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Association between carotid area calcifications and periodontal risk: a cross sectional study of panoramic radiographic findings

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Abstract

Background: The aim was to investigate the extent to which it is possible to diagnose suspected carotid calcification from dental panoramic radiography (PR) and to establish an association to periodontal risk.

Methods: 824 PRs from one dental practice were investigated. Parameters considered were gender, age, bone loss - age index, tooth loss, periodontal risk and suspected carotid calcification (left, right, both sides). Periodontal risk was classified: low risk (under 4 missing teeth, bone loss - age index under 0.5), moderate risk (5 to 8 missing teeth and/or bone loss - age index 0.5 to 1.0) and high risk (more than 9 missing teeth and or bone loss - age index greater than 1.0).

Results: Of 824 patients, 349 were male (42.4%) and 475 female (57.6%); the mean age was 48.32 ± 16.52 years. In 9.0% (n = 74) of PRs, suspected carotid calcification was diagnosed (right: 5.5%, left: 2.3%, both sides: 1.2%). The mean tooth loss was 4.16 ± 5.39 teeth. In the case of 282 patients (34.2%), there was a low, in 335 patients (40.7%) a moderate, and in 207 patients (25.1%) a high periodontal risk. There was a significant correlation found between number of cases of suspected carotid calcification and periodontal risk, tooth loss and age ($p = 0.0001$). However, only age showed a significant association (OR: 4.9; CI: 2.4-9.8; $p < 0.0001$) in contrast to periodontal risk (OR 1.4; CI: 0.9-2.4).

Conclusion: PR can provide indication of carotid calcification as a secondary (chance) finding. In addition, periodontal risk may be correlated with positive findings of carotid calcification.

Background

Cardiovascular diseases such as coronary heart disease (CHD) and apoplexy, as well as cerebrovascular infarct, are amongst the most frequent causes of death in industrialized countries [1,2]. Also, some cerebrovascular insults are preceded by stenosis and/or calcification of the carotid artery [3]. Moreover, diagnosed calcification of the carotid artery can be a sign of additional calcification of the coronary arteries [3].

Early recognition of such calcifications could therefore minimize the risk of a subsequent stroke or coronary heart disease (CHD). Until now, sonography has been considered to be the "gold standard", amongst non-invasive techniques used to establish arteriosclerotic changes

in the extra-cranial vessels, such as the carotid artery [4]. However, ultrasound investigations are not routinely carried out as a preventative measure in all patients. More time-consuming methods of diagnosing calcification, such as computer tomography (CT), magnet resonance tomography (MRT) and electronic thermography (ET), as well as the invasive method of angiography, have special indications and are not routinely used for all patients [5]. Accordingly, alternative diagnostic aids to enable quick and economic investigations to be carried out are needed. A number of authors have commented on the importance and possibilities of diagnostics for calcification of the carotid artery using panoramic radiography (PR) [6,7]. This suggests that imaging of calcified plaque of the carotid artery using dental PR is possible with a high degree of reliability [7-12]. The probability interval of finding carotid calcification in a PR lies between 2.5% and 4.1% [5].

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The thought of using dental PR as an early and, above all, economic diagnostic tool for detecting calcification of the carotid artery is certainly worth considering. After all, a large number of patients regularly go for dental check-ups and do so more frequently than undergoing routine health checks. The PR is a basic diagnostic procedure in dental investigations. Calcification can be detected and documented as a secondary (chance) finding in PRs. If abnormal findings are established during the procedure, then a more precise diagnostic is to be recommended and initiated by specialists in internal medicine.

The oral cavity is a point of entry into the blood circulation for microorganisms. Therefore, inflammations in the area of the oral cavity such as, for example, periodontitis with accompanying highly pathogenic bacteria, in the sense of a chronic-relapsing bacteremia occurring over a long period of time and distributed throughout the whole body, can have a direct effect on the general health of the patient. A number of studies have described a corresponding association with different systemic diseases such as, for example, diabetes mellitus and premature births, but also cardiovascular diseases, myocardial infarction, as well as arteriosclerosis and strokes [13-22]. The stronger the oral infection is, the greater is the risk of a bacteremia [23,24], and consequently the risk of systemic diseases [13]. Above all, the correlation between periodontal disease and arteriosclerosis has been attributed particular importance [18,19,25]. Several systematic reviews and meta-analyses have assessed an evidence regarding an association between periodontal disease and cardiovascular diseases, e.g. arteriosclerosis and/or carotid calcification [18,26-29].

