19)	
Unknown	7	0	0	2	(28.57)	2	(28.57)	
Worry about getting infection in prosthetic knee or hip								
Strongly/Agree	100	3	(3.00)	62	(62.00)	34	(34.00)	
Neutral	165	5	(3.03)	76	(46.06)	83	(50.30)	
Disagree	148	8	(5.41)	62	(41.89)	71	(47.97)	
Strongly disagree	167	11	(6.59)	86	(51.50)	66	(39.52)	
Unknown	17	1	(5.88)	2	(11.76)	9	(52.94)	

RA = rheumatoid arthritis; DM = diabetes mellitus; TKR = total knee replacement; THR = total hip replacement.

*: Bleeding level of dental procedure is **Intermediate** if patients have had one or more of the less bloody procedures (Cavity filling, Bridge placement, Dental crown, Orthodontics) but none of the more bloody procedures (Root canal, Dental implant placement, Tooth extraction); **High** if patients have had one or more of the bloody procedures (Root canal, Dental implant placement, Tooth extraction); **None** if they have had none of these procedures.

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References

- [1] H. Maradit Kremers, D.R. Larson, C.S. Crowson, W.K. Kremers, R.E. Washington, C.A. Steiner, et al., Prevalence of total hip and knee replacement in the United States, *J Bone Joint Surg Am* 97 (2015) 1386–1397.
- [2] S.F. DeFroda, E. Lamin, J.A. Gil, K. Sindhu, S. Ritterman, Antibiotic prophylaxis for patients with a history of total joint replacement, *J. Am. Board Fam. Med.* 29 (2016) 500–507.
- [3] G.L. Lattimer, P.A. Keblish, T.B. Dickson Jr., C.G. Vernick, W.J. Finnegan, Hematogenous infection in total joint replacement. Recommendations for prophylactic antibiotics, *Jama* 242 (1979) 2213–2214.
- [4] E.F. Berbari, D.R. Osmon, A. Carr, A.D. Hanssen, L.M. Baddour, D. Greene, et al., Dental procedures as risk factors for prosthetic hip or knee infection: a hospital-based prospective case-control study, *Clin. Infect. Dis.* 50 (2010) 8–16.
- [5] D.D. Skaar, H. O'Connor, J.S. Hodges, B.S. Michalowicz, Dental procedures and subsequent prosthetic joint infections: findings from the Medicare Current Beneficiary Survey, *J. Am. Dent. Assoc.* 142 (2011) 1343–1351.
- [6] P.B. Lockhart, M.T. Brennan, H.C. Sasser, P.C. Fox, B.J. Paster, F.K. Bahrani-Mougeot, Bacteremia associated with toothbrushing and dental extraction, *Circulation* 117 (2008) 3118–3125.
- [7] L. Legout, E. Beltrand, H. Migaud, E. Senneville, Antibiotic prophylaxis to reduce the risk of joint implant contamination during dental surgery seems unnecessary, *Orthop Traumatol Surg Res* 98 (2012) 910–914.
- [8] R. Solensky, Allergy to β -lactam antibiotics, in: J.T. Li (Ed.), *Maintenance of Certification Clinical Management Series*. American Academy of Allergy, Asthma & Immunology, Corvallis Clinic, 2012.
- [9] M.H. Thornhill, M.J. Dayer, B. Prendergast, L.M. Baddour, S. Jones, P.B. Lockhart, Incidence and nature of adverse reactions to antibiotics used as endocarditis prophylaxis, *J. Antimicrob. Chemother.* 70 (2015) 2382–2388.
- [10] Centers for Disease Control, Antibiotic resistance threats in the United States, in: *Services DoHaH Ed*, 2019. <https://www.cdc.gov/drugresistance/biggest-threats.html> 2019.
- [11] P.B. Lockhart, J. Blizzard, A.L. Maslow, M.T. Brennan, H. Sasser, J. Carew, Drug cost implications for antibiotic prophylaxis for dental procedures, *Oral. Surg. Oral. Med. Oral. Pathol. Oral. Radiol.* 115 (2013) 345–353.
- [12] T.P. Sollecito, E. Abt, P.B. Lockhart, E. Truelove, T.M. Paumier, S.L. Tracy, et al., The use of prophylactic antibiotics prior to dental procedures in patients with prosthetic joints: evidence-based clinical practice guideline for dental practitioners. A report of the American Dental Association Council on Scientific Affairs, *J. Am. Dent. Assoc.* 146 (2015) 11–16 e18.
- [13] R.H. Quinn, J.N. Murray, R. Pezold, K.S. Sevarino, The American Academy of orthopaedic surgeons appropriate use criteria for the management of patients with orthopaedic implants undergoing dental procedures, *J Bone Joint Surg Am* 99 (2017) 161–163.

