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Correlation between periodontal status and biting force in patients with chronic periodontitis during the maintenance phase of therapy

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Abstract

Aim: The association between periodontal status and biting force is unclear. The aim of this study was to investigate the relation between periodontal status and biting force in patients with chronic periodontitis during the maintenance phase of periodontal treatment.

Material and Methods: A total of 198 patients, who had entered a periodontal maintenance programme, were examined for the presence of restorations on the occlusal surface, probing pocket depth, clinical attachment loss (CAL), bleeding on probing, and mobility of teeth. Quantitative analysis of total biting force, occlusal contact area and biting pressure (defined by biting force per 1 mm^2 of occlusal contact area) was performed using microcapsular pressure-sensitive sheets.

Results: A multiple stepwise regression analysis showed that total biting force and occlusal contact area were positively associated with the number of present teeth and negatively associated with female gender, mean CAL and mean probing pocket depth. Biting pressure was positively associated with CAL.

Conclusions: Reduced periodontal support was found to be associated with decreased total biting force and with increased biting pressure (defined as force per 1 mm^2 of occlusal contact area).

Key words: biting force; biting pressure; maintenance phase; occlusal contact area; periodontal treatment; periodontitis

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Biting ability, including biting force and occlusal contact area, is a useful objective measure of masticatory function. Maximal biting force was positively correlated with masticatory performance, which was determined by the increase in dissolved gelatin from the surface of the standardized gummy jellies (Okiyama et al. 2003). Masticatory effectiveness, indicated by the percentage of sugar extracted from chewing gum in 20 strokes, was also shown to relate to maximal biting force (Heath 1982).

Biting ability is affected by the following factors: age (Yeh et al. 2000, Morita et al. 2003, Ikebe et al. 2005), gender (Morita et al. 2003, Ikebe et al. 2005), number of present teeth (Morita et al. 2003), types of prosthesis (Miyaura et al. 2000), salivary flow (Yeh et al. 2000) and temporomandibular joint disorder (Tortopidis et al. 1999). Ageing, female gender and reduction in the number of present teeth were negatively associated with biting force (Yeh et al. 2000, Morita et al. 2003, Ikebe et al. 2005). Biting force was also found to be positively correlated with salivary flow, regardless of age or gender (Yeh et al. 2000). The maximum biting force in the healthy subjects was higher than that in subjects with temporomandibular joint disorders (Tortopidis et al. 1999).

Conflict of interest and source of funding statement

The authors declare that they have no conflict of interests.
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The relation between biting ability and periodontal status is controversial. A study using pressure-sensitive sheets showed that the biting ability of subjects with healthy periodontia was significantly greater than that of chronic periodontitis patients (Alkan et al. 2006b). Monitoring the occlusal change using pressure-sensitive sheets has been reported to be useful for evaluating treatment prognosis in periodontal surgery (Alkan et al. 2006a). However, an epidemiological study using the sheet found that the periodontal condition had little effect on biting ability (Morita et al. 2003).

This study investigated the relation between the periodontal condition and biting ability in patients who had entered the maintenance phase of periodontal treatment.

Material and Methods

Subjects

A total of 198 patients, who attended the Department of Preventive Dentistry, Okayama University Hospital from September 2006 to June 2007, were recruited for this study. They had been diagnosed with chronic periodontitis and were in the maintenance phase of periodontal treatment. Individuals were excluded if they had temporomandibular dysfunction, more than 20% of sites with bleeding on probing (BOP), acute periodontitis that required medication with antibiotics in the previous 6 months and had no occlusal contacts between maxillary and mandibular teeth. In addition, patients with systemic diseases requiring antibiotic cover or patients who had received periodontal therapy 6 months before the study were excluded in the study. The subjects included 182 non-smokers, 14 current smokers and two past smokers. The study protocol was approved by the Ethical Committee of the Okayama University Graduate School of Medicine, Dentistry and Pharmaceutical Sciences. Written informed consent was obtained from all the subjects who agreed to participate.

Clinical examination

Two well-calibrated dentists recorded the following clinical data: probing pocket depth (PPD), clinical attachment loss (CAL), BOP, tooth mobility (Miyaura et al. 1999), and presence or absence of restoration on the occlusal surface of pre-molars and molars. The PPD and CAL were measured with a colour-coded probe (CP-8, Hu-Friedy, Chicago, IL, USA). The CAL was measured as the distance between the cemento-enamel junction and the base of the periodontal pocket. Both PPD and CAL, rounded to the nearest 1 mm, were assessed at six sites (mesio-buccal, mid-buccal, disto-buccal, mesio-lingual, mid-lingual and disto-lingual) for all teeth present. The BOP was recorded as present or absent after probing. Percentage of teeth with restorations on the occlusal surface in pre-molars and molars, mean PPD and CAL, percentage of teeth with CAL $\geqslant$ 4 mm, percentage of mobile teeth and percentage of the BOP-positive sites were calculated for each subject.

