A Review of Dental Anatomy and Dental Injury Associated With Anesthesia

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Dental injury during airway management is a common complication encountered during the administration of general anesthesia. This article gives an overview of the frequency of dental injuries, dental anatomy, conditions that increase the risk of dental injury, and mechanism of injury, as well as discusses injury management and avoidance of dental trauma. Although this article does not encompass all situations and variables, it covers these topics in a useful and easily remembered manner that the anesthetist can easily incorporate into practice.

Keywords: Adverse anesthetic events, difficult intubation, perioperative dental injury.

Objectives
Upon completion of this course, the reader will be able to:
1. Discuss the incidence of dental injury during general anesthesia.
2. Describe basic dental anatomy and the identification of both deciduous and adult teeth and common dental pathology.
3. Discuss the mechanism of dental injury during anesthesia.
4. Outline the steps of care provided to patients following dental injury.
5. Describe various methods that may be employed to minimize dental trauma.

Introduction
Dental injury is a known complication of airway management during general anesthesia. Intraoperative dental injury has been a recognized problem since 1936, when Magill recommended the use of adhesive plaster for the protection of the teeth during endotracheal intubation. Damage to the native dentition, teeth that have been restored, or permanent or removable prosthetics (crowns, bridges, and partial or complete dentures) is linked to endotracheal intubation, but may also transpire with the insertion or removal of oropharyngeal airways, oral retractors, and bite blocks. Dental injury is more frequent in patients with “hidden” oral and dental pathology that is not detected preoperatively, chiefly involving the maxillary central incisors. Soft-tissue injury may accompany dental injury or may occur separately. Minor abrasions or lacerations of the lips, tongue, oral pharynx, and esophagus frequently occur with difficult endotracheal intubation. Enamel fractures, tooth subluxation, fractures of the tooth crown or root, or tooth avulsion are frequently reported. These injuries have a substantial physical and economic impact and are one of the leading causes of malpractice claims against anesthesiologists. In the United States, dental injuries account for 25% of the available closed insurance claims against anesthesia providers reviewed by the American Society of Anesthesiologists’ Professional Liability Committee.

This Journal course will survey the history of anesthesia-associated dental injury, review dental anatomy and tooth identification, review the mechanisms of dental injury, discuss techniques that may minimize dental and oral tissue trauma during anesthesia, and suggest a strategy for the management of perioperative dental injuries.

Frequency of Dental Injury During Anesthesia
Although dental injury is a known complication of airway management, the reported incidence varies widely between 0.04% and 12%. Table 1 lists the published incidence and the most frequent types of dental injuries occurring during anesthesia.

Most of the published literature estimating dental injury is retrospective in design, with a reported incidence...
between 0.04% and 1.38%. In these studies, the anesthesia provider was the individual immediately aware of the dental injury. Whereas tooth dislocation, crown fracture, or tooth avulsion would be obvious to the anesthesia provider, microfractures of tooth enamel, or a “roughening” of the tooth edge, may be detected only by the patient or following a dental examination. Accordingly, prospective studies with a preoperative and postoperative dental examination have found a higher incidence of dental injury following anesthesia administration.

Fung and Chan followed up 404 adult patients receiving endotracheal general anesthesia. Each patient had a detailed preoperative and postoperative dental examination by an oral surgeon who was blinded to the anesthetic management. Objective oral tissue trauma (soft-tissue lacerations of the lips, tongue, and gingiva) occurred in 6.9% of these patients. A total of 9 patients experienced tooth fracture, with an incidence of dental injury of nearly 0.2%.

