Comparison of periodontal conditions among three elderly populations in Japan and Germany


Abstract
Aim: There is a growing interest in comparing periodontal conditions between countries. This study compared periodontal disease conditions in three elderly populations- one from Japan and two from Germany.

Materials and Methods: We compared periodontal data of 70-year-old subjects from the Niigata Study with 65–74-year-old subjects from the Study of Health in Pomerania (SHIP) and from West Germany (DMS III). A total of 489, 399 and 549 dentate subjects were analysed, respectively. Recording protocols were standardized. Linear or logistic models were used to compare Niigata Study with SHIP.

Results: Elderly German subjects in SHIP and DMS III had significantly more severe periodontal conditions and fewer remaining teeth compared to those in Niigata Study, though differences were less pronounced for DMS III. German subjects showed a significantly different pattern of various periodontal risk factors compared to Japanese subjects. Even after adjustment for putative periodontal risk factors, SHIP subjects still presented significantly higher adjusted values for most periodontal parameters compared to Niigata Study subjects ($p < 0.05$).

Conclusions: Periodontitis was more prevalent in SHIP compared with Niigata Study, even after comprehensive risk factor adjustment. Only to a very small extent, differences between studies could be explained by the risk factors explored.

Conflict of interest and source of funding statement
Niigata Study was supported, in part, by a Grant-in-Aid for Scientific Research (09470469), from the Japanese Ministry of Education, Science, and Sports, and by a Grant-in-Aid from the Ministry of Health, Labour and Welfare of Japan (H10-Iryo-001). Funding for this comparison study was partly provided by The JSPS Institutional Program for Young Researcher Overseas Visits. SHIP is part of the Community Medicine Research net (CMR) of the University of Greifswald, Germany, which is funded by the Federal Ministry of Education and Research (grant no. ZZ9603) and the Ministry of Cultural Affairs, as well as the Social Ministry of the Federal State of Mecklenburg-West Pomerania (http://www.community-medicine.de). B. H. was financed by an unlimited educational grant by GABA International, Switzerland. DMS III was funded by the two Federal dental organizations, the Bundeszahnärztekammer (BZÄK) and the Kassenzahnärztliche Bundesvereinigung (KZBV). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript. The authors declare that there are no conflicts of interest in this study.
There is a growing interest in comparing chronic diseases between countries, because country-specific, economic and historical background on one side and specific distributions of subject-based risk factors on the other side inherently impact health or disease (Crimmins et al. 2011). However, the current literature deals either with aspects of individual risk factors rather than factors driving health conditions in populations, or only descriptively compares the periodontal status among countries (Demmer & Papapanou 2010, König et al. 2010). Such comparisons, however, have shortcomings because periodontal disease prevalences are influenced by various methodological factors including the periodontal disease definition and the periodontal recording protocol (Albandar 2011). In such reviews, it was unable to rank or group countries on a sound basis because reviews were restricted to compiled and aggregated data, which only allow a narrative rating. In addition, varying distributions of periodontal risk factors are not considered and adjusted for (König et al. 2010) when periodontal disease measures are compared. It must be stressed that only direct study comparisons with access to subject level data provide a better understanding of the degree of discrepancies in periodontal conditions between countries and may clarify, to what extent this differential can be explained by subject based risk factors (Holtfreter et al. 2012b).

The proportion of elderly people continues to grow in most developed countries, especially in Japan, Italy and Germany (United Nations 2010). These countries could be characterized as an aged society, since the proportion of the population aged 65 years or older had already exceeded 14% in 2010 (United Nations 2010). Moreover, in 2060 the proportion of the elderly population is estimated to be around 30% in the two European countries and around 40% in Japan (United Nations 2010). Thus, it is of utmost interest to compare periodontal disease status in elderly populations and to evaluate possible reasons for such differences considering individual risk factors covered in respective studies.

Since SHIP sampled subjects from a region in East Germany, where subjects are less healthy than their West German counterparts with higher rates of risk factors (Meisinger et al. 2006, Janhsen et al. 2008), we additionally provided information on periodontal conditions and periodontal risk factor distributions from a representative West German sample. Thus, the main purpose of this study was to (i) investigate crude estimates of various periodontal variables between elderly populations from the Niigata Study (Japan), the Study of Health in Pomerania (SHIP, Germany) and the Third German Oral Health Study (DMS III, Germany), (ii) determine risk factor adjusted differences in periodontal conditions between the Niigata Study and SHIP and (iii) evaluate the contribution of periodontal risk factors to inter-study differences in periodontal conditions between Niigata Study and SHIP.