Measurement of biting ability

Biting force, occlusal contact area and biting pressure were measured by a pressure-sensitive sheet (Dental Prescale, Type-R 50H, Fuji Film, Tokyo, Japan) and analysed by an image scanner (Occluzer, FPD-707, Fuji Film). The pressure-sensitive sheet consisted of two paper sheets and numerous microcapsules containing a colour-forming material between them (Suzuki et al. 1997). The microcapsules are broken to react with a colour-developing material when the sheet is bitten on. According to the magnitude of the pressure applied, different densities of colour are formed. The biting force and occlusal contact area are calculated after scanning the sheet with an image scanner (Occluzer), taking into consideration the area and different densities of colour. The biting force (N) was determined as the sum of the degree of colouration and the area at each contact point. The area discoloured by biting was recorded as the occlusal contact area (mm^2). The biting pressure (MPa) is the biting force per 1 mm^2 of the occlusal contact area (Miyaura et al. 1999).

The subjects were seated with their heads upright and in an unsupported natural head position. After several trial attempts to maintain an intercuspal bite, the sheet was placed into the patient's mouth so that the midline of the arch coincided with the midline of the sheet. Care was taken to include all of the teeth in the mouth. The buccal mucosa was retracted so as not to deform the sheet. Each patient was instructed to bite as forcefully as possible for about 3 s. Subjects, who were wearing removable partial dentures, were asked to remove the denture before measuring biting ability.

Statistical analysis

To determine the sample size required for multiple regression, a power analysis (Milton 1986) was used. We had planned a study that included four independent variables in a model anticipated to explain 10–20% of the variance in given dependent variables, i.e., biting force, occlusal contact area and biting pressure, on the basis of the previous research results (Morita et al. 2003). Further, we wished to select a sample large enough to assure that any independent variable contributing an additional 5% of the explained variance to the model would be significant at the 0.05 level. Using this procedure, the sample size required was 149–167.

Data were analysed using a statistical package (15.0 J for Windows, SPSS Japan, Tokyo, Japan). Gender differences in age, clinical parameters and biting ability were evaluated using Student's *t*-test and a significant value of $p < 0.0045$ was used, according to Bonferroni's correction because of the multiple comparisons for 11 variables. Correlations between the biting ability and age or clinical indices were analysed by calculating Pearson's correlation coefficients. Multiple stepwise regression analysis was performed to rank the effect of the following factors (the independent variables) on the biting force, occlusal contact area and biting pressure (the dependent variables). Factors selected as independent variables were age, gender, number of present teeth, percentage of teeth with restorations on the occlusal surface of pre-molars and molars, mean PPD and CAL, and percentage of mobile teeth.

Results

The age and gender distribution of the subjects are shown in Table 1. Mean CAL and percentage of teeth with CAL $\geqslant$ 4 mm in males were greater than those in females ($p < 0.001$) (Table 2). There was no gender difference in the biting force ($p = 0.095$), occlusal contact area ($p = 0.097$) and biting pressure ($p = 0.495$).

Pearson's correlation coefficients between age and other parameters are shown in Table 3. Age was negatively correlated with biting force ($r = -0.21$; $p < 0.01$) and occlusal contact area ($r = -0.22$; $p < 0.01$). The number of present teeth was positively correlated with the biting force ($r = 0.53$; $p < 0.001$) and occlusal contact area ($r = 0.55$; $p < 0.001$). Moreover, the number of teeth present was weakly but statistically significantly negatively correlated with biting pressure ($r = -0.17$; $p < 0.05$). The percentage of teeth with restorations on the occlusal surface of pre-molars and molars had a low negative correlation with mean PPD ($r = -0.14$; $p < 0.05$) and total occlusal contact area ($r = -0.16$; $p < 0.05$). Similarly, biting force and total occlusal contact area were weakly correlated with mean PPD ($r = -0.30$; $p < 0.001$ and $r = -0.29$; $p < 0.001$, respectively). Biting force and total occlusal contact area had moderately negative correlations with mean CAL ($r = -0.42$; $p < 0.001$ and $r = -0.44$; $p < 0.001$, respectively), while biting pressure was weakly but positively correlated with mean CAL (Fig. 1), percentage of teeth with CAL $\geqslant$ 4 mm and percent mobile teeth ($r = 0.18$; $p < 0.05$ for all). Biting force and total occlusal contact area had moderately negative correlations with the percentage of teeth with CAL $\geqslant$ 4 mm ($r = -0.37$; $p < 0.001$ and $r = -0.39$; $p < 0.001$, respectively). Similarly, biting force and total occlusal contact area had moderately negative correlations with the percentage of mobile teeth ($r = -0.36$; $p < 0.001$ and $r = -0.39$; $p < 0.001$, respectively). There was no statistically significant association of the percentage of sites that bled on probing and any occlusal parameters.