Table 1. Published Incidence of Dental Injury

<table>
<thead>
<tr>
<th>Author, year</th>
<th>Research type and country</th>
<th>Study duration, years</th>
<th>Age, years</th>
<th>Cases of dental injury</th>
<th>Incidence, percent</th>
<th>Type of injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burton &amp; Baker,1 1987 Retrospective; New Zealand</td>
<td>1.25</td>
<td>18-78</td>
<td>73</td>
<td>—</td>
<td>1, 3, 2</td>
<td></td>
</tr>
<tr>
<td>Bory et al,15 1991 Retrospective; France</td>
<td>10</td>
<td>—</td>
<td>126</td>
<td>—</td>
<td>3, 2</td>
<td></td>
</tr>
<tr>
<td>Chen et al,20 1990 Prospective; Taiwan</td>
<td>0.5</td>
<td>All ages</td>
<td>—</td>
<td>12.08</td>
<td>3, 2, 1, 4</td>
<td></td>
</tr>
<tr>
<td>Chopra et al,16 1990 Retrospective; Holland</td>
<td>10</td>
<td>—</td>
<td>39</td>
<td>0.04</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Fung &amp; Chan,9 2001 Prospective; Taiwan</td>
<td>—</td>
<td>18-85</td>
<td>9</td>
<td>0.196</td>
<td>3, 1</td>
<td></td>
</tr>
<tr>
<td>Gaudio et al,6 2010 Retrospective; Italy</td>
<td>8</td>
<td>83</td>
<td>1.38</td>
<td>1, 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lockhart et al,3 1986 Retrospective; USA</td>
<td>5</td>
<td>22-82</td>
<td>32</td>
<td>0.07</td>
<td>2, 1, 3</td>
<td></td>
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<tr>
<td>Nakahashi et al,21 2003 Retrospective; Japan</td>
<td>3</td>
<td>—</td>
<td>124</td>
<td>2.1</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Newland et al,5 2007 Case-control; USA</td>
<td>14</td>
<td>—</td>
<td>78</td>
<td>0.09</td>
<td>2, 5</td>
<td></td>
</tr>
<tr>
<td>Singleton et al,17 1993 Retrospective; Australia</td>
<td>—</td>
<td>—</td>
<td>14</td>
<td>0.7</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Vallejo et al,18 2012 Retrospective; USA</td>
<td>8</td>
<td>&lt; 18; 18-65</td>
<td>360 total</td>
<td>0.055 Pediatric; 0.044 adult</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Vogel et al,19 2009 Retrospective; Switzerland</td>
<td>11</td>
<td>All ages</td>
<td>170</td>
<td>1.13</td>
<td>3, 5, 1</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Published Incidence of Dental Injury

Type of injury in order of most frequent occurrence: 1 = tooth avulsion, 2 = chip/enamel fracture, 3 = fracture of crown/bridge, 4 = pulp necrosis, 5 = tooth dislocation.

Dental Anatomy

Before a discussion of dental injury occurring during anesthesia and the proper communication of these injuries can occur, a basic knowledge of tooth anatomy and identification is necessary. The human dentition consists of 2 complete sets of teeth, the deciduous or “baby” teeth and the permanent or “adult” teeth. The teeth are divided into maxillary and mandibular arches that are symmetric about the midsagittal plane or midline. This results in 4 dental quadrants, namely the maxillary (or upper) right and left as well as the mandibular (or lower) left and right quadrants (Figures 1 and 2). The maxillary and mandibular teeth interdigitate into the patient’s occlusion or “bite.”

The deciduous dentition consists of 20 teeth that erupt between 6 and 24 months of age. Generally, the anterior teeth erupt before the posterior teeth, with the mandibular teeth erupting before the corresponding maxillary teeth. The anatomical arrangement of these teeth in a single quadrant, starting from the midline and moving posteriorly is central incisor, lateral incisor, canine, first molar, and second molar. These teeth may be described by their full anatomical name, such as the deciduous right maxillary first molar, or more commonly in the United States, by identifying each tooth with capital letters sequentially from maxillary right to left and mandibular left to right as A through T (Figure 3). The sizes of the deciduous teeth are generally smaller in all dimensions compared with the permanent teeth, including the roots, which predisposes them to displacement.
avulsion with the application of lateral forces.

The permanent dentition consists of 32 teeth that erupt between 6 and 21 years of age. Eruption of an underlying permanent tooth causes resorption of the deciduous tooth root, leading to loosening of the tooth and eventual loss, termed exfoliation. The anatomical arrangement of the permanent dentition in a single quadrant, starting from the midline and moving posteriorly is as follows: central incisor, lateral incisor, canine, first premolar, second premolar, first molar, second molar, and third molar. These teeth may also be described by their full anatomical name, such as the permanent right maxillary first molar, or more commonly in the United States, by identifying each tooth with numbers sequentially from maxillary right to left and mandibular left to right as 1 through 32 (see Figures 1 and 2). The third molars or “wisdom teeth” are often impacted and not fully visible or may have been previously removed to prevent or treat the presence of numerous pathological conditions. In addition, the removal of multiple premolars, typically in a symmetric fashion, is also relatively common for orthodontic purposes and may lead to confusion if not identified.

