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ORIGINAL ARTICLE

An investigation of tooth loss factors in elderly patients using panoramic radiographs

Masaru Konishi[1,2] · **Rinus Gerardus Verdonschot**[3] · **Naoya Kakimoto**[3]

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Abstract

Objectives The aim of this study was to observe the dental condition in a group of elderly patients over a period of 10 years in order to clarify important risk factors.

Materials and methods Participants were elderly patients (in their eighties) who took panoramic radiographs between 2015 and 2016, and for whom panoramic radiographs taken around 10 year earlier were also available. The number of remaining and lost teeth, the Eichner Index, the presence or absence of molar occlusion, the respective condition of dental pulp, dental crowns, alveolar bone resorption, as well as periapical lesions were investigated through the analysis of panoramic radiographs. Additionally, other important variables were collected from patients' medical records. From the obtained panoramic radiograph sets, the patients' dental condition was investigated, and a systematic comparison was conducted.

Results The analysis of the panoramic radiographs showed that the number of remaining teeth decreased from an average of 20.8–15.5, and the percentage of patients with 20 or more teeth decreased from 69.2 to 26.9%. A factor analysis investigating tooth loss risk suggested that tooth loss was associated with the bridge, P2 or greater resorption of the alveolar bone, and apical lesions, and gender (with males having a higher risk compared to females).

Conclusions Teeth showing P2 or greater alveolar bone resorption, bridge, and apical lesions on panoramic radiographs are most likely to be lost in an elderly patient's near future. Consequently, this group should be encouraged to visit their dental clinics regularly and receive comprehensive instruction on individual self-care methods.

Keywords Frailty · Tooth loss · Panoramic radiography · Elderly patients

Introduction

Oral frailty due to a decrease in oral function in the elderly is one of the causes of whole-body frailty [1]. Preventing oral frailty is therefore of consequence when aiming to avert whole-body frailty. Tooth loss is one of the factors leading to oral frailty and it is essential for the elderly to avoid tooth loss in order to prevent worsening of oral functions.

The main causes of permanent tooth loss in the oral region are the emergence of dental caries and its sequelae as well as periodontal disease [1–3]. On the other hand, it has been reported that in addition to these local causes in the oral cavity, various systemic diseases also influence the cause of tooth loss. Hypertension, heart diseases, stroke, and diabetes mellitus arising from the metabolic syndrome have been reported to be relevant systemic diseases exacerbating periodontal disease and contribute to tooth loss [4–9]. Furthermore, the hormonal abnormalities and osteoporosis after menopause have also been reported to be related to tooth loss [10]. In addition to local and systemic causes, areas of residence, income, and educational backgrounds have also been reported to contribute to tooth loss [11–16].

According to a 5-year follow-up study, using intraoral full-mouth radiographs, in which marginal bone level, fillings, crowns, root canal post, root fillings, apicectomy,

✉ Masaru Konishi
mkonishi@hiroshima-u.ac.jp

1 Department of Oral and Maxillofacial Radiology, Hiroshima University Hospital, 1-2-3 Kasumi, Minami-ku, Hiroshima 734-8553, Japan

2 Department of Oral and Maxillofacial Surgery, Tango Furusato Hospital, 673 Kobama, Kyotango, Kyoto 629-3113, Japan

3 Department of Oral and Maxillofacial Radiology, Graduate School of Biomedical and Health Sciences, Hiroshima University, 1-2-3 Kasumi, Minami-ku, Hiroshima 734-8553, Japan

periapical lesions, and caries were investigated; a reduced marginal bone level as well as periapical lesions and apicectomy were associated with tooth loss [17].

Panoramic radiographs are routinely taken in dental clinics, and the alveolar bone resorption and apical lesions can easily be observed from a single radiograph. Also, the tendency to digitize these radiographs makes it possible to preserve the image for a long time without the deterioration of image quality. Therefore, it has become possible to easily compare the changes of the teeth and jaw bones over a long period of time through an investigation of digitized panoramic radiographs taken at different time points.

