Death related to dental treatment: a systematic review

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Objective. The aim of this study was to identify factors associated with death in relation to dental care.
Study Design. A systematic review was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. PubMed, Dental and Oral Sciences Source, Web of Science, and the Cochrane database were searched, and the references of all retrieved articles were analyzed. Studies were included if death had occurred within 90 days of the dental appointment, and if the patient's age, procedure, and information regarding cause or time of death were provided. Factors associated with death were assessed by multivariate analyses and logistic regression.
Results. Fifty-six publications, including retrospective studies and case reports/series that reported 148 fatalities, were analyzed. On average, 2.6 deaths were reported per year. The leading cause of deaths was anesthesia/sedation/medication−related complications (n = 70). Other causes were cardiovascular events (n = 31), infection (n = 19), airway−respiratory complications (n = 18), bleeding (n = 5), and others (n = 5). Age ($P < .0001$), disease severity ($P < .02$), disease stability ($P < .006$), dental provider characteristics ($P < .05$), level of consciousness/sedation ($P < .02$), and drug effects ($P < .03$) had significant associations with death.
Conclusions. Reports of death were rare; however, specific risk factors associated with dentistry were identified. A better understanding of these factors is important for the development of guidelines that help prevent fatalities in dentistry. (Oral Surg Oral Med Oral Pathol Oral Radiol 2017;123:194-204)

The dental profession has a history of seeking and implementing methods that reduce the likelihood of adverse outcomes as a result of dental treatment.[1-9] In fact, numerous reference texts and journals are dedicated to this topic.[10-13] However, adverse events continue to occur as a result of patient, provider, and procedural factors in a manner that is either predictable or unpredictable. Accordingly, there is a need for studies to assess these factors to better understand the risks involved in the provision of dental care.[14,15]

Death is a rare, but most significant, adverse event of dental treatment. Some of our understanding of this rare event comes from studies that have investigated death as an adverse outcome of sedation and general anesthesia complications.[16-23] However, dental treatment−related deaths have occurred for reasons besides sedation procedures; yet there is a dearth of studies that have comprehensively assessed these factors.[24] Notably absent are systematic analyses that consider detailed important patient, provider, and procedural factors associated with fatal outcomes. Such analysis could help in the development of evidence-based recommendations to prevent such events. Thus, the purpose of this systematic review was to identify factors associated with death in association with dental care.

MATERIALS AND METHODS

Search strategy

A systematic review of the literature was performed based on the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-analyses statement.[25] An electronic search of PubMed (no date restriction), Dental and Oral Sciences Source (DOSS, no date restriction), the Web of Science (1960−October 2015), and Cochrane databases was performed with the help of a medical librarian (M.I.) at the University of Kentucky Medical Center (Lexington, KY). The databases were searched for the period between August 8 and November 11, 2015. A list of articles from PubMed was obtained by compiling individual searches, with "human" as the species, using the National Library of Medicine Medical Subject Heading (MeSH) terms: ("Dentistry"(MeSH]) AND "Mortality"(MeSH]), (("Death"(MeSH] AND jsubsetd(text])), (("Dentistry"(MeSH]) AND "Death"(MeSH]))) NOT

Statement of Clinical Relevance

Over the past 56 years, fatalities have been reported in the literature about three times a year in association with the provision of dental care. Distinct patient, provider, and procedural factors (i.e., anesthesia/sedation) have significant associations with these adverse events.

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"Cadaver"(MeSH])), (("Dentistry"(MeSH]) AND "Fatal Outcome"(MeSH])), (("Dentistry"(MeSH]) AND "Mortality"(MeSH])) and (("Dentistry"(MeSH]) AND "Mortality"(MeSH] AND Filters: Dental journals). Duplicates between searches were eliminated by combining searches with the "OR" qualifier. The DOSS search was based on the search title (TI) and descriptor (DE) "TI fatal* OR TI death OR TI mortality OR DE mortality," and "Chair OR office OR procedure." The Web of Science search was performed in the Science Technology Domain using the following parameters: "TITLE (dental OR dentist*)" and "TITLE (death OR mortality OR fatal*)," as well as citations of articles that met the inclusion and exclusion criteria. To focus on more contemporary data and procedures, publications from 1960 forward were considered, and searches were limited to articles written in English or Spanish. Articles in Spanish were translated by one of the authors (N.G.R.). Following the searches, reference lists of all eligible studies were reviewed to identify additional studies, and duplicate articles were removed.

Inclusion criteria

Articles were included if the report involved a dental patient who had died within 90 days after being seen in an outpatient clinic or hospital setting for a dental procedure and included a description of the patient's age, information regarding the administration of anesthesia or a dental procedure, and information regarding the cause and time of death. Excluded were editorials, letters, guidelines, and animal studies. Articles involving patients with a head and neck space infection, infective endocarditis or head and neck malignancy that was present before being seen by the dentist, infections transmitted or potentially transmitted from dental personnel to a patient, conditions that originated from orofacial trauma (e.g., bone fracture) occurring before presentation to a dental practitioner, and procedures considered beyond the scope of general dentistry (e.g., involving osteotomy, orthognathic surgery, head and neck cancer surgery or treatment, transoral resections, a tracheotomy, or head and neck reconstruction) were excluded.

Study selection and data extraction

From the list of articles identified from each database, two reviewers (N.G.R. and C.S.M.) individually assessed the title and abstract of each article to identify those that met the eligibility criteria. Any discrepancy was resolved through discussion. The full text of the selected articles was assessed by the same two reviewers, and data were extracted by using a predesigned data form and entered into an Excel database relative to patient, provider, and procedural factors in addition to details about the article's publication region and date. The *preoperative* factors recorded were patient's age and gender; medical history, pre-existing conditions, and comorbidities; American Society of Anesthesiologists (ASA) physical status classification; stability/control of medical conditions; metabolic equivalents; emotional/anxiety state or need for behavior management; preoperative orofacial health status; medications; and preoperative vitals. The *operative* factors recorded were setting of treatment; type and specialization of provider; involvement of an anesthetist; anesthetic/sedative technique used affecting level of consciousness during procedure; dental procedure performed or initiated; invasiveness of procedure; duration of procedure; and drugs administered and likelihood of drug interactions/adverse effects occurring because of the drug administered. *Postoperative* factors recorded were setting of the adverse event; pain level documented; time of health deterioration; nature of adverse events and complications; cause of death; and time span between procedure and death. In cases in which age was reported as "mid-20s" or "mid-70s" or the first decade, second decade, and so on, the assigned age was 25, 75, 5, 15, and so on, respectively. In addition, a narrative summary was entered to provide a complete description of the events that had occurred to ensure that potentially relevant data were obtained.

Time to death was entered in units of hours with respect to time of treatment initiation. In cases for which the exact interval of time between initiation of treatment and time of death was not provided, the following was performed. When death was attributed to asphyxiation and it was clear that the time to death was fairly immediate, a time to death of 10 minutes (0.1667 hour) was entered. If time to death was assessed or reported as less than 1 hour but not a specific number of minutes, a time of 1 hour was entered. If time to death was determined to be within a range, the mean value of that range was entered. If a patient was assessed as having died within several days, a time of 3 days (72 hours) was entered.

