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# A computed tomographic evaluation of effect of mandibular advancement device at two different horizontal jaw positions in patients with obstructive sleep apnea

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ABSTRACT

*Statement of problem:* Studies pertaining to the objective assessments of the efficacy of mandibular advancement device in patients with obstructive sleep apnea are scarce.
*Purpose:* The purpose of this clinical study was to evaluate the effect of MAD at two different horizontal positions of mandible on upper airway dimensions through computed tomography.
*Material and methods:* Twenty-nine consenting participants satisfying predetermined inclusion and exclusion criteria were enrolled and an adjustable two-piece MAD was fabricated at 50% maximum mandibular protrusion and after 4 weeks was adjusted to 70% protrusion. CT scans were obtained at baseline, 4 weeks after delivering MAD with 50% mandibular protrusion, and then after 4 weeks with 70% mandibular protrusion. Cross sectional area with diameters (lateral and anteroposterior) of upper airway was measured at three specific anatomic levels (retropalatal-RP, retroglossal-RG, and epiglottal-EG). Data were analyzed using the Student t-test for parametric analysis.
*Results:* Intragroup comparison revealed a statistically significant increase in lateral & anteroposterior dimensions as well as cross sectional area at all three anatomical levels at 4 weeks after MAD with 50% mandibular protrusion compared with baseline and 4 weeks after MAD with 70% mandibular protrusion compared with baseline. However, the difference between lateral and anteroposterior dimensions with MAD at 70% protrusion compared with MAD at 50% protrusion was not statistically significant. The difference between cross-sectional area was found to be statistically significant.
*Conclusion:* Mandibular advancement device at 70% mandibular protrusion is more effective compared with the device at 50% protrusion in relieving oropharyngeal obstruction seen in OSA.

## 1. Introduction

Obstructive sleep apnea (OSA) is a common chronic disorder with high prevalence of 2–4% in the adult population especially among middle-aged men.[1] This condition is characterized by repetitive episodes of upper airway collapse during sleep-partial (hypopnea) or complete (apnea), consequently leading to reduction/cessation of the airflow.[2]

Studies have reported that impaired mechanosensitivity at the level of upper airway has been associated with OSA[3,4] and has a relationship with its severity.[4,5] There is mechanical trauma to the upper airway as a result of apneic-hypopneic episodes, inflammation and oxidative stress seen with OSA.[6,7] The obstructive events lead to increased breathing efforts due to progressive asphyxia, until the person is awakened. This obstruction is also commonly associated with snoring due to increased inspiratory pressure due to critical narrowing of airway during sleep.[8] A compromised respiratory system, either due to any physiologic abnormality or anatomic insufficiency such as a small upper airspace, can predispose a person to significant breathing disorders during sleep.[9] To maintain sufficient airflow in such conditions, the dependence on the pharyngeal muscles is increased. It is also well reported that there is a major compensatory role of non-diaphragmatic respiratory muscles in patients with neuromuscular weakness and restrictive lung diseases for maintenance of adequate ventilation during wakefulness.[10] However, due to reduced/absent compensation during sleep, sleep apnea may result due to severe hypoventilation.

Obstructive sleep apnea (OSA) symptoms can range from increased average sleep propensity and daytime sleepiness, snoring, hypopnes/apneas during sleep to association with various metabolic disorders such

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as cardiovascular and cerebrovascular conditions and may be a cause of increased morbidity and mortality.[11,12] Various treatment modalities for OSA has been mentioned in the literature including continuous positive airway pressure (CPAP),[13] oral appliances, surgery,[14] and pharmacological management. CPAP has been the gold standard of the treatment of choice especially in severe OSA. However, due to lower patient compliance owing to claustrophobia, bloating and nasal dryness and stuffiness associated with CPAP usage, the use of oral appliances such as MAD for management of mild to moderate OSA has come to light. According to the guideline published by American Academy of sleep Medicine in 1995, MAD was indicated as first-line therapy for mild OSA and a second-line therapy for moderate to severe OSA.[15]

