Acta Odontologica Scandinavica. 2016; 74: 115–120

ORIGINAL ARTICLE

A cross-sectional study of the associations between periodontitis and carotid arterial calcifications in an elderly population

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Abstract

Objective. To evaluate if the presence of periodontitis is associated with carotid arterial calcifications diagnosed on panoramic radiographs in an elderly population. ***Materials and methods.*** Study individuals were randomly selected from the Swedish civil registration database representing the aging population (60–96 years) in Karlskrona, Sweden. Bleeding on probing (BOP) and the deepest probing measurement at each tooth were registered. The proportions of teeth with a probing depth ≥5 mm and the proportion of teeth with bleeding on probing were calculated. Analog panoramic radiographs were taken and the proportion of sites with a distance ≥5 mm between the alveolar bone level and the cement–enamel junction (CEJ) were assessed. A diagnosis of periodontitis was declared if a distance between the alveolar bone level and the CEJ ≥5 mm could be identified from the panoramic radiographs at >10% of sites, probing depth of ≥5 mm at one tooth or more and with BOP at >20% of teeth. ***Results.*** Readable radiographs were obtained from 499 individuals. Carotid calcification was identified in 39.1%. Individuals were diagnosed with periodontitis in 18.4%. Data analysis demonstrated that individuals with periodontitis had a higher prevalence of carotid calcifications (Pearson $\chi^2 = 4.05$ $p < 0.05$) and with a likelihood of 1.5 (95% CI = 1.0, 2.3, $p < 0.05$). ***Conclusions.*** Data analysis demonstrated a significant association between periodontitis and carotid calcification.

Key Words: *Carotid arterial calcifications, panoramic radiographs, periodontitis*

Introduction

Over the past decades, the lifespan in Western societies has steadily increased. The main cause of serious illness or death has shifted from acute infections to chronic diseases [1,2]. In developed countries cardiovascular diseases (CVD) comprise a variety of heart and vascular conditions and are responsible for ~30% of all cases of mortality [1]. Atherosclerosis is the primary reason for myocardial infarction, stroke and thromboembolic events. Development of atherosclerosis is a lifelong process, starting in early childhood, with clinical manifestations many years after [3]. Atherosclerotic disease is common in the area where the carotid artery bifurcates into the internal and external carotid arteries [4]. It is widely accepted that age, gender, high blood pressure, smoking, dyslipidaemia and diabetes are major risk factors for the development of cardiovascular disease [5]. Chronic inflammation may also result in atherosclerosis and is considered a risk factor for cardiovascular disease [6,7].

Over the last 10 years, epidemiological studies have focused on potential associations between chronic oral infections and cardiovascular disease. In a systematic review assessing the incidence of cardiovascular events a statistically significant increased risk for atherosclerotic cardiovascular disease was reported in individuals with periodontitis [8]. Periodontitis is a bacterially-induced, chronic inflammatory disease that destroys connective tissues and alveolar bone, resulting in tooth loss [9].

Periodontitis may result in bacteraemia. The bacteria may invade the endothelial layer and further spread into deeper tissue and activate the host inflammatory response by multiple mechanisms [10,11]. Atheromas can grow due to macrophage-secreted

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(Received 14 January 2015; accepted 6 May 2015)

ISSN 0001-6357 print/ISSN 1502-3850 online
DOI: 10.3109/00016357.2015.1050603

growth factors mediating smooth muscle cell proliferation [7]. Data have shown that patients with periodontitis have higher C-reactive protein values (hs-CRP) in serum indicating a generalized inflammatory effect of the disease [12–14]. Periodontitis has been associated with endothelial dysfunction and subclinical carotid atherosclerosis (intima media thickness) correlating with future cardiovascular disease events including stroke [15–21] and it has also been demonstrated that an infection with major periodontal pathogens is associated with a future stroke [22].

