Role of Computed Tomography in the evaluation of orthodontic treatment in adult patients with Obstructive Sleep Apnea Syndrome (OSA)

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Objective: The aim of this study was to investigate pharyngeal size differences between pre- and post-trials of a Mandibular Advancement Device (MAD), using a computed tomography (CT),in the treatment of Obstructive Sleep Apnea (OSA) adult patients.
Materials and Methods: Eighteen patients with mild to moderate OSA (mean Apnea/Hypopnea Index, AHI, of 16.7) were treated with a MAD to wear at night only.
After 3 months of treatment, three-dimensional changes in pharyngeal dimensions were measured on CT images performed with a sixteen detector-row CT scanner (Light Speed Plus; GE Medical Systems). Two consecutive axial sections from the hard palate to the epiglottis were obtained with and without the appliance.
Measurements were made of the following airway areas (mm^2) and lengths (mm): RF (nasopharynx); ROF (naso-oropharynx); OF (oropharynx); IPF (hypopharynx); SPL (soft palate length); SPT (soft palate thickness); Rgn (retrognation)-hyoid bone; hyoid bone-C_2; Rgn-C_2; PhL (oropharynx length); pharynx posterior wall thickness at three level. The angle between the hard and the soft palate (APDM) was also calculated.
Results: AHI improved significantly (from 16.7 to 11.2) when the appliance was used. Measurements from CT scans showed statistically significant expansion in the naso-oropharynx area (RF $p<.014$; ROF $p<.050$), in the Rgn-C^2 length ($p<.005$) and in the angle between the hard and the soft palate (APDM $p<.001$).
Conclusions: Our findings confirm the effectiveness of MAD in the treatment of patients with mild to moderate OSA. The use of MAD significantly expands the areas of the upper airway lumen most involved in the collapse.

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Introduction

Sleep apnea in adults is characterized by repetitive apneic and hypopneic episodes occurring during sleep. The frequency of apneas and hypopneas per hour is used to assess the severity of OSA (apnea/hypopnea index - AHI -): mild (Ml), AHI 5-14/hr; moderate (Mo), AHI 15-30/hr; severe (S), AHI>30/hr [1].

The prevalence of OSA in the general population of people between 30 and 60 years of age is 4% among men and 2% among women. Prevalence rises dramatically with age to an estimated 28% to 67% among elderly men and 20% to 54% among elderly women.[2-3]

The clinical manifestation of OSA includes excessive daytime sleepiness, snoring, recurrent awakening, unrefreshing sleep, choking or gasping during sleep, witnessed apneas, irritability, daytime fatigue and impaired concentration that leads to poor work performance and a decrease in productivity.

The consequences of OSA, as a result of disordered breathing, are related to hypoxemia and hypercapnia associated with recurrent respiratory events, systemic hypertension, cardiac arrhythmias, myocardial infarction and cerebral vascular accidents.[4]

The treatment of OSA should target the potential contributing factors identified by the anamnesis, clinical examination and upper airway imaging.

Treatment options include: behavioural interventions and non-surgical and surgical interventions. The non-surgical therapy, that is chosen most often for patients with moderate or severe OSA, consist of continuous positive airway pressure (CPAP).

The use of CPAP in the treatment of OSA was first described in

Obiettivo: Scopo del lavoro è stato valutare le modificazioni dimensionali della regione orofaringea misurate con TC, in soggetti adulti affetti da apnea ostruttiva del sonno trattati con MAD.

Materiali e Metodi: Diciotto pazienti affetti da apnea ostruttiva del sonno di grado lieve-moderato (Indice di Apnea/Ipopnea, AHI, 16.7) sono stati trattati con un MAD da indossare la notte. Dopo 3 mesi di trattamento, sono state valutate le variazioni dimensionali dell'area faringea su scansioni TC ottenute con tomografo spirale multistrato (16 strati) modello Light Speed Plus. Sono state eseguite due serie consecutive di scansioni, senza e con il MAD, dalla volta palatale al piano glottico, relative alle seguenti aree (mm^2) e lunghezze (mm): RF (rinofaringea); ROF (rino-orofaringea); OF (orofaringea); IPF (ipofaringea); SPL (lunghezza del palato molle); SPT (spessore del palato molle); Rgn (retrognation)-osso ioide; osso ioide-C_2; Rgn-C_2; PhL (lunghezza orofaringe); spessore della parete posteriore del faringe a tre livelli; angolo palato duro/molle (APDM).