Efficacy of the treatment modalities may be assessed objectively by nocturnal polysomnography[16] or imaging techniques and subjectively by various questionnaires such as epworth sleep score (ESS), berlin questionnaire and stop bang questionnaire answered by the patient and his or her spouse. In the present study computed tomography (CT) was used for evaluation of efficacy of an adjustable MAD appliance given to the participants with OSA since it offers many advantages, such as providing three-dimensional multiple images with a lower radiation exposure than standard CT.[17] Most common site of obstruction seen in OSA has been the oropharynx and airway constriction occurs at this level.[18,19] The retropalatal, retroglossal and epiglottal regions constitute important landmarks of the upper airway, hence these landmarks were selected for CT evaluation.

## 2. Materials and method

Participants satisfying predetermined inclusion and exclusion criteria were selected for the study and written informed consent was obtained from the willing participants. A total of 29 participants provided consent for participation in the present study. Ethical clearance was obtained from institutional ethical committee of King George's Medical College, Lucknow. Initially, tools and technique including screening tool, CT imaging as well as sleep study (polysomnography) were standardized. Polysomnography test was done for all the enrolled participants. Data related to age, gender, height, weight, BMI, AHI, palate classification, jaw relation, protrusion, overjet was collected.

A pre CT imaging was carried out before MAD delivery. Computed tomography was performed with participants in supine position, awake during quiet nasal breathing with mouth closed. Slices were obtained at retropalatal (RP), retroglossal (RG), and epiglottal (EG) levels. Cross sectional area (Fig. 3) with diameters (anteroposterior and lateral) of upper airway was measured using image analysis software (Figs. 1 and 2). Then maxillary & mandibular impressions were made and participant's maximum protrusion and maximum inter-incisal opening were recorded with a ruler by measuring the distance between labial surfaces of selected incisor teeth in each patient. Thereafter, interocclusal record was registered at 50% of maximum protrusion and 20% of maximum interincisal opening. An adjustable two-piece MAD was fabricated at 50% maximum mandibular protrusion and was delivered to each participant. The participants were instructed to wear the appliance for a minimum of 6 h for a period of 4 weeks, post which they were recalled. Computed tomography was repeated in the same manner as earlier with participants wearing the device adjusted at 50% mandibular protrusion and CT images were recorded with measurements made at previously mentioned levels (Figs. 1–3). Thereafter, the MAD was adjusted at 70% mandibular protrusion by addition of self-cure autopolymerising resin and the participants were provided with this MAD with the same instructions as previously. Computed tomography was repeated with participants wearing the device adjusted at 70% mandibular protrusion after 4 weeks. Cross sectional area and diameters were measured at different anatomic levels of upper airway as mentioned previously (Figs. 1–3).

Mean, standard deviation, *P*-value were calculated for observations. Continuous variables were compared by *t*-test ($P < 0.05$).

## 3. Results

On demographic assessment, the mean age of the study sample was 47 years, of which 85% were men and 15% were women with mean height and weight 165.1 cm and 77.5 kg respectively (Table 1). All subjects in the study were of the same racial origin (Indian). The mean BMI of patients was 28.4 kg/m$^2$. Mean mandibular protrusion in the participants was 9.2 mm (Table 1). Mean AHI was 19.2 per hour in these subjects while overjet dimension was observed 2.6 mm (Table 1). Mallampatti palate classification showed that class I, II, III and IV were observed in 0,15, 62.5 and 22.5% respectively (Table 2). Jaw relation was recorded as standard procedure and class I, II and III were observed in 95,5 and 0% respectively (Table 2).

