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Oral health in patients treated by positive airway pressure for obstructive sleep apnea: a population-based case–control study

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Abstract
Purpose Recent epidemiological evidence suggests that patients with obstructive sleep apnea (OSA) have an increased risk of periodontal disease. Little is known about the oral health of OSA patients treated by continuous or bi-level positive airway pressure (CPAP/BiPAP). The aim of this population-based case–control study was to compare oral health variables (amount of plaque, calculus, gingival inflammation, and masticatory function) between CPAP/BiPAP users and control subjects.
Methods The study population was retrieved from a French cohort examined between 2012 and 2013 at the *Centre d'Investigations Préventives et Cliniques* of Paris. Cases were selected if they reported to be treated by CPAP/BiPAP; controls were age-, gender-, and BMI-matched based on a 1:2 ratio. Univariate and logistic regression analyses were performed for group comparisons.
Results Over a total of 20,436 subjects, 287 CPAP/BiPAP users (mean age (SD) 57.6 years (11.5); 76.3 % males) who underwent medical and dental examinations were compared with 574 matched controls (no OSA, no CPAP/BiPAP). CPAP/BiPAP users reported significantly higher prevalence of diabetes (15.6 vs. 10.3 %; p=0.012; odds ratio (OR) 1.68), history of hypertension (36.5 vs. 26.1 %; p=0.003; OR 1.62), cardiovascular diseases (14.1 vs. 8.8 %; p=0.029; OR 1.69), and sleep complaints (59 vs. 34.4 %; p=0.0001; OR 2.75). CPAP/BiPAP users also showed higher levels of depression and stress compared to controls. However, no group difference was observed for the amount of dental plaque, calculus, gingival inflammation, and masticatory function.
Conclusion Oral health of OSA patients treated by CPAP/BiPAP is comparable to that of matched controls in terms of amount of plaque, gingival inflammation, and masticatory function.

Keywords Oral health · Gingival inflammation · Obstructive sleep apnea · Continuous positive airway pressure

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Introduction

Obstructive sleep apnea (OSA) is a common sleep breathing disorder characterized by recurrent collapses of the upper airway during sleep resulting in intermittent hypoxemia and sleep fragmentation [1]. Severe and untreated OSA is associated with increased risk of cardiovascular diseases (e.g., hypertension, stroke, and coronary disease) [2], metabolic disorders (e.g., metabolic syndrome, diabetes) [3, 4], and neurocognitive impairments (e.g., fatigue, somnolence, depression) [5]. Obesity and craniofacial anatomical abnormalities, which contribute to reduced airway caliber, are known risk factors for OSA [6, 7].

Recent epidemiological studies support an association between OSA and a chronic infectious and inflammatory disease of the periodontal tissues, namely periodontitis [8–11].

Precisely, OSA patients are more likely affected by periodontitis than controls, with a prevalence of periodontitis that appears to increase with the severity of OSA [8]. A recent meta-analysis based on the four studies confirms the plausibility of the association between OSA and periodontitis, estimating a pooled odds ratio of 1.65 [12]. However, the nature of this association remains unclear [8, 13, 14], and evidence is insufficient to talk about a cause–effect relationship. Rather, common pathways related to a systemic pro-inflammatory status may be advocated as possible explanatory mechanisms that deserve further investigations.

If OSA patients present with an increased risk of periodontitis, little is known about the oral health of patients treated by positive airway pressure, the "gold standard" treatment for OSA. Continuous positive airway pressure (CPAP) and bi-level positive airway pressure (BiPAP) used during sleep are highly efficacious treatments to reduce OSA events, restore sleep quality, and decrease cardiovascular morbidity [15, 16]. The aim of the present population-based case–control study was to assess the oral health, particularly the amount of plaque and gingival inflammation, of OSA patients treated by CPAP/BiPAP.

Methods

Study population

The study population was retrieved from a French cohort of volunteers who underwent medical and oral examinations between 2012 and 2013 at the *Centre d'Investigations Préventives et Cliniques* (IPC) of Paris. The IPC medical center is subsidized by the French National Healthcare System (*Caisse Nationale d'Assurance Maladie*) and provides free medical and dental examinations every 5 years to workers, retirees, and low-income and isolated people and their families living in Paris and the surrounding areas. Following the authorization of the *Commission Nationale de l'Informatique et des Libertés* (CNIL), the IPC center performed analyses of anonymous data collected during voluntary health checkups. All these volunteers read and signed an informed consent for the anonymous use of all their recorded variables. After undergoing standardized health examinations, the patients received medical counseling for medical problems that should be referred to their practitioners.

