The Significance of Bone in Periodontal Disease

Urs Brägger and Niklaus Peter Lang

Although the connective tissue attachment represents the key issue in periodontal health or disease and in periodontal therapy, the assessment of alveolar bone changes renders valuable indirect evidence for periodontal stability, progression of disease, or repair mechanisms. In periodontal disease bacterial products trigger host cells to release mediators, which may imbalance the steady state between resorption of bone and apposition of osteoid. Modulation of the host's prostaglandin or interleukin-1 synthesis by drug therapy could support the antimicrobial concept of periodontal therapy. Cross-sectional and long-term assessments of alveolar bone have been used to estimate the progression rate of periodontal disease. Inherent limitations of bone assessments in radiographs have to be considered when drawing conclusions from measurements that represent remodeling in periodontal lesions after therapy. Both bone quantity and quality seem to be of secondary importance with respect to the progression of disease, as well as response to therapy. Other risk factors that affect the microbial ecology and/or the host's immune system seem to be the primary determinants for the periodontal health status. (Semin Orthod 1996;2:31-38.) Copyright © 1996 by W.B. Saunders Company

Periodontal disease is a general term used to describe inflammatory diseases that are triggered by bacteria and affect the gingiva, the supporting connective tissue and the alveolar bone. The two main characteristics of periodontitis in contrast to gingivitis are, at least from a clinical and diagnostic point of view, the connective tissue attachment loss assessed by clinical probing and loss of alveolar bone which follows various patterns around the teeth.

The clinical characteristics combined with factors such as the age of the patient at the onset of the disease process, the rate of progression of the disease and associations with diseases in other parts of the body may be used to differentiate various forms or expressions of periodontal diseases. According to the proposal of the first European Workshop on Periodontology in 1993, periodontal diseases are clinically divided into early onset periodontitis, adult periodontitis, and necrotizing periodontitis. Secondary descriptors such as the distribution pattern of the lesions in the dentition, the rate of progression, the response to treatment, the relation to systemic diseases, microbiological characteristics, and ethnic group associations may be added provided that the relevant information is available.

Although the connective tissue attachment represents the key issue in periodontal health or disease and in periodontal therapy, the assessment of alveolar bone changes renders valuable indirect evidence for periodontal stability, progression of disease or even repair mechanisms.

Remodeling of Alveolar Bone

Alveolar bone represents anchoring tissue for periodontal fibers and hence, is considered to be part of the supporting tissues of the teeth.
Masticatory forces acting on teeth are compensated by the periodontal ligament and are transferred to the alveolar bone. Alveolar bone is constantly in a state of physiological remodeling.

As long as a balance exists between the cellular activities leading to resorption of bone and apposition of osteoid, the physiological basal bone remodeling is the expression of a vital functional supportive tissue which is able to adapt to changes in the surrounding structures (orthodontic tooth movement, osseointegration).

The cellular remodeling by the coupled actions of osteoclasts and osteoblasts is regulated by systemic and local factors such as arachidonic acid metabolites, growth factors, and cytokines. As actively resorbing cells, osteoclasts, have the capacity to dissolve mineral with proton pumps that lower the local pH. They seem to be able then to hydrolyze the organic matrix by secreted enzymes. Osteoblasts are also involved in bone resorptive processes by mediating the effects of resorptive agents recognized by receptors and by producing cytokine-like molecules.

In chronic periodontal lesions alveolar bone does not contain an inflammatory infiltrate. Nevertheless, mediators released by host cells which were triggered by bacterial products cause an imbalance in the steady state of bone remodeling. This results in localized or generalized bone resorption around the teeth. In necrotizing forms of periodontal disease the inflammatory infiltrate may even reach into the alveolar bone.

One typical cytokine playing an important role in bone destruction associated with periodontal disease is interleukin-I. Bacteria harbored in subgingival plaque have the ability to stimulate interleukin-I production and in periodontally diseased tissue samples elevated interleukin-I levels have been detected.

