Scientific Thought and Clinical Practice

10 years of BaSS

DENSITOMETRIC ANALYSIS IN PERIODONTOLOGY

U.K.Gursoy (DDS, PhD)
I. Marakoglu (DDS, PhD)

University of Cumhuriyet Faculty of Dentistry
Department of Periodontology
Sivas Turkey

Summary:

Beginning from the exploration of x-ray, densitometric analysis is in common use of medical diagnosis. Today densitometric analysis begins to take place in dental clinics especially in periodontology with precise bone density change detection. Although microdensitometry and photodensitometric analysis were most common methods to assess bone density changes, recent developments in radiography and nuclear medicine let the clinicians use computer supported densitometric techniques also. Both in disease progression and healing process, early changes which could affect the treatment and maintenance procedures could easily be designated by the help of densitometric analysis. It seems that densitometric analysis, with its ability to detect minor changes in alveolar bone and easy usage, will take conventional radiographs place.

Key Words: Densitometric Analysis; Alveolar Bone; Periodontology.

Introduction

Periodontitis is a host mediated inflammatory disease induced by a group of bacteria, which results in a loss of connective tissue attachment and alveolar bone. As loss of attachment and alveolar bone are essential characteristics in periodontal disease, those changes must be detected in a clear and objective manner1.

Nevertheless, main objective of the periodontal therapy is the reconstruction of gingiva, cementum, bone and periodontal ligament on a previously infected root surface. Over the last two decades 6 to 12 month surgical re-entries has been the gold standard of evaluation for most clinical regenerative studies. One of the greatest limitations with this form of analysis is recruiting the patients for re-entry. Although clinical soft tissue measurements, like pocket depth measurements or bleeding indexes have played an important role in the assessment of regenerative procedures, they do not provide any information regarding the hard tissue response to the therapy2.

Conventional radiography, which is used both in evaluation of disease progression and healing period, is a non-invasive diagnostie tool that detects by measuring the alveolar bone height. Alveolar bone loss is conventionally calculated by measuring the distance between the alveolar crest and cemento-enamel junction on radiographs. However, the reduction seen on the conventional radiography is the bone loss occurred, not the continuing loss3. Healthy cortical bone covers the resorption changes on conventional radiograph readings on periodontal defect when active periodontal destruction happened in active disease period. Hence, conventional radiography is an insensitive technique for detecting small bony lesions or sites in which periodontitis had just started or progressed4. Today, with the help of new enhanced digital image analyse techniques, changes in alveolar bone can be detected not only in bone height but also in density. Assessing of alveolar bone density provides us to detect early bone loss and gain around the teeth when bone loss is still permanent3.

Densitometric analysis is being performed in medicine for a long time, beginning from shortly after the discovery of X-ray. First attempt was to evaluate the mineral structure of teeth in 1930's5. In the past, bone density measurement techniques were associated with large precision errors relative to estimated rates of change. Technical and biological factors generally affect the ability to interpret bone loss rates. Technology of bone densitometry has undergone rapid changes over last decade with dual-energy X-ray absorptiometry6. Nowadays, bone density can be reliably evaluated from radiographs, computerized tomography(CAT scans), peripheral bone densitometry by single photon apsorptiometry(SPA), dual-photon absorptiometry(DPA), and dual energy X-ray technology (DEXA) as well as peripheral dual energy X-ray pDEXA7.

In dental research, microdensitometry was used for densitometric analysis in jaws8 and later phodensitometry9, subtraction radiography10 and computer assisted densitometric image analysis (CADIA)11 techniques was performed. Even if they were not so common in use, quantitative computed tomography12 and 125I-absorptiometry13 were performed to detect alveolar bone density changes also.

