Evaluation of the results of periodontal treatment by means of digital subtraction of radiographic images

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Abstract

This article presents general principles and a sample case of application of digital subtraction of x-rays for objective evaluation of results of treatment in dentistry.

Purpose: Evaluation of the results of surgical periodontal treatment by means of digital subtraction of radiographic images taken before and 12 month after surgery.

Material and methods: For evaluation of the results of guided tissue regeneration treatment of deep bony defects digital periapical x-rays were taken before and 12 months after surgery. Pairs of images obtained during treatment were calibrated to equalize vertical x-ray beam angulation followed by calibration to radiological contrast and density. Next the comparison of images taken before and after treatment was performed by means of special computer software designed to subtract content of given images.

Results: Digital subtraction showed that the radiological density in regions where surgery was performed has decreased over a period of 12 months meaning that the mineral content which is responsible for absorbing x-ray photons has increased. Some local foci of subsurface hypomineralization were found on subtractions images. These foci couldn't be detected clinically because hypomineralization was taken place within bone.

Conclusions: Digital subtraction of x-rays taken before and after surgery treatment is detailed and objective method of evaluating results particularly when changes of surface and subsurface bone mineralization around teeth must be examined.

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Introduction

Radiological examination has been used in periodontology for many years. X-rays are used: to evaluate the level and condition of the alveolar ridge, to search for factors which may influence periodontal disease such as calculus, overhangs, etc., to prepare treatment plans and finally to evaluate the results of treatment. Panoramic images are generally employed to obtain informations about the general dental status while intraoral periapical images give detailed information regarding particular teeth and their supporting bone. Periapical views are therefore the images of choice for making a long-term evaluation of the results periodontal treatment particularly when surgical methods have been applied [1]. Radiological evaluation of the results of treatment is based on comparison of images of the same teeth taken "before" and "after" treatment. In the case of periodontal treatment "after" usually means several months or even years later. The time factor must be considered is such cases because changes in the degree of mineralization of the bone supporting teeth is directly connected with the changes in calcium and phosphate levels which may take a considerable time to appear. Ideally to make true comparisons between images, the following factors must be considered. Images should be obtained with the same vertical and horizontal angulation of the central x-ray beam, the same electrical settings – especially voltage (kV) and amperage (mA) and with the same x-ray machine, followed by standardised developing procedure involving similar conditions of temperature, time and quality of chemicals used [2]. Variations in any of the factors mentioned above will result in images of different contrast, density, tooth length may vary, location of interdental bone in relation to cemento-emanel junction may be incorrect. As a result it is impossible to make true comparisons. Comparison between "before" and "after" treatment images is based on the observer's perception which of course, may vary

between observers especially when one of them is the surgeon who carried out the treatment. Finally the results of such comparisons are difficult to present in a form of statistics which is used in international research publications. These limitations can be overcome by the use of another method of comparing images – a subtraction of digital images.

Digital subtraction overview

The rapid development of digital methods of visualisation in dentistry started in 1984 when Trophy, a French company, introduced the first digital x-ray sensor. Now digital x-rays are used in every day practice, in the form of a sensor or digital phosphor plate, which enables the practitioner to see images directly on a computer screen. Dentists who have some older "conventional" x-ray machines can now convert them to a digital form by means of flatbed scanners and are thus also able to see them directly on a computer screen. Some special programs can compare images and present the results in graphic or numerical form.

The digital subtraction method is based on the fact that every digital image is composed of very small particles called pixels and each of these pixels has only one colour. Pixels are so small that the human eye cannot see them separately but fuses them into one bigger part which may be seen as a mixture of different colours. Because radiographs consists of black, grey and white images the pixels which compose the image will range from black through grey to white. In fact, there are 256 different colours in the grey range of shades starting from 0, which is black, and ending on number 256, which is white [3]. It must be understood that a computer can "see" numbers instead of colours of pixels and it is only we, humans who need these graphic representations of numbers to "see something" on the screen. Once it is understood that these images are combinations of pixels with different numbers, some mathematical operations can be performed on them, the results can be presented in a numerical form and these can be used by computers, or in a graphic form which can to be seen by humans. When the computer program used for subtraction compare two images composed of identical pixels the resulting image will be grey. If on "after image" some new elements will be obtained a resulting image will show these new elements as whiter than the earlier ones. Also on some "after image" some elements may be less obvious or disappear. For example following periodontal bone loss the resulting image will show these elements as darker than earlier fragments. Data about gained or lost elements can be obtain in the form of numbers [4]. It must be remembered that these elements are pixels and that each pixel has its number. Despite the fact that the proper technique for taking a radiograph involves the use of holders for films or sensors, the correct vertical and horizontal angulation of the central x-ray beam and correct settings of the apparatus it is still almost impossible to obtain two absolutely identical images [5]. A great advantage of the computer program used is that it allows some "fine tuning" of the two images which are to be compared, before the procedure of digital subtraction is carried out. This is necessary because only pixels which are located in the identical position on both images can be compared and the operator of the program must give this information to the computer. The points usually chosen include the CEJ, apices of teeth, fragments of fillings etc. The more identical points on both images the better the quality of subtraction will be because the program can set the "after" image in the correct position in relation to the "before" image. This part of fine tuning of images can help to match images which were produced using slightly different vertical and horizontal angulation of the x-ray central beam. Once this has been done a carefull comparison of the density and contrast of the two images can be made. Author's experience is that most images have a slightly different density or contrast, or both. That is especially seen when conventional x-rays are converted to the digital mode by means of a flatbet scanner or when images are obtained by different digital sensors. That is why a second part of the fine tuning must be performed prior to subtraction. That step which may be called equalization of contrast and density allows the use a mathematical model of the average contrast and density of one image to be applied to another. After this second step has been taken the two images are ready for subtraction.

