Clin Oral Invest (2013) 17:1295–1299
DOI 10.1007/s00784-012-0810-5

ORIGINAL ARTICLE

Effects of open mouth and rubber dam on upper airway patency and breathing

Kazuhiro Iwatani · Koichiro Matsuo · Soichiro Kawase · Nina Wakimoto · Akira Taguchi · Tadashi Ogasawara

Received: 22 March 2012 / Accepted: 20 July 2012 / Published online: 3 August 2012

Abstract
Objectives Rubber dams increase the quality and safety of dental treatment. However, the condition of a rubber dam over an open mouth may also obstruct the route for respiration. We tested whether an open mouth with or without a rubber dam would affect upper airway patency and breathing pattern.
Materials and methods Twenty young healthy volunteers were imaged with a magnetic resonance (MR) system under three conditions: mouth closed, mouth open, and rubber dam with mouth open. Respiration was concurrently monitored with plethysmography. MRI slices of the upper airway were obtained at 5-mm thicknesses, and the size of the cross-sectional area of the upper airway was measured by image analysis software. Respiratory cycle duration and tidal volume were also measured with digital signal analysis software.
Results The volume of the upper airway became significantly decreased with the mouth open. Analysis of each cross-sectional area of the upper airway revealed that while the oropharyngeal area was significantly narrower with an open mouth, the retropalatal and hypopharyngeal areas were not affected. Placing a rubber dam had no additional influence on upper airway patency but was seen to significantly shorten mean respiratory duration and decrease tidal volume.
Conclusions Open mouth position plays the largest role in decreased upper airway patency, and open mouth position with a rubber dam may further disrupt breathing pattern.
Clinical relevance Breathing pattern may become deteriorated by airway obstruction during dental treatments requiring a rubber dam.

Keywords Upper airway · Open mouth · Rubber dams · Breathing · Magnetic resonance imaging · Plethysmography

K. Iwatani · K. Matsuo (✉) · S. Kawase · N. Wakimoto · T. Ogasawara
Department of Special Care Dentistry,
Matsumoto Dental University,
1780 Hirooka Gobara, Shiojiri,
Nagano 399-0781, Japan
e-mail: kmatsuo@po.mdu.ac.jp

A. Taguchi
Department of Oral and Maxillofacial Radiology,
Matsumoto Dental University,
1780 Hirooka Gobara, Shiojiri,
Nagano 399-0781, Japan

Introduction

The use of rubber dams increases the quality and safety of dental treatment. During amalgam placement, composite resin restoration, and fissure sealant application, rubber dams keep teeth dry and clean and reduce microbial contamination from saliva [1, 2]. Rubber dams reduce accidents during dental procedures by preventing patients from ingesting or aspirating dental items, irrigating solutions, and debris [3]. They also protect the soft tissues of the mouth, such as the buccal mucosa, lips, and tongue, from trauma by rotary dental instruments. The rubber dam is particularly useful for patients with neuromuscular disease who experience dysphagia because it significantly enhances airway protection from leakage of water, contaminated solutions, and debris to the oropharynx and larynx [4, 5].

During dental treatment with a rubber dam, patients with neuromuscular disease or who are otherwise unable to maintain an open mouth often require a mouth prop. It is well known that open mouth position increases upper airway collapsibility during both sleep and wakefulness [6, 7]. Head position also significantly alters upper airway size [7–9]; neck extension and flexion increase and decrease upper airway size, respectively. While breathing at rest, air may flow through either the nose or the mouth, or both. During dental procedures requiring a rubber dam and prop, air must predominantly flow through the nose because the mouth is kept open and its entrance is covered. This may alter upper airway patency and breathing pattern, especially if the patient has a diminished respiration capacity. Therefore, in this pilot study on normal conscious young volunteers, we examined whether the conditions of an open mouth with or without a rubber dam would alter upper airway patency and breathing pattern.

