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Title: "Is overweight/obesity a risk factor for periodontitis in young adults and adolescents?: a systematic review

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Abbreviations in the Main document

Acronyms	Full Version
WHO	World Health Organization
BMI	Body Mass Index
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta- Analyses
PICO	Population Intervention Comparator Outcome
NLM	National Library of Medicine's
MeSH	Medical Subject Headings
NOS	Newcastle Ottawa Scale
CPI	Community periodontal index
CDC	Center of Disease Control and Prevention
HbA1c	Glycosylated Haemoglobin
TNF-α	Tumour Necrosis Factor Alpha
IL-6	Interleukin-6
CRP	C-Reactive Protein
LPS	Lipopolysaccharides
AGE	Advanced Glycation End-products

Abstract:

Background: Obesity in young adults and adolescents is associated with chronic co-morbidities. This project investigated whether being overweight or obese is a risk factor for periodontitis in adolescents (13-17 years) and young adults (18-34 years).

Methods: A search of 12 databases was conducted using MeSH/Index and Emtree terms. Based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses, articles published between 2003-2016 were screened that reported periodontal and anthropometric measures. The Newcastle Ottawa scale was used to appraise the quality of studies.

Results: Of 25 eligible studies from 12 countries, 17 showed an association between obesity and periodontitis (odds ratios ranged from 1.1 to 4.5). The obesity indicators of body mass index, waist circumference, waist-hip ratio and body fat percentage were significantly associated with measures of periodontitis of bleeding on probing, plaque index, probing depths, clinical attachment loss, calculus, oral hygiene index and community periodontal index. Two prospective cohort studies in the review showed no significant association between obesity and periodontitis, but these studies had limitations of study design and used inappropriate epidemiological diagnostic measures of periodontitis.

Conclusion: There was evidence to suggest that obesity is associated with periodontitis in adolescents and young adults.

Systematic Review Registration: PROSPERO Registration Number: CRD42016046507

Introduction

The obesity epidemic is on the rise in adolescents (13-17 years) and young adults (18-30 years) (1-3), categorizing them as a "vulnerable group" (4). Lifestyle transitional changes among these age groups increases their susceptibility to energy imbalance often leading to weight gain and health consequences in later life (5). Non-communicable diseases and co-morbidities, such as cardiovascular disease, type 2 diabetes and some forms of cancers are associated with obesity (5-8) as well as oral diseases such as tooth decay (9) and periodontitis (10). Obesity has been reported to be associated with periodontitis in adults compared to non-obese individuals (11-14) due to increased levels and proportions of periodontal pathogens (15) and pro-inflammatory cytokines (16, 17).

Periodontitis (gum disease) is a silent condition, resulting in periodontal tissue destruction and tooth loss (18). It is associated with non-modifiable risk factors (age, gender, ethnicity and genetics) and modifying factors (diabetes mellitus, cardiovascular diseases and obesity) (19). The global burden of periodontitis is as high as 30-35% (18). with prevalence of periodontitis in adolescents and young adults reported in national surveys as high as 24% in the USA (20) and 7% in Australia (21).

To further understand and tackle the health burden of communities as populations' age, it is important to determine the association of obesity and periodontal disease in young adults and adolescents. Based on the hypotheses that: (i) systemic inflammation is associated with obesity in young adults/adolescents that may affect susceptibility to chronic co-morbidities; and (ii) periodontitis is a result of exposure to risk factors that can affect any age group; the aim of this review is to determine if overweight/obesity is associated with periodontitis in adolescents and young adults.

Methodology

The review was conducted using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The PICO (Population Intervention Comparator Outcome) criteria were used to devise the review question.

Scope of review

A systematic electronic search was conducted on PubMed/MEDLINE (National Library of Medicine, Bethesda, MD), EMBASE, COCHRANE, LILACS, DARE, BIOSIS, TRIP, PROQUEST, CINAHL, Google Scholar and WOS databases. PROSPERO portals of systematic review registration was searched for any registered protocol on this topic. The systematic review was registered as a protocol with PROSPERO (2016: CRD42016046507).

Search terms

The search terms used in the systematic review aligned with the National Library of Medicine (NLM) Medical Subject Headings (MeSH), Emtree terms and free text terms. Table 1 shows the search terms employed to generate the search syntax.

Inclusion and Exclusion criteria

Studies considered eligible were: (i) original studies on the association of periodontitis and overweight/obesity in young adults and adolescents; (ii) studies reporting periodontitis as a primary outcome; (iii) cross-sectional studies, cohort studies and case-control studies; (iv) studies conducted between January 1990 untill August 2016. This time period was chosen because the 1990's was a period when systemic diseases became a focus of research in terms of oral health. Exclusion criteria were: previous systematic reviews, literature reviews, mini reviews, dissertations, short commentaries, letters to the editor, *in vitro* studies and randomised controlled trials. Studies on middle age and older adults were also excluded. A PRISMA flow diagram was constructed showing the identification, screening, eligibility and included studies (Figure 1). Obesity was defined using body mass index (BMI), waist circumference (WC), waist to hip ratio (WHR) or waist to height ratio (WhtR) in the included studies. The definition of periodontitis was based on case definition adopted by the individual studies. Age distribution was defined for adolescents as 13-17 years and young adults as 18-34 years.

Covidence ™ – Cochrane review production tool

The results of all searches were entered into the web-based reviewing platform Covidence ™ following removal of duplicated search items. Titles and abstracts of all research papers were independently reviewed by two researchers (SK and GB). After screening of titles and abstracts, the selected studies were extracted and were critically reviewed by reading the full text papers based on the inclusion and exclusion criteria. Any conflicts were mutually addressed via discussion with the third researcher (SB).

Missing data and contacting the authors

A full text review of the included studies was carried out and a table of synthesis was constructed. Authors of 32 studies that did not report the age distribution of participants were contacted via email and age distribution data was requested in relation to body composition measures, covariates and periodontal outcomes. All authors responded to the data request query, however none of them was able to provide the requested data.

Quality appraisal

The Newcastle Ottawa Quality Assessment Scale (NOS) was used for quality appraisal of included studies by two independent reviewers (SK and GB) (Table 2), a validated tool for quality assessment of observational and non-randomised studies. The results of NOS is a star based (☆) system of assessment with three domains i.e. Selection (Maximum 5 stars), Comparability (Maximum 2 stars) and Outcome (Maximum 3 stars).

Results

Search results

The search produced 7312 studies. Of these, 6415 studies were available after duplicates were removed and when screened using title and abstract. A total of 126 studies were found to be eligible for full text review. Full text reviews resulted in 57 studies for data extraction. Of these, 32 studies were considered ineligible due to inadequate classification of age distribution for adolescents and young adults. This resulted in a yield of 25 studies for the review.

Characteristics of studies

The review included 18 cross-sectional, five case-control and two prospective cohort studies (Table 3). The studies, published between 2003 and 2016, were from 12 countries: The United States (7), Sweden (5), Japan (4), and one study from each of Egypt (22), Brazil (23), Turkey (24), South Korea (25), Mexico (26), Iran (27), Italy (28), Serbia (29) and Russia (30). Thirteen studies reported on only adolescents (24, 25, 28-38), eight studies were based on young adults (22, 23, 27, 39-43) and four studies included a combination of adolescents and young adults (44-47). Four studies were based on national surveys, i.e. three US studies (45-47) and one South Korean study (25).

Case definition of periodontitis

The case definition of periodontitis varied among the studies included in this systematic review. Seven studies used the Community Periodontal Index (CPI) (24, 25, 30, 33, 39, 41, 42), two studies used a combination of probing depths and clinical attachment loss (45, 47), two studies used a combination of probing depths and bleeding on probing (42), two studies used clinical attachment loss (31, 32, 34, 46), two studies used radiographic bone loss (34, 37) to measure periodontitis. Five studies provided no information on their case definition of periodontitis (22, 27-29, 36).

Protocol used for periodontal examination

Ten studies used a partial-mouth protocol (24, 31, 32, 37, 39, 40, 43, 45-47), seven studies used a full-mouth protocol (22, 23, 27, 35, 36, 38, 44) and one study employed full mouth radiographic assessment to define periodontitis (34). Other studies used different protocols for the periodontal examination. Kawabata *et al*., used 10 selected teeth (two molars in each posterior sextant, upper right and lower left central incisor) (42), Franchini *et al.,* used first upper and lower molars, central and lateral incisors teeth (28), Tomofuji *et al.,* used two molars in each posterior segment and upper right and lower left central incisors (41), Irigoyen-Camacho *et al.,* used right upper central and right lower central incisors (33), and Lee *et al.,* used six permanent index teeth (first molars in each posterior sextant and the upper right and lower left central incisors) (25). Two studies did not describe their periodontal examination protocol (29, 30).

Anthropometric measures and obesity definitions

Anthropometric measures of BMI, waist circumference, hip circumference and waist-hip ratio were frequently used as indicators of obesity in the included studies. Obesity was defined using the Cole criteria, ⩾ 95th percentile, adjusted for age and gender (BMI-SDS, BMI-standard deviation score) and the International Obesity Task Force definition (BMI≥ 30kg/m^2) (48). The BMI was calculated using one or more of the following classifications; Quetelet's index of obesity (49); the Center of Disease Control and Prevention (CDC) age and sex specific growth charts (50); four categories from the National Institute of Health (1998) (51); standard definition by Cole *et al*., (2000) (48) and WHO (1997) (52); growth references for children and adolescents percentiles (WHO 2007) (53); International Classification of Disease (ICD) - overweight, obesity and other hyperalimentation E66 ICD-10; WHO expert consultation paper on appropriate BMI for Asian populations (54).