Figure 1. **Periapical x-ray image of lateral maxillary incisor before treatment**

Figure 2. **Periapical x-ray image of lateral maxillary incisor 12 months after treatment matching**

The following section presents the digital evaluation of the results of surgical treatment of a periodontal defect in the region of lateral maxillary incisor by means of Emdogain.

The case

A patient aged 44 with a 9 mm periodontal pocket surrounding the left maxillary lateral incisor was referred to periodontal specialist for surgical treatment (*Fig. 1*). After completing hygienic procedures the teeth in region 21-24 were splinted by means on fiber/flow composite combination. This was followed by application of Emdogain into periodontal pocket round tooth 22 using the standard protocol. After soft tissue healing was complete the sutures were removed and the patient was advised about proper hygienic procedures and given a recall schedule. 12 months after surgery periapical digital radiograph of tooth 22 was taken to observe the results of the treatment (*Fig. 2*). It can be clearly seen that direct comparison of the two images is

Figure 3. Periapical x-ray image of lateral maxillary incisor before treatment with marked fixed points

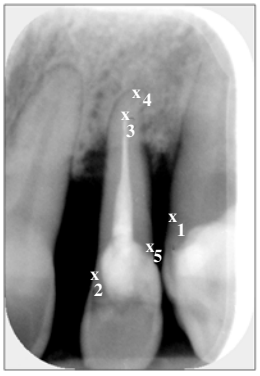


Figure 4. Periapical x-ray image of lateral maxillary incisor 12 months after treatment with marked fixed points

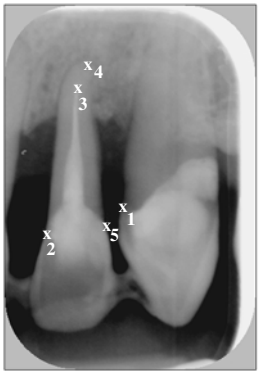


Figure 5. Image of lateral maxillary incisor 12 months after treatment modified according to fixed points

Figure 6. Image of lateral maxillary incisor 12 months after treatment modified according to fixed points and histogram matching

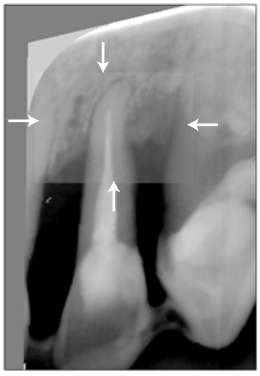


Figure 7. Effect of subtraction of "before" and "after" treatment x-ray images with colour filter

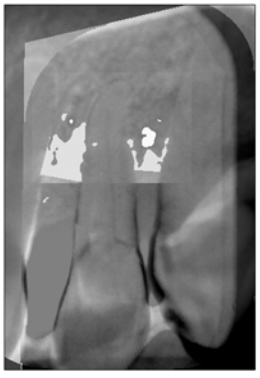


Figure 8. Periapical x-ray image of lateral maxillary incisor before treatment with marked regions of interest

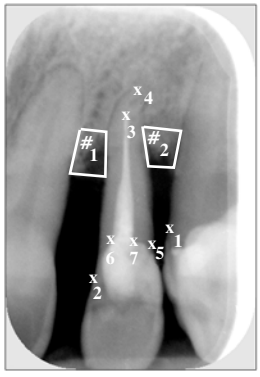
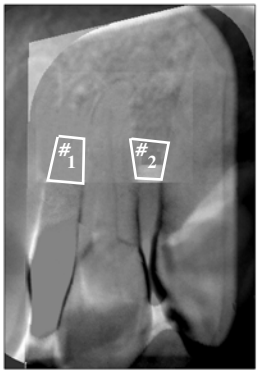