With this pattern of tooth eruption, there is a period when children possess a combination of deciduous and permanent teeth, termed the mixed dentition period. This period occurs from approximately 6 to 12 years of age, beginning with the eruption of the first permanent tooth, generally the permanent mandibular first molar, and ending with exfoliation of the last deciduous tooth, generally the deciduous maxillary second molar.

Although the anatomy of different teeth varies greatly, all teeth are composed of 2 main components, the crown and the root (Figure 4). The crown is covered with enamel and is mostly visible in the oral cavity. The root is covered with cementum and is located in the alveolar bone or “socket,” generally covered with the gingiva or gum tissue. The cementoenamel junction or CEJ delineates the anatomical transition from crown to root and is often not visible clinically. The anterior teeth (incisors and canines) typically possess a single root while the
posterior teeth (premolars and molars) typically have between 1 and 3 roots. The enamel is a very hard, avascular, and nonneural tissue. The cementum is a bonelike tissue that is attached to the surrounding alveolar bone via the periodontal ligament. Beneath the outer layer of enamel and cementum is the dentin, which comprises most of the tooth and provides underlying strength. In the center of the root and crown are the pulp canal (or canals) and a chamber, respectively. These areas comprise the neurovascular and lymphatic supply for the tooth, with each root having at minimum 1 canal and sometimes several. These structures are noted in Figure 5.

In the absence of pathology, a tooth is generally a very solid structure that is capable of withstanding tremendous forces, because the enamel enclosing the crown of the tooth is the hardest substance in the human body. In a study by Braun et al,23 the mean maximum bite force was found to be 738 N (Newtons). Although extremely strong in compressive strength, it is relatively brittle, particularly when exposed to lateral forces. Tooth roots, when surrounded by solid alveolar bone, are also quite strong in compression but can be compromised with lateral forces.

**Dental Pathology**

There are numerous conditions, both acquired and congenital, that weaken the dentition and increase the likelihood of injury. Congenital disease can substantially alter the strength and function of the dentition. Amelogenesis imperfecta is a congenital defect in enamel formation that results in a much weaker enamel layer, with subsequent increase in wear and fracture.24 Dentinogenesis imperfecta is a congenital defect in dentin formation, which, while possessing a normal enamel layer, is prone to fracture because of the lack of underlying support.24 Ectodermal dysplasia often presents with dental abnormalities such as multiple congenitally missing teeth and malformed, peg-shaped teeth, which may be heavily restored or reconstructed, even at a very young age.24,25

The most prevalent acquired dental pathology is dental caries or “cavities,” which is the destruction of enamel, dentin, and cementum by acidic byproducts produced by oral microbes during the metabolism of carbohydrates. Dental caries occurs in all age groups and can be limited to a single tooth or present throughout the full dentition. The resulting weakness and lack of underlying support in the tooth structure increases the risk of tooth fracture of the affected areas of the crown (Figure 6). Restorations or “fillings” are repairs made to affected areas after the removal of caries. Restorations, while typically strong, are inherently weaker than natural tooth structure. Dental restorations may be easily identified with a visual

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**Figure 4. External Tooth Anatomy (Mandibular First Premolar)**

Arrows indicate cementoenamel junction. Crown (covered in white enamel) is superior to arrows. Root (covered in yellow cementum) is inferior to arrows.

**Figure 5. Internal Tooth Anatomy (Mandibular First Premolar)**

Abbreviations: A, enamel; B, dentin; and C, pulp canal. Root is sectioned just superior to the cementoenamel junction.
inspection noting the presence of metallic material (silver or gold) in the crown of the tooth. Restorations can also be more cosmetic using a nonmetallic composite resin. These fillings are “tooth-colored” and may be missed with a visual inspection, especially to the untrained eye.