Cause of death was categorized as follows: airway/respiratory complications (e.g., laryngeal edema, physical airway obstruction, asphyxiation, air emphysema); local or systemic bleeding or coagulation-related (e.g., local or systemic bleeding, disseminated intravascular coagulation); cardiovascular-related (e.g., cardiac arrest, myocardial infarction, cerebrovascular accident [CVA], aneurysm, fulminant heart failure); anesthesia/sedation/medication-related (e.g., drug effect, interaction or adverse effect, overdose, incorrect medication); infection-related (e.g., bacterial, fungal,

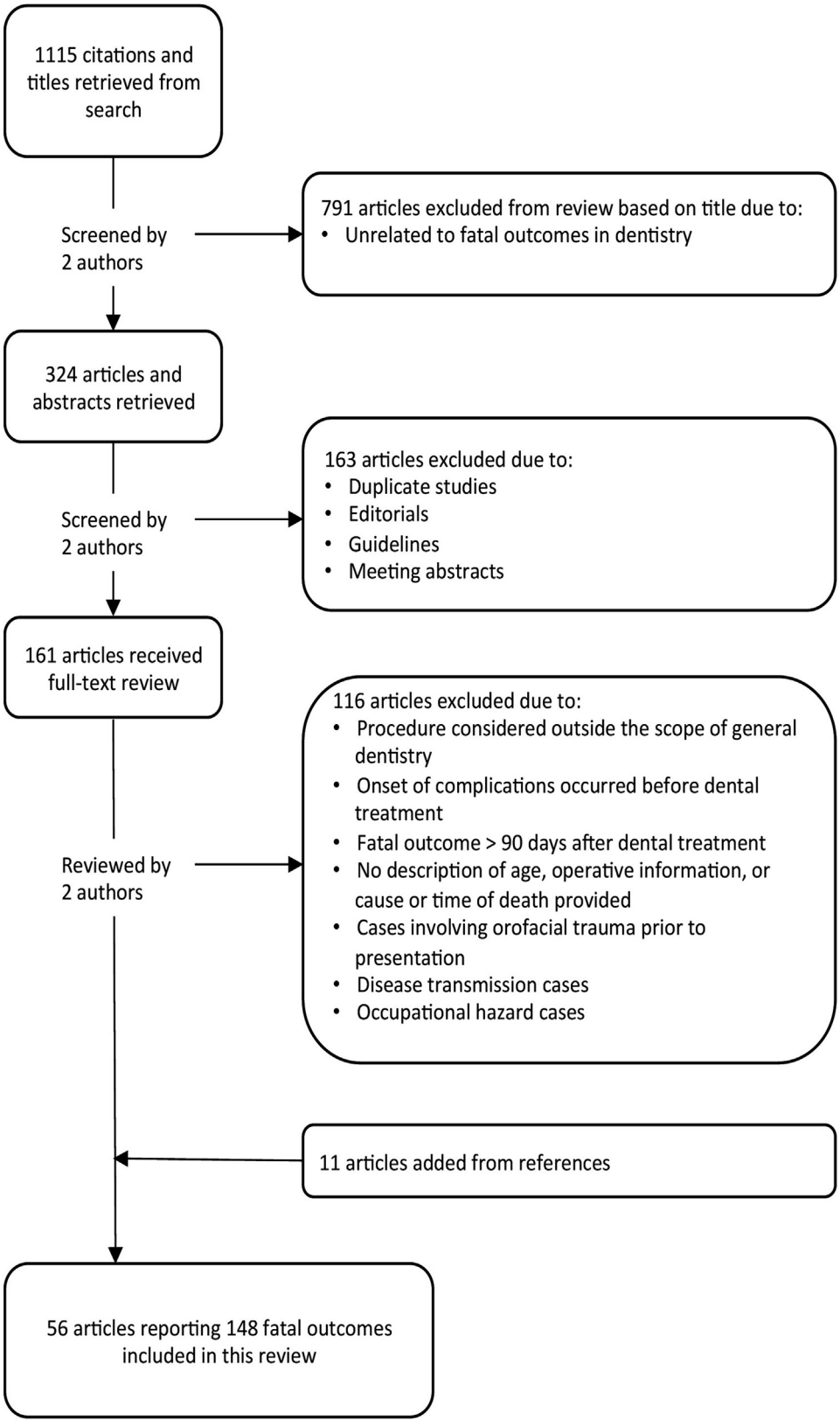

Fig. 1. Flow chart depicting the studies identified, included and excluded with explanations.

osteomyelitis, pneumonia, infective endocarditis); or other.

Quality (quantitative) assessment

Because the included articles were predominantly case reports and case series, the quality of the data was difficult to ascertain by using standard methods.[26] Instead, we assessed the quantity of information provided on the basis of the reporting of (1) preoperative health information, 11 criteria; (2) operative information, 8 criteria; and (3) postoperative information, 6 criteria. The quantity of information reported was divided by the total number of factors possible (i.e., 25). Studies reporting fewer than 70% of the factors were considered poor, 71% to 79% fair, 80% to 89% good, and greater than 90% excellent.

Statistical analysis

The majority of statistical analyses focused on categorical associations. Because of the small percentages observed in multiple analyses, two-sided Fisher's exact tests were utilized at the 0.05 significance level. In addition, analysis of variance (ANOVA) or the Kruskall-Wallis test, depending on the distribution, was used for continuous variables. Bonferroni-adjusted *P* values were obtained when making pairwise comparisons. Variables that were significantly associated with cause of death were included in individual logistic regression models, and backward elimination at the 0.05 level was then implemented. Analyses were performed in SAS version 9.4 (SAS Institute, Cary, NC).

RESULTS

A systematic search of the four databases yielded 1115 articles for potential inclusion. Figure 1 details the inclusion/exclusion process that resulted in the 324 articles eligible for full text review. After cross-referencing, 56 studies that reported 148 fatalities were extracted and analyzed. Seven reports presenting 54 deaths were retrospective studies (level III evidence),[16,17,19,21,22,27,28] 31 were case reports (level IV evidence),[29-59] and 18 publications were case series presenting 63 deaths (level IV evidence).[20,24,60-76] The risk of bias was high because of the low level of evidence and the many variables that were inconsistently reported. In addition, 7% (111 of 148) of the reports were determined to be poor in the quantity of information published, 23.6% (35 of 148) were fair and only two studies (1.4%) were good (i.e., reported at least 80% of the factors sought by the investigators).

Seventy cases occurred in North America, 70 in Europe, seven in Asia, and one in South America. The average age of the patients was 34.6 years (range 2−82 years). There were 70 males and 67 females, and in 11 cases, the gender was not specified.

Table I shows important characteristics associated with cause of death. The leading cause of death was anesthesia/sedation/medication-related effects (n = 70), with 94% of these cases being associated with anesthesia or sedation procedures. Thirty-one deaths were attributed to cardiovascular events, 19 to infection, 18 to airway/respiratory issues, five to bleeding, and five to other causes. Preoperative factors significantly ($P < .05$) associated with cause of death were age, ASA physical status classification, and stability of systemic disease. Operative factors significantly associated with cause of death were provider, anesthesiologist, highest level of sedation, and anesthesia/sedation/medication-related effects. Postoperative factors significantly associated with cause of death were setting of the event and setting where adverse progression began. These factors are discussed below.

Age was significantly associated with cause of death ($P < .0001$). That is, mean age less than 26 years was significantly associated with airway/respiratory-related deaths and medication-related deaths, that is, the administration sedation or general anesthesia. In contrast, infection and cardiovascular events were associated with deaths in older persons (mean ages of 47 and 59 years, respectively).

Overall, medical disease severity (n = 52) and stability were infrequently reported (n = 41 cases). However, in the publications reporting this information, most persons who had died of an anesthesia/sedation/medication-related event were quite healthy and medically stable before initiation of the procedure ($P < .01$). In contrast, cardiovascular deaths were associated with more severe conditions and less stable health status.