Materials and Methods

Niigata Study
Niigata Study, an epidemiological survey for the elderly in Niigata City, Japan, was conducted in 1998 as described previously (Hirotomi et al. 2002). Study subjects were recruited from community-based target populations born in 1927, residing in Niigata City. Based on the registry of Niigata City, a written invitation with a brief description of the study aim, as well as a questionnaire, was sent to all the 4542 target inhabitants. The response rate was 81.4% (n = 3695). Among them, 600 subjects were randomly selected with approximately the same number of each gender and 599 participated in the study. The study population consisted of community dwelling, independently living elderly people aged 70 years. The Niigata Study was reviewed and approved by the Ethics Committee of the Faculty of Dentistry, Niigata University. All participants gave written informed consent.

For this study, 489 subjects were analysed after excluding 45 edentulous, 57 with any missing value in covariates and eight subjects who were edentulous on the side from which periodontal examinations were considered for analyses according to the application of the half-mouth protocol.

Study of Health in Pomerania
SHIP is a prospective population-based cohort study in Pomerania, Germany, conducted in 1997–2001 as described previously (John et al. 2001, Hensel et al. 2003). Briefly, a two-stage cluster sampling design was adopted. From the entire population of 212,157 inhabitants, 7008 adults aged 20–79 years, with German citizenship and main residency within the target region, were randomly selected, proportional to each community population size, and stratified by age and gender. After 746 subjects were excluded (126 died, 615 moved away, five had severe medical problems), 6262 inhabitants were invited. The net random sample included 4308 individuals. The response rate was 68.8%. For this comparative study, 683 subjects aged 65–74 years were considered. The SHIP study protocol was approved by the local Ethics committee of the University of Greifswald and all participants gave informed written consent. The analysis was conducted on 399 subjects after excluding 229 edentulous and 55 with any missing value in covariates.

The Third German Oral Health Study in 1997
The Institute of German Dentists conducted a national cross-sectional survey of oral health in the German resident population in 1997 (DMS III) (Micheelis & Reich 1999). Random cluster samples stratified by Federal State and by community category were drawn, altogether 90 municipalities. Random samples were selected from the records of registration offices from each of these municipalities. For this comparative study, analyses were restricted to West Germans aged 65–74 years, who were born in 1923–1932. For those, sample size was 1680. According to several reasons (death, moved away or severe medical problems) 57 subjects were removed resulting in 1623 65–74-year-old subjects being invited. The net random sample included 891 subjects (response 54.9%).
Comparison of periodontal conditions

III, informed consent was obtained from all participants. The analysis was conducted on 549 subjects after excluding 204 edentulous, 29 with incomplete periodontal data and 109 with any missing value in covariates. Details on oral examination and assessment of covariate data for Niigata Study, SHIP and DMS III are provided in the Appendix S1.

Comparison of studies

Definition of periodontal disease

To reduce the methodological bias caused by different examination protocols in Niigata Study, SHIP and DMS III, periodontal data were consistently translated into a half-mouth protocol at two sites per tooth. Data on CAL assessed in crowned teeth in Niigata Study were set to missing according to the SHIP protocol.

The following periodontal parameters were calculated: prevalence of PPD/CAL, extent of PPD/CAL and mean PPD/CAL. Prevalence was defined as the percentage of subjects having at least one site with a given condition. Extent was defined as the percentage of sites per person with a given condition. Because extent variables were heavily skewed, we opposed subjects with high (>75% quantile) versus subjects with normal extent values (≤75% quantile) for logistic models. Furthermore, the CDC-AAP definition for periodontal disease was determined based on mesiobuccal sites of half-mouth teeth (Page & Eke 2007). Because the CDC-AAP definition necessitates the presence of at least two teeth, results are based on subjects with at least two teeth with periodontal measurements.

In the Table S1, we additionally present comparisons between the Niigata Study and SHIP based on a half-mouth protocol at four sites per tooth. Accordingly, the CDC-AAP definition was determined based on mesiobuccal and distobuccal sites at half-mouth teeth.

Definitions of covariates

We covered a wide range of putative periodontal risk factors, based on published literatures, which might affect periodontal prevalence and severity in both populations. Covariates were restricted to those that were measured in both studies (Niigata study and SHIP) to minimize methodological bias and with comparable precision to prevent differential methodological bias in both studies. Definitions of covariates were established as accurate as possible to assess within the three studies. The following covariates were included: age, gender (male/female), smoking status (current non-smoker/current smoker), number of cigarettes/day (0/1–10/10>10), education (<10/10–11/≥12 years), satisfaction with relationships with their family or friends (very satisfied/not very satisfied), general health status (excellent or very good/good/less good or bad), high serum glucose level (≥11.1 mmol/l), history of diabetes mellitus (yes/no), BMI (<25/25–<30/≥30 kg/m²), dental visits in the last 12 months (yes/no), having a family dentist (yes/no), frequency of daily tooth brushing (≥2 times/once/less frequently) and use of inter-dental care devices (yes/no).

