Evaluation of trabecular bone texture changes attributed to aging on the plain radiograph of calcaneus using fractal analysis

Ion Stefan [1], Andrei Prie [1], Radu Badea [2], Constantin Vertan [3]

[1] Emergency Hospital Baia Mare, Traumatology Department, Baia Mare
[2]University of Medicine and Pharmacy "Iuliu Hatieganu" Cluj-Napoca, Medical Imagery
[3]Image Processing and Analysis Laboratory, "Politehnica" University, Bucharest
Corresponding author: Ion Stefan. E-mail: IonStefan@gmx.net

The aim of the study was to determine if fractal analysis of the trabecular structure of the calcaneus, as it appears on the plain lateral radiograph, can detect alterations attributed to aging. Aging is accompanied by changes of trabecular bone structure due to the remodeling process. This process is accelerated in the group of postmenopausal women.

1. Materials and Methods

We analyzed 2 sets of 12 radiographs from two groups of women. The first group with ages between 26 and 38 years (mean age = 33 years), the second with ages between 48 and 65 years (mean age = 56 years)

Radiographs were digitized using a Fujifilm FinePix 2600 Zoom digital camera. The colored images were transformed to grayscale images.

Three ROI were selected on each radiograph. Selection and saving of ROI was done with software CalcaneuPrj (author: Bogdan Ionescu). ROI 1 corresponds to the thalamic region, ROI 2 to Ward's triangle and ROI 3 to the region where the posterior plantar group of trabeculae intersects the thalamic group (*Fig. 1*).

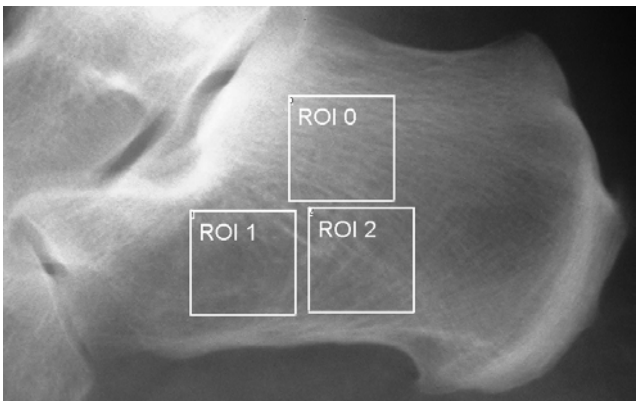

Figure 1 Position of the three ROI

Because there is a brightness gradient due to thickness difference of bone and soft tissue, a dynamic thresholding technique (software: ImageJ; plugin's author: Gary Chinga) was used to segment the images (*Fig. 2,3,4*).

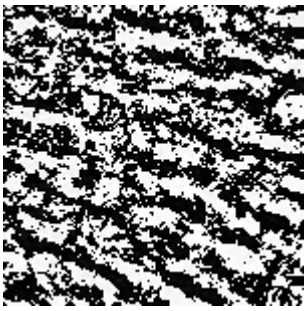

Fig. 2 Segmented ROI 0.

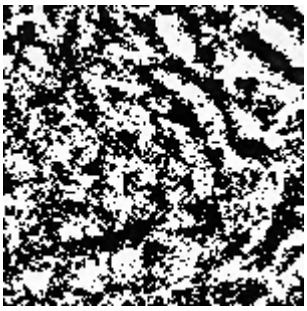

Fig. 3 Segmented ROI 1

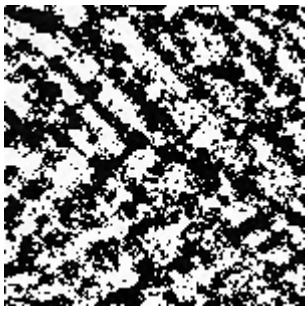

Fig. 4 Segmented ROI 2

The box-counting fractal dimension (BCFD) of each ROI was determined using HarFA 4.9 (authors: Martin Nezadal and Oldrich Zmeskal). Each radiograph was characterized successively by pairs of the 3 parameters. The results for the two sets were represented graphically. The spatial distribution of the points on the graphs was evaluated using a nearest neighbour approach.