Examiner calibration and statiscal power calculation

Of the 25 studies, twenty studies reported examiner calibration (22-24, 27-29, 31-36, 39-43, 45-47), and only three studies provided details of a statistical power calculation (22, 28, 44).

Covariates

The covariates of age, gender, smoking habits, ethnicity, diabetes type, glycosylated haemoglobin (HbA1c) levels and lipid profiles and the frequency of dental visits were frequently reported in the studies. Some studies included parent education and country, use of antibiotics and other medications, consumption of sugary food, sugar sweetened soft drinks, physical activity, watching television or computer use, socioeconomic status, and frequency of tooth brushing.

The association between obesity and periodontitis

Seventeen (68%) studies showed a significant association between obesity and periodontitis (Table 4) (22, 24, 26-29, 31, 32, 35-37, 40, 41, 43, 47, 55, 56). Eight studies showed no association between obesity and periodontitis (five cross-sectional, two prospective cohort and one case-control study) (23, 25, 30, 34, 38, 42, 44, 57).

Of these 17 studies that suggested an association between obesity and periodontitis, seven were on young adults (22, 27, 39-41, 43, 45) and nine on adolescents (22, 23, 25, 28, 29, 31, 32, 35, 36) and one study included both adolescents and young adults. The indicators of BMI, WC, WHR and body fat percentage were significantly associated with periodontal measures (bleeding on probing, plaque index, probing depths, clinical attachment loss, calculus, oral hygiene index and CPI index).

The multiple variable analysis within the studies showed odds ratios of 1.1. to 4.5 for association between obesity and periodontitis. Not all studies provided a statistically significant evidence of an association between overweight/obesity and periodontitis. There were two prospective cohort studies included in the review. Of these studies, Kawabata *et al.,* did not provide sufficient information on the obesity and periodontitis association and was focused on the relationship between prehypertension/hypertension and periodontal disease (42). de Castilhos *et al.,* study showed no significant association between obesity and periodontitis, however the association was observed in gingivitis and obesity in regards to calculus and gingival bleeding (23).

In addition to poor periodontal health, individuals with obesity had poor compliance towards oral hygiene (28, 35, 37); consumed a fat-rich diet frequently and vegetables infrequently (41); had high added sugar (43); increased oral microbial counts (37); decreased salivary flow rates (36, 54); low pH (31) and high IgA levels (25). In one study, no significant association was observed between radiographic alveolar bone loss and obesity (34).

Discussion

This review indicated that being overweight or obese, having a high body weight, high BMI and a large waist circumference may be risk factors for periodontal disease as assessed by plaque index, bleeding on probing, probing depth, clinical attachment loss and alveolar bone loss in adolescents and young adults. Seventeen of 25 studies showed a positive association between being overweight/obese and periodontitis (22, 24, 26-29, 31, 32, 35-37, 40, 41, 43, 47, 55-57).

Of the two prospective cohort studies in the review, de Castilhos *et al.,* suggested a statistically significant association between obesity and gingival index and calculus, which are pre-cursors of periodontal disease (23). However, no significant association was observed between obesity and periodontitis. Kawabata *et al.,* study focused on pre-hypertension/hypertension and periodontitis and did not report on the association between obesity and periodontitis, but included obesity as a covariate (42). The outcomes of these two prospective cohort studies are inconclusive. New longitudinal cohort studies are required to determine the temporal relationship between obesity and periodontitis in younger cohorts.

In the studies which utilized multiple anthropometric measures, waist circumference was strongly associated with periodontitis compared to BMI (22, 25, 27, 34, 45), suggesting that accumulation of visceral fat could be better predictor of periodontitis than BMI.

Several mechanisms were proposed to explain the association of obesity and periodontitis. First, adipose tissues secrete cytokines such as tumour necrosis factor alpha (TNF-α) and interleukin 6 (IL-6) (16). TNF-α is associated with inflammation of the periodontium, and is mainly released by monocytes and macrophages in the junctional epithelium circumscribed around the gingival sulcus (58), leading to the destruction of alveolar bone and cartilage in periodontal tissues (59). It also triggers leucocytosis and synthesis of C-reactive protein (CRP) and amyloid A (60). Secondly, lipopolysaccharide (LPS) from gram-negative bacteria harboured in periodontal tissues triggers the secretion of TNF-α and IL-6 via adipose tissue. LPS promote hepatic dyslipidaemia and decrease insulin sensitivity, leading to increased obesity and diabetes risk (61, 62). Thirdly¸ insulin resistance induced by apoptosis of the beta-cells of the pancreas, and cytokines produced by adipose tissues, interrupts insulin signalling resulting in insulin resistance (63). Advanced glycation end products (AGEs) promote the production of pro-inflammatory cytokines leptin, TNF-α and IL-6 leading to periodontal inflammation (62, 63). Finally, dietary free fatty acids have been proposed as a component of the mechanism that links inflammation to obesity, diabetes, and periodontal infection, which in turn modulates production of advanced glycation end-products and insulin resistance.

Lula *et al.,* reported consumption of added sugar and sugar-rich diet as an associative factor for obesity and periodontitis (43). The glucose content of added sugars contributes to postprandial hyperglycaemia and pro-inflammatory cascade that may persist for 16 hours. These postprandial peaks exert oxidative stress and modulate a hyper-inflammatory state, which has been associated with periodontal disease and obesity (43). Furthermore, Baumgartner *et al.,* study suggested that diet low in refined carbohydrate is associated with reduced gingival bleeding from 35% to 13% (64). Consumption of added sugars i.e. high fructose products obtained from cane and beet sugar, may induce a hyper-inflammatory state or meta-inflammation. This state leads to abdominal obesity, dyslipidaemia, insulin resistance and periodontal disease. A pilot study by Woelber *et al.,* on oral health optimised diet and its effect on periodontal inflammation suggested that diet low in carbohydrate, rich in omega-3 PUFA, Vitamin C and D and fibres can significantly reduce periodontal inflammation (65).

Studies among adults have reported that a diet rich in milk and dairy products has a protective effect on periodontal health. The South Korean survey (2007-2010) on dietary sources of milk and dairy products and their relationship with periodontal disease in a sample of 1690 adults underwent periodontal assessment and nutritional assessment using 24 hour dietary recall. Multiple logistic regression analysis showed an inverse relationship between consumption of dairy products and risk for periodontitis, following adjustment for age, BMI, energy intake, income, smoking/alcohol intake (66). A study of 942 Japenese adults who underwent a periodontal examination and a diet survey (food frequency questionnaire) reported that daily intake of dairy products or lactic acid rich food products had a beneficial effect on periodontal disease (67).

Heterogeneity of studies

There was a high level of heterogeneity observed in the studies included in the systematic review that limits our ability to conduct a meta-analysis. We identified methodological problems with the study design such as the lack of power calculation in most of the studies. Other variations included the report of body composition thresholds and periodontitis case definitions which might affected the association between obesity and periodontitis. Numerous variations were centered around the sampling frame, inclusion/exclusion criteria, study design, clinical examination protocols and periodontal probes used, examiner reliability and social determinants such as age, gender, education, ethnicity and other covariates which may have affected the association. Despite this, a consistent pattern emerged to suggest that risk of periodontitis is associated with obesity at a young age. Hence, heterogeneity may have affected the magnitude of the risk, rather than precluding the risk.

Due to the differences between studies when comparing measures of body composition, periodontal outcome, sampling methds, protocol and probes used, an attempt by the reviewers to quantify the relationship between obesity and periodontitis through meta-analysis or other statistical methods would most likely produce an effect size estimate that is at best spurious if not misleading and unhelpful for future research. Rather, the reviewers have focussed on limiting the subjectivity of this narrative review by employing robust methodology for the formulation of the review question (PRISMA, PICO), thorough and reproducible literature searches and objective reporting of study results.

Recommendations for future research

From this study, we determined that obesity and periodontitis are chronic conditions with multiple influences. The recommendation for future researchers for obesity and periodontitis studies in adolescents and young adults are presented in Table 5 according to the structure suggested by Brown *et al.*, for formulating research recommendations in systematic reviews (68).

The association between obesity and periodontitis may not be a product of a single influencing factor, but the result of a synergy of multiple factors. Hence, prospective studies should consider the inclusion of multiple measures to better identify those factors that may link obesity and periodontitis and to develop an ecological framework to examine this relationship. Particularly in reference to dietary habits, oral health behaviour (tooth brushing, flossing, interdental cleaning or using a fluoride rinse), water fluoridation, and other factors.

Additional factors recommended in future studies are; (i) multiple measures of body composition; (ii) use of a full-mouth protocol with universal periodontal probe or Florida probe to measure the periodontal measures of pocket depth, clinical attachment loss, bleeding on probing and plaque index; (iii) adopting a universal case definition of periodontitis (69); (iv) using an appropriate definition for obesity such as International Obesity Task Force and Cole's criteria for young adults and adolescents (48).