Computed tomographic evaluation was done in all participants, first a diagnostic CT scan was done at baseline and then after delivery of MAD another post CT was done. Mean of lateral & anteroposterior dimensions, and cross-sectional area at predetermined levels was calculated at baseline, after provision of MAD with 50% protrusion, and with MAD at 70% mandibular protrusion (Table 3). Intragroup comparison revealed that, changes in lateral dimensions at retropalatal level (RP) was statistically significant at 4 weeks post MAD delivery at 50% protrusion compared with baseline with a percent mean change of −3.38 (P = 0.035). Also, a statistically significant difference was observed at 4 weeks post MAD delivery at 70% protrusion compared with baseline with percent mean change of −5.09 (P = 0.025). However, when lateral dimensions were compared with 50% mandibular protrusion and 70% mandibular protrusion, the difference was not statistically significant with percent mean change of −1.65 (P = 0.260) (Table 4). Anteroposterior dimensions at retropalatal level showed a statistically

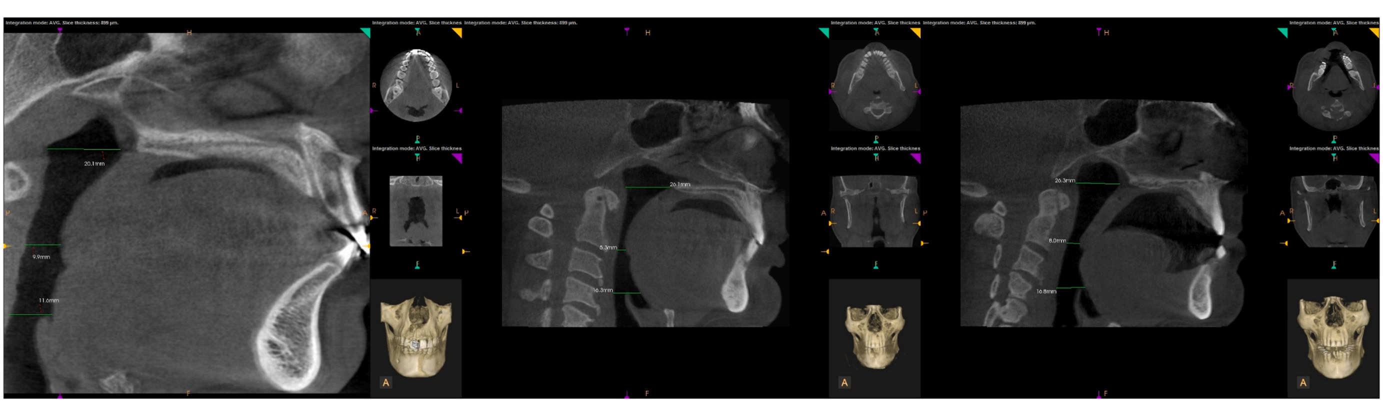

**Fig. 1.** Pharyngeal anteroposterior dimensions at retropalatal, retroglossal and epiglottal levels measured at baseline, 4 weeks after MAD at 50% protrusion, and 4 weeks after MAD at 70% protrusion.