The aim of this study was to investigate, in a dental practice, the extent to which the suspicion (prevalence) of carotid calcification can be diagnosed as a secondary (chance) finding in dental PRs and which factors: age, gender, number of missing teeth and periodontal risk are correlated with the occurrence of carotid calcification, and to establish an association to periodontal risk. In this context, it was the intention to determine what value for health the appropriate diagnostics could have based on dental PR in everyday practice.

Methods

This study was a cross-sectional study based on exclusive available panoramic radiographs (PR) from one specific private dental practice in Germany. The study was reviewed and approved by the ethics committee of the University Medical Center Goettingen, Germany (No. 9/10/08).

Panoramic radiograph (PR)

Only dental PRs generated between 1984 and 2009 were evaluated in this investigation (n = 1521). All PRs were

performed with the orthopantomograph (x-ray machine) OP 10 E (Siemens, Bensheim, Germany). The x-ray parameters were for women 75 kV, 6 mA, 15 sec. and for men 75 kV, 10 mA, 15 sec; the position of the patients in the orthopantomograph was individually adjusted. The PR images were prepared manually according to a pre-established and standardized protocol on conventional films by one and the same skilled operator (dental assistant).

PR pictures that showed defects resulting from the imaging process or the area of interest for carotid calcification could not be observed sufficiently, respectively, were sorted out in advance and were not considered in the investigation (n = 56/4%). Furthermore, in case there was more than one PR of the same patient only the most recent PR was evaluated. On the evaluated PRs no identifiers were present.

Data evaluation

The selected PR pictures were used to produce the patient-related data from the documented treatment documents. Amongst others, the following parameters were recorded: gender, patient age at the time the PR was taken, and the date of the PR recording.

Panoramic radiograph examination

The PRs were viewed and assessed by a previously calibrated investigator (RT). The calibration was carried out by "self-education" using 10 selected PR pictures for which the findings had been established (5 with/5 without carotid calcification). The five PRs with putative positive findings of carotid calcification were also assessed by a medical radiologist. Three cases were confirmed.

All PR pictures were examined one time. The examination of the PRs took place under standardized conditions in a darkened room on an x-ray viewer with darkening device (light box).

At the beginning of the investigation, the corresponding PRs were examined in terms of possible carotid calcifications (suspected diagnosis) on the right side, left side or on both sides.

In addition, the number of missing teeth (tooth loss, the reason for tooth loss was unknown), as well as an assessment of (max) bone loss were documented. For this purpose, accordingly, in the lateral tooth area, the greatest bone destruction, the root length (distance from the enamel-cement-junction (ECJ) to the tip of the root (in mm), as well as bone loss: distance of the enamel-cement-junction (ECJ) to the limbus alveolaris (LA) in millimeter (mm), were measured using a millimeter-scaled periodontal probe (PCP 15, Hu-Friedy, Chicago, US). Then the calculation of the degree of bone loss was carried out by dividing the maximum bone loss (mm) by the root length (mm) and converting this figure to a

percentage. Patients without posterior teeth were assigned a root length of 1 mm, bone loss of 1 mm and so a bone reduction of 100%. By dividing the bone reduction by the age of the patient at the time the radiograph was taken, the bone loss/age-index could be calculated.

Based on the parameter number of missing teeth and bone loss/age index, following of concept of Lang and Tonetti [30], an estimate of the periodontal risk was made in a modified form:

- low risk: number of missing teeth ≤ 4 , bone reduction index ≤ 0.5 ,
- moderate risk: number of missing teeth 5 to 8 and/or bone reduction index 0.51-1.0,
- high risk: number of missing teeth ≥ 9 and/or bone reduction index ≥ 1.1 ;

The most unfavorable factor determined the overall degree of risk.

Statistical analysis

The statistical analysis was carried out with the aid of SPSS for Windows, Version 15.0 (SPSS Inc., USA). The continuous variables were assessed in terms of their normal distribution using the Kolmogorov-Smirnov test. For comparing samples (carotid calcification: yes or no), non-parametric tests were always used. When comparing two independent, non-normally distributed samples, the Mann-Whitney U test was applied (age, tooth loss). The categorized data were analyzed with the aid of the Chi-square test or Fisher's exact test (gender, periodontal risk). A two-sided significance test was made of all tests and, for all statistical analysis a value of $p < 0.05$ was taken as being significant. In addition, a multivariate logistic model (binary logistic regression) for the association of carotid calcification with following parameters was performed: gender, age, tooth loss, periodontal risk, max. bone loss.