Risultati: Il trattamento con MAD ha migliorato significativamente l'AHI (da 16.7 a 11.2). Le misurazioni sulle scansioni TC hanno mostrato una significativa espansione dell'area rino-orofaringea (RF p<.014; ROF p<.050), della lunghezza Rgn-C_2 (p<.005) e dell'angolo APDM (p<.001).

Conclusioni: Si conferma l'efficacia del MAD nel trattamento dei pazienti adulti affetti da OSA lieve-moderato. L'uso del MAD espande significativamente le aree del lume faringeo maggiormente coinvolte nel collasso.

Key words: OSA,MAD, CT scan.

1981. Since then it has proven to be the treatment with the firmest evidence base; however, meta-analysis of several RCTs showed evidence of different outcomes depending on OSA severity.[5-10]

Oral appliances are a recommended and an efficient treatment for patients with mild to moderate OSA who have not responded to lifestyle modification or who cannot tolerate CPAP.[11-13] A review by the American Sleep Disorders Association[14] evaluated the different types of oral appliances used for treating snoring and OSA. Twenty-one publications were selected, involving 320 patients. Despite considerable variations in design, most of the devices are conceived to advance the mandible, such as MAD (Mandibular Advancement Device) or NAPA (Nocturnal Airway Patency Device).

The clinical effects of these oral appliances were extremely reliable and approximately half of all treated patients affected by all degree of OSA attained an Apnea/Hypopnea Index (AHI) of less than 10.[14]

The purpose of this study was to investigate potential changes in upper airway dimensions during the use of MAD in adult patients affected by mild to moderate OSA by using a computed tomography (CT) evaluation in awake supine position.

Materials and Methods

The first 25 patients who were referred to our Department of Orthodontics from the Departments of Otolaryngology or Neurophysiology were evaluated for the present study.

Inclusion criteria were: mild to moderate OSA (AHI >5 and <30) [1], 18-75 years old, BMI 20-35, no

Objectif: Le but de cette étude était d'étudier des différences pharyngeal de taille entre pré et ppost-traitement avec un dispositif mandibulaire d'avancement (MAD), en utilisant une tomographie en ordinateur (CT), dans le traitement des patients adults avec Apnée Obstructive de sommeil (OSA). Matériaux et méthodes: Dix-huit patients avec OSA légères et modérées (index moyen d'Apnea/Hypopnea, à AHI, de 16.7) ont été traités avec un MAD à porter la nuit seulement. Après 3 mois de traitement, des changements tridimensionnels des dimensions pharyngeals ont été mesurés sur des images de CT exécutées avec un sixteen detector-row CT scanner (Light Speed Plus; GE Medical Systems). Deux coupes longitudinales consécutives du palais dur à l'épiglotte ont été obtenues avec et sans l'appareil. Des mesures ont été faites de secteurs suivants surfaces (mm2) et longueurs (mm): RF (nasopharynx); OF (naso-oropharynx) ; ROF (oropharynx); IPF (hypopharynx); SPL (longueur douce de palais); SPT (épaisseur douce de palais); Rgn (os retrognation)-hyoïde; bone-C2 hyoïde; Rgn-C2; PhL (longueur d'oropharynx); épaisseur de paroi postérieure de pharynx à trois niveaux. L'angle entre le palais dur et mou (APDM) a été également calculé. Résultats: AHI s'est amélioré de manière significative (de 16.7 à 11.2) quand l'appareil a été employé. Les mesures des scansion de CT ont montré statistiquement l'expansion significative dans le secteur d'naso-oropharynx (rf p(RF p<.014; ROF p<.050), idans la longueur Rgn-C2 (p<.005) et dans l'angle entre le palais dur et mou (APDM p<.001). Conclusions: Nos résultats confrment l'efficacité des MAD dans le traitement des patients avec légère et modérées OSA. L'utilization de MAD fait une espansion significative dans le lumen qui fait parti du collapse.