Patients of all ages may have other more extensive restorations, such as veneers (ultrathin covering of ceramic or composite material bonded to the anterior portion of the tooth), crowns, or bridges, which may have metallic and/or nonmetallic components. Orthodontic appliances, common in adolescents, are now widespread in the adult population. Whether standard “braces” or fixed expansion and retention devices, these may be damaged owing to their relatively weak bond to the tooth via a composite adhesive or cement.

Adults and elderly patients often present with removable prostheses (partial or full dentures) that replace missing teeth. These are typically constructed of acrylic resins that are prone to damage. Removable prosthetics should be removed preoperatively to prevent damage and the possibility of dislodgment and subsequent ingestion or aspiration.

Periodontal or “gum disease” is present in 30% of the adult population. Periodontal disease results in the loss of alveolar bone surrounding the tooth root, weakening the underlying tooth attachment, and thereby increasing the risk of damage. Periodontal disease may be perceptible visually with an exposed root surface (Figure 7) and/or visibly mobile teeth, or may be relatively hidden without further dental evaluation.

Endodontic or root canal treatment, although often not evident visually, can predispose a tooth to fracture of the root and/or crown. Shortened roots, whether due to resorption of deciduous teeth or developmental defects of permanent teeth, decrease the underlying support and increase the risk of damage. The angulation of teeth, particularly when excessively flared such as in the anterior maxilla, can predispose teeth to damage because of their relatively unprotected location and thin, anterior alveolar bone (Figure 8).

Mechanism of Dental Injury
Dental injury during anesthesia is undoubtedly associated with endotracheal intubation. Dental injuries are more frequent with “difficult” or emergency airway management. It has been estimated that 75% of dental injury occurs during endotracheal intubation. We have previously discussed risk factors for dental injury and have reemphasized these in Table 2.

The mechanism of dental injury is the result of the application of substantial forces applied to the teeth by the laryngoscope blade, where the anterior teeth serve as a fulcrum for manipulation of the laryngoscope. These forces also may be generated with the insertion of oral airways, gags, bite blocks, Magill forceps, and rigid suction catheters, or biting oral pharyngeal airways or laryngeal mask airways on weakened and restored teeth. The maxillary central and upper incisors, particularly the left maxillary central and lateral incisors, are the most
vulnerable (Figure 9). The maxillary incisors are more pronounced and subsequently limit visualization of the hypopharynx during intubation. With the use of a standard Macintosh No. 3 blade in patients with limited mouth opening, the flange of the blade easily has an impact on the left maxillary incisors, increasing the risk of injury. Damage to these teeth is aesthetically displeasing and functionally disagreeable. Even without the presence of any of the mentioned conditions that weaken the teeth, damage can still occur.

Management of Dental Injury
When injury involving the dentition occurs, it can generally be classified as a fracture, displacement, or avulsion. Fractures of restorations, tooth structure, or roots vary tremendously in their severity and treatment (Figure 10). Following recovery from general anesthesia, the patient should be fully informed of the damage as well as the preventive measures that were undertaken in an attempt to avoid the damage.

The first step is to ensure that any loose fragment or fragments are accounted for and removed, because they may be displaced into the pharynx or nasopharynx and become a gastric or trachea aspiration hazard. If these cannot be located, chest radiography should be obtained to rule out the possibility of aspiration of the fragments. Attention should then turn to evaluation for mobility of any portions of retained tooth or restoration and, if needed, removal or stabilization. A dental consultation should be obtained as soon as possible. Depending on the severity of the injury, treatment may vary from no treatment, minor smoothing or repair of a restoration or tooth structure, root canal treatment, or even extraction and subsequent replacement.

Displacement of the dentition in the setting of anesthesia usually results in either a posterior or anterior displacement of the crown of the tooth from its normal position (Figure 11). This may involve a fracture of the crown below the gingiva, fracture of the root, or perhaps fracture of the surrounding alveolar bone resulting in movement of the entire tooth. Treatment should once again focus on locating any missing fragments, assessing mobility, and if appropriate, reducing the displaced portion into its original position and stabilizing it in place. Depending on the method of securing the airway, evaluation of the occlusion may not be possible until the airway device is removed. Ensuring that the opposing teeth have the proper occlusal relationship and do not result in continued trauma after intubation is vital. Again, a dental consultation should be obtained as soon as possible.

