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Body Mass Index as a Predictive Factor of Periodontal Therapy Outcomes

ABSTRACT

Body mass index (BMI) and obesity are associated with the prevalence, extent, and severity of periodontitis. This study investigated the predictive role of overweight/obesity on clinical response following non-surgical periodontal therapy in patients with severe periodontitis. Two hundred sixty adults received an intensive course of non-surgical periodontal therapy. Periodontal status at baseline and 2 months was based upon probing pocket depths (PPD), clinical attachment levels (CAL), and whole-mouth gingival bleeding (FMBS) as assessed by two calibrated examiners. Generalized estimating equations (GEE) were used to estimate the impact of BMI and overweight/obesity on periodontal treatment response while controlling for baseline status, age, smoking status (smoker or non-smoker), and full-mouth dental plaque score. BMI (continuous variable) and obesity (*vs*. normal weight) were associated with worse mean PPD ($p < .005$), percentage of PPD > 4 mm ($p = .01$), but not with FMBS ($p > .05$) or CAL ($p > .05$) at 2 months, independent of age, smoking status, or dental plaque levels. The magnitude of this association was similar to that of smoking, which was also linked to a worse clinical periodontal outcome ($p < .01$). BMI and obesity appear to be independent predictors of poor response following non-surgical periodontal therapy.

KEY WORDS: obesity, overweight, periodontitis, wound healing, chronic disease, prognosis.

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INTRODUCTION

Obesity is a chronic disease (Bray, 2004;WHO, 2013) and an emerging epidemic public health problem (WHO consultation, 2000). In 2008, 35% of adults (age 20+ yrs) were overweight (body mass index [BMI] ≥ 25 kg/m^2), and the prevalence of obesity (BMI ≥ 30 kg/m^2) doubled since 1980, reaching an estimated 502 million (WHO, 2008; Finucane *et al.*, 2011).

Obesity modulates host immune responses, resulting in increased susceptibility to infections (Falagas and Kompoti, 2006). Adipocytes can release a variety of inflammatory mediators and trigger a systemic pro-inflammatory state (Maury and Brichard, 2010; Ouchi *et al.*, 2011). This has been shown to have a negative effect on wound-healing processes related to other chronic disorders, although the mechanisms are yet to be fully understood (Wilson and Clark, 2003; Bagchi and Preuss, 2013). Indeed, an increased prevalence of wound complications has been reported in obese individuals, including infection, dehiscence, hematoma and seroma formation, pressure ulcers, and venous ulcers (Wilson and Clark, 2004). The majority of these complications could be due to localized hypoperfusion and ischemia due to wound tension and to an impaired immune response linked to systemic factors like stress, anxiety, and depression (Wilson and Clark, 2004).

Periodontitis is a chronic inflammatory disease initiated by dental plaque biofilm and perpetuated by a dysregulated immune response within the gingival tissue (Kornman *et al*., 1997). The prevalence of periodontitis remains high globally, with most recent estimates in the United States suggesting that 47% of the adult population suffers from the disease (Eke *et al.*, 2012).

A recent systematic review including a meta-analysis concluded that obese and overweight/obese individuals together are 1.8 times and 2.3 times more likely to suffer from periodontitis independent of traditional risk factors in comparison with normal-weight control individuals, respectively (Suvan *et al*., 2011).

Obesity has been shown to be associated with adverse post-surgical outcomes such as infectious complications and compromised healing (Wilson and Clark, 2003; Doyle *et al.*, 2010). The hypothesis of altered immune response and wound-healing associated with obesity raises the question of a possible modifying effect of obesity on periodontal therapy clinical response. Based upon recently conducted systematic reviews and literature searches (Chaffee and Weston, 2010; Suvan *et al.*, 2011), there is limited evidence on the relationship among BMI, overweight or obesity, and periodontal therapy clinical response.

The aim of this study was to ascertain whether BMI is a predictor of the response to non-surgical periodontal therapy measured at 2 mos following therapy in a sample of patients suffering from severe periodontitis.

