Bone Densitometric Study of Mandibular Density Using Dental Panoramic Radiographs

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Summary

The precision of the method of microdensitometry on panoramic radiographs (PR), using a five step copper stepwedge, was examined. Two PRs, one after the other, were made for each of the six examined patients. All the PRs were digitised. Gray levels were measured on the stepwedge and on the region of the interest. Measured gray level values were expressed in equivalents of the stepwedge thickness using 3rd degree polynomial. Comparing the values of the equivalents in the region of interest on the first and the second digitised image of the same patient, the differences were within 10%. The results revealed that the method detects mineral bone changes, which surpass more than 10% of the density on PR.

Key words: *densitometry, mandible, panoramic radiographs.*

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Introduction

The radiographic picture is the easiest way to diagnose bone conditions. However, a minimum bone mass loss of 30%, and sometimes as much as 50-60% is needed before significant osteopenia can be detected radiographically. Panoramic radiograph (PR) has been used in dentistry for a long time. It is irreplaceable in prosthetics diagnosis and treatment planning. It is also of great help in oral pre-extraction and pre-operation surgery for location of certain anatomic structures. Other, more precise techniques, such as computed tomography and magnetic resonance imaging have improved the precision of diagnosis, but also increase treatment costs.

It is very important to control the condition of the jaw bone structures, especially bone density in the maxilla and the mandible for possible resorptive changes of the residual ridges after tooth extraction or during full or removable partial denture wearing.

Numerous bone-mass measuring techniques are currently used: gamma-photon absorptiometry (1-4), X-ray dual-photon absorptiometry (5-9), single- and dual-photon absorptiometry (9-11), dual-energy absorptiometry (12-16), quantitative computed tomography (12-16) and neutron activation analysis (17, 18).

Scandinavian investigators (19, 20) have devised standardized methods for measuring the extent of alveolar bone loss on PRs.

It is also possible to use the PR as the simplest and cheapest method for evaluation of bone density in the maxilla and mandible. Difficulties in standardizing head positioning, X-ray projection, radiation dose, and the anatomic variability of the bony structures have made it more difficult to compare the rate of local mineral loss in the jaws in different images (14). The differences for the exposure, film processing and digitalisation should be compensated by the stepwedge (SW).

Therefore, many SWs of different material and consistency have been used: an aluminium SW (21--24), copper (25-27), nickel (28, 29), or some solutions like CsCl or $CaCl_2$ (13) which simulate bone density, ethanol simulating fat and water simulating soft-tissue equivalent (30). Dental radiographs, standardized by this method, could provide measures of the relative amounts of bone mineral content.

The aim of this study was to examine the reproducibility of the procedure and to determine the level of accuracy of the method of intraoral microdensitometry using a copper SW composed of 5 steps on dental PRs.

Materials and methods

Ten patients took part in this study. The procedure and the aim of the study were explained to all the patients who gave written informed consent. Two PRs were made for each patient, one after the other (within 5 minutes), under almost the same conditions (the position of the patients and the radiograph, exposure time). The Rtg machine (Siemens) was operated at 69 kV with a constant current of 16 mA/s and an exposure time of 16 sec. Images were recorded using Kodak film for PRs. All films were processed together in an automatic processor.

During the exposure, a copper SW was attached to the bottom of the film cassette (not covering any bone structure of the mandible) to give a reference image on the radiographs. It was composed of 5 steps of thickness 0.1 - 0.5 mm. In this way eventual differences between the exposures, film processing and digitalisation could be compensated.

PRs were digitised by the Lynotype-Hell (8-bit, 300 DPI) transparent scanner.

The grey levels (GL) of each step on the SW and on four, randomly chosen points on the mandible, in the region of interest (ROI), were measured by using Scion image (Beta 4.0.2) software. For this purpose black and white colours were inverted (Figure 1).

As it is not sufficiently precise to compare two different images of the same patient through the GL, optical densities (OD) for each point of measurement were calculated as follows:

$OD = -\log I_i/255$
OD - optical density and
I_i - measured intensity of GL.