Clinical and biological investigations

Each subject underwent a complete medical examination, including morphometric, biological, and environmental parameters. Blood pressure measurements were taken by a trained nurse with an electronic device (OMRON® 705 IT, OMRON Healthcare Company, Japan), three times consecutively with the subject in a supine position and respecting a 10-min interval of rest before measurements. The mean of the second and third measurements was used for the analysis. Standard biological parameters, like glycemia, were measured under fasting conditions. A self-administered standardized questionnaire was used to assess medical history, tobacco consumption, medication use, lifestyle, depression, and stress. Cardiovascular diseases were assessed as a combined variable of different questions investigating the history or presence of myocardial infarction, angina pectoris, and coronary artery diseases. Hypertension was assessed separately. Physical exercise was evaluated based on self-report of daily walk activity (1 h/day). The depression level was scored on a 0–13-point scale, with a depressive status assessed when rated ≤6 [17]. Similarly, the stress level was scored on a 0–16-point scale [18]. Socioeconomic deprivation was assessed using the 11–item questionnaire of *Evaluation de la Précarité et des Inégalités de santé pour les Centres d'Examen de Santé* (EPICES score). At the patient level, this score considers the multidimensional aspects of socioeconomic deprivation (material and social deprivation) and is not limited to employment status or education level [19].

The use of CPAP or BiPAP was assessed by a specific question: "Do you regularly use CPAP or BiPAP devices for obstructive sleep apnea?" Although self-reported, a high reliability may be expected since CPAP and BiPAP devices are provided by the French National Healthcare System for patients with a polysomnographically diagnosed severe or symptomatic OSA.

Oral examination

Five trained dentists performed a standardized full-mouth clinical examination. Dental plaque and supragingival calculus were visually assessed and rated using a 3-grade ordinal scale. A simplified plaque index (PI), which was based on the Silness and Loe PI [20] and included ratings of a low amount (plaque cannot be seen with the naked eye), moderate amount (limited quantity of plaque can be seen with the naked eye), or high amount of plaque (abundance of soft matter within the gingival pocket and/or on the tooth and gingival margin), was used. Similarly, the calculus index was rated using three ordinal levels: a low amount (no calculus or supragingival calculus covering not more than one third of the exposed tooth surface), moderate amount (supragingival calculus covering more than one third but not more than two thirds of the exposed tooth surface and/or the presence of individual flecks of subgingival calculus around the cervical portion of the tooth), or high amount (supragingival calculus covering more than two thirds of the exposed tooth surface and/or a continuous heavy band of subgingival calculus around the cervical portion of the tooth). Gingival inflammation was evaluated using a simplified modified gingival index (MGI) that was based on

that described by Lobene et al. [21]. Gingival inflammation was rated as low (the absence of inflammation or mild inflammation, with slight changes in color and texture but not in all portions of the gingival marginal or papillary tissue), moderate (inflammation, including the preceding criteria in all portions of the gingival marginal or papillary tissue, with or without a bright gingival surface), or high (erythema, edema and/or marginal gingival hypertrophy or spontaneous bleeding, papillary congestion or ulceration). The number of teeth, with the exception of the third molars, and the number of masticatory units (as defined by functional pairs of natural or prosthetic opposing premolars and molars) [22] were recorded.

Post hoc inter-examiner reliability was calculated at 100 % for dental calculus and masticatory units, 86.7 % for dental plaque, and 80 % for gingival inflammation.

Statistical analysis

Data were electronically stored using custom-designed software. Based on the medical questionnaire, subjects who replied YES to the question "Do you regularly use CPAP or BiPAP for obstructive sleep apnea?" were identified as the case group (CPAP/BiPAP users). This group was compared with an age-, gender-, and BMI-matched group of control subjects who replied NO to the same question. Thus, the control group identified subjects with no diagnosis of OSA and never treated by CPAP/BiPAP.

Cases and controls were matched based on a 1:2 ratio and compared for the medical and dental variables including dental plaque, dental calculus, gingival inflammation, number of teeth, and functional masticatory units. For masticatory function, the variable was dichotomized into two categories: sufficient (≥5 units) vs. insufficient (<5 units) masticatory efficiency depending on the number of functional (occluding) premolar and molar units. The threshold of 5 masticatory units was chosen based on the WHO recommendations indicating that the retention of a minimum of 20 teeth is sufficient for adequate masticatory efficiency and ability [23].