Statistical analyses

Characteristics of study subjects are presented as numbers (percentages) or means with standard errors. Periodontal data are presented as means or percentages with standard errors. Comparisons between Niigata Study and SHIP as well as between Niigata Study and DMS III were done using chi-squared tests for categorical variables and Mann–Whitney U-tests for continuous variables.

Multivariable analyses were only performed for Niigata Study and SHIP, since assessment of putative risk factors for periodontal disease was not sufficient in DMS III. For continuous (mean) and dichotomous (prevalence and extent)-dependent variables, linear and logistic models were applied to assess differences in periodontal conditions between the two populations respectively. To correct for correlations of subjects within studies, modified robust sandwich estimators for clustered data were used. The variable “study” (reference: Niigata Study) and covariates were included into these models. Regarding covariates, we aimed to cover a wide variety of putative periodontal risk factors, which might affect periodontal prevalence and severity in both populations. Covariates were restricted to those that were comparably measured in both studies (Niigata study and SHIP) to minimize methodological bias and to those with comparable precision to prevent differential methodological bias in both studies. Linear regression coefficients (B) and odds ratios (OR) with their respective 95% confidence intervals (CI) were reported. Furthermore, adjusted means and mean predicted probabilities with their standard errors (SE) were reported for both studies respectively. In addition, crude periodontal disease estimates and study effects were determined stratified by the number of teeth. To determine, to what extent study effects were mediated by explored periodontal risk factors, change-in-evaluate for “study” was evaluated between the crude and the fully adjusted model. Because data from both studies were merged for multivariable analyses, preventing consideration of design and weight variables due to different sampling strategies, analyses were model based; for none of the studies, sampling weights or design-based variables were considered.

To visualize and compare periodontal conditions among the three populations, cumulative percentile plots of extent of PPD and CAL were drawn. In addition, box plots of mean PPD and CAL stratified by the number of teeth were generated.

Data analysis was performed with Stata/SE 12.0 (StataCorp 2011). The statistical significance level was set at p < 0.05.

Results

Comparison of study subjects

The characteristics of subjects by study population are presented in Table 1. Compared to SHIP, subjects in Niigata Study were better educated, more satisfied with relationships with their family or friends, reported their health status more often as excellent/very good, were less often obese and less often diagnosed as having diabetes mellitus in the past (p < 0.001). However, for SHIP subjects a more favourable condition was observed in current smoking status (p < 0.001) and frequency of daily tooth brushing (p = 0.001). Compared to West
Germans in DMS III, subjects in Niigata Study were better educated ($p < 0.001$) and less often diagnosed as having diabetes mellitus ($p < 0.05$). However, West Germans had a more favourable condition regarding current smoking status, self-rated general health ($p < 0.001$) and frequency of daily tooth brushing ($p < 0.001$). The percentage of edentulous subjects was significantly higher in SHIP and DMS III as compared to Niigata Study ($p < 0.001$).

### Comparison of periodontal status between studies

Prevalences of PPD $\geq 4$ and $\geq 6$ mm were significantly higher in SHIP than in Niigata Study ($p < 0.001$, Table 2). Similar results were seen for prevalences of CAL. All extent estimates of PPD and CAL were significantly higher in SHIP than in Niigata Study ($p < 0.001$). Subjects in Niigata Study and SHIP had on average 12.9% and 37.3% of sites affected with CAL $\geq 5$ mm respectively. Mean PPD and mean CAL were also significantly higher in SHIP subjects ($p < 0.001$) with the higher discrepancy for mean CAL. According to the CDC-AAP definition, only 2.0% of subjects in Niigata Study but 25.8% of SHIP subjects were categorized as having severe periodontal disease. Compared to Niigata Study, more severe periodontal conditions were found in DMS III, but differences were slightly smaller than for Niigata Study and SHIP.