Carotid artery calcification can be identified on panoramic dental radiographs [23–27]. Data suggest that periodontitis may be related to evidence of carotid calcification [28–32]. A recent literature review reporting on the associations between periodontitis and carotid calcification on panoramic dental radiographs concluded that periodontitis was more often identified among individuals with radiographic evidence of carotid calcification. This literature review also indicated that carotid calcification is more frequently found in panoramic dental radiographs from older adults [33].

The objective of the present study was to evaluate if periodontitis is associated with the presence of carotid arterial calcifications diagnosed on panoramic radiographs in an elderly population.

Materials and methods

Individuals

The Regional Ethics Committee Lund, Sweden, approved the study (LU 605-00, LU 744-00). All enrolled participants signed an informed consent form. Details of the study population have been presented elsewhere [34–36]. Study individuals were randomly selected from the Swedish civil registration database representing the aging population (60–96 years) in Karlskrona community, Sweden. The enrolment of study individuals occurred between 2001–2004. Study individuals were invited by mail. The study samples were selected randomly in age cohorts of 60, 66, 72 and 78 years. In the age cohorts of 81, 84, 87, 90, 93 and 96 years, all inhabitants were included. Study individuals were divided into sub-groups in the age cohorts between 60–72 years (young-old) and individuals between ages 78–96 years (old-old).

In the present report, dentate individuals with >10 teeth and with panoramic radiographs allowing for analysis of the area of interest for detection of carotid calcification were included.

Dental examinations

Two experienced dental hygienists performed routine clinical dental examinations. Periodontal probes (CP-12 probes, Hu-Friedy Inc. Chicago, IL) were used to measure probing depths (PD) at four sites of all existing teeth including fully erupted third molars. Within each individual, the presence of bleeding or not, and the PD value using the value at the site of each tooth with the deepest PD was used to calculate the proportions of teeth with a probing depth ≥ 5 mm and the proportion of teeth with bleeding on probing.

Analog panoramic radiographs (Orthopantomograph OP 100, Instrumentarium, Tuusala, Finland) were taken with a standard exposure of 75 kV/10 mA. The extent of alveolar bone loss was measured at the mesial and distal aspects of existing teeth (third molars not included). The number of inter-proximal sites that could be assessed from the panoramic radiographs was used to calculate the proportion of sites with a distance ≥5 mm between the alveolar bone level and the cement–enamel junction (CEJ). A millimeter graded transparent plastic ruler, a 2× magnification viewer and a light view box source provided the conditions by which the distances between the alveolar bone level and CEJ were measured. An independent experienced examiner (REP) masked to the information about medical and dental information, gender, age and survival status performed all the radiographic measurements.

Reliability measurements were made for double reading of X-rays. The ICC correlation coefficient between the two observer measurements for the distance between the apex and CEJ was 0.93 (95% CI = 0.91–0.96, $p < 0.01$) and was based on a total of 91 observations, with a mean difference of 0.94 mm (SD = ±1.3).

The periodontal diagnosis was defined by the extent of bone level loss, probing depth (PD) and bleeding on probing (BOP). Thus, a diagnosis of periodontitis was declared if a distance between the alveolar bone level and the CEJ ≥5 mm could be identified from the panoramic radiographs presented at >10% of sites, PD of ≥5 mm at one tooth or more and with bleeding on probing at >20% of teeth.

Statistical methods

The data were analyzed using descriptive statistics. Independent *t*-tests (equal variance not assumed) and non-parametric tests (Mann–Whitney U-test) were performed to assess group differences. The data were also analyzed using Pearson's χ^2 test and Mantel–Haenszel common odds ratio. Statistical significance was declared at $p < 0.05$. The SPSS PASW 22.0 statistical software (SPSS Inc., Chicago, IL) for an Apple computer was used in the analysis.

Table I. Comparisons between the young-old and the old-old age cohorts with >10 teeth.

