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ORIGINAL ARTICLE

Periodontitis severity in obstructive sleep apnea patients

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Abstract

Objectives This cross-sectional study investigated the stages of periodontitis in obstructive sleep apnea (OSA) patients and risk factors associated with periodontitis severity among them.

Materials and methods A total of 194 patients underwent a polysomnography/polygraphy and were referred to periodontal examination. According to apnea–hypopnea index (AHI), patients were classified as mild OSA (AHI < 15) and moderate to severe OSA (AHI ≥ 15), whereas periodontitis severity was determined by the clinical attachment level (CAL) according to the recent Classification of Periodontal Diseases and Conditions. Patients were grouped into two categories: stages 1 and 2, and stages 3 and 4.

Results Higher AHI values were reported in OSA patients exhibiting periodontitis stages 3 and 4 compared to OSA patients with periodontitis stages 1 and 2 ($p = 0.043$) and the non-periodontitis group ($p = 0.044$). A positive correlation was found between AHI and mean CAL ($r = 0.215$; $p = 0.004$), and between AHI and plaque scores ($r = 0.292$; $p < 0.001$). Following a multivariable regression analysis, AHI was a significant predictor of mean CAL ($\beta = 0.169$; $p = 0.031$), explaining 16.4% of variability in mean CAL (adjusted $R^2 = 0.164$; $p < 0.001$). Older patients had higher odds for an increased mean CAL ($\beta = 0.266$; $p = 0.001$), as well as patients smoking or formerly smoking ($\beta = 0.305$; $p < 0.001$) whereas visiting a dental medicine doctor once a year or more often was associated with a decreased mean CAL ($\beta = -0.182$; $p = 0.02$).

Conclusions OSA was associated with severe stages of periodontitis along with increased age, smoking, low frequency of dental visits, and poor oral hygiene.

Clinical relevance Screening for periodontitis is recommended for patients with more severe forms of OSA.

Keywords Epidemiology · Periodontal medicine · Risk factor(s) · Periodontal disease(s)/periodontitis · Sleep-disordered breathing · Polysomnography

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Introduction

Periodontitis is a chronic, non-communicable disease, with severe forms being the sixth most prevalent chronic disease worldwide affecting 7 to 11% of the world's population [1–3]. Periodontitis is caused by the dysregulation of the host inflammatory response to microbial colonization of exposed tooth surfaces resulting in the weakening of periodontal tissue function and subsequent tooth loss [4]. Obstructive sleep apnea (OSA) is a sleep-disordered breathing characterized by recurrent episodes of upper airway obstruction during sleep resulting in a complete cessation or reduction of the upper airway flow [5]. The prevalence of OSA is estimated to be 2–14% with higher occurrence in overweight and obese patients and middle-aged and older individuals [6, 7]. Although current evidence supports the association of OSA and periodontitis, the relationship is not fully clarified, mainly due to the lack of control for potential confounders and sample size estimation and different diagnostic procedures for clinical assessment of presence and severity of both periodontitis and OSA [8, 9].

Apart from being related to a similar set of risk factors, both diseases are considered to have an effect on systemic health due to the inflammatory response involved in their pathogenesis [10, 11]. Given the fact that periodontitis and OSA share similar environmental and systemic risk factors such as age, gender, smoking, obesity, diabetes, and hypertension [12, 13], several studies indicated a possible association between these two conditions [14–21].

In the last few decades, there were several attempts to classify periodontitis in order to determine whether different clinical forms represent different diseases or variations of a single disease [22]. Previous classifications proved inadequate to establish the diagnosis of periodontitis objectively due to new evidence regarding the pathophysiology of periodontitis, as well as the environmental and systemic risk factors related to periodontal diseases [23]. The most recent Classification of Periodontal Diseases and Conditions is based on staging and grading definition system in order to establish a set of objective criteria to facilitate diagnosis and clinical treatment of periodontitis, and to reduce methodological heterogeneity in future scientific research of periodontal diseases [24]. The new classification highlights the difference between stages 1 and 2 and stages 3 and 4, since patients with stages 3 and 4 are more prone to have one or more intrinsic or environmental risk factors [22]. Furthermore, patients with periodontal stages 3 and 4 represent more complex cases with possible adverse outcomes such as tooth loss and loss of masticatory function which requires an interdisciplinary treatment approach [22, 23].