MATERIALS & METHODS

Study Sample

The sample selected for this secondary analysis consisted of individuals participating in 5 clinical studies of non-surgical periodontal therapy (D'Aiuto *et al*., 2004, 2005, 2006; Tonetti *et al*., 2007) during a seven-year period at UCL Eastman Dental Institute. Identical inclusion/exclusion criteria were used for all studies, including that participants were ≥ 18 yrs old diagnosed with generalized severe periodontitis (defined as probing pocket depths of > 5 mm and marginal alveolar bone loss of > 30% with > 50% of the teeth affected) (D'Aiuto *et al.*, 2004). All patients were otherwise systemically healthy (based on medical history assessment), were not regularly taking any medications including non-steroidal anti-inflammatory drugs, were not on a weight loss program, and had not taken antibiotics within 3 mos of assessment, and, if female, were not pregnant or lactating. Participants had not received periodontal therapy within 6 mos of the study baseline assessment.

All participants included in the study received non-surgical periodontal therapy consisting of oral hygiene instructions and full-mouth mechanical periodontal debridement with hand and ultrasonic instruments performed within a 24-hour period of time with local anesthesia, by the same clinician. In studies where adjunctive procedures were included as the test intervention (*i.e.*, locally delivered antimicrobials), only the control group was included as part of this analysis.

Data Collection

Body mass index was calculated as kg/m² based upon height and weight of the individual, measured with a wall-mounted height measure and mechanical scales. Measurements of clinical response to periodontal therapy were defined as whole-mouth average PPD, clinical attachment levels (CAL), percentage of sites with PPD > 4 mm, and full-mouth bleeding score at 2 mos. Dental plaque levels and bleeding scores were expressed as full-mouth percentage of positive sites. All clinical variables were assessed at 6 sites *per* tooth for all teeth present in the mouth and performed by the same two calibrated examiners for all the studies. Demographic information, including age, ethnicity, and smoking history, was obtained *via* a medical history interview.

Data Analyses

The data were analyzed with Stata 10.0 (StataCorp). After descriptive statistics were obtained, generalized estimating equations (GEE) were used to evaluate the association among BMI, overweight or obesity, and the response to non-surgical periodontal therapy outcomes. GEE was used to account for the clustering (non-independence) of the data attributed to the participants being clustered within the 5 clinical studies. Although the studies had the same design, inclusion/exclusion criteria, examiners, and treatment clinician, when individual patient data are pooled, independence of the data cannot be assumed.

Each of the periodontal therapy outcome measurements used, namely, mean PPD, percentage of sites with PPD > 4 mm, and full-mouth bleeding score (FMBS) at 2 mos, was taken as an outcome variable in a separate GEE analysis. CAL levels were not associated with BMI or obesity at baseline or 2 mos and therefore were not included in subsequent analyses (data not shown).

Explanatory variables included BMI (kg/m² continuous measure) and the BMI categories overweight (BMI 25-29.99 kg/m²) or obese (BMI ≥ 30 kg/m²) at baseline, and gender, age, ethnicity (Caucasian or non-Caucasian), smoking status (smoker or non-smoker), and full-mouth plaque score at 2 mos. Two dummy variables were created from comparison of overweight with normal and obese with normal. The variables of primary interest were BMI (kg/m²) and BMI categories overweight and obese, with other variables included to adjust for their potential effects.

Initially, univariable analyses of the listed covariates or BMI measure were carried out to determine the influence of BMI, overweight or obese, age, gender, ethnicity, smoking status, and plaque score on the defined measure of periodontal status 2 mos following non-surgical therapy. All factors achieving statistical significance at the .10 level in the univariable analyses were then included in multiple regression models, with age and dental plaque scores forced into the model because of their inherent impact on clinical periodontal outcomes. In addition, for each GEE model, the relevant baseline value of the mean PPD, percentage of sites with PPD > 4 mm, or full-mouth bleeding score was included as a covariate, so that an analysis of covariance (ANCOVA) could be undertaken. A p value of less than .05 was deemed statistically significant in the multivariable analyses results.