Microdensitometric Analysis

Beginning from the mid 60's, microdensitometry offered a more quantitative and objective technique than the visual method evaluating radiographic bone height and mineralization. Several investigators used it in order to determine the size and quantity of trabeculae in bone14, amount of bone resorption in the area of bone implants15, and the effect of regenerative alterations of the alveolar bone after flap operation16. Israel14 has reported that size and quantity of trabeculae in bone can be determined by using microdensitometric analysis. Miller et al.15 reported Joyce-Loebel microdensitometery as a new system of measuring bone density in 1964 in order to measure bone density. This densitometer prints out a 2-dimensional analogue map of the density patterns seen in a photographic negative or other transperencies. This instrument has proved itself useful both in the quantitative and qualitative analysis of bone density as determined radiographically8. This technique takes an aluminium step-wedge as reference and determines the changes in bone mineralization by the help of this reference. Aluminium was chosen because its atomic number is close to calcium. In 1977 Turgut and Kansu16 combined a study about bone regeneration in post operative flap procedure by assessing the interdental bone density changes; and they stated the bone resorption till 3rd month postoperatively by using microdensitometry. Also in that study they found lower density scores in the posterior region in comparison to the anterior region and expressed the importance of anatomic structures in densitometric analysis. As they couldn't find any difference between the densitometric analyse results of men and women they noticed that sex does not affect the results of densitometry. In 1972 Matsue et al.17 stated that the microdensitometry is more quantitative and objective technique than the visual method of evaluating radiographic bone height and mineralization following transplantation.

1251-Absorptiometry

Radiographic and nuclear medicine diagnostic techniques reached the sensitivity that can detect small bone changes. A non radiographic diagnostic method, 125I-absorptiometry, introduced by Henrikson13, is the most precise method to detect periodontal bone mass changes. It is based on the absorption by bone of a low-energy gama beam by bone, originating from a radioactive source of 125I. This method has been shown to measure bone mass with a high degree of exactness and precision. The use of this system in posterior sites limited by technical considerations, and the nature of the beam of 125I makes precise alignment even more critical than with other techniques18.

Photodensitometric Analysis

Photodensitometric analysis has been developed in order to facilitate the densitometric analysis in posterior regions, especially in furcations. Photodensitometry is a quantitative method that is based on correlating bone density changes with a density reference device in the radiograph3. It implies the use of photodensitometer and a computer assisted transformation of the optical density into millimetres of aluminium equivalents. A microdensitometer together with a microcomputer is used in density readings18.

In 1990 after assessing the interdental bone density changes by photodensitometry, Dubrez et al.9 reported statistically significant bone gain in a postoperative 1-year period after scaling and root planning. Ersoy and Ataoğlu19 assessed the alveolar bone density by photodensitometry in patients they performed closed root surface curettage and they found 14.4% decrease in density in 2 months postoperatively, and later in 6 and 12 months they found an increase of 8.6% and 16.9%, respectively. In a similar study, Alptekin et al20 examined the effect of low dose doxycyclin on alveolar bone density in adult periodontitis patients by photodensitometric method and they could not found any significant effect. In that study they used transmission densitometry on assessing the scores. Colbert and Bachtell21 coined the term radiographic absorptiometry for similar analysis of radiographs with computer-controlled calculations of the radiographic image. Kuhl and Nummikoski3 measured the accuracy and precision of a radiographic absorptiometry method by using an occlusal density reference wedge in quantification of localised alveolar bone density changes and they found the accuracy of the intraoral radiographic absorptiometry method low when used for absolute quantification of bone density. However, they suggested that the precision of the method is good and the correlation is linear, indicating that the method can be used for serial assessment of bone density changes at individual changes.

Subtraction Radiography

Subtraction radiography, which has been used in medical diagnose for a long time, began to use in dental, especially in periodontal diagnosis18. Subtraction of 2 serially obtained radiographs is a technique that increases detectability21. Changes in density and/or volume of bone can be detected as lighter areas (bone gain) or dark areas (bone loss). Quantitative changes in comparison with baseline images can be detected using an algorithm for gray scale levels. This is accomplished by means of a computer. Radiographs taken with identical exposure geometry can be scanned using microphotometer that determines a grey-level value for each picture point. After superimposition of 2 subsequent radiographs, this technique can show differences in relative densities18. The success of the technique is contingent on the ability to cancel unchanged anatomical structures. Hence, it suffers from artefacts introduced by inexact replication of the projection geometry, uncontrolled variations in film exposure and processing, and tissue changes resulting from normal growth or development22,23.

