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Changes in the periodontium against the background of systemic vascular reactions in young individuals with obesity

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D – writing the article; E – critical revision of the article; F – final approval of the article

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Abstract

Background. Overweight and obesity are defined as abnormal or excessive fat accumulation that impairs health. The global prevalence of obesity has been increasing significantly among all age groups. Furthermore, obesity is a comorbid factor for numerous diseases, including cardiovascular and periodontal pathologies.

Objectives. The present study aimed to investigate the influence of overweight and obesity on the periodontium of young adults in relation to the functional state of the cardiovascular system.

Material and methods. The oral health status of 132 males and females aged 18–22 years was examined. They were divided into 4 groups according to their body mass index (BMI): normal weight; overweight; class I obesity; and class II obesity. A periodontal chart, the records on oral hygiene and caries, and periodontal indices were provided for each participant. The main functional parameters of the cardiovascular system were measured before and after the dental examination.

Results. Overweight or obesity did not affect the intensity of caries in young adults. The prevalence and severity of gingivitis were significantly higher in obese individuals. A moderate correlation was found between gingivitis and BMI in patients with class I and II obesity. Disturbances in the cardiovascular system function and in the autonomic nervous system tone were also diagnosed in obese patients. An impaired vascular response and significant functional changes in the cardiovascular system developed against the background of obesity. These changes show the development of subcompensation in young adults with obesity.

Conclusions. In obese individuals, significantly worse oral hygiene was observed as compared to normal-BMI patients. Moreover, the clinical manifestation and intensity of gingivitis in obese individuals were high even in those with satisfactory oral hygiene. In young obese individuals, the periodontal disease manifested as gingivitis is due to significant adaptive and compensatory mechanisms.

Keywords: periodontitis, gingivitis, oral manifestations, preventive dentistry, obesity

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Introduction

Overweight and obesity are characterized by the accumulation of abnormal or excessive amounts of fat that leads to health impairment. According to the widely accepted classification designed by the National Institutes of Health, the body mass index (BMI) is used to calculate the degree of excess/lack of weight.[1] Using this index, a patient can be defined as underweight, normal-weight, overweight, or obese.[1] Based on the latest World Health Organization (WHO) update (2022), approx. 60% of the European population is overweight or obese. Overweight and obesity are preconditions for a more severe course of infectious and non-infectious diseases, and they increase the mortality rate. The prevalence of obesity is dependent on region and country, and in 2019, the highest prevalence rates were registered in the USA (23.2%), Mexico (18.4%) and Turkey (17.5%).[2] Furthermore, in India, the prevalence of overweight and obesity among middle-school students aged 12–16 years was reported to be 20.3%.[3] Such a high prevalence of obesity can be explained by numerous factors, including changes in the modern diet, a decrease in physical activity, negative environmental factors, chronic stress, and the burden of inheritance.[4] Overweight and obesity significantly exacerbate the course of numerous somatic and infectious diseases. They are also significant risk factors for the development of cardiovascular diseases, such as atherosclerosis and heart failure. Indeed, the risk of death increases as BMI becomes more elevated. Consequently, obesity is a burden on the global healthcare system, as the treatment of obese patients requires a significantly higher usage of healthcare resources as compared to individuals with a normal BMI.[5]

The cardiovascular system of obese individuals undergoes several changes. Rheological changes to the blood are observed, as well as new small-caliber vessels and capillaries, which are created to provide blood supply to the newly formed excess of the adipose tissue. The processes of compensation occur to satisfy the growing need for extra blood supply to the larger tissue volume. Functional changes also occur, including increased heart rate (HR) and cardiac output (CO), along with structural changes, such as the hypertrophy of the left ventricular myocardium, the enlargement of the left atrium and the development of sinus node weakness syndrome.[6] Furthermore, obesity leads to the development of metabolic abnormalities, like dyslipidemia or insulin resistance, and chronic mild systemic inflammation.[5,7] Obesity is also a predisposing factor for several metabolic, musculoskeletal, digestive system, and liver diseases, and it induces alterations to the hard tissues of the teeth and the periodontium.[8–10]

The periodontium is a highly vascularized and innervated structure that is extremely sensitive to the influence of pathogenic factors. Even minor systemic changes in hemodynamics are reflected as disturbances in periodontal microcirculation.[11] Indeed, a capillaroscopic examination revealed morphological alterations in the periodontal microcirculation of patients with hypercholesterolemia.[11] These include changes in the total diameter of the afferent and efferent loops, and in the periodontal tissue density.[12] Other clinical manifestations include the formation of recessions, and dystrophic and resorptive processes in the jaw bones. Although many studies have indicated the existence of a connection between obesity and periodontal diseases, the available literature on the relationship between obesity/overweight and dental or periodontal health is generally ambiguous and controversial. Indeed, previous studies were mostly based on the epidemiological surveys of children or adult populations within a wide age range (8–14 and 18–55 years).[9,13–17]

The current research is part of a larger scientific effort dedicated to the study of the etiology, pathogenesis and treatment of periodontal diseases among young individuals with obesity. Young patients were chosen in order to explore the mechanisms responsible for the onset of periodontal diseases, and to identify the manifestation of the early stages of periodontal diseases and systemic vascular reactions typical for this age group.