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limitation of jaw movement, adequate dentition (more than 10 teeth in each arch). Informed consent was obtained from all patients before entry into the study. Four patients were excluded because they were affected by severe OSA. Four patients had undegone surgical procedures for the treatment of symptomatic anatomical obstruction of the upper airway that contributed to OSA. After surgery all patients showed either moderate or mild OSA (Table 1).

A total sample of twenty-one patients with mild to moderate obstructive sleep apnea was examined. OSA diagnosis was conducted by clinical-anamnestic evaluation (chronic snoring with witnessed apneas) and polysomnography. Daytime sleepiness was assessed by the Epworth Sleepiness Scale.

The average age of the 19 males and 2 females included in the study was 54 years ± 10.1 years (mean ± standard deviation); the average

Table 1 Apnea /Hypopnea Index pre-, post- surgical procedures and after three months of treatment with MAD. S=Severe; Mo= Moderate; (Ml) = Mild; N = Normal.

Patients (N=4)	Surgical Procedures	pre-AHI	post-AHI	post-MAD AHI
DSF	Turbinoplasty / UPP	64/h (S)	15.4/h (Mo)	10.5/h (Ml)
PG	Septoplasty / Turbinoplasty	51/h (S)	25/h (Mo)	18.5/h (Mo)
RG	Turbinoplasty	22/h (Mo)	22/h (Mo)	14.27h (Ml)
SV	Septoplasty	23/h (Mo)	11/h (Ml)	1.77h (N)

Objetivo: En este trabajo fueron evaluadas las modificaciones dimensionales de la región oro faríngea tramite TC, en sujetos adultos con apnea obstructiva del sueño, mediante tratamiento con MAD.
Materiales y Métodos: Dieciocho pacientes afectados por el síndrome de obstrucción de la respiración nocturna de grado leve - moderado (Índice de Apnea/Ipopnea, AHI, 16.7) fueron tratados con MAD con aplicación nocturna. A distancia de 3 meses de tratamiento, fueron evaluadas las variaciones dimensionales del área de la faringe con TC, obtenidas con tomógrafo a espiral multi extracto (16 ex) modelo Light Speed Plus. Fueron realizadas dos series seguidas de escansión con y sin MAD, del palatal al plano de la glótide, relativas a las siguientes areas (mm2) y longitud (mm): RF (rino faringea); ROF (rino-orofaringea); OF (orofaringea); IPF (ipofaringea); SPL (longitud del paladar blando); SPT (grosor del paladar blando); Rgn (retrognation)- hueso ioides; hueso ioides-C2; Rgn-C2; PhL (longitud orofaringe); grosor de la pared posterior de la faringe en tres niveles; ángulo del paladar duro/blando (APDM).
Resultados: El tratamiento con MAD mejoro notablemente el AHI (de 16.7 al 11.2). Las medidas realizadas con TC mostraron una notable expansión del área rino- oró faringe (RF p<.014; ROF p<.050), y de la longitud Rgn-C2 (p<.005) y del ángulo APDM (p<.001).
Conclusiones: fue confirmada la eficacia del MAD en el tratamiento de pacientes afectados por el síndrome de obstrucción de la respiración nocturna de grado leve - moderado OSA. La utilización del MAD expande significativamente las áreas de las faringes comprometidas.

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body mass index (BMI = kg/m^2) was 28 ± 3.6; the mean Apnea/Hypopnea Index (AHI) was 16.7 ± 7.2. Intraoral examination showed a Class II division I malocclusion in 16 patients, a Class II division 2 malocclusion in 3 patients and a Class I molar and canine relationship in 2 patients. All subjects presented with an excessive overbite (>4.5 mm). All patients were controlled monthly and after an average treatment period of three months, three-dimensional changes in pharyngeal shape were measured on CT images obtained with and without the appliance in two consecutive scanning sections.

