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Mouth Opening

A New Angle

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Background: **The authors hypothesized that craniocervical extension occurs during normal mouth opening.**

Methods: **Twenty volunteers were studied. Interdental distance was measured at four different degrees of craniocervical extension.**

Results: **Interdental distance increased from 28 mm (95% confidence interval, 25–30) in slight flexion to 46 mm (95% confidence interval, 42–49) at full extension. Nearly maximal mouth opening was obtained with 26° (95% confidence interval, 22–30) of craniocervical extension from neutral.**

Conclusion: **Craniocervical extension is an integral part of complete mouth opening in conscious subjects. Fixation of the craniocervical junction by disease, an internal or external fixation device, or technique may restrict mouth opening, with consequences for airway management.**

MOUTH opening and craniocervical mobility have long been identified as crucial to successful airway management.[1,2] Extension at the craniocervical junction is integral to basic airway maintenance maneuvers[3] and direct laryngoscopy,[4,5] and restricted mouth opening may make access to and control of the airway difficult. We have come to believe that craniocervical junction movement interacts with mouth opening and that restricted craniocervical mobility can result in reduced mouth opening ability.

Our interest was aroused by a surprising result in a study of direct laryngoscopy in patients with cervical spine disease.[6] The Mallampati examination emerged as the best predictor of difficult direct laryngoscopy. At the same time, one of us (H. A. C.) noted that patients who had had craniocervical fixation surgery reported that yawning could be a painful experience. We hypothesized that opening the mouth wide involves craniocervical extension and that mouth opening is constrained in patients with reduced extension, resulting in a reduced oral aperture and hence poor Mallampati scores.

This article is featured in "This Month in Anesthesiology." Please see this issue of ANESTHESIOLOGY, page 5A.

Materials and Methods

The study was approved by the local ethics committee (London, United Kingdom). Informed consent was obtained from 20 healthy adults. Subjects with any symptom or sign suggesting problems with mouth opening or neck movements were excluded. We excluded volunteers aged older than 45 years because mouth opening and neck extension are known to decrease with age.[7,8] The subjects' height, weight, and age were recorded. The subjects were asked to perform maximal mouth opening while their head was in four positions relative to their neck. Ideally, we would have liked to measure mouth opening and head position changes simultaneously and continuously, but we could not devise a methodology. Full flexion imposes a severe restraint on mouth opening, and we elected not to include that position. The four head/neck positions were (1) a position of slight flexion, in which a line joining the tragus of the ear and the canthus of the eye was horizontal; (2) the subject's self-adopted neutral position; (3) the position adopted when the subject attempted maximal mouth opening without restraint on head position (we called this the "extension-allowed position"); and (4) full head extension. The craniocervical angles were measured by observing the angle formed between horizontal and the line joining the canthus of the eye and the tragus of the ear. A builder's angle finder was used to measure the angles.[9]

In pilot studies, we had found that subjects unconsciously extend their heads on their necks when performing mouth opening. We devised a system, which minimized head movement during observations in the flexion and neutral positions. The subject wore a cycling helmet to which a laser pointer had been attached (fig. 1). The subject was seated in a chair so that the head was 1 m from a wall. The position of the laser beam on the wall was marked when the subject had adopted the flexion or neutral head/neck position, before the attempt at mouth opening was made. The mark on the wall was a piece of 1-cm square adhesive tape, which formed a target for the subject to aim the laser beam at. The subject kept the laser point on the target during mouth opening, which prevented him/her from extending further. The angle subtended by a vertical movement

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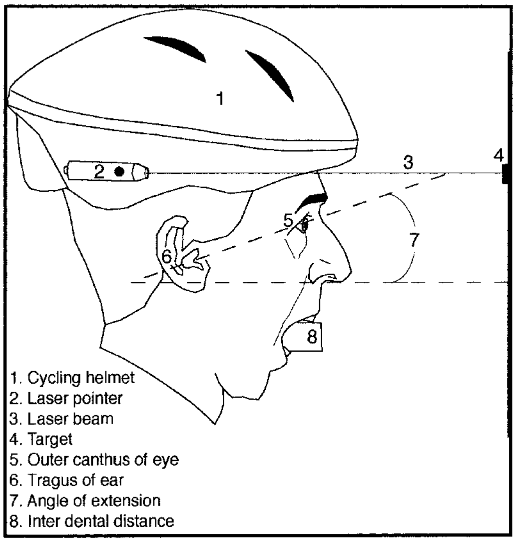

Fig. 1. Diagram of laser/cycle helmet apparatus to prevent unconscious head extension during measurement of interdental distance in flexion and neutral positions.

of the laser point of 1 cm at a distance of 1 m would be half a degree, using the formula $\tan^{-1}(a/b)$, where a is the vertical distance and b is the horizontal distance. We investigated the possibility that the subjects moved their heads in an anteroposterior plane during mouth opening in five of the volunteers, by observing the horizontal displacement of the tragus. There was less than 1 cm of movement during mouth opening in all of the positions. The interdental distance between the upper and lower incisors (IDD) was measured with a Willis bite gauge (SS White Mfg., Gloucester, United Kingdom).

Statistical Methods

Power Calculation. A power calculation was performed based on the results of a pilot study. Assuming an SD in the differences in IDD of 5 mm, a sample size of 20 subjects gave us at least 90% power to detect a difference in means of 10 mm between the positions using a paired *t* test with a 0.050 two-sided significance level, allowing for multiple comparisons.