Thus, the aims of this study were to investigate the stages of periodontitis in OSA patients and to identify risk factors associated with periodontitis severity among OSA patients applying the new Classification of Periodontal Diseases and Conditions.

Methods

The study was approved by the Ethics Committee of the University of Split School of Medicine (USSM). All procedures performed in this study were in accordance with the standards of the institutional ethics committee and with the Helsinki declaration [25]. Informed consent was obtained from all participants involved in this study following a thorough explanation of the periodontal examination procedure. This study was conducted following STROBE Statement (Strengthening the reporting observational studies in Epidemiology) guidelines for cross-sectional studies.

Participants

This study included 194 consecutive patients that underwent whole-night polysomnography (PSG) or polygraphy (PG) at the Split Sleep Medicine Center (SMC). Also, a comprehensive periodontal examination was performed at the Department of Dental Medicine, University Hospital of Split, from October 2018 to June 2019. The exclusion criteria were age younger than 18 and history of any OSA treatment prior to the study enrollment. All participants underwent an initial medical interview, physical examination, and anthropometric measurements. Neck circumference (NC) was measured using a flexible tape with a metric scale at the level of cricothyroid cartilage. The same metric scale was used to measure waist circumference (WC) halfway between the lower rib cage and the upper iliac crest and hip circumference (HC) at the widest point around participants' buttocks. Body mass index (BMI) was calculated for each subject. Excessive daytime sleepiness was evaluated using Epworth Sleepiness Scale (ESS) which was previously evaluated in the Croatian language [26]. History of chronic diseases such as arterial hypertension and diabetes mellitus was based on the STOP questionnaire completed by each participant supervised by a sleep physician or a sleep technician [26]. Participants were categorized by smoking history into non-smokers, former smokers (those who quit smoking at least 6 months prior to the enrollment in study), and smokers (current smokers and those who quit smoking within the past 6 months prior to the enrollment in the study). Current smokers were classified as heavy smokers (smoking more than 20 cigarettes a day), moderate smokers (10–19 cigarettes a day), and occasional smokers (less than 10 cigarettes a day) [27, 28].

Sleep assessment

Full-night PSG ($N=61$; Alice5LE, Philips Respironics, Eindhoven, Netherlands) or full-night PG ($N=133$; Alice Night-One Philips Respironics, Eindhoven, Netherlands; Somnocheck2 Weinmann, Germany) was performed in SMC. All data were stored on a computer, manually scored, and evaluated according to the published American Academy of Sleep Medicine (AASM) and European Sleep Research Society (ESRS) guidelines by a certified sleep physician and technician [29, 30].

Apnea was scored when there was a drop in the peak signal excursion by ≥ 90% of pre-event baseline using an oronasal thermal sensor, or an alternative apnea sensor, for ≥ 10 s with no requirement for a desaturation or an arousal. Hypopnea in adults is scored when the peak signal excursions drop by ≥ 30% of pre-event baseline using nasal pressure, or an alternative hypopnea sensor during a diagnostic study, for ≥ 10 s in association with either ≥ 3% arterial oxygen desaturation, from the pre-event baseline or the event is associated with an arousal.

Based on the recommendations of the AASM Scoring Manual Editorial Board [29], severity of OSA was classified according to the apnea–hypopnea index (AHI). In our study, non-OSA was defined with AHI < 5, mild OSA was defined with AHI 5–14.9, and moderate to severe OSA was defined with AHI ≥ 15. The participants' characteristics were compared across those three groups. Oxygen desaturation index (ODI) is a total number of ≥ 3% or ≥ 4% oxygen desaturations per hour of sleep. The percentage of sleep time with oxygen saturation below 90% has also been recorded and reported for each patient.