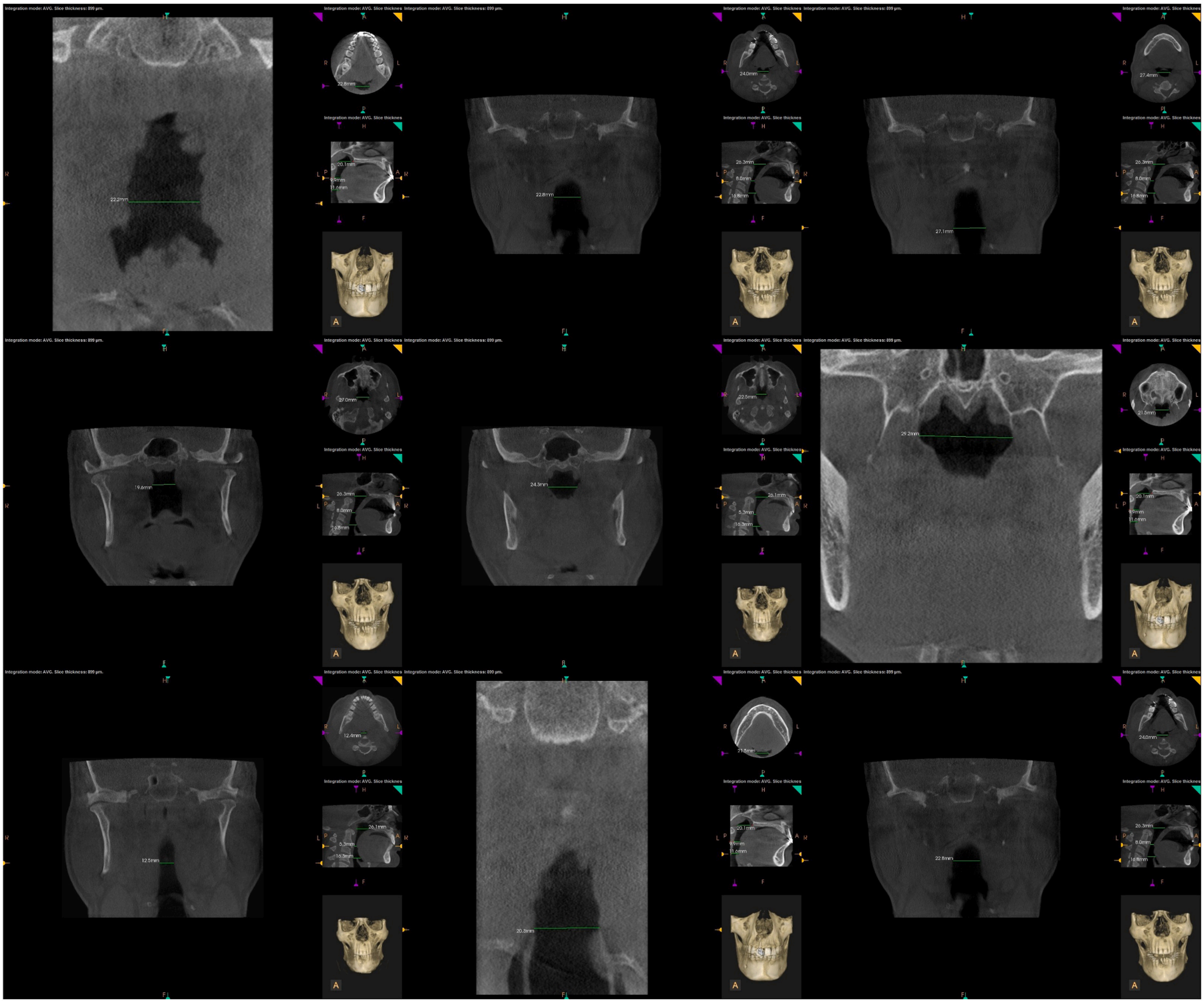

**Fig. 2.** Pharyngeal lateral dimensions at retropalatal, retroglossal and epiglottal levels measured at baseline, 4 weeks after MAD at 50% protrusion, and 4 weeks after MAD at 70% protrusion.

significant increase at 4 weeks post MAD delivery at 50% protrusion compared with baseline with a percent mean change of −5.33 ($P = 0.001$). Also, a statistically significant difference was observed at 4 weeks post MAD delivery at 70% protrusion compared with baseline with percent mean change of −6.07 ($P < 0.001$). However, when anteroposterior dimensions were compared with 50% mandibular protrusion and 70% mandibular protrusion, the difference was not statistically significant with percent mean change of −0.70 ($P = 0.451$). At epiglottal level, lateral dimensions showed a statistically significant increase at 4 weeks post MAD delivery at 50% protrusion compared with baseline with a percent mean change of −12.58 ($P < 0.001$). Also, a statistically significant difference was observed at 4 weeks post MAD delivery at 70% protrusion compared with baseline with percent mean change of −14.99 ($P < 0.001$). Lateral dimensions at 70% mandibular protrusion compared with 50% mandibular protrusion did not show a statistically significant increase with percent mean change of −2.13 ($P = 0.378$) Table 4).