Polysomnographic recordings

A study to evaluate sleep apnea conducted by complete cardiorespiratory monitoring was performed twice at first examination and after a treatment period of three months, using the Embletta Flaga Sapio Life System, eight channel, sampling frequency 20 Hz. The recordings included electrocardiogram, snoring, nasal and oral airflow, thoracic and abdominal chest movements (respiratory effort), finger oximetry and body position. Minimum events length was ten seconds.

Oral appliance

Based on our previous studies and literature data [11-14], we chose a Mandibular Advancement Device (MAD) monobloc typology oral appliance. Mean mandibular protrusive position scheduled for MAD is 4-6 mm. The appliances were individually created for each patient in the orthodontic laboratory of the Policlinico of Rome's Tor Vergata University from a construction bite that positioned the mandible into an edge-to-edge incisor relationship. An anterior round opening permits mouth-breathing when the appliance is in position. Figure 1 shows the appliance used in the study. The patients were instructed to wear their appliances throughout the night.

CT evaluation

After a mean treatment period of 3 months, all subjects underwent a CT study to determine changes in pharyngeal dimension (lengths –mm- or area -mm^2-) during the use of the Mandibular Advancement Device. The patients were placed in the supine position on the scanning table with the neck in a neutral position. At the start of the scan, the patients were instructed to hold their breath slightly and not to move their heads until completion of the scan. This procedure allowed the patients to simulate an apnea episode.

CT imaging was performed using the sixteen detector-row CT scanner (Light Speed Plus; GE Medical Systems, Milwakee, WI, USA). Two consecutive axial sections in the same operative condition were obtained with and without the appliance, from the hard palate to the epiglottis. The scans were performed in the same medical examination session, one immediately after the other.

Consecutive axial sections were obtained with a 2.5 mm width followed by sagittal and coronal reconstruction (1.25 mm, interval 0.625 mm), using a low-dose technique (80-100 Kw and 50 mAs), each section lasting 8-10 seconds. The computer-stored images were displayed on a monitor and the cross-sectional area of the lumen (mm^2) and lengths in the sagittal plane were measured using imaging-process software supplied by GE. All measurements were carried out by a single operator.

The airway areas (mm^2) measured were (Fig. 2-4):

- RF (nasopharynx): behind the hard palate (at the extension of the line joining ANS and PNS);
- ROF (naso-oropharynx): at the tip of the palatal uvula;
- OF (oropharynx): at the middle point of the line joining the tip of the palatal uvula and the coronal tip of the epiglottis;
- IPF (hypopharynx): at the coronal level of the epiglottis.

The airway lengths (mm) measured were:

- SPL (soft palate length): from the posterior superior tip of the hard palate to the tip of the palatal uvula;
- SPT (soft palate thickness): at the middle point of the soft palate (perpendicular to the major axis);
- Rgn-hyoid bone: from Rgn (retrognathion) to the middle point of the anterior curve of the hyoid bone;
- Hyoid bone-C_2: from the middle point of the anterior curve of hyoid bone to the most ante-

roinferior point of the second cervical vertebra;
- Rgn-C_2: between the point described above;
- PhL (oropharynx length): the distance from the posterior extension of the hard palate at the superior level and the line to the tip margin of the epiglottis at the inferior level.

The posterior pharyngeal wall thicknesses were also measured on three different levels:

1. superior: the thickness in front of the anterior atlas arch;
2. middle: the thickness in front of the body of epistropheus;
3. inferior: the thickness in front of the lower margin of C_3.

The angle between the major axis of the hard and soft palate (APDM) was also calculated.

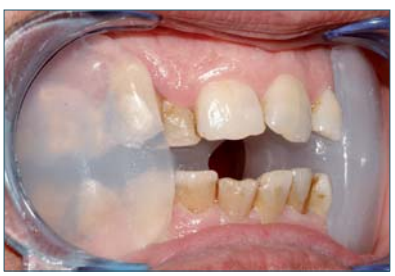

Fig. 1 The appliance used in the study.

Statistical Analysis

Descriptive statistics included mean and standard deviations. Non-parametric statistical tests were used to analyse the data. The mean differences in data between pre- and post-therapy were examined using Wilcoxon's matched pairs test. The level of significance was set at $P < 0.05$.

