Factors Involved In Dental Surgery Fires: A Review of the Literature

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Surgical fires are well-characterized, readily preventable, potentially devastating operating room catastrophes that continue to occur from 20 to 100 times per year or, by one estimate, up to 600 times per year in US operating rooms, sometimes with fatal results. The most significant risk factors for surgical fires involve (a) the use of an ignition source, such as laser or electrocautery equipment, in or around an oxygen-enriched environment in the head, neck, and upper torso area and (b) the concurrent delivery of supplemental oxygen, especially via nasal cannula. Nonetheless, while these 2 conditions occur very commonly in dental surgery, especially in pediatric dental surgery where sedation and anesthesia are regularly indicated, there is a general absence of documented dental surgical fires in the literature. Barring the possibility of underreporting for fear of litigation, this may suggest that there is another mechanism or mechanisms present in dental or pediatric dental surgery that mitigates this worst-case risk of surgical fires. Some possible explanations for this include: greater fire safety awareness by dental practitioners, incidental ventilation of oxygen-enriched environments in patient oral cavities due to breathing, or suction used by dental practitioners during procedures. This review of the literature provides a background to suggest that the practice of using intraoral suction in conjunction with the use of supplemental oxygen during dental procedures may alter the conditions needed for the initiation of intraoral fires. To date, there appear to be no published studies describing the ability of intraoral suctioning devices to alter the ambient oxygen concentration in an intraoral environment. In vivo models that would allow examination of intraoral suction on the ambient oxygen concentration in a simulated intraoral environment may then provide a valuable foundation for evaluating the safety of current clinical dental surgical practices, particularly in regard to the treatment of children.

Key Words: Surgical fire; Operating room; Dentistry; Dental treatment; Airway fire.

Dental surgical fires comprise a subset of surgical fires, and yet a chronologic bibliography of literature on surgical fires from 1949 to 2009 lists only

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2 papers, one from 1964, another from 1971, specifically related to dentistry, both of which address dangers relevant only to the era when flammable anesthetics were still the norm.[1] Reviewing current literature on dental surgical fires yields more articles dedicated to the promotion of the use of lasers in dentistry[2–5] than to articles examining the safety of those lasers with respect to dental surgical fires or to dental surgical fire hazards in general.[1] Similarly, both recent articles on fire safety for dental surgery[6–9] and a review of dental fire safety literature in general primarily offer more summaries of existing safety protocols than case studies.[8] One editorial from 2012 cites the documentation of dental surgical fire from 1992, which involved the unusual circumstance of a spark from a broken burr lighting a patient's moustache on fire.[6]

This paucity of case studies may be due to underreporting.[10,11] It is unclear whether all states are now required to report surgical fires. In 2003, Washington, California, and Tennessee were the only states to do so, and federal reporting was triggered only in cases of equipment failure.[12] By 2010, still only half of US states were required to report adverse events.[13] Variation from state to state with regard to reporting may be a factor as well, insofar as hospital fires would be almost impossible to hide, while dental office fires might easily be concealed. Nevertheless, while a relatively greater number of medical as opposed to dental procedures where fire is a risk may lead to fewer dental fires being documented, it seems reasonable to expect at least a similar proportion of documentation of dental to surgical fires. Alternatively, it may simply be true that proportionately fewer dental surgical fires actually occur. Insofar as the use of supplemental oxygen via nasal cannula is especially implicated in such fires,[14] this may be particularly significant in pediatric dentistry, where procedural sedation is often indicated even for nonsurgical procedures, especially for children with special health care needs.[15] In view of this shortage of specific cases of documented dental surgical fires, then, it may be that dental procedures involving the use of supplemental oxygen circumstantially reflect a factor that mitigates surgical fire risk. Some possible explanations for this risk mitigation include: greater fire safety awareness by dental practitioners, ventilation of oxygen-enriched environments in patient oral cavities due to breathing, or suction used by dental practitioners during procedures. To investigate this further, first requires examining what evidence there is for the broader category of surgical fires.

In examining the full scope of surgical fires, one finds that the circumstances leading to and the means for preventing surgical fires have long been well-characterized.[16,17] They have been described as completely preventable[18] and as 1 of 3 "never events," along with left-behind surgical materials and wrong-site surgery, that should *never* occur in medical practice.[19] Nonetheless, they continue to occur, often with devastating[10] and sometimes fatal consequences.[14,16,17] Surgical fires have long been a peril of surgery,[20] especially during the period when the most prevalent anesthetics were flammable.[10] Barker and Polson[21] may have been among some of the first to attempt to identify and recreate the conditions of an actual operating room fire. With the decline in use of flammable anesthetics, the general concern for and awareness of fire safety in the operating room declined[10]; this awareness has yet to return to previous levels.[22,23] Subsequently, the vastly increased use of laser and electrocautery equipment has reintroduced an increased risk of surgical fires,[10] despite many long-standing safety protocols for laser equipment.[1] Given that lasers may not in fact offer any significant advantage over the older, nonthermal methods they are meant to replace,[24] as confirmed ignition sources[20] they actually *create*—rather than simply increase—a risk of surgical fires that would not otherwise be present.