Whole-night PSG/PG recordings lasting less than 6 h were not accepted, and if needed, second PSG/PG was undertaken. Following the sleep assessment, the individuals who accepted to participate in the study were referred to periodontal examination.

Periodontal assessment

Prior to the periodontal examination, periodontal anamnesis was taken based on a questionnaire regarding the frequency of dental check-ups, personal and family history of periodontitis, smoking and oral hygiene habits, clinical symptoms of periodontitis, and the reasons of a tooth loss if there was any.

All clinical measurements were performed by two experienced examiners (MR, PS) that were blinded for the PSG/PG reports of the patients and all other medical data. The intraexaminer and interexaminer reliability was reached after examining 10 patients when the measurement accuracy reached a value greater than 95%. The clinical periodontal examination was performed using the UNC 15-mm periodontal probe (Devemed GmbH, Tuttlingen, Germany) and assessed all present teeth on 6 sites per tooth (mesio-buccal, buccal, disto-buccal, mesio-oral, oral, disto-oral aspects) and included the following standard periodontal measurements: probing pocket depth (PPD), gingival recession (GR), and clinical attachment level (CAL) expressed in millimeters. PPD was defined as the distance between the gingival margin and bottom of the gingival sulcus. GR was defined as the distance between the cemento-enamel junction and the gingival margin. CAL was calculated as the sum of PPD and GR. The full mouth bleeding score (FMBS) and the full mouth plaque score (FMPS) were measured at six sites per tooth and assessed dichotomously, then calculated as percentage of total site bleeding on probing/with plaque presence [31, 32]. The number of teeth; mean pocket depth (PD); mean CAL; FMBS; FMPS; number of teeth with PD of 4, 5, and ≥ 6 mm; percent of sites with PD of 4, 5, and ≥ 6 mm; and number of teeth with interdental CAL of 1–2, 3–4. and ≥ 5 mm were periodontal variables assessed for each participant and included in the analysis.

With aim of diagnosing periodontitis and determining the stages of periodontitis, we followed protocols published in consensus paper of Tonetti et al. [33]. In order to diagnose a periodontitis case, we used interdental CAL detectable at ≥ 2 non-adjacent teeth, and for determining stages, we used interdental CAL at the site of greatest loss and tooth loss [32]. Since we did not have radiographic data to more precisely distinguish stage severity, we divided patients into two groups: those with stages 1 and 2 and those with stages 3 and 4. Stages 1 and 2 (mild to moderate periodontitis) had CAL < 5 mm and there were no tooth loss due to periodontitis whereas stages 3 and 4 (severe periodontitis) had CAL ≥ 5 mm and there was tooth loss as a consenquence of periodontitis. Mean CAL was considered primary outcome measure and all other periodontal variables were considered secondary outcome measures.

Statistical analysis

Statistical analysis was performed in SPSS (SPSS 14.0 Student Version for Windows). Taking into account the required significance level and power, we performed a sample size calculation in MedCalc (MedCalc for Windows, version 19.1.2.) following the collection of a sample of 77 patients admitted to Split Sleep Medicine Center. The sample size of 140 participants was calculated based on a correlation coefficient of mean CAL and AHI ($r=0.2347$) in the sample, when α-level was set at 0.05 and β-level was 0.20, indicating an 80% power. The final sample was increased to 194 due to the large number of participants with less than 16 teeth. Depending on the analysis, OSA was assessed either on an ordinal scale ranging from mild OSA (AHI < 15) to moderate/severe OSA (AHI ≥ 15) or on a continuous scale measured with

an AHI count following PG/PSG. Participants were diagnosed with periodontitis according to the new classification and divided into stages [33, 34]. After the assessment of the normality of distribution for variables included in the study, median and interquartile range were reported for continuous variables. When the analysis was performed comparing three subsets of participants (no periodontitis, stage 1 and 2 periodontitis, stage 3 and 4 periodontitis), group differences for continuous variables were tested using Kolmogorov–Smirnov test and post hoc comparisons were performed using Mann–Whitney U test for independent samples.