2. Results

Table 1 contains BCFD values for the 26-38 years group. Table 2 contains BCFD values for the 48-65 years group

Table 1 BCFD values for the 26-38 years group

Case no.	1	2	3	4	5	6	7	8	9	10	11	12
ROI 0	1,868	1,841	1,871	1,875	1,843	1,863	1,858	1,894	1,866	1,865	1,865	1,870
ROI 1	1,863	1,795	1,869	1,873	1,845	1,858	1,858	1,886	1,887	1,865	1,889	1,876
ROI 2	1,865	1,849	1,882	1,882	1,844	1,865	1,866	1,882	1,875	1,867	1,872	1,886

Table 2 BCFD values for the 48-65 years group

Case no.	13	14	15	16	17	18	19	20	21	22	23	24
ROI 0	1,882	1,885	1,873	1,880	1,904	1,878	1,876	1,899	1,895	1,893	1,894	1,872
ROI 1	1,888	1,898	1,876	1,871	1,899	1,879	1,865	1,898	1,898	1,904	1,903	1,873
ROI 2	1,865	1,887	1,864	1,869	1,881	1,879	1,884	1,892	1,902	1,899	1,905	1,888

The following graphs resulted by plotting BCFD of one ROI against BCFD from another ROI of the same radiograph (*Fig. 5,6,7*).

