MAJOR ARTICLE

Dental Procedures as Risk Factors for Prosthetic Hip or Knee Infection: A Hospital-Based Prospective Case-Control Study

Elie F. Berbari,[1] Douglas R. Osmon,[1] Alan Carr,[2] Arlen D. Hanssen,[3] Larry M. Baddour,[1] Doris Greene,[1] Leo I. Kupp,[5] Linda W. Baughan,[5] W. Scott Harmsen,[4] Jayawant N. Mandrekar,[4] Terry M. Therneau,[4] James M. Steckelberg,[1] Abinash Virk,[1] and Walter R. Wilson[1]

Departments of [1]Medicine, Division of Infectious Diseases, [2]Dental surgery, [3]Orthopedic Surgery, and [4]Biostatistics and Epidemiology, Mayo Clinic College of Medicine, Rochester, and [5]Department of Periodontics, Burnsville, Minnesota; and [6]Department of Endodontics, Virginia Commonwealth University, Richmond, Virginia

(See the editorial commentary by Zimmerli and Sendi, on pages 17–9.)

Background. The actual risk of prosthetic joint infection as a result of dental procedures and the role of antibiotic prophylaxis have not been defined.

Methods. To examine the association between dental procedures with or without antibiotic prophylaxis and prosthetic hip or knee infection, a prospective, single-center, case-control study for the period 2001–2006 was performed at a 1200-bed tertiary care hospital in Rochester, Minnesota. Case patients were patients hospitalized with total hip or knee infection. Control subjects were patients who underwent a total hip or knee arthroplasty but without a prosthetic joint infection who were hospitalized during the same period on the same orthopedic floor. Data regarding demographic features and potential risk factors were collected. Logistic regression was used to assess the association of variables with the odds of infection.

Results. A total of 339 case patients and 339 control subjects were enrolled in the study. There was no increased risk of prosthetic hip or knee infection for patients undergoing a high-risk or low-risk dental procedure who were not administered antibiotic prophylaxis (adjusted odds ratio [OR], 0.8; 95% confidence interval [CI], 0.4–1.6), compared with the risk for patients not undergoing a dental procedure (adjusted OR, 0.6; 95% CI, 0.4–1.1) respectively. Antibiotic prophylaxis in high-risk or low-risk dental procedures did not decrease the risk of subsequent total hip or knee infection (adjusted OR, 0.9 [95% CI, 0.5–1.6] and 1.2 [95% CI, 0.7–2.2], respectively).

Conclusions. Dental procedures were not risk factors for subsequent total hip or knee infection. The use of antibiotic prophylaxis prior to dental procedures did not decrease the risk of subsequent total hip or knee infection.

Because of the aging US population, it is estimated that, by 2030, ~4 million total hip or knee arthroplasties will be performed annually in the United States [1]. Although the overall outcome of joint arthroplasty is excellent, prosthetic joint infection (PJI) is a rare but well-recognized complication that causes significant morbidity and mortality [2, 3]. The attributable financial cost of management of each episode of PJI is estimated to be 3–4 times the cost of a primary total joint arthroplasty and usually exceeds $50,000 [4].

Whether dental procedures increase the risk of prosthetic hip or knee infection has been actively debated for almost 3 decades [5–21]. To date, there have been no well-designed, case-control or cohort studies that have definitively linked any type of dental procedure with an increased risk of PJI. A recent review of the literature by Uckay et al [21] of 12 published cases of prosthetic joint infection that were attributed to a dental procedure found that the delay between a dental procedure and prosthetic joint infection ranged from

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Reprints or correspondence: Dr Elie F. Berbari, Mayo Clinic College of Medicine, 200 First St SW, Rochester, MN 55905 (berbari.elie@mayo.edu).