A representative experiment elucidating the mechanisms that regulate bone remodeling was presented by Ishihara et al. The study examined the role of interleukin-I and prostaglandin in an in vitro model in which bone resorption was induced by lippopolysaccharides from Actinobacillus actinomycetemcomitans. By blocking the action of molecules known to mediate resorption, tissue destruction was hindered in the model.

From such studies it could be concluded that adjunctive to the antimicrobial concept of periodontal therapy, the modulation of the hosts prostaglandin or interleukin-I synthesis could be beneficial for patients suffering from periodontal disease. Several studies testing the effects mainly of nonsteroidal anti-inflammatory drugs on progression rates of periodontal disease have already documented more favorable conditions in the drug modulated situation.

Cross-sectional and Long-term Assessments of Alveolar Bone

Representative studies on the evaluation of alveolar bone to describe the progression rate of periodontal disease in patient cohorts of different ages were performed by Papapanou et al. and Papapanou and Wennström.

The patients represented a selected group seeking dental care and were considered at higher risk for caries and periodontal disease compared with a random sample of the population. From 283 subjects full mouth radiographic examinations were available that were taken 10 years apart by means of a standardized parallel technique. The distance between the cementoenamel junction and the most coronal level at which the periodontal ligament space retained its normal width was measured to the nearest 0.5 mm. In 75% of the subjects a mean bone loss of greater than 0.5 mm was calculated, whereas 7% of the subjects showed a mean loss of greater than 3 mm. Fifty-five percent of the tooth sites had lost between 0.5 and 2.0 mm in periodontal bone height and 16% showed a longitudinal bone loss of greater than 2 mm. The mean annual reduction of alveolar bone height varied between 0.07 and 0.14 mm in the age group of 25 to 65 years. The older age groups tended to show a significantly greater rate of bone loss (0.28 mm per year). The study also noted that molar teeth had a less favorable prognosis for both tooth mortality and alveolar bone loss than had the remainder of the dentition.

Several epidemiological studies have indicated that even though the prevalence of gingival inflammation is generally high, advanced periodontal disease affects only a small portion of the population ranging from 2% to 8% in individuals younger than 45 years of age and about 30% in the age range of 65 to 75 years.

In long-term studies on patients not involved
in periodontal treatment programs it was observed that comparatively few individuals yielded sites with progressive disease for a period of time.\textsuperscript{10,21-25}

These observations may influence decision making when assessing treatment needs and planning treatment goals. An interesting strategy basing on the amount of remaining bone support was proposed by Wennström et al.\textsuperscript{26} The model assumed that a reasonable treatment goal would be the maintenance of the alveolar bone height of one third of the root length at 75 years of age. This would allow the maintenance of a functional dentition for a lifetime at least including the single rooted teeth. In the data analyses by Wennström et al\textsuperscript{26} a rate factor was determined for each tooth site with range of age being used as a threshold level above which intensive therapeutic procedures would be needed to meet the goal of the proposed model.

All the epidemiological studies have indicated that on the bases of cross-sectional and longitudinal assessments of alveolar bone changes using conventional radiographic techniques, only a small portion of the population suffers from severe periodontal destruction.

Evaluation criteria of the radiographic appearance of the crestal lamina dura were tested as a potential indicator for predicting disease activity.\textsuperscript{27} From 51 treated adult periodontitis patients, 1,809 interproximal sites were included in a 3-year study on maintenance. The standard for disease progression was a 2 mm loss of attachment or a 3 mm increase in probing pocket depth. Presence of the crestal lamina dura was described when a consistent radiopaque, thin, white line without break of its superior and inferior margins was present. Absence was noted when no lamina dura was detectable or if a break in its continuity was found. From the 1,809 interproximal sites, 303 showed radiographically a lamina dura and in 1,506 sites an absence of the lamina dura was noted. From these 1,506 sites only 2% had lost clinical attachment above the threshold, whereas none of the sites with an intact lamina dura showed a probeable loss of attachment. Hence the presence of a lamina dura was considered to be an excellent positive predictor of periodontal stability.