Results

Subjects

In total, 824 PRs (= 100%) from the patient population (54%) were included in the study. Of these, 349 were male (42.4%), and 475 were female (57.6%); the mean age of the patients at the time of the panoramic radiograph imaging was 48.32 ± 16.52 years (Table 1). The difference in age between the two genders (male: 47.67 ± 15.32 , female: 48.8 ± 17.35) at the time the radiograph were taken was not significant ($p = 0.45$) (Table 1).

Panoramic radiograph examination

Carotid calcification

Suspected carotid calcification was determined in a total of 9% of the patients ($n = 74$). In 45 patients (5.5%), the

Table 1 Patient characteristics: Mean age (\pm sd), gender, mean teeth loss (\pm sd), periodontal risk, and suspected carotid calcification

Factor		
age in years (mean \pm sd)		48.32 \pm 16.52
gender (n = 824)	female	n = 475
	male	n = 349
tooth loss (mean \pm sd)		4.16 \pm 5.39
periodontal risk	low	n = 282
	moderate	n = 335
	high	n = 107
carotid calcification	all	n = 74 (9%)
	right sides	n = 45 (5.5%)
	left sides	n = 19 (2.3%)
	both sides	n = 10 (1.2%)

(sd: standard deviation)

carotid calcification was on the right side, in 19 patients (2.3%) on the left side, and in 10 patients on both sides (1.2%). In the remaining 750 patients (91.0%), no carotid calcification was found (Table 1).

Tooth loss

The mean tooth loss was 4.16 ± 5.39 (min: 0; max 28); so that, on average, the patients still had 23-24 teeth (Table 1). 259 patients still had all of their teeth, and 10 patients were toothless.

Periodontal risk

In accordance with the definition used, 282 patients (34.2%) had a low risk, 335 patients (40.7%) had a moderate risk, and 207 patients (25.1%) had a high risk of periodontitis (Table 1).

Distribution of carotid calcification according to age, gender, loss of teeth, and periodontal risk

Age

The 750 patients in whom carotid calcification was not suspected were, on average, 46.94 ± 16.14 years old, whereas the 74 patients in whom carotid calcification was detected were, on average, 62.34 ± 13.70 years old. The difference was significant ($p < 0.001$) (Table 2).

Gender

In 24 (6.9%) out of 349 male and 50 (10.5%) out of 475 female subjects, carotid calcification was suspected. Accordingly, there was a tendency in the female subjects to have a higher prevalence of carotid calcification than the male patients, but the difference was, however, not significant ($p = 0.084$) (Table 2).

Tooth loss

Patients with no suspected carotid calcification had a mean tooth loss of 3.81 ± 5.08 . Patients with a suspected carotid calcification had 7.62 ± 7.05 missing teeth. The difference was significant ($p < 0.0001$) (Table 2).

Table 2 Distribution of age, gender, tooth loss, and periodontal risk according to diagnosis of suspected carotid calcification and level of significance (p < 0

Factor	carotid calcification		significance (p < 0, 05)	
	yes (n = 74)	no (n = 750)		
age in years (mean ± sd)	62.34 ± 13.70	46.94 ± 16.14	p < 0.0001	
gender	female	n = 50 (11%)	n = 425 (89%)	p = 0.07
	male	n = 24 (7%)	n = 325 (93%)	
periodontal risk	tooth loss	7.62 ± 7.05	3.81 ± 5.08	p < 0.0001
	low (n = 282)	n = 9 (3.2%/12.2%)	n = 273 (96.8%/36.4%)	p < 0.0001
	moderate (n = 335)	n = 33 (9.9%/44.6%)	n = 302 (90.1%/40.3%)	
	high (n = 107)	n = 32 (15.5%/43.2%)	n = 175 (84.5%/23.3%)	

(sd: standard deviation)

Risk of periodontitis

Of the 282 patients with a low risk of periodontitis, 9 (3.2%) had suspected carotid calcification (12.2% of all suspected cases). In patients with a moderate risk of periodontitis (n = 335), carotid calcification was suspected in 33 subjects (9.9%), and in subjects with a high risk of periodontitis (n = 207), this value was 32 (15.5%). These are 44.6% or 43.2%, respectively, of all cases of suspected carotid calcification. The influence of a risk of periodontitis was significant (p < 0.0001) (Table 2).