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Table 1. Definition of Terms

Term	Definition
Prosthetic hip or knee infection	Isolation of the same microorganism from ⩾2 cultures from joint or periprosthetic fluid specimens or the presence of acute inflammation consistent with infection on histopathological examination (as determined by the pathologist) or the presence cutaneous sinus tract communicating with the prosthesis, or the presence of purulence in a joint space (as determined by the surgeon).
Low-risk and high-risk dental procedures	Low-risk dental procedures include restorative dentistry, dental filing, endodontic treatment, and fluoride treatment. High-risk dental procedures include dental hygiene, mouth surgery, periodontal treatment, dental extraction, and therapy for dental abscess.
Flora of potential oral or dental origin	Microorganisms that colonize the oropharyngeal region or cause transient bacteremia after dental or oral procedures.
Antibiotic prophylaxis	An antibiotic administered on the same day but prior to a dental procedure as documented by the treating dentist in the dental records.
Antibiotic surgical prophylaxis	A dose of antibiotic delivered within 120 minutes of the incision of a knee or hip arthroplasty.
Surgical site infection	Wound infection as defined per the Centers for Disease Control and Prevention [42].
Diabetes mellitus	Based on the American Dental Association definition [43].
Immunocompromise	The presence of any of the following conditions: rheumatoid arthritis, current use of systemic corticosteroids/immunosuppressive drugs, diabetes mellitus, presence of a malignancy, and a history of chronic kidney disease.

24 h to 9 months. Despite the lack of data, multiple surveys of health care providers indicate that a significant number of them recommend antibiotic prophylaxis (AP) for dental procedures in patients with a prosthetic joint [16–18]. The American Academy of Orthopedic Surgeons (AAOS) and the American Dental Association (ADA) recognized the confusion that characterized this issue and convened an expert panel in 1997 and 2003 [22, 23]. In an advisory statement, the panel recommended that routine antibiotic prophylaxis for dental procedures in patients with a prosthetic joint not be administered and that it should be considered only in selected patients with total joint arthroplasty who undergo high-risk dental procedures. Recently, the safety committee of the AAOS posted a new information statement on its Web site recommending that clinicians consider antibiotic prophylaxis for all patients with total joint replacement prior to any dental procedure [24].

We therefore conducted this case-control study that was designed to determine whether dental procedures with or without antibiotic prophylaxis are risk factors for prosthetic hip or knee infection.

METHODS

Study setting and participants. This large, single-center, prospective case-control study was conducted during the period 2001–2006 and examined the risk of prosthetic hip or knee infection associated with dental procedures. The study was approved by the institutional review board of the Mayo Clinic (Rochester, MN), and written informed consent and release of outside dental and medical records was obtained from each patient (or his or her surrogate). All authors analyzed, interpreted, and had full access to the data, were responsible for drafting the manuscript, and verified the completeness and accuracy of the reported data. The final report was written with input from all of the authors.

Surveillance for case patients and control subjects at the Mayo Clinic was conducted from 1 December 2001 through 31 May 2006. Case patients were patients with a diagnosis of prosthetic hip or knee infection (Table 1) who were hospitalized at the Mayo Clinic. Control subjects were patients who were hospitalized on an orthopedic service. Paired matching was not preformed on any variable. Frequency matching was used between case patients and control subjects on the location of joint arthroplasty. Structured forms were used to interview patients and abstract medical records data, including details of dental procedures.

Data collection. Dental records were requested by faxing the patient's dentist(s). If the dental records were not obtained after a faxed request, the primary investigator contacted by telephone the treating dentist to obtain the records. Only dental records from 3 patients (1 case patient and 2 control subjects) were not available for the final analysis. Variables previously

reported to be associated with an increased risk of prosthetic hip or knee infection were collected [2, 3].

Dental records were reviewed and classified by A.C., L.I.K., and L.W.B. and were blinded to the case or control status of each patient. Dental procedures were categorized into low-risk and high-risk dental procedures (Table 1) [25]. These categorizations are surrogate measures of risk of procedure-associated bacteremia that were used in the ADA/AHA prior guidelines. These surrogates are useful to the general dentist to better understand risk categories [24]. The microbiologic characteristics of hip or knee infection were determined using the routine microbiologic techniques used in the clinical laboratory that isolated these specimens. Surgical records were reviewed by A.D.H. The study date used for case patients and control subjects was the Mayo Clinic hospital admission date. Details of all dental visits for both case patients and control subjects were abstracted from the study date and the previous 2 years (observation period). If the joint arthroplasty occurred <2 years before the study date, detailed dental records were abstracted backwards to the date of the joint arthroplasty.