In this study, we compared patients' recently taken panoramic radiographs with those taken at least 10 years ago. The aim of this study was to investigate the changes in dental condition over the last 10 years and to clarify the risk factors of tooth loss which can lead to the oral and physical frailty in the elderly patient population.

Materials and methods

Patients of 80 years and older were included in this study and had to have taken panoramic radiographs from January 2015 to December 2016 (and also had to have panoramic radiographs available in our database from over 10 years ago). Age, gender, the interval between panoramic radiographs, the number of remaining and lost teeth, the Eichner Index (a measurement of a person's occlusal situation), the presence of molar occlusion, the bone mineral density, the presence or absence of hypertension, heart disease, stroke, and diabetes mellitus were also taken into account. For systemic diseases, we interviewed patients and/or their family or referred to their medical records at other departments at the same hospital. The conditions of their dental pulp, dental crowns, alveolar bone resorption, and periapical lesions as specific oral factors were also examined. All assessment criteria used are shown in Table 1. An example case in this study was shown in Fig. 1. The previous and present panoramic radiographs were taken by the same equipment (Auto 2000EX; Asahi Roentgen Ind. Co. Ltd., Kyoto, Japan). From the obtained two panoramic radiographs, the dental conditions were investigated, and comparison analyses were conducted using Wilcoxon, Kruskal–Wallis, and Fisher's exact tests. For the related factor analyses concerning tooth loss over five teeth by patients or tooth loss by teeth, multiple logistic regression analyses were used. All statistical analyses were performed using JMP for Windows (version 12.0, SAS Institute, Cary, NC, USA).

Table 1 Assessment criteria concerning the elderly's dental condition

Item	Assessment criteria
Pulp condition	Vital or non-vital (root fillings or beyond C3 caries)
Crown condition	No treatment teeth without caries (i.e. normal teeth), partial restoration, full crown (single), bridge, dental caries
Alveolar bone resorption	P1: alveolar crest-1/3 of root, P2: alveolar crest-1/3–1/2 of root, P3: alveolar crest-1/2–2/3 of root, P4: alveolar crest2/3 or more of root
Periapical lesion	Presence or absence of radiolucency within the periapical area
Molar occlusion	Bilateral or one side or none

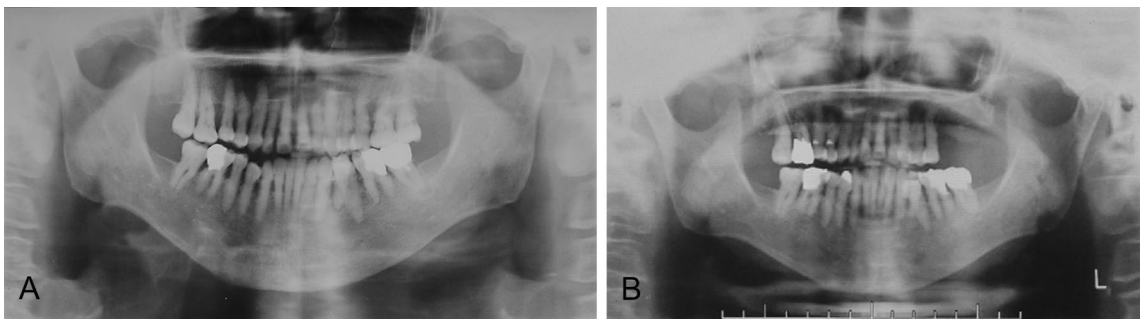

Fig. 1 Comparison examples between previous and present panoramic radiographs. **a** Previous radiograph: 70 years old. **b** Present radiograph: 81 years old. The interval was about 11 years. The patient was female and had hypertension and diabetes mellitus. The number of remaining teeth was changed from 28 to 26, Eichner index from A to B, and molar occlusion was the same, both bilateral. The conditions of two lost teeth (left maxillary first and second molar) was followings, pulp conditions were vital, crown conditions were normal, alveolar bone resorption was both P4, and no periapical lesions on the previous radiograph

We have obtained permission from the Epidemiological Research Ethics Review Committee of Hiroshima University for this study (registration number: E-581).