When OSA and periodontal parameters were assessed with dichotomous or ordinal scales, contingency tables were created and differences calculated using Fisher's exact test. In order to perform a multivariable regression analysis, mean CAL value expressed in millimeters was included as dependent outcome variable. Predictors included in the model were age, gender, AHI, WHR, neck circumference (NC), hypertension (dichotomous), diabetes (dichotomous), teeth brushing (categorized as *Less than once a day* and *Once a day or more often*), smoking (categorized as *Smoker* and *Non-smoker/former smoker*), and dental medicine doctor (DMD) visits (categorized as *Less than once a year* and *Once a year or more often*). An R^2 statistic (coefficient of determination) was computed to assess the percent of variance in CAL that is explained by the set of previously reported predictor variables. For each predictor included in the model, a regression coefficient was reported with the belonging significance. The regression analysis was performed only on 179 participants because edentulous participants were excluded from this analysis. The main reason for the exclusion of these patients was no possibility to measure mean CAL in edentulous participants. Statistical significance was set at $p < 0.05$.

Results

Out of 220 recruited patients, 194 (132 men and 62 women) agreed to participate in the study and 26 participants did not accept to participate due to private and/or business commitments, yielding a response rate of 88%. Out of 194 enrolled participants, 15 were edentulous; therefore, periodontal examination could not be performed, nor could the mean CAL be calculated. Since the main outcome variables were mean CAL and AHI, these participants were excluded from the analysis (Fig. 1).

The demographic and clinical characteristics and oral hygiene measures of participants according to comprehensive periodontal examination are presented in Table 1. Participants with more severe forms of periodontitis were older with higher body mass index and were more frequently smokers when compared to all other participants assessed for periodontitis. Their waist to hip ratio and weight were higher only compared to non-periodontitis group (Table 1). There was no difference in oral hygiene according to periodontal examination (Table 1). Periodontal status of participants is presented in Table 2.

Table 3 summarizes differences in clinical measures indicating OSA severity in investigated groups established following a comprehensive periodontal examination. Following whole-night polygraphy or polysomnography, a higher AHI was reported in the group of participants exhibiting periodontitis stages 3 and 4 when compared to participants with periodontitis stages 1 and 2 ($p = 0.043$) and non-periodontitis group ($p = 0.044$). A positive correlation was found

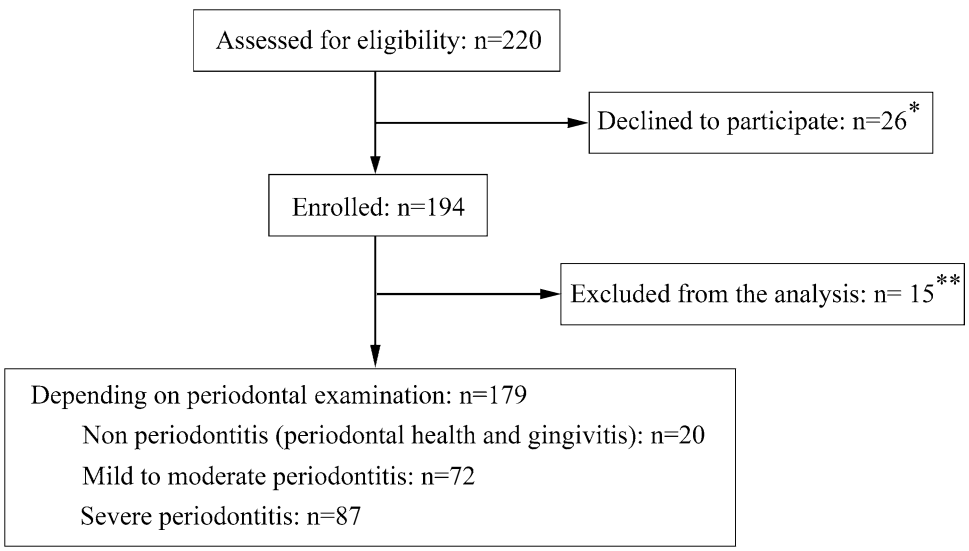

Fig. 1 Flow diagram of study participants. *Out of 220 participants assessed for eligibilitiy, 194 of them agreed to participate in the study and 26 declined to participate due to private and/or business commitments. **Out of 194 enrolled in the study, 15 of them were edentulous and were excluded from the analysis