Methods

Data acquisition

This was a randomized cross-over study where the subjects acted as their own controls. The sample size of the study was determined based on previous reports [8–10]. This study's protocol was approved by the Institutional Review Board of Matsumoto Dental University. Twenty healthy, asymptomatic young adults (16 men, 4 women; mean±SD age, 26.5±2.4 years) participated after giving informed consent. All participants had no history of breathing disorders and no pacemaker implants, ferromagnetic clips, or other metal materials in their body. Body mass index (BMI) of all subjects was less than 25 (mean BMI, 21.8±1.6).

Subjects were imaged with a 1.5-T Magnetic Resonance (MR) system (Signa HDxt, GE Healthcare) in a supine position. The head was set to have the upper occlusal plane perpendicular to the MR bed and was immobilized with a head holder to prevent motion. Subjects were instructed to neither speak nor swallow saliva during MR imagings to acquire clear images. If soft tissues moved accidentally, an additional image was recorded. MR images were recorded for three mouth conditions: resting (RT), mouth open (MO), and rubber dam with mouth open (RD). For RT, the mouth was closed and the subject was asked to relax (Fig. 1a). For MO, the mouth was kept open by biting on a mouth prop (large size, Sekimura, Osaka, Japan) with the right-side molars (Fig. 1b). The mouth prop was placed in the mouth with its anterior edge set on the cusp of the canines. For RD, a clamp was made from general purpose acrylic resin (Unifast II, GC, Tokyo, Japan), and a frame was assembled from disposable wooden chopsticks for compatibility with the MR system (Fig. 1c). The rubber dam was placed on the lower-left second molar while the mouth was positioned identically to that of MO (Fig. 1c). The recording order of the three conditions was randomized to reduce measurement bias.

Respiration was monitored with a respiratory plethysmograph [11]. The elasticized plethysmograph bands which were specialized for the MR system (AD instruments, Nagoya, Japan) were placed around the chest and abdomen prior to MR imaging. Each band measured the change in cross-sectional area of the chest and abdomen while monitoring respiratory phase and tidal volume. Respiratory signals were collected with a digital data recorder (PowerLab 8/30, ADinstruments, CO, USA) and recorded on a laptop computer at a 1.0-kHz acquisition rate. Respiration was recorded for 1 min for each mouth condition just after MR imaging to minimize the interference from the MR system.

Data reduction

The upper border of the upper airway was defined as the line tracing the superior margin of the hard palate, and the lower border was set as the line along the lower border of the fifth cervical vertebra on the MR image (Fig. 2a). MRI slices of the upper airway were obtained at 5 mm thicknesses parallel to the anterior and posterior nasal spines (Fig. 2b). The size of the cross-sectional area of the upper airway was measured with image analyzing software (Image-J, NIH, MD, USA). By adjusting the contrast of the MR images, the upper airway was imaged as a high-contrast black area. This area was then measured as the number of pixels by the software. Because the length of the upper airway differed among subjects, the measured cross-sectional areas were arranged and calculated as 16 slices to be uniform among subjects. The volume of the upper airway was calculated as the sum of the cross-sectional areas of the upper airway. MRI processing was done separately by two investigators. To assess intra- and inter-rater reliability, images of five subjects were randomly chosen, and a total of 240 MRI slices were assessed by the two investigators. For inter-rater reliability, two investigators independently measured the cross-sectional areas of the upper airway. For intra-rater reliability, an investigator measured the same cross-sectional area more than 1 month after the first measurement.

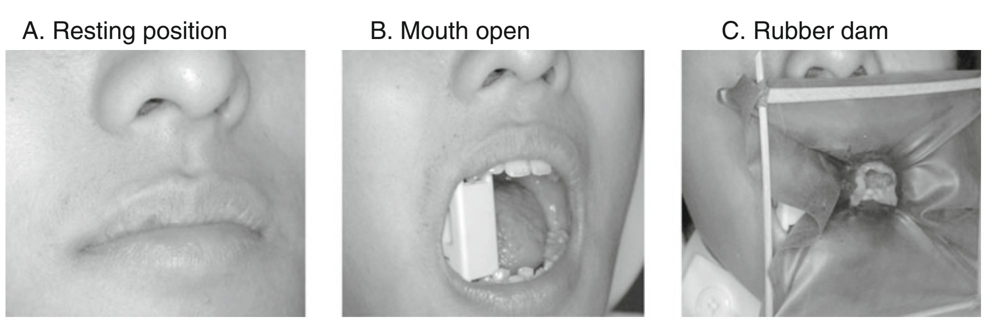

Fig. 1 Mouth conditions during MR imaging. **a** RT; the mouth was closed. **b** MO; a mouth prop was placed on the right side of the jaw. **c** RD; a rubber dam and clamp made from acrylic resin were placed on the left second molar in the MO position