Deaths attributed to anesthesia/sedation/medication-related effects (Supplemental Table SI) were significantly associated with the level of provider training ($P < .04$) and presence/absence of an anesthesiologist ($P < .002$). These deaths were more frequently associated with higher levels of sedation compared with cardiovascular-related deaths ($P < .02$). The majority of anesthesia/sedation-related deaths (n = 37) were associated with use of halothane, the patient being placed in the upright or sitting position, sedative drug overdose, respiratory depression, anoxia, and/or inadequate monitoring and emergency procedure implementation. Twenty deaths were associated with unintentional overdose. Of note, eight deaths were associated with local anesthesia administration. These deaths had associations with drug overdoses in children or sudden CVA in adults. There were six cases of adverse drug effects and two cases of mistaken drug administration; three were caused by hypersensitivity reactions; one drug-related death was

Table I. Characteristics* associated with cause of death categories

Variable	*Airway/respiratory* [16,19,20,22,35,37,41,58,61,62,66,68] *(N = 18)*	*Cardio vascular* [16,19,20,21,28,31,36,54,60,62,64,65,68,71-73,76] *(N = 31)*	*Anesthesia/sedation/ medication-related* [16,17,19,21,22,24,39,40, 43,50,51,52,59,62-64,69,72,74,75,76] *(N = 70)*	*Infection/sepsis* [19,27-30,33,34,42,44,45, 48,49,55-57,67,70] *(N = 19)*	P *value*
Age, y	25.7 ± 18.8	58.9 ± 16.1	22.3 ± 17.1	47.4 ± 20.1	<.0001
Gender					.25
Male	8 (47)	8 (38)	32 (46)	13 (68)	
Female	9 (53)	13 (62)	38 (54)	6 (32)	
ASA					.02
1	3 (30)	4 (24)	12 (80)	4 (40)	
2	1 (10)	3 (18)	0 (0)	0 (0)	
3	6 (60)	6 (35)	3 (20)	4 (40)	
4	0 (0)	4 (24)	0 (0)	2 (20)	
Medical Status					.01
Stable	3 (38)	1 (25)	17 (89)	5 (50)	
Unstable/poor control	5 (63)	3 (75)	2 (11)	5 (50)	
Provider When Care Was Initiated					.04
General dentist	4 (50)	3 (43)	23 (85)	4 (80)	
Dental specialist	4 (50)	2 (29)	3 (11)	1 (20)	
Board-certified dental specialist	0 (0)	2 (29)	1 (4)	0 (0)	
Anesthesiologist Involved					.002
No	8 (57)	9 (64)	19 (34)	6 (100)	
Yes	6 (43)	1 (7)	28 (50)	0 (0)	
Dentist was the anesthetist	0 (0)	4 (29)	9 (16)	0 (0)	
Anesthesia					.02
0 (No medication administered)	0 (0)	1 (4)	1 (1)	0 (0)	
1 (Local anesthetic administered)	5 (31)	9 (33)	8 (12)	0 (0)	
2 (Nitrous oxide/oral sedation)	1 (6)	0 (0)	10 (14)	0 (0)	
3 (Intravenous sedation)	2 (13)	7 (26)	8 (12)	1 (50)	
4 (General anesthesia)	8 (50)	10 (37)	42 (61)	1 (50)	
Operative Setting					.86
Hospital	1 (6)	1 (4)	4 (6)	1 (11)	
Outpatient	16 (94)	25 (96)	58 (94)	8 (89)	
Invasiveness Category					.18
Category 0	2 (12)	3 (15)	17 (38)	3 (19)	
Category 1	10 (59)	12 (60)	17 (38)	11 (69)	
Category 2	5 (29)	5 (25)	11 (24)	2 (13)	
Setting Where Adverse					<.0001
Progression Began					
Setting of dental treatment	12 (71)	21 (78)	62 (91)	0 (0)	
After dismissal	5 (29)	4 (15)	6 (9)	17 (94)	

(*continued on next page*)

Table I. Continued

Variable	*Airway/respiratory* [16,19,20,22,35,37,41,58,61,62,66,68] (*N = 18*)	*Cardio vascular* [16,19,20,21,28,31,36,54,60,62,64,65,68,71-73,76] (*N = 31*)	*Anesthesia/sedation/ medication-related* [16,17,19,21,22,24,39,40, 43,50,51,52,59,62-64,69,72,74,75,76] (*N = 70*)	*Infection/sepsis* [19,27-30,33,34,42,44,45, 48,49,55-57,67,70] (*N = 19*)	P *value*
Already severely compromised preoperatively?	0 (0)	2 (7)	0 (0)	1 (6)	
Time to Death, h	20 (1.4, 60)	39 (4, 120)	4 (1, 72)	408 (288, 720)	.0003
<4 h	5 (31)	4 (18)	27 (46)	0 (0)	<.0001
4−24 h	4 (25)	6 (27)	12 (20)	0 (0)	
24 h to 1 wk	6 (38)	11 (50)	12 (20)	3 (17)	
1 wk to 60 d	1 (6)	1 (5)	8 (14)	15 (83)	
Not specified	2	9	11	1	

Mean ± standard deviation (SD) is given for age and median (interquartile range) is given to time to death (because of skewness in times). Frequencies (percentages) are given for categorical variables. Data may not add to total because not all information was available in each publication.

Age − Airway/respiratory-related and anesthesia/sedation/medication-related are both significantly different from cardiovascular-related (cerebrovascular accident [CVA], myocardial infarction [MI]) and infection/sepsis-related (Bonferroni adjusted $P < .01$).

ASA − the distribution of American Society of Anesthesiologists (ASA) values are significantly different for airway/respiratory relative to cardiovascular-related (CVA, MI) and infection/sepsis-related (unadjusted $P < .05$) and visually different from anesthesia/sedation/medication-related ($P = 0.09$); however, Bonferroni adjusted P values are insignificant because of lack of power.

Medical Status − *Stable:* If no signs or symptoms reported, none or minimal abnormal laboratory test results that do not elevate risk, not taking medications or could only have minor interactions with planned treatment, or antibiotic prophylaxis not indicated. *Unstable (poor control):* If presence of signs/symptoms, abnormal vital signs or laboratory tests, taking medications (e.g., anticoagulants, bisphosphonates, steroids, etc.) that could have significant impact on planned treatment, or antibiotic prophylaxis indicated: The probability of good systemic stability is notably larger for anesthesia/sedation/medication-related deaths than for the other causes of death types ($P \leq .03$); however, Bonferroni adjusted P values are insignificant because of lack of power.

Provider Where Condition Initiated − P values from pairwise comparisons do not agree with the overall test; however, results are still suggestive that the distribution of causes of death types are different for general dentists relative to dental specialists and board cert dental specialists.

Anesthesiologist − there was a difference in the distribution of cause of death types for situations in which there was no anesthesiologist versus an anesthesiologist was involved (Bonferroni adjusted $P = .01$) and for situations in which an anesthesiologist was involved versus a dentist as the anesthetist (Bonferroni adjusted $P = .03$).

Highest Level of Sedation − the distribution of the highest level of sedation categories is different for cardiovascular-related (CVA, MI) deaths relative to anesthesia/sedation/medication-related deaths (Bonferroni adjusted $P = .01$).

Invasiveness Categories − 0 = noninvasive; 1 = biopsy, periodontal procedures, gingival surgery, simple extractions <5 erupted teeth, extractions(s) (the number or surgical not specified); 2 = implant surgery/placement, extractions >6 erupted teeth or impacted tooth/teeth, surgical extractions, osseous surgery, sinus lift surgery, bone biopsy, orthognathic surgery.

Setting Where Adverse Progression Began − For the majority of infection deaths, adverse progression occurred after dismissal, whereas adverse progression tended to begin at the setting of dental treatment for the other three causes of death.

*Indicates could not be determined in all cases.