There is a need for studies to clearly illustrate the age distribution according to the WHO criteria to define adolescents (70). Hence, a consensus is needed to clearly define the age range for people who are young adults. More importantly high evidence based studies (e.g. prospective cohort) in large population representative samples with long term follow-ups, devised using a pre-specified hypothesis are essential to truly understand the temporal relationship between body composition and the onset or extent and severity of periodontitis in young adults and adolescents.

Strengths and limitations

The strengths of this systematic review include the development of hypotheses and focused review question on obesity and periodontitis association in young adults and adolescents using the PICO strategy. Other potential strengths lies in the generation of broader search strategy using a wide array of search terms (Mesh terms, Emtree terms and Free text terms), a comprehensive search for evidence using several databases for electronic searching; snowballing technique and hand searching of studies. Our criteria also included non-English articles. The use of explicit and reproducible inclusion/exclusion criterion-based selection of relevant evidence using PICO, the rigorous use of NOS for appraisal of validity and the summary table of synthesis reporting study characteristics and outcomes are other important strengths of this review.

Despite the rigorous search strategy, it is expected that more information on this review question may lie embedded in publications focusing on studies of comorbidities such as cardiovascular disease, metabolic syndrome or diabetes and periodontitis. The results and value of these collateral data existing as part of previously conducted investigations remains unknown. Additional researchers might have investigated the association between obesity and periodontitis in young adults and adolescent, however not reported it due to a lack of positive findings, therefore resulting in a publication bias. A limitation of this review was that it comprised mainly of cross-sectional and case-control studies, which are low quality study design according to hierarchy of evidence.

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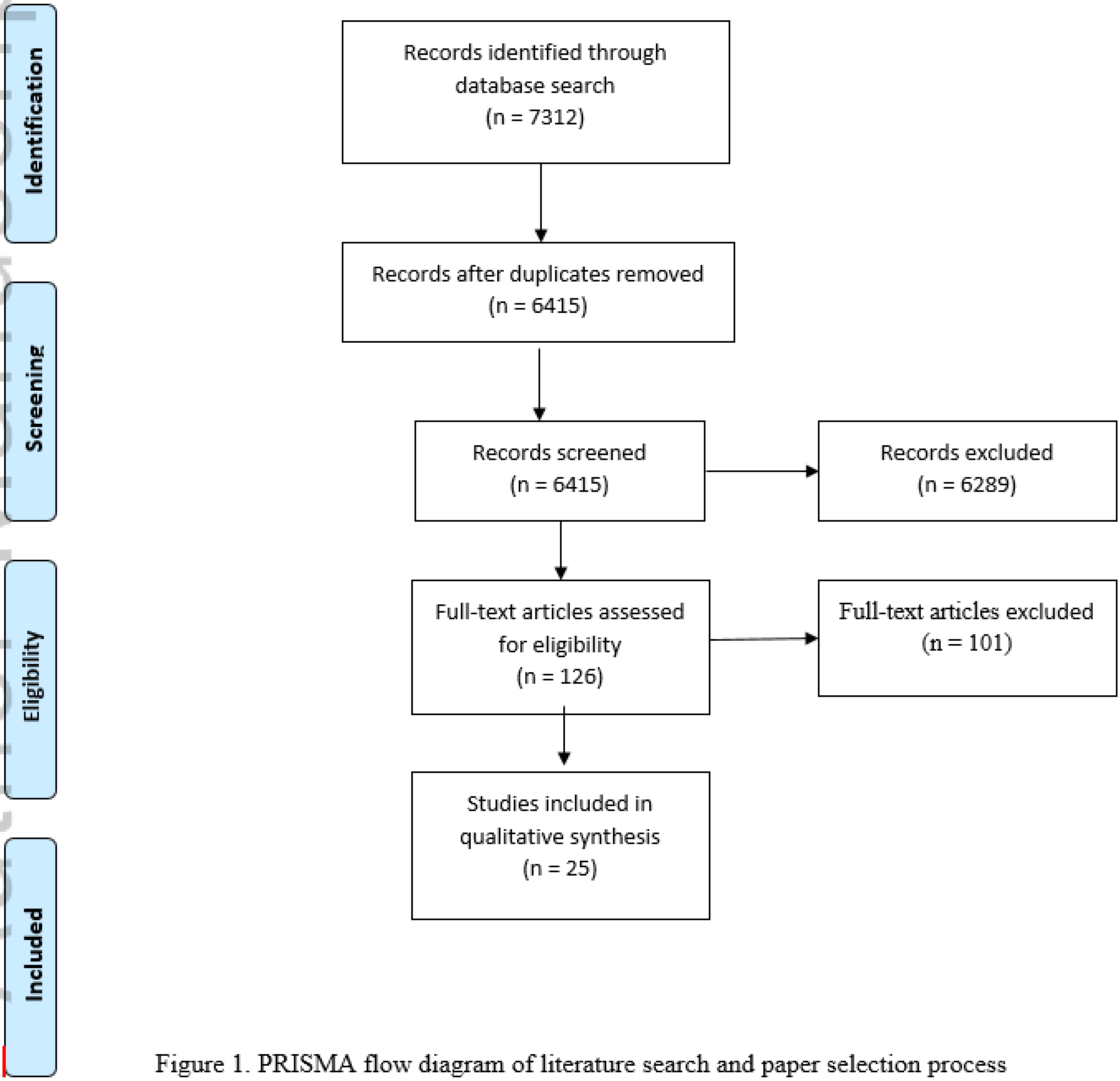

Figure 1. PRISMA flow diagram of literature search and paper selection process

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Figure 1 PRISMA flow diagram of literature search and paper selection process

Table 1. Population Intervention/Exposure Comparator Outcome – Search Terms

PICO	Search Terms
Population	Young adults, adolescent, teenager, youngsters
Intervention/Exposure	Overweight, obesity, morbid obesity, abdominal obesity, central obesity, adiposity, adipose, BMI, body mass index, weight gain, body weight, waist circumference, waist hip ratio
Comparator	Non-obese, normal weight
Outcome	Periodontal disease, periodontitis, adult periodontitis, chronic periodontitis, dental, oral, gum disease, gingival disease, mouth

Table 2. Quality assessment of included studies using Newcastle Ottawa scale (N=25)				
Author, Year, Country	Selection	Comparability	Outcome	Score
Wood et al., 2003	☆☆☆☆	☆	☆☆☆	8
AL-Zahrani et al., 2003	☆☆☆	☆	☆☆☆	7
Lundin et al., 2004	☆☆	☆	☆☆	5
Lalla et al., 2006	☆☆☆	☆	☆☆☆	7
Reeves et al., 2006	☆☆☆☆☆	☆	☆☆☆	9
Lalla et al., 2007	☆☆	☆	☆☆☆	6
Ekuni et al., 2008	☆☆		☆☆☆	5
Sarlati et al., 2008	☆☆☆	☆	☆☆	6
Amin et al., 2010	☆☆		☆☆	4
Furuta et al., 2010	☆☆	☆	☆☆☆	6
Franchini et al., 2011	☆☆☆☆☆	☆	☆☆☆	9
Modeer et al., 2011	☆☆	☆	☆☆☆	6
Merchant et al., 2011	☆	☆	☆☆☆	5
Tomofuji et al., 2011	☆☆☆	☆	☆☆☆	7
de Castilhos et al., 2012	☆☆☆☆	☆☆	☆☆☆	9
Zeilger et al., 2012	☆☆☆☆	☆	☆☆☆	8
Irigoyen-Camacho et al.,2013	☆☆☆☆☆	☆	☆☆	8
Fadel et al., 2014	☆☆☆☆	☆	☆☆☆	8
Lula et al., 2014	☆☆☆	☆	☆☆☆	7
Markovic et al., 2014	☆☆☆☆	☆	☆☆☆	8
Galkina et al., 2015	☆☆	☆	☆☆	5
Lee et al.,	☆☆☆☆☆	☆	☆☆☆	9

2015				
Zeilger et al., 2015	☆☆☆☆	☆	☆☆☆	8
Kawabata et al., 2016	☆☆☆☆	☆	☆☆☆	8
Kesim et al., 2016	☆☆☆	☆	☆☆☆	7

Table 3. Characteristics of included studies (N=25)			
Author, Year, Country	Study design Statistical power calculation	Number of participant Age range, gender	Examiner Calibration
Wood et al., 2003 United States	Cross-sectional NHANES 1988 to 1994 N/A	N=17660 18-34 years 35-49 years 50-64 years 65 years and above	Yes
AL-Zahrani et al., 2003 United States	Cross-sectional NHANES 1988-1994 N/A	N=13665 Young adults, 18-34 years, n= 5608 Middle-aged 35-59 years, n= 5092 Older adults 60-90 years, adults n= 2965 6466 male, 7199 female	Yes
Lundin et al., 2004 Sweden	Case-control N/A	N=33 adolescents and young adults, 13-24 years 11 male, 22 female	N/A
Lalla et al., 2006 United States	Case-control N/A	N=342 182 cases 99 male, 83 female Participants with diabetes 6-18 years 160 controls no diabetes 6-18 years 80 male, 80 female 6-11 years n=177 79 cases, 98 controls 12-18 years n= 155 94 cases, 61 controls	Yes
Reeves et al., 2006 United States	Case-control NHANES 1988-1994 Yes	N=2452 self-reported non-smokers 13-16 years n=1022 17-21 years n=1430 111 cases with periodontitis 2341 healthy controls Participants non-smokers	Yes