Results

There were 31 patients aged 80 years or older who took panoramic radiographs between 2015 and 2016 and who had taken panoramic radiographs more than 10 years earlier. Five of 31 patients were excluded from the current study because of the unclear images and/or the lack of systemic disease data. The 26 included patients included 14 males and 12 females. The mean age when taking the baseline and follow-up radiograph was 71.4 ± 2.5 and 83.3 ± 2.5 years. The average interval of having taken the radiographs was around 11 years and 9 months. The average number of the remaining teeth at the baseline radiograph was 20.5 ± 6.8 (min/max: 3–28) and the average number of remaining teeth at the follow-up radiograph was 15.5 ± 6.5 (min/max: 0–26). The number of tooth loss was zero in two of 26 patients. Three patients lost more than ten teeth and one patient lost 12 teeth. The proportion of patients with 20 or more remaining teeth changed from 18/26 (69.2%) to 7/26 (26.9%). The presence of molar occlusion was bilateral for 21 patients and none for five patients at baseline, and bilateral for 12 patients, one sided for seven patients, and none for seven patients at follow-up. There was a statistically significant difference between the baseline and follow-up presence of molar occlusion ($p < 0.001$).

As the bone mineral density was not examined with ten of 26 patients (four males, six females), this data was excluded from the following multiple logistic regression analysis. In these ten patients, the bone mineral density in seven of ten patients (one male, six females) showed the same or higher than that of similarly aged persons. The number of lost teeth was three, four, and five in lower group and zero, one, two, four, five, seven, and nine in the same or higher group of bone mineral density. There was no statistically significant difference between the two groups ($p = 0.91$).

The results of a multiple logistic regression analysis concerning the factors pertaining to a tooth loss greater than five teeth are listed in Table 2. There was statistically difference between the tooth loss greater than five and gender. Conversely, there were no statistically significant differences concerning the number of lost teeth, number of remaining teeth over 20 at baseline, the Eichner index, and presence or absence of heart diseases, stroke, and diabetes mellitus. With respect to gender, male patients showed significantly more teeth loss than female patients. The results of a multiple logistic regression analysis concerning the dental factors pertaining to tooth loss are listed in Table 3. There were no statistically significant differences concerning the type of teeth or pulp condition associated with tooth loss. Conversely, there were statistically significant differences associated with tooth loss for the bridge, alveolar bone resorption from P2 to P4, and teeth with periapical lesions.

Table 2 Multiple logistic regression analysis for tooth loss greater than five teeth by patients ($n = 26$)

Independent variable	Factors	No. of lost teeth 5 < ($n = 13$)	No. of lost teeth 5 ≥ ($n = 13$)	Odds ratio	95% confidence interval	*P* value
Gender	Female (reference)	8	4	1.00	–	0.0153*
	Male	5	9	18.04	0.95–341.27	
No. of teeth at baseline	0–19 (reference)	5	3	1.00	–	0.1080
	20	8	10	0.05	0.00–2.87	
Eichner index	A (reference)	4	5	1.00	–	
	B	6	6	1.37	0.14–13.59	0.7853
	C	3	2	4.29	0.06–311.76	0.5051
Hypertension	Absence (reference)	5	8	1.00	–	
	Presence	8	5	0.18	0.01–2.39	0.1492
Heart diseases	Absence (reference)	9	10	1.00	–	
	Presence	4	3	2.73	0.15–48.80	0.4810
Stroke	Absence (reference)	8	10	1.00	–	
	Presence	5	3	0.15	0.01–2.08	0.1181
Diabetes Mellitus	Absence (reference)	10	10	1.00	–	
	Presence	3	3	6.00	0.25–143.55	0.2379

*Statistically significant

Table 3 Multiple logistic regression analysis for tooth loss (number of teeth = 533)