A photographic subtraction technique was first described by Ziedses des Planetes in 1934 and has been used mainly for angiographic examinations. The theory of photographic subtraction has been described in detail by Hardstedt and Welander. Hardstredt determined the conditions for optimal results and described the requirements that have to be met with regard to film density, contrast, exposure and processing24.

In early attempts, Hausman et al.25 detected differences in crestal bone height of 0,87mm with reliability. Jeffcoat et al.24 have shown a strong relationship between probing attachment loss detected using sequential measurements made with an automated periodontal probe and bone loss detected by subtraction radiography.

Because many physiologic as well as pathologic changes of dental interest occur with bone, digital subtraction radiography should be of value whenever it is of significant interest to study such changes longitudinally. It should be particularly valuable in research aimed at studying the effects of different treatment procedures or the progression of lesions left untreated24. Studies of observer performance in radiographic diagnosis of periapical lesions have demonstrated significant variations among examiners regarding the size of such lesions, as well as of changes in size between examinations26-28. It has been found that examiners could completely fail to perceive lesions which were detected at earlier stages in a series of radiographs of periapical lesions with increasing size28. In diagnosis of periodontal disease there is a need for accurate detection of subtle changes in the crest of alveolar bone, for which the conventional radiographic technique is less well suited29. Under most ideal conditions, digital subtraction images permit the detection of 5% change in mineral mass per volume, whereas traditional visualisation of serial radiographs requires a change of at least 30%22,30. This method has a great diagnostic potential, even in clinical practice, because of the development of personal computers with capability for digitising and image processing 18.

Computer Assisted Densitometric Image Analysis (CADIA)

CADIA is one form of subtraction radiography that allows the investigator to quantify changes by comparing the radiographic density in a predetermined region of interest(ROI) between baseline and follow up radiographs2. In this system, a video camera, which interfaced with an image processor, and a computer that allow the storage and mathematical manipulation of the images, measures the light transmitted through a radiograph, and the signals from the camera are converted into grey-levels18. Bragger et al1 reported that CADIA is an objective method to quantitatively follow alveolar bone density changes over time and appears to be the most sensitive of previously described radiographic interpretation techniques. They compared the ability of CADIA to detect alveolar bone changes on radiographs with interpretation of digital subtraction images and conventional radiographic interpretation. In their evaluations of bone loss at osteoctomy/osteoplasty sites and they found 72.7% negative change by digital subtraction images, 50.9% negative change by conventional interpretation, and 81.8% density change by CADIA. In an other study, Bragger et al11 performed crown lengthening procedures for restorative purposes and assessed the density changes by CADIA: a statistically significant density loss was assessed 4-6 weeks post surgically at test sites treated by periodontal surgical procedures, compared to corresponding controls. Deas et al31 using replicate measurements of clinical attachment levels and CADIA, demonstrated that the prevalence of progressing lesions in periodontitis (38% of sites per patient) as detected by this radiographic method, might be much higher than previously thought. The CADIA system appears to offer an objective method to follow alveolar bone density changes quantitatively over time. The density change information stored in a digital form and its detection does not depend on human perception or a diagnostic decision making process. In contrast to the perhaps most precise method for assessment alveolar bone mass, the 125I-absorptiometry, this method is not restricted to the anterior region, and viewing and analysing of a larger area of diagnostic interest or several areas at the same time is possible. Patient exposure to X-rays is not increased since routinely taken dental radiographs may be analysed. However, there are some disadvantages of the system; it requires superimposable serial radiographs that can be obtained by applying custom-made bite-blocks and a Rinn system modificafion 1.