Methodological Limitations of Bone Assessments in Radiographs

Clinical assessment of the periodontal condition can be performed by evaluating the severity of the inflammation (bleeding on probing) and changes in the level of the soft tissue attachment (recession, probing pocket depth, probing attachment level). Indirect assessment of the severity of the of periodontal destruction or the progression rate may be supported by radiographic evaluations.

Interpretation of the results of both clinical and radiographic evaluation methods, with regard to their reliability in reflecting the anatomical situation, should be carried out critically, since the anatomical relationships can only be evaluated with certainty by means of histological sections.

In a review by Jenkins et al,\textsuperscript{28} the limitations of the evaluation of early periodontal bone loss in adolescents were outlined. Assessments based on the radiographic distance between the cemento-enamel junction and the alveolar crest were considered to be subjective. There is still debate whether or not the threshold for the presence of periodontal disease is at a 2 or 3 mm distance from the cemento-enamel junction (CEJ). Furthermore, the definition of reference points such as the CEJ, the appearance of the periodontal ligament space and the radiographic appearance of the alveolar crest depend on a number of factors difficult to control in epidemiologic or cross-sectional studies.

To test the reliability of radiographic images from periodontal lesions to represent the true severity of tissue destruction, open bone defect measurements during periodontal surgery are needed. Two hundred thirty-seven periodontal sites in 23 patients were examined using panoramic, periapical, and bitewing radiographs.\textsuperscript{29} The radiographs were taken with splints in situ containing steel balls for calculation of the enlargement of objects in the radiographs. Furthermore, metal wires as part of the splints served as references for measuring the distances from the occlusal plane to the alveolar crest. Measurements of the pocket probing depth were also recorded with the splints in situ. Before periodontal surgery (bone sounding) and after flap reflection and removal of all granulation tissue, the distances between the references in the splints
and the bone levels were probed. The enlargement calculated amounted to 27% in the upper and 26% in the lower arch for the panoramic radiographs. For bitewing and periapical radiography 8% of enlargement was observed in the maxilla and 4% to 5% in the mandible. All methods underestimated the bone loss compared with the open bone measurements. Bone sounding before surgery with local anesthesia was the most accurate method with at the most a 5% discrepancy relative to the true values. Periapical radiography was more accurate than panoramic and bitewing radiographs. Bone loss was underestimated by 13% to 32% in orthopantomograms, 11% to 23% in bitewings and 9% to 20% in periapical radiography.

When considering the limitations of a radiographic technique, the variability among different observers has to be accounted for. In the study by Akesson et al.29 a substantial variability among the five observers was noted with respect to the underestimation of the lesions in the radiographs.

Radiographic underestimation of the severity of periodontal defects scheduled to be treated by guided tissue regenerative techniques was evaluated in a study by Tonetti et al.30 Estimation of the true defect depth assessed during surgery was best when adding a 1.5 mm distance to the probed clinical attachment level.

According to Hämmerle et al.31 the estimation of the true defect size in radiographs is a function of the severity of the lesion. A clear underestimation of alveolar bone loss was observed in moderate periodontal lesions, whereas in deep lesions, an overestimation of the degree of tissue destruction was noted (Fig 1).

A review of some recent articles on the radiographic diagnosis of the periodontal tissue status for use as a tool to assist in decision making for disease progression assessments, treatment choice assessments, and evaluation of treatment out-