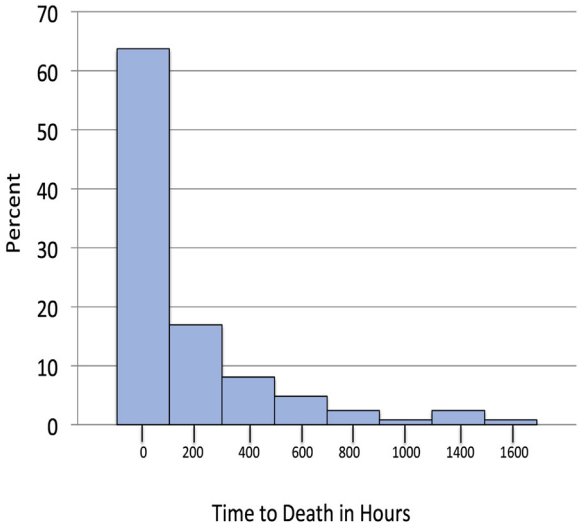

Fig. 2. Percentage of deaths with respect to time to death.

attributed to stopping warfarin (Coumadin) 4 days before tooth extractions that resulted in a CVA; and one death resulted from aspiration of vomitus in association with conscious sedation.

With respect to cardiovascular-related deaths (Supplemental Table SII), the following causes were reported: intracerebral and subarachnoid hemorrhage, myocardial infarction, cardiac arrest, arrhythmia, abdominal aneurysm, and fulminant heart failure.

Deaths attributed to infection (Supplemental Table SIII) occurred after dental treatment in all cases and involved spreading odontogenic infections; extractions; contamination of water line resulting in pneumonia; spreading of infection from overextended gutta percha into the maxillary sinus; infective endocarditis; osteomyelitis; Ludwig angina resulting from nonsterile iatrogenic air embolism; mucormycosis; and sepsis.

Respiratory-related deaths (Supplemental Table SIV) were associated with airway obstruction caused by hypersensitivity reaction, hereditary angioedema, asphyxia, aspiration of a cotton roll, iatrogenic air emphysema/embolism, and asthma attack. In the five bleeding-related fatalities (Supplemental Table SV), death was associated with alcoholism and hemorrhage, disseminated intravascular coagulation, hematoma, and anticoagulation resulting in spontaneous hemorrhage.

Logistic regression was performed with backward elimination to identify the variables that were important with respect to cause of death. Although significant predictors were not found with respect to airway/respiratory-related deaths, age was a significant predictor of anesthesia/sedation/medication-related effect deaths (odds ratio [OR] 0.94; 95% confidence interval [CI] 0.93−0.96; $P < .0001$) and deaths caused by infection/sepsis (OR 1.03; 95% CI 1.01−1.05; $P = .01$). In the setting of cardiovascular-related death, both age (OR 1.14; 95% CI 1.07−1.22; $P < .0001$) and setting where adverse progression began (i.e., before dismissal; OR 13.49; 95% CI 1.3−135.5; $P = .03$) were significant risk factors. Of note, invasiveness of the dental procedure was not significantly associated with death.

The distribution of deaths by time is provided in Figure 2 and Table I. Overall, the majority of deaths (>60%) occurred less than 100 hours after initiation of care. Of the 124 cases that reported time, death occurred within 4 hours in 43 cases (34.7%), between 4 and 24 hours in 17 (13.7%), between 24 hours and 1 week in 34 (27.4%), and after 1 week in 30 (24.2%). In the majority of cases, adverse progression toward death began in the dental setting. In bivariate analysis (see Table I), time of death was associated with cause of death ($P < .0001$). Specifically, infection/sepsis was associated with longer times to death (median 408 hours) compared with other causes of death ($P < .0001$). Time to death was the shortest and cases were most numerous (n = 32) when administration of anesthesia/sedation/medications was involved (median 4 hours). Over 50% of airway/respiratory-related deaths occurred within 24 hours of the procedure.

Table II shows preoperative, operative, and postoperative factors significantly associated with time to death. Preoperatively, time to death was shorter in patients who were young, were female, and had ASA classification <4. In the operative setting, anesthesia/sedation/medication-related deaths occurred faster than when sedative drugs were not administered. During the postoperative period, receiving care in a hospital setting was associated with longer times to death.

Table III shows the number of deaths reported by decade. Infection-related deaths demonstrated an increasing trend, deaths caused by cardiovascular disease demonstrated a decreasing trend, and anesthesia/sedation/medication-related deaths were reported variably over time.

DISCUSSION

Over the past 55 years, death has been reported as a rare occurrence in dentistry. In fact, this systematic review demonstrates that fewer than three deaths are reported per year in association with dental care. This figure, when considered with the estimated annual number of dental visits worldwide,[77,78] translates to an estimated risk of death during a dental procedure being less than 1 in 10 million (based on the estimate that at least 25% of the world population of 6.2 billion people sees a dentist annually). This suggests that dentistry provides a very

Table II. Factors significantly associated with time of death ($P < .05$)*

Preoperative	*Age* (n = 124) Being older was associated with longer times to death Spearman r = 0.33 ≥40 h (median = 120 h) <40 h (median = 23 h)	*Gender* (n = 121) Males tended to have longer times to death Males (median = 60 h) Females (median = 24 h)	*ASA* (n = 36) ASA = 4 tended to have longer times to death ASA = 1 (median = 48 h) ASA = 2 (median = 30 h) ASA = 3 (median = 30 h) ASA = 4 (median = 264 h)
Operative	*Operation setting* (n = 98) Times to death were longer in the hospital relative to outpatient Hospital (median = 156 h) Outpatient (median = 24 h)	*Dental procedure performed* (n = 106) Times to death were longer when a dental procedure was performed vs not initiated Performed (median = 45 h) Not initialized (median = 2 h)	*Anesthesia/sedation/medication-related effects* (n = 30) Times to death were shorter when a medication-related event occurred relative to no/mild drug interaction Anesthesia/sedation/medication−related (median = 16 h) No/mild drug (median = 168 h)
Postoperative	*Postoperative setting* (n = 105) Times to death tended to be shorter for outpatient relative to hospital or home setting Outpatient (median = 2 h) Hospital (median = 84 h) Home (median = 24 h)	*Setting where adverse progression began* (n = 117) Times to death tended to be shorter in settings of dental treatment relative to after dismissal Setting of treatment (median = 4 h) After dismissal (median = 144 h)	

*These associations represent descriptive findings and there is the possibility of type I errors.

Table III. Deaths reported by decade

	Airway/respiratory complications	*Local or systemic bleeding*	*Cardiovascular events*	*Anesthesia/sedation/ medication-related complications*	*Infection*	*Other causes*	*Total deaths*
1960−1969	0	0	0	2	1	0	3
1970−1979	4	1	15	40	0	0	60
1980−1989	0	1	4	9	0	1	15
1990−1999	6	1	5	10	3	2	27
2000−2009	5	1	4	1	4	1	16
2010−2015	3	1	3	8	11	1	27
							148

safe environment for a variety of oral health care procedures. Nevertheless, the number of deaths reported per decade has not decreased substantially; thus, there appears to be room for improvement in preventing this outcome.

This systematic review sought to identify several important factors associated with orofacial health, the provision of dental care, and death resulting from dental treatments in an effort to better understand the risks associated with this potential adverse outcome. Anesthesia/sedation/medication-related effects were the most frequent factors associated with death (47.3%), followed by cardiovascular events (20.9%), infection (12.8%), airway/respiratory issues (12.2%), and bleeding (3.4%). Of note, there were reports of death associated with several patient, provider, and procedural factors. Specifically, the patient's age, drugs administered, providers involved, and setting where care was provided were important risk factors.