Assessment of data obtained for changes in dimensions at retroglossal level (RG) revealed that there was a statistically significant increase in lateral dimensions at 4 weeks post MAD delivery at 50% protrusion compared with baseline with a percent mean change of −10.31 ($P = 0.031$). Also, a statistically significant difference was observed at 4 weeks post MAD delivery at 70% protrusion compared with baseline with percent mean change of −15.40 ($P < 0.001$). However, when lateral dimensions were compared with 50% mandibular protrusion and 70% mandibular protrusion, the difference was not statistically significant with percent mean change of −4.62 ($P = 0.207$) (Table 4). Anteroposterior dimensions at retroglossal level (RG) showed a statistically significant increase at 4 weeks post MAD delivery at 50% protrusion compared with baseline with a percent mean change of −13.82 ($P = 0.001$). Also, a statistically significant difference was observed at 4 weeks post MAD delivery at 70% protrusion compared with baseline with percent mean change of −15.64 ($P < 0.001$). However, when anteroposterior dimensions were compared with 50% mandibular protrusion and 70% mandibular protrusion, the difference was not statistically significant with percent mean change of −1.60 ($P = 0.208$) (Table 4). At epiglottal level, anteroposterior dimensions showed a statistically significant increase at 4 weeks post MAD delivery at 50% protrusion compared with baseline with a percent mean change of −9.59 ($P < 0.001$). Also, a statistically significant difference was

