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ORIGINAL ARTICLE

Is there a relation between local bone quality as assessed on panoramic radiographs and alveolar bone level?

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Abstract The aim was to explore the relation between radiographic bone quality on panoramic radiographs and relative alveolar bone level. Digital panoramic radiographs of 94 female patients were analysed (mean age, 44.5; range, 35–74). Radiographic density of the alveolar bone in the premolar region was determined using Agfa Musica® software. Alveolar bone level and bone quality index (BQI) were also assessed. Relationships between bone density and BQI on one hand and the relative loss of alveolar bone level on the other were assessed. Mandibular bone density and loss of alveolar bone level were weakly but significantly negatively correlated for the lower premolar area (r=-.27). The BQI did not show a statistically significant relation to alveolar bone level. Radiographic mandibular bone density on panoramic radiographs shows a weak but significant relation to alveolar bone level, with more periodontal breakdown for less dense alveolar bone.

Keywords Periodontitis · Oral radiograph · Panoramic radiograph · Bone density

Introduction

Oral radiographs are an important diagnostic tool in dental practice. Both teeth and surrounding structures can be inspected on intraoral or extraoral radiographs. When assessing jaw bone on oral radiographs, both bone quality and bone quantity can be evaluated. Assessment of jaw bone quantity is performed on a daily basis when screening for or diagnosis of periodontitis [8, 9, 43]. Bone quality is most often evaluated in the periapical region when endodontic problems are encountered [5, 24]. Overall jaw bone quality, however, is less often assessed, although it could be an important aid in diagnosis of bone diseases such as osteoporosis [11, 12, 14, 20, 30, 38] or to identify individuals at higher risk of alveolar (periodontal) bone loss [35]. Bone quality differs between individuals [31] and can be assessed on different types of radiographs. Various approaches have been used to determine jaw bone quality.

On panoramic radiographs, a range of indices are described for jaw bone quality assessment. Morphologic indices are, for example, the Mandibular Cortical Index (MCI; Fig. 1) [15] and the Bone Quality Index (BQI; Fig. 2) [21]. The MCI describes the appearance of the lower mandibular cortex as smooth (C1), with semilunar erosions (C2) or as porous (C3). The BQI is a method to describe the bone quality depending on the amount and the proportion of cortical and trabecular bone. There are four classes: I, homogenous cortical bone; II, thick cortical bone with marrow cavity; III, thin cortical bone with dense trabecular bone of good strength; IV, very thin cortical bone with low density trabecular bone of poor strength. Other indicators concentrate on bone density rather than bone morphology.

Research on the relation between osteoporosis and periodontal disease suggest a greater propensity to lose alveolar bone in subjects with osteoporosis [3, 10]. In other words, osteoporosis, or low systemic bone mineral density (BMD), should be considered a risk factor for periodontal disease progression [7]. However, there are a variety of confounding factors, such as age, genetics, bacterial infections, systemic disease, stress, socio-economic status, oral hygiene and smoking [34, 45]. Osteoporotic patients are shown to have a lower jaw BMD than controls [1, 33, 42],

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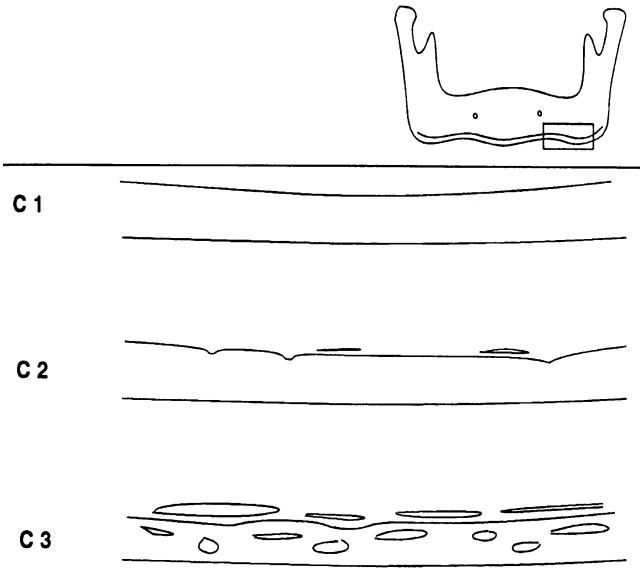

Fig. 1 The Mandibular Cortical Index (MCI) divides the radiographic appearance of the inferior mandibular cortex into three categories: smooth (*C1*), with semilunar erosions (*C2*) or porous (*C3*) [14]

and more in general, mandibular bone density would correlate to skeletal bone density [39]. In addition, film densitometry of mandibular bone is shown to correlate to vertebral densitometric data according to a number of studies [16, 17, 19]. Other studies cannot confirm a clear correlation between the quality and/or quantity of oral and systemic bone [25].