- [14] Advisory statement, Antibiotic prophylaxis for dental patients with total joint replacements. American Dental Association; American Academy of Orthopaedic Surgeons, J. Am. Dent. Assoc. 128 (1997) 1004–1008.
- [15] Antibiotic prophylaxis for dental patients with total joint replacements, J. Am. Dent. Assoc. 134 (2003) 895–899.
- [16] S. Hamedani, A clinical practice update on the latest AAOS/ADA guideline (December 2012) on prevention of orthopaedic implant infection in dental patients, J. Dent. 14 (2013) 49–52.
- [17] K.B. Ward, C. G, M.E. Nunn, A.G. Wee, Current practices of the 2012 antibiotic prophylaxis recommendations for orthopaedic implants in a Mid-West city, Int. J. Health Sci. 3 (2015) 199–210.
- [18] T. Colterjohn, J. de Beer, D. Petrucci, N. Zabtia, M. Winemaker, Antibiotic prophylaxis for dental procedures at risk of causing bacteremia among post-total joint arthroplasty patients: a survey of Canadian orthopaedic surgeons and dental surgeons, J. Arthroplasty 29 (2014) 1091–1097.
- [19] C.M. McNally, R. Visvanathan, S. Liberali, R.J. Adams, Antibiotic prophylaxis for dental treatment after prosthetic joint replacement: exploring the orthopaedic surgeon's opinion, Arthroplast Today 2 (2016) 123–126.
- [20] P. Cuijpers, N. Smits, T. Donker, M. ten Have, R. de Graaf, Screening for mood and anxiety disorders with the five-item, the three-item, and the two-item Mental Health Inventory, Psychiatr. Res. 168 (2009) 250–255.
- [21] JotCD. Association, New CDA Position Statement on Dental Patients with Total Joint Replacement, Canadian Dental Association, 2013.
- [22] N.Z.D. Association, in: New Zealand Dental Association Code of Practice: Antibiotic Prophylaxis for Patients with Prosthetic Joint Replacements Undergoing Dental Treatment, 2013, pp. 3–9.
- [23] C.G. Daly, Antibiotic prophylaxis for dental procedures, Aust. Prescr. 40 (2017) 184–188.
- [24] W.M.H. Rademacher, G. Walenkamp, D.J.F. Moojen, J.G.E. Hendriks, T.A. Goedendorp, F.R. Rozema, Antibiotic prophylaxis is not indicated prior to dental procedures for prevention of periprosthetic joint infections, Acta Orthop. 88 (2017) 568–574.
- [25] A.D. Association, Antibiotic prophylaxis prior to dental procedures, in: Association AD, 2021.
- [26] D.D. Skaar, T. Park, M.F. Swiontkowski, K.M. Kuntz, Is antibiotic prophylaxis cost-effective for dental patients following total knee arthroplasty? JDR Clin. Trans. Res. 4 (2019) 9–18.
- [27] E.E. Stanley, T.P. Trentadue, K.C. Smith, J.K. Sullivan, T.S. Thornhill, J. Lange, et al., Cost-effectiveness of dental antibiotic prophylaxis in total knee arthroplasty recipients with type II diabetes mellitus, Osteoarthritis Cartilage Open 2 (2020), 100084.