RESULTS

The combined database was comprised of 260 cases ranging in age from 27 to 77 yrs, of whom 93 were BMI overweight and 55 BMI obese. Across BMI groups, the sample included patients of similar age, but more males and non-Caucasians were identified within the overweight and obese groups (Table 1). Greater proportions of current smokers, however, were found in the normal BMI group (Table 1), and greater average levels of dental plaque, bleeding, PPD, and percentage of pockets > 4 mm were found with increasing BMI values at baseline and 2 mos after periodontal therapy (Fig.). No individuals in this sample had missing data for any of the listed covariates.

Univariable Analysis

Univariable GEE analyses demonstrated that BMI as a continuous measure, obesity, and smoking status were all significantly associated with mean PPD, mean percentage of sites with PPD > 4 mm, and FMBS at 2 mos (Table 2). Age, gender, and ethnicity were not found to be statistically significant predictors of the outcome variables. FMPS was significantly associated with FMBS but not with mean PPD and percentage of PPD > 4 mm at 2 mos. Overweight was not significantly associated with the outcome variables at 2 mos.

Multivariable Analysis

The multivariable GEE models indicated that not all of the explanatory factors included in the models were statistically significant independent predictors of all aspects of disease presentation at 2 mos (Table 3). Age was not a significant predictor, while smoking status, plaque, BMI kg/m², and obesity

Table 1. Baseline and Two-month Study Sample Characteristics (N = 260) Based on WHO Category of BMI

Variables, Mean (SD)	Normal (18.5-24.99 kg/m^2) N = 112	Overweight (25-29.99 kg/m^2) N = 93	Obese (≥ 30 kg/m^2) N = *55*	*p* value
BMI (kg/m^2)	22.57 (1.83)	26.96 (1.34)	32.94 (2.47)	
Age, yrs	46.30 (8.38)	47.27 (8.93)	46.55 (6.87)	.701
Gender: Male (%)	43 (38.4)	54 (58.1)	26 (47.3)	**.019**
Ethnicity: Non-Caucasian (%)	33 (29.5)	29 (31.2)	27 (49.1)	**.035**
Smoking status: Smoker (%)	47 (42.0)	25 (26.9)	15 (27.3)	**.045**

Bold denotes statistically significant result (ANOVA for continuous and Friedman test for categorical variables) if $p \leq .05$.
BMI = Body Mass Index; WHO = World Health Organization.