The results of multiple stepwise regression analysis indicated that total biting force and total occlusal contact area were positively correlated with the number of teeth present ($\beta = 0.40$; $p < 0.001$ and $\beta = 0.42$; $p < 0.001$, respectively) and negatively correlated with mean CAL ($\beta = -0.22$; $p = 0.003$ and $\beta = -0.25$; $p = 0.001$, respectively). Total biting force and total occlusal contact area were also negatively correlated with female gender ($\beta = -0.27$; $p < 0.001$ and $\beta = -0.28$; $p < 0.001$, respectively). Total biting force and total occlusal contact area were weakly and negatively correlated with mean PPD ($\beta = -0.16$; $p = 0.013$ and $\beta = -0.15$, $p = 0.021$, respectively). Mean CAL was the only independent variable ($\beta = 0.18$; $p < 0.010$) that was significantly associated with biting pressure when it was used as a dependent variable.

Table 1. Age and gender distribution of subjects

Age group (years)	Male	Female	Total
30–39	1	5	6
40–49	2	6	8
50–59	16	38	54
60–69	22	49	71
70–79	13	33	46
80–89	5	7	12
90–99	1	0	1
Total	60	138	198

Table 2. Age, clinical parameters and biting ability (mean ± SD)

	Male	Female	Total
Age	65.4 ± 10.1	63.5 ± 10.5	64.4 ± 10.4
Number of present teeth	23.4 ± 5.3	24.3 ± 4.3	24.0 ± 4.6
% of teeth with restorations on the occlusal surface of pre-molars and molars	61.9 ± 28.7	72.4 ± 24.4	69.2 ± 26.2
Mean probing pocket depth (mm)	1.9 ± 0.4	1.7 ± 0.3	1.8 ± 0.4
Clinical attachment loss (CAL)			
Mean CAL (mm)	3.1 ± 1.0	2.5 ± 0.7*	2.7 ± 0.9
% of teeth with CAL $\geqslant$ 4 mm	53.3 ± 30.2	34.8 ± 25.9*	40.4 ± 28.5
% of mobile teeth	14.4 ± 19.3	8.9 ± 13.6	10.6 ± 15.7
% of sites with bleeding on probing	7.7 ± 5.9	7.2 ± 5.6	7.3 ± 5.7
Total biting force (N)	526 ± 313	451 ± 281	474 ± 292
Total occlusal contact area (mm^2)	15.7 ± 10.1	13.3 ± 8.2	14.0 ± 8.9
Biting pressure (force per mm^2 occlusal contact area)	35.8 ± 8.9	34.9 ± 8.1	35.2 ± 8.3

*$p < 0.001$, significantly different from males (*t*-test with Bonferroni's correction).

Table 3. Pearson's correlation coefficients between occlusal parameters and other clinical parameters

	Total biting force	Total occlusal contact area	Biting pressure (force per mm^2 occlusal contact area)
Age	−0.21**	−0.22**	0.05
Number of present teeth	0.53***	0.55***	−0.17*
% of teeth with restorations on the occlusal surface of pre-molars and molars	−0.14*	−0.15*	0.04
Mean probing pocket depth (mm)	−0.30***	−0.29***	0.08
Clinical attachment loss (CAL)			
Mean CAL (mm)	−0.42***	−0.44***	0.18*
% of teeth with CAL $\geqslant$ 4 mm	−0.37***	−0.39***	0.18*
% of mobile teeth	−0.36***	−0.39***	0.18*
% of sites with bleeding on probing	−0.11	−0.11	0.04

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

Discussion

The multiple stepwise regression analysis in this study demonstrated that the biting force and occlusal contact area were significantly (albeit weakly) correlated with mean CAL after adjusting for the number of present teeth and gender, both of which have been reported to relate to the biting ability (Morita et al. 2003, Ikebe et al. 2005). These results suggest that reduced periodontal support may be a factor in determining the masticatory ability of patients with chronic periodontitis in maintenance therapy.

