Mandibular Advancement Achieved through a Stepped Mouthpiece Design Can Change the Size of the Upper Airways

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Introduction

Factors which affect the deposition of inhaled aerosols in the lungs are important as good lung deposition is important for the treatment of respiratory diseases with inhaled aerosols. The geometry and the volume of the upper airways are known to affect the deposition of aerosol in the lungs.[1] The design of both inhalers and inhaler mouthpieces, specifically change in the vertical diameter, has also been shown to affect lung and upper airway deposition.[2-3] Acoustic pharyngometry (Eccovision; Sleep Group Solutions; North Miami Beach, FL) is a non-invasive technique which can be used to measure the cross-sectional area of the upper airway.[4] It has previously been used to determine the effect of different horizontal movements (in mm increments) of the lower jaw generated by oral appliances designed for use in patients with sleep apnea.[5] A recently published validation study of acoustic pharyngometry suggested that seated pharyngometry measurements correlated with supine magnetic resonance imaging measurements.[6] We have employed acoustic pharyngometry to measure the impact of prototype stepped mouthpieces on the dimensions of the upper airways. The design of the stepped mouthpiece prototypes facilitates both vertical and horizontal movements (mandibular advancements) of the lower jaw.

Method

Figure 1a. Illustration of the upper airways.

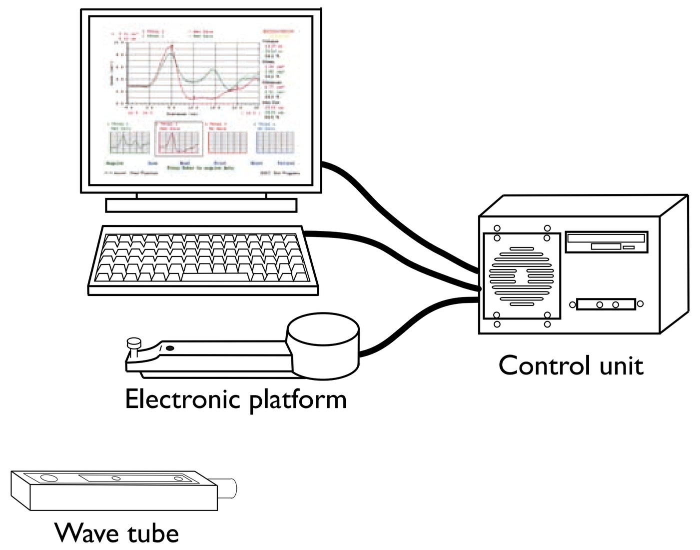

Figure 1b. The acoustic pharyngometer.

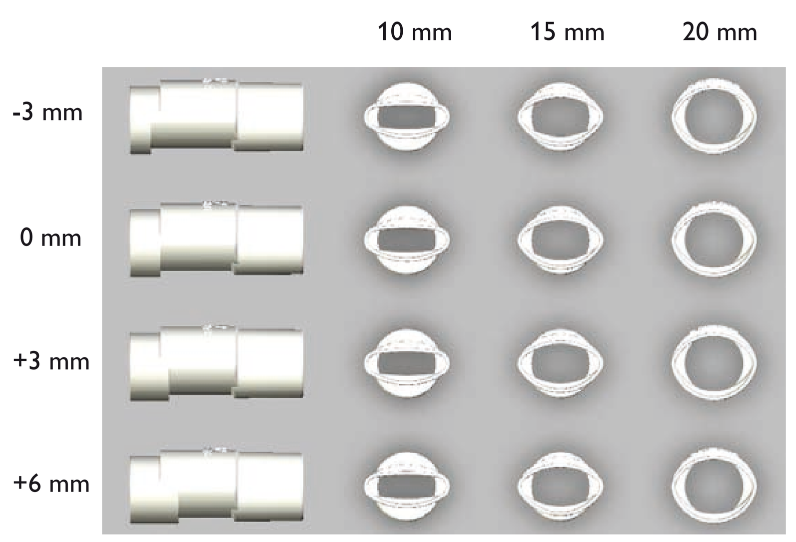

Figure 1c. The stepped mouthpieces used in the study for horizontal and vertical mandibular advancement.