Figure 1 shows cumulative percentile plots of extent of PPD $\geq 4$ mm.
Comparison of periodontal conditions

Table 2. Comparison of periodontal parameters based on a half-mouth protocol at two sites per tooth among Niigata Study, SHIP and DMS III respectively

<table>
<thead>
<tr>
<th></th>
<th>Niigata Study (N = 489/441)</th>
<th>SHIP (N = 399/342)</th>
<th>DMS III (N = 543/549)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prevalence of (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PPD ≥4 mm</td>
<td>40.9 (2.2)</td>
<td>65.7 (2.4)</td>
<td>*</td>
</tr>
<tr>
<td>PPD ≥6 mm</td>
<td>10.2 (1.4)</td>
<td>23.8 (2.1)</td>
<td>*</td>
</tr>
<tr>
<td>CAL ≥3 mm</td>
<td>90.0 (1.4)</td>
<td>98.8 (0.6)</td>
<td>*</td>
</tr>
<tr>
<td>CAL ≥5 mm</td>
<td>45.1 (2.4)</td>
<td>81.0 (2.1)</td>
<td>*</td>
</tr>
<tr>
<td>Percentage of sites per subject with (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PPD ≥4 mm</td>
<td>5.8 (0.5)</td>
<td>16.4 (1.0)</td>
<td>*</td>
</tr>
<tr>
<td>PPD ≥6 mm</td>
<td>0 (0–7.7)</td>
<td>10.0 (0–25.0)</td>
<td>12.5 (0–33.3)</td>
</tr>
<tr>
<td>CAL ≥3 mm</td>
<td>51.7 (1.6)</td>
<td>76.5 (1.4)</td>
<td>*</td>
</tr>
<tr>
<td>CAL ≥5 mm</td>
<td>50.0 (20.8–83.3)</td>
<td>83.3 (58.3–100.0)</td>
<td>75 (45.5–96.2)</td>
</tr>
<tr>
<td>Mean PPD (mm)</td>
<td>1.8 (0.02)</td>
<td>2.7 (0.04)</td>
<td>*</td>
</tr>
<tr>
<td>Mean CAL (mm)</td>
<td>2.9 (0.1)</td>
<td>4.1 (0.1)</td>
<td>*</td>
</tr>
<tr>
<td>CDC-AAP definition (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No or mild</td>
<td>63.3 (2.4)</td>
<td>21.7 (2.3)</td>
<td>28.1 (2.0)</td>
</tr>
<tr>
<td>Moderate</td>
<td>34.7 (2.4)</td>
<td>52.5 (2.8)</td>
<td>50.2 (2.2)</td>
</tr>
<tr>
<td>Severe</td>
<td>2.0 (0.7)</td>
<td>25.8 (2.5)</td>
<td>21.7 (1.8)</td>
</tr>
<tr>
<td>Number of teeth (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1–8</td>
<td>54 (11.0%)</td>
<td>141 (35.3%)</td>
<td>131 (23.9%)</td>
</tr>
<tr>
<td>9–15</td>
<td>95 (19.4%)</td>
<td>116 (29.1%)</td>
<td>123 (22.4%)</td>
</tr>
<tr>
<td>16–20</td>
<td>82 (16.8%)</td>
<td>74 (18.5%)</td>
<td>139 (25.3%)</td>
</tr>
<tr>
<td>21–24</td>
<td>108 (22.1%)</td>
<td>50 (12.5%)</td>
<td>100 (18.2%)</td>
</tr>
<tr>
<td>25–28</td>
<td>150 (30.7%)</td>
<td>18 (4.5%)</td>
<td>*</td>
</tr>
<tr>
<td>Mean (dentate only)</td>
<td>19.0 (0.33)</td>
<td>12.3 (0.36)</td>
<td>15.3 (0.31)</td>
</tr>
</tbody>
</table>

CAL, clinical attachment level; DMS III, The German Oral Health Study in 1997 (restricted to West Germans); PPD, probing pocket depth; SHIP, Study of Health in Pomerania.

Data are presented as percentage (standard error) or mean (standard error) and median (25–75% quantile).

*N presents the number of subjects available for PPD and tooth count-related variables and for CAL-related variables respectively.

*409, 314 and 520 subjects were available in Niigata Study, SHIP and DMS III respectively.

*Tooth count was based on full-mouth data.

*p < 0.05 for Mann–Whitney U-test or Chi-square test. Comparisons were made between Niigata Study and SHIP and between Niigata Study and DMS III.

and ≥6 mm (two panels in the left column) and CAL ≥3 and ≥5 mm (two panels in the right column) by study population. Regarding extent measures of PPD, the differences between the two German populations and Niigata Study decreased as the threshold increased. For example, the percentages of subjects with ≥20% sites with PPD ≥4 mm were 8.2%, 34.1% and 41.4% in Niigata Study, SHIP and DMS III respectively. However, these percentages dropped to 1.4%, 8.0% and 6.5%, respectively, when applying the threshold of PPD ≥6 mm. A greater discrepancy across the three populations was seen in CAL compared with PPD.