Table 1 Demographic characteristics and oral health measures of OSA patients according to periodontal examination

		Non-periodontitis (periodontal health and gingivitis) $N=20$	Mild to moderate periodontitis (stages 1 and 2) $N=72$	Severe periodontitis (stages 3 and 4) $N=87$	P
Gender (N (%))	Male	12 (60)	46 (63.89)	66 (75.86)	0.168
	Female	8 (40)	26 (36.11)	21 (24.14)	
Age		46.5 (35.75–60.25)[B]	56 (44.75–61.25)[B]	61 (50.5–68)[A]	0.003
Height (m)		1.745 (1.6775–1.83)	1.82 (1.68–1.88)	1.785 (1.7–1.83)	0.316
Weight (kg)		85 (68.5–95)[A]	90 (77–110.25)[C]	96.5 (88–110)[C]	0.011
BMI		28.06 (24.18–30.52)[B]	28.31 (24.91–30.85)[B]	31.02 (28.05–33.79)[A]	0.001
Neck circumference (cm)		40 (35.75–43)	41 (37–43.75)	41 (39–45)	0.118
Waist to hip ratio (WHR)		0.9 (0.83–0.95)[B]	0.94 (0.88–0.98)	0.96 (0.91–1.02)[C]	0.008
ESS (sum score)		6.5 (2.75–8.25)	6 (4–9)	6 (4–9)	0.905
Smoking status	Non-smoker	11 (55)	47 (65.28)	32 (36.78)	0.007
	Current smoker	3 (15)	12 (16.7)	29 (33.33)	
	Former smoker	6 (30)	13 (18.06)	26 (29.89)	
Frequency of teeth brushing	Less than once a day	2 (10)	5 (6.94)	7 (8.14)	0.671
	Once or twice a day	13 (65)	54 (75)	68 (79.07)	
	More than twice a day	5 (25)	13 (18.06)	11 (12.79)	
Frequency of dentist appointments	Less than once a year	6 (30)	21 (29.17)	29 (33.33)	0.951
	Once a year	8 (40)	33 (45.83)	35 (40.23)	
	More than once a year	6 (30)	18 (25)	23 (26.44)	
Frequency of dental scaling	Never	5 (25)	18 (25)	17 (19.54)	0.792
	Less than once a year	7 (35)	25 (34.72)	33 (37.93)	
	Once a year	7 (35)	26 (36.11)	28 (32.18)	
	More than once a year	1 (5)	3 (4.17)	9 (10.34)	
Diabetes	Yes	5 (25)	35 (49.3)	41 (48.24)	0.133
	No	15 (75)	36 (50.7)	44 (51.76)	
Hypertension	Yes	0 (0)	6 (8.45)	13 (15.29)	0.1
	No	20 (100)	65 (91.55)	72 (84.71)	

Data are presented as frequency (percentage) for contingency tables and P values reported following Fischer exact test. Data are presented as median (interquartile range) for continuous variables, with P values based on non-parametric Kruskal–Wallis test, and post hoc comparisons were performed using Mann–Whitney test for independent samples. Post hoc difference comparisons reported as follows: [A]$p<0.05$ significantly different in comparison to other two investigated groups, [B]$p<0.05$ significantly different from severe periodontitis group, [C]$p<0.05$ significantly different from non-periodontitis group

between AHI and mean CAL (r = 0.215; $p=0.004$), as well as between AHI and plaque scores (r = 0.292; $p<0.001$).