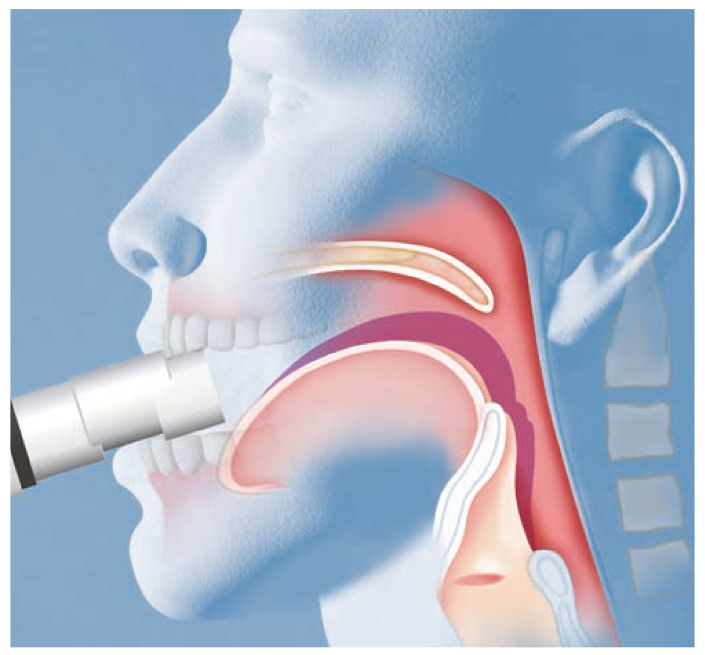

Figure 1d. Vertical and horizontal mandibular advancement might increase the volume of the upper airway (purple shaded area).

During acoustic pharyngometry, sound waves are launched from a loudspeaker along a wave tube into the subject's airways. They are then reflected and a microphone located at the subject's mouth records both the incident and reflected waves.[5] The difference between the two signals is then analyzed and changes in the area of the airways inferred as a function of distance from the recording microphone. From this, a graphic representation (pharyngogram) of the variations of the pharyngeal cross-sectional area (cm^2) through the length of the upper airways (cm) can be obtained (Fig. 2). Computer processing of the incident and reflected sound waves from the airways provides an area distance curve representing the lumen from which the cross-sectional area and volume can be derived.

Acoustic pharyngometry was used to analyze the upper airways of four healthy male subjects (four of the authors), age range 45-65 years, using prototype stepped mouthpieces for mandibular advancements. The upper airways analyzed included the oral cavity, the oropharynx, the epiglottis, the hypopharynx, and the glottis. The prototype stepped mouthpieces were 28 mm wide with three different oval orifices to be placed between the teeth with maximal vertical dimensions of 10 mm (small), 15 mm (medium), and 20 mm (large). The horizontal movements were generated by offsets of -3 mm (lower jaw moved back), ±0 mm (teeth aligned), +3 mm and +6 mm (lower jaw moved forward). The acoustic pharyngometry measurements were made during both exhalation (two recordings at functional residual capacity) and inhalation (two recordings during mid-inhalation), during tidal breathing with nose-clips.