Quantitative Computed Tomography (QCT)

Computed tomography rapidly gets used in medicine in order to assess the bone minerelization quantitatively. QCT can be performed in single-energy or dual-energy modes, which differ in accuracy, precision and radiation. Kiemetti et al12 determined the mineral density of the trabecular bone of the mandible by single-energy QCT and compared the results with the bone mineral densities of their lumbar area. The bone mineral density of the lumbar area and that of the femoral collum correlated well with each other, but the bone mineral density of the trabecular bone of the mandible did not correlate with either of the other two bone mineral density measurements. Kribbs et al32 found that in elderly subjects mandibular density did not correlate with any skeletal measurements except vertebral bone.

One of the most recent advances in the assessment of bone changes involves the use of nuclear medicine. Nuclear medicine techniques for the study of bone metabolism use a bone seeking radiopharmaceutical, such as diphosphonate subject, which labelled with a radionucleide, Tc 99m. This compound is injected intravenously, and after a waiting period to allow for bony uptake and clearance of the radiopharmaceutical, uptake by the bone is measured with a miniaturised semiconductor probe radiation detector 18.

As it provides the clinician with the basis for applying preventive or corrective measures, early detection of periodontal bone loss is important. Reduction of alveolar crestal bone density is one early sign of periodontal disease and precedes the loss of height of the alveolar bone crest. However, conventional comparisons of radiographs cannot detect small changes reliably due to great variations in the anatomical structure and radiographic image density and contrast33. Conventional radiographs do not let to have ideas about the continuing bone reposition or resorption18. There are several studies that mention the bone density changes before loss in bone crest height34.

In conclusion, it should be noted that the densitometric analysis represents the future in dental imaging because of its ability to detect bone changes that is often undetected when using the conventional radiographs.

References

1. Bragger U, Pasquali L, Rylander H, Carnes D, Kornman KS. Computer assisted densitometric image analysis in periodontal radiography. A Methodological Study. J Clin Periodontol 1988; 15:27-37
2. Toback GA, Brunsvold MA, Nummikoski PV, Master LB, Mellonig JT, Cochran DL. The accuracy of radiographic methods in assessing the outcome of periodontal regenerative therapy. J Periodontol 1999;70: 1479-1489
3. Kuhl ED, Nummikoski PV. Radiographic absorptiometry method in measurement of localised alveolar bone density changes. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2000;89:375-81
4. Bragger U, Bürgin W, Fourmousis I, Schmid G, Schild U, Lang NP. Computer-assisted densitometric image analysis of digital subtraction images:In vivo error of the method and effect of thresholding. J Periodotol 1998;69:967-974
5. Goodwin PN. Methodologies for the measurement of bone density and their precision and accuracy. Seminars in Nuclear Medicine 1987;Vol XVII, No 4: 293-304
6. Pasariello R, Albanese CV, Kvasnova M. Bone densitometry in clinical practice. Eur Radiol 1997;7(Suppl. 2):2-10
7. Becker W, Hujoel PP, Becker BE, Willingham. Osteoporosis and implant failure: An exploratory case-control study. J Periodontol 2000;71 :625-631
8. Matsue I, Collings CK, Zimmerman ER, Vail WC. Microdensitometric analysis of human autogenous alveolar bone implants. J Periodontol 1970;41:489-495
9. Dubrez B, Graf JM, Vuagnat P, Cimasoni G. Increase of interproximal bone density after subgingival instrumentation quantitative radiographical study. J Periodontol 1990;6 1:725-731
10. Janssen PTM, van Aken J. Problems around the in vitro and in vivo application of quantitative digital subtraction radiography. J Clin Periodontol 1989;16:323-330
11. Bragger U, Pasqulai L, Kornman KS. Remodelling of interdental alveolar bone after periodontal flap procedures assessed by means of computer-assisted densitometric image analysis(CADIA). J Clin Periodontol 1988;15:558-564
12. Kiemetti E, Vainio P, Lassila V, Alhavla E. Trabecular bone mineral density of mandible and aiveolar height in postmenopausal women. Scand J Dent Res 1993;101:166-70
13. Henrikson CO. Iodine as a source for odontoİogical roentgenology. Acta Radiol 1976;13;377
14. Israel H. Microdensitometric analysis for study of skeletal growth and aging in the living subject. Amer J of Physical Anthropology 1968;29: 287
15. Miller CS, Parsons FG, Kofsky IK. Simplified two dimensional microdensitometry. Nature 1964;202: 1196.
16. Turgut E, Kansu H. Flap operasyonunu takiben standardize edilen paralel teknikle alman seri radyograflarin mikrodensitometrik analizleriyle kemik rejenerasyonunun takibi. Hacettepe Un Dishekimliği Fakultesi Dergisi 1977; 1:48-56