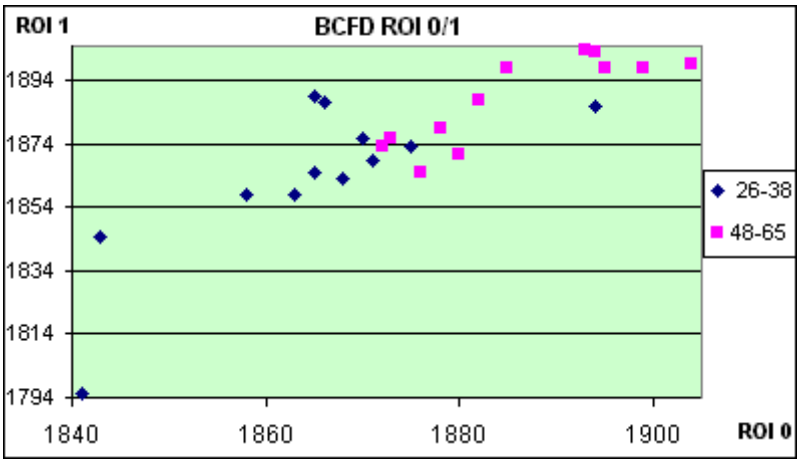

Figure 5 BCFD of ROI 0 plotted against BCFD of ROI 1

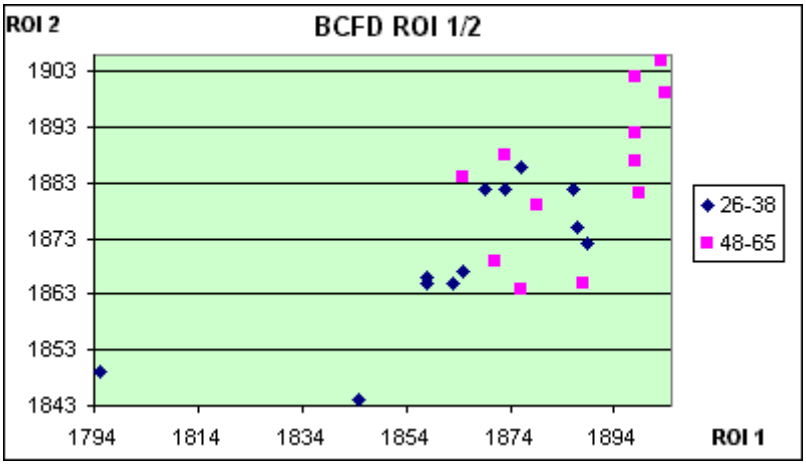

Figure 6 BCFD of ROI 1 plotted against BCFD of ROI 2

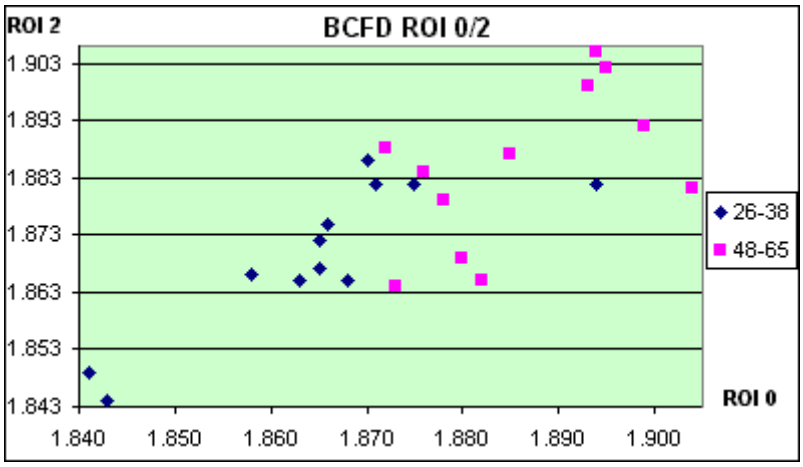

Figure 7 BCFD of ROI 0 plotted against BCFD of ROI 2

Examining these charts it is obvious that for all regions of interest BCFD is higher for the 48-65 group(Fig. 8). A tendency for spatial separation of the points from the two sets is also apparent.

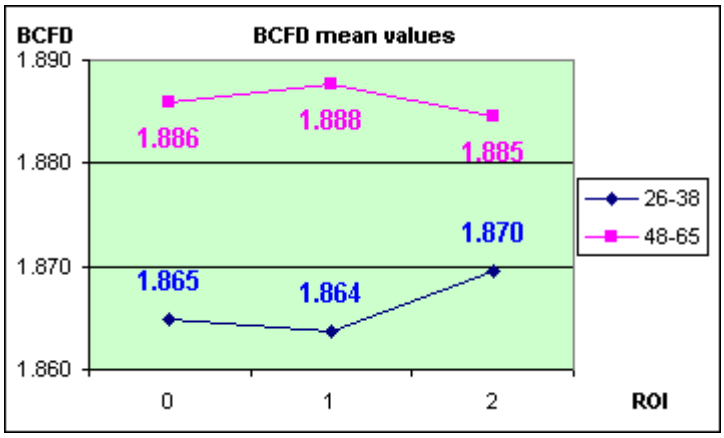

Figure 8 Mean values of BCFD for each ROI from the 2 sets

We tried to quantify the apparent spatial separation of the points corresponding to the two sets of radiographs using a nearest neighbor method. Tesselations of Voronoi were drawn (software: VoronoiPainter; author: Marko Krajnc) (*Fig. 9,10,11*).

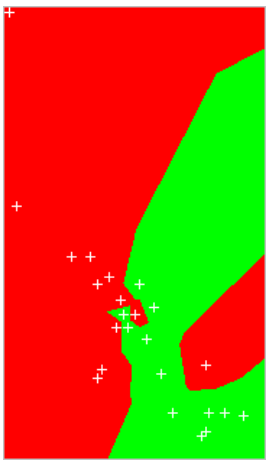

Figure 9 Tesselations of BCFD for ROI 0 plotted against BCFD for ROI 1. Red = 26-38 years

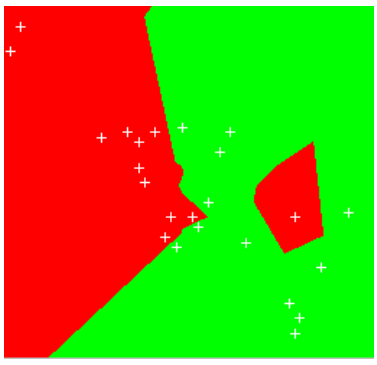

Figure 10 Tesselations of BCFD for ROI 0 plotted against BCFD for ROI 2. Red = 26-38 years group; green = 48-65 years group.

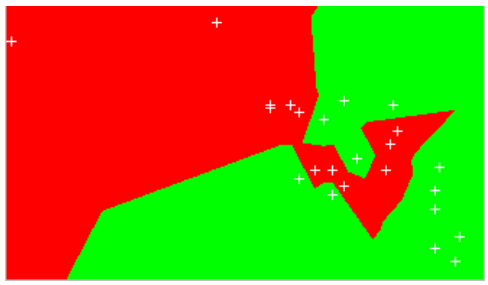

Figure 11 Tesselations of BCFD for ROI 1 plotted against BCFD for ROI 2. Red = 26-38 years group; green = 48-65 years group.