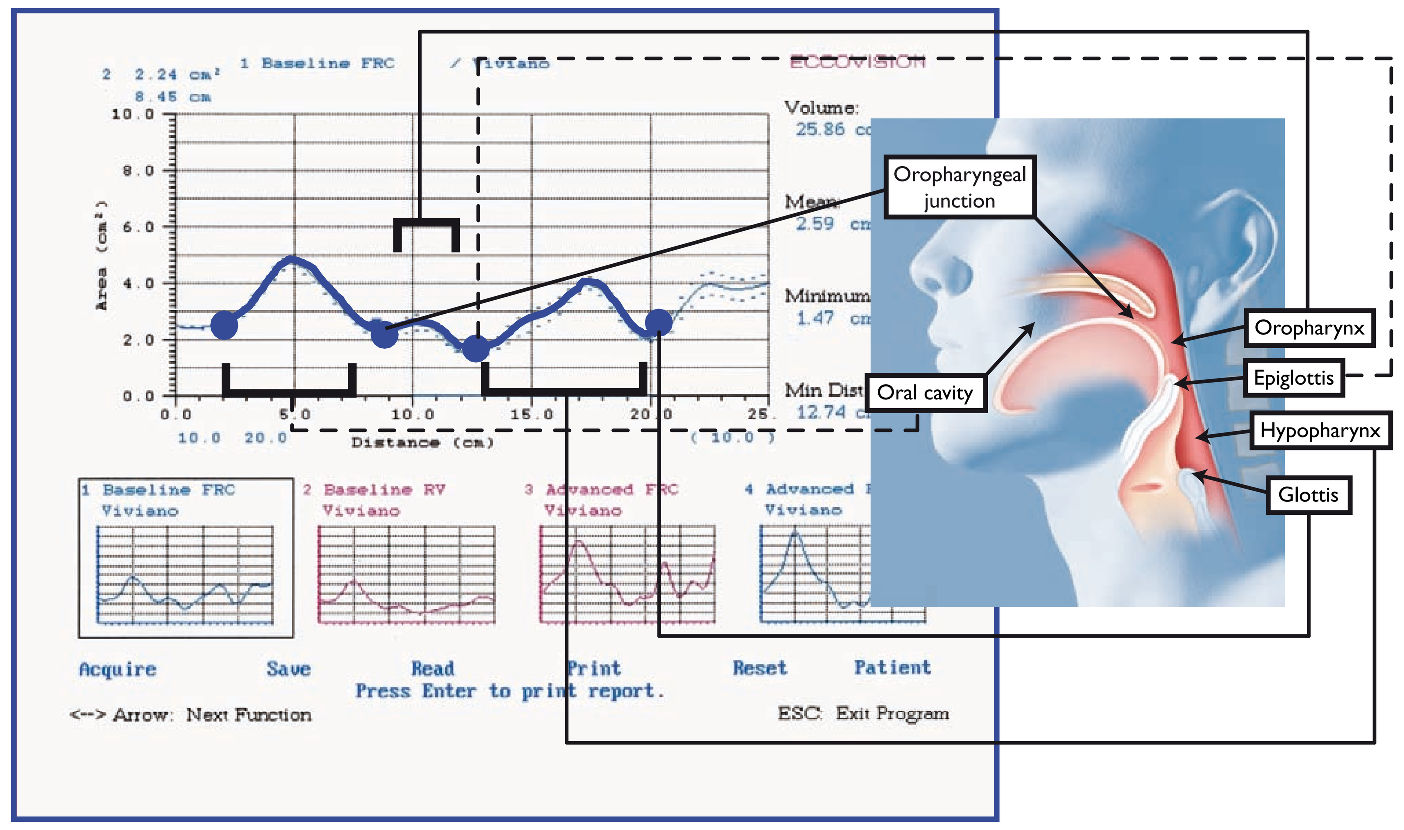

Figure 2. Example of a pharyngogram with related anatomical (upper airway) landmarks.