Variable	Young-Old (n = 433)			Old-Old (n = 281)			Significance
Remaining teeth, n	23.0 ± 4.4			18.7 ± 5.0			$p < 0.001$
BoP (%)	24.1 ± 21.4			27.1 ± 24.2			$p = 0.10$
Periodontitis	Positive	Negative		Positive	Negative		χ^2 =10.1
Composite definition (%)	16.2	83.8		26.0	74.0		$p < 0.001$ OR = 1.8, 95% CI = 1.3, 2.6, $p < 0.001$
Carotid calcification (%)	Positive	Negative	NR*	Positive	Negative	NR*	χ^2 = 7.3
	23.1	44.6	32.3	33.7	39.5	26.7	$p < 0.01$ OR = 1.7, 95% CI = 1.2, 2.4 $p < 0.01$

* Non Readable (NR) radiographs were not included in the χ^2 analysis.

Results

The present study included 714 individuals with ≥10 teeth as assessed from the panoramic radiographs. The area of interest for detecting carotid calcifications was not readable on 215 radiographs (30.1%), leaving a total of 499 individuals (313 women; 62.7%) in the study. Thus, the study included 293 (58.7%) in the age cohort between 60–72 years (young-old) and 206 (41.3%) individuals between ages 78–93 (old-old). On average, study individuals had 21.3 remaining teeth (SD = ±5.1). The average proportion of teeth with BOP was 25.3% (SD = ±22.6%). A positive finding suggesting carotid calcification was identified in 195/499 individuals (39.1%). Using the composite definition of periodontitis, 91 out of the 499 individuals had a diagnosis of periodontitis (18.4%).

Differences in relation to age and gender

Results from the data analysis for the comparisons between the young-old and old-old cohorts are presented in Table I. Statistical analysis failed to demonstrate differences in BOP by age category. The prevalence of periodontitis as defined above was higher in the older cohort (Pearson χ^2 = 10.1, $p < 0.001$) with a likelihood of 1.8 (95% CI = 1.3, 2.6, $p < 0.001$). A diagnosis of periodontitis was higher among men (Pearson χ^2 = 12.9, $p < 0.001$) with a likelihood of 2.0 (95% CI = 1.4, 2.9, $p < 0.001$). Based on panoramic readings, the older cohort had significantly more signs of carotid calcification with a likelihood of 1.7 (95% CI = 1.1, 2.4, $p < 0.01$). In the younger age cohort, signs of carotid calcification were significantly higher among men (Pearson χ^2 = 5.2, $p < 0.05$) with a likelihood of 1.8 (95% CI = 1.1, 2.9, $p < 0.05$). Males had more evidence of carotid calcifications than women (Pearson χ^2 = 4.6, $p < 0.05$), with a likelihood of 1.5 (95% CI = 1.0, 2.2, $p < 0.05$).

Relationship between periodontitis and the evidence of carotid calcification

Data analysis demonstrated that individuals with periodontitis had a higher prevalence of carotid calcifications (Pearson χ^2 = 4.05 $p < 0.05$) and with a likelihood of 1.5 (95% CI = 1.0, 2.3, $p < 0.05$).

Discussion

The present study has shown that there was a significant association between periodontitis and carotid arterial calcifications as measured on panoramic radiographs in this aging population (60–96). The prevalence of periodontitis as well as signs of carotid calcification was higher in the older cohort. Using the composite definition of periodontitis, 18.4% had a diagnosis of periodontitis and with higher likelihood among men. This observation is consistent with other studies demonstrating worse periodontal conditions among men [37,38]. In a recent publication by Kassebaum et al. [39] severe periodontitis was reported to be the sixth most prevalent condition in the world and the prevalence of periodontitis was reported to increase with age. Depending on the criteria used to define periodontitis, the prevalence of periodontitis in the US varies between 12–76% [38,40]. A past experience of periodontitis can be assessed by attachment loss and/or loss of alveolar bone, whereas assessment of present disease requires additional measurement such as BOP and PD. A high agreement between panoramic radiographs, periapical radiographs and posterior bite-wing radiographs with regards to periodontal bone height measurements has been demonstrated [41,42].