Statistical analysis. A dental propensity score was calculated for each patient that took into account covariates that would predict the propensity of each patient to visit a dentist. This propensity score was calculated using logistic regression, the dependent variable being whether the patient had a dental visit during the period of dental information abstraction (yes vs no). Covariates included in the propensity score were place of residency, education level, history of kidney disease, history of malignancy, diabetes mellitus, use of systemic corticosteroids, rheumatoid arthritis, use of other immunosuppressive medications, smoking history, body mass index, American Society of Anesthesiologists (ASA) score, reported number of teeth brushings per week, joint age at hospital admission, sex, and age at joint implantation (Table 2). The score was designed to control for the propensity of each patient to visit a dentist. The use of the propensity score in this setting would allow a more robust method for controlling multiple risk factors [26–28].

The primary risk factor of interest in this study is whether a patient had a high-risk or low-risk dental procedure and whether, at the time of the procedure closest to the study date, the patient had antibiotic prophylaxis. The risk factor is defined as 4 levels: (1) patient did not have a dental procedure in the observation period (this class was used as the reference level in all models); (2) edentulous patients (none of whom had a dental visit in the observation period); (3) patient had a dental procedure(s) in the observation period without antibiotic prophylaxis; and (4) patient had a dental procedure(s) in the observation period with antibiotic prophylaxis . Other variables assessed for association with a prosthetic hip or knee infection are shown in Table 3.

Logistic regression was used to assess variables for association with the odds for prosthetic hip or knee infection. The multiple variable models reported included the dental procedure, antibiotic prophylaxis, the dental visit propensity score, patient sex, and joint age at study date, as well as other covariates having a univariate P value of $\leqslant .10$. The α level was set at .05 for statistical significance. Odds ratios (and 95% confidence intervals [CIs]) were computed on the basis of the logistic regression model estimates [29].

With the observed proportion of 30% of control patients with high-risk dental procedure without antibiotics, we had 80% power to detect a difference of ~15% among the case patients without having high-risk dental procedure with a 2-sided test and 5% level of significance. Similar difference could be detected when comparing high-risk dental procedure with antibiotic prophylaxis relative to no high-risk dental procedure and comparing high-risk dental procedure with antibiotic prophylaxis relative to high-risk procedure without antibiotic prophylaxis.

RESULTS

Three hundred and thirty-nine case patients with prosthetic hip or knee infection and 339 corresponding control subjects were enrolled; their demographic features are displayed in Tables 2 and 3. Eleven patients (1.6%) refused research participation. Dental records for 3 patients were not available for the final analysis. Forty-seven (14%) of the case patients and 26 (8%) of the control subjects were edentulous at the time of enrollment. Among dentate patients, 192 (57%) of the case patients and 161 (47%) of the control subjects underwent a low-risk dental procedure during the 2-year observation period. In addition, 164 (48%) of the case patients and 116 (34%) of the control subjects underwent a high-risk dental procedure. High-risk and low-risk dental procedures were performed in 90% and 82%, respectively, of the case patients during the 12 months prior to the study date (Table 2). To compare the status of oral health between case patients and control subjects during the 24 months that preceded the enrollment date, data on frequency of tooth brushing and number of dental hygiene visits were collected. Measurement of pocket probing depth was seldom documented in the dental record and was therefore not analyzed. Among dentate patients, the mean number ($\pm$ standard deviation [SD]) of reported tooth brushings per week was 11.7 ± 5.7 and 11.9 ± 5.5 for case patients and control subjects, respectively (OR, 1.0; 95% CI, 0.97–1.02; $P = .72$). Eighty-eight (54%) and 152 (63%) of the dentate case patients and control subjects, respectively, had >1 dental hygiene visit. A patient with at least 1 dental hygiene visit relative to a patient with no visits had an OR for developing prosthetic hip or knee infection of 0.7 (95% CI, 0.5–1.03; $P = .07$).

