# Cardiothoracic Anesthesia, Respiration And Airway

# Lower flange modification improves performance of the Macintosh, but not the Miller laryngoscope blade

*[La modification de la partie inférieure du manche améliore la performance de la lame du laryngoscope Macintosh, mais non celle du Miller.]*

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**Purpose:** In order to minimize the potential for dental damage and to improve laryngeal visualization during tracheal intubation, two commonly used laryngoscope blades were modified and compared in a clinical setting: the Miller laryngoscope blade and the Macintosh laryngoscope blade. Modified versions of both laryngoscope blades with a lowered heel (Callander modification) at the proximal end of the blade were compared to standard blades.

**Methods:** Forty patients scheduled for general anesthesia requiring endotracheal intubation were studied prospectively. Preoperatively, the patients' airways were evaluated according to Mallampati score, thyromental distance and interincisor gap. After induction of anesthesia laryngoscopy was performed with the original laryngoscope and its modified counterpart in random order. A lateral *x-ray* of the neck was taken after the optimal view had been obtained, and blade-tooth distance, laryngeal view, blade-tooth contact and need for assistance were measured. Using angular calculations the laryngoscopes were analyzed at different insertion depths on graph paper, and the results were compared with data from the lateral *x-rays*.

**Results:** With a modified Macintosh blade the blade-tooth distance was significantly greater in comparison to the original design (2.5 ± 2.1 cm *vs* 0.2 ± 0.1 cm, $P < 0.01$). Consequently the number of blade-tooth contacts was significantly lower (20% *vs* 75%, $P < 0.05$). The best laryngeal view could be obtained using a modified Macintosh laryngoscope. With a modified Miller laryngoscope laryngeal visibility was not improved and assistance was required more often to achieve adequate intubating conditions (35% *vs* 5%, $P < 0.05$).

**Conclusion:** A reduction of the proximal flange of a Miller blade decreases the blade's effectiveness for laryngeal visualization, whereas a similar modification of a Macintosh blade increases blade-tooth distance, decreases the number of blade-tooth contacts and provides a better laryngeal view.

***Objectif*** *: Pour réduire le risque de dommage aux dents et pour améliorer la visualisation du larynx pendant l'intubation endotrachéale, deux lames de laryngoscope fréquemment utilisées ont été modifiées et comparées en situation clinique, celles des laryngoscopes Miller et Macintosh. Les versions modifiées des deux lames, munies d'un talon plus bas à l'extrémité proximale (modification Callander), ont été comparées aux lames régulières.*

***Méthode*** *: Quarante patients devant subir une anesthésie générale avec intubation endotrachéale ont fait l'objet d'une étude prospective. L'évaluation préopératoire des voies respiratoires selon le score de Mallampati a révélé la distance thyromentonnière et l'espace interincisive. Après l'induction de l'anesthésie, la laryngoscopie a été réalisée avec le laryngoscope original et sa version modifiée*

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*suivant un ordre aléatoire. Une fois la vision optimale obtenue, une radiographie latérale du cou a été prise, puis la distance entre la lame et les dents, la vision laryngée, la présence de contact entre la lame et les dents et la nécessité d'une assistance ont été évaluées. D'après le calcul des angles, une analyse graphique des laryngoscopes a été faite pour différentes profondeurs d'insertion et les résultats comparés avec les données de la radiographie latérale.*

***Résultats** : Avec la lame Macintosh modifiée, la distance dent-lame a été significativement plus grande qu'avec la lame originale (2,5 ± 2,1 cm vs 0,2 ± 0,1 cm, P < 0,01). Le nombre de contacts dent-lame a donc été significativement plus bas (20 % vs 75 %, P < 0,05). La meilleure vision laryngée a pu être obtenue avec une lame Macintosh modifiée. Avec le laryngoscope Miller modifié, la visibilité du larynx n'était pas améliorée et une assistance a été plus souvent requise pour atteindre des conditions d'intubation adéquates (35 % vs 5 %, P < 0,05).*

***Conclusion** : Une réduction du manche proximal de la lame Miller diminue la qualité de la visualisation laryngée obtenue tandis qu'une modification similaire de la lame Macintosh améliore la distance dent-lame, diminue le nombre de contacts dent-lame et fournit une meilleure vision du larynx.*