The study aimed to investigate the influence of overweight and obesity in young people with diverse BMI on the oral health status in relation to the functional state of the cardiovascular system. This was achieved by exploring the prevalence and structure of periodontal diseases in individuals aged 18–22 years.

Material and methods

Study design and sampling

The study is part of a larger research topic: "Pathogenetic approach in the treatment of inflammatory periodontal diseases in young individuals with obesity", realized in the Department of Therapeutic Dentistry of Poltava State Medical University, Ukraine, and it was meant to discover the mechanisms of the onset and development of oral cavity diseases in patients with obesity.

The research involved 132 male and female students of Poltava State Medical University aged 18–22 years. The inclusion criteria were: age of 18–22 years; diverse BMI; Ukrainian nationality; and informed signed consent to participate in the research. The exclusion criteria were as follows: pregnancy; breastfeeding; drug use; alcoholism; mental illness; participation in another study at least 2 months before inclusion in the present one; active tuberculosis; viral hepatitis; and the presence of non-removable orthodontic appliances in the oral cavity. The oral cavity examination was performed at the Clinical Facility of the Department of Therapeutic Dentistry of Poltava State

Medical University. The patients were split into 4 groups according to their BMI: group I (n = 33) – normal BMI (18.5–24.9 kg/m^2); group II (n = 36) – overweight (BMI of 25–29.9 kg/m^2); group III (n = 31) – class I obesity (BMI of 30–34.9 kg/m^2); and group IV (n = 32) – class II obesity (BMI of 35–39.9 kg/m^2).

To meet the research objectives, and according to the sample size calculation (with 95% confidence intervals (*CI*s)), the sample comprised a group of 132 individuals representing both genders. The sample size calculation was performed according to the recommendations for cross-sectional studies, using the "Sample Size Calculator" program (https://www.gigacalculator.com/calculators/power-sample-size-calculator.php). The minimum size of each group was calculated to be 29, with a type I error rate α = 5% (the estimated prevalence of 26.9%; 95% *CI*: 22.4–27.3) and a margin of error of 85%.

Determination of the oral health status

The periodontal chart for each patient was registered with the automated computer detecting system pa-on Parometer® (orangedental, Biberach, Germany). This probe allows the objective assessment of periodontal health, the follow-up of the dynamics of the periodontal status indicators and the prediction of the development of pathological changes in the periodontium by considering local and individual common risk factors for the onset of periodontal diseases (Fig. 1). During the measuring process, the same unified load of 20 g is applied and the measurements are taken with a disposable tip. The device enables the assessment of the functional state of the periodontium by determining the periodontal pocket depth (PPD), clinical attachment loss (CAL), gingival recession, and the degree of tooth mobility.

The initial periodontal status was evaluated using the decayed, missing, and filled teeth (DMFT) index, the Green–Vermillion oral hygiene index (OHI), the approximal plaque index (API), the papillary-marginal-alveolar index (PMA), the Community Periodontal Index (CPI), the papillary bleeding index (PBI), Schiller's iodine test, and the white tongue coating (WTC) index.

Periodontal charts were completed for all patients. The periodontal diagnosis was determined using the Classification of Periodontal and Peri-Implant Diseases and Conditions.[18]

Determination of the cardiovascular system function and the autonomic nervous system tone

The initial state of the central nervous system and any functional disturbances were determined by means of Wayne's questionnaire.[19–22] The questionnaire refers to 9 parameters, which are evaluated by a doctor during an objective functional examination of the patient. Each parameter is evaluated on a scale of 3–8 points. The result is calculated as a total sum of the points scored. In healthy individuals, the score for all parameters should not exceed 15 points. If a score of 15 points is exceeded, then autonomic dysfunction syndrome is diagnosed.

Evaluation of the functional hemodynamic state

The functional state of the patient's hemodynamics was determined before and after the dental examination. The dental examination lasted for 30 ±3 min. To characterize the autonomic nervous system tone, HR, systolic blood pressure (SBP) and arterial diastolic pressure (ADP) were