Among the 339 case patients, 259 (74%) had a diagnosis of prosthetic hip or knee infection established within 10 days be-

Table 2. Characteristics of Case Patients and Control Subjects enrolled in the Case Control Study, 2001–2006

Characteristic	Case patients (n = 339)	Control subjects (n = 339)
Demographic characteristic		
Female sex	168 (50)	180 (53)
THA/TKA	164/175	164/175
Age at hospital admission, median years (range)	69.5 (25.7–91.2)	71.4 (36.0–94.8)
Education, median grade (range)	12 (6–17)	13 (6–17)
Joint age		
Median joint age (range)	15.5 months (1 day through 296 months)	49.9 months (1.2–414 months)
<12 months	151 (45)	5 (21)
12–24 months	43 (13)	41 (12)
25–48 months	56 (17)	49 (14)
49–60 months	19 (6)	29 (9)
>60 months	70 (21)	145 (43)
Residency at hospital admission		
Olmsted County	18 (5)	49 (14)
Six surrounding counties	29 (9)	36 (11)
Balance of Minnesota	85 (25)	77 (23)
Surrounding states[a]	150 (44)	123 (36)
Balance of United States	57 (17)	54 (16)
Operative factors		
Procedure time, median min (range)	131 (24–673)	133 (40–505)
Tourniquet time, median min (range)[b]	92 (0–215)	90 (0–201)
Dental procedures		
Time from most recent dental procedure to hospital admission		
Low-risk dental procedure		
No low-risk procedure	192	161
⩽12 months	82 (82)	74 (77)
12–24 months	18 (18)	22 (23)
High-risk dental procedures		
No high-risk procedure	192	161
<12 months	115 (90)	181 (92)
12–24 months	13 (10)	16 (8)
Time from implant to initial dental procedure		
Low-risk dental procedure		
No low-risk procedure	192	161
<12 months	41 (41)	37 (24)
1–2 years	13 (13)	15 (10)
>2 to 5 years	24 (24)	31 (20)
>5 to 10 years	10 (10)	37 (24)
>10 years	12 (12)	32 (21)
High-risk dental procedures		
No high-risk procedure	164	116
<12 months	58 (43)	63 (32)
1–2 years	13 (10)	19 (10)
>2 to 5 years	25 (20)	36 (18)
>5 to 10 years	17 (13)	43 (22)
>10 years	15 (12)	36 (18)

NOTE. Data are no. (%) of patients, unless otherwise indicated. THA, total hip arthroplasty; TKA, total knee arthroplasty.

[a] Surrounding states include: Wisconsin, Illinois, Iowa, South Dakota, and North Dakota.

[b] For TKA only.

Table 3. Host-Related Factors and Postoperative Wound Environment and Risk of Prosthetic Hip or Knee Infection