Figure 9. Image of subtraction of "before" and "after" treatment x-ray images with colour filter and marked regions of interest



very problematic. The two images were taken with slightly different vertical and horizontal angulations of the central x-ray beam. As a result the length of tooth 22 on the "before" and "after" treatment images is different, as well as the distance between the crowns of teeth 22 and 23. Analysis of the density and contrast of the images also shows differences. This can be especially well seen when the density of the root filling on both images is compared in relation to the density of the surrounding roots. Therefore any conclusions about the density of the bone and level in relation to length of tooth 22 are questionable. The application of digital subtraction program may overcome some of the problems mentioned above and provide some more accurate information about the result of treatment. To perform the analysis both images must be tuned by a computer program so the pixels located in the same position on both x-rays can be compared. First step in the procedure is alignment of the "after" image according to some fixed points present on both images. As mentioned in the previous part the more fixed points which can be used the better the degree of alignment that can be obtained. After marking fixed points (*Fig. 3*, *Fig. 4*) matching of images can be performed and the result can be seen on *Fig.* 5 By comparing *Fig. 4* and *5* changes in the length and shape of root of tooth 22 can be seen as well as differences in bone level. Because there are differences in density and contrast between the two images a second step, that of the equalization mentioned in previous part, must be performed prior to subtraction. After completing both these procedures the images are ready for the subtraction process. Superimposition of the two images and the effect of subtraction are presented in *Fig. 6*. Because of the different initial content of the "before" and "after" images some parts of final subtraction, i.e. the borders of the image, cannot be compared. The central part of *Fig. 6* where tooth 22 is located contains important information. The square part of the final image (marked with red arrows) represents the area were contrast/density equalization was performed. Since only that part of the final image contains true information about the effects of subtraction. For better visualization of changes a colour filter was used to show areas where higher (blue) and lower (yellow) mineralization are present. Unchanged areas are grey-coloured (*Fig. 7*). A graphic form of presenting

Table 1. **Grey level changes in regions 1 and 2**

Region	Type	Mean	Varians	Skew	Min	Max	Area	MaxCount	MaxCountAt
1	Gain	160.4336	104.8561	0.51599	136	192	2198	105	157
	Unch	139.0367	52.31566	0.79442	116	181	735	61	141
	Loss	116	3	0.3849	114	119	6	2	1
2	Gain	151.826	28.45347	0.328646	141	165	523	44	147
	Unch	132.1751	69.58103	0.096635	111	153	1491	70	127
	Loss	110.8997	29.24077	-0.28153	96	123	299	29	109

results can be obtained by the use of data which may be used for statistical analysis. To obtain proper data, particular areas of interest should be marked on either the "after" or the "before" image. An example of such regions marked on "before" image is presented in *Fig. 8*. and the final subtraction with the region of interest from where the data was collected is shown in *Fig. 9*. The data from regions 1 and 2 are presented in *Tab. 1*.

Results and concluding remarks

From the data presented it can be concluded that the radiological density in these regions has decreased over a period of 12 months meaning that the mineral content which is responsible for absorbing x-ray photons has increased. This is especially well seen in region 1 where both the gain/loss ratio, as well as the area of gain/area of loss ratio are high. In region 2 both hyper and hypomineralization can be observed. Although the gain/loss ratio is high, the area of gain/area of loss ratio is much lower. The observations about region 2, especially those concerning the presence of local foci of hypomineralization, are of great importance. These foci cannot be detected clinically because the process is within bone. Spreading of subsurface demineralization may reduce the positive result of this particular form of surgical treatment meaning that in this particular case actually increasing the depth of the periodontal pocket on the distal aspect of the lateral incisor. On the other hand the hypomineralization detected may be due to the bone remodelling phenomenon which can be often observed in regions where surgical treatment has been performed. Further x-ray observations are necessary to support this assumption fully.

References

1. Fritz ME, Jeffcoat MK, Reddy M, Koth D, Braswell LD, Malmquist J, Lemons J. Guided bone regeneration of large mandibular defects in a primate model. J-Periodontol, 2000 Sep; 71(9): 1484-91.
2. Eley BM, Cox SW. Advances in periodontal diagnosis. 2. New clinical methods of diagnosis. Br Dent J, 1998 Jan 24; 184(2): 71-4.
3. Christgau M, Wenzel A, Hiller KA, Schmalz G. Quantitative digital subtraction radiography for assessment of bone density changes following periodontal guided tissue regeneration. Dentomaxillofac Radiol, 1996; 25: 25-33.
4. Christgau M, Hiller K-A, Schmalz G, Kolbeck C, Wenzel A. Quantitative digital subtraction radiography for the determination of small changes in bone thickness: an in vitro study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod, 1998; 85: 462-72.
5. White S, Pharoah M. Oral Radiology. Principles and Interpretation. 5th edition: Mosby, 2003; 297-313.