A large number of laryngoscope blade designs have been developed with the aim of facilitating tracheal intubation while avoiding dental trauma.[1–3] Dental trauma is the most common complication of tracheal intubation, and several factors influence its likelihood, including the skill of the laryngoscopist, patient anatomy, and laryngoscope blade design.[4,5] As dental trauma associated with airway instrumentation results from contact between the proximal flange of the blade and the maxillary incisors, modifications of the laryngoscope blade have been suggested by several investigators: Bizzarri and Giuffrida[6] designed a laryngoscope without any flange, whereas Ibler,[7] Callander and Thomas[8] and Bucx *et al.*[9] proposed removing only the proximal part of the flange. In the present study we applied the Callander[8] modification to a standard #4 Macintosh laryngoscope blade and a #4 Miller laryngoscope (both laryngoscopes: Mercury Medical; Clearwater, FL, USA; Figure 1).

Marks *et al.*[10] described in his study the methodological problems of laryngoscope evaluations and developed an objective, theoretical basis for laryngoscope comparisons using angular parameters with depth of insertion profiles. Following his approach the laryngoscope blades were evaluated *in vitro* using Cartesian graph paper, and in patients using lateral neck *x-rays* with a dedicated radiological measurement system. The aims of the present study were: 1) to compare the different laryngoscope blades with respect to blade-tooth distance and contact, usability and laryngeal visibility, 2) to assess laryngoscope performance using objective, theoretical parameters.

FIGURE 1 Modified Macintosh laryngoscope #4 (top), modified Miller laryngoscope #4 (bottom).

## Methods

After approval by the hospital Ethics Committee we studied 40 ASA I–II elective surgery patients scheduled for inhalation anesthesia requiring endotracheal intubation. Written informed consent was obtained from each patient on the day before surgery. Patients were excluded if they had a history of gastroesophageal reflux disease, were edentulous, if they had abnormalities of the head or neck, or any indication for rapid sequence induction. Patient demographic characteristics were recorded, and the following preoperative airway characteristics were assessed: Mallampati classification, body mass index, interincisor gap, thyromental distance, impairment of head and neck movement.

A computer-generated random number table was used to randomize patients in two steps: first for the type of laryngoscope, and second for blade sequence. A sealed envelope method was used for allocation concealment. Patients were randomized accordingly into one of four groups: 1) Macintosh #4, modified Macintosh #4; 2) modified Macintosh #4, Macintosh #4; 3) Miller #4, modified Miller #4; 4) modified Miller #4, Miller #4.

In the operating room, the patient's head was placed on a pillow to achieve the anatomic sniffing position, after which routine monitors were applied and *iv* access was established. Anesthesia was induced with propofol 2–3 $mg \cdot kg^{-1}$ *iv,* remifentanil infused


FIGURE 2 The line IT connects the contact points of the blade with the teeth (I) and the tip of the laryngoscope (T). A measurement for eye line deviation is the angle formed by EIT, the line IE being the actual line of view. As the angle EIT decreases, the closer is the approximation of the actual eyeline (IE) to the ideal eyeline (IT). SJ connects the midpoint of the symphisis menti with the mandibular condyles, the line is perpendicular to IT. Point M lies on the upper surface of the blade on the line SJ. The angle MIT is a measure for how close the laryngoscope can move towards the mandible. If M is in front of the line IT, MIT is positive, signifying forward space encroachment, otherwise MIT has a negative value, signifying forward space enhancement and thus a better laryngoscope performance.