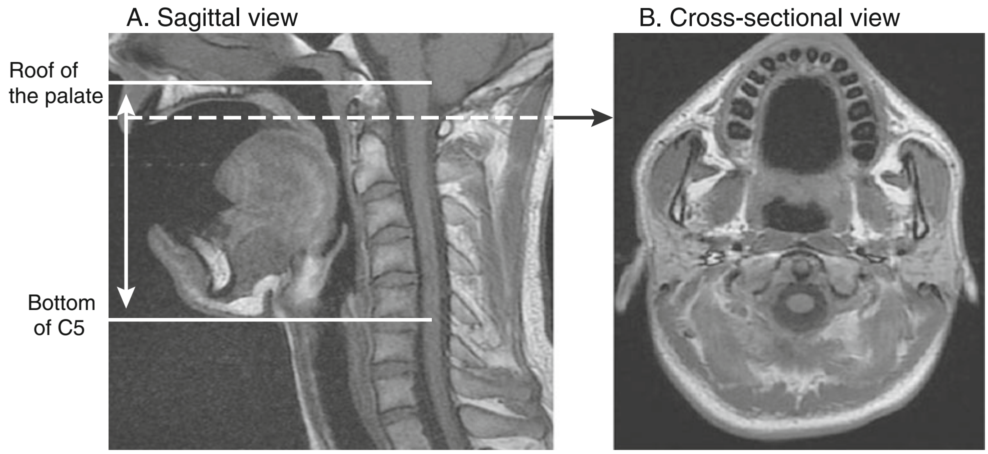

Fig. 2 Representative MR image in the **a** sagittal view along the midline and **b** cross-sectional view. Cross-sectional areas were measured from the line along the roof of the hard palate to the bottom line of the fifth cervical vertebra in 5-mm slices

Pearson's correlation coefficients were $r=0.91$ and 0.81 ($p<0.05$) for the intra- and inter-rater reliability test, respectively, to confirm adequate reliability of the measurements.

Respiratory data were processed with digital signal analysis software (Labchart 7.1, ADinstruments). The peak of the end of inspiration was automatically extracted from the plethysmograph data using a peak detection function of the software, and these points were confirmed manually by an investigator after data extraction. The time and amplitude of each peak of end inspiration were recorded on a spreadsheet. Respiratory cycle duration was defined as the time from the end of one inspiration to the end of the next inspiration. Tidal volume was defined as the amplitude of the peak volume at the end of inspiration and expressed in mV.

Data analysis

Since we found the distribution of the collected data to be significantly different from that of a normal distribution according to the Shapiro–Wilk test, we adopted nonparametric tests for our statistical analyses. The Friedman test was used to test differences in cross-sectional area and volume of the upper airway among the three mouth conditions. Multiple comparisons were performed using the Wilcoxon signed-rank test with Bonferroni correction. Since multiple respiratory data readings were taken for each mouth condition, the Kruskal–Wallis test was used to test the duration of respiratory cycles and tidal volume among the three mouth conditions. The Mann–Whitney *U* test with Bonferroni correction was used for multiple comparisons. The critical value for rejecting the null hypothesis was $\alpha<0.05$. Statistical analyses were performed using IBM SPSS Statistics version 20.0.

Results

The volume of the upper airway was significantly decreased for MO and RD compared with RT ($p<0.001$, Fig. 3a) but did not differ noticeably between MO and RD. The mean± SD of each cross-sectional area is shown in Fig. 3b. Mouth position significantly affected cross-sectional area from the 5th to the 13the slices. These areas represented the oropharynx from the base of the tongue to the epiglottis. The fifth and sixth slices were significantly decreased for RD in comparison with RT, and the cross-sectional areas from the 7th to the 13th slices were significantly smaller for MO and RD than for RT ($p<0.05$, except for the 11th slice). The retropalatal (1st to 4th slices) and hypopharyngeal areas (14th to 16th slices) were not significantly affected by mouth condition.