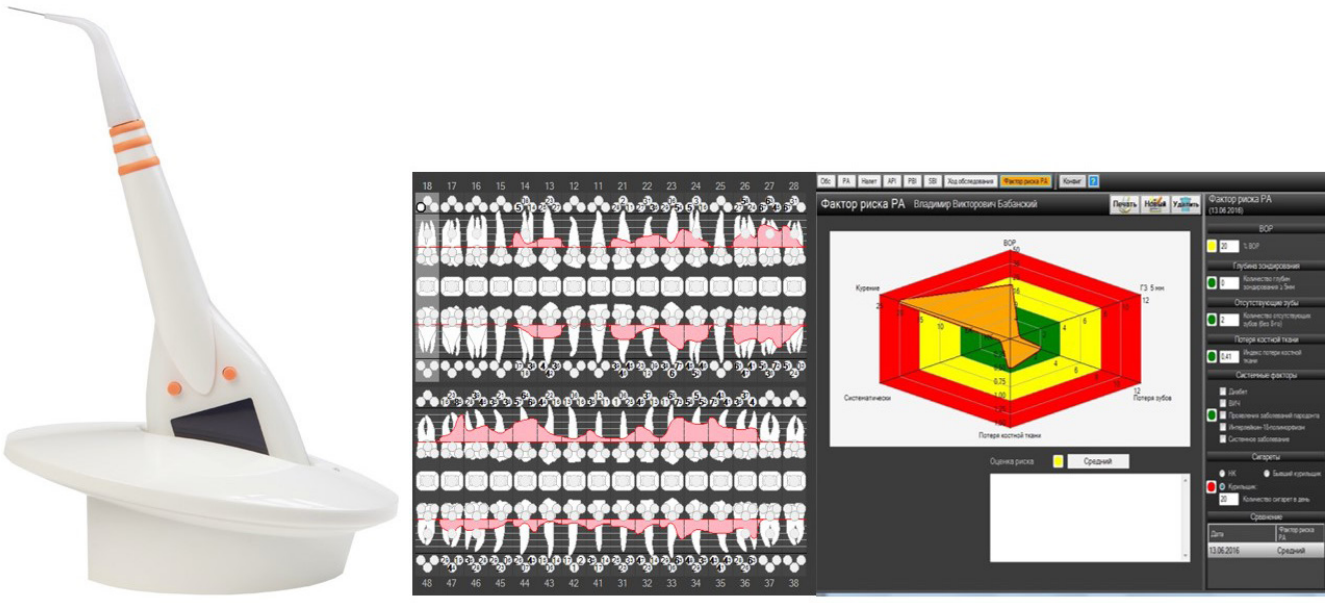

Fig. 1. pa-on Parometer® and an example of a periodontal chart

determined. The HR was determined using the fingertip pulse oximeter OX-832 (Dongguan Crayfish Electronic Technology, Dongguan, China), while SBP and ADP were measured using the A&D UA-200 manual tonometer (A&D Company, Tokyo, Japan). Common, widely accepted and simple medical indices, which are employed by general physicians during routine check-ups, were used for the determination of the hemodynamic parameters.

Kerdo's vegetative index (VI) was calculated as follows (Equation 1):

$$VI = (1 - ADP / HR) \times 100 \text{ [a.u.]} \quad (1)$$

where:
VI – Kerdo's vegetative index;
ADP – arterial diastolic pressure; and
HR – heart rate.

A value of VI = 0 indicates a complete vegetative balance of the cardiovascular system (eutonia); if VI < 0, then the parasympathetic tone prevails (parasympathetico-tonia), whilst VI > 0 signifies the predominance of the sympathetic nervous system (sympatheticotonia).[23–25]

Blood circulation, which determines the adaptation strategy, was assessed with Robinson's index (RI), which is called the 'double product' (Equation 2)[26,27]:

$$RI = SBP \times HR / 100 \text{ [a.u.]} \quad (2)$$

where:
RI – Robinson's index;
SBP – systolic blood pressure; and
HR – heart rate.

An increase in RI indicates an increase in the intensity of the heart's work. A decrease in RI at rest indicates an increase in the aerobic capacity of the body; hence, the adaptive capacity of the cardiovascular system increases during this period.[28]

Based on the anthropometric data and the vegetative tone data, the adaptive potential (AP) in terms of hemodynamics, which evaluates the level of adaptation in points, was determined (Equation 3)[29–31]:

$$AP = 0.011 \times HR + 0.014 \times SBP + 0.008 \times ADP + 0.014 \times age + 0.009 \times body\ weight - 0.009 \times height - 0.27 \quad (3)$$

where:
AP – adaptive potential;
HR – heart rate;
SBP – systolic blood pressure; and
ADP – arterial diastolic pressure.

The interaction between the contractility of the myocardium and the vascular capacitive-conductive function, as well as the productivity of the sinus node, the activity of which is affected by the central and adrenergic nervous system, were determined with the myocardial index (MI) (Equation 4)[19,32]:

$$MI = (SBP / ADP - 1) \times HR / (1 - ADP / SBP) \text{ [a.u.]} \quad (4)$$

where:
MI – myocardial index;
SBP – systolic blood pressure;
ADP – arterial diastolic pressure; and
HR – heart rate.

Heart stroke volume (HSV) was calculated using the following formula (Equation 5)[19,32]:

$$HSV = (SBP - ADP) \times 200 / (SBP + ADP) \text{ [L]} \quad (5)$$

where:
HSV – heart stroke volume;
SBP – systolic blood pressure; and
ADP – arterial diastolic pressure.

Cardiac output (CO) was calculated as follows (Equation 6)[32,33]:

$$CO = HSV \times HR \text{ [L/min]} \quad (6)$$

where:
CO – cardiac output;
HSV – heart stroke volume; and
HR – heart rate.

Total peripheral vascular resistance (TPVR) was calculated with the formula (Equation 7)[33,34]:

$$TPVR = 1{,}333 \times 60 \times (SBP + ADP) / (CO \times 2) \text{ [dyn·s/cm}^5\text{]} \quad (7)$$

where:
TPVR – total peripheral vascular resistance;
SBP – systolic blood pressure; and
ADP – arterial diastolic pressure; and
CO – cardiac output.

Bias

The possible sources of bias include the fact that the retrospective analysis concerned patients who were treated by 3 of the authors (MS, TP and IS). Additionally, the other 2 authors (KN and VP) extracted data from the selected clinical records. However, an independent biostatistician conducted the statistical analysis.