Many adverse events associated with dentistry (e.g., bleeding, syncope, infection, osteonecrosis, hospitalization, and death) are preventable; however, the factors related to these adverse events must be fully understood to implement the best preventive practices. Although it is clear that not all fatalities associated with dentistry have been reported in the literature, the majority of those reported were associated with medication-related effects, particularly higher levels of anesthesia and sedation. Sedation-related deaths have been studied by several investigators,[17-21,23,64] and the accumulation of these reports suggests that the rate of death associated with sedation and general anesthesia ranges from 1 in 348,602 to 1 in 1,733,055 cases[20,65,79] and that very young patients (i.e., under age 5 years) are at greatest risk.[22,23] In our data set, cardiovascular-related deaths were about half as frequent as anesthesia/sedation/medication-related deaths, which suggests that the rate is less than one in a million. This is consistent with the report that myocardial infarction and cardiac arrest are

extremely rare, with incidence rates of 0.003 and 0.002 cases per dentist per year, respectively.[80] Moreover, our data suggest that infection-associated deaths and airway/respiratory-associated deaths are much less frequent than anesthesia/sedation/medication-related deaths and that deaths associated with bleeding and coagulation issues are rare.

Our findings show that that airway/respiratory-related deaths and anesthesia/sedation/medication-related deaths occurred more often in younger patients and that infection and cardiovascular deaths were more common after age 45 years. With the realization that most of the deaths in the young occurred in healthy, medically stable individuals, it becomes clear that there are likely other contributory factors. Our data strongly point to anesthesia/sedation drug administration, provider issues, and depth of sedation. Although the quality of information regarding provider background and training was generally lacking, differences in provider level of training were evident in cases of deaths related to anesthesia/sedation/medication compared with other categories of cause of death ($P < .002$). Thus, we speculate that provider knowledge regarding drug selection and utilization, frequency of attendance at continuing education courses, and use of standardized checklists that would minimize mistakes are topics for additional research. In comparison, cardiovascular deaths were often associated with higher levels of sedation in patients who had more severe and/or less stable health issues suggesting that the risk/benefit ratio of dental care in these patients should be carefully assessed. Possibly, a formula that weights important patient and procedural factors in a manner that overcomes the weaknesses of our current assessment approach for managing these patients would be of benefit.

The majority of deaths identified occurred less than 100 hours after initiation of dental care. Within this data set, respiratory deaths occurred faster compared with infection-related deaths. Because of the rapidity of de-evolution in respiratory-related deaths, providers need to be knowledgeable about emergencies, be prepared to manage such emergencies, implement preventive procedures, and be capable of performing emergency procedures. In contrast, the slower course of infection-related deaths strongly suggest that practitioners be able to recognize the features of an evolving and progressing infection and closely monitor the postoperative course of patients with orofacial infections to ensure that an accurate diagnosis has been made, proper care has been provided, and progress in recovery is being made.[27]

There are several limitations to this systematic review. First, the cases studied had level III and IV evidence, and such studies generally rely on historical information and thus suffer from recall bias. Second, the quality and quantity of information provided in the cases included were low. Many reports did not include information on the characteristics of the patient or the factors associated with the operative and perioperative period, and the information may have come from historical memory, which increases the risk of bias. Third, in "cause of death" category, the assignment of the cause was based on the authors' consensus impression of the main cause of death based on the evidence in the report; however, a case could often have been assigned to more than one category. For example, in at least two cases of death attributed to CVA-related causes, the patients had received local anesthesia with epinephrine, which may have contributed to the fatal episode; however, the main cause of death was assigned as stroke. Also, in three cases, death was attributed to airway-related causes that involved general anesthesia, and these cases could have been assigned to the anesthesia/sedation/medication-related category. Fourth, advances in drugs and monitoring over the last few decades may make some of the data derived from publications more than 20 years old rather obsolete. Fifth, the reporting of death in dentistry with respect to journal publication is voluntary; additional cases of death are hidden in malpractice claims[79] and/or in the gray literature, which we did not analyze. Also, readers should be aware that our search identified 334 more cases of death, which were excluded because of lack of information or because the time of death was more than 90 days from the dental appointment. This and additional exclusion criteria may have biased our analysis. Finally, our findings may have underestimated the number of deaths because some fatalities may not have been interpreted by the involved practitioners as being associated with dental procedures, and thus these cases would never have been reported.

CONCLUSIONS

Prevention of fatalities through proper physical assessment and accurate analysis of the factors identified here is important for improving risk management. It is possible that the factors described in this report can serve to establish a simple scoring system that can group patients into categories (low risk, intermediate risk, and high risk) to predict the risk for adverse outcomes. Such a scoring system or checklist, if validated, could be integrated with practice guidelines and help reduce fatalities in dentistry in the near future.

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SUPPLEMENTARY DATA

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.oooo.2016.10.015.

Supplemental Table SI. Anesthesia-sedation-medication-related deaths

Author (Year)	*Age (years) gender*	*Comorbidity status*	*Medications*	*Type of anesthesia*	*Dental procedure performed*	*Cause of death*	*Time to death in Hours*
Bourne (1970)[62]	9 M	None	NS	N_2O, GA	Extractions	Halothane-associated ventricular fibrillation and cerebral anoxia - patient seated upright	NS
Bourne (1970)[62]	30 M	NS	NS	N_2O, GA	RDC	Halothane-associated cardiac arrest - patient seated upright	NS
Bourne (1970)[62]	34 F	None	NS	N_2O, GA	Extraction	GA-associated ventricular fibrillation cerebral anoxia - patient seated upright	NS
Bourne (1970)[62]	39 F	None	NS	N_2O, GA	Extractions	Halothane-associated cardiac arrest - patient seated upright	NS
Bourne (1970)[62]	29 F	None	NS	LA,GA	LA	Lignocaine with 1:80,000 norepinephrine-associated CVA (brain hemorrhage of congenital aneurysm	264
Bourne (1970)[62]	18 F	None	NS	N_2O, GA	Extractions	Halothane-associated cardiopulmonary arrest - patient seated upright	168
Bourne (1970)[62]	30 M	None	NS	GA	Extractions	GA-associated cardiopulmonary arrest - patient seated upright and semi-upright	108
Bourne (1970)[62]	7 F	None	NS	LA, GA	NS	GA-associated cardiopulmonary arrest	24
Bourne (1970)[62]	41 M	NS	NS	N_2O, GA	Extraction	Halothane-associated ventricular fibrillation and cerebral anoxia - patient seated upright	12
Bourne (1970)[62]	5 F	None	NS	N_2O, GA	NS	GA-associated cardiopulmonary arrest - patient seated upright	4
Bourne (1970)[62]	14 F	None	NS	GA	None; extractions planned	Sedation-associated cerebral anoxia - patient seated upright	1
Bourne (1970)[62]	31 F	NS	NS	N_2O, GA	Extractions	Halothane-associated cardiopulmonary collapse - patient seated semi-upright	NS
Bourne (1970)[62]	8 M	None	NS	GA	Extractions	Contaminated general anesthetic given resulting in over-sedation and cerebral anoxia - patient seated upright	72
Brierley and Miller (1966)[63]	40 M	Prior nephrectomy	NS	GA	Extraction	Halothane-associated cerebral anoxia — patient seated semi-upright	672
Chicka et al. (2012)[22]	4.1 M	Sleep apnea	NS	LA	Restorative treatment	LA overdose	1
Chicka et al. (2012)[22]	3.9 M	NS	NS	LA, N_2O, OS	Restorative treatment	LA and oral sedation overdose	72
Chicka et al. (2012)[22]	3 M	NS	NS	N_2O, OS	Restorative treatment	Sedation overdose	24
Chicka et al. (2012)[22]	3 F	NS	NS	LA, N_2O, OS	Restorative treatment	Oral sedation overdose	4
Chicka et al. (2012)[22]	2 M	9I	NS	N_2O, OS	Restorative treatment	Oral sedation overdose	1
Chicka et al. (2012)[22]	2.5 F	NS	NS	LA	Restorative treatment	LA overdose	1
Chicka et al. (2012)[22]	3 F	NS	NS	GA	Restorative treatment	Likely GA overdose	2
Coplans and Curson (1982)[17]	45 F	NS	NS	GA	NS	Halothane-associated acute hepatic necrosis following 2 separate GAs 6-weeks apart	504
Coplans and Curson (1993)[19]	3 M	NS	NS	GA	NS	Drug (GA) induced respiratory depression	NS
Coplans and Curson (1993)[19]	29 F	6L	Paracetemol	GA	NS	Halothane and paracetamol-associated fulminant hepatic necrosis	168