In order to assess the association of OSA and periodontitis in our study, a multivariable regression analysis was performed using AHI and CAL as main variables to determine the severity of both diseases. Since it was not possible to determine periodontal parameters in order to calculate mean CAL for edentulous participants, analysis was performed only on 179 participants. As seen in Table 4, AHI remains a significant predictor of mean CAL (β = 0.169; $p=0.031$). Specifically, the reported model explained 16.4% of variability in mean CAL (adjusted $R^2=0.164$; $p<0.001$), with AHI, age, smoking, and DMD visits found as significant predictors. Older participants had higher odds for an increased mean CAL (β = 0.266; $p=0.001$), participants smoking or formerly smoking were more likely to have an increased mean CAL (β = 0.305; $p<0.001$) whereas visiting a DMD once a year or more often was associated with a decreased mean CAL (β = −0.182; $p=0.02$).

Discussion

In this study patients with more severe forms of periodontitis (stages 3 and 4), according to the recent Classification of Periodontal Diseases and Conditions, had more severe forms of OSA. Increased mean CAL and plaque scores were associated with an increased AHI. Along with increased age and smoking or formerly smoking, AHI was a significant

Table 2 Periodontal parameters in OSA patients according to periodontal examination

		Non-periodontitis (periodontal health and gingivitis) $N=20$	Mild to moderate periodontitis (stages 1 and 2) $N=72$	Severe periodontitis (stages 3 and 4) $N=87$	P
Number of teeth		26.5 (22.75–28)^{B}	25 (21–27)^{B}	20 (16–25)^{A}	< 0.001
Localization of periodontal disease	Localized	NA	31 (43.06)	6 (6.9)	< 0.001
	Generalized	NA	41 (56.94)	81 (93.1)	
Plaque (FMPS)		41.5 (21–60.5)^{A}	59.5 (49.75–74.25)^{A}	76 (57–94.5)^{A}	< 0.001
Bleeding (FMBS)		9 (5.75–17.75)^{A}	22 (12–34.25)^{C}	27 (13–44)^{C}	0.002
Pocket depth (PD)		1.75 (1.5–2)^{A}	2.3 (2–2.6)^{A}	2.8 (2.45–3.2)^{A}	< 0.001
Number of sites with PD of ≥ 6 mm		0 (0–0)^{B}	0 (0–0)^{B}	2 (1–7)^{A}	< 0.001
Number of sites with PD of 5 mm		0 (0–0)^{A}	1.5 (0–3.25)^{A}	6 (3–12)^{A}	< 0.001
Number of sites with PD of 4 mm		1.5 (0–3)^{A}	10 (3.75–17.25)^{A}	16 (9.5–22)^{A}	< 0.001
Mean clinical attachment level (CAL)		1.85 (1.6–2.025)^{A}	2.5 (2.1–2.725)^{A}	3 (2.7–3.45)^{A}	< 0.001

Data are presented as median (interquartile range) for continuous variables, with reported P values of differences among all three observed groups of respondents following Kruskal–Wallis test; post hoc comparisons were performed using Mann–Whitney test for independent samples. Data are presented as frequency (percentage) for contingency tables. Post hoc difference comparisons reported as follows: $^{A}p < 0.05$ significantly different in comparison to other two investigated groups, $^{B}p < 0.05$ significantly different from severe periodontitis group, and $^{C}p < 0.05$ significantly different from non-periodontitis group

Table 3 Differences in clinical measures indicating OSA severity according to periodontal examination

		Non-periodontitis (periodontal health and gingivitis) $N=20$	Mild to moderate periodontitis (stages 1 and 2) $N=72$	Severe periodontitis (stages 3 and 4) $N=87$	P
AHI		12.85 (6.9–30.45)^{B}	14.35 (8.2–33.025)^{B}	20.3 (12.6–35.3)^{A}	0.042
ODI		12.05 (4.15–29.475)	12.85 (6.775–28.05)^{B}	18.9 (10.825–33.575)^{C}	0.025
Mean saturation (%)		95.05 (93.75–96.375)	94.4 (93.85–96)	94.3 (92–95.1)	0.169
Minimal saturation (%)		85 (81.5–88)	83 (77.5–86)	81 (75–85)	0.171
Saturation below 90 (min)		0.8 (0.1–8.3)	3.6 (0.7–20.6)	9.3 (0.8–36.9)	0.062
OSA severity	Mild OSA AHI < 15	11 (55)	37 (51.39)	29 (33.33)	0.038
	Moderate to severe OSA AHI ≥ 15	9 (45)	35 (48.61)	58 (66.67)	