In the multivariate logistic model, only age showed a significant association to carotid calcification (p < 0.0001) with an odds ratio (OR) of 4.9 (confidence interval [CI]: 2.4 - 9.8). The periodontal risk showed no significant association (p = 0.12) with an OR 1.4 (CI: 0.9 - 2.4). The results of the multivariate logistic model are given in Table 3.

Discussion

In the present study, the prevalence of the diagnosis of suspected carotid calcification was found to be 9.0%. At the same time, the right side, with a value of 5.5%, had prevalence twice that for the left side (2.3%). The majority of the patients investigated (65%) had a moderate to high risk of periodontitis; on average, there were 4.16 ± 5.39 teeth missing. In addition, it was possible to establish a significant correlation between cases of suspected calcification with the risk of periodontitis, the number of

missing teeth, and the age of the patients. However, only age showed a significant association (OR: 4.9; p < 0.0001).

In the international literature, depending on the study, prevalence of carotid calcification in PRs were found to be between 0.4 and 4.0% [5,31-37]. The large range of values given for prevalence of positive findings of carotid calcification in PRs could be explained by the different age groups, different distributions of gender, ethnicity and lifestyles of the particular patients investigated [5]. In the present study, the prevalence rate of 9% is clearly higher than that found in comparable studies and, at the same time, calcification was found both unilaterally and bilaterally - on the right side more frequently than on the left side or on both sides. Other studies have also reported an increased appearance of unilateral carotid calcification on the right side [5,38], with Ariayi et al. reporting that most positive findings were found bilaterally [5]. In contrast, Ohba et al. reported that most calcification of the arteria carotis lay on the left side [35]. In addition, women appear to be more frequently affected than men [5,36]. In the present study, women were also more frequently affected. The difference, however, was not significant, i.e. gender showed no significant association to carotid calcification (OR: 1.6). Another study revealed no influence of gender, too [39].

One explanation for the increased prevalence of a diagnosis of suspected carotid calcification in this study

Table 3 Multivariate logistic model for association of carotid calcification with following parameters: gender, age, tooth loss, periodontal risk, max. bone loss

Parameter	regressions coefficient	standard failure	significance (p - value)	odds ratio (OR)	95% confidence intervall
gender	0.47	0.27	0.08	1.61	0.95 - 2.7
age	1.59	0.36	0.000	4.88	2.4 - 9.8
tooth loss	0.02	0.03	0.39	1.02	0.97 - 1.1
periodontal risk	0.38	0.25	0.12	1.47	0.9 - 2.4
max. bone loss	0.001	0.01	0.93	1.00	0.99 - 1.0

compared to others could be false-positive findings. It cannot be excluded that plaque from the arteria carotis is mistaken as calcification in the cartilago triticea, thereby resulting in possible false-positive findings [40,41]. Also, it should be considered that the study was carried out by a dentist from the practice who indeed was calibrated before, but not however by a specialist trained in radiology and a corresponding qualification. The results of one study regarding the effectiveness of a training program for the detection of carotid calcification in dental PRs revealed that only approximately 1/3 of the carotid calcifications identified by two trained dentists were also confirmed by a radiologist specializing in mouth, jaw and facial radiology [42]. Likewise, it can be assumed that of the 9.0% of suspected cases of carotid calcification in the study presented here, only about 3% would be confirmed findings. Therefore, it would seem that the prevalence of suspected cases of carotid calcification in our study is similar to that in comparable studies. However, it is quite conceivable that the diagnosed carotid calcifications in PRs show true calcification more precisely. In some studies, positive Doppler sonography results for the arteria carotis have been verified using conventional PR [43,44]. In other studies, on the one hand, 34.7% of carotid calcifications found in dental PRs were also found with ultrasound [39]; on the other hand, 62.3% were confirmed by CTs. The sensitivity was 22.2% and the specificity 90% [45].

In contrast, Tanaka et al. reported the ineffectiveness of findings of suspected carotid calcification in dental panorama tomography for assessing the risk of vessel disease and their further development to the point of death in 80-year-old patients [12]. However, one should critically question whether results for 80-year-old patients can be unconditionally translated to the effectiveness of the procedure in the case of younger patients and the course of their illnesses. Accordingly, Friedländer et al. reported that 37% of patients with a cerebral insult starting from the arteria carotis showed a corresponding carotid calcification in the PR [7].

The results of the study presented here showed an age-dependent frequency of positive findings of carotid calcifications. The fact that the risk of a stroke and a heart attack increases with age is well known [46]. At the same time, from the 50th year of life on, the extent of arteriosclerosis of the arteria carotis appears to be closely correlated with coronary heart disease and is an important indicator for identifying patients with coronary heart disease [46]. The results of the study presented here therefore confirm that, with increasing age, there is also an increase in suspected cases of carotid calcification and an age-dependent risk of carotid calcification (OR: 4.9).