Variable	No. (%) of case patients	No. (%) of control subjects	Odds ratio[a] (95% CI)	*P*	Overall *P*
Preoperative factor					
Body mass index					<.001
<25	76 (22)	51 (15)	1.0 (Reference)		
25–30	89 (26)	124 (37)	0.4 (0.3–0.7)	<.001	
31–39	113 (33)	138 (41)	0.5 (0.3–0.7)	<.001	
⩾40	61 (18)	26 (8)	1.4 (0.7–2.5)	.32	
Diabetes mellitus	69 (20)	42 (12)	1.8 (1.2–2.8)	.006	
Prior operation on the index joint	130 (38)	86 (25)	1.9 (1.3–2.6)	<.001	
Prior arthroplasty on the index joint	107 (32)	55 (16)	2.4 (1.6–3.5)	<.001	
Immunocompromise[b]	208 (61)	149 (44)	2.2 (1.6–3)	<.001	
Operative factors					
ASA score					<.001
ASA 1	15 (4)	24 (7)	1.0 (Reference)		
ASA 2	140 (41)	199 (59)	0.9 (0.4–1.8)	.78	
ASA 3	138 (41)	94 (28)	1.7 (0.8–3.6)	.14	
ASA 4	10 (3)	4 (2)	4.9 (0.9–26.2)	.06	
Missing data	36 (11)	20 (6)			
Antibiotic surgical prophylaxis	259 (76)	277 (82)	0.5 (0.3–0.8)	.003	
Procedure time					
<2 h	151 (45)	137 (40)	1.0 (Reference)		<.001
⩾2 but <3 h	92 (27)	129 (38)	0.6 (0.4–0.9)	.01	
⩾3 but <4 h	40 (12)	43 (13)	0.9 (0.6–1.5)	.73	
⩾4 h	46 (14)	17 (5)	2.7 (1.5–5)	.002	
Postoperative factors					
Postarthroplasty wound drainage	89 (26)	5 (1)	18.7 (7.4–47.2)	<.001	
Postarthroplasty wound dehiscence	13 (4)	4 (1)	2.5 (0.8–7.7)	.12	
Postarthroplasty wound hematoma	21 (6)	5 (1)	3.5 (1.3–9.5)	.01	
Postarthroplasty surgical site infection[d]	54 (16)	0 (0)	…	…	
Postoperative urinary tract infection	17 (5)	6 (2)	2.7 (1.04–7.1)	.04	
Distant organ infection [c]	89 (26)	52 (15)	2.2 (1.5–3.25)	<.001	

NOTE. ASA, American Society of Anesthesiologists.

[a] Adjusted for sex and joint age.

[b] Rheumatoid arthritis or current use of systemic steroids/immunosuppressive drugs or diabetes mellitus or presence of a malignancy or a history of chronic kidney disease.

[c] Urinary tract infection, respiratory tract infection, cellulitis, other organ infection.

[d] Unable to calculate odds ratio.

fore or after the study date. Staphylococci were the most commonly encountered organisms (Table 4). Thirty-five (10.3%) of the prosthetic hip or knee infection cases were caused by flora of potential oral or dental origin (Table 4).

Data on age, sex, ethnicity, joint age, and education of case patients and control subjects are shown in Table 2. Control subjects had older prostheses, compared with case patients (median joint age, 49.9 vs 15.5 months) (Table 2). Control subjects were admitted to the hospital for an arthroplasty of a different site or side of the index total hip or knee arthroplasty (in 191 [57%] of cases), for aseptic revision of the index arthroplasty (130 [38%]), or for other orthopedic procedures (16 [5%]).

Variables that were analyzed as risk factors for prosthetic hip or knee infection with an associated *P* value of <.10 are shown in Table 3. The administration of a homologous blood transfusion and prior history of psoriasis, native septic arthritis, smoking, and index joint injection were not associated with an increased risk of prosthetic hip or knee infection.

In a multivariable model, low-risk or high-risk dental procedures performed within 6 months or 2 years of the hospital admission date were not significantly associated with an increased risk of prosthetic hip or knee infection, compared with no dental procedure (Table 5). The OR estimate for patients who underwent high-risk dental procedures with antibiotic prophylaxis within 6 months of hospital admission was 0.5 (95% CI, 0.3–0.9). We believe that this result may be related to potential unknown confounders or to the multiple comparisons preformed. To assess the effect of antibiotic prophy-

Table 4. Microbiological Findings for 339 Case Patients with Prosthetic Hip or Knee Infection at the Mayo Clinic, 2001–2006

