Intraoral Computer-Assisted Microdensitometric Study

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Summary

The precision of a method of microdensitometry on digitized images, using six step copper stepwedge (SW), was studied. Two retroalveolar radiographs were made for each of the six examined patients. Lynotype-Hell (8-bit, 300DPI) transparent scanner was used to scan the radiographs. All the images were, prior to the measurements, inverted. The digitized radiographs were saved in the Issa-program for archiving radiographs, while the optical density (OD) was measured by using software Scion image for 6 steps of the SW and 7 regions of interest (ROI). The gray levels (GLs) were converted into the ODs for both images by formula $OD = -\log I_i /255$, *where* I_i *= measured intensity. ODs 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. The results revealed that the method detects mineral bone changes, i.e. OD changes, which surpass more than 7% of density on the images.*

Key words: *microdensitometry, bone structure, retroalveolar radiograph.*

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Introduction

Bone-mass measuring techniques are used to evaluate relationships between different regions of the skeleton, to distinguish the diseased from the normal state, and to monitor bone-mass changes in the progress of disease or treatment.

The most common and the simplest way to determine bone density is by routine radiographs. However, a minimum bone mass loss of 30%, and sometimes as much as 50 - 60%, is needed before significant osteopenia (loss of bone) can be detected radiographically (1). Newer techniques, such as radiographic morphometry, have been useful in evaluating cortical thickness or to estimate the actual mineral content (2).

Because conventional visual analysis techniques are not sufficiently precise to detect subtle changes in bone density, other techniques are needed.

Gamma-photon absorptiometry has been used to determine regional bone mass in extremities (3-6), X-ray dual-photon absorptiometry (7-11), single-photon absorptiometry (11-13), dual-energy absorptiometry (14-18) and quantitative computed tomography (14-18) have been used to determine bone density, and neutron activation analysis has been used to measure accurately total body calcium (2, 19).

Microdensitometry has been available for over 40 years, and the first more precise results (precision of 1.5%) with this technique when the heel was scanned were noted by Mack (20).

The basic principle of this method is the standardisation of the ODs of the radiographs (21) with various types of materials of recognizable densities. A common method for densitometric standardization is to include an aluminium SW with each exposure in order to provide a basis for comparison of ODs. Aluminium atomic number is very similar to the effective atomic number of the bone. Effective atomic number provides a measure of the X-ray absorption characteristic of a material, as a function of energy. Two materials with similar effective atomic numbers will attenuate X-rays in a similar manner (1, 2, 22-29). However, in dental applications, an aluminium SW thick enough to produce a useful range of densities is too bulky to be incorporated into a practical film-holding device. Therefore, in the manner of the easiest X-ray-film manipulation, many other materials such as a copper (22, 30, 31), nickel (32, 33) in various thicknesses or some solutions such as CsCl or $CaCl_2$ (15) to simulate bone density, ethanol for fat and water for soft-tissue equivalent (34) are in use.

The SW included with each exposure in this technique allows for densitometric film corrections to be made, and dental radiographs, standardized by this method could provide measures of relative amounts of bone mineral content.

According to Duckworth (22), the following criteria should be considered desirable in establishing objectives for standardization of the intraoral radiograph:

- the projection used should minimize distortion of the anatomic structures of interest
- the method should provide information about the degree of standardization achieved
- the ionizing radiation exposure should be the minimum necessary to provide diagnostic information
- the method should be flexible enough to allow monitoring of all sites in the mouth
- the method should not be uncomfortable to the patient
- the method should not require extensive training for use
- the method should use readily available materials.

Each standardized dental radiograph should be scanned (2, 19, 23-27) or digitized by a video camera (28, 29, 35). After that the conversion of gray values from the SW to equivalent thicknesses of the material of the recognizable densities (aluminium, copper, nikle, CsCl, $CaCl_2$, ethanol, water) (28) should be made. The aluminium SW thickness is then converted into vol% of the mineral content (28). Programs for the measurement of the degree of GL are available on Internet pages (28, 36).

The described method provides determination of the relative bone density *in vivo* and *in vitro*.

The aim of the study was to examine the error level and reproducibility of the procedure and to determine the level of accuracy of the method of intraoral microdensitometry on the retro-alveolar radiographs.

Materials and methods

Six patients took part in this study. The patients were examined at the Department of Oral Surgery, Dental Polyclinic, Perkovčeva 3, Zagreb. Two radiographs were made for each of the patients, one after the other, under the same conditions (the same position of the patients and the radiograph, the same length of the radiation and the same exposition).

The differences between the exposition, film developing, and digitalisation are thus compensated by the help of referent SW and by the calculated and corrected ODs from the different radiographs of the same patient exposed at a different time.