Statistical analysis

The OriginPro program, v. 8.5.1.315 (OriginLab Corporation, Northampton, USA), was used for statistical

processing. The data was expressed as mean ± standard deviation ($M \pm SD$). The one-factor analysis of variance (one-way ANOVA) was used for processing the unrelated samples, and Bonferroni's correction was used for multiple comparisons. Student's t test was used for paired samples. The difference between the groups was considered statistically significant at $p < 0.05$. Correlation relationships were determined using Spearman's rank correlation test. The statistical analysis of the percentage data was conducted using the variation statistic method by Øyvind.

Results

The BMI in group I was 22.69 ±0.29 kg/m^2, in group II, it was 27.84 ±0.21 kg/m^2, in group III, it was 32.00 ±0.28 kg/m^2, and in group IV, it was 38.18 ±0.68 kg/m^2.

Periodontal health of the examined individuals

A relationship between BMI and the prevalence of inflammatory changes in the gums was revealed, and generalized catarrhal gingivitis was diagnosed. The percentage of individuals with intact periodontium was significantly higher in the group with a normal BMI. Intact periodontium was diagnosed in 45.5% of individuals in group I, 25.0% in group II, 19.4% in group III, and 9.4% in group IV. Gingivitis associated with biofilm alone was diagnosed in 54.5% of individuals in group I, 75.0% in group II, 13.0% in group III, and 9.4% in group IV. Dental plaque-induced gingivitis, mediated by systemic risk factors (obesity), was diagnosed in 67.6% of individuals in group III and 81.2% of persons in group IV.

A moderate correlation was detected between gingivitis and BMI in groups III and IV ($r = 0.57$ and $r = 0.64$, respectively). The analysis of local disease-causing factors in relation to pathological changes in the gums was carried out in all patients as well. The assessment of the oral health status in terms of various indices is presented in Table 1.

In all groups, a high level of correlation ($r = 0.6–0.9$) was found between all oral hygiene indices, which is natural. Oral hygiene was significantly worse in obese patients as compared to the normal-BMI group. The indices determining the prevalence and severity of gingivitis were also significantly higher in obese individuals as compared to patients with a normal BMI, as was the WTC index. In group I, a positive correlation was found between DMFT and the WTC index ($r = 0.51$). In groups I and II, a strong ($r > 0.75$) and moderate ($r = 0.64$) correlation was observed between the presence of gingivitis and OHI and API, respectively, while the correlations were weak in groups III and IV. Clinical attachment loss was not diagnosed in any of the groups.

Table 1. Assessment of the participants' oral health status with the oral cavity indices

Oral cavity index	Group I	Group II	Group III	Group IV	p-value
DMFT	2.66 ±0.37	3.35 ±0.40	2.71 ±0.59	4.25 ±0.85	$p_{I–II} > 0.05$ $p_{I–III} > 0.05$ $p_{I–IV} > 0.05$ $p_{II–III} < 0.05$* $p_{II–IV} < 0.05$* $p_{III–IV} > 0.05$
OHI	1.17 ±0.07	0.95 ±0.07	1.42 ±0.10	1.40 ±0.07	$p_{I–II} > 0.05$ $p_{I–III} > 0.05$ $p_{I–IV} > 0.05$ $p_{II–III} < 0.05$* $p_{II–IV} < 0.05$* $p_{III–IV} > 0.05$
API [%]	18.2 ±3.3	9.1 ±2.8	8.9 ±1.9	7.1 ±2.1	$p_{I–II} < 0.05$* $p_{I–III} < 0.05$* $p_{I–IV} < 0.05$* $p_{II–III} > 0.05$ $p_{II–IV} > 0.05$ $p_{III–IV} > 0.05$
PMA [%]	11.40 ±1.36	10.63 ±1.80	15.40 ±1.17	15.64 ±0.80	$p_{I–II} > 0.05$ $p_{I–III} < 0.05$* $p_{I–IV} < 0.05$* $p_{II–III} < 0.05$* $p_{II–IV} < 0.05$* $p_{III–IV} > 0.05$
CPI	1.57 ±0.09	1.69 ±0.10	1.85 ±0.09	2.02 ±0.09	$p_{I–II} > 0.05$ $p_{I–III} < 0.05$* $p_{I–IV} < 0.05$* $p_{II–III} > 0.05$ $p_{II–IV} < 0.05$* $p_{III–IV} > 0.05$
PBI	6.4 ±0.9	13.6 ±2.4	19.7 ±2.3	22.9 ±2.6	$p_{I–II} < 0.05$* $p_{I–III} < 0.05$* $p_{I–IV} < 0.05$* $p_{II–III} < 0.05$* $p_{II–IV} < 0.05$* $p_{III–IV} > 0.05$
Schiller's test	1.41 ±0.05	1.43 ±0.05	1.67 ±0.05	1.71 ±0.05	$p_{I–II} > 0.05$ $p_{I–III} < 0.05$* $p_{I–IV} < 0.05$* $p_{II–III} < 0.05$* $p_{II–IV} < 0.05$* $p_{III–IV} > 0.05$
WTC index	1.56 ±0.20	1.35 ±0.17	2.09 ±0.13	2.56 ±0.20	$p_{I–II} > 0.05$ $p_{I–III} > 0.05$ $p_{I–IV} < 0.05$* $p_{II–III} < 0.05$* $p_{II–IV} < 0.05$* $p_{III–IV} > 0.05$

DMFT – number of decayed, missing, and filled teeth; OHI – Green–Vermillion oral hygiene index; API – approximal plaque index; PMA – papillary-marginal-alveolar index; CPI – Community Periodontal Index; PBI – papillary bleeding index; WTC – white tongue coating index; * statistically significant.