Data are presented as median (interquartile range) for continuous variables, with reported P values of differences among all three observed groups of respondents following Kruskal–Wallis test; post hoc comparisons were performed using Mann–Whitney test for independent samples. Post hoc difference comparisons reported as follows: $^{A}p < 0.05$ significantly different in comparison to other two investigated groups, $^{B}p < 0.05$ significantly different from severe periodontitis group, and $^{C}p < 0.05$ significantly different from mild to moderate periodontitis group

predictor of an increased mean CAL in obstructive sleep apnea patients.

Tobacco smoking and uncontrolled diabetes were implemented into the new classification scheme as important risk factors in individual patient prognosis regarding the diagnosis of periodontitis leaving the possibility to add other risk factors when the relevant evidence occurs [24]. Therefore, we performed this study in order to establish possible association between OSA severity and periodontitis. We stratified patients as mild and moderate to severe OSA assessed following whole-night PSG/PG and compared periodontal parameters according to the new classification [29, 34]. Taking into account all possible confounders derived from multifactorial characteristics of both diseases, our study showed that patients with more severe forms of OSA were diagnosed with more severe stages of periodontitis (stages 3 and 4).

A similar methodology to our study was used in the study of Loke et al. [28], who proposed that future studies should include a larger sample size. Using a larger sample size, in our study, we have shown the association between more severe forms of OSA and periodontitis indicating that OSA might be considered a relevant risk factor along with increased age and smoking. In addition, Gamsiz-Isik et al. [20] investigated the association of periodontitis and OSA and showed that OSA patients were more prone to have

Table 4 Regression analysis of mean CAL based on the multivariable regression model including AHI, age, gender, WHR, NC (neck circumference), hypertension, diabetes, teeth brushing, smoking status, and DMD visits among patients assessed in the study

	B	β	t	P
(Constant)	1.751		1.921	0.057
Age	0.015	0.266	3.349	0.001[A]
AHI	0.008	0.169	2.171	0.031[A]
Gender	0.275	0.136	1.466	0.145
WHR	−0.139	−0.016	−0.184	0.854
NC	−0.017	−0.093	−0.934	0.352
Hypertension	0.019	0.010	0.122	0.903
Diabetes	0.103	0.035	0.459	0.647
Teeth brushing once a day or more	0.418	0.120	1.49	0.138
Smoker or former smoker	0.662	0.305	4.158	< 0.001[A]
DMD visits once a year or more often	−0.360	−0.182	−2.35	0.020[A]

[A]Statistically significant predictors in the multivariable regression model of mean CAL

periodontitis due to increased serum inflammatory markers. One might presume whether systemic condition such as OSA causing oxygen desaturation might affect different organ systems and tissues including periodontal tissues [35]. Also, it might be speculated how OSA could promote periodontitis over prolonged time particularly given the confounding effects of aging and diabetes. Patients who are diagnosed with OSA are exposed to both intermittent hypoxia and hypercapnia which are both assumed to have a role in various forms of plasticity and as such are important features in the likely development of metabolic dysfunction [36, 37].

In the present study, plaque scores highly correlated with AHI even though the majority of OSA patients reported frequency of tooth brushing to be once or twice a day. Higher plaque scores were previously reported in OSA patients, indicating that higher plaque values might be associated with mouth breathing which causes drying of the oral cavity and increases the risk of bacterial colonization [20, 28]. In addition, previous studies have reported that plaque scores might also be affected by gender, educational level, and rate of dental visits [14, 15, 19, 38]. One might speculate if aforementioned mediators combined with mouth breathing could have enhanced the association of plaque scores and OSA in our study.