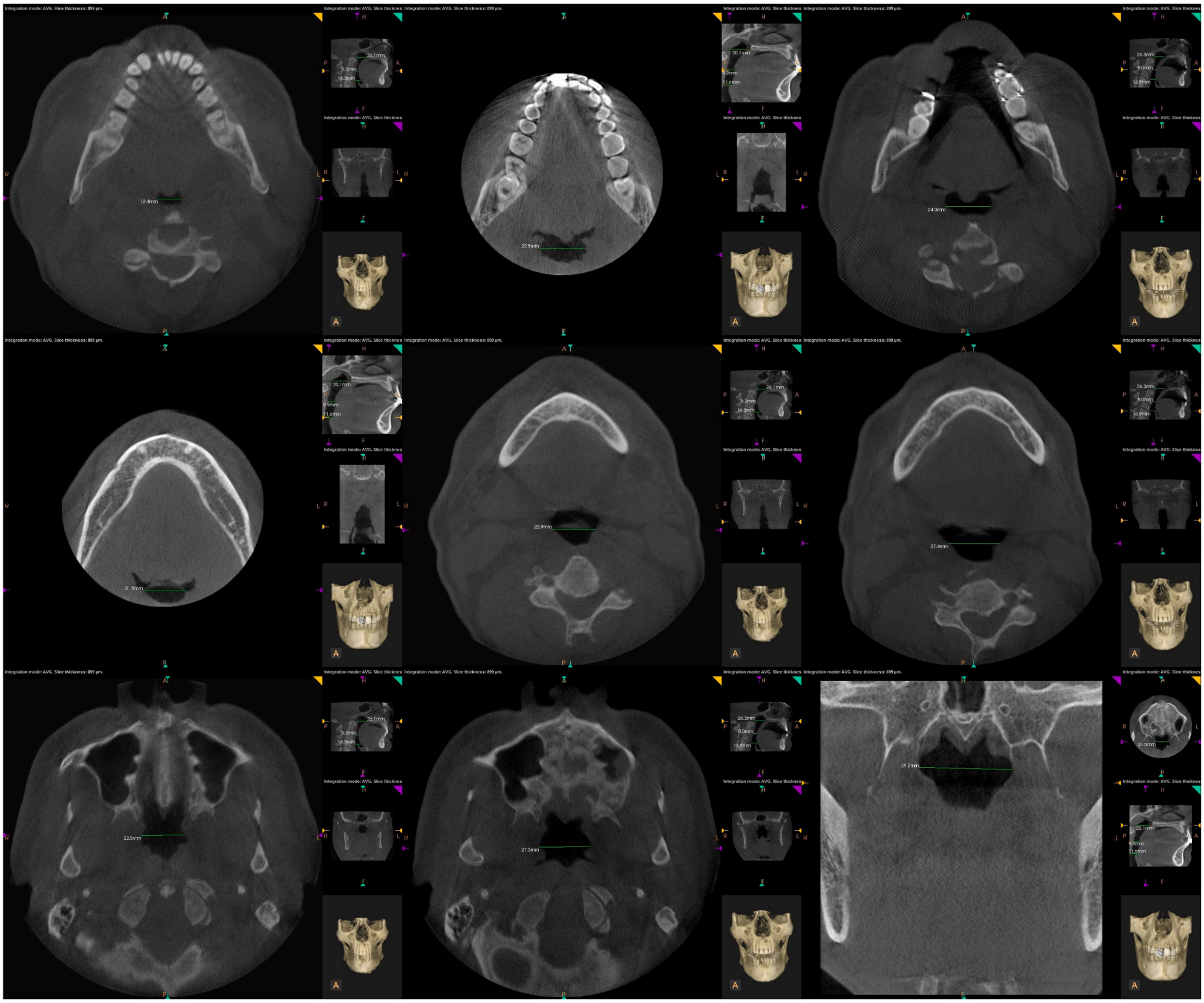

**Fig. 3.** Pharyngeal cross-sectional dimensions at retropalatal, retroglossal and epiglottal levels measured at baseline, 4 weeks after MAD at 50% protrusion, and 4 weeks after MAD at 70% protrusion.

**Table 1**
Demographic presentation of the sample.

| Variable | Age (Yr) | Height (cm) | Weight (Kg) | BMI (Kg/m$^2$) | AHI (per hour) | Protrusion (mm) | Overjet (mm) |
|---|---|---|---|---|---|---|---|
| **Mean ± SD** | 47 ± 10.3 | 165.1 ± 7.3 | 77.5 ± 9.16 | 28.4 ± 3.5 | 19.2 ± 6.8 | 9.2 ± 1.87 | 2.6 ± 1.26 |
| **Range (Min-Max)** | 23–67 | 141–185.4 | 55–103 | 23.8–36 | 5.5–61.5 | 7–15 | 0–6 |

**Table 2**
Intraoral findings.

| Variable | Class | % (N) |
|---|---|---|
| Palate classification | I | 0(0) |
| | II | 15(6) |
| | III | 62.5(25) |
| | IV | 22.5(9) |
| Jaw relation | I | 95(38) |
| | II | 5(2) |
| | III | 0(0) |

observed at 4 weeks post MAD delivery at 70% protrusion compared with baseline with percent mean change of −11.36 ($P < 0.001$). Anteroposterior dimensions at 70% mandibular protrusion compared with 50% mandibular protrusion did not show a statistically significant increase with percent mean change of −1.61 ($P = 0.157$) (Table 4).

Cross-sectional area at retropalatal level showed a statistically significant increase at 4 weeks post MAD delivery at 50% protrusion compared with baseline with a percent mean change of −8.08 ($P = 0.008$). Also, a statistically significant difference was observed at 4 weeks post MAD delivery at 70% protrusion compared with baseline with percent mean change of −8.38 ($P = 0.006$). Cross-sectional area at 70% mandibular protrusion compared with 50% mandibular protrusion also showed a statistically significant increase with percent mean

**Table 3**
Pharyngeal dimensions at predetermined levels at baseline, 4 weeks after MAD at 50% protrusion, and 4 weeks after MAD at 70% protrusion.