Avulsion of an entire tooth also occurs. If a deciduous tooth is avulsed, it should not be reimplanted because it could damage the underlying permanent tooth. However, if a permanent tooth is avulsed, it should be reimplanted as soon as possible, ideally immediately, and stabilized appropriately. If not possible, or if the provider is uncomfortable doing so, the tooth should be handled only by the crown and placed in a liquid storage medium. A dental consultation should then be obtained as soon as possible. The most ideal medium is a balanced salt solution used in ophthalmologic procedures or as a commercial product, such as the Save-A-Tooth kit (3M, which includes Hank’s balanced salt solution as its storage medium). Other good storage mediums include normal saline or low-fat milk.

Table 2. Risk Factors for Perioperative Dental Injury

<table>
<thead>
<tr>
<th>Risk Factor</th>
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<tbody>
<tr>
<td>Preexisting dental pathology</td>
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<tr>
<td>Dental caries</td>
</tr>
<tr>
<td>Periodontal disease</td>
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<tr>
<td>Congenital dental defects</td>
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<tr>
<td>Mobile/exfoliating deciduous teeth</td>
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<tr>
<td>Restorations of anterior teeth</td>
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<tr>
<td>Metallic and/or ceramic crowns</td>
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<tr>
<td>Veneers</td>
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<tr>
<td>Bridges</td>
</tr>
<tr>
<td>Partial dentures</td>
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<tr>
<td>Complete dentures</td>
</tr>
<tr>
<td>Orthodontic appliances and/or retainers</td>
</tr>
<tr>
<td>Expected difficult endotracheal intubation</td>
</tr>
<tr>
<td>Large maxillary incisors/anterior teeth</td>
</tr>
<tr>
<td>Excessively flared maxillary incisors/anterior teeth</td>
</tr>
<tr>
<td>Limited temporomandibular joint mobility/opening</td>
</tr>
<tr>
<td>Retrognathia</td>
</tr>
<tr>
<td>Short thyromental distance</td>
</tr>
<tr>
<td>Macroglossia</td>
</tr>
</tbody>
</table>

Figure 9. Incidence of Dental Injury During Endotracheal Intubation

The most frequently injured teeth during endotracheal intubation are the anterior maxillary central and lateral incisors. The left central and lateral incisors are the most frequently injured during conventional endotracheal intubation. Vertical line indicates midline.

*Source: Chen et al.20
#Source: Lockhart et al.3
All solutions should be kept cold and the tooth evaluated and reimplanted as soon as possible. Depending on the circumstances involved with the injury and initial treatment rendered, there is a high likelihood of the patient needing endodontic (root canal) treatment at minimum, or ultimately replacement of the tooth if it cannot be reimplanted or must later be removed. Additionally, if a periodontally compromised tooth is avulsed, it will not likely be amenable to reimplantation.

Excluding the risk of aspiration, dental trauma, although still potentially severe, does not generally pose a major emergency. In all instances, both for patient care and for medicolegal reasons, the anesthesia provider should obtain a dental consultation as soon as possible. Complete evaluation, diagnosis, and subsequent treatment often involves obtaining dental radiographs, which may not be available intraoperatively, or even in the facility. If the facility has an associated dental provider, intraoperative consultation and management, particularly when splinting or reimplantation is necessary, should be pursued. Although this is generally limited to academic medical centers, prompt evaluation and management can be extremely beneficial to all involved.

**Avoidance of Perioperative Dental Injury**

It is the authors’ experience that many dental injuries occurring during the administration of anesthesia are the result of compromised dentition that predisposed the patient to injury. These situations are often evident to a dental professional when evaluating the situation after the fact, but highlight the need for proper preoperative evaluation and informed consent of the risks of anesthesia. Obtaining a dental history and performing an intraoral examination will allow the anesthesia provider to prepare an airway management plan to reduce the likelihood of injury. Special emphasis should be given to the overall state of oral health and hygiene, the presence of caries, restorations, mobile teeth, and partial or complete dentures and noted in the preanesthetic evaluation. The anesthesia documentation should contain a section for preoperative evaluation that allows for charting of preoperative findings, ideally including a graphical representation of the dentition (similar to Figures 1 and 2) for ease of entry. For example, if a patient presenting with periodontal disease, as noted in Figure 7, is examined, the anesthetist could note that there is periodontal disease or exposed root surfaces associated with teeth 7, 8, 9, and 10. The patient must be informed of any increased risks of perioperative dental injury during the informed consent process.