Figure 1. (A) Radiographic appearance of alveolar bone destruction associated with periodontitis. Pocket probing depths reached values of 11 to 14 mm. Estimation of the true degree of bone loss is difficult. The tooth may appear to have a hopeless prognosis. (B) Clinical appearance of the periodontal lesion after flap reflection and removal of granulation tissue. There is almost no periodontal tissue left. Splinting to the neighboring teeth was indicated for patient comfort and to allow scaling/root planing. (C) The same tooth no. 13 as in Figure 1A 7 years later. At 3 to 4 month intervals supportive care was performed. The probing pocket depths were 4 to 6 mm. The splint had to be repaired several times. The originally hopeless appearing tooth 13 was saved for a prolonged period of time. The quality of the tissue on the root surface after repair of the lesion cannot be assessed by means of the radiographic appearance.
comes, was carried out.\textsuperscript{32} Whereas for periodontal research purposes sophisticated and sensitive methods, such as digital substraction radiography were developed, it was stated that there exists a striking discrepancy between the quality of radiographs taken in daily practice and the valuable information that could be gained from properly applied diagnostic procedures. There exists also an urgent need for improved education in this field to raise the quality of radiographic diagnosis.

**Bone Quantity**

An interesting question regarding the prognosis of teeth has always been how much alveolar bone would suffice for tooth longevity. This is reflected in the careful registration of tooth mobility and crown to root ratios which is still part of most periodontal examination procedures.

Longitudinal studies on the progression of periodontal disease have indicated that chances for further loss of periodontal support are higher, in the presence of a history of already existing periodontal tissue loss.\textsuperscript{33} Nevertheless, performing appropriate active treatment and providing supportive therapy will result in predictable maintenance of the attachment levels in most cases. Longitudinal studies\textsuperscript{34,35} have shown that dentitions with dramatically reduced periodontal support may be maintained over years without further progression of disease provided competent active and maintenance therapy was guaranteed. Even in cases with seemingly hopeless teeth a correct perioprosthetic treatment including the reconstruction with full-arch bridges might secure a functional dentition over years.\textsuperscript{36}

The relative importance of the amount of alveolar bone was tested in an in vivo model situation.\textsuperscript{37,38} The progression rate of periodontal disease over 8 years was followed in a group of 52 adult patients who had various forms of cleft lip, alveolus, and palate. At the sites adjacent to the cleft a discrepancy between the alveolar bone height measurements in radiographs and the levels of the clinical attachment had been observed.\textsuperscript{39} In these patients a low level of oral hygiene and generalized signs of inflammation were found and therefore, they were considered at high risk for progression of periodontal disease and development of caries. The rate of progression of periodontal disease over 8 years, however, was not found to be different at the cleft sites when compared with matching control teeth (Fig 2), within the same patients, which were not affected by the cleft (Table I).

These data were supported by findings from experimental studies in the dog model.\textsuperscript{40} Teeth with a long connective tissue support and reduced level of alveolar bone were created according to a procedure described by Nyman and Karring.\textsuperscript{41} The progression rate of periodontal disease at those sites was compared with progression at sites with regular anatomy. No significant differences were revealed.\textsuperscript{40}

![Figure 2. A 19-year-old man with unilateral cleft lip, alveolus, and palate. Progression of periodontal disease was assessed and compared at sites adjacent to the cleft (T), at control sites distant to the cleft (C\textsubscript{1}) and at contralateral control sites in the quadrant not affected by the cleft (C\textsubscript{2}).](image)

### Table 1. Number of Test and Control Sites Exhibiting Change in the Radiographically Assessed Bone Height

<table>
<thead>
<tr>
<th>Change in BL (%) between 1979 and 1987</th>
<th>T (N = 53)</th>
<th>C\textsubscript{1} (N = 42)</th>
<th>C\textsubscript{2} (N = 31)</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥30</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>+25</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>+20</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>+15</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>+10</td>
<td>5</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>+5</td>
<td>1</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>0</td>
<td>12</td>
<td>13</td>
<td>12</td>
</tr>
<tr>
<td>−5</td>
<td>17</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>−10</td>
<td>8</td>
<td>12</td>
<td>9</td>
</tr>
<tr>
<td>−5</td>
<td>2</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>−20</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>−25</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>≤30</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Abbreviations: BL, radiographic alveolar bone height; T, sites adjacent to cleft; C\textsubscript{1}, control site distant from cleft; C\textsubscript{2}, contralateral control site in unaffected quadrant; N, number of sites; +, increase in alveolar bone height; −, loss in alveolar bone height.
From these studies it can be concluded that a dentogingival unit with a long connective tissue attachment is not more prone to plaque-induced attachment loss. The discrepancy between alveolar bone height levels and clinical attachment levels indicates that the alveolar bone height, as visualized in radiographs, is of limited value for the diagnosis of the degree of periodontal destruction. Hence radiographs should not be used as the sole determining factor for the exclusion of such teeth to function as an isolated unit or to be used as an abutment for a prosthetic appliance (Fig 3).