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Supplemental Table SI. Continued

Author (Year)	*Age (years) gender*	*Comorbidity status*	*Medications*	*Type of anesthesia*	*Dental procedure performed*	*Cause of death*	*Time to death in Hours*
Coplans and Curson (1993)[19]	32 M	NS	NS	N_2O, GA	NS	Adverse drug (suxamethonium) reaction	24
Coplans and Curson (1993)[19]	25 M	NS	NS	GA	Conservative dentistry	Contaminated general anesthetic (wrong drug: mixture of methohexitone and halothane) given resulting in over-sedation and cerebral anoxia	0.1667
D'Eramo (1992)[64]	58 M	History of 2 CVAs	NS	LA	Extractions	Stopped coumadin 4 days before extractions resulting in CVA	336
D'Eramo et al. (2003)[21]	25 M	NS	NS	IV, GA	Extractions planned	GA-associated ventricular fibrillation and cerebral anoxia	48
Garriott and Di Maio (1982)[69]	25 F	NS	NS	IV	Oral surgery procedure	IV-associated respiratory failure. Combined lethal dose of diazepam and pentazocine	72
Garriott and Di Maio (1982)[69]	7 M	Asthma	NS	IV	Endodontic therapy	IV sedation-associated respiratory depression and failure. Combined lethal dose of diazepam and pentazocine	1.7833
Garriott and Di Maio (1982)[69]	38 F	Seizures	Dilantin and phenobarbital	IV	Oral surgery procedure	IV sedation-associated respiratory depression and failure. Combined lethal dose of diazepam and pentazocine	1
Hersh et al. (1991)[39]	5 F	None	NS	LA, N_2O	Extractions	Local anesthesia overdose	96
Hine and Pasi (1972)[40]	2.3 M	NS	NS	LA, IV	Corrective dental surgery	Alphaprodine overdose resulting in severe respiratory depression	7
Kupiec et al. (2011)[43]	6 M	Asthma	NS	N_2O, OS	NS dental procedure completed	Toxic levels of methadone mistakenly given in dental oral sedation cocktail	4
Lytle and Stamper (1989)[72]	17 M	NS	NS	IV	NS	GA-associated vomiting resulting in respiratory complications	4
Lytle (1974)[76]	30 F	NS	NS	GA	NS	Propoxyphene-associated fatal allergic reaction resulting in obstructed airway	15
Malamed (1999)[24]	4 M	NS	NS	LA	NS	LA overdose	48
Malamed (1999)[24]	68 F	Angina	NS	LA	Extractions	LA overdose	1
No author[51]	17 F	NS	NS	LA, IV	Extraction	Pentazocine overdose and respiratory failure	2
No author[50]	10 F	None	NS	GA	NS	GA-associated respiratory failure	1
No author (Calif Board Dent Examiners)[52]	6 F	NS	NS	LA, N_2O	Restorative treatment	LA overdose	408
Robinson (1989)[74]	22 F	NS	NS	LA	NS	Fatal reaction to LA presumed to be hypersensitivity reaction	0.2
Robinson (1989)[74]	30 M	NS	NS	N_2O, IV, GA	NS	Sedation (meperidine, diazepam, nitrous oxide) overdose	NS
Robinson (1989)[74]	3 M	NS	NS	N_2O, OS	NS	Chloral hydrate overdose	1
Schulman and Owens (1996)[75]	5 M	Sickle cell anemia	NS	GA	NS	GA-associated respiratory complications related to sickle cell anemia	720
Tarsitano (1965)[59]	3.75 F	NS	NS	LA, IV	NS	LA and sedation overdose respiratory failure	3.5
Tomlin (1974)[16]	28 F	Obesity	NS	NS	Extractions	Halothane-associated respiratory failure	NS

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Supplemental Table SI. Continued

Author (Year)	*Age (years) gender*	*Comorbidity status*	*Medications*	*Type of anesthesia*	*Dental procedure performed*	*Cause of death*	*Time to death in Hours*
Tomlin (1974)[16]	34 F	NS	NS	GA	NS	GA-associated respiratory failure	NS
Tomlin (1974)[16]	41 F	NS	NS	GA	Extractions	Halothane-associated respiratory failure	NS
Tomlin (1974)[16]	40 M	NS	NS	GA	NS	Halothane-associated respiratory failure − patient seated in upright position	672
Tomlin (1974)[16]	34 F	NS	NS	GA	Extraction	GA-associated hepatic degeneration associated with anoxia due to inhalation of vomitus	360
Tomlin (1974)[16]	6 F	NS	NS	N_2O	NS	Respiratory failure due to lack of oxygenation during nitrous-oxide inhalation	144
Tomlin (1974)[16]	30 M	NS	NS	GA	NS	GA overdose (methohexitone) and respiratory failure	120
Tomlin (1974)[16]	7 F	NS	NS	LA, GA	PBNP	Halothane-associated cardiopulmonary failure	24
Tomlin (1974)[16]	28 M	NS	NS	GA	Extractions	General anesthesia-associated cardiopulmonary failure	22
Tomlin (1974)[16]	44 M	NS	NS	N_2O, GA	Extractions	Halothane-associated cardiopulmonary failure	2
Tomlin (1974)[16]	14 F	NS	NS	GA	NS	Possibly arrhythmia due to epinephrine in local anesthesia or sedation associated cardiopulmonary failure	2
Tomlin (1974)[16]	21 F	Dental abscess and tonsillitis	NS	GA	Extractions PBNP	Halothane-associated cardiopulmonary failure related to underlying severe myocarditis	2
Tomlin (1974)[16]	56 F	NS	NS	GA	PBNP	GA-associated cardiopulmonary failure	2
Tomlin (1974)[16]	9 M	NS	NS	GA	Extractions	Halothane-associated cardiopulmonary failure	1.5
Tomlin (1974)[16]	39 F	NS	NS	GA	Extractions	Halothane-associated cardiopulmonary failure	1.1667
Tomlin (1974)[16]	30 M	NS	NS	N_2O, GA	Extractions PBNP	Halothane and trichloroethylene -associated cardiopulmonary failure	1
Tomlin (1974)[16]	7 F	NS	NS	LA	NS	Respiratory depression and failure due to GA and large dose of LA	1
Tomlin (1974)[16]	20 F	NS	NS	N_2O, GA	NS	Respiratory failure due to lack of oxygenation during nitrous-oxide inhalation	1
Tomlin (1974)[16]	22 F	NS	NS	LA with noradrenaline	NS	Possible death due to LA noradrenaline-induced arrhythmia leading to pulmonary edema	1

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Supplemental Table SI. Continued

Author (Year)	*Age (years) gender*	*Comorbidity status*	*Medications*	*Type of anesthesia*	*Dental procedure performed*	*Cause of death*	*Time to death in Hours*
Tomlin (1974)[16]	29 F	NS	NS	LA, GA	PBNP	Rupture of congenital berry aneurysm after induction with methohexitone and administration of LA containing 1:80,000 noradrenaline	1
Tomlin (1974)[16]	5 M	NS	NS	N_2O, GA	NS	Halothane-associated respiratory arrest	27
Tomlin (1974)[16]	32 M	NS	NS	N_2O, GA	Extractions	GA-associated respiratory failure − patient unattended during recovery	1
Tomlin (1974)[16]	35 M	Unrecognized viral myocarditis	NS	N_2O, GA	Extractions planned	Halothane-associated cardiopulmonary arrest	NS
Tomlin (1974)[16]	3 F	NS	NS	GA	Extractions	GA-associated cardiopulmonary arrest	NS

CVA, cerebrovascular accident; *F*, female; *GA*, general anesthesia; *IV*, intravenous sedation; *LA*, local anesthesia; *M*, male; *N_2O*, nitrous-oxide inhalation; *NS*, not specified; *OS*, oral sedation; *PBNP*, planned but not performed.