Results

Eighteen patients (nine moderate and nine mild OSA) completed the study; clinical and polisomnogra-

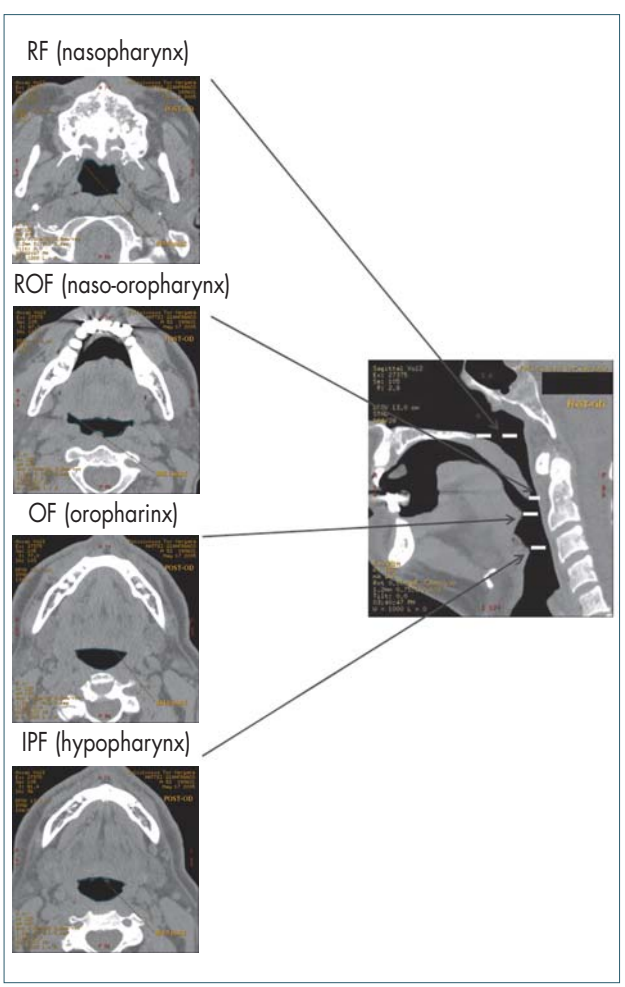

Fig. 2 Levels of areas (mm^2) TC measurements.

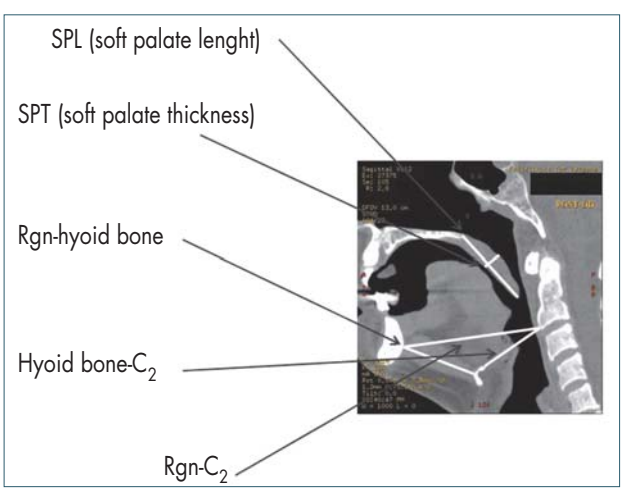

Fig. 3 Levels of lengths (mm) TC measurements.

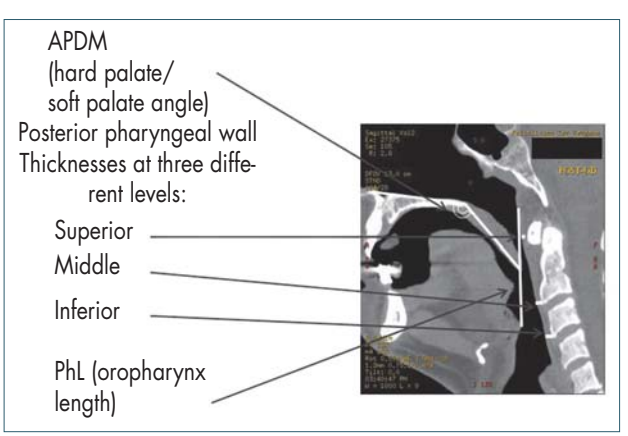

Fig. 4 Levels of lengths (mm) TC measurements.