Independent variable	Factors	Odds ratio	95% confidence interval	p-value
Tooth Type	Upper incisor (reference)	1.00	–	–
	Upper premolar	1.00	0.43–2.41	0.9816
	Upper molar	1.23	0.53–2.81	0.6286
	Lower incisor	1.29	0.58–2.89	0.5267
	Lower premolar	1.11	0.46–2.66	0.8096
	Lower molar	2.01	0.83–4.90	0.1218
Crown condition	Normal (reference)	1.00	–	–
	Partial restoration	1.42	0.62–3.18	0.3959
	Full crown (single)	2.03	0.77–5.32	0.1527
	Bridge	3.11	1.14–8.37	0.0274*
	Caries	1.28	0.35–4.19	0.6983
Pulp condition	Vital (reference)	1.00	–	–
	Non-vital	1.38	0.63–3.07	0.4204
Alveolar bone resorption	P1 (reference)	1.00	–	–
	P2	2.62	1.44–4.88	0.0016*
	P3	13.6	6.30–30.39	< 0.0001*
	P4	60.5	19.69–218.35	< 0.0001*
Periapical lesion	Absence (reference)	1.00	–	–
	Presence	3.65	1.80–7.51	0.0003*

*Statistically significant

Discussion

Through the investigation of panoramic radiographs for elderly patients separated over 10 years, we showed that the number of remaining teeth decreased from an average of 20.8 (i.e. lost teeth excluding wisdom teeth: 7.2) to 15.5 (i.e. lost teeth excluding wisdom teeth: 12.5). According to a 2005 Survey of Dental Diseases by Ministry of Health, Labour and Welfare of Japan, similar period to our study, the average number of lost teeth was roughly 13.1 from 70 to 74 years of age [18]. Moreover, according to their newer 2016 survey, the average number of lost teeth was 12.9 from 80 to 84 years of age. The average number of lost teeth in our study at baseline was smaller than that of the Survey of Dental Diseases in 2005 (7.2 and 13.1) though the average number of lost teeth at follow-up in our study was similar to the 2016 Survey of Dental Diseases (12.5 and 12.9).

The rate of patients with 20 or more teeth has fallen from 69.2% (mean age: 71.4 years old) to 26.9% (mean age: 83.3 years old) in our study. According to the results of the same survey in 2005 and 2016, the rates of people having over 20 teeth was 42.4% in 2005 for people aged 70 to 74, and 44.2% in 2016 for people aged 80 to 84. The rate of patients having 20 or more teeth at baseline was higher than that at the 2005 survey, but our data at follow-up showed lower rates than their 2016 survey. As the panoramic radiograph taken at baseline in our study was taken in order to receive treatment (i.e. our participants were patients), it is possible that the remaining teeth condition was comparatively poor compared to healthy individuals who were examined in the Survey of Dental Diseases by Ministry of Health, Labour and Welfare.

During the follow-up period, the rate of patients with more than 20 teeth decreased from 69.2 to 26.9%, and the number of patients with bilateral occlusal support of the molar region also decreased from 21 to 12, and occlusal support of the molar region significantly decreased during follow-up periods. The number of twenty teeth was a suitable criterion for chewing hard foods [19]. Loss of remaining teeth to less than twenty and molar occlusion not only decreases masticatory ability but also the ability to ingest important nutrients [20, 21]. This is evidenced by reports showing that the loss of occlusal support in the molar region potentially leads to malnutrition [22]. As many of the patients in our study displayed reduced occlusal support in the molar region during the follow-up period, it could be speculated that they might be facing undernourishment.

From the analysis on the oral risk factors of tooth loss in our study, it was found that teeth having a bridge, alveolar bone resorption of P2 or more, and/or a periapical lesion were significant predictors of teeth loss. The survival rate of the bridge was reported at 87 and 69% for 10 and 15 years, respectively [23]. Bridges have the greatest incidence of complications among all prostheses and significant factors involved in its breakdown are caries, periapical diseases, loss of retention, esthetics, periodontal diseases, and tooth fractures [24].

Regarding marginal bone resorption and periapical lesions observed through the intraoral full-mouth radiographs, both have been previously associated with tooth loss [25, 26]. Our results therefore fully corroborate with these earlier findings.