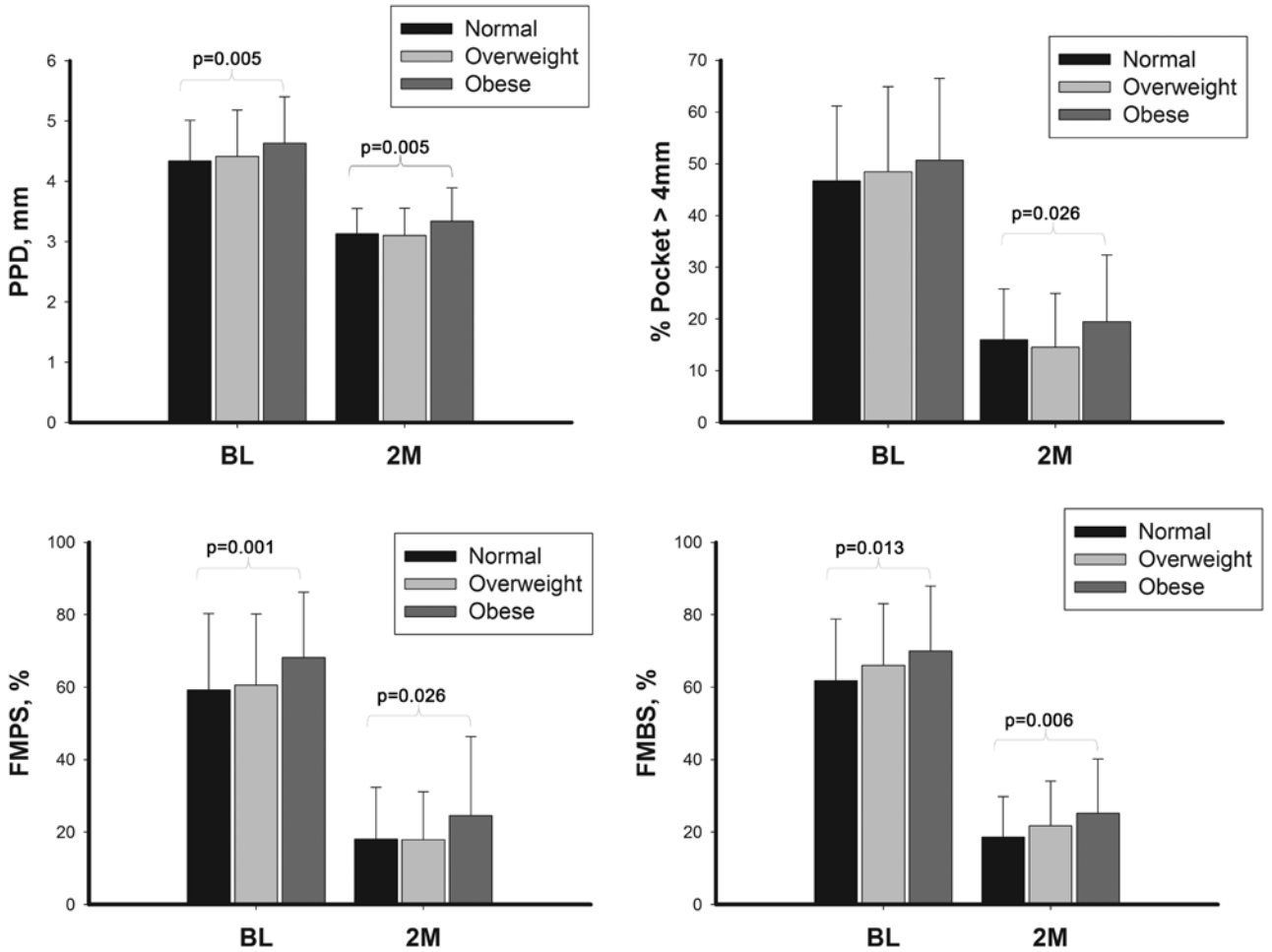

Figure. Differences in probing pocket depths (PPD), percentage of periodontal pockets > 4 mm, full-mouth dental plaque scores (FMPS), and full-mouth gingival bleeding scores (FMBS) across body mass index (BMI) groups at baseline (BL) and 2 mos (2M) after periodontal therapy. Bars represent mean ± SE. *p* values resulted from within-group comparisons (ANOVA).

were significantly associated with poorer periodontal treatment outcomes at 2 mos.

BMI and Periodontal Status 2 mos following Treatment (Model 1)

BMI (kg/m^2) had a statistically significant linear relationship with mean PPD ($p = .013$) and percentage of PPD > 4 mm ($p = < .001$), but not with FMBS ($p = .164$), independent of baseline values of each clinical variable and age, smoking status, or plaque. For every BMI increase of 10 kg/m^2, the mean percentage of sites with PPD > 4 mm increased by 2.5% (95% CI 1.10%, 3.80%).

Overweight or Obesity and Periodontal Status 2 mos following Treatment (Model 2)

Overweight compared with normal BMI status did not demonstrate a statistically significant association with mean PPD, percentage of sites with PPD > 4 mm, or FMBS at 2 mos after

Table 2. Summary of Univariable GEE Analysis Results (Coefficient, 95% CI)