Table 3. *Continue*			
Lalla et al., 2007 United States	Cross-sectional N/A	N=700 350 diabetic (cases) 350 non-diabetic (controls) 6-11 years n=183 98 male, 85 female 12-18 years n=167 99 male, 68 female Participants diabetic children	Yes
Ekuni et al., 2008 Japan	Cross-sectional N/A	N= 618 18-24 years (Mean age 21.6 years) 296 male, 322 female	Yes
Sarlati et al., 2008 Iran	Case-control N/A	N=80 18-34 years 40 overweight/obese cases 5 male, 35 female 40 normal weight controls 5 male, 35 female	Yes
Amin et al., 2010 Egypt	Cross-sectional N/A	N=380 20-26 years 170 male, 210 female (55.2%)	Yes
Furuta et al., 2010 Japan	Cross-sectional No sampling procedure was performed.	N=2225 18-19 years 1264 male, 961 female Participants with hepatic abnormalities	Yes
Franchini et al., 2011 Italy	Cross-Sectional/Observational comparative study Yes	N=98 10-17 years 48 male, 50 female 66 overweight/obese, 32 normal weight	Yes
Modeer et al., 2011 Sweden	Cross-sectional N/A	N=104 11-17.9 years 52 Obese Cases 29 male, 23 female 52 Normal weight controls 29 male, 23 controls	Yes

Table 3. *Continue*			
Merchant et al., 2011 United States	Cross-Sectional N/A	N=155 <20 years 126 Type 1 diabetic 64 male, 62 female 29 Type 2 diabetic 15 male, 14 female	Yes
Tomofuji et al., 2011 Japan	Cross-sectional N/A	N= 801 18-25years 413 male, 388 female Participants University students	Yes
de Castilhos et al., 2012 Brazil	Prospective Cohort N/A	N=720 23-24 years 379 male, 339 female	Yes
Zeilger et al., 2012 Sweden	Cross-sectional N/A	N=87 Mean age 14.7years 29 obese cases 18 male, 11 female 58 normal weight 36 male, 22 female	N/A
Irigoyen-Camacho et al.,2013 Mexico	Cross-sectional Yes	N= 257 15 years 137 male, 120 female Participants n=161 public school, n=96 private school	Yes
Fadel et al., 2014 Sweden	Case-control N No	N=55 13-18 years 27 obese cases 15 male, 12 female 28 normal weight controls 14 male, 14 female	Yes
Lula et al., 2014 United States	Cross-sectional NHANES 1988-1994 Yes	N=2437 18-25 years 1249 male, 1385 female	Yes

Table 3. *Continue*			
Markovic et al., 2014 Serbia	Cross-sectional Yes	N=422 187 male, 235 female 6-11 years 12-18 years	Yes
Galkina et al., 2015 Russia	Cross-sectional N/A	N=168 12-17 years 104 male, 64 female	N/A
Lee et al., 2015 South Korea	Cross-sectional 4th KNHANES 2007 Yes	N=941 12-18 years 512 male, 429 female 12-14 years n=467 15-18 years n=465	N/A
Zeilger et al., 2015 Sweden	Cross-sectional N/A	N=75 12-18 years 42 male, 33 female Participants obese	N/A
Kawabata et al., 2016 Japan	Prospective cohort N/A	N=2588 18-27 years 1278 male, 1310 female	Yes
Kesim et al., 2016 Turkey	Cross-sectional Yes	N= 4,534 6-17 years 2,018 male, 2,516 female 6-11 years 278 male, 322 female 12-17 years 518 male, 879 female	Yes
NHANES – National Health and Nutrition Examination Survey; KNHANES – Korean National Health and Nutrition Examination Survey			

Table 4. Case definitions, protocol, anthropometrics, covariates and outcome of studies							
Author	Case definition	Protocol, Probe	Periodontal outcomes	Anthropometric measures and obesity definition	Covariates	Results	Sig
Wood et al., 2003 (46)	Extent scores of PAL based on Carlos et al., 1986 definition was used to categorise participants in to three groups (71). 1. Normal subjects had 0–33% of sites with PAL≥ 3 mm. 2. Early periodontitis had 33–66% of sites with PAL≥3 mm. 3. Severe periodontitis had 67–100% of sites with PAL≥3 mm.	Partial mouth protocol.	PALm, PDm, GBm indices, CIm.	Body weight (kg), Height (cm),BMI kg/m^2 WC (cm), WHR, HC (cm), FFM. Bioelectric impedance analysis (LBM, FFM, Skin fold thickness) was carried out using RJL system, Detroit, MI, USA. Obesity was measured using Quetelet Index of obesity (52).	Age, gender, smoking status (current smoker), a history of diabetes (self-reported) and socioeconomic status (poverty income ratio i.e. un-imputed income).	No significant association was observed in PAL and body composition measures in 18-34 years. In individuals 35 years and older: • An increasing percentage of PAL was significantly associated with WHR ($p<0.05$) and BMI ($p<0.01$), and FFM ($p<0.05$). • Adjusted PD significantly correlated with WHR, BMI and skin fold thickness at $p<0.01$ but not FFM. • Adjusted GB significantly associated with WHR, FFM and BMI at $p<0.005$, but not skin fold thickness. • Adjusted CI significantly associated with WHR, BMI and skin fold thickness at $p<0.01$ and FFM at $p<0.05$.	No
Al-Zahrani et al.,2003 (45)	≥1 site with attachment loss (AL) of ≥ 3 mm and probing depth	Partial-mouth protocol. Randomly	PD, CAL.	Weight (kg), Height (m), BMI (kg/m^2), WC (cm) BMI: Four categories:	Age, race, gender, education, poverty index, smoking,	Prevalence of periodontitis = 14% in the total population. Age-specific prevalence of periodontitis in obese individuals (BMI ≥30 kg/m^2).	Yes

	(PD) of ≥4 mm.	assigned one upper and one lower quadrant. Third molars, partially erupted teeth, and retained roots were excluded. N/A		1. Underweight (BMI < 18.5 kg/m^2). 2. Normal weight (BMI 18.5–24.9 kg/m^2). Overweight (BMI 25–29.9 kg/m^2). 3. Obesity (BMI ≥30 kg/m^2). 4. (NIH, 1998) (51). WC was defined according to WHO 1998 criteria as obesity i.e. WC ≥102cm men and WC ≥88cm women (52).	diabetes, and time elapsed since last dental visit.	• Young adults (12.49%). • Middle age adults (19.45%). • Older adults (21.76%). Age stratified analysis showed a significant association between obesity (BMI) and periodontal disease in young adults in crude analysis as compared to other age groups. • Young adults (OR 1.85, CI 1.31-2.60. p<0.01). • Middle age (OR 1.28, CI 0.97-1.68). • Older adults (OR 1.85, CI 0.99-1.62). Age stratified analysis showed a significant association between high WC and periodontal disease in young adults in crude analysis. • Young adults (OR 2.14, CI 1.52-3.01. p<0.001). • Middle age (OR 1.13, CI 0.88-1.44). • Older adults (OR 1.01, CI 0.77-1.31). Association of periodontal disease and BMI in young adults attenuated when controlling for covariates of gender, race, smoking, poverty index, education, diabetes and time since last dental visit (OR 1.85 – 1.75 p<0.01), while association of PD and WC increased after controlling for covariates (OR 2.14 – 2.27 p<0.001).	
Lundin et al., 2004	Pathological periodontal pocket was	Full mouth protocol.	GBI% and PD were measured at 6	Body weight (kg), Height (cm), BMI (kg/m^2).	Age, gender, smoking habit (number of	In univariate model no statistical correlation of BMI was found with age, number of periodontal pockets (≥4mm),	No

(44)	defined as depth ≥4mm. Alveolar bone loss was defined as 2mm or more distance of CEJ to the alveolar crest.	2 or 4 Bitewing radiographs or 2 periapical radiographs. Graded Periodontal probe (Type LM Instruments)	sites per tooth excluding 3rd molars. 2 or 4 Bitewing radiographs or 2 periapical radiographs were taken to detect alveolar bone loss. Gingival crevicular fluid samples were collected at six sites using paper strips to measure TNFα and IL-8 levels.	Age-specific index was used to define range of obesity (Cole et al., 2000) (48).	cigarettes per day and years of smoking).	smoking, TNFα and IL-8. When grouped, subjects with BMI>40 and BMI<40 had no significant differences in age, gender, smoking, pathological periodontal pocket and levels of the biochemical variables (TNFα and IL-6). TNFα in GCF and BMI>40 were positively correlated ($p<0.01$) in individuals without pathological periodontal pockets. When comparing groups with and without pathological periodontal pockets (≥4 mm) a positive correlation was found between BMI and TNFα. TNFα in GCF may be affected by the obese condition through a systemic effect.	
Lalla et al., 2006 (32)	At least one site with attachment loss >2 mm on at least two teeth.	Partial mouth protocol (one randomly assigned maxillary and the diagonally opposite mandibular quadrant). Periodontal probe.	Missing teeth, Dental caries, and dental restoration. PI and GI was recorded 4sites per tooth for primary and permanent dentition (Loe and Silness 1963) (72, 73).	BMI (kg/m^2). BMI for age and percentile rank calculated based on Center for Disease Control and Prevention age- and sex-specific growth charts (50).	Diabetes history and its type, age, sex, ethnicity, frequency of dental visits, dental examiner, insulin regimen, oral hypoglycemic medications, other medications, hbA1c and lipid profiles.	A positive and statistically significant association between number of affected teeth (at least one site with >2mm of attachment loss) and BMI was reported ($r = 0.12$ $p<0.03$). BMI-for-age percentiles were similar in both age groups, with actual BMI significantly higher in older children 25.0 +- 7.5 kg/ m^2 compared with 19.2 +-4.4 kg/m^2 at $p<0.001$. Children with diabetes had more dental plaque, gingival inflammation, bleeding on examination, clinical attachment loss than non-diabetics ($p<0.001$).	Yes