In addition, the significant correlation between an increased risk of periodontitis and the occurrence of

suspected cases of carotid calcifications, as well as the number of missing teeth is noticeable. However, a significant association to carotid calcification could not be found (OR: 1.5; $p > 0.05$). Other studies have likewise shown that an increased loss of alveolar bone which, as a rule, is associated with a periodontal history is correlated with an increased occurrence of carotid calcification [8,43,47]. Corresponding to Engebretson et al., bone loss is associated with carotid calcification (OR: 3.6; CI:1.4 - 9.7) [47]; in this study the OR for max. bone loss was 1.0 (CI: 0.99 - 1.0). At the same time, confirmed positive findings in Doppler sonography are connected with a high probability of periodontal disease [48]. In addition, the thickness of the intermedia of the arteria carotis appears to be associated with the presence of periodontitis [48]. Several case-control studies and cross-sectional studies have confirmed the existence of an association between periodontitis and cardiovascular diseases [25,49-55]. Madianos et al. concluded in their review a risk ranged from 0 to 3.3-fold for the occurrence of periodontal disease and CHD or a significant association between these both diseases, respectively [56]. On the basis of different meta-analyses, the odds ratio of this association was stated by 1.1 to 2.2 [27-29]. In the present study the odds ratio was 1.5 (CI: 0.0 - 2.4). Christou et al. showed with a limited number of subjects ($n = 15$) that, in addition to high blood pressure, the presence of periodontal disease was significantly correlated with a positive finding of carotid calcification [57].

With a large subject population the results presented here confirm the close correlation between the two diseases and make clear the fact that an interdisciplinary concept is necessary in dental and medical diagnostics for the determination of the risk of the two diseases. Consequently, the identification of such changes in the PR can be viewed as a contribution on the part of dentistry to secondary (chance) findings precautionary diagnostics. At the same time, one should take into account and weigh up the fact that in healthcare, in addition to the sensitivity and specificity of an investigation method, it is important how frequent these examinations are actually used by the population. Since most of the population receives dental care, PRs are carried out with certain regularity. Therefore, it should be considered whether, as a result of the use of better radiological diagnostics and the recording of secondary (chance) findings in dental practices, benefits can be achieved for patients in terms of health and economic value.

Limitation of the study: This cross sectional study was an investigation exclusively carried out on the basis of available PRs: a supplementary clinical dental and inter-dentist examination of the patients was not done. Accordingly, a positive finding of carotid calcification was not verified by means of further diagnostics (CT,

sonography). For this reason, the positive findings were only suspected cases of carotid calcification.

Likewise, the assessment of periodontal risk was only made with by means of radiologically determined parameters, such as missing teeth, and the bone reduction age index. These were selected based on the periodontal risk assessment concept of Lang and Tonetti [30] in a modified and reduced version for the assessment of periodontal history and judgment of further periodontal risk. Additional parameters, such as smoking and systemic factors, were not used for risk assessment, as these data were not available to the same extent for all patients or they were incomplete, respectively. Nevertheless, one should keep in mind that smoking is a "high" risk factor for periodontal disease and CHD and represents an important confounder [58-60]. Furthermore, other dental infections, e.g. periapical infections or active caries decay, are also infections of oral disease burden, however, these infections were not considered in this study.

Conclusion

PR can, as an additional diagnostic tool, provide an indication of carotid calcification as secondary (chance) finding. An unambiguous exclusion of changes due to calcification is, however, not possible. In addition, age, tooth loss, and periodontal risk are closely correlated with positive findings of carotid calcification. However, only age showed a significant association with a increase risk for carotid calcification.

Considering the corresponding anamnesis and the establishment of further risk factors for arteriosclerosis, such as smoking and diabetes mellitus, in a patient, the dentist must carry out more precise diagnostics in relation to the presence of carotid calcifications in PR. Close communication with the internist responsible is a fundamental prerequisite for achieving the implementation of further diagnostics with sonography or CT.

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Authors' contributions

RT has made substantial contributions to conception and design of the study; he carried out the examination and performed the statistical analysis. WB was the head of the study and made substantial contributions to conception and design of the study. SR has been involved in revising it

critically for important intellectual content and given final approval of the version to be published. DZ conceived of the study, and participated in its design and coordination, interpretation of data and wrote the manuscript. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

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