When bone quality and bone quantity are analysed on oral radiographs, it should be kept in mind that besides osteoporosis, other diseases can affect jawbone characteristics. Tumours and cysts of the jaws and other bone diseases influence radiographic bone quality [36].

The aim of the present study was to investigate the relation between bone quality as seen on panoramic radiographs and loss of alveolar bone level. Bone quality was assessed by radiographic bone density and using the BQI. The hypothesis to be rejected was that there is no relation between local bone quality and the alveolar bone level.

Materials and methods

Digital panoramic radiographs of 94 female patients were assessed. Inclusion criteria were as follows:

1. Minimum age of 35 years
2. Absence of considerable infection or bone pathology (cysts, tumours)
3. Presence of all premolars in the lower jaw and at least four teeth per quadrant
4. Cemento-enamel junction clearly visible on both sides (no destruction due to caries or restorations).

All panoramic exposures were made with a Cranex TOME® (Soredex, Helsinki, Finland) multimodal machine by the same radiographic operator. The panoramic radiographs were acquired with storage phosphor plates (MD10XHQ®, Agfa, Mortsel, Belgium) and read out in an ADC Solo® phosphor plate scanner (Agfa). The Agfa MUSICA® software was used to view the images and determine the density. No additional image enhancement was applied apart from the standard software settings. All exposures were done by the same radiographer within a limited time period (consecutive patients).

The radiographic bone density, expressed in gray value, was determined in between the premolars in the mandible, at the lower third of the root [41].

The alveolar bone level was expressed as a percentage and calculated as follows: $A/B \times 100$ with "*A*" being the distance (in mm) from cemento-enamel junction to alveolar crest. The measuring point at the alveolar crest was defined as the most coronal location of the bone margin adjacent to the ligament space. "*B*" stands for the distance (in mm) from the cemento-enamel junction to the apex (Fig. 3) [13]. Measurements were done between the premolars, more specifically distal from the first and mesial from the second premolar, as to be able to relate the data to the local bone density measurements. Results were averaged for analysis. The percentages expressed the loss of alveolar bone level, relative to the root length. Because of normal anatomical variance [44], a loss up to 10% was not considered 'bone loss' for statistical analysis.

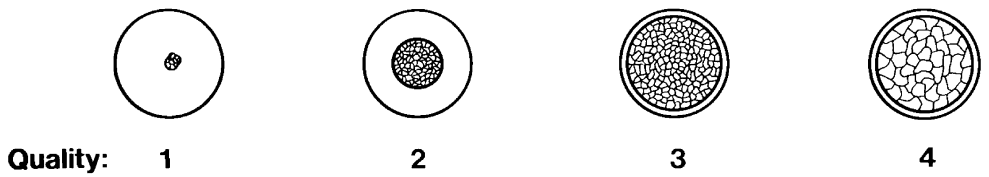

Fig. 2 The Bone Quality Index (BQI) describes the bone quality based on the amount and the proportion of cortical and trabecular bone. The four classes are *I* homogenous cortical bone, *II* thick cortical bone with marrow cavity; *III* thin cortical bone with dense trabecular bone of good strength, *IV* very thin cortical bone with low density trabecular bone of poor strength [21]. For the current study, only two categories were used: quality 1 and 2 were considered high quality (1) and quality 3 and 4 low quality bone (2)

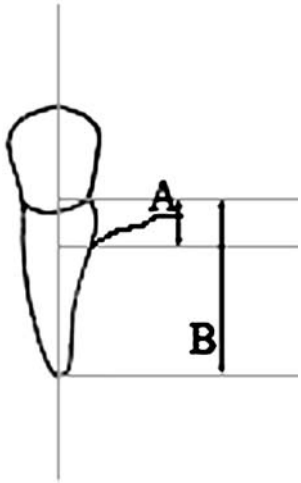

Fig. 3 Alveolar bone level loss was calculated as $A/B \times 100$, with A being the distance from the cemento-enamel junction to the alveolar crest and B being the distance from the cemento-enamel junction to the root apex. The distance was measured on the lines perpendicular to the root axis, intersecting the points of interest: cemento-enamel junction, alveolar crest and root apex [13]. The measuring point at the alveolar crest was defined as the most coronal location of the bone margin adjacent to the ligament space

The BQI was assessed [21]. As this index is considered a rather robust way of evaluating bone quality [22] and this was observed in the data set, we opted for a binarisation of the data and recoding of two categories only: high bone quality, being the combination of quality 1 and 2 (1) and low bone quality, pooling quality 3 and 4 (2). Two observers did a test–retest assessment of the panoramic radiographs for all measurements.

Statistical analysis was performed with Medcalc® vs 9.2.0.2. (Medcalc, Mariakerke, Belgium). Because data did not show normal distribution, Spearman's rho was used to investigate the relation between bone density measurement and alveolar bone level. For relating the BQI to alveolar bone level, the Kruskal–Wallis test was performed. Inter-observer repeatability was tested with the concordance correlation coefficient. This coefficient does not only take into account the deviation of each individual measurement but also the deviation of the regression line from the 45° line through the origin. The level of significance was set at $p<0.05$.