Statistical comparisons between groups were performed using Pearson's chi-square test or Fisher's exact test for categorical variables, and, according to the data distribution, *T* test or Mann–Whitney *U* test for continuous variables. Odds ratio (OR) and corresponding 95 % confidence intervals (CI) were calculated for all categorical variables to assess the strength of the association. In order to evaluate the impact of CPAP/BiPAP treatment on the dental variables of interest, conditional logistic regression analysis was also used to control for possible confounders that were not taken into account in the matching paradigm. For this analysis, plaque, calculus, and gingival inflammation were then dichotomized into low vs. moderate/high. Statistical analyses were performed using SPSS (Statistical Package for the Social Sciences, IBM SPSS Statistics, Version 22 for Macintosh). A p value <0.05 was considered to be statistically significant.

Results

Between 2012 and 2013, 45,557 volunteers received medical and dental examinations at the IPC center. After removing subjects with missing data, the study population was composed of 31,442 subjects who answered the target question about CPAP or BiPAP treatments. Of these, 470 (1.5 %) were regular CPAP/BiPAP users. Only part of the population (65 %) received both medical and dental examinations and was used for the case–control matching. Finally, 287 CPAP/BiPAP users were matched on age, gender, and BMI with 574 controls (ratio 1:2). Demographic and medical characteristics of the final matched population (n=861) are shown in Table 1. Compared to controls, CPAP/BiPAP users reported significantly higher prevalence of diabetes (15.6 vs. 10.3 %; p=0.012; OR 1.68), history of hypertension (36.5 vs. 26.1 %; p=0.003; OR 1.62), history of cardiovascular diseases (14.1 vs. 8.8 %; p=0.029; OR 1.69), and history of cancer or precancerous lesions (7.9 vs. 4.1 %; p=0.039; OR 2.02) (Table 2). Moreover, 59 % of CPAP/BiPAP users reported to have sleep disorders (i.e., troubled sleep) compared to 34 % of the control group (p=0.0001; OR 2.75), and showed higher mean levels of depression and stress. No group difference was observed for the socioeconomic variable, namely the EPICES score.

Interestingly, no significant group difference was noted for the amount of dental plaque, calculus, gingival inflammation, number of missing teeth, and masticatory function units between CPAP/BiPAP users and controls (Table 3). This was confirmed also by the logistic regression model, in which the main confounding variables were taken into account. The majority of the sample (94 %) displayed low level of dental plaque and low level of gingival inflammation. A sufficient masticatory function was observed in more than 80 % of the subjects, in both the CPAP/BiPAP user and control groups, while only a minority presented with more than ten missing teeth.

Discussion

This is the first population-based case–control study describing the oral health status of OSA patients treated by CPAP/BiPAP. The present findings show that CPAP/BiPAP users have similar amounts of plaque, calculus, and gingival inflammation as well as similar number of teeth and masticatory units than age-, gender-, and BMI-matched controls. Since these oral health variables can be considered as risk factors (e.g., dental plaque accumulation) or proxies (e.g.,

Table 1 Demographic, clinical, and biological variables for CPAP/BiPAP users vs. controls