Determination of the cardiovascular system function and the autonomic nervous system tone

The functional state of the cardiovascular system and the tone of the autonomic nervous system were significantly different in obese and normal-BMI individuals.

In some obese individuals, the deterioration of the functional state of the cardiovascular system and of the tone of the autonomic nervous system were diagnosed. There were correlations between Wayne's score and the WTC index in group III (r = 0.52) and group IV (r = 0.53) (Table 2).

Functional changes in the cardiovascular system before and after the dental examination

Patients with BMI > 25 kg/m^2 had a significantly higher HR before and after the oral cavity examination (which is a stress factor) as compared to the individuals with a normal BMI. According to the VI measurements, sympatheticotonia (the activation of the sympathetic nervous system) was prevalent in all groups before the examination (the 1st stage of stress – alarm reaction stage). After the examination, a transition from sympatheticotonia to parasympatheticotonia was observed in 80% of group I, while the level of sympatheticotonia was still high in obese individuals after the check-up. The RI score before and after the examination was significantly higher in obese individuals as compared to normal-BMI and overweight individuals.

Before the check-up, AP was tensive (>2.1) in all groups, and it returned to the regular state only in patients with a normal BMI after the examination. The AP decreased in the other groups after the examination, but it was still high. The MI was significantly higher before the dental examination in patients with BMI > 30 kg/m^2. A positive correlation was observed between HSV and BMI, and these indicators were directly proportional to each other. The CO significantly decreased in each group after the dental examination, and it was directly proportional to BMI in all groups. The TPVR was slightly higher in the group with a normal BMI before the examination than it was in overweight and obese individuals. After the examination, TPVR was likely to decrease in patients with a normal BMI, while changes in overweight and obese patients were not significant. The data is presented in Table 3.

Table 2. Functional state of the cardiovascular system and the tone of the autonomic nervous system assessed by means of Wayne's scale

Assessment	Group I	Group II	Group III	Group IV	p-value
Wayne's score	5.68 ±0.70	5.70 ±1.13	13.38 ±1.90	13.72 ±1.20	$p_{I–II} > 0.05$ $p_{I–III} < 0.05$* $p_{I–IV} < 0.05$* $p_{II–III} < 0.05$* $p_{II–IV} < 0.05$* $p_{III–IV} > 0.05$
Normal [%]	100	100	93.5	96.9	–
Disturbance [%]	–	–	6.5	3.1	–

* statistically significant.

In group I, moderate correlations were found between CPI and HSV (r = 0.51), and between CPI and TPVR (r = –0.52). In group III, moderate correlations were found between PBI and RI (r = –0.50), and between PBI and AP (r = –0.53). Similar results were found for group IV, which showed moderate correlations between PBI and RI (r = –0.56), and between PBI and AP (r = –0.54). In group III, a moderate correlation was found between WTC and RI (r = 0.51), AP (r = 0.55) and Wayne's score (r = 0.52). In group IV, correlations were found between OHI and RI (r = –0.54), and between OHI and AP (r = –0.51).

Discussion

In the current study, no relationship was found between the intensity of dental caries and BMI in young adults. The development of caries was likely caused by the overconsumption of carbohydrates, a weak buffer capacity of saliva, inadequate salivation, and the neglect of oral hygiene, but not the presence or absence of obesity. Such results can also be explained by the relatively young age of the patients, i.e., 18–22 years. A significant correlation was found between obesity and BMI and the presence of gingivitis in young adults. The prevalence and severity of gingivitis in young subjects with class I and class II obesity were significantly higher than in the other groups. Dental plaque-induced gingivitis, mediated by the systemic risk factor obesity, was predominant in obese individuals. A study on obese females aged 18–35 years showed a significantly higher prevalence of caries and periodontal diseases in obese individuals, and the level of oral hygiene was 2.5 times worse than the national level.[17] According to the results of bacteriological studies, lower quantities of *Streptococcus mutans* were found in obese individuals as compared to individuals with a normal BMI, which is surprising.[17] In a study on 19–55-year-old overweight and obese adults, it was found that obese individuals showed significant differences in eating behavior, which included the overconsumption of sweets.[14] Obese individuals also had poorer oral hygiene and, as a result, a higher prevalence of periodontal disease, which correlated with BMI.[14] Young obese adults were mostly diagnosed with the disturbances regarding the cognitive restraint and emotional eating components of eating behavior.[4] In the clinical observations of 7–15-year-old obese children, a higher intensity of primary and permanent teeth caries was detected.[16] In addition, a higher prevalence of gingivitis, a poorer level of oral hygiene, a decrease in salivation, and a decrease in the buffer capacity of saliva were found, in comparison with normal-BMI children.[16] In a study on 8–11-year-old children, a significant relationship was found between overweight, obesity and the prevalence of caries.[13] A higher prevalence of caries, gingivitis and

Table 3. Functional changes of the cardiovascular system in response to a stress factor (dental examination) in young people with a diverse body mass index (BMI)