Median (interquartile range, IQR) respiratory cycle duration was 4.04 s (IQR, 3.22–5.82 s) for RT, 3.67 s (IQR, 3.04–5.14 s) for MO, and 3.46 s (IQR, 2.84–4.68 s) for RD (Fig. 4a). It was decreased significantly for MO and RD compared with RT ($p<0.05$). Tidal volume was significantly lower for RD than for RT ($p<0.001$), but not for MO ($p=0.24$, Fig. 4b).

Discussion

The present study demonstrated that an open mouth with a rubber dam significantly altered upper airway patency and breathing pattern in normal conscious subjects. Opening the mouth significantly decreased the volume and cross-sectional areas of the upper airway compared with closed mouth position, but addition of the rubber dam did not appear to further alter upper airway patency. Respiratory cycle duration was shortened and tidal volume was lower for MO and RD compared with RT, although the difference in tidal volume between RT and MO did not reach statistical significance. Taken together, our findings suggest that mouth opening increases upper airway collapsibility as previous studies have reported and that addition of a rubber dam may shallow breathing rhythm.

Results from our analysis of cross-sectional areas showed that, with the mouth open, the airway space of the

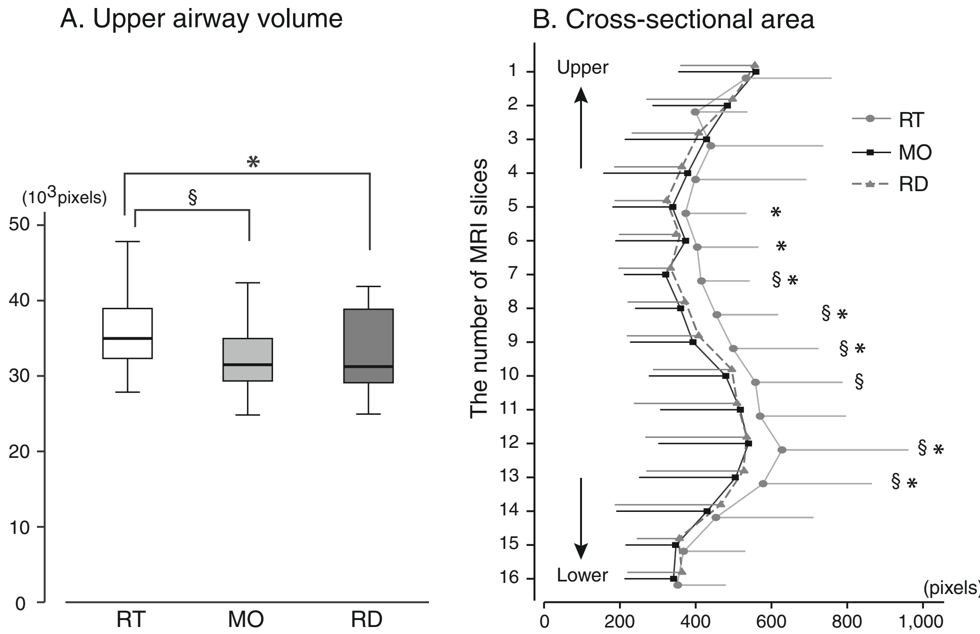

Fig. 3 **a** Box and whisker plot of upper airway volume and **b** average±SD size of cross-sectional area for the three mouth conditions. *Error bars* represent 1 SD. **a** Upper airway volume was significantly lower for MO and RD than for RT **b** Cross-sectional areas were significantly lower for MO and RD than for RT for the oropharyngeal region but not for the retropalatal or hypopharyngeal regions. §$p<0.05$ for RT vs. MO. *$p<0.05$ for RT vs. RD

oropharyngeal region from the uvula to the base of the epiglottis was significantly decreased. On the other hand, airway space in the retropalatal region and hypopharynx did not change significantly with the mouth open. Previous studies have also reported that an open mouth increased upper airway collapsibility during sleep in normal subjects and in patients with sleep apnea [6, 8]. In a supine position, gravity pulls the tongue backward when the mouth is open, which narrows the oropharyngeal area of the upper airway. Our findings and those of the others suggest that, during dental treatment, pharyngeal airway patency may decrease.