Further studies are needed to clarify the reason as to why reduced periodontal support affects biting ability. Reduced periodontal support might decrease the threshold level of the mechanoreceptor function because the loading forces during mastication induced by the masticatory muscles are controlled by the mechanoreceptors of the periodontal ligament (Hannam 1976). Moreover, patients who are aware of the reduced periodontal tissue

support may unconsciously limit their biting force. Because the biting ability is closely related to masticatory performance (Okiyama et al. 2003) and dietary selection (Heath 1982), reduced periodontal support might also affect the selection of food.

In addition to the negative correlation between biting force or occlusal contact area and mean CAL, biting pressure was weakly but positively associated with mean CAL ($r = 0.18$; $p < 0.05$). Therefore, if periodontal destruction is associated with increased biting pressure, it could result in overload to the reduced periodontium during mastication. Peripheral neural mechanisms might be impaired by the reduced ligament support of the teeth during the progression of the disease. This assumption is supported by the study (Johansson et al. 2006), which showed that subjects with reduced periodontium had greater holding forces between a pair of opposing incisors than healthy subjects. Because excessive occlusal force may be a risk factor of periodontal destruction (Harrel 2003) and recurrence of periodontitis is a major cause of tooth loss during supportive periodontal treatment (König et al. 2002), careful monitoring of excessive occlusal forces should be considered during supportive periodontal treatment.

Total biting force and total occlusal contact area were negatively associated with mean CAL. The results were consistent with those of a clinical study using pressure-sensitive sheets, which showed that biting force and occlusal contact area of chronic periodontitis patients were lower than those of control subjects with healthy periodontium (Alkan et al. 2006b). However, the findings of the present study did not agree with those of an epidemiological study using pressure-sensitive microcapsular sheets, which reported that stepwise multiple linear regression found no correlation between periodontal status and biting ability (Morita et al. 2003). The reason for the discrepancy between the studies may be because of differences in the severity of periodontal disease. The mean CAL in the study by Morita et al. (2003) was 1.96 mm, which was lower than that of the present study (2.7 mm) and that of the study by Alkan et al. (2006b) (4.16 mm for periodontitis patients). Biting force and occlusal contact area might be influenced by moderate to severe loss of periodontal tissue support, but not slight loss.

The disparity in the results could also be due to the increased periodontal inflammation in the study subjects of Morita et al. (2003) compared with that in the present study. The mean percentage of BOP in the study by Morita et al. (2003) (18.1) was higher than that of the present study (7.7). Because periodontal inflammation has been reported as a factor that affects the threshold level of mechanoreceptors (Van Steenberghe et al. 1981), periodontal inflammation might have modified the relation between biting ability and CAL in the study by Morita et al. (2003).

In contrast with our findings, a study that measured maximum biting force at 4 mm mouth opening reported that reduced periodontal tissue support did not limit biting force (Kleinfelder & Ludwig 2002). The number of study subjects, the difference of the measuring device and the measurement area (molar regions *versus* all arch) might explain the differences in results between the two studies.

The number of present teeth and male gender were positively associated with biting force and occlusal contact area and these results were in agreement with those of other studies (Morita et al. 2003). No gender difference was