Microbiological finding	No. (%) of patients
Staphylococcus aureus	95 (28)
Coagulase-negative staphylococci[a]	101 (30)
Beta-hemolytic streptococci[b]	13 (4)
Polymicrobial infection	38 (11)
Negative culture results	33 (10)
Anaerobes[b]	12 (4)
Peptostreptococcus species[b]	5
Propionibacterium acnes	4
Bacteroides species	1
Staphylococcus saccharolyticus	1
Actinomyces species[b]	1
Enterobacteriaceae	10 (3)
Viridans group streptococci[b]	11 (3)
Enterococcus species	10 (3)
Pseudomonas aeruginosa	2 (1)
Other[b]	14 (4)
Corynebacteria species	2
Streptococcus pneumoniae	3
Streptococcus-like organisms not further identified[b]	2
Abiotrophia/*Granulicatella* species[b]	2
Sporothrix schenckii	1
Mycobacterium chelonei	1
Gemella species[b]	1
Candida albicans	1
Coccidioidomycosis immitis	1

[a] One case of infection due to *Staphylococcus lugdunensis*.
[b] Organism of potential oral or dental origin.

laxis on the risk of PJI, low-risk and high-risk dental procedures with antibiotic prophylaxis were compared with the same risk procedure without prophylaxis. The OR estimate was 0.7 (95% CI, 0.3–1.5) for low-risk procedures and 0.7 (95% CI, 0.3–1.4) for high-risk procedures performed within 6 months of hospital admission. In addition, the OR estimate was 1.2 (95% CI, 0.7–2.2) for low-risk procedures and 0.9 (95% CI, 0.5–1.6) for high-risk procedures performed within 2 years before hospital admission date.

We performed several subgroup analyses. An analysis that included the 35 patients with prosthetic hip or knee infection with dental flora pathogens and a randomly selected group of 35 control patients showed no increased risk of total hip or knee infection, regardless of the use of antibiotic prophylaxis (Table 6). To address whether dental procedures are a risk factor for subsequent prosthetic hip or knee infection in the subgroups of patients who were immunocompromised, had diabetes mellitus, had a prior arthroplasty, had duration of PJI symptoms of <8 days, or were within a year of joint arthroplasty, we performed subgroup analyses. High-risk and low-risk dental procedures were not risk factors for prosthetic hip or knee infection in any of these subgroups.

DISCUSSION

In this hospital-based, case-control study of prosthetic hip or knee infection, case patients were no more likely than control subjects to have undergone a high-risk or low-risk dental procedure. The topic of antibiotic prophylaxis for prevention of PJI or endocarditis following dental procedures has generated considerable discussion that is based on limited evidenced-based data [21–24,30–32].

The use of antibiotic prophylaxis prior to dental procedures did not alter the subsequent risk of prosthetic hip or knee infection in the current study. Prior clinical trials that were randomized and placebo-controlled examined the incidence of transient bacteremia following dental procedures and demonstrated mixed results regarding the efficacy of antibiotic prophylaxis [33, 34]. Although the adverse risk of antibiotic prophylaxis in the individual patient may seem remote and unlikely, the risk to the overall population with a joint arthroplasty and to society at large seems prohibitive [35]. The ADA/AAOS 2003 advisory panel recommends that antibiotic prophylaxis be considered in subsets of patients who are believed to be at increased risk for post–dental procedure PJI [22, 23]. A recent information statement by the AAOS has advocated the consideration of routine and indefinite use of antibiotic prophylaxis prior to dental procedures in all patients with a joint arthroplasty [24]. Our study suggests that the risk of prosthetic hip or knee infection following dental procedures is not increased in the overall cohort or in groups previously identified as being at high risk [23]. The subgroup of patients with a joint age of <1 year is of particular interest because of the proximity of the dental procedure to the study date and the potential heightened alertness among health care providers and patients regarding the need for antibiotic prophylaxis during this time period.

The possibility that the inclusion of all cases of prosthetic hip or knee infection in the analysis might dilute the results was considered and was addressed in the analysis of patients with infection limited to potential flora of dental or oral origin. No association was found in this subset. The power to detect a statistically significant association was limited in this subset.