We placed the rubber dam on the lower second molar so as to force the tongue as far back as possible. A posterior tongue shift by the rubber dam might be a contributor to upper airway collapsibility, but the present study found no significant decrease in upper airway patency for RD compared with MO. This suggests that even if a rubber dam is placed on the lower second molar, it does not remarkably impact upper airway patency and that any decrease in upper airway patency is primarily due to the mouth being physically open.

We observed that open mouth position and placing a rubber dam significantly influence breathing pattern. Previous studies reported that upper airway resistance was increased by the mouth opening during sleep in normal subjects and in patients with sleep-disordered breathing or during midazolam sedation [6, 7, 10]. In contrast, Verin et al. [9] showed no significant effect of an open mouth alone on upper airway resistance in normal conscious subjects. The difference in results among these studies likely lies in the neuromuscular tone being active or sedated. We found that breathing rhythm tended to be shorter and shallower

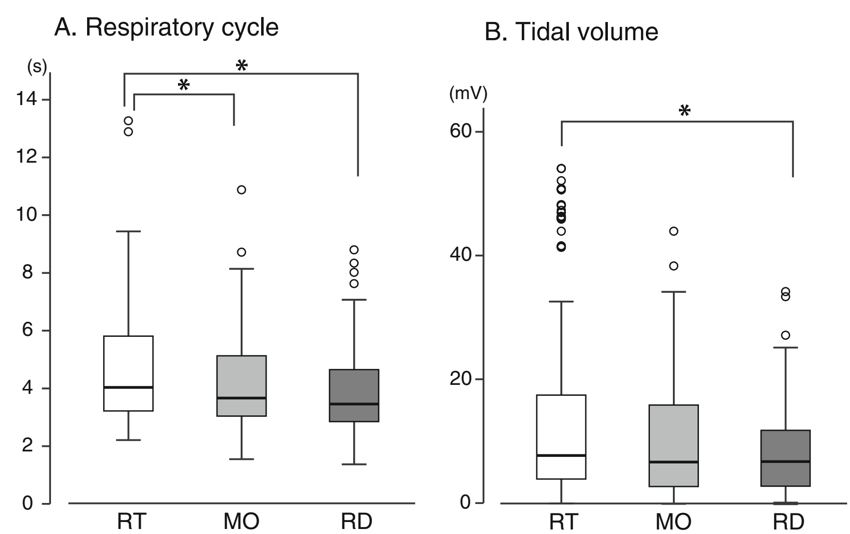

Fig. 4 Box and whisker plots of **a** respiratory cycle duration and **b** tidal volume for the three mouth conditions. Outliers outside of three box lengths from the median are represented as *circles*. **a** Respiratory cycle duration was significantly shorter for RD and MO than for RT **b** Tidal volume was significantly smaller for RD than for RT. *$p<0.05$

with the mouth open. We did not measure upper airway resistance or airway pressure in this study, but our findings indicate that open mouth position leads to an increase in upper airway resistance by decreasing upper airway patency, which is normally not significant during wakefulness in normal subjects. It appears that the rubber dam exacerbates breathing pattern changes by completely covering the mouth entrance for air; obstruction of one breathing route increased upper airway resistance, thus resulting in shallower breathing.