Each point was withdrawn and reintroduced in the tesselation determined by the rest of the points. This operation allowed to categorize a "correct" or "incorrect " positioning of each point (*Fig.12,13*).

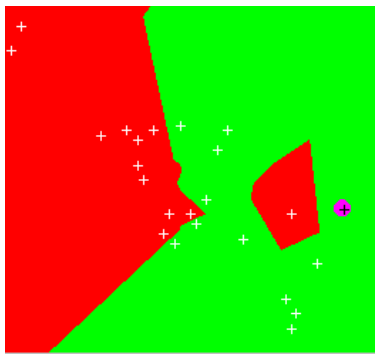

Fig. 12 Marked point will be withdrawn.

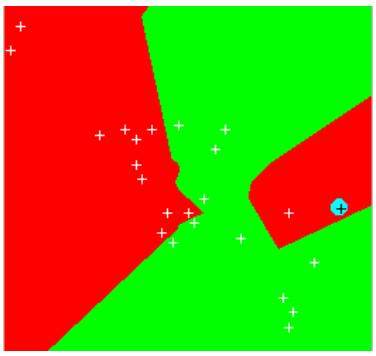

Fig. 13 Aspect of the tesselation after withdrawal of the point. If reintroduced, the point falls into the wrong region.

The correct and incorrect decisions are presented in the tables 3, 4, 5.

Table 3

1	2	3	4	5	6	7	8	9	10	11	12
right	right	wrong	wrong	right	right	right	wrong	right	right	right	wrong
13	14	15	16	17	18	19	20	21	22	23	24
right	right	wrong	wrong	right	right	wrong	right	right	right	right	wrong

Decisions for BCFD of ROI 0 plotted against BCFD of ROI 1: 8 wrong decisions out of 24.

Table 4

1	2	3	4	5	6	7	8	9	10	11	12
right	right	right	wrong	right	right	right	wrong	right	right	right	wrong
13	14	15	16	17	18	19	20	21	22	23	24
right	right	wrong	right	wrong	wrong	wrong	right	right	right	right	wrong

Decisions for BCFD of ROI 0 plotted against BCFD of ROI 2: 8 wrong decisions out of 24.

Table 5

1	2	3	4	5	6	7	8	9	10	11	12
right	right	right	right	right	right	right	right	right	right	right	wrong
13	14	15	16	17	18	19	20	21	22	23	24
wrong	right	right	wrong	right	wrong	wrong	right	right	right	right	wrong

Decisions for BCFD of ROI 1 plotted against BCFD of ROI 2: 7 wrong decisions out of 24.

3. Discussion and conclusions

A radiograph of the calcaneus is very often solicited in outpatient practice for various reasons. It would be very challenging to try to extract as much information as possible from this acquisition.

Fractal analysis of radiographs of calcaneus offers information about the complexity of the trabecular pattern. In this study we tried to find out, to what extent, fractal analysis alone can distinguish changes of the trabecular pattern between two groups separated by a single criterion – age. We assumed that analysing more regions of interest and correlating the results would enhance the possibility to separate the two groups. It would add probably information related to the heterogenity of

trabecular structure. We proposed also a nearest neighbor classification algorithm. The results we obtained may represent the training examples for further query instances.

Our study shows that fractal dimension of the trabecular bone increases with age. Similar result are reported by Lespessailles et al., 2002. Other studies concluded that FD is higher in subjects with lower bone mass, history of osteoporotic fractures (Bollen et al.,2001). Subjecting a radiograph to the described algorithm, we have 2/3-3/4 chances to find the correct answer about age group. Errors are more often in the elderly group, probably due to more dispersed values of BCFD.

4. References

[1] Bollen A-M, Taguchi A, Hujoel PP,Hollender LG, Fractal dimension on dental radiographs, Dentomaxillofac Radiol (2001) 30, 270 – 275

[2] Lespessailles E, Poupon S, Niamane R, Loiseau-Peres S, Derommelaere G, Harba R, Courteix D, Benhamou CL., Fractal analysis of trabecular bone texture on calcaneus radiographs: effects of age, time since menopause and hormone replacement therapy.Osteoporos Int 2002 May;13(5):366-72