| | Lateral (Mean ± SD) | | | Anteroposterior (Mean ± SD) | | | Cross-sectional (Mean ± SD) | | |
|---|---|---|---|---|---|---|---|---|---|
| | RP | RG | EG | RP | RG | EG | RP | RG | EG |
| **Base - Line** | 25.76 ± 3.74 | 8.05 ± 3.14 | 19.15 ± 5.80 | 28.30 ± 4.79 | 21.99 ± 5.51 | 31.59 ± 5.03 | 575.04 ± 145.57 | 137.31 ± 57.76 | 464.05 ± 145.02 |
| **4 wks (50%)** | 26.63 ± 2.70 | 8.88 ± 3.31 | 21.56 ± 5.62 | 29.81 ± 4.56 | 25.03 ± 5.92 | 34.62 ± 5.17 | 621.55 ± 133.20 | 174.73 ± 82.64 | 586.72 ± 158.43 |
| **4 wks (70%)** | 27.07 ± 3.07 | 9.29 ± 3.65 | 22.02 ± 4.40 | 30.02 ± 4.43 | 25.43 ± 5.85 | 35.18 ± 4.31 | 623.25 ± 133.09 | 219.60 ± 139.98 | 588.70 ± 157.54 |

**Table 4**
Intragroup comparison between pharyngeal dimensions at baseline, 4 weeks after MAD at 50% protrusion, and 4 weeks after MAD at 70% protrusion.

| Lateral | RP | | RG | | EG | |
|---|---|---|---|---|---|---|
| | %mean change | P value | %mean change | P value | %mean change | P value |
| **Baseline-4 wks (50%)** | −3.38 | 0.035* | −10.31 | 0.031* | −12.58 | <0.001* |
| **Baseline-4 wks (70%)** | −5.09 | 0.025* | −15.40 | <0.001* | −14.99 | <0.001* |
| **50%-70%** | −1.65 | 0.260 | −4.62 | 0.207 | −2.13 | 0.378 |
| **Anteroposterior** | **RP %mean change** | **P value** | **RG %mean change** | **P value** | **EG %mean change** | **P value** |
| **Baseline-4 wks (50%)** | −5.33 | 0.001* | −13.82 | 0.001* | −9.59 | <0.001* |
| **Baseline-4 wks (70%)** | −6.07 | <0.001* | −15.64 | <0.001* | −11.36 | <0.001* |
| **50%-70%** | −0.70 | 0.451 | −1.60 | 0.208 | −1.61 | 0.157 |
| **Cross-sectional** | **RP %mean change** | **P value** | **RG %mean change** | **P value** | **EG %mean change** | **P value** |
| **Baseline-4 wks (50%)** | −8.08 | 0.008* | −27.25 | 0.004* | −26.43 | <0.001* |
| **Baseline-4 wks (70%)** | −8.38 | 0.006* | −59.93 | 0.001* | −27.50 | <0.001* |
| **50%-70%** | −0.27 | 0.046* | −25.67 | 0.020* | −0.3 | 0.008* |

change of −0.27 (P = 0.046) (Table 4). Cross-sectional area at retroglossal level (RG) showed a statistically significant increase at 4 weeks post MAD delivery at 50% protrusion compared with baseline with a percent mean change of −27.25 (P = 0.004). Also, a statistically significant difference was observed at 4 weeks post MAD delivery at 70% protrusion compared with baseline with percent mean change of −59.93 (P = 0.001). Cross-sectional area at 70% mandibular protrusion compared with 50% mandibular protrusion also showed a statistically significant increase with percent mean change of −25.67 (P = 0.020). At epiglottal level, Cross-sectional area at showed a statistically significant increase at 4 weeks post MAD delivery at 50% protrusion compared with baseline with a percent mean change of −26.43 (P < 0.001). Also, a statistically significant difference was observed at 4 weeks post MAD delivery at 70% protrusion compared with baseline with percent mean change of −27.50 (P < 0.001). Cross-sectional area at 70% mandibular protrusion compared with 50% mandibular protrusion also showed a statistically significant increase with percent mean change of −0.33 (P = 0.008) (Table 4).