Supplemental Table SII. Cardiovascular disease-related deaths

Author (Year)	*Age (years) gender*	*Comorbidity status*	*Medications*	*Type of anesthesia*	*Dental procedure performed*	*Cause of death*	*Time to death in Hours*
No author [ASOS Committee](1974)[68]	5 NS	NS	NS	GA	NS	Cardiopulmonary collapse	NS
No author [ASOS Committee](1974)[68]	25 NS	NS	NS	GA	NS	Toxic viral myocarditis, arrhythmia, cardiac arrest	NS
Funayama et al. (1994)[36]	71 M	Cirrhosis	NS	LA	Surgical extraction	Hematoma/swelling of floor of mouth associated with cirrhosis and impaired coagulation resulting in cardiopulmonary arrest	24
Bourne (1970)[62]	63 F	Previous coronary thrombosis	NS	GA	Extractions planned	Myocardial infarction	NS
No author [ASOS Committee] (1974)[68]	45 NS	NS	NS	GA	NS	Myocardial infarction	NS
No author [ASOS Committee](1974)[68]	55 NS	NS	NS	LA, IV	NS	Myocardial infarction	NS
No author [ASOS Committee](1974)[68]	45 NS	NS	NS	LA, IV	NS	Myocardial infarction	NS
No author [ASOS Committee](1974)[68]	65 NS	NS	NS	GA	NS	Myocardial infarction	NS
No author [ASOS Committee](1974)[68]	75 NS	NS	NS	LA, IV	NS	Myocardial infarction	NS
No author [ASOS Committee](1974)[68]	55 NS	NS (ASA 2-3 reported)	NS	GA	NS	Cardiac arrest	120
No author [ASOS Committee](1974)[68]	55 NS	NS	NS	LA	NS	Myocardial infarction	4
Lytle (1974)[76]	67 M	Heart disease, history of rheumatic fever	NS	LA, GA	Extractions	Cardiac arrest, likely due to recent myocardial infarction	2
Lytle and Stamper (1989)[72]	63 M	Heart disease	NS	LA, IV	Extractions	Myocardial infarction	4
D'Eramo (1992)[64]	70 F	Myocardial infarction	NS	LA	Extraction	Cardiac arrest	18
Coplans and Curson (1993)[19]	65 F	Rheumatic fever	NS	NS	Extractions	Severe cardiovascular pathology leading to cardiovascular collapse	0.1667
Kunkel et al. (2007)[71]	77 M	Coronary artery disease, angina	NS	LA, GA	Surgical extraction	Myocardial infarction	552
D'Eramo et al. (2008)[65]	77 F	CHF	NS	LA	Extractions	Acute fulminant CHF and pulmonary edema, leading to cardiac arrest	48
D'Eramo et al. (2008)[65]	76 F	Diabetes	No prescription medications	LA, IV	Extractions	Cardiac arrest	30
Smith et al. (2014)[28]	65 M	CHF, prosthetic heart valve	NS	NS	Extraction(s)	Ventricular fibrillation associated with congestive heart failure	72
Smith et al. (2014)[28]	62 F	CHF, 1R	NS	NS	Extraction(s)	Cardiac arrest associated with CHF	48
Smith et al. (2014)[28]	82 M	CHF, heart disease	NS	NS	Extraction(s)	Acute coronary syndrome associated with sepsis and atrial fibrillation	24
Nkansah et al. (1997)[20]	75 F	NS	NS	IV	Extraction(s)	Cardiac arrest / CVA	120
No author [ASOS Committee](1974)[68]	35 NS	NS	NS	GA	NS	CVA	NS
Lytle (1974)[76]	56 F	Polycythemia	NS	N_2O, GA	NS	CVA - subarachnoid hemorrhage	144
Massalha et al. (1996)[73]	59 F	NS	NS	LA	Extractions	CVA – intracerebral hemorrhage/ hematoma	72
Massalha et al. (1996)[73]	54 F	NS	NS	LA	RDC	CVA – intracerebral hemorrhage/ hematoma	120

(*continued on next page*)

Supplemental Table SII. Continued

Author (Year)	*Age (years) gender*	*Comorbidity status*	*Medications*	*Type of anesthesia*	*Dental procedure performed*	*Cause of death*	*Time to death in Hours*
D'Eramo et al. (2003)[21]	60 M	NS	NS	IV	Extraction(s)	Abdominal aneurysm	24
Barbas et al. (1987)[31]	52 F	NS	NS	None	Root canal therapy	CVA − cerebral hemorrhage/hematoma	120
Boakes et al. (1972)[60]	50 F	NS	NS	LA	Extraction(s)	CVA − brain hemorrhage	48
Tomlin (1974)[16]	65 M	NS	NS	LA with noradrenaline	Surgical extractions	Likely developed severe arrhythmia resulting in cardiac arrest	1
Okada et al. (1989)[54]	58 F	Hypertension	Thiazide	LA with noradrenaline	LA	CVA − subarachnoid hemorrhage	2

ASA, American Society of Anesthesiologists classification; *CHF*, congestive heart failure; *CVA*, cerebrovascular accident; *F*, female; *GA*, general anesthesia, *IV*, intravenous sedation; *LA*, local anesthesia; *M*, male; N_2O, nitrous oxide inhalation; *NS*, not specified.