Results

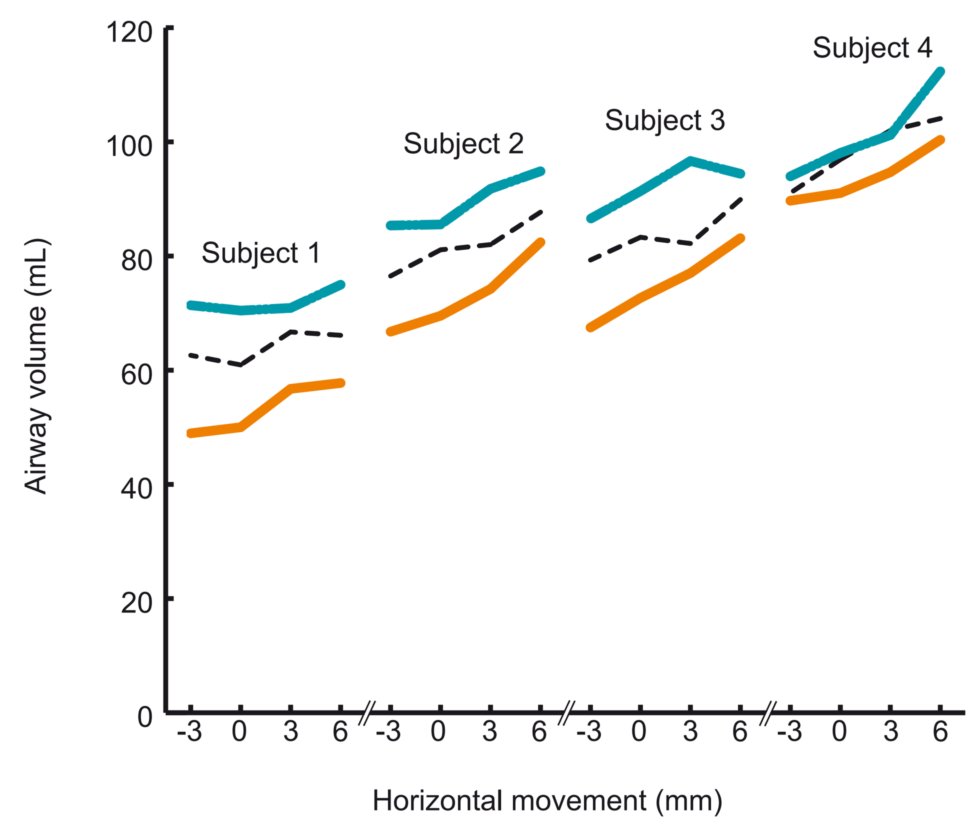

Figure 3. The changes in airway volume (0 to 20 cm) during inhalation are shown for the four subjects. The impact of the vertical movement of the lower jaw is shown as ▬ for the 10 mm diameter mouthpiece orifice, as ▪ ▪ for the 15 mm orifice, and as ▬ for the 20 mm orifice. The impact of the horizontal movement of the lower jaw is shown as a function of the X-axis scale of -3, ±0, +3 and +6 mm.

The impact of the vertical movement of the lower jaw was obvious in three of the four subjects (subjects 1-3), whereas the impact of the horizontal movement of the lower jaw was pronounced in all four subjects. There was no difference in airway volume between measurements performed during inhalation and exhalation. The changes in volume occurred in different parts of the upper airways as shown in the example in Figure 4. In this example, when using the medium sized stepped mouthpiece and the +3 mm and +6 mm mandibular advancements, the main changes in cross-sectional area occurred in the oropharynx (~12 - ~17 cm on the X-axis) and in the hypopharynx (~17 - ~24 cm on the X-axis).