A retrospective power calculation confirmed that we had included sufficient subjects in our study. This was based on a one-way repeated-measures analysis of variance for the IDD scores, and assuming a mean IDD variance of 500, an SD of 50 at each position, a between-positions correlation of 0.05, and a significance level of 5% indicates that a sample size of 19 will have 90% power to detect a difference across the four IDD values. Power calculations were made using nQuery Advisor v3.0 (Statistical Solutions Ltd., Cork, Ireland).

A one-way analysis of variance was performed for craniocervical angle measured at each of the four positions. Adjacent angles (flexion *vs.* neutral, neutral *vs.* extension allowed, and extension allowed *vs.* full extension) were compared using paired *t* tests. A similar analysis was performed for IDD. Statistical analyses were performed with Stata version 7.0 (StataCorp, College Station, TX).

Table 1. Craniocervical Position, Mean Craniocervical Angle, and Mean IDD

Position	CCA, ° (95% CI)	IDD, mm (95% CI)
Flexion	0	28 (25, 30)
Neutral	18 (16, 21)	34 (29, 37)
Extension allowed	44 (40, 48)	44 (40, 47)
Full extension	73 (69, 79)	46 (42, 49)

The interdental distances (IDDs) are all significantly different from one another ($P = 0.0004$, $P < 0.0001$, $P = 0.0028$ for flexion *vs.* neutral, neutral *vs.* extension allowed, extension allowed *vs.* full extension, respectively). The craniocervical angles (CCAs) in the four positions were all significantly different from one another ($P < 0.0001$). Comparisons were made using the paired *t* test.

CI = confidence interval.

Demographics.

There were 10 men and 10 women in the study. The median age was 32 yr (range, 24–43), and median height was 171 cm (range, 162–181). The median value of weight was 67 kg (range, 57–110), and the median body mass index was 23.5 (range, 19–40).

Results

The mean IDD increased by a total of 18 mm between the flexion and full extension positions. A one-way analysis of variance of IDD values demonstrated a statistically significant difference between the IDDs ($P < 0.0001$). The IDDs measured at each position were significantly different from one another at the 5% significance level ($P = 0.0004$, $P < 0.0001$, $P = 0.0028$ for flexion *vs.* neutral, neutral *vs.* extension allowed, and extension allowed *vs.* full extension, respectively; table 1). More than half of the increase in IDD occurred between the neutral and extension-allowed positions table 2).

A statistically significant difference was found between the craniocervical angles ($P < 0.0001$) using a one-way analysis of variance. All of the pairs of angles investigated using the paired *t* test were significantly different from

Table 2. Changes in Mean Craniocervical Angle and Mean IDD between Positions

Change in Position	CCA, ° (95% CI) [% of Total Change]	IDD, mm (95% CI) [% of Total Change]
Flexion to neutral	18 (16, 21) [25]	6 (3, 8) [33]
Neutral to extension allowed	26 (22, 30) [36]	10 (8, 13) [56]
Extension allowed to full extension	29 (25, 33) [40]	2 (1, 4) [11]

Fifty-six percent of the total increase in interdental distance (IDD) occurred between the neutral and extension-allowed positions.

CCA = craniocervical angle; CI = confidence interval.

one another at the 5% significance level ($P < 0.0001$; table 1).

Discussion

Our results support the hypothesis that mouth opening and craniocervical flexion/extension are related. All the subjects extended from neutral when asked to open their mouths without restraint on head position (mean of 26° [95% confidence interval, 21–30]). This increase in extension was only 36% of the total increase in craniocervical angle but allowed more than half (56%) of the total increase in IDD between the flexion and full extension positions. We call this angle the "gape-facilitating angle." When craniocervical extension beyond the neutral position was prevented, the subjects' mean IDD was 12 mm less than their mean at full extension (26% of the mean maximal IDD).

We do not know why mouth opening diminishes at angles of neck extension below the gape-facilitating angle, but limitation of mandibular excursion by compression of soft tissue behind the mandible probably plays a part. In addition, the muscles responsible for active mouth opening (lateral pterygoids, digastrics, geniohyoids, and mylohyoids)[10] may be working at reduced advantage when the neck is flexed. It is therefore possible that the reduction in IDD we observed would not be encountered in an anesthetized patient whose mouth was actively opened by an anesthesiologist. We cannot therefore state with confidence what significance our findings have for airway management until suitable investigations have been conducted in anesthetized patients. Nevertheless, our study suggests that airway management in patients with craniocervical rigidity (caused for example by disease, fixation devices, or manual stabilization) may be adversely affected by not only the disadvantages inherent in craniocervical rigidity, but also those of reduced mouth opening consequent on the craniocervical rigidity.

An association between cervical spine disease and limitation of mouth opening has been reported previously,[11–14] but these reports suggested that the limitation of mouth opening was due to an association between cervical spine disease and temporomandibular joint disease, rather than any effect of cervical spine mobility.

In conclusion, we report a mechanism involved in normal mouth opening, which has not to our knowledge been described previously. Mandibular movement and craniocervical movement are interrelated. Humans achieve full mouth opening by extending approximately 26° from the neutral position. Patients with restricted craniocervical movement may have reduced mouth opening ability. This phenomenon may contribute to the difficulties with airway management that can occur in patients with reduced craniocervical extension.

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