Supplemental Table SIII. Infection-related deaths

Author (Year)	*Age (years) gender*	*Comorbidity status*	*Medications*	*Type of anesthesia*	*Dental procedure performed*	*Cause of death*	*Time to death in Hours*
Mehrotra (1965)[48]	36 M	None	NS	NS	Extractions	Cavernous sinus thrombosis and septicemia followed dental extractions	600
Coplans and Curson (1993)[19]	62 M	Prosthetic heart valve	NS	NS	Restorative dentistry	Infective (bacterial) endocarditis; non-administration of prophylactic antibiotics	1440
Coplans and Curson (1993)[19]	46 M	Unrecognized congenital bicuspid heart valve	NS	NS	Extensive restorative dentistry	Infective (bacterial) endocarditis; non-administration of prophylactic antibiotics	720
Ely et al. (1993)[33]	22 M	None	NS	GA	Surgical extractions	Ludwig's angina and left parapharyngeal abscess associated with pressuring nonsterile air embolism from dental drill	408
Schmitt et al. (2004)[57]	43 M	NS	NS	NS	Extraction	Infective (bacterial) endocarditis; non-administration of prophylactic antibiotics	1680
Dhoble et al. (2009)[67]	61 M	NS	NS	NS	Extractions	Infective (bacterial) endocarditis; non-administration of prophylactic antibiotics	408
Ardiç et al. (2011)[30]	34 F	NS	NS	NS	Extraction(s)	Infective (bacterial) endocarditis	720
Holmes and Udey (2011)[27]	17 F	None	NS	IV	Multiple extractions	Spreading odontogenic infection resulting in sepsis and organ failure	NS
Holmes and Udey (2011)[27]	20 M	None	NS	NS	Extraction	Spreading odontogenic infection resulting in sepsis and cardiac arrest	120
Ricci et al. (2012)[55]	82 F	None	NS	NS	NS	Legionnaire's pneumonia and septic shock after exposure to contaminated dental unit waterline	192
Santana-Cabrera et al. (2012)[56]	32 M	None	NS	NS	Extractions	Spreading odontogenic infection from maxillary sinus to brain	288
Antunes et al. (2013)[29]	45 F	Diabetes	NS	NS	Extraction	Spreading odontogenic infection associated with necrotizing fasciitis, septic shock and organ failure	144
Levine (2013)[44]	30 M	None	NS	NS	Nonsurgical endodontics	Spreading odontogenic infection associated with root canal filling material overextended into sinus resulting in severe bacterial infection of left eye, cavernous sinus and massive brain infection	72
Lopez et al. (2013)[45]	69 M	Prosthetic heart valve	NS	NS	NS	Infective (bacterial) endocarditis; non-administration of prophylactic antibiotics	1440
Moore et al. (2013)[49]	34 M	NS	NS	NS	NS	Infective (bacterial) endocarditis; administration of prophylactic antibiotics uncertain	672

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Supplemental Table SIII. Continued

Author (Year)	*Age (years) gender*	*Comorbidity status*	*Medications*	*Type of anesthesia*	*Dental procedure performed*	*Cause of death*	*Time to death in Hours*
Smith et al. (2014)[28]	77 F	Prosthetic heart valve endocarditis, DIC	NS	NS	Extraction	Complication of endocarditis, DIC	288
Kim et al. (2001)[42]	57 M	Diabetes	Chlorpropamide, insulin	NS	Extractions	Spreading odontogenic infection associated with mucormycosis, cavernous sinus thrombosis and respiratory failure	312
Fogarty et al. (2006)[34]	74 M	COPD and recent pneumonia	Montelukast, albuterol, fluticasone propionate/salmeterol, tiotropium bromide, amoxicillin/clavulanate	NS	Extractions	Spreading odontogenic infection associated with invasive mucormycosis, pneumonia and respiratory /cardiopulmonary arrest	1032
Gen et al. (2013)[70]	60 F	Diabetes	Oral hypoglycemic agents	NS	Extractions	Spreading odontogenic infection associated with rhino-orbital-cerebral mucormycosis and intracranial extension	360

COPD, chronic obstructed pulmonary disease; *DIC*, disseminated intravascular coagulation; *F*, female; *GA*, general anesthesia; *IV*, intravenous sedation; *M*, male; *NS*, not specified.

Supplemental Table SIV. Airway-related deaths

Author (Year)	*Age (years) gender*	*Comorbidity status*	*Medications*	*Type of anesthesia*	*Dental procedure performed*	*Cause of death*	*Time to death in Hours*
Coplans and Curson (1993)[19]	23 M	Seizures, cerebral palsy	Phenytoin	GA	NS	Bronchospasm, airway obstruction	0.1667
Bork and Barnstedt (2003)[61]	30 F	HAE	NS	LA	RDC	HAE-associated airway obstruction	41
Bork and Barnstedt (2003)[61]	27 F	Undiagnosed HAE	NS	NS	RDC	Possible HAE-associated airway obstruction	16
Bork and Barnstedt (2003)[61]	32 F	Undiagnosed HAE	NS	NS	RDC	HAE-associated airway obstruction	16
Bork and Barnstedt (2003)[61]	46 M	Undiagnosed HAE	NS	LA	RDC	HAE-associated airway obstruction	12.5
Fuentes-Garcia et al. (2009)[35]	20 M	San Filippo syndrome, mitral valve prolapse, seizures	Diazepam, valproate sodium, lamotrigine, baclofen, piracetam	GA	RDC	Nasal hemorrhage-associated airway obstruction	120
Nkansah et al. (1997)[20]	22 M	Asthma	Salbutamol	IV	RDC	Asthma attack, airway obstruction	24
Bourne (1970)[62]	5 F	NS	NS	LA	RDC	Aspiration of extracted tooth leading to airway obstruction	0.1667
No author [ASOS Committee](1974)[68]	15 NS	NS	NS	GA	NS	Aspiration of vomitus associated with GA	1440
Tomlin (1974)[16]	19 F	NS	NS	GA	RDC	Airway obstruction, anatomic abnormality of mandible	NS
Tomlin (1974)[16]	5 F	NS	NS	LA	RDC	Aspiration of foreign body (tooth) into trachea led to asphyxia	1
Chicka et al. (2012)[22]	5 F	NS	NS	N_2O/oral sedation	RDC	Aspiration of foreign body (cotton roll) into trachea led to asphyxia	48
Sterzik et al. (2015)[58]	23 F	Fainting	NS	GA	None	Airway obstruction, misintubation	1
Davies and Campbell (1990)[66]	50 M	Mildly abnormal LFT, osteoarthritis	None	GA	Osseous surgery for implants	Air emphysema/air embolism	72
Davies and Campbell (1990)[66]	48 F	NS	NS	IV	Osseous surgery for implants	Air emphysema/air embolism	36
Davies and Campbell (1990)[66]	16 M	None	NS	GA	Osseous surgery for implants	Air emphysema/air embolism	1.75
Gangemi et al. (2009)[37]	75 M	Diabetes, cardiopathy, chronic bronchitis	NS	None	Dental impression	Impression material-induced pharyngeal swelling and fatal hypersensitivity reaction	2
Kawashima et al. (2013)[41]	74 M	Cirrhosis	NS	LA	RDC	Airway obstruction (tracheal compression from lingual alveolar bone fracture and bleed)	168

F, female; *HAE*, hereditary angioedema; *LFT*, liver function tests; *GA*, general anesthesia; *IV*, intravenous sedation; *LA*, local anesthesia; *M*, male; *N_2O*, nitrous oxide inhalation; *NS*, not specified; *RDC*, routine non-invasive dental care.

Supplemental Table SV. Bleeding-related deaths

Author (Year)	*Age (years) gender*	*Comorbidity status*	*Medications*	*Type of anesthesia*	*Dental procedure performed*	*Cause of death*	*Time to death in Hours*
Lytle (1974)[76]	47 M	Alcohol abuse	NS	LA, IV	Minor procedure (type not disclosed)	Massive gastrointestinal hemorrhage, longstanding history of alcoholism	NS
McKechnie (1989)[47]	59 M	NS	Diuretic	NS	Surgical extraction	DIC associated with undiagnosed prostate carcinoma	192
Marshall et al. (1993)[46]	24 F	Seizures	Phenytoin, carbamazepine, clonazepam	GA	Surgical extractions	DIC and gross intrapulmonary hemorrhage,	40
D'Eramo et al. (2008)[65]	57 M	CHF, undisclosed liver disease	NS	GA	Extractions	Alcoholic liver disease: persistent oozing and hemorrhage from extraction sites led to traumatic intubation complicating airway management	144
Smith et al. (2014)[28]	77 M	CHF, atrial fibrillation	NS	NS	Extractions	Atrial fibrillation and anticoagulation that led to retroperitoneal hemorrhage	480

CHF, congestive heart failure; *DIC*, disseminated intravascular coagulation; *F*, female; *IV*, intravenous sedation; *GA*, general anesthesia; *LA*, local anesthesia, *M*, male; *NS*, not specified.