Variables	CPAP/BiPAP users (n=287)	Controls (n=574)	p value
Age (years) [mean (SD)]	57.66 (11.56)	58.15 (10.53)	0.584
Sex M [n (%)]	219 (76.3)	423 (73.7)	0.455
BMI [mean (SD)]	30.47 (5.71)	30.63 (5.84)	0.925
Smokers [n (%)]			0.636
Never/former	239 (83.3)	469 (81.7)	
Current	48 (16.7)	105 (18.3)	
Glycemia (mmol/L) [mean (SD)]	107.69 (33.5)	111.52 (35.06)	0.660
Diabetes [n (%)]	45 (15.6)	56 (10.3)	*0.018*
Systolic blood pressure (mmHg) [mean (SD)]	136.2 (17.35)	139.35 (19.45)	0.809
Diastolic blood pressure (mmHg) [mean (SD)]	80.23 (10.13)	82.72 (10.28)	0.310
History of hypertension [n (%)]	99 (36.5)	141 (26.1)	*0.003*
History of cardiovascular diseases [n (%)]	38 (14.1)	48 (8.8)	*0.029*
History of cancer or precancerous lesions [n (%)]	20 (7.9)	21 (4.1)	*0.039*
Hours of sleep/night [mean (SD)]	6.17 (1.47)	6.54 (1.44)	*0.047*
<6 [n (%)]	62 (21.8)	105 (18.6)	0.273
≥6 [n (%)]	225 (78.2)	461 (81.4)	
Sleep disorders [n (%)]	160 (59)	191 (34.4)	*0.0001*
Headaches [n (%)]	96 (37.1)	164 (31.9)	0.170
Medication use [n (%)]	64 (22.3)	195 (34)	*0.0001*
Anti-diabetic medication use [n (%)]	39 (13.6)	48 (10.3)	*0.021*
Anti-hypertensive medication use [n (%)]	96 (39)	122 (25.8)	*0.0001*
Hypnotic medication use [n (%)]	35 (15.2)	50 (10.8)	0.109
Depression score [mean (SD)]	3.14 (3.57)	2.77 (3.82)	*0.017*
<6 [n (%)]	75 (75.8)	171 (80.7)	
≥6 (depressive)	24 (24.2)	41 (19.3)	0.369
Stress score [mean (SD)]	5.51 (2.94)	4.29 (3.31)	*0.002*
EPICES score [n (%)]			0.664
<30	56 (44.4)	125 (47.3)	
≥30	70 (55.6)	139 (52.7)	

Significant p values are displayed in italics

CPAP continuous positive airway pressure, *BiPAP* bi-level positive airway pressure

missing teeth) [24] of periodontitis, it can be suggested that treated OSA patients are not at increased risk of periodontal diseases.

As shown in other studies, a higher prevalence of cardiovascular and metabolic comorbidities (medical history) was observed in treated OSA patients than in controls [1, 3, 15, 25]. As expected, a higher prevalence of sleep disorders was also reported by the CPAP/BiPAP group than by the controls. This questionnaire-based variable should be interpreted as a report of having troubled sleep (e.g., difficulties in getting a

Table 2 Odds ratios for categorical variables for CPAP/BiPAP users vs. controls

Variables	Odds ratios (95 % CI)* for CPAP/BiPAP users vs. controls
Diabetes	1.68 (1.10–2.56)
History of hypertension	1.62 (1.18–2.22)
History of cardiovascular diseases	1.69 (1.08–2.67)
History of cancer or precancerous lesions	2.02 (1.07–3.29)
Sleep disorders	2.75 (2.04–3.71)

CI confidence interval, *CPAP* continuous positive airway pressure, *BiPAP* bi-level positive airway pressure

*p<0.05

Table 3 Dental variables for CPAP/BiPAP users vs. controls

Dental variables	CPAP/BiPAP users (n=287)	Controls (n=574)	p value (univariate analysis)	p value (logistic regression)[a]
Amount of plaque [n (%)]			0.083	0.093
Low	271 (94.4)	541 (94.3)		
Moderate	15 (5.2)	21 (3.7)		
High	1 (0.3)	12 (2.1)		
Amount of calculus [n (%)]			0.392	0.695
Low	106 (36.9)	188 (32.8)		
Moderate	134 (46.7)	276 (48.1)		
High	47 (16.4)	110 (19.2)		
Gingival inflammation [n (%)]			0.114	0.742
Low	256 (89.2)	488 (85)		
Moderate	26 (9.1)	62 (10.8)		
High	5 (1.7)	24 (4.2)		
Masticatory function [n (%)]			0.122	0.896
Sufficient ≥5	247 (86.1)	468 (81.7)		
Insufficient <5	40 (13.9)	105 (18.3)		
Missing teeth [mean (SD)]	4.86 (5.41)	5.62 (6.07)	0.070	
<10 [n (%)]	248 (86.4)	420 (81.7)	0.312	0.241
≥10	39 (13.6)	94 (18.3)		

[a] Adjusted on potential confounders: diabetes, smoking, history of cardiovascular diseases, history of hypertension, depression, stress, sleep disorders

sleep, poor sleep quality) rather than a diagnosis of specific sleep disorders. Indeed, a considerable proportion of CPAP/BiPAP users (41 %) judged to sleep well (no sleep disorders) despite the use of the CPAP/BiPAP device. This is true also for the control group, which included subjects reporting sleep disorders in the absence of diagnosed or treated OSA.