17. Matsue I, Zimmerman ER, Collings LK, Best JT. Microdensitometric analysis of human autogenous bone implants II. Two dimensional density and pattern analysis of interproximal alveolar bone. J Periodontol 1971 ;42:435-438
18. Carranza FA, Newman MG. Clinical Periodontology Philadelphia, W.B.Saunders Company, 1996 pp 380-381
19. Ersoy M, Ataoglu T. Kapali kok yuzey kuretajinin alveolar kemik densitesi uzerine etkisi. Selcuk Un. Dishekimligi Fak. Dergisi 1996;6: 101-105
20. Alptekin NO, Duran I, Gozlu M, Erdem EO, Ozkaya T. Eriskin periodontitis tedavisinde donusumlu uygulanan dusuk doz doksisiklinin alveoler kemik densitesine etkisi. Cumhuriyet Un. Dishekimligi Fak. Dergisi 1999;2:42-47
21. Colbert C, Bachtell RS. Radiographic absorptiometry (Photodensitometry). In: Cohn SH, editor. Non-invasive measurements of bone mass and their clinical application. Boca Raton:CRC Press.1981 pp.52-84
22. Ortman LF, Duniford R, McHenry K, Hausmaın E. Subtraction radiography and computer assisted densitometric analysis of standardised radiographs. A comparison study with 125I absorptiometry. J Periodont Res 1985;20:644-651
23. Webber RL, Ruttiman UE, Grondahl HG. X-ray image subtraction as a basis for assessment of periodontal changes . J Periodont Res 1982;17:509-511
24. Gröndahl HG, Gröndahl K, Webber RL, Bethesda MD. A digital subtraction technique for dental radiography. J Oral Surg 1983;55:96- 102.
25. Hausmann E, Allen K, Carpio L. Computerised methodology for detection of alveolar crestal bone loss from serial intraoral radiographs. J Periodontol 1992;63:657
26. Duinkerke ASH, Poel ACM. Variations in the interpretation of periapical radiolucencies. Oral Surg. 1975;40:414-422
27. Goldman M, Pearson AH, Darzenta N Endodontic success -Who's reading the radiographs? Oral Surg 1972;33:432-437
28. Duinkerke ASH, Poel ACM van de, Doesburg WH, Lemmens WAJG. Densitometric analy sis of experimentally produced periapical radiolucencies. Oral Surg 1977;43:782-797
29. Lang NP, Hill RW. Radiographs in periodontics J Clin Periodontol 1977;4:16-28
30. Hausmann E. Radiographic and dental imaging in periodontal practice. J Periodontol 2000;71:497-503
31. Daes D, Pasquali LA, Yuan CH, Komman KS. The relationship between the probing attachment loss and computed radiographic analysis in monitoring the progression of periodontitis. J Periodontol 1991;62: 135
32. Kribbs PJ, Chesnut CH, Ott SM, Kilcoyne RE Relationships between mandibular and skeletal bone in a population of normal women. J Prosthet Dent 1990;63:86-89
33. Nummikoski PV, Steffensen B, Hamilton K, Dove SB. Clinical validation of a new subtraction radiography techmnique for periodontal bone loss detection. J Periodotol 2000;71,508-605

RECENT ADVANCES IN REGENERATIVE PERIODONTAL THERAPY- A COMBINATION OF AUTOGENOUS BONE GRAFTING AND ENAMEL MATRIX PROTEINS

Vojislav Leković, DDS, PhD
Zoran Aleksić, DDS, MS

University of Belgrade, Faculty of Dentistry, Perio Dpt.