The prevention of dental injury during endotracheal intubation requires the use of proper technical skills and appropriate airway devices. The applied forces during technically correct laryngoscopy are directed away from the maxilla and are distributed by the tongue into the surrounding musculature and mandible. In the presence of known dental pathology or during difficult intubation, the maxillary central and lateral incisors may be used as a fulcrum to improve the laryngeal view. Dental injury may occur even in the hands of the most skillful anesthetist.

The edentulous patient may be encouraged to retain his or her dentures to provide for an adequate mask seal following induction. Should dentures be retained during endotracheal intubation, it must be remembered that the acrylic resin is quite brittle and the dentures may not be stable in the oral cavity. Should the removal of dentures or other prostheses be necessary, these must be handled and stored very carefully in water, because dropping them may result in irreparable damage and excessive dryness can also lead to damage.

The dentition may be protected by custom mouthguards, generic mouthguards, or gauze rolls applied over the anterior teeth during endotracheal intubation. Generic dental mouthguards, such as those found in sporting goods stores, have been employed to protect the dentition during endotracheal intubation. These devices provide a “cushioning” effect and distribute the applied forces.
force during laryngoscopy on multiple teeth, rather than a single tooth. Brosnan and Radford\textsuperscript{29} studied 80 patients, 40 of whom had the insertion of a mouthguard before intubation. Insertion of the mouthguard required only an additional 7 seconds for the completion of intubation.\textsuperscript{29} This would be a simple application to afford added dental protection. However, the use of a mouthguard does not always prevent the occurrence of dental injury.\textsuperscript{30}

Suspension laryngoscopy is employed for both diagnostic and operative care of the larynx. The dentition is particularly vulnerable to injury during these procedures; dental injury during suspension laryngoscopy has been shown to occur in up to 6.5% of patients, a substantially higher incidence compared with retrospective studies of dental injury.\textsuperscript{31} Accordingly, the patient should be informed of these risks. The use of custom-fit dental guards, created preoperatively by a dental professional, should be considered to afford added protection during suspension laryngoscopy. When this is not feasible because of time or access to care, one should consider using a generic rubber mouthguard to aid in protection.

The recent introduction of videolaryngoscopes containing optics in the tip of the selected laryngoscope blade provides a video image that improves the glottis view, particularly during difficult endotracheal intubation.\textsuperscript{32,33} The use of videolaryngoscopy has been demonstrated to decrease the applied force to the dentition during laryngoscopy. In a study of 44 men and women undergoing conventional laryngoscopy with a Macintosh blade, the recorded forces on the maxillary incisors ranged from 0 to 87 N, whereas the forces produced by the videolaryngoscopy ranged from 0 to 45 N.\textsuperscript{34} Lee and colleagues\textsuperscript{35} have found that 3 currently available videolaryngoscopes (C-MAC, Karl Storz Endoscopy-America Inc; GlideScope, Verathon Inc; and McGrath MAC, Medtronic) all provided a decrease in peak force compared with conventional laryngoscopy. Videolaryngoscopy appears to be an acceptable alternative to conventional laryngoscopy for patients with preexisting dental pathology.

Finally, a fiberoptic approach to airway management will minimize undue lateral or compressive forces on native and pathological dentition. A nasal fiberoptic avoids the placement of any oral airway devices in patients with poor dentition.

Conclusion

Oral tissue injury and dental trauma is a known complication of airway management during general anesthesia. A preoperative dental history and examination are essential to identify teeth at risk and facilitate the development of an anesthetic plan to minimize further dental damage. Future research should focus on the true incidence of anesthesia-associated dental injury, which would best be completed with prospective studies.

\textbf{REFERENCES}


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DISCLOSURES
The authors have declared no financial relationships with any commercial interest related to the content of this activity. The authors did not discuss off-label use within the article.