Covariate	PPD at 2M	*p* value	% PPD > 4 mm at 2M	*p* value	FMBS at 2M	*p* value
Age (yrs)	–0.002 (–0.006, 0.003)	.497	–0.025 (–0.182, 0.132)	.754	–0.001 (–0.091, 0.892)	.987
Gender	0.037 (–0.066, 0.141)	.482	0.517 (–2.865, 3.89)	.765	–0.3493 (–4.550, 3.852)	.871
Ethnicity	–0.043 (–0.115, 0.029)	.245	–0.239 (–3.188, 2.709)	.874	–3.0215 (–6.216, 0.173)	.640
Smoking status	**0.171 (0.066, 0.275)**	**< .001**	**3.794 (0.364, 7.224)**	**.030**	**1.813 (0.588, 3.039)**	**.004**
FMPS at 2M	0.003 (–0.002, 0.008)	.183	0.029 (–0.075, 0.132)	.589	**0.321** (0.224, 0.417)	**0.001**
BMI kg/m^2	**0.0066 (0.001, 0.013)**	**.055**	**0.166 (0.028, 0.304)**	**.018**	**0.317 (0.139, 0.495)**	**< .001**
Overweight	–0.016 (–0.051, 0.019)	.372	–1.283 (–2.192, –0.374)	.006	1.093 (-3.053, 5.239)	.605
Obese	**0.112 (–0.006, 0.229)**	**.064**	**2.532 (–0.202, 5.267)**	**.070**	**2.685 (–0.238, 5.608)**	**.072**

Bold denotes statistically significant result if $p \leq .10$ in the direction of poorer clinical response from the generalized estimated equation (GEE) model.
Gender: Male = 1, Female = 0.
Ethnicity: Caucasian = 0, Non-Caucasian = 1.
Smoking: Smoker = 1, Non-smoker = 0.
FMPS = full-mouth % of sites with plaque.
BMI (Body Mass Index) normal = reference category for dummy variables 'BMI Overweight' and 'Obese'.
PPD: Probing pocket depths.
% PPD > 4 mm: full-mouth % of sites with probing pocket depths greater than 4 mm.
FMBS: full-mouth % of sites with bleeding upon probing.

Table 3. Summary of Multivariable GEE Analysis Results (Coefficient, 95% CI)

Model	Explanatory Variables	PPD at 2M	*p* value	% PPD > 4 mm at 2M	*p* value	FMBS at 2M	*p* value
Model 1	BMI kg/m^2	**0.009 (0.002, 0.016)**	**.013**	**0.245 (0.110, 0.379)**	**< .001**	0.243 (-0.996, 0.587)	.164
	Smoking	**0.185 (0.102, 0.267)**	**< .001**	**4.193 (1.165, 7.222)**	**.007**	**1.635 (0.599, 2.670)**	**.002**
	Plaque	0.003 (-0.001, 0.007)	.196	0.021 (-0.074, 0.115)	.668	**0.312 (0.213, 0.412)**	**< .001**
Model 2	Overweight*	0.013 (-0.041, 0.068)	.630	-0.683 (-1.459, 0.092)	.084	1.377 (-1.569, 4.325)	.360
	Obese*	**0.134 (0.011, 0.236)**	**.031**	**3.152 (0.683, 5.620)**	**.012**	1.325 (-2.769, 5.421)	.526
	Smoking	**0.179 (0.091, 0.267)**	**< .001**	**3.937 (0.632, 7.242)**	**.020**	**1.432 (0.612, 2.251)**	**< .001**
	Plaque	0.002 (-0.001, 0.007)	.170	0.016 (-0.066, 0.097)	.708	**0.319 (0.219, 0.419)**	**< .001**

Age and corresponding baseline variables are included as covariates in all models.
Bold denotes statistically significant result if $p \leq .05$ from the generalized estimated equation (GEE) model in the direction of poorer clinical response.
*Reference category = BMI (Body Mass Index) normal.
Smoking: Smoker = 1, Non-smoker = 0.
Plaque = full-mouth % of sites with plaque.
PPD: Probing pocket depths.
% PPD > 4 mm: full-mouth % of sites with probing pocket depths greater than 4 mm.
FMBS: full-mouth % of sites with bleeding upon probing.

adjustments for multiple covariates. Obesity compared with normal BMI status, however, remained a statistically significant predictor of mean PPD ($p = .031$) and percentage of PPD > 4 mm ($p = .012$), but not FMBS ($p = .526$), at 2 mos in the same multivariable model.