Hemodynamic parameter		Group I	Group II	Group III	Group IV	*p*-value
HR (1) [beats/min]		72.72 ±1.34	79.80 ±2.10	83.32 ±2.10	80.03 ±1.61	$p_{I–II} < 0.05$* $p_{I–III} < 0.05$* $p_{I–IV} < 0.05$* $p_{II–III} > 0.05$ $p_{II–IV} > 0.05$ $p_{III–IV} > 0.05$
HR (2) [beats/min]		69.50 ±0.88	74.80 ±1.90	78.03 ±2.87	76.34 ±2.07	$p_{I–II} < 0.05$* $p_{I–III} < 0.05$* $p_{I–IV} < 0.05$* $p_{II–III} > 0.05$ $p_{II–IV} < 0.05$* $p_{III–IV} > 0.05$
VI (1) [a.u.]	general	3.98 ±1.82	5.03 ±3.53	8.45 ±3.78	5.70 ±3.10	–
	<0 (parasymphatheticotonia)	33.4%	27.8%	22.6%	28.1%	–
	around 0 (eutonia)	–	2.8%	3.2%	12.5%	–
	>0 (symphatheticotonia)	66.6%	69.4%	74.2%	59.4%	–
VI (2) [a.u.]	general	–9.59 ±2.40	7.17 ±3.10	0.52 ±3.30	–4.90 ±3.60	–
	<0 (parasymphatheticotonia)	78.8%	30.5%	45.2%	53.1%	–
	around 0 (eutonia)	–	8.4%	13.0%	6.25%	–
	>0 (symphatheticotonia)	21.2%	61.1%	41.8%	40.65%	–
RI (1) [a.u.]		85.20 ±2.30	95.31 ±3.40	107.62 ±3.37	106.14 ±3.30	$p_{I–II} < 0.05$* $p_{I–III} < 0.05$* $p_{I–IV} < 0.05$* $p_{II–III} < 0.05$* $p_{II–IV} < 0.05$* $p_{III–IV} > 0.05$
RI (2) [a.u.]		82.30 ±1.09	98.51 ±3.43	98.53 ±4.51	98.32 ±3.40	$p_{I–II} < 0.05$* $p_{I–III} < 0.05$* $p_{I–IV} < 0.05$* $p_{II–III} > 0.05$ $p_{II–IV} > 0.05$ $p_{III–IV} > 0.05$
AP (1)		2.34 ±0.03	2.35 ±0.05	2.63 ±0.05	2.78 ±0.05	$p_{I–II} > 0.05$ $p_{I–III} < 0.05$* $p_{I–IV} < 0.05$* $p_{II–III} < 0.05$* $p_{II–IV} < 0.05$* $p_{III–IV} > 0.05$
AP (2)		2.10 ±0.02	2.39 ±0.05	2.55 ±0.06	2.74 ±0.05	$p_{I–II} < 0.05$* $p_{I–III} < 0.05$* $p_{I–IV} < 0.05$* $p_{II–III} > 0.05$ $p_{II–IV} < 0.05$* $p_{III–IV} < 0.05$*
MI (1) [a.u.]		121.36 ±3.03	134.82 ±4.39	150.21 ±4.11	149.91 ±5.65	$p_{I–II} < 0.05$* $p_{I–III} < 0.05$* $p_{I–IV} < 0.05$* $p_{II–III} < 0.05$* $p_{II–IV} < 0.05$* $p_{III–IV} > 0.05$
MI (2) [a.u.]		109.75 ±2.40	128.63 ±4.59	129.14 ±4.63	130.34 ±4.87	$p_{I–II} < 0.05$* $p_{I–III} < 0.05$* $p_{I–IV} < 0.05$* $p_{II–III} > 0.05$ $p_{II–IV} > 0.05$ $p_{III–IV} > 0.05$
HSV (1) [L]		46.04 ±1.60	46.85 ±1.74	53.77 ±3.47	55.87 ±2.48	$p_{I–II} > 0.05$ $p_{I–III} < 0.05$* $p_{I–IV} < 0.05$* $p_{II–III} < 0.05$* $p_{II–IV} < 0.05$* $p_{III–IV} > 0.05$

Hemodynamic parameter	Group I	Group II	Group III	Group IV	*p*-value
HSV (2) [L]	44.31 ±1.58	46.12 ±1.88	49.18 ±2.02	53.61 ±2.24	$p_{I–II} > 0.05$ $p_{I–III} < 0.05$* $p_{I–IV} < 0.05$* $p_{II–III} > 0.05$ $p_{II–IV} < 0.05$* $p_{III–IV} > 0.05$
CO (1) [L/min]	3,761.23 ±140.40	3,977.60 ±178.20	4,474.86 ±257.00	4,504.60 ±242.63	$p_{I–II} > 0.05$ $p_{I–III} < 0.05$* $p_{I–IV} < 0.05$* $p_{II–III} > 0.05$ $p_{II–IV} > 0.05$ $p_{III–IV} > 0.05$
CO (2) [L/min]	3,082.90 ±117.60	3,447.80 ±188.70	3,785.50 ±170.15	3,989.77 ±204.00	$p_{I–II} > 0.05$ $p_{I–III} < 0.05$* $p_{I–IV} > 0.05$ $p_{II–III} > 0.05$ $p_{II–IV} > 0.05$ $p_{III–IV} > 0.05$
TPVR (1) [dyn·s/cm^5]	2,649.20 ±111.83	2,118.90 ±114.80	2,261.70 ±101.84	2,284.63 ±135.40	$p_{I–II} < 0.05$* $p_{I–III} < 0.05$* $p_{I–IV} > 0.05$ $p_{II–III} > 0.05$ $p_{II–IV} > 0.05$ $p_{III–IV} > 0.05$
TPVR (2) [dyn·s/cm^5]	2,242.72 ±78.00	2,252.60 ±138.90	2,052.05 ±129.53	2,011.66 ±119.60	$p_{I–II} > 0.05$ $p_{I–III} > 0.05$ $p_{I–IV} > 0.05$ $p_{II–III} > 0.05$ $p_{II–IV} > 0.05$ $p_{III–IV} > 0.05$