phic parameters at first examination and after a mean treatment period of 3 months with MAD are shown in Table2.
Three patients dropped out of the study due to non-compliance, dental prosthesis problems unrelated to MAD, lack of follow-up. Basal AHI showed a wide range (from 5.6 to 28.3).
Changes in cross-sectional naso-oropharinx area measurements on CT scans are shown in Table 3-6.
Statistical analysis showed that the use of the MAD produced a statistically significant reduction of the AHI that varies from the baseline value of 16.7 to 11.2 (P<.001).
The use of the MAD produced only a slight reduction in daytime sleepiness, as shown in the results of Epworth Sleepiness Scales questionnaire. The score decreased from 7.2 to 6.7 which is a mild basal degree of this symptom.
CT scan measurements showed a statistically significant increase in the nasopharynx area from 330.4 to 374.7 mm^2 (p<.014) and in the naso-oropharynx area from 114.2 to 123.8 mm^2 (p<.05); the angle between the major axis of the hard and soft palate (APDM) increased from 112.8° to 118.1° (p<.001); the length between the retrognathion and the anterior edge of the lower margin of C_2 increased from 67.8 to 69.6 mm (p<.005).
The positive results of the MAD treatment showed that it is a well accepted and a well tolerated treatment. Side effects including excessive salivation and transient discomforts to the teeth were minor and tolerable and tended to disappear spontaneously after a few days.

Discussion

OSA has become a significant public health problem; there is a

Table 2 Clinical and polisomnographic parameters at the inclusion (1) and after three months of treatment with MAD (2).

Patients (N=18)	BMI-1	BMI-2	ESS-1	ESS-2	AHI-1	AHI-2
Mean	28	28.1	7.2	6.7	16.7	11.2
SD	3.6	3.3	4.7	5.1	7.2	7.4
P		NS		NS		<.001

Table 3 Changes in naso-oropharynx airway areas (mm2) measurements on CT scans:
RF (nasopharynx): behind the hard palate (at the extension of the line joining ANS and PNS);
ROF (naso-oropharynx): at the tip of the palatal uvula;
OF (oropharynx): at the middle point of the line joining the tip of the palatal uvula and the coronal tip of the epiglottis;
IPF (hypopharynx): at the coronal level of the epiglottis; 1=without MAD, 2=with MAD.

Patients (N=18)	RF-1	RF-2	ROF-1	ROF-2	OF-1	OF-2	IPF-1	IPF-2
Mean	330.4	374.7	114.2	123.8	146.7	144.7	214.4	194.7
SD	150.3	146.4	102.4	100.4	102.3	101.6	140.3	115.8
P		<.014		<.05		NS		NS

Table 4 Changes in airway lengths (mm) measured on CT scans:
SPL (soft palate length): from the posterior superior tip of the hard palate to the tip of the palatal uvula;
SPT (soft palate thickness): at the middle point of the soft palate (perpendicular to the major axis);
APDM (the angle between the major axis of the hard and soft palate); 1=without MAD, 2=with MAD.

Patients (N=18)	SPL-1	SPL-2	SPT-1	SPT-2	APDM-1	APDM-2
Mean	41.8	42.2	10.4	10.0	112.8	118.1
SD	4.4	4.5	1.6	2.1	9.1	9.8
P		NS		NS		<.001

Table 5 Changes in airway lengths (mm) measured on CT scans:
Rgn-hyoid bone: from Rgn (retrognathion) to the middle point of the anterior curve of the hyoid bone;
Hyoid bone-C2: from the middle point of the anterior curve of hyoid bone to the most anteroinferior point of the second cervical vertebra; Rgn-C2: between the point described above;
PhL (oropharynx length): the distance from the posterior extension of the hard palate at the superior level and the line to the tip margin of the epiglottis at the inferior level; 1=without MAD, 2=with MAD.