Previous studies have reported that head position alters upper airway patency as much as mouth opening does [7–9, 12], where neck extension and flexion widens and narrows pharyngeal airway patency, respectively. Furthermore, several studies demonstrated that the combination of head flexion with jaw opening most greatly narrows the pharyngeal airway. Along with our findings, these reports have important clinical implications. In the clinical setting of lower molar treatment, the neck of the patient tends to be flexed and the mouth is open. In individuals with neuromuscular disease, difficulty in maintaining upper airway patency due to weak muscle tone in the pharynx [13], or anatomical abnormalities of the mandible, such as Pierre Robin Syndrome with a retrognathic mandible [14], the risk of airway collapsibility may increase. For normal subjects, the alteration of airway patency and breathing pattern by an open mouth and rubber dam probably do not noticeably influence oxygenation during dental treatment because of reserve capacity. Because we did not conduct the subjective assessment of breathing difficulty or discomfort, our results could not directly imply that an open mouth position with a rubber dam would cause breathing difficulty. However, the findings in this study of healthy young volunteers suggest that patients with obstructive respiratory diseases or neuromuscular disease might experience deterioration of oxygenating ability during dental treatments requiring such neck and mouth positions. To further verify this inference, it will be necessary to expand this pilot study to one with a greater number of subjects that includes both healthy controls and individuals with respiratory disorders.

In conclusion, we demonstrated that mouth opening played the largest role in decreased upper airway patency and that placing a rubber dam alone did not influence upper airway patency in normal conscious subjects. We also found that an open mouth with a rubber dam altered breathing rhythm, making it shorter and shallower, likely due to the fact that the subject's airway was obstructed by the mouth being both open and covered by the rubber dam. The rubber dam is an invaluable tool for dental treatment, especially in patients with special needs. However, our findings in this preliminary study of healthy young volunteers indicate that an open mouth position with a rubber dam may deteriorate breathing pattern by airway obstruction, particularly in individuals with respiratory disorders.

Acknowledgments We are grateful to all the volunteers for their support. This research was supported by a grant-in-aid (21792163) from the Ministry of Education, Culture, Sports, Science, and Technology, Japan.

Conflict of interest The authors declare that there is no conflict of interest.

References

1. Cochran MA, Miller CH, Sheldrake MA (1989) The efficacy of the rubber dam as a barrier to the spread of microorganisms during dental treatment. J Am Dent Assoc (1939) 119:141–144
2. Simonsen RJ (2002) Pit and fissure sealant: review of the literature. Pediatr Dent 24:393–414
3. Ahmad IA (2009) Rubber dam usage for endodontic treatment: a review. Int Endod J 42:963–972
4. Friedlander AH, Mahler M, Norman KM, Ettinger RL (2009) Parkinson disease: systemic and orofacial manifestations, medical and dental management. J Am Dent Assoc 140:658–669
5. Yarom N, Barnea E, Nissan J, Gorsky M (2005) Dental management of patients with myasthenia gravis: a literature review. Oral surgery, oral medicine, oral pathology, oral radiology, and endodontics 100:158–163
6. Meurice JC, Marc I, Carrier G, Series F (1996) Effects of mouth opening on upper airway collapsibility in normal sleeping subjects. Am J Respir Crit Care Med 153:255–259
7. Morikawa S, Safar P, Decarlo J (1961) Influence of the head-jaw position upon upper airway patency. Anesthesiology 22:265–270
8. Isono S, Tanaka A, Tagaito Y, Ishikawa T, Nishino T (2004) Influences of head positions and bite opening on collapsibility of the passive pharynx. J Appl Physiol 97:339–346
9. Verin E, Series F, Locher C, Straus C, Zelter M, Derenne JP, Similowski T (2002) Effects of neck flexion and mouth opening on inspiratory flow dynamics in awake humans. J Appl Physiol 92:84–92
10. Ayuse T, Inazawa T, Kurata S, Okayasu I, Sakamoto E, Oi K, Schneider H, Schwartz AR (2004) Mouth-opening increases upper-airway collapsibility without changing resistance during midazolam sedation. J Dent Res 83:718–722
11. Gross RD, Atwood CW Jr, Grayhack JP, Shaiman S (2003) Lung volume effects on pharyngeal swallowing physiology. J Appl Physiol 95:2211–2217
12. Ando N, Ogasawara T, Kawase S, Okada Y, Matsuo K (2010) The influence to airway narrowing in dental practice postures. J Jpn Disability Oral Health 31:38–44
13. Benditt JO (2006) The neuromuscular respiratory system: physiology, pathophysiology, and a respiratory care approach to patients. Respir Care 51:829–837, discussion 837-829
14. Shprintzen RJ, Singer L (1992) Upper airway obstruction and the Robin sequence. Int Anesthesiol Clin 30:109–114