Note: (1) – before the dental examination; (2) – after the dental examination. HR – heart rate; VI – Kerdo's vegetative index; RI – Robinson's index; AP – adaptive potential; MI – myocardial index; HSV – heart stroke volume; CO – cardiac output; TPVR – total peripheral vascular resistance; * statistically significant.

dental plaque was observed in 11–18-year-old obese individuals as compared to individuals with a normal BMI.[15] Meanwhile, other studies indicated no relationship between obesity and oral diseases in adults.[35]

Oral hygiene was found to be unsatisfactory in all individuals examined, although the worst levels were found in individuals with class I and class II obesity. However, periodontal disease and obesity were mutually dependent factors in young people. A significantly higher prevalence of gingivitis was found in 87% of obese adults. Mostly, gingivitis was associated with dental plaque, but was mediated by the systemic risk factor obesity. In obese individuals, the severity of the disease, reflected by PMA, CPI, PBI, and Schillers's test, was not correlated with their oral hygiene status. Indeed, the severity of the disease was not only caused by dental plaque, but also by a modified reaction to dental plaque. This reaction was due to inflammation and hypoxia in the periodontal tissues, which were caused by an impaired blood supply.

In overweight and normal-BMI patients, the severity of gingivitis was correlated with the amount of dental plaque. In obese individuals, an impaired colonization resistance of the oral cavity was also observed. This indicates that the modification of the local, non-specific protective responses of the oral cavity, as well as greater susceptibility to pathogenic and opportunistic oral cavity microorganisms, caused the development of the disease.[36] Against the background of obesity, the activation of free-radical oxidation, the development of alterations in the nitrosative stress response and an increase in the concentration of connective tissue monomers were observed in the periodontium. This indicates the development of destructive processes in the periodontium in response to the systemic inflammatory processes caused by the secretion of numerous pro-inflammatory adipocytokines by the adipose tissue.[37,38] Obese individuals have more tongue plaque deposits as compared to individuals with a normal BMI, which may indicate gastrointestinal diseases and metabolic disorders.[39]

Significantly higher values of the indices of the cardiovascular system functional state were observed in obese adults. They were over 2 times higher than those found in individuals with a normal BMI. Autonomic dysfunction syndrome was detected only in a few individuals; it was manifested as the dysfunction of the autonomic nervous system, and functional (inorganic) disorders in all systems and organs of the body. Autonomic dysfunction appears as the suppression of one part of the nervous system through the hyperactivation of another. However, under physiological conditions, an increased function of one part of the autonomic nervous system results in compensatory tension in the regulatory mechanisms of another. The system shifts to the new level of functioning and homeostatic parameters are restored. Suprasegmental formations and segmental autonomic reflexes play a crucial role in these processes. When in a tense state, or a state

of adaptation failure, the regulatory function is disrupted and the activity of one part of the nervous system increases, resulting in changes in other parts of the system.[40]

The small number of patients with disturbances in the functional state of the cardiovascular system and the autonomic nervous system tone can be explained by their young age and a significant adaptive potential.

A high proportion of obese individuals (78%) complained of constant fatigue, and the correlation between a poor level of oral hygiene and complaints of constant fatigue was also high (r = 0.85). This suggests that obese patients do not take oral hygiene measures, and skip tooth brushing and flossing due to constant fatigue. The assessment of the cardiovascular system function was conducted before and after the oral cavity examination to monitor the patient's response to the stress factor, which was the dental examination. Any dental intervention, even a routine dental examination, evokes an acute stress reaction in all patients. This is primarily caused by a feeling of fear while waiting for dental manipulations, the anxiety of experiencing pain, previous negative experiences, and childhood fears, among other reasons.[41–43] Indeed, the concentration of cortisol in saliva was reported to be 2 times higher in adults before dental treatment than after treatment.[43] By definition, stress is a non-specific neurohumoral response of the body to an exogenous or endogenous (pain) trigger.

Each individual has a different response to stress, which is reflected in the physiological reactions of systems and organs, and behavioral and neurohumoral changes in the body. This complex of reactions is specific for each individual and is called stress resistance. The specific changes are dependent on the functional state of the cardiovascular system and symphathetic innervation. A higher resting HR was recorded in obese subjects as compared to patients with a normal BMI. Nonetheless, HR decreased slightly in all subjects after the dental examination. Sympatheticotonia (the activation of the sympathetic nervous system) prevailed in patients before the examination, which is typical for the 1st stage of stress (the alarm reaction stage) and is accompanied by the activation of the sympathoadrenal system.[44]

After the dental examination, parasympatheticotonia (parasympathetic innervation) was prevalent in 80% of individuals with a normal BMI, which is typical for the resting state.[23,24] In obese patients, even after the examination, sympathetic innervation dominated. Such a phenomenon, in our opinion, may indicate the rigidity of blood vessels, as they cannot quickly adapt to changes. The RI was significantly higher in obese individuals before the examination, which indicates an increase in the body's oxygen needs and tension in the work of the heart. However, there was a significant decrease in RI after the examination. The RI was almost the same before and after the examination in subjects with BMI < 30. A directly proportional correlation was observed between RI and BMI. High AP was also observed in all groups before the examination, which indicates tension in the adaptive and compensatory capacity. After the examination, AP returned to normal only in individuals with a normal BMI. Significantly higher AP was recorded in individuals with high BMI.

Before the dental examination, MI, HSV and CO were high in all groups, which indicates the activation of the sympathoadrenal system as a response to stress. However, MI, HSV and CO were yet significantly higher in obese individuals. Increases in MI, HSV and CO, even after the examination, indicate the development of compensatory processes in obese individuals, which are aimed at supplying more tissues with blood. This is made possible through increasing the intensity of the work of the heart, which leads to "wear and tear"; consequently, compensatory mechanisms are no longer able to provide sufficient blood supply to tissues and organs. This is why damage occurs to target organs that are most sensitive to hypoxia, including the periodontium.[45]

Several studies have demonstrated the exacerbation of periodontal diseases in patients with chronic or severe systemic diseases; similar mechanisms of developing chronic and acute vascular reactions in the periodontal tissues have been observed in patients with some non-infectious and infectious diseases.[46–48] Indeed, in patients with coronavirus disease 2019 (COVID-19), a cytokine storm and thromboembolic complications were observed.[46] Such complications cause alterations in the oral cavity immune response and result in a severe course of periodontitis; a similar immune response is observed in obese individuals. However, in COVID-19 patients, systemic inflammation develops acutely, while in obesity, it is a chronic process.[46] Chronic cardiovascular diseases, such as atherosclerosis, lead to dyslipidemia and chronic inflammation, which contribute to severe periodontal tissue alterations.[47] Furthermore, a pathological link between periodontal diseases and prostatitis was found, and patients with moderate and severe prostatitis had a significantly worse periodontal status.[48] Currently, it is thought that an inflammatory systemic factor that modifies the host immune response to periodontal pathogens plays an important role in the development of periodontal diseases.

There is relative oxygen starvation of the brain in obese individuals, since the volume of blood supplied to the brain remains relatively unchanged, which is clinically manifested as drowsiness and constant fatigue. At the beginning of the dental examination, an increase in TPVR was observed only in individuals with a normal BMI, which indicates an adequate reaction in response to the stress factor. There was also a decrease in TPVR immediately after the stressful examination. The TPVR did not change significantly after the examination in obese individuals. In our opinion, this indicates the development of the dysfunction of the cardiovascular system in obese individuals. We are strongly convinced that obesity has a direct effect on the development and course of periodontal disease in young individuals by triggering a systemic inflammatory

process, and acts indirectly by modifying the circulatory system. The pathogenesis of periodontal disease in obese individuals is presented in Fig. 2.

Limitations

The study was limited by its small sample size. If the sample size had been larger, then some results might have been statistically significant. Another limitation of the study is that it did not measure the dynamics of observations, so it was not possible to detect how the oral health status changed over time.

Conclusions

Obesity and overweight did not influence the intensity of caries in young individuals. However, oral hygiene was worse in obese individuals than in normal-BMI individuals. Furthermore, the prevalence and severity of gingivitis were significantly higher in obese individuals, and the course of the disease was also modified. In young adults with obesity, significant functional changes developed in the cardiovascular system and an impaired vascular response to acute stress was observed. The reaction of obese patients to stress was more intense, which was manifested by significant changes in the already compromised cardiovascular system. Therefore, it is necessary to consider these specific factors during an oral examination. In our opinion, the age of 18–22 years is critical for gingivitis treatment in all patients, especially those suffering from obesity. Most often, irreversible damage to the periodontium (CAL) has not yet happened.

Ethics approval and consent to participate

This cross-sectional, observational study was approved by the Committee on Ethical Issues and Biomedical Ethics of Poltava State Medical University, Ukraine (No. 197).

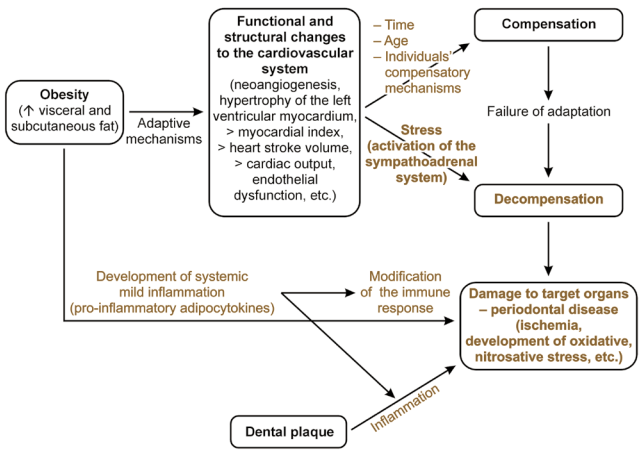

Fig. 2. Scheme of the pathogenesis of periodontal disease and obesity development in young people

Data availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Consent for publication

Not applicable.

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