Previous studies investigated populations of untreated OSA patients and found an association between OSA and periodontitis [8–12, 14]. The biological plausibility of this association relies upon the hypothesis that these two conditions contribute to common systemic inflammatory pathways leading to increased cardiovascular and metabolic risk [11]. Moreover, a mutual relationship between OSA and periodontitis may be assumed: the co-existent OSA may increase the presence and severity of periodontitis, and severe periodontitis may contribute to the occurrence of OSA consequences (e.g., cardiovascular morbidity) [8]. However, recent evidence did not confirm a dose–response relationship between the severity of OSA (as measured by the apnea/hypopnea index, AHI) and the severity of periodontitis (as measured by periodontal parameters, like probing pocket depth or clinical attachment level), although the amount of dental plaque was significantly correlated with OSA severity [13]. It is noteworthy that the methodological differences and limitations among the few studies published on the topic do not allow drawing definitive conclusions and the nature of the relationship between OSA and periodontitis is yet to be understood. Still, a significant association between OSA and periodontal disease was observed in all studies, and therefore, an effect of OSA treatment on the prevention or the progression of periodontal diseases may be hypothesized [12]. Although the present study was not designed to test this hypothesis, it provides new evidence to support further clinical studies and suggest possible explanations.

Indeed, some different scenarios can be theorized. Firstly, CPAP/BiPAP-treated OSA patients may have similar good oral health compared to controls (i.e., subjects without treatment for diagnosed OSA) due to the positive effects of CPAP/BiPAP treatment on OSA and OSA-related pathologies, such as cardiovascular health and systemic inflammation [15, 16, 26]. This may also impact on gingival inflammation. Alternatively, it could be advocated that CPAP/BiPAP users may differ from untreated OSA patients (which were not examined in the present study) for their habits of mouth breathing during sleep. As known, mouth breathing is highly common in patients with OSA, both adults and children, and it may adversely affect oral health [27–30]. Chronic mouth breathing per se may lead to dryness of the oral cavity and the pharynx, impair the self-cleaning ability of the oral cavity during sleep, and facilitate oral bacterial colonization [23, 28]. In this perspective, mouth breathing associated with OSA may be the mediating factor that predisposes to the development of gingivitis and periodontitis [8]. In CPAP/BiPAP-treated patients, mouth breathing is significantly reduced due to the nasal or mouth mask wearing during sleep [31]. Moreover, CPAP/BiPAP devices with heated humidification and facemask are proved to prevent upper airway dryness during

the treatment [32]. All these factors may be advocated as possible explanatory mechanisms underlying the putative beneficial effects of CPAP/BiPAP treatment on oral health.

However, alternative hypotheses may be also considered. It is possible that CPAP/BiPAP-treated patients have a good oral hygiene and thus oral health because these are the patients following regular medical and dental checkups, as well as more prone to seek medical attention in the event of experiencing any symptoms or discomfort. Thus, it cannot be excluded the influence of selection and surveillance bias by which patients with one condition (e.g., gingivitis) were more likely to be diagnosed and treated with a separate and possibly unrelated condition (e.g., OSA) purely based on their increased exposure to the medical community.

This study presents with some limitations. Although relying on the national healthcare system, the case and control definition was based upon a self-administered questionnaire and the efficacy and adherence to CPAP/BiPAP treatment were not possibly assessed. Moreover, the presence of subjects with undiagnosed or asymptomatic OSA, as well as other sleep breathing disorders (e.g., snoring, mouth breathing) in the control group, cannot be ruled out.

Finally, the observational study design allows describing the CPAP/BiPAP-treated population vs. matched controls, but it cannot be used to support further speculations on the possible relationship between OSA treatments and oral health; rather, the present findings suggest the need for future clinical trials designed to study OSA and oral/periodontal health. Particularly, comparing treated and untreated OSA patients and evaluating specific periodontal variables, such as periodontal pocket depth, clinical attachment level, and bleeding on probing (which were not assessed in this study), could help in elucidating the nature of this possible association.

In conclusion, OSA patients treated by CPAP/BiPAP have amounts of plaque, gingival inflammation, and masticatory function comparable to those of age-, gender-, and BMI-matched controls. Further clinical trials evaluating specific periodontal variables are awaited to assess the impact of OSA treatment on periodontal diseases.

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