Bone Quality

Elders et al42 examined the association between periodontitis and systemic bone mass. Sixty women between the ages of 46 and 55 years were available for an intraoral examination including the assessment of the number of teeth present, probing pocket depth measurements and the presence or absence of bleeding on probing. In the dentate subjects vertical bitewings were obtained and the distance between the alveolar bone crest and the cementoenamel junction was measured according to a method described by van der Linden.43 The bone mineral content of the lumbar spine was measured by dual photon absorptiometry, and, in addition, the metacarpal cortical thickness was measured in radiographs of both hands. No statistically significant correlations between the systemic bone mass and the signs of periodontal disease could be detected. It was concluded that general bone mass does not play an important role in the onset of periodontal disease.

Klemetti et al44 examined 227 postmenopausal women 48 to 56 years of age who were part of a 5-year study on osteoporosis and the identification of risk factors. One hundred twenty-five of these women had teeth in both jaws,

Figure 3. (A) Minimal bone support around the root of tooth 21 in a 19-year-old woman with unilateral cleft lip, alveolus and palate. (B) After 7 years of function as an abutment for a fix partial denture (21 × 24), radiographically stable periodontal conditions were documented.
whereas 102 had teeth only in the mandible. The periodontal conditions were assessed using the criteria of the Community Periodontal Index for Treatment Needs resulting in scores for health, for bleeding on probing, for the presence of calculus, for the presence of probing depths of 4 to 5 mm and probing depths of 6 mm or greater in ascending order. From panoramic radiographs the mesial and distal index bone height/root length was assessed. The bone mineral density was measured from the femoral neck using dual energy roentgenogram absorptiometry. The women were grouped into four classes of general mineral status of the skeleton. Thirty-six of these women belonged to the osteoporotic risk group with the lowest values for bone mineral density. No correlation regarding the number of remaining teeth nor the alveolar bone height with the bone mineral mass was found. Grouping into classes of different bone mineral status indicated that those women with good mineral status had lower bone height measurements around their teeth. In this context it should also be realized that epidemiological data by Salonen et al indicated that women older than 40 years of age had more favorable alveolar bone conditions compared with age-matched men. Obviously, it seems reasonable not to consider osteoporosis as a risk factor for the development and progression of periodontal disease. Other risk factors, however, which affect the host’s immune system and/or the microbial ecology have been shown to increase the chances for development of periodontal disease or may result in a higher progression rate. These are:

- Poorly controlled insulin dependent diabetes mellitus
- Rheumatoid arthritis
- Neutropenia
- Genetic predisposition, especially for the early onset forms of periodontitis
- A spouse with advanced periodontal disease
- Virus infection affecting the immune system
- Smoking habits

Personal risk factors are also being considered as playing an important role in the initiation of periodontal disease. Periodontitis has to be considered as being a consequence of an unfavorable host-parasite interaction and yet, the disease may be initiated by specific bacterial groups. Because presumptive periodontopathogenic bacteria may also be associated with stable periodontal conditions, it could be suggested that not only the immune factors reacting to the presence of bacteria, but also host factors, may be responsible for diminished resistance against tissue breakdown. Such host factors may include psychosocial stress, lifestyle factors such as a diet, alcohol, smoking, and deficiencies in the immune system. These factors certainly need further systematic study.

References