## 4. Discussion

Null hypothesis stating that there will exist no difference between effect of MAD at two different horizontal jaw relations was rejected in the present study based on the statistical analysis of the data obtained. Upper age limit for the study population was set at 67 years as central sleep apnea is more common in patients over this age.[20] The study population consisted of 85% male and 15% females. Three to four times higher prevalence of OSA in men than women has been reported.[1,20,21] The mean BMI of patients in this study was 28.4 kg/m2 and mean weight of subjects in this study was 77.5 kg and height was 165.1 mm, which showed obesity as a risk factor for OSA. Weight loss has been shown to aid in improvement in sleep apnea and related sequelae.[22] Ma et al. also reported through their study the association between obesity and sleep breathing disorders.[23] Obesity exaggerates the tendency of airway passage closure.[24] 63% of the sample had class III palate and 93% had class I jaw relation, also maximum number of patients had full mouth opening and good periodontal status. Standard modality for diagnosis and evaluation of treatment efficacy in OSA patients is polysomnography.[16] In the present study, CT was used for evaluation and through data evaluation it was interpreted that evaluation of treatment outcomes in OSA patients can be assessed using CT. Cone beam CT scanning uses a focused beam and thus the patient's radiation exposure is far less.[17]

An adjustable two piece MAD was provided to the participants for the management of OSA as they offer the advantage of easier customization, cost-effectiveness, and adjustability of mandibular protrusion as was the need of this study.[15,25] MAD increases pharyngeal patency through mechanical influence of mandibular advancement.[26] The improved airway patency is achieved through this forward positioning, as the tongue is attached to the mandible and thus is also pulled forward.[27] Hence, folds and compression in the upper airway are reduced. As hypothesized by Isono et al.,[28] the base of the tongue is anatomically connected to the lateral wall of the soft palate through the palatoglossal arch, and therefore there is stretching of soft palate due to mandibular advancement, thus the velopharyngeal segment stiffens. Hence, the effect of MAD on upper airway has been studied and is further established with the data obtained through this study.

Previous studies have been conducted to evaluate changes in pharyngeal dimensions after MAD therapy using cephalometric analysis, but very few studies have been conducted using CT scan. On computed tomographic analysis, the mean percentage change in lateral and anteroposterior dimensions, and the cross-sectional area at the retropalatal, retroglossal, and epiglottal level was statistically significant with MAD at 50% and 70% mandibular protrusions compared with baseline, which was consistent with the findings of Kaur et al. and Shigeta et al.[29,30] Kaur et al. reported that MADs advances the mandible and lowers the tongue position, reduces the distance between hyoid and the mandibular plane, and widen the upper oropharynx (retropalatal and retroglossal) in some subjects.[29] Mean percentage change in lateral and anteroposterior dimensions at the retropalatal, retroglossal, and epiglottal level was not statistically significant when comparison was made between MAD at 50% and 70% mandibular protrusions, however, cross-sectional dimensions showed statistically significant increase at 70% mandibular protrusion compared to 50%. Hence, it can be deduced that MAD at 70% mandibular protrusion is more effective in increasing the upper airway dimensions, and therefore relieving the oropharyngeal obstruction compared with MAD at 50% mandibular protrusion.

The limitations of the current pilot study were limited sample size and shorter follow-up periods. Long-term, multicentre studies with larger sample size are required in the future.

## 5. Conclusion

1. Cross-sectional area of the upper airway increased with the provision of MAD, more with MAD at 70% mandibular protrusion compared with 50%. Hence, MAD at 70% protrusion may aid in relieving the oropharyngeal obstruction associated with OSA.
2. Increase in the lateral and anteroposterior dimensions of the upper airway with MAD at 70% mandibular protrusion is not statistically significant compared with MAD at 50% mandibular protrusion.

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