			For permanent dentition measures of probing depths and location of gingival margin were measured. Attachment loss were computed from probing depths and location of gingival margin scores.			Number of teeth with attachment loss ≥ 2mm were found significantly higher in diabetic children from both age groups (6-11 years & 8-12 years).	
Reeves et al., 2006 (47)	Presence of 1 or more periodontal sites with both a loss of tissue attachment of 3 mm or more and a probing depth of 3 mm or more subjects not meeting the criteria based on the case definition provided above were classified as controls.	Partial mouth protocol (randomly selected one upper and one lower quadrant).	Probing depths, Loss of tissue attachment were recorded from mesio-facial and mid-facial sites of 28 teeth excluding third molar.	Weight (kg), Height (cm), BMI (kg/m^2) Skinfold thickness and WC (cm). Adiposity was assessed by triceps, subscapular, supra-iliac, thigh, and sum of skinfold thickness (triceps subscapular) measures.	Age, sex, race/ethnicity, poverty index ratio, last dental visit, self-reported calcium intake. Additional confounders included were insulin use, non-fasting serum glucose level, self-reported vitamin C intake.	No significant relationship was found between BMI and periodontitis. Skinfold thickness was not associated with periodontitis. Weighted prevalence of periodontitis was 3.3% in individuals with periodontitis were 7kg heavier, with WC of 8cm larger than the control of same age. Adjusted models for adolescents aged 17-21years showed 6% increased risk of periodontitis for every 1kg increase in body weight and 5% increased risk of periodontitis for every 1cm increase in WC. Crude and adjusted models for adolescents aged 13-16 years showed no association	Yes

						between periodontitis in relation to body weight (OR 1.00, CI 0.98 – 1.0) and WC (OR 1.00, CI 0.98 – 1.02). .	
Lalla et al., 2007 (31)	3 definitions used to define periodontitis. 1. One site with CAL≥2mm and GI≥2 at the same site. 2. At least two teeth with one site having GI≥2. 3. At least two teeth with one site with CAL≥2mm.	Partial mouth protocol, one randomly assigned maxillary and the diagonally opposite mandibular quadrant. Manual periodontal probe.	Following were evaluated four sites or all fully erupted teeth except third molars PI (72), GI (bleeding) (73), Probing depths, Location of the gingival margin. CAL were calculated by computing probing depths with location of the gingival margin.	BMI kg/m^2, BMI percentiles for age.	Age, gender, ethnicity, dental visits, plaque index and dental examiners, type and duration of diabetes, insulin regimen, HbA1c over two year period and Lipid profiles.	BMI indexed for age was similar between age groups 6-11 years and 12-18 years, actual BMI was higher in the age group 12-18 years. A strong association was observed between HbA1c and periodontitis using the combined case definition of CAL and GI. Logistic regression showed clinical attachment loss was found weakly associated with BMI, but significant. No significant relationship was observed in diabetes duration or BMI-for-age and measures of gingival/periodontal disease in this cohort. Periodontitis and BMI indexed for age were associated in the whole population (OR 1.02, p=0.006) and in the older subgroup aged 12-18 years (OR 1.06, p=0.007).	Yes
Ekuni et al., 2008 (39)	CPI score 3 and 4 was defined as periodontitis group. CPI score 0-2 was defined as control group.	Partial mouth using CPI method.	CPI (WHO community periodontal index) (74). Total number of teeth Decayed, missing and	BMI≥30kg/m^2 is obesity. Body fat was measured using the bio-impedance method and a Body Fat Analyzer (TBF-202; Tanita Co.,	Age, sex	The overall prevalence of periodontitis in this study was estimated as 7.9%. The average BMI of participants in periodontitis group (21.8, SD 2.4, p<0.009) was significantly higher than the control group (BMI 20.9, SD 2.6). Age was also found to be significantly	Yes

			filled teeth.	Tokyo, Japan).		higher in periodontitis group (21.8, SD 1.4, p<0.002) as compared to the control group (21.1, SD 1.6). Risk of periodontitis increased by 16% with each unit increase in BMI. Subjects with periodontitis had 16% increased risk of periodontitis with 1kg/m^2 increase in BMI (adjusted OR 1.16 – CI 1.03 -1.31). No significant association was observed between Body fat and periodontitis.	
Sarlati et al., 2008 (27)	No case definition was used to define periodontitis. Measures of PPD and CAL were used as mean values to compare in relation to BMI and WC.	Full mouth protocol (four sites per tooth). Williams Probe.	Following measures with used four sites per tooth PPD, CAL, PI (75).	BMI, WC. BMI: Four categories: 1. Underweight (BMI < 18.5 kg/m^2). 2. Normal weight (BMI 18.5–24.9 kg/m^2). Overweight (BMI 25–29.9 kg/m^2). 3. Obesity (BMI ≥30 kg/m^2). WC ≥102cm for men and ≥88cm for women were considered obesity. BMI and WC were defined using WHO criteria (52)	Age, gender, education, time elapsed since the previous dental visit, smoking and diabetes. Women who reported that they had diabetes during pregnancy were considered non-diabetics.	PPD (p<0.002) was significantly associated with BMI showing higher PPD in overweight/obese (2.82, SD 0.40) as compared to normal weight (2.56, SD 0.36). CAL (p<0.000) was significantly associated with BMI showing higher CAL in overweight/obese (1.98, SD 0.5) as compared to normal weight (1.63, SD 0.33). PI was not shown to be significantly different between overweight/obese and normal weight. Increased WC was associated with significantly higher CAL in overweight/obese group as compared to normal weight (2.02, SD 0.49 versus 1.61, SD 0.33, p<0.000). PPD was significantly higher in the high WC group compared to normal WC group	Yes

						(2.58, SD 0.32 versus 2.55, SD 0.37, $p<0.000$). PI was higher in high WC as compared to normal WC, but did not reach statistical significance (75.6, SD 22.3, $p=0.054$).	
Amin et al., 2010 (22)	N/A.	Full mouth protocol. Periodontal probe.	GI was recorded for all permanent teeth except third molars (Loe, 1967) (76). CAL on six sites per tooth for all fully erupted permanent teeth using the Ramfjord method and only the highest measurement was recorded (77). CPI on index teeth (74).	BMI, WC BMI and WC were defined for obesity based on WHO criteria (52). BMI: Four categories 1. Underweight (BMI < 18.5 kg/m^2). 2. Normal weight (BMI 18.5–24.9 kg/m^2). 3. Overweight (BMI 25–29.9 kg/m^2). 4. Obesity (BMI ≥30 kg/m^2) (52). WC≥ 102cm in men and 88cm in women is obesity.	Smokers, pregnant women, diabetics, and individuals with endocrine disorders excluded from study. Non-regular tooth rushing, periodontal treatment and antibiotic use also excluded.	Obese females (2.1 mm) had significantly higher CAL as compared to normal and overweight females (0.2 mm, 1.5 mm), with a statistically significant correlation between CAL and BMI ($r = 0.9$, $p < 0.01$). High WC was significantly associated with CAL in females with mean CAL of 1.9 mm and a statistically significant correlation ($r = 0.8$, $p = 0.003$). Obese females had a mean GI of 1.8 as compared to normal weight (GI 0.3) and overweight (GI 0.8) females, with a statistically significant correlation between GI and BMI ($r = 0.9$, $p < 0.01$). Periodontitis prevalence, measured as CPI score 3-4, by weight category in men was; Obese (56.4%), Overweight (53.5%), Normal (45.5%). In Women; Obese (63.9%), Overweight (56.7%), Normal (25.0%). Males with high WC had significantly higher GI (0.8) as compared to normal WC (0.4) individuals; the correlation was statistically significant ($r = 0.6$, $p = 0.01$). Females with high WC had a mean GI 1.5 as compared to normal WC (0.5), with	Yes