Transient bacteremia is commonly associated with physiologic activities such as chewing and brushing, as well as dental and oral procedures. There is a wide variation in the reported frequencies of bacteremia among patients resulting from dental procedures, and the number of bacterial species recovered from blood cultures is large. The majority of these transient bacteremias are due to viridans group streptococci, nonpathogenic gonococci, β-hemolytic streptococci, and gram-positive anaerobes [6, 20, 25, 36]. In contrast, the majority of prosthetic hip

Table 5. Analysis of Dental Procedures Performed within 6 Months and within 2 Years of Hospital Admission and Risk of Prosthetic Hip or Knee Infection among Case Patients and Control Subjects at the Mayo Clinic, 2001–2006

Variable	Case patients (n = 303)[a]	Control subjects (n = 318)[a]	Odds ratio (95% confidence interval)[b] 6 Months	P	2 Years	P
Low-risk dental procedure[c]						
Any	192 (57)	161 (47)	1.0 (Reference)		1.0 (Reference)	
Edentulous	47 (14)	26 (8)	1.8 (0.9–3.7)	.10	1.7 (0.8–3.4)	.16
Low-risk procedure without antibiotic prophylaxis	41 (12)	65 (19)	1.1 (0.6–2.1)	.77	0.6 (0.4–1.1)	.11
Low-risk procedure with antibiotic prophylaxis	59 (17)	87 (26)	0.7 (0.3–1.5)	.33	0.8 (0.5–1.2)	.29
High-risk dental procedure[d]	164 (48)	116 (34)	1.0 (Reference)		1.0 (Reference)	
Edentulous	47 (14)	26 (8)	1.7 (0.9–3.5)	.13	1.7 (0.8–3.4)	.16
High-risk procedure, without antibiotic prophylaxis	33 (10)	49 (14)	0.8 (0.4–1.7)	.60	0.8 (0.4–1.6)	.56
High-risk procedure, with antibiotic prophylaxis	95 (28)	148 (44)	0.5 (0.3–0.9	.01	0.7 (0.5–1.1)	.14

NOTE. Data are no. (%) of patients, unless otherwise indicated.

[a] One or more of the covariates in the model were missing in 36 case patients and 21 control subjects.

[b] The model includes the covariates of sex, joint age, dental propensity score, body mass index >40, procedure time >4 h, immunocompromised host, American Society of Anesthesiologists score, wound healing complications, prior arthroplasty or surgery on the index joint, use of antibiotic surgical prophylaxis, postoperative urinary tract infection, and distant organ infection.

[c] Restorative dentistry or dental fillings or endodontic treatment or fluoride treatment.

[d] Dental hygiene or dental filing or mouth surgery or periodontal treatment or dental extraction or therapy for dental abscess.

or knee infections are due to staphylococci [2, 3]. There is a significant discrepancy between the low grade bacteremia caused by dental procedures ($<10^4$ colony-forming units (CFU)/mL) and physiologic activities and the high-density bacteremia needed to get hematogenous seeding in animal models ($3–5 \times 10^8$ CFU/mL) [37–39]. Transient bacteremia occurs in up to 51% of individuals during routine daily activities, such as tooth brushing, flossing, and chewing [39]. Guntheroth estimated a cumulative exposure of 5370 min of bacteremia over a 1-month period in dentate patients resulting from random bacteremia from chewing food and from oral hygiene measures. This is compared with duration of bacteremia, lasting 6–30 min, that is associated with a single tooth extraction [37].

Poor dental hygiene and periodontal or periapical infections may produce bacteremia even in the absence of dental procedures. The incidence and magnitude of bacteremias of oral origin are directly proportional to the degree of oral inflammation and infection [40, 41]. In our study, patients with >1 dental hygiene visit were 30% less likely to develop prosthetic hip or knee infection, although this difference was not statistically significant. The association between the frequency of dental hygiene visits and the reduced risk of prosthetic hip or

Table 6. Analysis of Dental Procedures Performed within 2 Years of Hospital Admission and Risk of Prosthetic Hip or Knee Infection among 35 Case Patients with Infection due to Potential Oral Organisms and 35 Control Subjects at the Mayo Clinic, 2001–2006