Box plots of (a) mean PPD and (b) mean CAL by number of teeth and study population are shown in Fig. 2. A gradual increase of mean PPD and mean CAL was observed with a decreasing number of teeth, although less steep in Niigata study.

Multivariable model evaluating study effects between Niigata Study and SHIP

Table 3 shows the results of logistic and linear models evaluating study effects for SHIP versus Niigata Study. SHIP subjects were estimated to have a 2.16 times higher probability of having at least one site with PPD ≥6 mm compared to Niigata Study subjects (p < 0.001). Adjusted prevalences of PPD ≥6 mm were 10.6% and 20.4% in Niigata Study and SHIP respectively. For prevalences of CAL, higher odds ratios were found than for prevalences of PPD.

The chance of having a high percentage of sites with increased PPD values was significantly higher in SHIP compared with Niigata Study with odds ratios being 2.06 for the 4 mm threshold and 2.16 for the 6 mm threshold. For the extent of CAL, subjects in SHIP had significantly higher chances to present high extent values compared with subjects from Niigata Study. The adjusted probability of having a high extent of CAL ≥6 mm in SHIP was nearly 30% higher compared to Niigata Study. Similarly, SHIP subjects had significantly higher values in mean PPD and mean CAL than those in Niigata Study (for full model see Table S2).

When stratified according to the number of teeth (Table 4), prevalence and extent of periodontal diseases were higher in subjects with 1–18 teeth as compared to subjects with 19–28 teeth in both studies. In

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addition, study effects were consistently significant in both subgroups with (in tendency) stronger disparities between Niigata Study and SHIP (as indicated by higher ORs) for prevalence estimates of CAL, mean CAL, the CDC-AAP definition and the number of teeth in subjects with 1–18 teeth.

Explanation of study effects between Niigata Study and SHIP through periodontal risk factors

Inclusion of potentially effect mediating periodontal risk factors attenuated study effects on mean PPD [crude: $B = 0.91$ (0.91; 0.91); full model: $B = 0.76$ (0.67; 0.85)], whereas for mean CAL, estimates did not change [crude: $B = 1.28$ (1.28; 1.28)]; full model: $B = 1.30$ (1.27; 1.34).

In addition, we evaluated the predictive value of “study” comparing $R^2$ values between models including all risk factors and the one including additionally “study.” The proportion of explained variance rose from 32.3 to 37.4% (difference 5.1%) for mean PPD and from 15.4 to 25.9% (difference 10.5%) for mean CAL. Thus, 62.6% and 74.1% of variation in mean PPD and mean CAL, respectively, remained unexplained.

Discussion

To further promote inter-study comparisons using original data as opposed to descriptive or narrative reviews, which perform a rather crude comparison of published periodontal data (Demmer & Papapanou 2010, König et al. 2010, Dye 2012, Petersen & Ogawa 2012) and are afflicted by severe methodological flaws, we directly compared periodontal conditions in three elderly populations from Japan and Germany. We recognize that our proposed method has flaws and shortcomings, but it provides a better insight into inter-study comparisons than narrative reviews have done so far and it may provide a stimulus for future reviews.

We found a great differential in periodontal conditions between Japanese and Germans. Even after adjustment for putative periodontal risk factors, all periodontal parameters were significantly higher in SHIP.
Table 3. Adjusted predicted probabilities/adjusted linear predictions and odds ratios/linear regression coefficients for study effects regarding several periodontal parameters

<table>
<thead>
<tr>
<th>Prevalence (%) of</th>
<th>Niigata Study (N = 489/441)</th>
<th>SHIP (N = 399/342)</th>
<th>Study effects</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPD ≥6 mm</td>
<td>10.6 (0.8)</td>
<td>20.4 (0.1)</td>
<td>2.16 (1.85; 2.53)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>CAL ≥5 mm</td>
<td>47.6 (1.0)</td>
<td>80.4 (0.8)</td>
<td>4.53 (3.78; 5.43)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>High percentage of sites per subject (%) with</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PPD ≥6 mm</td>
<td>10.6 (0.8)</td>
<td>20.4 (0.1)</td>
<td>2.16 (1.85; 2.53)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>CAL ≥5 mm</td>
<td>10.0 (0.3)</td>
<td>37.1 (0.3)</td>
<td>5.31 (5.13; 5.51)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mean PPD (mm)</td>
<td>1.8 (0.02)</td>
<td>2.6 (0.02)</td>
<td>0.76 (0.67; 0.85)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mean CAL (mm)</td>
<td>2.8 (0.01)</td>
<td>4.2 (0.01)</td>
<td>1.30 (1.27; 1.34)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Number of teeth (dentates only)</td>
<td>19.1 (0.3)</td>
<td>12.3 (0.3)</td>
<td>-6.83 (−8.01; −5.64)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

CAL, clinical attachment level; PPD, probing pocket depth; SHIP, Study of Health in Pomerania.