Obesity was an independent predictor of poorer periodontal treatment outcome at 2 mos ($p = .012$), such that those patients who were obese had, on average, 3.2% (95% CI 0.7% to 5.6%) more sites with PPD > 4 mm than those with a BMI within the normal range (after adjustment for baseline percentage of sites with PPD > 4 mm, age, and smoking status at 2 mos). The magnitude of this association was similar to that of smoking, where smokers had, on average, 3.9% (95% CI 0.6 to 7.3) more sites at 2 mos with PPD > 4 mm than did non-smokers.

DISCUSSION

This analysis provides evidence of a predictive role of continuous and categorical measures of BMI and clinical periodontal parameters following non-surgical periodontal therapy. It confirmed a linear association across increasing values of BMI and severity and extent of periodontitis. These associations were independent of differences in age, gender, smoking status, and dental plaque levels.

Previously published research has suggested a positive association among BMI, overweight or obesity, and the prevalence, extent, and severity of periodontitis. To date, there are few reports of an association between BMI and disease presentation following periodontal therapy (Zuza *et al.*, 2011; Lakkis *et al*., 2012; Altay *et al.*, 2013). The analyses presented indicated a linear relationship between BMI (kg/m^2 as a continuous measure) and periodontal status at 2 mos following treatment, measured as mean PPD and percentage of PPD > 4 mm, while FMBS at 2 mos was not statistically significant. For mean PPD and percentage of PPD > 4 mm, coefficients were small, suggesting a modest magnitude of effect.

The categorical analyses showed no evidence of a relationship between overweight and periodontal status 2 mos following non-surgical periodontal therapy. This lack of association was consistent with all explanatory variables considered, that is, mean PPD, percentage of sites with PPD > 4 mm, and FMBS 2 mos following treatment.

When analyzed as a continuous variable, increase in BMI and obesity compared with normal BMI was an independent predictor of poorer periodontal status 2 mos following non-surgical periodontal therapy. This association was consistent with two of the outcome variables considered, that is, mean PPD and percentage of sites with PPD > 4 mm, but not for FMBS 2 mos following treatment. The relationship between body weight and treatment outcomes may be influenced by a number of factors, as has been reported in previously published studies of periodontal status before therapy, including the known influence of plaque on bleeding on probing.

In Table 3, the magnitude of the association observed between obesity and clinical periodontal parameters is almost equal to that of smoking status. In the first of these analyses, having a BMI > 30 kg/m^2 resulted in 3.2% more sites with PPD > 4 mm, on average, than if the individual had a BMI between 18.5 and 24.99 kg/m^2. The similar magnitude of effect for a smoker compared with a non-smoker was 3.9% more sites, on average, with PPD > 4 mm at 2 mos. In a full dentition, 3.2% more sites equates to 6 sites, or one tooth. The association with mean PPD appears to be more modest with obesity, resulting in obese patients having a 0.14 mm greater mean PPD, on average, at 2 mos following therapy than those with BMI in a normal range. It is interesting to note that the magnitude of effect for smoking, although modest, has a 0.18 mm greater mean PPD at 2 mos following therapy than that for non-smokers.

The full-mouth level of dental plaque following periodontal therapy was not an independent predictor of mean PPD or the percentage of PPD > 4 mm at 2 mos in the univariable analyses. However, it was statistically significantly associated with FMBS. In both cases, the relationship between BMI as a continuous variable or obesity and both mean PPD and the percentage of sites > 4 mm remained unchanged when adjusted for plaque.