Variable	Odds ratio (95% confidence interval)	P
Low-risk dental procedure[a]	1.0 (Reference)	
Edentulous [b]	…	.06
Low-risk procedure without antibiotic prophylaxis	1.2 (0.8–3.4)	.86
Low risk procedure with antibiotic prophylaxis	0.4 (0.1–1.8)	.22
High-risk dental procedure[c]	1.0 (Reference)	
Edentulous[a]	…	.22
High-risk procedure without antibiotic prophylaxis	0.5 (0.1–1.9)	.28
High-risk procedure with antibiotic prophylaxis	0.8 (0.3–2.8)	.77

[a] Restorative dentistry or dental fillings or endodontic treatment or fluoride treatment.

[b] Unable to calculate odds ratios and 95% confidence intervals, because no case patients and only 2 control subjects were edentulous in this subgroup.

[c] Dental hygiene or dental filing or mouth surgery or periodontal treatment or dental extraction or therapy for dental abscess.

knee infection can be attributable to a presumed relationship between poor oral hygiene, the extent of dental health, and the frequency and extent of daily bacteremias. We believe that reported PJIs attributed to dental procedures are more likely to have been caused by bacteremia related to routine daily activities than by bacteremia related to dental procedures. Accordingly, it is inconsistent to recommend prophylaxis of prosthetic hip or knee infection for dental procedures but not to recommend prophylaxis for these same patients during routine daily activities. We believe that a recommendation for universal prophylaxis for routine daily activities is impractical and unwarranted. We agree with the AAOS/ADA 2003 statement, which emphasized maintaining good oral hygiene and eradicating dental disease to decrease the frequency of bacteremia from routine daily activities [22, 23].

Case patients were substantially more likely than control subjects to have underlying comorbid conditions, prior arthroplasty, immunocompromised conditions, higher ASA score, higher body mass index, prolonged joint implantation procedure time, postoperative complications of wound healing, urinary tract infection, or deep organ infection. In addition, perioperative antibiotic prophylaxis was found to be beneficial. Efforts should be made to modify these risk factors when possible to decrease the risk of prosthetic hip or knee infection in patients undergoing joint arthroplasty.

Referral bias was minimized by choosing hospitalized control subjects from the same institution on the same orthopedic service. The potential for differential recall bias between case patients and control subjects was minimized by obtaining dental records. Classification bias was minimized by blinding the reviewer of the dental records to the case or control status of the patient. The multivariable analysis controlled for differences between case patients and control subjects (in particular, joint age). Because some of the infections in this study were acquired intraoperatively and others were acquired hematogenously, it is conceivable that there was a diluting effect on dental procedures. Although a separate analysis of patients with hematogenously acquired infection is favored, accurate differentiation between PJI acquired intraoperatively or perioperatively and PJI acquired by hematogenously is problematic in most cases. For example, certain species of viridans streptococci are predominantly found in dental flora, whereas others, such as peptostreptococci, can be of intestinal origin. However, because of the study design, we did not collect the isolates, and therefore, speciation was not done. A subgroup analysis of patients with a short duration of symptoms (with presumed hematogenous infection) was performed and revealed no association between high-risk or low-risk dental procedures and the risk of PJI. Furthermore, analysis of the reported hematogenous PJI cases showed that 50% of them occurred in the first 12 months after prosthesis implantation [10]. Finally, this study may not have detected a small increase in PJI following dental procedures because of the fact that the number of case patients and control subjects needed to detect a minor increase in PJI following dental procedures would be extremely high and not feasible in a single-center study.

In conclusion, this large prospective, single-center, case-control study did not demonstrate an increased risk of prosthetic hip or knee infection following dental procedures. Antibiotic prophylaxis was not associated with a statistically significant reduction of the risk for prosthetic hip or knee infection. Current opinion–based policies for administering antibiotic prophylaxis to patients with prosthetic hip or knee arthroplasty who undergo dental treatment should be reconsidered [22–24].

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