Our results coincide with those of several other studies that investigated the association between OSA severity and periodontal disease [15, 17–20]. Al-Jewair et al. [9] reported a mounting evidence of significant association between both diseases although previous meta-analysis showed high heterogeneity between the studies resulting in low quality of evidence. In previous studies, categorization of OSA severity varied due to different AHI cutoff points as well as the categorization of periodontitis severity due to clinical parameters essential for making a diagnosis. Definitions and classification of periodontitis differed between the studies emphasizing the need for classification that would provide more reliable and consistent results [8, 9]. However, new studies are warranted to investigate the causality and association between two diseases [9].

In contrast to our results, numerous studies found no association between periodontitis and OSA [38–40]. However, Kale et al. [40] and Sales-Peres et al. [39] only estimated OSA risk using validated questionnaires whereas in our study OSA diagnosis was confirmed by the PSG/PG which is the gold standard for diagnosing OSA. Polysomnography was used in the study of Nizam et al. [38] investigating periodontal inflammation among OSA patients divided by disease severity but was more focused on biochemical and microbiological parameters, without categorizing periodontitis severity.

Among the limitations of our study, its cross-sectional design narrowed conclusions of the possible bidirectional relationship between periodontitis and OSA. Some criticism related to the importance of AHI in comparison with age, smoking, and DMD visits in our model should be addressed. A synergistic effect of intertwined relationship of predisposing factors might influence both periodontitis and OSA, and thus compromise the possibility of drawing clear conclusions about the true importance of AHI in comparison to age, smoking, and DMD visits in our model. Also, we were unable to determine and classify grades of periodontitis since we could not determine the primary criteria regarding the periodontitis grade (direct and indirect evidence of progression) [33, 34]; therefore, we focused on stages. Since we did not have radiographic data, we divided patients into two groups, those diagnosed as stages 1 and 2 and those diagnosed as stages 3 and 4 of periodontitis respectively. Furthermore, although PSG is accepted as the gold standard in the assessment of OSA [41], the current economically constrained times prevented us from performing PSG in all patients. We are aware that the use of PG might lower the sensitivity of the scoring procedure, resulting in some patients not being recognized as having OSA or patients with under recognition of OSA severity [42]. However, it

has been stated that portable respiratory PG may be used as an alternative to PSG in patients with a high pre-test probability of moderate to severe OSA [43] which was the case in our study.

Conclusion

In this cross-sectional study, we found that moderate to severe OSA patients had more severe stages of periodontitis (stages 3 and 4). Thus, along with well-recognized risk factors including increased age, smoking, low frequency of dental visits, and poor oral hygiene, we provided the clear evidence that OSA severity is associated with advanced forms of periodontitis.

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Author contribution Petra Stazić contributed to conception, design, data acquisition, analysis, and interpretation, and drafted and critically revised the manuscript. Marija Roguljić contributed to conception, design, data acquisition, analysis, and interpretation and critically revised the manuscript. Zoran Đogaš contributed to conception, design, and data interpretation and critically revised the manuscript. Linda Lušić Kalcina contributed to design, data analysis, and interpretation, and critically revised the manuscript. Ivana Pavlinac Dodig contributed to design, data analysis, and interpretation, and critically revised the manuscript. Maja Valić contributed to design, data analysis, and interpretation, and critically revised the manuscript. Darko Božić contributed to data interpretation, and critically revised the manuscript. Renata Pecotić contributed to conception, design, and data interpretation and critically revised the manuscript. All authors gave final approval and agree to be accountable for all aspects of the work.

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Declarations

Ethics approval The study was approved by the Ethics Committee of the University of Split School of Medicine (USSM). All procedures performed in this study were in accordance with the standards of the institutional ethics committee and with the Helsinki declaration [25].

Informed consent Informed consent was obtained from all individual participants included in this study.

Conflict of interest The authors declare no competing interests.

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