To compare the two images of the same patient, taken at a different time, the SW OD values, corrected through the regression curve to fit the copper thickness, should be equal. Thus, expressing OD in equivalents of copper thickness (corrected through the regression formula of the third degree polynomial function (31, 32)), two different images are compensated for the eventual difference in exposure, processing and digitalisation.

Optical densities of each step of the SW were correlated with the copper thickness of the related step and the regression formula was thus derived from the relationship of the OD and the actual thickness of the related step, through the third degree polynomial function. Optical densities of the ROI were then calculated in the copper thickness equivalents, using the formula mentioned above (EQ ROI). The differences between each actual copper step and the copper equivalent were calculated and by the relation between them (100 - calculated equivalent*100/ actual thickness) the percentage of error was calculated.

The same procedure was perfomed for all the patients.

Results

The data and procedure of one of the patients are presented in Table 1, Figure 2, Table 2 and Figure 3.

Table 1 shows the values of GL, SW and ROI and their ODs from the first PR. By the correlation between the OD SW1 and the thickness of the SW (SWT) the regression curve and the formula were calculated for the first PR, which is shown in Figure 2. The formula was used to express all ROIs in equivalents of the SWT (EQ ROI 1). SWT EQ (stepwedge thickness equivalent) was subtracted from the real SWT to determine the difference between them and the error in % was calculated for the difference between SWT and SWT EQ - ERROR % SW1). The same procedure was performed for the second PR of the same patient (Table 2, Figure 3).

Comparing the Eq SWT of each step of the copper SW for the first image with the same (corrected) values for the second image, the difference between them was within 6.25% for the EQ SWTs and 10% for the ROIs. After the same calculation for all 10 patients the error of the SWTs was within 7.5% and the error between the same ROIs on the first and the second PR was within 10%.

Discussion

The increasing use of panoramic radiographs of the jaws as a part of the prosthetic examination has made additional diagnostic and research data available.

In the recent literature there are many studies trying to compare two non-standardized digitized images of the same patients. These result were less precise (33).

It is impossible to determine the density of the structures on PRs, or to compare the two PRs of the same patient without a SW. The SW is used to compensate differences in exposure, film processing and digitising. Many authors reported using Al SW (21--24), which it is too bulky for the film cassette of the PR. Therefore, Cu SW was chosen. Devlin used Ni SW (28, 29) composed of 13 steps. The length of a SW of 13 steps is often too large to be positioned in the area of a PR and not to cover the bony structures. Although it is more precise to have many steps, the five step-SW was constructed for this study so as not to cover any hard tissue (all the measured gray levels in the region of interest were within the highest and the lowest gray level of SW).

Other authors reported correcting SW OD values by subtracting the OD values of the immediately adjacent soft-tissue image (21-24, 28, 29). In this study it was not the procedure. The SW was positioned correctly. Anyhow, the varying shadows of soft tissues could affect the results. However, the error was within 7.5% for the SW.

The difficulty of standardizing the position of the head leads to projection errors on the radiograph. It is also difficult to locate exactly the same point of ROI on X-ray images, and this might be the reason for the bigger error for ROI between the first and the second PR (10%) than between the SW (7.5%).

As conventional visual analysis techniques are not sufficiently precise to detect subtle changes in bone density, PR microdensitometry is the method of choice because of its low cost. It can detect changes of more than 10% mineral bone loss, as the difference of 10% is within the error of the method. However it is much more than one can visualise on the PR, as sometimes as much as 50-60% mineral bone reduction is needed before it can be detected radiographically. However, subtracting the soft tissue images might improve the precision of the method and reduce the error to less than 10 percent.

Conclusions

The comparison of the values of equivalents of the SW in the region of the interest, on the first and the second digitised image of the same patient reveald that the difference between them is within 10%. Each value, with the difference higher than 10% should be attributed to the change in the bone density of the measured bone structure.

This study indicates that the described microdensitometeric method detects the mineral bone changes in both, maxilla and mandible, which surpass more than 10 percent of density on PR.