Patients (N=18)	Rgn Hyoid bone-1	Rgn Hyoid bone-2	Hyoid bone-C2-1	Hyoid bone-C2-2	Rgn C2-1	Rgn C2-2	PhL-1	PhL-2
Mean	35.3	35.8	40	41.3	67.8	69.6	61.2	62.3
SD	5.6	6.3	6.1	6.8	6.1	6.7	8.5	8.5
P		NS		NS		<.005		NS

Table 6 Changes in the posterior pharyngeal wall thicknesses (mm) measured on CT scans on three different levels:
superior: the thickness in front of the anterior atlas arch;
middle: the thickness in front of the body of epistropheus;
inferior: the thickness in front of the lower margin of C3; 1=without MAD, 2=with MAD.

Patients (N=18)	Super.-1	Super.-2	Middle-1	Middle-2	Infer.-1	Infer.-2
Mean	3.7	3.2	4.1	4.0	4.1	3.9
SD	1.8	1.6	1.9	1.5	1.5	1.8
P		NS		NS		NS

growing medical awareness of sleep disorders and their consequences, including OSA, and an increasing demand for sleep service facilities. On the other hand, guidelines [15-17] aim to produce recommendations that involve different specialists to understand how patients may be diagnosed and what treatments are currently available.

In this study, oral appliances have been used in patients with mild to moderate OSA who have not responded to lifestyle modifications or as a treatment alternative in patients who cannot tolerate CPAP and its common side effects (rhinitis, nasal bridge sores, discomfort, claustrophobia, abdominal bloating, noise).

In more than 90% of our patients a Class II malocclusion with increased overbite has been observed.

Of the many oral devices that have been proposed for the treatment of OSA, we used a Mandibular Advancement Device (MAD), a modified monobloc which has been documented as effective and successfully used in our Department.

A review by the American Sleep Disorders Association[14] evaluated the different types of oral appliances used for treating snoring and OSA. Twenty-one publications were selected, involving 320 patients. Despite considerable variation in the design of the devices, most of them are designed to advance the mandible, such as MAD (mandibular advancement device) or NAPA (nocturnal airway patency device). The clinical effects of the oral appliances were extremely reliable and approximately half of all treated patients affected by all degree of OSA attained an AHI of less than 10.

This study confirmed that MAD is a successful treatment for mild to moderate OSA patients by significantly reducing 30% of the AHI (from 16.7 to 11.2, p<.001); this allows to a mean reduction of a degree in severity of OSA which falls from moderate to mild in the treated group.

Treatment options for OSA are used in order to remove obstruction in the upper airway.

Surgical procedure (turbinoplasty, septoplasty, uvulopalatopharyngoplasty -UPPP-), may be necessary to correct anatomical obstruction before oral device therapy or CPAP.

The present study included four patients previously treated by surgical intervention; MAD improved post-intervention AHI in three out of four patients, reducing severity

by one degree in two patients and brought it back to normal in one patient (Table 1).

Our findings confirm the effectiveness of oral devices after surgical interventions when the latter failed to adequately manage OSA symptoms and AHI reduction.

Obesity is a important risk factor for OSA, particularly in the upper body; deposition of fat in upper airway muscles and soft tissues can reduce airway lumen.[18] The patients in our study were all overweight at the beginning of the study (mean BMI=28). This condition was reconfirmed at a three month follow-up (mean BMI=28.1). Therefore, AHI improvement was independent of weight loss.

One of the main mechanisms in the pathogenesis of OSA is the intermittent and repeated collapse of upper airway during sleep. In OSA, a combination of causes narrow the airway lumen. During wakefulness, the neuromuscular compensation hinders these causes whereas at the onset of sleep the loss of the compensation mechanism and a reduction in muscle tone leads to a collapse in the airways.

Sunner et al [19] in 2002 investigated MRI of the pharynx and treatment efficacy of a MAD in 13 OSA patients; ultrafast magnetic resonace imaging of the pharynx was performed at rest during transnasal shallow respiration and during performance of the Muller manoeuvre, both with and without the MAD. The results of this study indicate that the MAD examined was effective in about 50% of patients and that MRI may predict clinical and polysomnographic efficacy.