For dichotomous periodontal variables (prevalence and high extent), logistic models were adapted; Odds Ratios (OR) with 95% confidence intervals and adjusted predicted probabilities were reported. For extent measures (i.e. percentage of sites per subject with PPD ≥6 mm or CAL ≥5 mm) we generated dichotomous variables, opposing subjects with high (>75% quantile) versus subjects with low or normal extent values (<75% quantile) to be used as dependent variables in logistic regression models. All models were adjusted for age, gender, smoking status, education, satisfaction with relationships with their family or friends, general health status, high serum glucose level, history of diabetes mellitus, BMI, dental visits in the last 12 months, having a family dentist, frequency of daily tooth brushing and use of inter-dental care devices. For continuous periodontal variables (mean PPD/CAL and number of teeth), linear models were used; regression coefficients (B) with 95% confidence intervals and adjusted linear predictions with their standard errors were reported.

N presents the number of subjects available for PPD and tooth loss-related variables and for CAL-related variables respectively.

Compared with Niigata. However, for mean PPD, but not for mean CAL, effect estimates for “study” were reduced after inclusion of periodontal risk factors. Adjusted inter-study differences were consistent if subjects were grouped according to the number of teeth.

In this study, the overall portions of explained variance were 37.4% and 25.9% for mean PPD and mean CAL, respectively, while unmeasured factors related to study population explained a sizable portion of variation both models (5.1 and 10.5%). In line, study effects were not (mean CAL) or only slightly (mean PPD) attenuated after inclusion of periodontal risk factors. Thus, putative periodontal risk factors considered in this study were only moderately able to explain inter-study differences in periodontal conditions. These unexpected findings are in contrast to results of a similar study, which compared the periodontal disease prevalence between the Oral Infections and Vascular Disease Epidemiology Study (INVEST, New York) and SHIP (Holtfreter et al. 2012b). Inter-study differences in mean CAL/PPD were mostly explained by differences in age, gender, ethnicity, education and use of inter-dental care devices. In total, periodontal risk factors contributed mainly to the overall proportion of explained variation of mean PPD/CAL, whereas “study” explained less than 2% of the variations in mean PPD/CAL (Holtfreter et al. 2012b).

Compared to this study, differences were most striking for mean PPD, for which the overall explained portion of variation was about 22% higher.

What may be possible explanations for these contradictory findings? Regarding a proper consideration of putative periodontal risk factors, residual confounding in estimating study-related differences in periodontal parameters may present one major issue. Social determinants including socio-economic status (SES), social contact, or stress were probably insufficiently adjusted for. In this study, detailed information was only available for school education. Income was not comparably assessed in both studies and afflicted by a high number of missing values and was thus not considered in this study. Moreover, a less accurate definition of smoking status as current non-smokers/smokers, non-consideration of smoking intensity and missing adjustment for haemoglobin A1c levels (Selvin et al. 2011) might have contributed to residual confounding.

In this study, differentials in periodontal disease status between Niigata Study and SHIP might also be explained by disparities in BMI distributions. Prevalences of overweight and obesity were 17.4% in Niigata, but 81.5% in SHIP. The traditional Japanese diet with low-fat intake (Wilcox et al. 2009) considerably contributes to a low BMI in Japanese populations (Willcox et al. 2007). In contrast, a more Westernized diet leads to a higher BMI and more metabolic disorders, as seen in the SHIP study. Thus, the disadvantageous interplay of diet, a higher BMI and a higher prevalence of diabetes mellitus might partly explain worse periodontal conditions (Suvan et al. 2011) seen in SHIP subjects.