Numerous possible mechanisms to explain the association observed between obesity and periodontitis have been proposed: first, obesity as widely associated with a systemic and locally increased inflammatory response; second, obesity's influence on dental plaque quantity and composition; and finally, a combination of both. The hypothesis of greater inflammatory burden triggered by obesity is shared among other co-morbidities and not just periodontitis. Adipose tissue has been shown to alter macrophage as well as T- and B-cell functions (Maury and Brichard, 2010). Similarly, these factors have been identified as crucial during the onset and progression of chronic periodontitis. Further, variations in immune response could also result from the altered insulin sensitivity attributed to adipocyte function (Maury and Brichard, 2010). Like diabetes, abnormalities in the immune response may result in compromised healing associated with altered insulin sensitivity. A recent cross-sectional survey of 200 individuals demonstrated increased serum levels of pro-inflammatory adipokines/mediators (plasminogen activator inhibitor-1, C-reactive protein, fibrinogen) and triglycerides across BMI categories and worsening clinical periodontal parameters (Akman *et al*., 2012). Further research is needed to understand the exact wound-healing pathways responsible for different clinical responses in obese individuals. Two recently reported studies demonstrated statistically significant higher levels of circulating pro-inflammatory cytokines 3 mos after non-surgical periodontal therapy in obese compared with non-obese patients. Clinical periodontal outcomes at 3 mos did not show statistically significant differences in these study samples, contrary to the results from our analysis (Zuza *et al*., 2011; Altay *et al*., 2013). This discrepancy could be ascribed to the small sample size of the studies (fewer than 30 cases *per* group) and to the non-surgical therapy performed.

The validity of BMI as a measurement tool in investigating the association of obesity to disease or health risks is controversial (Vazquez *et al.*, 2007). In this project, analyses of body fat measurements together with BMI might have provided further insight into the nature of the association. Future studies of the relationship between periodontitis and body composition should

include visceral fat measures and appropriate methodology to continue validation of body composition measurements in assessing associated health risks and to facilitate understanding of possible mechanisms.

Our sample was representative of a severe periodontitis population with high levels of clinical disease, bleeding, and dental plaque. Our findings could therefore be limited in applicability to patients with milder forms of periodontitis. Further, we cannot exclude that individuals selected for these secondary analyses had undiagnosed glucose intolerance/prediabetes, which could have influenced the clinical periodontal outcomes. However, our sample was well-balanced in terms of age and gender and included primarily chronic periodontitis cases. In addition, it was representative of the United Kingdom population statistics of the prevalence of obesity, with 21.15% of the sample being classed as obese (BMI > 30) and the English population prevalence being estimated as 23.8% (Rennie and Jebb, 2005).

Although consistent and statistically significant, clinical relevance of the effect of magnitude of BMI or obesity on periodontal outcomes after 2 mos of healing remains unclear. Results may have been influenced by study limitations associated with sample size and unequal numbers in BMI categories. In addition, there are limitations to interpretation associated with the *post hoc* secondary analysis experimental design, although variation in clinical assessment and treatment was minimized by examiner and treatment clinician stability. This study does not constitute a high level of evidence in the context of evidence-based health care levels of scientific evidence; however, it is valuable in generating hypotheses for further design of future studies.

Obesity compared with normal BMI status was independently predictive of a worse response to periodontal therapy as assessed by periodontal status at 2 mos. In this severe chronic periodontitis sample, the magnitude of this effect was nearly that of smoking status.

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REFERENCES

Akman PT, Fentoglu O, Yilmaz G, Arpak N (2012). Serum plasminogen activator inhibitor-1 and tumor necrosis factor-alpha levels in obesity and periodontal disease. *J Periodontol* 83:1057-1062.

Altay U, Gurgan CA, Agbaht K (2013). Changes in inflammatory and metabolic parameters after periodontal treatment in patients with and without obesity. *J Periodontol* 84:13-23.

Bagchi D, Preuss HG (2013). Obesity epidemiology, pathophysiology and prevention. 2nd ed. Boca Raton, FL: CRC Press.

Bray GA (2004). Obesity is a chronic, relapsing neurochemical disease. *Int J Obes Relat Metab Disord* 28:34-38.

Chaffee BW, Weston SJ (2010). Association between chronic periodontal disease and obesity: a systematic review and meta-analysis. *J Periodontol* 81:1708-1724.

D'Aiuto F, Parkar M, Andreou G, Suvan J, Brett PM, Ready D, *et al*. (2004). Periodontitis and systemic inflammation: control of the local infection is associated with a reduction in serum inflammatory markers. *J Dent Res* 83:156-160.