By 2003, at least 2 major new industry efforts had provided guidelines for limiting and preventing the again increasing risk of surgical fires,[11,25] yet a closed claims analysis in 2004 found that nearly 1 in 5 surgical fires resulted from cautery equipment[26]; and another analysis in 2006 found that 100% of examined cases were caused by an electrosurgical unit.[27] By 2007, surgical fires occurred frequently enough to become mainstream news and were more common than was generally assumed.[28] Despite half a decade of effort since 2003 to disseminate best practices for preventing surgical fires, peer-reviewed articles such as Stoneham et al[30] still advocated unsafe operating room practices. For example, Zheng and Gravenstein[29] specifically expressed concern that the method of carotid cross-clamping proposed by Stoneham et al,[30] particularly for the up to 1 hour duration they described, might increase the likelihood of an oxygen concentration greater than 30% in the surgical field,[29,30] in direct contradiction to many widely circulated safety protocols.[11,18,25] By 2011, more detailed guidelines had been disseminated by official agencies[31–33] and dental researchers alike,[7,20] and yet, over the past 25 years the number of surgical fires due to electrocautery alone increased more than 400%,[18] representing approximately 4% of surgical anesthesia claims.[34]

Since the decline in use of flammable anesthetics, the most significant factor in causing surgical fires has been the presence of a pooled or trapped oxygen-enriched environment, whether in tissue,[16] under surgical drapes,[35,36] or in the environment generally.[14] This increased risk of an oxygen-enriched environment can occur through an equipment leak,[20] through the use of an uncuffed as opposed to cuffed endotracheal tube during general anesthesia,[37] or most commonly via the administration of supplemental oxygen, typically with a nasal cannula.[14] The majority of surgical fires have affected the upper torso, head, and neck region.[14,20] Lasers and electrocautery equipment have most frequently been the ignition source.[14,27] Surgical drapes[36] and patients themselves[14] are very often the ignited fuel source.

From a review of literature concerning surgical fires, the most significant contributing factors for surgical fires are (a) the use of an ignition source, such as laser or electrocautery equipment, in or around an oxygen-enriched environment in the head, neck, and upper torso area in conjunction with (b) the concurrent delivery of supplemental oxygen, typically via nasal cannula. Taken together, these 2 risk factors were the basis for the 2010 recommendation by the Anesthesia Patient Safety Foundation (APSF) to avoid such circumstances altogether. The APSF considers this combination of practices to be outside the norm for safe surgical practice.[14]

The fact that a majority of *all* surgical fires occur during head and neck surgery[20] would seem to suggest logically that there should be a greater risk of surgical fires for dental surgery. Nevertheless, dental surgical fires appear to be rarer than surgical fires,[1] though whether this is due to a greater dental fire safety awareness is not clear.[6–9] Though this may seem to mitigate any concern for dental surgical fires, the danger posed by such a fire in a pediatric setting makes dismissing or minimizing this concern untenable.

While procedural sedation is common in pediatric dentistry,[38] children's incomplete pulmonary development places them at greater risk for hypoxia during sedation.[39] Given that respiratory compromise is a leading cause of dental pediatric sedation morbidity and mortality,[40,41] the use of supplemental oxygen, at *all* levels of pediatric sedation,[42] is typically indicated as a safeguard against such compromise, particularly for hypoxia.[7] To the extent that the use of cuffed endotracheal intubation helps to mitigate the risk of creating an oxygen-enriched environment in the surgical area, this prevails only when general anesthesia is utilized, when the cuff does not malfunction, and when the use of such a device is available or appropriate for a given pediatric patient.[37] In other cases where lasers or electrocautery equipment are used, this reproduces the 2 most exacerbating circumstances for procedural fires: (a) the use of an ignition source in or around an oxygen-enriched environment in the head, neck, and upper torso area in conjunction with (b) the concurrent delivery of supplemental oxygen, typically via nasal cannula.