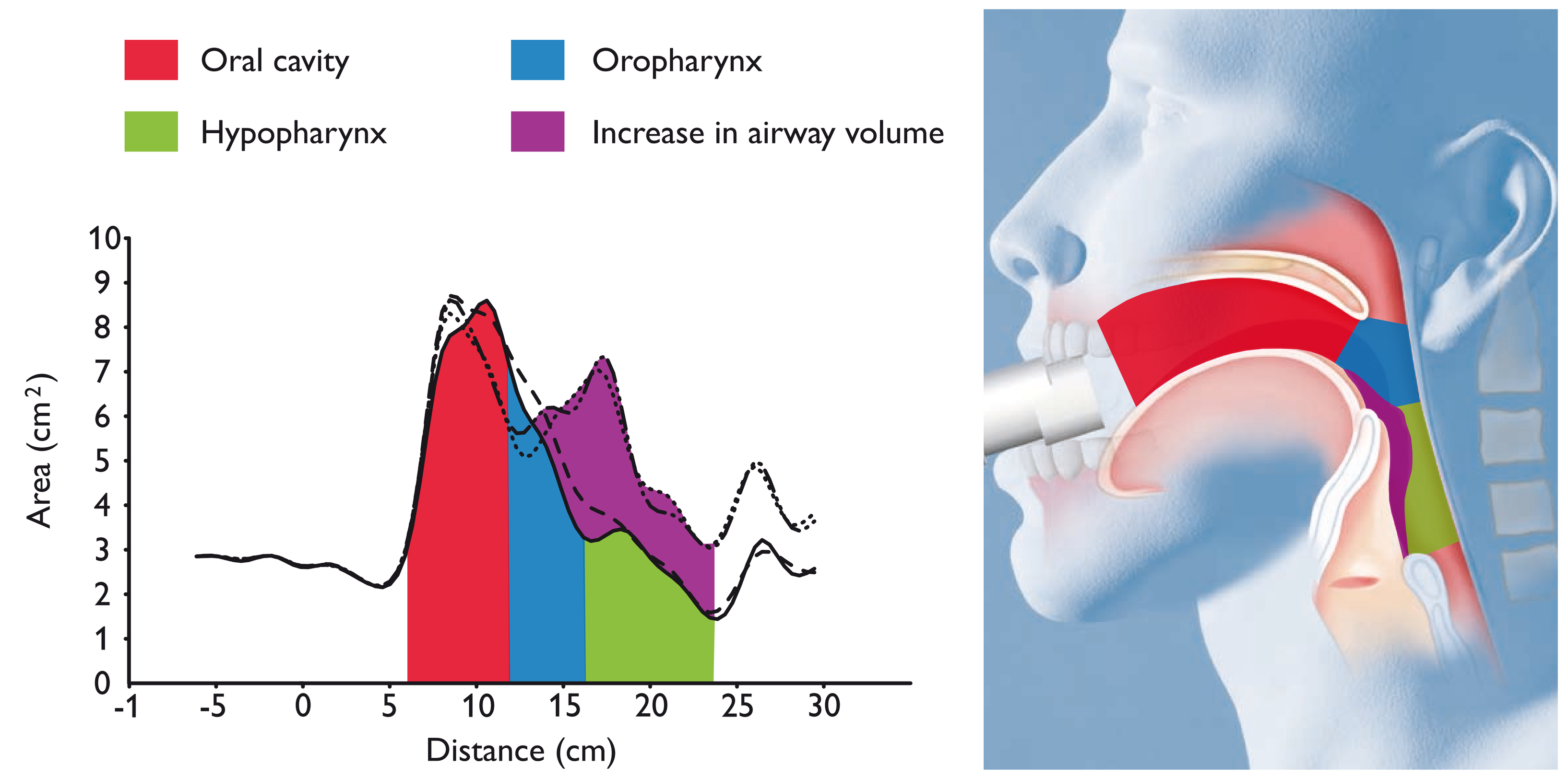

Figure 4. The figure shows the changes in the size of the upper airways in subject 4 when using the medium size (15 mm, vertical size) stepped mouthpiece. The horizontal movement of -3 mm (—) did not change the size from the ±0 mm (– –), whereas the advancements of +3 mm (···) and +6 mm (– ·· –) caused a shift in the cross-sectional area of the oropharynx and the hypopharynx.

Conclusions

Mandibular advancements through the use of stepped mouthpieces were shown to increase the volume of the upper airways. The use of acoustic pharyngometry enabled a detailed analysis of the changes from the oral cavity to the glottis. The incorporation of stepped mouthpieces in inhalers might increase the amount of aerosol deposited in the lungs, and warrants further research.

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