The same copper SW was attached to each film, composed of 6 steps, first step 0.05 mm thick. For each exposure, the SW was attached to the same place on the film (at the bottom of the film, not covering the bone or the tooth structure). The exposure conditions and the film developing conditions were the same for all patients. Lynotype-Hell (8-bit, 300DPI) transparent scanner was used to scan the radographs. The digitized radiographs were saved in the Issa-program for archiving radiographs, while the density was measured by using Scion image software for OD measurements (GL measurements). Prior to the measurements, all the images were inverted.

The digitized radiographs were expressed in pixels - picture elements with 256 GLs ($D_{i,j}$), where each pixel has its own level (from 0 - white to 255 - black).

GLs of the SW (each step) and the regions of interest were measured on each radiograph. In this study, 7 ROIs were chosen upon the criteria to include different range of GLs. The chosen ROIs were: region of the film without the bone structures shown, incisal ridge of the tooth, tooth crown 5mm from the incisal ridge, intraradicular region, apical region of the root, periapical region 5mm from the root and bone structure without the tooth.

It is not precise to use two diffferent images of the same patient when comparing their GLs, therefore ODs for both images were calculated by formula OD = -log I_i/255, where I_i = measured intensity.

To compare two images of the same patient, taken at a different time, SW OD values on both images should be equal. However for numerous reasons (exposure and film processing conditions) they are not.

Concerning the Cu SW thickness for each step as the known value on both images of the same patient, the easiest way is to convert the ODs to the equivalent of copper thickness.

Therefore, ODs 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. The regression formula was used to express all ODs in EQ SWT.

Then ODs of the ROI were calculated in the copper thickness equivalents, using the same formula.

The differences between each actual copper step and the copper equivalent were calculated (SWT--EQ SWT) and through the relation between them the percentage of the error for the ROI on two different images of the same patient were calculated (ERROR % SW) (ERROR % ROI 1-2).

Results

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

Table 1. shows the values of GL, SW and ROI and their calculated OD on the first image of the patient. The correlation between the OD SW1 and the SWT produced the regression curve with the formula, which was used to calculate EQ SWT (Figure 2.). The same formula was used to express all ROIs in equivalents of SWT.

EQ SWT was substracted from the real SWT, and the difference between them was presented in the percenages (ERROR % SW1, ERROR % SW2).

The same procedure was used for the second digitized image of the same patient (Table 2, Figure 3).

Comparing the SWT equivalents of each step of the copper SW with the real SWT for the first and the second image, there was no difference between them (error in % was 0).

Comparing EQ ROI 1 and EQ ROI 2, the error between them was up to 5.2%.

After the same calculation for all 6 patients, the results revealed that the error of the SWTs did not exist, and the error between the same ROIs on the first and the second digitized image was up to 7%.

Discussion

It is very difficult to determine the bone density of small structures in the maxilla and mandible, or even to compare two images of the same patient without the SW. The SW is used to compensate the differences between two or more images of the same object, for the exposure, film processing and digitizing. Many authors reported using Al, Ni or Cu SW (1, 2, 22-29, 30-33). The aluminium SW is too bulky for insertion on the film, so the intraoral handle should be placed above the film, which is complicated both for the dentist and the patient. On the other hand, Devlin used Ni SW composed of 13 steps (32, 33), placed on the panoramic radiographs, whose length is often too large to be positioned in the area of the film not to cover any bone structures. Although it is more precise to have many steps, the six step - SW was constructed for this study. All the GLs of structures measured on the digitzed images were within the range of the GLs of the thickest and the thinnest step of the SW.

Other authors reported correcting SW OD values and OD ROI values by subtracting the OD values of the immediately adjacent soft tissue image (23--26, 32, 33).

In this study it was not a procedure because of the precise placemant of the SW (on the part of the film not covered by any soft or hard tissue).

Anyhow, the varying shadows of soft tissues could affect the results, although error was within 7%.

The difficulty of standardizing the position of the film leads to projection errors on the radiograph. It is also difficult to locate exactly the same point of ROI on the digitized images.

This might sometimes be the reason for greater error for ROI between the first and the second digitized image than for the SW.

As conventional visual analysis techniques are not sufficiently precise to detect subtle changes in bone density, microdensitometry is the method of choice because of its low cost.

It can detect changes of more than 7% mineral bone loss, i.e. 7% changes in OD values, as the difference of 7% is within the error of the method.

However, subtracting the soft tissue images might improve the precision of the method.

Conclusion

This study indicates that the described microdensitometric method detects mineral bone changes in both the maxilla and mandible, which surpass more than 7% of the density on the digitized images.