Whether the absence of documentation for pediatric dental surgical fires in the literature is due to underreporting or other factors,[22] the circumstance nevertheless presents a striking puzzle. While the pediatric dental techniques of oral or intravenous sedation with supplemental oxygen might be characterized in a nondental surgical setting as something to be avoided as much as possible,[14] one might ask what additional factor short of good luck could be at work in pediatric settings to mitigate the presence of the most exacerbating factors for an increased risk of surgical fires.

In fire safety protocols for medical surgical settings, diluting or ventilating an oxygen-enriched environment seems infrequently or weakly emphasized. In dentistry, exhaustion of the surgical area by suction is an integral part of all procedures both surgical and nonsurgical. Bruley[10] distinguishes between the type of fires characteristic of flammable anesthetic era and the current fires he describes as insidious, insofar as their onset depends to a greater extent upon a complex interaction of circumstances. In prior eras, the danger consisted primarily of flammable anesthetics themselves becoming exposed to an ignition source; now, the danger arises more from an oxygen-enriched environment potentially making any material in the operating room flammable, even when the material may be fire-resistant.[7,9,43]

While the model of the fire triad identifies 3 necessary components to create the conditions for a fire—an ignition source, a fuel source, and an oxidation source,[18] it does not yet completely specify the conditions at which ignition will occur. In general, fire prevention involves removing one of the legs of the fire triad.[18] This may be by extinguishing or not lighting an ignition source, by wetting or removing a fuel source, by diluting or exhausting any oxidizer, and by other means.[33] In circumstances where an oxidizer must accumulate to provide the right conditions for ignition to occur,[16] natural or mechanical ventilation of the space being filled up with oxidizer might similarly delay or inhibit ignition.

Spontaneous ventilation is present during oral, minimal, moderate, and some types of deep sedation and general anesthesia. This ventilation would be expected to affect the fire triad by disrupting the potential pooling of supplemental oxygen in the oral cavity provided by the nasal cannula. Alternatively, intraoral suction may draw off sufficient oxygen in an oxygen-enriched environment such that the onset of combustion is delayed, if not inhibited entirely. Either mechanism affects the fire triad; of the 2 mechanisms, intraoral suction would be more readily simulated in an in vitro model.

Recommendations from the APSF indicate that the fraction of inspired oxygen (FIO_2) should not exceed 30% when supplemental oxygen is used.[18] However, in one case a mixture of 75% nitrous oxide and 25%

oxygen resulted in combustion when a spark ignited a patient's moustache.[6] In another case, polyvinyl endotracheal tubes that were flammable at 25% oxygen caught fire.[22] Barker and Polson[21] used a flow-rate of 6 L/min in order to recreate the conditions of an actual surgical case and obtained a 50% concentration of oxygen under the surgical drapes. Roy and Smith[16] used oxygen concentrations in their experiment from 100% to less than 50% at 2 flow rates, 15 L/min and 10 L/min. These circumstances indicate that even when following APSF safety recommendations, unsafe surgical conditions may still result.

Thus, as recently as 2012, it has been suggested that the long-standing safety assumptions about surgical fires may need revisiting, particularly with regard to a more cautious use of oxygen.[17] Gibbs,[44] in one of the most recent articles to discuss this safety issue, instead identifies the involvement of numerous systematic factors, ie, limited training and/or health care provider experience that addresses this generally low-incidence event, failures of internally based policy reviews and enforcement mandates, and a lack of time or talent at facilities to properly address effective preventive measures. Gibbs[44] (p 6712) noted "Vigilance actions alone have been unsuccessful so hospitals now have to take a systematic approach to implementing safer processes and providing the resources for surgeons and other stakeholders to optimize the OR environment."

In general, these 2 recent recommendations point to forms of intervention into the fire triangle that either mitigate the risks posed by oxygen[17] or emphasize the anesthesiologist, surgeon, and surgical assistant as stakeholders in the operatory.[44] This suggests that another way to diminish the risk of oxygen-enriched surgical environments might be to exhaust the surgical environment of oxygen. Our review of the literature, then, provides the background to suggest that the practice of using intraoral suction in conjunction with the use of supplemental oxygen during dental procedures may provide a mechanism that reduces the risk of creating the conditions needed for the initiation of intraoral fires. To date, there appear to be no published studies on this. To determine the highest oxygen concentration at any given oxygen flow rate that intraoral suction proves capable of depleting or exhausting so that surgical oxygen levels remain reliably and safely below the combustible level may elucidate an additional critical factor in the control of the fire triad in the operatory. Similarly, to evaluate the capacity of intraoral suction to delay the onset of ignition may also provide additional safety considerations or protocols to reduce the risk of dental surgery fires and surgical fires in general. Such research might thus provide a valuable foundation for evaluating the safety of current clinical dental surgical practices, especially with regard to the treatment of children.

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