It was reported that several systemic diseases were associated with oral conditions [6, 27–31]. Although there was no correlation with the diabetes mellitus and tooth loss over five teeth in the current study, it has been previously reported that this association does exist [6, 28, 29]. Specifically, it has been suggested that inflammation of periodontal tissue due to diabetes mellitus and worsening of periodontitis are predicative of tooth loss. The association of tooth loss with hypertension, cerebrovascular disease, and heart disease is still controversial and there is currently no evidence of any fitting mechanism to explain this association [4–8, 30, 31]. There was no statistical relationship between tooth loss over five teeth and hypertension or stroke or heart disease in our study. However, Al-Shammari et al. reported that the relationship of tooth loss due to periodontal disease and the presence of hypertension was statistically significant [32]. Mechanisms that directly or indirectly exacerbate periodontal disease by inflammation, thereby leading to tooth loss, have also been reported. One possibility is that we have used a small sample size which might be more prone to outliers. In the 2016 Survey of Dental Diseases by Ministry of Health, Labour and Welfare, the average number of lost teeth was 8.6 at age of 70–74 years and 12.9 at age of 80–84 years [18]. As the difference of the average value was 4.3 teeth, the number of five teeth or more was considered as the criteria of many lost teeth and the statistical analysis was conducted. From the results of a multiple logistic regression analysis concerning the factors pertaining to tooth loss over five teeth, the gender was listed as the risk factor. It was suggested that the male should be possible to be a risk factor of losing a lot of teeth from 70 to 80 s. In the 2005 and 2016 Survey of Dental Diseases by Ministry of Health, Labour and Welfare, the number of teeth in male and female was 15.3 and 15.0 from 70 to 74 in 2005, 15.1 and 15.5 from 80 to 84 in 2016. Even in both years, there were few differences of teeth number between male and female.

The associations of osteoporosis and tooth loss are reported as osteoporosis is one of the exacerbation factors of the periodontitis [33]. Osteoporosis is more likely to develop when the menopause reduces female hormones, because these hormones control bone metabolism. In the current study, there was no statistically significant difference between the bone mineral density and the number of tooth loss in the patients obtained data. As the panoramic radiographs can be used to predict osteoporosis [34, 35], we consider additional measurements regarding bone mineral density and osteoporosis to be a suitable avenue to pursue in future research.

Our investigation is focused on the analysis of panoramic radiographs and did not take oral hygiene and other important factors into account. Therefore, it is necessary to continue to examine the relationships between the tooth loss and the systemic diseases by increasing the number of cases and, for example administer oral hygiene questionnaires, in the future.

Limitations of this study

Panoramic radiography occasionally has a dissimilar magnification ratio and degree of image distortion which strongly depends on the positioning at the time of imaging. Consequently, the comparison is not always made under the exact same conditions. Additionally, the image may be blurred by the different settings of the image layer. Also, especially for the elderly, it may be difficult to maintain proper posture during panoramic radiography.

As the available clinical data were limited, all potentially important information on systemic diseases may not have completely become available from patient/family consultations and/or the available medical records. Consequently, in the present study, the exact causal relationship between tooth loss and systemic diseases might not have become completely revealed as detailed information such as the timing of occurrence, duration of disease, extent of disease, laboratory dates, and prescribed medication were not always made available in the report. As the number of the patients was admittingly small, the sample size needs to be increased in further investigations concerning the relationship between tooth loss and systemic diseases.

Conclusion

This study investigated panoramic radiographs of elderly patients with a 10-year time difference. We found that the number of remaining teeth decreased from an average of 20.8–15.5, and the percentage of patients with 20 or more teeth decreased from 69.2 to 26.9%. A factor analysis investigating the tooth loss suggested that this was associated with the gender, the bridge, P2 or greater resorption of the alveolar bone, and the presence/absence of apical lesions. These patients should be encouraged to visit their dental clinics regularly and receive comprehensive instruction on individual self-care methods.

Although the clinical data used in this study were, admittingly, limited, additional data will be collected in future endeavors to clarify the risk factors of tooth loss in the elderly and to provide an optimal prediction of the prognosis of this group's dental health.

Compliance with ethical standards

Conflict of interest Masaru Konishi, Rinus Gerardus Verdonschot, Naoya Kakimoto declare that they have no conflict of interest.

Human and animal rights statements All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1964 and later versions. This article does not contain any studies with animal subjects performed by the any of the authors.

Informed consent Informed consent was obtained from all patients for being included in the study.

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