D'Aiuto F, Nibali L, Parkar M, Suvan J, Tonetti MS (2005). Short-term effects of intensive periodontal therapy on serum inflammatory markers and cholesterol. *J Dent Res* 84:269-273.

D'Aiuto F, Parkar M, Nibali L, Suvan J, Lessem J, Tonetti MS (2006). Periodontal infections cause changes in traditional and novel cardiovascular risk factors: results from a randomized controlled clinical trial. *Am Heart J* 151:977-984.

Doyle SL, Lysaght J, Reynolds JV (2010). Obesity and post-operative complications in patients undergoing non-bariatric surgery. *Obes Rev* 11:875-886.

Eke PI, Dye BA, Wei L, Thornton-Evans GO, Genco RJ (2012). Prevalence of periodontitis in adults in the United States: 2009 and 2010. *J Dent Res* 91:914-920.

Falagas ME, Kompoti M (2006). Obesity and infection. *Lancet Infect Dis* 6:438-446.

Finucane MM, Stevens GA, Cowan MJ, Danaei G, Lin JK, Paciorek CJ, *et al*. (2011). National, regional, and global trends in body-mass index since 1980: systematic analysis of health examination surveys and epidemiological studies with 960 country-years and 9.1 million participants. *Lancet* 377:557-567.

Kornman KS, Page RC, Tonetti MS (1997). The host response to the microbial challenge in periodontitis: assembling the players. *Periodontol* 2000 14:33-53.

Lakkis D, Bissada NF, Saber A, Khaitan L, Palomo L, Narendran S, *et al*. (2012). Response to periodontal therapy in patients who had weight loss after bariatric surgery and obese counterparts: a pilot study. *J Periodontol* 83:684-689.

Maury E, Brichard SM (2010). Adipokine dysregulation, adipose tissue inflammation and metabolic syndrome. *Mol Cell Endocrinol* 314:1-16.

Ouchi N, Parker JL, Lugus JJ, Walsh K (2011). Adipokines in inflammation and metabolic disease. *Nat Rev Immunol* 11:85-97.

Rennie KL, Jebb SA (2005). Prevalence of obesity in Great Britain. *Obes Rev* 6:11-12.

StataCorp Stata Statistical Software: Release 13. College Station, TX, USA: StataCorp LP.

Suvan J, D'Aiuto F, Moles DR, Petrie A, Donos N (2011). Association between overweight/obesity and periodontitis in adults. A systematic review. *Obes Rev* 12:e381-e404.

Tonetti MS, D'Aiuto F, Nibali L, Donald A, Storry C, Parkar M, *et al*. (2007). Treatment of periodontitis and endothelial function. *N Engl J Med* 356:911-920.

Vazquez G, Duval S, Jacobs DR Jr, Silventoinen K (2007). Comparison of body mass index, waist circumference, and waist/hip ratio in predicting incident diabetes: a meta-analysis. *Epidemiol Rev* 29:115-128.

WHO (2008). Global Database on Body Mass Index. URL accessed on 10/10/2013 at: http://apps.who.int/bmi/index.jsp?introPage=intro_3.html.

WHO (2013). WHO Overweight and Obesity Fact Sheet No311. URL accessed on 10/10/2013 at: http://www.who.int/mediacentre/factsheets/fs311/en/

WHO (no authors listed) (2000). Obesity: preventing and managing the global epidemic: report of a WHO consultation. *World Health Organ Tech Rep Ser* 894:i-xii, 1-253.

Wilson JA, Clark JJ (2003). Obesity: impediment to wound healing. *Crit Care Nurs Q* 26:119-132.

Wilson JA, Clark JJ (2004). Obesity: impediment to postsurgical wound healing. *Adv Skin Wound Care* 17:426-435.

Zuza EP, Barroso EM, Carrareto AL, Pires JR, Carlos IZ, Theodoro LH, *et al*. (2011). The role of obesity as a modifying factor in patients undergoing non-surgical periodontal therapy. *J Periodontol* 82:676-682.