Furthermore, differential cohort life-time experiences, as expressed through fully adjusted effects of “study,” exhibited strong effects on periodontal disease status. Cohort effects, including historical differences in social and economic environments, which might act on periodontal disease prevalence in other pathways than those factors explored in our analysis, might partly explain differences in periodontal conditions between Niigata and SHIP. SHIP subjects included in this study were born just before the start of Second World War. After the war most of them have spent their lives in the former German Democratic Republic, where poor social conditions and poor health care might have aggravated general
and oral health care (Schutzhold et al. 2013). On the contrary, people in Japan and West Germany experienced a high economic growth from the 1950s on and have been provided with a wide coverage of dental treatment (Schulenburg 1987, Nomura 2008). Thus, socio-economic conditions including the insurance system and the past economic growth may explain major differences in periodontal conditions between Japan and SHIP.

Another explanation may be that the German oral health system does a poor job at preserving teeth, as mirrored in the much higher tooth loss and edentulism rates in Germany compared with Niigata (Table 1) or New York (Holtfreter et al. 2012b). The forceps levels to extract periodontally involved teeth were rather low in Germany (Splieth et al. 2002) and teeth with periodontal disease may have been extracted at a less severe stage in Germany than in the United States or Japan. Nevertheless, residual teeth were still periodontally affected (Holtfreter et al. 2012b) and there is a stronger gradient between number of residual teeth and mean PPD/CAL in Germany as compared to Niigata Study (Fig. 2). Consistently, differences in extent measures between subjects with 1–18 versus 19–28 remaining teeth (Table 4) were higher for SHIP than for the Niigata Study. Obviously, dentists in Niigata were better able to prevent periodontal disease and tooth loss. However, variables of dental care provision and regularity of dental visits were not captured in our analysis. Thus, they may in part account for the observed country differential.

This study has some limitations that need to be considered. First, response rates differed largely between studies, ranging from 81.4% (Niigata Study) to 54.9% (DMS III). In DMS III, responders were more often male and presented better oral health and hygiene patterns compared to non-responders (Michaelis & Reich 1999). In SHIP, response rates were 69.7% in 60- to 69-year-olds and 56.3% in 70- to 79-year-olds (Hensel et al. 2003) and responders were more often males than females. Assuming further that responders had a better oral and general health status than non-responders, periodontal conditions might have been slightly underestimated in the two

### Table 4. Comparison of periodontal parameters between Niigata Study and SHIP, respectively, and estimation of odds ratios/linear regression coefficients for study effects (SHIP versus Niigata Study) stratified by the number of teeth. Analyses were based on a half-mouth protocol at two sites per tooth

<table>
<thead>
<tr>
<th></th>
<th>1–18 teeth</th>
<th>19–28 teeth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Adjusted predicted probabilities and linear predictions</td>
<td>Study effect</td>
</tr>
<tr>
<td>Prevalence of (%)</td>
<td>Niigata Study (N = 205/160)</td>
<td>SHIP (N = 303/246)</td>
</tr>
<tr>
<td>PPD ≥ 6 mm</td>
<td>12.2 (2.3)</td>
<td>24.8 (2.5)</td>
</tr>
<tr>
<td>CAL ≥ 5 mm</td>
<td>53.1 (4.0)</td>
<td>85.0 (2.3)</td>
</tr>
<tr>
<td>Percentage of sites per mouth with (%)</td>
<td>OR (95% CI) for High extent</td>
<td>Niigata Study (N = 205/160)</td>
</tr>
<tr>
<td>PPD ≥ 6 mm</td>
<td>2.0 (0.6)</td>
<td>5.3 (0.7)</td>
</tr>
<tr>
<td>CAL ≥ 5 mm</td>
<td>23.1 (2.4)</td>
<td>45.5 (2.1)</td>
</tr>
<tr>
<td>Mean PPD (mm)</td>
<td>1.8 (0.05)</td>
<td>2.7 (0.05)</td>
</tr>
<tr>
<td>Mean CAL (mm)</td>
<td>3.5 (0.12)</td>
<td>4.6 (0.11)</td>
</tr>
<tr>
<td>Number of teeth (denotes only)</td>
<td>11.5 (0.3)</td>
<td>9.2 (0.3)</td>
</tr>
</tbody>
</table>

CAL, clinical attachment level; PPD, probing pocket depth; SHIP, Study of Health in Pomerania.

For dichotomous periodontal variables (prevalence and high extent), logistic models were adapted; Odds Ratios (OR) with 95% confidence intervals and adjusted predicted probabilities were reported. For extent measures (i.e. percentage of sites per subject with PPD ≥ 6 mm or CAL ≥ 5 mm) we generated dichotomous variables, opposing subjects with high (>75% quantile) versus subjects with low or normal extent values (≤75% quantile) to be used as dependent variables in logistic regression models. All models were adjusted for age, gender, smoking status, education, satisfaction with relationships with their family or friends, general health status, high serum glucose level, history of diabetes mellitus, BMI, dental visits in the last 12 months, having a family dentist, frequency of daily tooth brushing and use of inter-dental care devices. For continuous periodontal variables (mean and number of teeth), linear models were used; regression coefficients (B) with 95% confidence intervals and adjusted linear predictions with their standard errors were reported. N presents the number of subjects available for PPD and tooth loss-related variables and for CAL-related variables respectively. *p < 0.05.
German populations. Thus, actual differences in periodontal conditions between the German populations and the Niigata Study may be underestimated in this study.