						statistically significant correlation between GI and WC (r = 0.7, p = 0.003). BMI and WC were significantly associated with periodontitis in young adult females. WC was significantly associated with periodontitis in young adult males.	
Furuta et al., 2010 (40)	One or more teeth with PPD ≥ 4 mm.	Partial mouth protocol (randomly selected one maxillary and one mandibular quadrant at two sites per tooth).	PPD, Percentage of sites with BOP, Number of teeth present Decayed teeth.	BMI (kg/m^2). Two BMI categories were defined using WHO criteria (78). : 1. Normal weight (BMI<25 kg/m^2). 2. Overweight/obese (BMI≥25 kg/m^2). Following were measured using venous blood samples serum ALT, total cholesterol, serum level of hemoglobin. Urinalysis, blood pressure and pulse rate were also measured.	Serum ALT, total cholesterol and hemoglobin levels. Urinalysis, blood pressure. smoking, dental flossing, visit to dentist, interdental cleaning, flossing, regular dental clinic attendance.	Periodontitis was present in 5.8% in males, 3.2% in females. Overweight/Obese individuals with periodontitis was 13% in males and 11% in females. BMI and serum level of ALT were associated significantly with periodontitis in males. Adjusted logistic regression showed overweight and obese females had higher levels of periodontitis than normal weight females (OR 4.5, 95% CI 1.8-10.7). Adjusted logistic regression showed males with high levels of serum ALT were significantly more likely to have periodontitis as compared to males with low ALT (OR 2.3, 95% CI 1.0-5.2). BMI was significantly associated with periodontitis in both males and females. Serum ALT was significantly associated with periodontitis in males only.	Yes
Franchini et al., 2011 (28)	PI and GI was defined based on Loe and Silness, (1963) (72).	First upper and lower molar and central and lateral	PI, GI (Loe and Silness, 1963) (72).	Weight (Kg), Height (cm). BMI percentile for	Age, weight, height, blood pressure, psychological profile (multi-	Overweight and obese subjects showed a poor attitude towards oral hygiene as compared to normal weight individuals. Plaque index and gingival index scores	Yes

	No definition of periodontitis provided	incisors were the examined teeth. No deciduous tooth sites were recorded to exclude the effect of exfoliation or immature status of the gingival complex on plaque accumulation and inflammation.		corresponding to BMI≥ 25kg/^{2} and BMI≥ 30kg/m^2 were used as cut-off for overweight and obesity (Cole et al., 2000) (48). WC (cm) and HC were recorded. .	dimensional self-concept scale), insulin resistance (HOMA-IR), oral hygiene habits, preventive attitudes. Subjects affected by major chromosomal pathologies and major medical conditions excluded.	were significantly higher in overweight/obese as compared to normal weight individuals. Most of the normal weight subjects were free of gingival inflammation (65.6%), however only 29% of overweight/obese individuals had healthy gingiva. Two way Anova analysis showed PI scores were found significantly less in normal weight females as compared to normal weight males (p<0.01). In logistic regressions, GI showed a strong positive correlation with PI and male gender. Overweight and obesity, HOMA index and age were found to be not predictive of gingival inflammation.	
Modeer et al., 2011 (35)	1 or more site with pocket depth > 4mm.	Full mouth protocol, six sites per tooth, third molars excluded. Graded Periodontal Probe (LM Instruments OY, Finland).	VPI%, BOP%, pathological periodontal pocket. Supra and sub-gingival calculus was recorded. Incipient alveolar bone loss was	Body weight (kg), Height (m). Individuals with obesity had BMI≥30); Patients with Normal weight i.e. controls (BMI<25) (48). Body mass was expressed as BMI (kg/m^2), as well as by BMI adjusted for age	Age, medication, dietary habits, oral hygiene habits, parental educational level and country of birth.	Obese subjects had significantly lower frequency of tooth brushing (p<0.006), use of dental floss (p<0.040) and less use of electric toothbrush (p<0.041) as compared to the control group. Higher frequency of BOP% (25%) and pathological periodontal pockets, IL-8 and IL-1β were observed in obese subjects compared with controls (p< 0.001). No significant difference was observed in supra-gingival calculus and sub-gingival calculus in obese and controls.	Yes

			measured using two bitewing radiographs. GCF was collected from tooth number 16 and 41 and volume of GCF calculated using Periotron 8000. GCF samples were analysed in relation to inflammatory markers (TNFα, adiponectin, IL-1β, IL-6, IL-8 and PAI-1).	and sex (BMI-SDS) (79).		BMI-SDS was significantly ($p< 0.030$) associated with the pathological periodontal pockets (>4 mm) even after adjusting for the variables BOP (>25%), and sub-gingival calculus (OR 1.87 of adjusted BMI-SDS). Age and sex adjusted BMI was significantly associated with periodontal pocket.	
Merchant et al., 2011 (34)	≥3mm alveolar bone loss at one or more permanent teeth was classified as periodontal damage on radiograph.	Full mouth radiographic assessment. Williams-marking periodontal probe (Hu-Friedy, Chicago, IL, USA).	Bitewing radiographs to measure alveolar bone loss. Measurement of alveolar bone loss was conducted on mesial and distal sites of all permanent	BMI (kg/m^2), WC (cm). BMI was calculated by dividing weight in kg by squared height in meters, and age and sex specific z-scores were obtained by using the Centers for Disease Control and Prevention growth	Covariance analysis was conducted for age, sex, race, education level, family income, duration of diabetes, diabetes control, time between study visit and date	WC was reported to be higher in individuals with periodontal damage as compared to periodontal healthy individuals in both type 1 and type 2 diabetes, but did not reach statistical significance. Periodontal damage was significantly associated with high triglycerides level and lower c-peptide levels in type 2 diabetics ($p<0.01$). Periodontal damage was higher in type 2	No

			teeth except third molars.	curves (50).	of radiograph, treatment history, tooth brushing and date of dental visit. Other measured covariates were blood pressure, hypertensive medications, frequency of Flossing, brushing and dental visits. A1c, Total cholesterol, HDL-C and triglycerides were measured. LDL-C was also measured.	diabetes as compared to type 1 diabetics (55% versus 29%, p<0.02). Increasing age and males were associated with type 2 diabetes and periodontal damage. HDL was lower and LDL was higher in type 2 diabetics than in type 1 diabetes, but did not reach statistical significance.	
Tomofuji et al., 2011 (41)	CPI score 3 or 4 was referred as periodontitis. CPI 0 to 2 were referred as controls.	CPI index on index teeth. Simplified oral hygiene index for dental plaque and calculus index measured on index teeth;	CPI (74) Simplified oral hygiene index and calculus index (80).	Patients were classified as 1. Underweight (BMI<18.5 kg/m^2). 2. Normal weight (BMI of 18.5 to 22.9 kg/m^2). 3. Overweight (BMI >23 kg/m^2). Using Appropriate	Sex, age, eating habits based on eight questions, oral health behavior and exercise status. Blood pressure was measured in	Overweight individuals had higher risk of periodontitis with higher oral hygiene index scores (OR 15.4, 95% CI 3.3-72.2, p<0.001) and debris index (OR 1.8, 95% CI 0.6-5.7, p<0.28). The risk of periodontitis was higher in individuals who consumed fatty diet (p = 0.021). The risk of periodontitis reduced in overweight with frequent consumption of	Yes

		two molars in each posterior segment and upper right and lower left central incisors, six sites per tooth. CPI Probe.		body-mass index for Asian populations (49).	right upper arm.	vegetables (OR 2.8, 95% CI 1.2-6.6, p<0.008). In periodontitis group, overweight students were significantly associated with frequent consumption of fatty diet (56.5%) and lower consumption of vegetables (10.9%) as compared to the control group.	
de Castilhos et al., 2012 (23)	Gingivitis: all sites were probed, waiting 10 s to verify the presence or absence of gingival bleeding. Periodontal pocket: all sites were probed, pocket should have probing depth ≥4 mm in at least one site. Calculus: all sites were probed for detection of calculus. The variable was dichotomized	Full mouth protocol.	Gingival bleeding Calculus, Periodontal pocket.	Weight (kg), Height (cm), BMI, WC. At 15 years: the following cut-off were used to categorize BMI eutrophic (BMI in z score for age and sex 1 SD), overweight (BMI > 1 and <2 SD) or obesity (BMI ≥2 SD) (53). At age 18 to 23 year, the BMI were categorised as given below: Overweight (BMI 25 and _29.9 kg/m2) and Obesity (BMI 30 kg/m^2) (51).	Sex, skin color, smoking, schooling, family income, asset index, use of dental floss, brushing frequency percentage dietary intake from carbohydrate, C-reactive protein.	Prevalence of dental outcomes reported were: • Gingivitis = 37.5% • Calculus = 87.4% • Periodontal pocket = 3.3% Obese individuals were more likely to have two or more teeth with gingival bleeding. However, after adjusting for mediators the effect was shown to be significant. Odds of gingival bleeding were reduced as WC increased from level 1 to level 2. Dental calculus was associated with obesity, this association was not mediated by diet, oral hygiene or inflammation. WC was associated with calculus at level 2 with high risk. Periodontal pockets and risk for bleeding gums were not associated with obesity or WC. Gingivitis was significantly associated	No

	in absence or presence of dental calculus.			1998). WC were categorized according to sex in normal (men < 94 cm, women < 80 cm), Level 1 (men >94 and <102cm women >80 and <88cm Level 2 (men ≥102 cm; women ≥88 cm (52).		with obesity, this association was mediated by oral hygiene behaviour and systemic inflammation markers. No significant association was observed between obesity and periodontitis.	
Zeilger et al., 2012 (37)	Incipient marginal bone loss was classified as positive if the distance between CEJ to alveolar bone crest was ≥2mm.	Partial mouth protocol, consisting of first molars, right upper central and right lower central incisors.	VPI (81), Bleeding on probing (81) were measured at six sites per tooth. Probing depths, supra-gingival calculus. Supra-gingival calculus was recorded on all teeth as present or absent; sub-gingival calculus was recorded as present or absent on	BMI In children, age specific BMI ranges were used to define obesity according to Coles criteria (ISO-BMI>30)I (kg/m^2) (48). Obesity was defined in adolescent using age and gender adjusted BMI (BMI-SDS) (79).	Medical condition, medication, meal frequency and oral hygiene habits, smoking habits, as well as their parent's education and country of birth.	Obese samples were associated with low frequency of tooth brushing (p<0.002) and higher visible plaque index scores (p<0.005) compared to normal weight controls. None of the subjects showed signs of alveolar bone loss. Microbiological analysis showed threefold higher amounts of bacterial cells in the obese individual's plaque samples as compared with normal weight controls. Out of six bacterial phyla's determined, five were found at higher counts in the obese subjects. All families in these phyla's were significantly higher (p<0.001) in the obese samples. Out of the totally 40 different bacterial species, 32 species were present in significantly higher amount (p<0.01) in the obese subjects compared to normal weight controls.	Yes

			proximal surface of first molar and premolar on the radiograph taken as well as clinically probing the gingival sulcus. Incipient alveolar bone loss was recorded by two bitewing radiograph. Stimulated saliva was collected by asking patient to chew on 1g of paraffin wax for 5min. Saliva secretion rate and amount of saliva collected were determined in milliliters per minute. Plaque samples were collected for microbiologic			In bivariate logistic regression the measures of VPI, chronic disease, medication, lack of daily tooth brushing in the evening or morning, salivary flow rate, bacterial count and type were significantly associated with obesity ($p<0.005$). Multivariate logistic regression analysis showed a significant association of obesity with bacterial count ($p<0.006$) after adjusting for all the potential confounders.	

			al processing using paper points and were stored at -70 degree Celsius. Checkerboard DNA-DNA hybridization was used for analyses of the plaque samples.				
Irigoyen-Camacho et al., 2013 (33)	CPI 3 or 4 (74).	Using WHO criteria, the teeth examined in 15 year old were right upper central and right lower central incisors. WHO periodontal probe.	CPI (74) Periodontal loss of attachment index was only applied if CEJ was clearly visible. Plaque score were determined by Simplified Debris index (DI-S) (80).	Anthropometry was performed by a qualified dietitian for weight (kg) and heights (m) and age- and sex-specific Z-score for anthropometric data were obtained. IOTF ISO-BMI age- and sex-specific cut-off points were used to identify normal weight, overweight (OW) and obese (OB). IOTF proposed that the adult cut-off points (25 kg/m^2 for overweight and 30 kg/m^2 for obesity) be linked to body.	Smoking habit, number of cigarettes per week and duration of smoking, sex and school type.	About one third (32.7%) of the students had DI-S >1. High DI-S was detected in 31.3% and in 41.0% of non-smokers and smokers ($p = 0.230$). CPI≥3 was found in 3.1% individuals and CPI≥2 was found in 26.9% individuals. No students had deep periodontal pockets (CPI score 4). The results of the multinomial logistical regression model fitting CPI≥2 identified an association with BF% (OR = 1.06), having poor oral hygiene (OR = 20.09) and smoking (OR = 2.49). Overweight/obesity was associated with CPI≥2 (OR = 1.78) adjusting for school attended (public school OR = 0.35), oral hygiene (DI-S >1, OR = 23.92) and tobacco consumption (smoker OR = 1.81).	Yes

				mass index percentiles for children and adolescents aged 2–18 years old (48). BMI cut off points for 15.6years (48): Overweight: • Males 23.6kg/m^2 • Females 24.17kg/m^2. Obese: • Males 28.6kg/m^2 Females 29.96kg/m^2 BF% was recorded using Tetra-polar leg–leg bioelectrical impedance analysis.			
Fadel et al., 2014 (36)	Not available.	Full mouth technique for pocket depth and bleeding on probing. Marginal gingival bleeding and modified	Probing pocket depth and bleeding on probing was measured on 4 sites per tooth. Marginal gingival bleeding (81)	BMI (kg/m^2), WC, WHR. Obesity was defined based on definition of IOTF for 13 to 18 years old (48). Hbalc, hsCRP.	Smoking, age, gender, medication. Dietary assessment score was generated based on information on meal	hsCRP levels were high among obese group = 4.3 (SD 3.8) mg/L. Obese individuals had lower salivary secretion rate ($p<0.001$), pronounced pH drop after the glucose rinse ($p<0.05$) and higher IgA levels ($p<0.001$) as compared to controls. Individuals with obesity had significantly more decayed tooth surfaces ($p<0.02$) and	Yes

		plaque control was recorded from two crossed upper and lower quadrants. DMFT. Oral bitewing radiographs for assessment of approximal caries and alveolar bone levels in relation to CEJ in posterior region. Plaque sampling from the periodontal pockets.	and modified plaque control record (75) was recorded from two crossed upper and lower quadrants. the numbers of decayed and filled teeth and tooth surfaces were registered in modification to the World Health Organization (WHO) criteria (74). Four bitewing radiographs for assessment of approximal caries and alveolar bone levels in relation to CEJ in posterior region Unstimulated salivary samples collected for		frequency and amount of 33 specific sugary and snack products commonly consumed in Sweden. Questionnaire on general health, oral hygiene, fluoride use and smoking habit. HbA1c and HsCRP levels were also measured Assessment of plaque pH, collection and measurement of cytokine in GCF, sub-gingival plaque sampling and microbial profiling.	gingival bleeding ($p<0.001$) than controls even after controlling for confounders (smoking, age, gender and medication). There was no significant difference between microbial profiles of obese and controls. All plaque samples showed high proportions of *Streptococcus oralis, Porphyromonas gingivalis and Fusobacterium nucleatum.*	

			estimating salivary secretion rate and IgA concentration was measured using ELISA. Plaque pH was determined using pH strips insertion in interproximal areas between the teeth at 7 intervals after rinsing with 10ml of 10% glucose solution for 1 minute. GCF was collected, stored and analyzed for concentration of nine inflammatory cytokines. Sub-gingival plaque samples were collected for microbial profiling of 18				

			microbial species using checkerboard DNA-DNA hybridization technique.				
Lula et al., 2014 (43)	PD≥3mm and BOP at one or more site.	Partial-mouth protocol, Randomly assigned one upper and one lower quadrant.	BOP, PD at the mesio-buccal and mid-buccal sites of all teeth, excluding third molars, partially erupted teeth and residual roots. .	BMI (kg/m^2) data were used to classify Participants. 1. Normal weight (<25). 2. Overweight (BMI25–29.99). 3. Obese (BMI≥30) (52).	Age, race-ethnicity, education, poverty-income ratio, serum cotinine as an indicator of smoking status and self-reported diabetes record. Dietary added sugar intake and frequency and carbohydrate	Prevalence rate (PR) of periodontitis in whole population was 18.8%. The periodontitis prevalence in individuals with obesity was 31.9%. Crude and adjusted analysis showed a significant association of periodontitis with obesity (OR 2.63, OR 2.22), added sugar (OR 1.54, OR 1.42) and high education level (OR 0.48, OR 0.79) ($p<0.001$)	Yes
Markovic et al., 2014 (29)	No case definition provided for periodontitis. GI and DI-S used to measure gingival index and plaque scores respectively. DMF/dmf was	Standard dental examination. Dental probe and mirror.	Simplified Debris index (DI-S) (80) Gingival index (Loe and Silness, 1963) (72) DMF/dmf indexThe oral hygiene was	Weight (kg), Height (cm), BMI and Percentile for Age adjusted BMI (kg/m^2). BMI aligned with WHO growth references for children and adolescents, 5th and 85th percentile is categorized as 'normal weight,' children and	Age, sex, daily consumption of sugary food, sugar sweetened soft drinks, physical activity, watching television or computer use, socioeconomic status,	Overweight/obese children and adolescents (12-18 years) had higher gingival index score as compared to normal weight individuals ($p<0.001$). Normal weight children and adolescents had higher DMFT scores as compared to overweight/obese individuals ($p<0.01$). Spearman correlation showed BMI was significantly associated to gingival index ($p<0.001$), no correlation was observed between plaque index and nutritional status.	Yes

	code 0 for no decayed, missing filled teeth and code 1 for at least 1 decayed, missing and filled teeth.			adolescents with a BMI between the 85th and 95th percentile are classed as 'at risk of overweight,' and those with BMI greater than the 95th percentile as 'overweight' (53).	frequency of tooth brushing.	Logistic regression showed overweight/obese had two times higher risk of having high plaque index score as compared to normal weight individuals. Multiple variable analysis adjusted for all confounders showed tooth brushing and being at risk of overweight remained associated with plaque index (OR2.5, 95%CI 1.2-4.7, p<0.01).	
Galkina et al., 2015 (30)	CPI scores based on WHO criteria (74).	N/A	CPI (74) Tartar/Calculus index, Dental caries, Periodontal disease, fluorosis was also measured. Simplified oral hygiene index OHI-S (80).	BMI Obesity of varying severity (E66 ICD-10) was measured using WHO criteria.	N/A	It was established that the prevalence of caries in children diagnosed with exogenous-constitutional obesity was 75 ± 0.03%. 79% of participants had signs of periodontal disease. Chronic catarrhal gingivitis: localized form (from 3 to 7 teeth) and generalized. The CPI index was 3.43 ± 0.05 segments, with bleeding spread to 1.7 ± 0.2 sextants. • Tartar - by 1.5 ± 0.16. • Pathological pockets - by 0.23 ± 0.3.	No
Lee et al., 2015 (25)	CPI score =1.	Six permanent index teeth, first molars in each posterior sextant and the upper right and lower left central	CPI (74).	Weight (kg), Height (cm), WC. Abdominal obesity was defined as WC (cm) ≥ sex and age-specific 90th percentiles according to 2007 Korean Children and	Age, gender, income, brushing frequency, dental visits in last year, frequency of eating between meals blood pressure,	Individuals with higher CPI scores were significantly associated with male gender, older age and low HDL levels (<40mg/dl). Among 216 participants with gingivitis, 7.7% participants had high risk of metabolic syndrome, 32% participants had HDL levels below 40mg/dl and 8.8% had abdominal obesity. There was no significant difference	No

		incisors, were selected for the periodontal examination.		Adolescent Growth Standard (Korea Centers for Disease Control and Prevention 2007) (82). Metabolic syndrome was defined based on National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III) guidelines for adolescents (83). Participant had metabolic syndrome if they had three or more conditions. • Abdominal obesity; • Fasting glucose level ≥110 mg/dl; • Elevated blood pressure • Hypertriglyceridemia: serum triglyceride level ≥ 110 mg/dl; and low HDL cholesterol: serum HDL cholesterol ≤40 mg/dl.	serum triglyceride, HDL cholesterol, fasting blood sugar, physical activity time per week.	observed between the WC in individuals with or without gingivitis (70.85, 71.40). In multiple variable analysis, abdominal obesity was found to have increased odds of gingivitis (OR 1.33, 95% CI 0.59-2.99) when adjusted for confounders of age, gender, income, dental check-up, frequency of brushing, frequency of eating between meals, and physical activity.	
Zeilger et al., 2015	PD ≥4mm at one or more site was	Full mouth protocol,6 sites per	VPI (81), BOP (81) were	Height (cm), Weight (kg), BMI.	Medical conditions, medications,	No significant difference was observed between adolescents with and without PD≥ 4mm in regard to age, gender, BMI-SDS,	No

(38)	considered as occurrence of pathological periodontal pocket.	tooth. Graded periodontal probe (LM-instruments, Parainen, Finland).	measured at six sites per tooth. PD, supra-gingival calculus were recorded on all teeth as present or absent; sub-gingival calculus was recorded as present or absent on proximal surface of first molar and premolar on the radiograph taken as well as clinically probing the gingival sulcus.	BMI-SDS adjusted for age and gender (79).	meal frequency, oral hygiene habit, smoking habit, parent education and country of birth, blood pressure. Serum HDL, TSH, hsCRP, IL-1β, IL-6, IL-8, MCP-1, TNF-α and leptin levels were also measured.	tooth brushing habits, social demographics, medical history or VPI%. Adolescents with PD≥4 mm had significantly higher BOP> 25%, diastolic blood pressure (P = 0.008) and IL-6 (P < 0.001), Leptin (P = 0.018), MCP-1 (P = 0.049) and TSH (P = 0.004).	
Kawabata et al., 2016 (42)	Periodontal disease was defined using two criteria. • PPD ≥4mm (CPI 3 or 4) (39). • PPD ≥4mm	10 teeth selected for examination two molars in each posterior sextant, upper right and lower left central incisor.	CPI (74) was measured at six sites per tooth BOP% , plaque and calculus was assessed using simplified oral hygiene index.	Height (cm), Weight (kg) Categories of BMI were the following (78) 1. Underweight (BMI < 18.5 kg/m^2). 2. Normal weight (BMI 18.5–24.9 kg/m^2). 3. Overweight (25–29.9 kg/m^2).	Age, gender, blood pressure, oral health behaviour, general health condition, diet, soft-drinks, habitual physical activity, daily	No association was reported between obesity and periodontitis in the study. The study focused on relationship between hypertension, prehypertension and periodontitis controlling for covariates, of which obesity was one.	No

	and BOP>30 % (84).	CPI probe (YDM, Tokyo, Japan).	PPD was measured in 10 teeth used for CPI.	4. Obesity (≥30 kg/m^2). For the analysis overweight and obesity were combined together due to lower number of participants.	alcohol consumption, smoking, frequency of tooth brushing, use of dental floss, regular dental check-up.		
Kesim et al., 2016 (24)	CPI = 0 (healthy), CPI > 0 (unhealthy).	Partial mouth: six sextants six sites per tooth. WHO 621 Trinity periodontal probe (Campo Mourao; PR Brazil).	CPI (74). DMFT (adolescent) and measured in the permanent dentition. dmft (6-11 years) measured in primary dentition.	BMI (kg/m^2), WC (cm), body fat percentage. Body fat percentage was measured by bioelectrical impedance analysis (BIA).	Inhabitation, socio-economic status, parents level of education and employment status, Media consumption, sleep duration and nutritional habits. Individuals with growth disorders or using medications were excluded.	BMI and WC was found significantly associated with CPI>0 scores in boys. In Univariate analysis, • DMFT scores were significantly associated with BMI and WC in both genders. • CPI scores were significant for these indices only among boys. • DMFT scores were significantly associated with fat percentage only among girls. In multiple binary logistic regression models, • BMI significantly predicted CPI scores only in boys. • BMI significantly predicted DMFT scores in both genders. According to CPI, there were significant differences between the frequencies of the BMI groups at the age of 16 (boys only) and 17 (girls only) ($p<0.05$).	Yes

PAL – periodontal attachment loss; PALm – periodontal attachment loss mean; PDm – mean pocket depth; GB – gingival bleeding index; GBm – mean gingival bleeding index; Clm – mean calculus index; BMI – body mass index; WC – waist circumference; WHR – waist hip ratio; HC – hip circumference; FFM – free fat mass; LBM – lean body mass; PD – Probing depth; CAL – Clinical attachment loss; PPD – probing pocket depth; TNF- α – Tumor necrosis factor alpha; IL-6 – Interleukin 6; GCF – gingival crevicular fluid; PI – plaque index; GI – gingival index; GR – gingival recession; HbA1c – glycosylated hemoglobin; CPI – community periodontal index; DMFT – decayed missing filled teeth; NIH – National institute of health; ALT – Alanine aminotransferase; HOMA-IR – insulin resistance; VPI% –visible plaque index percentage; BoP – bleeding on probing; BMI-SDS – age and sex adjusted body mass index; IL-8 – interleukin 8; IL-1 β – interleukin 1 beta; HDL – High density lipoprotein; LDL – Low density lipoprotein; CRP – C reactive protein; ABL – Alveolar bone loss; CEJ – Cemento-enamel junction; hsCRP –High sensitivity C-reactive protein; IgA – Immuno-globulin A; WHO – World Health Organisation; ICD – International classification of disease codes; TSH –Thyroid Stimulating Hormones; MCP - Monocyte chemotactic protein; dmft – deciduous (decayed, missing, filled tooth); GBI% - gingival bleeding index percentage; PLI – O'Leary Plaque index; ALT - alanine aminotransferase; PAI-1 – Plasminogen activator inhibitor 1; HbA1c – glycosylated hemoglobin; A1c – glycosylated hemoglobin; BF% - Body fat percentage; DI-S – Simplified Debris Index; IOTF – International Obesity Task Force; Sig – Significant

Table 5. Research Recommendations (based on format from Brown *et al*., 2006)

Core elements	Recommendation for future research
(E) Evidence (current)	Systematic review identified predominantly cross-sectional, case control and few cohort studies Future studies should focus on understanding the role of fat in obesity and periodontitis association.
(P) Population	Adolescents and young adults WHO specific age distribution for adolescents and young adults
(I) Intervention/Exposure	WHO defined BMI and BMI categories for adolescents and young adults Use of multiple body composition measures such as waist circumference, waist-hip ratio, waist to height ratio and body fat percentages.
(C) Comparison	Normal weight individuals (BMI<25kg/m^2)
(T) Time stamp	August 2017
(O) Outcomes	Periodontal disease according to Eke et al., 2012 case definition of periodontitis. Full mouth periodontal assessment using calibrated Florida probe system. Periodontal measures of clinical attachment loss, probing depth, plaque index and bleeding on probing on six sites per tooth. Include age, gender, smoking, diet diary and blood markers (CRP, Lipid profile and apolipoprotein B) as covariates in analyses.
(d) Disease burden	Around 1.9 billion adults aged 18 years and older were overweight and over 600 million adults were obese (WHO, 2014) The worldwide prevalence of periodontitis is 35% in adults
(t) Timeliness	Cohort follow-up of young adults over a period of

	years, Clinical trials on dietary intervention and its effect on obesity and periodontitis with 6-month follow-up
(s) Study type	Prospective cohort studies or clinical trials