at a rate of 1 $\mu g \cdot kg^{-1} \cdot min^{-1}$ over two minutes, and cisatracurium 0.15 $mg \cdot kg^{-1}$ *iv*. Following induction, all laryngoscopies were performed by one experienced anesthesiologist, accustomed to both Macintosh and Miller blades. During the study period anesthesia was maintained with infusions of propofol (8 $mg \cdot kg^{-1} \cdot hr^{-1}$) and remifentanil (0.5 $\mu g \cdot kg^{-1} \cdot min^{-1}$). Adequacy of muscle relaxation was assessed by acceleromyography (TOF-Watch, Organon; West Orange, NJ, USA), and depth of anesthesia was measured with a bispectral index (BIS) XP monitor (Aspect Medical Systems; Newton, MA, USA). In all patients BIS values remained < 55 throughout the study period. The laryngoscope was introduced at the right side of the mouth and moved towards the midline, shifting the tongue leftwards. With the epiglottis held anteriorly (Miller blade) or posteriorly (Macintosh blade), optimum visibility of the glottis was established. Once the best laryngeal view had been obtained, a research assistant measured the perpendicular tooth-to-heel distance from the tip of the upper incisors to the heel of the laryngoscope. The visibility as obtained by the laryngoscopist was graded according to Cormack and Lehane (1: glottis visible; 2: only posterior part of glottis visible; 3: only epiglottis visible; 4: no laryngeal structures visible). A lateral *x-ray* of the neck was taken, and the laryngoscope was removed thereafter. If $SpO_2$ decreased to a value < 90% the patient was ventilated immediately via face mask with 100% oxygen. Only after restoration of oxygen saturation would a second laryngoscopy be attempted. Assistance during laryngoscopy was limited to counteracting anteflexion of the head when anteflexion impaired laryngeal view, or retracting the upper lip, when it obstructed the laryngeal view. Any blade-tooth contact was recorded. As soon as all measurements had been recorded and *x-rays* were completed, the patient's trachea was intubated, and the study protocol was considered complete. For intubation there were no restrictions with regard to type of laryngoscope or extent of assistance. The remainder of intraoperative and postoperative care was at the discretion of the attending anesthesiologist.

The angular parameters of the laryngoscope blades for different insertion depths were calculated according to the method of Marks *et al.*[10] with photographs of the laryngoscope blades placed on Cartesian graph paper. In patients the angular parameters were derived from *x-ray* laryngoscopies taken when optimal laryngeal visibility had been achieved. These parameters were calculated as follows (Figure 2): J is a point between the mandibular condyles; S is in the middle of the symphysis menti; I is the point where the incisors touch the laryngoscope; T is the tip of the laryngoscope, where it ideally touches the hyoid bone. The line IT corresponds to the ideal line of view and represents the reference line. The point M lies on the blade surface at the level of the mandible on the line JS. If the point M lies in front of the line IT, the angle MIT has a positive value and signifies forward space encroachment. If M lies behind the line IT, MIT has a negative value and signifies space enhancement. Thus, MIT provides a measure of how closely the laryngoscope can move towards the mandible, a more negative MIT angle indicates better laryngoscope performance. A measure for the eyeline deviation is derived from the angle EIT, with the line IE being the actual line of view and IT being the optimal line of view. A smaller angle (typically for straight blades) formed by the lines IE and IT implies less deviation from the ideal line of view. A combination of both

TABLE I Demographic data, preoperative airway evaluation

| *Group* *Sex (male/female)* | *Macintosh (n = 20)* *15/5 (75/25%)* | *Miller (n = 20)* *12/8 (60/40%)* |
|---|---|---|
| Age (yr) | 52.2 ± 13.4 | 61.3 ± 17.0 |
| Weight (kg) | 68.7 ± 16.6 | 61.2 ± 14.2 |
| Height (cm) | 171 ± 10.7 | 168.8 ± 13.7 |
| BMI | 23.4 ± 5.3 | 21.5 ± 4.9 |
| Mallampati I | 8 (40%) | 7 (35%) |
| Mallampati II | 6 (30%) | 9 (45%) |
| Mallampati III | 4 (20%) | 3 (15%) |
| Mallampati IV | 2 (10%) | 1 (5%) |
| Interincisor gap (cm) | 5.2 ± 0.9 | 4.9 ± 1.9 |
| Thyromental distance (cm) | 5.8 ± 0.7 | 6.1 ± 0.7 |
| Neck movement impaired | 4 (20%) | 3 (15%) |

BMI = body mass index. Neck movement impaired: neck movement < 90°.

scores (EIT + MIT) offers the possibility to compare different laryngoscopes at different insertion depths on a theoretical basis. A lower combination score signifies a better laryngoscope performance. The angles derived from the radiographs, determined from the point of optimal laryngeal visibility, were calculated with a high resolution system (accuracy ± 0.1°) by an experienced radiologist.

A sample size calculation was performed after 20 patients with regard to blade-tooth distance (power: 1-ß = 0.8) and a group size of 20 patients per laryngoscope group was calculated. Demographic data were compared using analysis of variance. Student's t test, Chi-square test, and Mann-Whitney U test were applied as appropriate. Data are presented as means ± standard deviation, unless specified otherwise. A $P$ value < 0.05 was considered statistically significant.

## Results

The demographic data were similar in both groups, and there were no between-groups differences with respect to Mallampati classification, interincisor gap, thyromental distance or impairment of head and neck movement (Table I).

The blade-tooth distances, laryngeal visibility results according to Cormack and Lehane, the number of interventions during laryngoscopy and times from start of laryngoscopy until laryngeal visibility could be optimized no further, are presented in Table II. In the modified Macintosh group an increased blade-tooth distance (2.5 ± 2.1 cm *vs* 0.2 ± 0.1 cm, $P$ < 0.01) and a lower blade-tooth contact frequency were observed (20% *vs* 75% blade-tooth contact, $P$ < 0.05). Laryngoscopic views graded according to Cormack/Lehane were better in the modified Macintosh group than in the original Macintosh group ($P$ < 0.05), whereas there was no significant difference in the Miller group. The aid of an assistant, who helped by counteracting anteflexion of the head or by retracting the upper lip, was necessary during seven laryngoscopies with the modified Miller blade, *vs* one laryngoscopy with the original Miller blade ($P$ < 0.05). There were no differences with respect to duration of laryngoscopy between modified and original blades.

The theoretical angle calculations at different insertion depths are presented in Figures 3 and 4. Figure 5 shows how the angles are modified by different laryngoscope shapes. The modified Macintosh blade (Figure 3) had a better combination score at insertion depths > 11 cm, in patients we found significantly less forward space encroachment (MIT -6.7 ± 3.5° *vs* 1.7 ± 1.8°, $P$ < 0.01) and a slightly increased eye line deviation (EIT 8.1 ± 5.3° *vs* 5.0 ± 1.2°, $P$ = n.s.). The modified Miller blade (Figure 4) scored better *in vitro* at an IT score > 12 cm (Figure 3) and in patients for

TABLE II Visibility Cormack/Lehane, heel-tooth distance, heel-tooth contact, angular parameters (Macintosh: $n$ = 20, Miller: $n$ = 20)

| | *Macintosh* | *Mod. Macintosh* | *Miller* | *Mod. Miller* |
|---|---|---|---|---|
| C / L grade I | 10 (50%) | 14 (70%) | 11 (55%) | 8 (40%) |
| C / L grade II | 6 (30%) | 4 (20%) | 4 (20%) | 5 (25%) |
| C / L grade III | 3 (15%) | 2 (10%) | 3 (15%) | 2 (10%) |
| C / L grade IV | 1 (5%) | 0 | 2 (10%) | 5 (25%) |
| C / L mean | 1.8 ± 0.8 | 1.4 ± 0.6* | 1.8 ± 1.0 | 2.2 ± 1.2 |
| Distance (cm) | 0.2 ± 0.1 | 2.5 ± 2.1† | 0.2 ± 0.1 | 0.3 ± 0.1 |
| Contact | 15 (75%) | 4 (20%)* | 18 (90%) | 16 (80%) |
| EIT-° | 5.0 ± 1.2 | 8.1 ± 5.3 | 4.2 ± 0.5 | 1.9 ± 0.2¶ |
| MIT-° | 1.7 ± 1.8 | -6.7 ± 3.5† | 7.1 ± 1.0 | 0.1 ± 0.0¶ |
| Assistance | 1 | 3 | 1 | 7‡ |
| Time (s)+ | 7.6 ± 1.6 | 7.1 ± 1.3 | 9.1 ± 2.2 | 9.7 ± 3.0 |

C / L = Cormack/Lehane; † $P$ < 0.01, * $P$ < 0.05 (Macintosh *vs* modified Macintosh); ¶ $P$ < 0.01, ‡ $P$ < 0.05 (Miller *vs* modified Miller); + time from start of laryngoscopy until optimal view could be obtained. For definitions of EIT and MIT, refer to text.

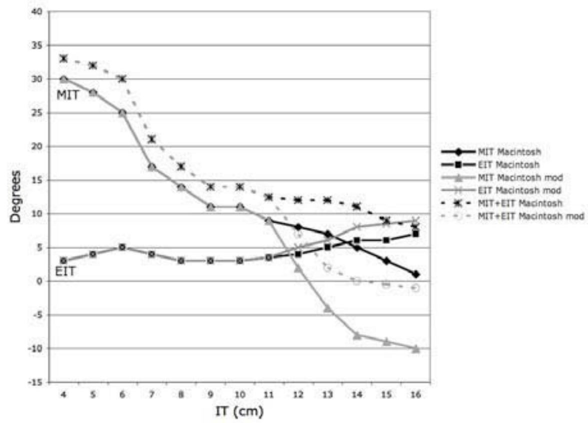


FIGURE 3 Plots of MIT and EIT angles for an original and a modified Macintosh #4 blade at different insertion depths (IT). Deviation from the ideal line of view (EIT) increases in both blades by IT > 11 cm, with a higher deviation for the modified blade. MIT as a measure for forward space encroachment decreases and reaches negative values by IT > 12 cm for the modified Macintosh blade. The combination score (MIT + EIT) is better at depths > 11 cm for the modified Macintosh blade.

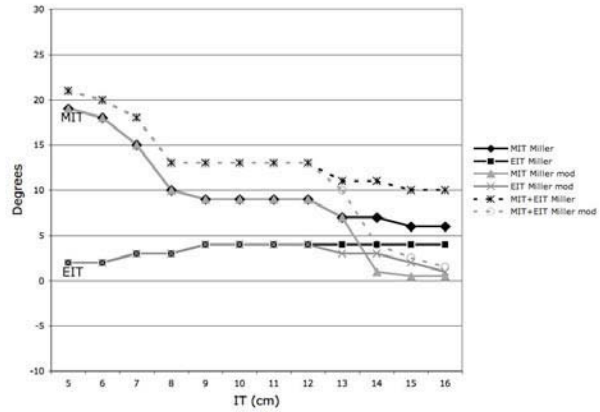


FIGURE 4 Plots of MIT and EIT angles for an original and a modified Miller #4 blade at different insertion depths (IT). Deviation from the ideal line of view remains constant for the original Miller blade and decreases for the modified blade by IT > 12 cm. MIT as a measure for forward space encroachment also decreases significantly at the same insertion depth. The combination score (MIT + EIT) is better at depths > 12 cm for the modified Miller blade.

MIT (0.1 ± 0.0° *vs* 7.1 ± 1.0°, $P < 0.01$) and EIT (1.9 ± 0.2° *vs* 4.2 ± 0.5°, $P < 0.01$) when optimal laryngeal view was achieved (all values represent modified *vs* original blade, means ± standard deviation).

Between the first and the second laryngoscopy, the $SpO_2$ of two patients decreased transiently below 90%. These patients were ventilated by mask according to protocol until an $SpO_2$ = 98% was attained. There was one episode of tachycardia (heart rate = 120 $min^{-1}$) in a patient with a history of atrial fibrillation. The BIS values confirmed an adequate depth of anesthesia for this patient. In all patients with a Cormack and Lehane score > 3 successful intubation was possible using a different laryngoscope and/or extended assistance (e.g., external laryngeal pressure) after the study had been completed. No patient experienced a dental injury.

## Discussion

In this study we have shown that modification of the proximal flange improves the performance of the Macintosh laryngoscope blade, but results in inferior performance with the Miller blade.

Reducing the proximal part of the flange of a Macintosh laryngoscope resulted in a lower frequency of laryngoscope-tooth contacts. In accordance with other studies[9,11–14] the distance between flange and teeth was increased significantly, while the visibility of laryngeal structures was improved in comparison to the original Macintosh blade. According to Lockhart *et al.*,[15] 51% of dental traumas in anesthesiology occur during tracheal intubation by contact of the laryngoscope's flange with the maxillary left incisor. An increased blade-tooth distance and less blade-tooth contact can therefore be assumed to be associated with a decreased risk of dental injury. In accordance with Marks *et al.*[10] and Yardeni *et al.*[16] the theoretically derived angular parameters of the modified Macintosh blade are reliable estimations for the actual measurements in patients. The better combination score of forward space encroachment and eyeline deviation correctly predicts a better laryngoscope performance for the modified Macintosh blade.

The modification of the Miller blade did not improve the blade's performance. No improvement of laryngeal view or increase of laryngoscope-tooth distance was observed. Our experienced anesthesiologist had problems intubating the trachea with the modified Miller blade in seven cases without assistance. Assistance during laryngoscopy consisted of counteracting anteflexion of the head when anteflexion impaired laryngeal view, or retraction of the upper lip, when it obstructed the laryngeal view.

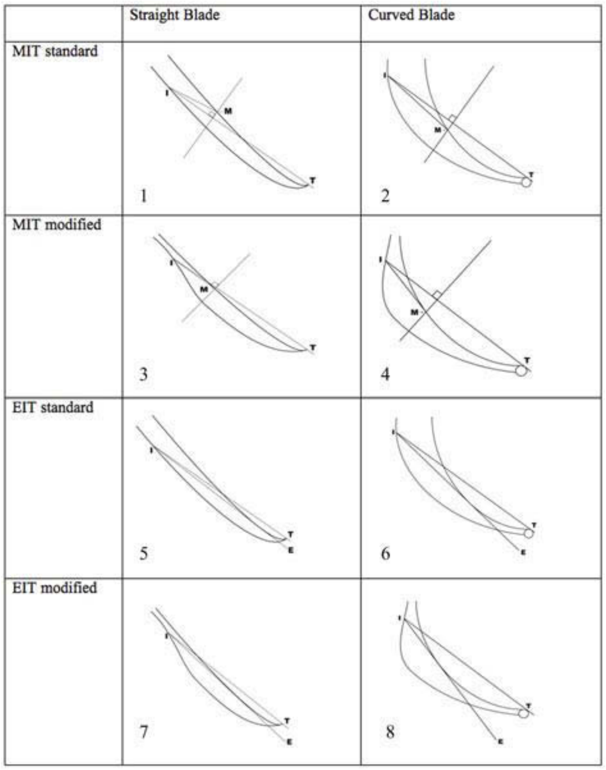


FIGURE 5 The Callander modification of a curved or a straight blade leads to different angles for MIT and EIT: the location of point M signifies the amount of space the blade occupies behind the mandible. Point M in front of IT indicates space encroachment; a smaller angle and therefore less encroachment can be seen in the modified straight blade (3) in comparison to the original straight blade (1). Point M behind the line IT indicates space enhancement: both the negative MIT angle in the original Macintosh (2) and the even more negative MIT angle in the modified Macintosh (4) indicate space enhancement. EIT is a measure for the deviation from the ideal line of view, a small EIT implies a small deviation of the actual line of view from the ideal line of view. Both straight blades (5,7) show a small EIT; the original curved blade (6) and even more the modified curved blade (8) show a larger EIT angle and thus a larger deviation of the actual line of view from the ideal line of view.

A pronounced tendency towards anteflexion was observed with both modified laryngoscope blades. This finding was also observed by Bucx *et al.*[9] and is most likely the result of different relations of torque and force for these modified blades.

This study had several limitations. First, it was not possible to evaluate all four laryngoscope blades in each patient, due to unacceptable radiation exposure and laryngeal tissue stress. Moreover, in this study we focused upon optimal laryngoscopic views, yet it has to be emphasized that a good laryngoscopic view does not always equate with easy tracheal intubation. The patient was intubated after the second *x-ray*. Successful intubation of the trachea was not one of the study endpoints, as it would not have been justifiable to intubate the patient's trachea twice. Another limitation is that a longer teeth flange distance has not yet been proven to decrease the incidence of dental damage. Other methods to decrease dental injury in at-risk patients include tooth protectors,[17] angulated blades,[18] blades with soft heels or with no heel at all.[6] So far, no single approach has proven to be superior with respect to the prevention of tooth damage. Although larger controlled trials, comparing different laryngoscopes with regard to laryngeal visibility[19] or frequency of blade-tooth contact[11] have been conducted, trials with dental injury damage as a primary outcome parameter would be ethically challenging, and are still lacking. Finally, the majority of patients in this study did not feature any airway abnormalities, and our results may not be applicable to patients with difficult airways. Further studies with laryngoscope blades with a Callander modification focusing on this patient group, may be warranted.

In conclusion, a Callander modification of the Miller laryngoscope blade is associated with significant disadvantages, requiring increased need for assistance in airway management and no improvement of laryngeal vision. In contrast, a Callander modification of the Macintosh laryngoscope blade with a reduced flange at the proximal end provides more distance between maxillary incisors and the laryngoscope, and an improved laryngeal view. This modification of the Macintosh blade decreases the frequency of contact between blade and incisors, and may potentially decrease the likelihood of dental trauma.

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