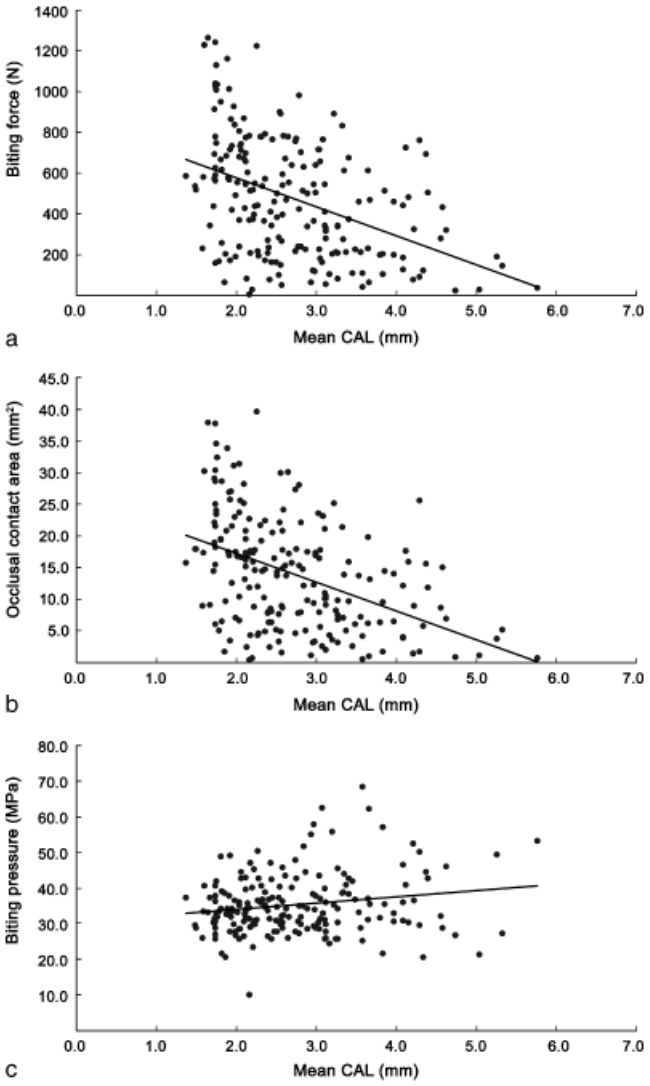

Fig. 1. Relationship between mean clinical attachment loss (CAL) and biting ability ($n = 198$). Mean CAL is negatively associated with biting force (N) (a) and occlusal contact area (b), and positively associated with biting pressure (the biting force per 1 mm^2 of the occlusal contact area: MPa) (c). The solid lines represent regression lines.

Table 4. Stepwise multiple regression analysis of biting ability

Dependent variables	Independent variables	Non-standardized		Standardized β	p	R^2
		B	SE			
Total biting force	Number of teeth present	25.52	4.15	0.40	<0.001	0.37
	Mean CAL	−74.73	25.19	−0.22	0.003	
	Gender	−168.33	38.18	−0.27	<0.001	
	Mean PPD	−132.22	52.80	−0.16	0.013	
Total occlusal contact area	Number of teeth present	0.80	0.12	0.42	<0.001	0.41
	Mean CAL	−2.54	0.75	−0.25	0.001	
	Gender	−5.40	1.13	−0.28	<0.001	
	Mean PPD	−3.63	1.56	−0.15	0.021	
Biting pressure (force per mm^2 occlusal contact area)	Mean CAL	1.77	0.68	0.18	0.010	0.03

Independent variables were age, gender (male: 0, female: 1), number of teeth present, % of teeth with restorations on the occlusal surface of pre-molars and molars, mean probing pocket depth (PPD), mean clinical attachment loss (CAL), and % of mobile teeth.

observed in biting ability (Table 2); however, gender was selected as a significant independent variable that would influence biting force and occlusal contact area (Table 4). The discrepancy is ascribed to the difference in the degree of mean CAL between the sexes, i.e., males had larger mean CAL and larger biting ability than females in this study.

Age was not selected as an independent variable in the multiple stepwise regression analysis in this study. This is consistent with that of another study (Miyaura et al. 1999). Some studies showed that ageing was a significant contributing factor for reduction of biting ability (Yeh et al. 2000, Ikebe et al. 2005). The variation in results might be explained by the difference in the statistical method. In the present study and that by Miyaura et al. (1999), the number of present teeth was adjusted for when evaluating the effect of ageing on biting ability; however, Yeh et al. (2000) and Ikebe et al. (2005) did not take into consideration the number of teeth present. The number of teeth might strongly affect the biting ability rather than ageing.

When analysed by calculating Pearson's correlation coefficients (Table 3), there was a statistically significant association of the percentage of mobile teeth with biting force, occlusal contact area and biting pressure; however, it was not selected as an independent variable during the multiple stepwise regression analysis. The percentage of mobile teeth was not part of the final regression models because of Pearson's correlation coefficients between mean CAL and the percentage of mobile teeth was 0.61 ($p<0.001$) (data not shown). In addition, biting force, occlusal contact area and biting pressure were slightly more correlated with mean CAL than the percentage of mobile teeth (Table 3). Because mean CAL had been selected as an independent variable earlier than the percentage of mobile teeth during the multiple stepwise regression analysis and adding the percentage of mobile teeth had little influence, the percentage of mobile teeth was not used in the multiple regression analysis.

In conclusion, total biting force and total contact area were positively associated with CAL after adjusting for the number of present teeth and gender. These results suggest that reduced periodontal support negatively affects masticatory ability.

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Clinical Relevance

Scientific rationale for the study: The association between biting force and periodontal status is controversial. This study evaluated the association of periodontal status and biting force in patients with chronic periodontitis during the maintenance phase of periodontal therapy.

Principal findings: Mean clinical attachment loss was negatively associated with total biting force and total occlusal contact area, independent of the number of teeth present and gender, both of which were considered to be related to biting force.

Practical implications: These results suggest that reduced periodontal support negatively affects masticatory ability. Moreover, increased biting pressure in patients with reduced periodontal support could result in overload to the periodontium during mastication. If so, careful monitoring for excessive occlusal forces during supportive periodontal treatment may be indicated.