Data from 'The National Health and Nutrition Examination Survey (NHANES) 2009–2010' reported the prevalence of moderate and severe periodontitis in the adult American population to be

38.5%. Periodontitis was based on clinical parameters into (1) *severe periodontitis*, as the presence of two or more interproximal sites with ≥6 mm attachment level (AL) and one or more interproximal site with ≥5 mm PD; (2) *moderate periodontitis*, as two or more interproximal sites with ≥4 mm AL or two or more interproximal sites with PD ≥5 mm; or (3) *mild periodontitis*, defined as two or more interproximal sites with ≥3 mm AL and two or more interproximal sites with ≥4 mm PD or one site with ≥5 mm [40]. The definition of periodontitis used in the present study combined clinical parameters PD >5 mm at one or more teeth, radiographic parameters as a distance between bone level and the CEJ ≥5 mm at >10% of sites and with BOP at >20% of teeth. In spite of these more strict criteria for periodontitis, 18.4% of the individuals were identified in the present study as having periodontitis. Severe periodontitis was found in 8.5% among individuals ≥65 years in the NHANES (National Health and Nutritional Examination Survey) study by Eke et al. [40]. Most likely, the diagnosis of periodontitis in our study is more comparable to the *severe* form according to the definitions used by Eke et al. [40].

To be included, the study individuals had to have a minimum of >10 teeth and in the dental examination all teeth were measured at four sites including fully erupted third molars. The presence of bleeding or not and the PD value using the value at the site of each tooth with the deepest PD were registered. Kingman et al. [43] showed that half-mouth protocol correctly identified 60% of patients with attachment loss ≥3 mm, whereas full-mouth examination of the same sites identified 74%. According to Kingman et al. [43], our study with full mouth examination should correctly identify more patients with periodontitis compared to a half-mouth examination.

In the present study alveolar bone loss was assessed from panoramic radiographs. It has been demonstrated that findings of carotid calcifications on panoramic radiographs are in agreement with ultrasonography assessments [28]. Associations between periodontitis and the evidence of carotid calcifications on panoramic radiographs (PMX) have previously been reported using both small populations [28,30] and larger populations [25,44]. The present study included 499 individuals and the results are in agreement to what has previously been reported from four studies. Ravon et al. [28] demonstrated a dose–response relationship between absence and presence and the size of carotid calcification and severity of periodontitis. In a recent review the authors concluded that periodontitis was more often identified among individuals with radiographic evidence of carotid calcifications on panoramic radiographs and is consistent with the result in the present study [33].

Carotid artery calcification in the area of the carotid artery bifurcation can be detected on panoramic radiographs in the range of 2–5% of the population [33]. In the present study, a positive finding suggesting carotid calcification was identified in 195/499 individuals (39.1%). The frequency of carotid calcification is high in the present study. One explanation could be the high age of the individuals. Previous studies and literature reviews have shown that carotid calcifications are more frequent in older individuals [44,45]. In the present study, carotid calcifications were frequently detected among men in the younger age cohort. This could, to some degree, explain why life expectancy is shorter for men. There is a general agreement that men in the Western world have a shorter life expectancy than women and that men on average are younger than women at stroke onset [46].

In our study we never met the frailest individuals as they were unable to come to the research clinic and, accordingly, could not undergo dental examination or panoramic radiographic examination. This is of course a limitation of the present study, but is also inevitable when working with a group of elderly individuals. The results reported in the present study, however, reflect the situation among elderly individuals healthy enough to be able to attend a dental examination.

Only 10 individuals (2%) reported a current smoking habit, therefore data were not corrected for smoking habits.

In summary the results of the present study suggest that if a panoramic radiograph is taken the clinician should assess the inter-vertebral space between C3 and C4, especially if the patient has a diagnosis of periodontitis, is of older age and male gender. In cases where carotid calcifications are found the patient should be referred to medical evaluation.

Acknowledgements

We acknowledge the contribution of Rigmor Persson (REP), University of Washington, in assessing the radiographs. We also want to acknowledge Ingrid Jonasson, Blekinge Institute of Technology, for clinical data collection and Johanna Renvert, University of Kristianstad, for data management.

***Declaration of interest*:** The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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