Hyun Kyung et al.[20] in 2004 used cine CT to investigate pharyngeal size and shape differences between pre- and post-trials of a MAD in 14 OSA patients. Three-dimensional changes in pharyngeal shape measured on cross-sectional CT images during two respiratory cycles after oral appliance delivery were estimated by the variables (1) lateral dimension, (2) anterior-posterior dimension, (3) cross-sectional area at five vertical level. During apnea, measurement at retropalatal and retroglossal levels decreased most but the cross-sectional area of these levels increased significantly ($p < .05$) with the appliance.

In our study Computed Tomography scans were used to measure changes in the upper airway dimension of OSA patients wearing MAD. Radiological imaging is not a routine assessment of OSA patients. This causes a lack of standard measurements of upper airways. Therefore, we arbitrary chose the areas and the linear distances to evaluate on CT scans but ensured a broad "mapping" of the naso-oropharynx region. Among the available radiological imaging techniques, we chose CT for a variety of reasons, listed below:

- an optimum level of visualization of bone structure (that serves as a reference point for measurement) and of the airway lumen (the dimensional changes of which were evaluated with MAD).
- short-term of the scanning allowing to hold breathing for the duration of the examination and

Table 1

	Normal mean value	Mean value in OSA patients
Sagittal analysis		
SNA (°)	82	80
SNB (°)	80	75
ANB (°)	2	5
N perp.A (mm)	0	-1
N perp.Pg	-6	-7
SN	eq	68
GoMe	eq	63
Vertical analysis		
FMA (°)	25	23
Sn^GoGn (°)	32	30
Ar-Go (mm)	44	44
Bisp.-Me (mm)	66	61
Ar-Go/Bisp.-Me (mm)	69	72
Dental analysis		
IMPA (°)	90	94
1^PF (°)	105	107.1
Inter-incisor (°)	130	137.3
Overjet (mm)	2.5	4.4
Overbite (mm)	2.5	3.6
Oropharyngeal dimensions		
Phw1-Psp	–	20
MPW	–	9
Phw2-Tb	–	10

simulating if possible the apnea;
- low interference with metallic parts where present in the oral cavity;
- no contraindications linked with the use of magnetic field and no claustrophobic effect from the equipment;
- low cost for the hospital.

The main disadvantage of this technique was that patients were exposed to radiation, which, however, was minimized by using a low dosage protocol (80-100 kV e 50 mAs) to perform the scans.

The measurements of the scans in the patients wearing the MAD showed a significant 13% increase in the upper airway areas most affected in the collapse, i.e. the nasopharynx and naso-oropharynx. This expansion is probably from a cross-section of the air space.

No significant differences were observed in the length and thickness of the soft palate but the increase of APDM (the angle between the major axis of the hard and soft palate) showed the favourable effect of the MAD on the compliance of regional soft tissues, probably the muscles, in the main narrow segment of the upper airway during sleep. To fully understand how MAD works, further investigation is needed.

Finally, the significant increase in the linear distance between the retrognation and the second cervical vertebra can be ascribed to MAD's mandibular protrusive action.

In our findings some measurement changes were not statistically significant: this lack is probably due to the multi-factorial pathogenesis of OSA, caused by the interaction of many factors such us gender, age and obesity. Most of all, because of the complexity of the methods chosen nowadays to study in detail OSA patients, the scientific literature shows only studies on small patients population. Studies recruiting larger patients population are needed to increase the statistical weight of the results.

Conclusions

- MAD oral appliances are an effectiveness treatment option for adult patients with mild to moderate OSA and snoring who have not responded to lifestyle modification. It is a useful treatment alternative for patients who cannot tolerate positive airway pressure devices.
- Our findings confirmed the effectiveness of MAD in the treatment of patients with mild to moderate OSA by significantly reducing by 30% the AHI. This allowed a mean reduction in the degree of severity of OSA producing a moderate to mild decrease in the treated group. AHI improvement was independent of weight loss.
- CT scans were used to evaluate dimensional variations in the lumen of the naso-oropharynx in OSA patients wearing MAD. The use of MAD produced a significant expansion by 13% in the areas most involved in the collapse.

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