Results

The patient characteristics of the 94 subjects are shown in Table 1. The age range was 35 to 74, with a median of 44.

Table 1 Patient characteristics

	Median	Minimum	Maximum
Age	43	35	74
Jaw bone density	545	415	764
Percentage loss of alveolar bone level	20,0	13.6	32.3
Number of teeth missing	8	4	15

Bone density and level was measured between the premolars.

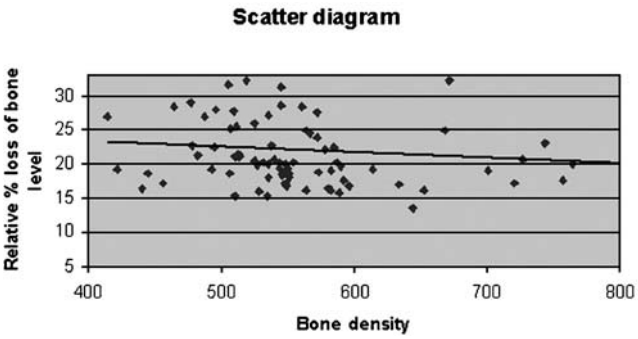

Fig. 4 Scatter plot showing negative correlation between bone density and relative percentage loss of alveolar bone level

Bone density in the lower jaw and the percentage loss of alveolar bone level were significantly correlated ($p<0.05$). The Spearman's coefficient of rank correlation was –0.27. The scatterplot is visualised in Fig. 4. The Kruskal–Wallis test showed a tendency towards a significantly higher loss of alveolar bone level in category 2 of the simplified BQI (low quality). The concordance correlation for the intra- and interobserver agreement were 0.99 and 0.98, respectively, for the density evaluation and 0.91 and 0.90, respectively, for the bone level assessment.

Discussion

There was a weak but significant relationship between mandibular radiographic bone density and the loss of alveolar bone level in the premolar area of the lower jaw. This area is most suitable for jaw bone density measurements because of its small intra- and inter-individual variability for what concerns anatomical size, shape, bone structure and function [41]. Previous studies suggested a relationship between alveolar bone level and skeletal bone density [13, 26, 32, 37, 39, 45], but other studies did not find such a correlation [4, 23].

Many factors have a more or less established place in the prediction of the severity of periodontal bone loss: age, genetics, bacterial infections, restorations, periapical status, socio-economic status, oral hygiene and smoking [28, 31]. Investigating the role of all of these falls out of the scope of the current study that evaluates the applicability of panoramic radiographs to detect the relation between loss of alveolar bone level and jaw bone quality. Possible explanations for the low correlation found between local bone density and jaw bone level in the current study were sought for. A first one could be that the gray level of the images was not a valid measure for bone density. We previously investigated this, comparing bone density measurements with and without the inclusion of a reference wedge [29]. Although the measurements without a reference wedge included showed some correlation towards

actual density, the accuracy was far higher in the 'reference' measurements. Another study indeed confirmed the value of an aluminium wedge, e.g. for the detection of subtle changes in jaw bone density as opposed to merely gray scale correction [2]. For clearing this out, it would be necessary to perform a clinical study, including a reference material when the panoramic radiograph is taken.

Perhaps, the structure of the trabecular bone, rather than only the density, is a factor influencing loss of periodontal bone level [18]. Structural analysis such as fractal dimension or three-dimensional images would be better fit for characterising the trabecular bone [6, 40].

It is clear that panoramic radiographs are very useful overview images, but for absolute linear measures, they are surely not the method of choice, unless the radiographs are standardised [27]. That is why it was opted to express the loss of alveolar bone level as a ratio, relative to the root length. Test–retest reliability was good in assessing the bone level on panoramic radiographs.

The question rises whether it is sufficient to use a simple jaw bone density assessment to predict the future loss of alveolar bone level. Obviously, a prospective study design is needed to verify this hypothesis. Moreover, thought should be given on the best method to assess jaw bone in an uncomplicated, standardised way.

A bone quality index might also be predictive of periodontal bone level loss if a more objective index could be developed. An attempt was made by Lindh et al. [22] to achieve such index, by including reference radiographs in the assessment protocol. Nevertheless, this scoring was based on intra-oral radiographs only, and it is up to now not investigated as a potential tool for panoramic radiography.

In conclusion, radiographic density of the local alveolar bone seems to influence periodontal bone level loss to some extend. If further studies are to be conducted in investigating local bone quality as a predictive factor for alveolar bone loss, it is advised to integrate a more structural analysis of the bone, e.g. the assessment of fractal properties or using three-dimensional imaging.

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