Second, the lack of standardization of periodontal examination could indicate inaccuracy of data combined, although examiners were well calibrated within each study (Micheelis & Reich 1999, Hirotomi et al. 2002, Hensel et al. 2003). Third, periodontal conditions in these studies were examined using different periodontal probes, a pressure-sensitive plastic probe in Niigata Study, a PCP-11 probe in SHIP and a WHO probe in DMS III. These may have resulted in some bias associated with digit preference (Holtfreter et al. 2012a) when comparing periodontal conditions between these populations. However, the number of teeth, which is robust and easy to determine, are very well-paralleled results on periodontal parameters, supporting the findings of a higher periodontal prevalence in both German studies as compared to Niigata. Fourth, we need to point out that because analyses were model based, standard errors in all studies might be underestimated, although to a minor degree (Holtfreter et al. 2009). Fifth, although the two populations from Niigata Study and SHIP had been randomly selected from the community, neither population is nationally representative, so that findings could only be generalized to respective populations. Sixth, in SHIP analyses were restricted to those aged 65–74 (70 years on average) to enable comparison with Niigata Study. The number of SHIP subjects aged 70 years would have been too small (N = 72) to receive reasonable results and thus we decided to enlarge sample size including subjects aged 65–74 years. Last but not least, differences in risk factor definitions between Niigata Study and SHIP might hamper comparisons. Different wordings for most item questions might have affected misclassification bias differently in both studies. However, as regards content, item questions were comparable.

Considering the various methodological difficulties connected with such comprehensive inter-study comparisons of the periodontal status or any other disease trait, it might seem that this approach reveals more problems than benefits. However, the alternatives are descriptive or narrative reviews, which perform a rather crude comparison of periodontal prevalences based on published estimates (Demmer & Papapanou 2010, König et al. 2010). Moreover, such reviews bear much more methodological problems, e.g. with regard to periodontal recording protocols or age distributions, and do not attempt to clarify underlying reasons for any discrepencies in periodontal estimates. In our view, comprehensive analyses as done in this and a previous study (Holtfreter et al. 2012b) provide more insights into inter-study differences in periodontal estimates and possible reasons for these than do narrative reviews. Thus, we support more comprehensive analyses when comparing disease prevalences between studies and/or countries.

To enhance comparisons of the periodontal status between studies in the future, assessment methods need to be converged or at best equalized (Peres et al. 2011). In doing so, a gold standard for periodontal recording protocols and general recommendations for the report of periodontal measures would be helpful. Also, surveys with comprehensive questionnaires on oral health behaviour and general health behaviour contribute to thorough inter-study comparisons. Finally, it would be desirable for the dental community to create a consortium with a comprehensive database, which allows the concomitant analysis of subject-based risk factors with country-specific characteristics. If enough cohorts would participate in such a database, recommendations for health policy on population level might be derived.

In conclusion, the findings of this study demonstrated that elderly subjects in SHIP and DMS III had significantly more severe periodontal conditions and tooth loss compared to those in Niigata Study. Multivariable analyses revealed that only to a very small extent, differences between Niigata Study and SHIP could be explained by the periodontal risk factors explored.

References


Clinical Relevance

Scientific rationale for the study: An analysis based on a direct comparison of available data seems to be essential for a more exact understanding of the discrepancies in periodontal conditions worldwide and for clarifying why some populations are more susceptible to the disease.

Principal findings: We found a significant difference in periodontal conditions between Japanese and German subjects, even after adjustment for putative periodontal risk factors.

Practical implications: The marked discrepancy in periodontal conditions between populations could not be explained by the traditional risk factors. Partly, it may be attributed to the aggregation of the differences in lifetime exposure to social adversity, living environment and dental treatment.

Appendix S1. Material and methods.

Table S1. Comparison of several periodontal parameters based on a half-mouth protocol at four sites per tooth between Niigata Study and SHIP.

Table S2. Complete linear regression models regressing mean CAL/PPD on study and covariates.

Supporting Information

Additional Supporting Information may be found in the online version of this article: