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ORIGINAL RESEARCH ARTICLE

Comparative Analysis of Data Efficiency Between Conventional Periapical Radiography and Digital Subtraction Radiography in Chronic Periodontitis Patients

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Abstract

Purpose: Advancements in technology have driven a shift towards digital techniques alongside conventional screening methods in dental radiology and across medical disciplines. This study aims to compare the efficacy of two radiographic techniques, periapical radiography and digital subtraction radiography, in assessing bone recovery processes.
Materials and Methods: Sixty mandibular premolar and molar regions in eighteen chronic periodontitis patients undergoing flap surgery were examined pre- and post-operatively using both periapical radiographs and digital subtraction radiography. Periodontal surgery outcomes were monitored by recording periodontal index, pocket depth, and gingival recession preoperatively (baseline) and at the 3rd and 6th months postoperatively. Standardized parallel periapical radiographs and via digital subtraction radiography images were analyzed by different observers to evaluate changes in alveolar bones and assess surgical outcomes.
Results: Results showed significant reductions in index values and pocket depths, along with an increase in gingival recession. Intraobserver consistency was found to be good and fair, while interobserver consistency was poor across the 0-3, 3-6, and 0-6 month periods. Radiographic evaluation demonstrated a statistically significant increase in digital subtraction radiography data compared to conventional radiography in defect recovery throughout the follow-up period.
Conclusions: This study demonstrated that the digital subtraction radiography technique is more efficient in detecting minimal changes in mineralised tissues that cannot be clearly traced by conventional radiographic techniques.

Keywords: Chronic Periodontitis; Dental; Digital substraction; Radiography

Introduction

Periodontal diseases, characterized by progressive destruction of periodontal supporting tissues, are among the most common inflammatory diseases in society, caused by certain microorganisms present in the oral cavity.[1–3] The level and mineral density of alveolar bone are maintained by a balance between bone formation and resorption regulated by local and systemic factors. Disruption of the balance between the host and microorganisms can lead to a situation where bone resorption exceeds bone formation, resulting in a decrease in bone height and/or density.[4]

Early diagnosis, monitoring, and evaluation of treatment outcomes play a crucial role in improving the clinical outcomes of periodontal disease.[2] In the context of periodontal diseases, radiographic methods are often used in addition to clinical methods to determine the presence and extent of bone loss. However, radiographs may not detect small amounts of alveolar bone loss.[5] Gröndahl et al.[6] reported that radiographs are insufficient for diagnosing early-stage periodontal diseases and measuring bone defect amounts in the buccal and lingual regions of teeth. Long-term follow-up of periodontal diseases is crucial for determining the disease progression. However, there are debates regarding the ability of radiographs to accurately detect small lesions with clinical significance.[7] Van der Stelt et al.[8] argued that there may be limitations in detecting small bone lesions due to structural noise in periapical radiographs, which could affect the visual detection of anatomical structures with diagnostic importance.Despite these limitations, radiographs are valuable for periodontal diagnosis. However, to enable radiographic follow-up in long-term studies, standard imaging conditions must be repeatable. Many researchers working on periodontal disease have addressed this issue by using devices to stabilize the X-ray tube, object, and film for evaluations at different times in the same patient.[9,10] Nowadays, in addition to methodological repeatability, three-dimensional imaging techniques, computer programs, and artificial intelligence applications have been introduced to track changes in alveolar bone level and density over time.[1,11,12] One of the image evaluation techniques used to detect changes in alveolar bone level and density is digital subtraction technique.

Digital subtraction radiography (DSR) is one of the methods that enhances the detectability of existing bone changes by aligning and subtracting images obtained at different times, thereby eliminating structural noise observed on radiographs.[13] DSR minimizes distractions from background images, enabling the eye to perceive actual changes between two images, facilitating the detection of early mineral changes in tissues and their monitoring.[9]

The purpose of this study is to monitor bone healing using the DSR technique after periodontal flap surgery in cases of chronic periodontitis with vertical bone defects and to compare the effectiveness of this technique with radiographic data. Additionally, the study aims to determine the extent to which the DSR technique is effective for routine clinical applications.

Material and Methods

Study Population

The study was conducted in accordance with the principles outlined in the Declaration of Helsinki and received approval from the Ethics Committee of Medical, Surgical and Pharmaceutical Research at Hacettepe University (IRB Approval No: LUT04/65, 2005). Informed consent was obtained from all participants after detailed explanation of the diagnostic, treatment, and follow-up procedures.

The study included 18 patients aged 18-60 years diagnosed with chronic periodontal disease at the Department of Oral Diagnosis and Radiology, Faculty of Dentistry, Hacettepe University who were scheduled for flap surgery. Patients with no systemic diseases affecting bone metabolism, diagnosed with chronic periodontal disease, and who had undergone initial periodontal treatment were included in the study. Due to ease of radiographic visualization and indication for flap surgery, teeth with vertical bone defects classified as subclasses B (4–6 mm) and C (7 mm and greater) according to Tarnow and Fletcher's[14] classification were followed. The use of parallel technique for radiography was preferred for its importance in detecting alveolar bone defect sizes and monitoring bone development after flap surgery.[15]

Periodontal Treatment Procedure

Periodontal pocket depth (PD) and gingival recession (GR) were assessed preoperatively and at the 3rd and 6th months postoperatively to evaluate the periodontal health of the patients. Gingival index (GI), plaque index (PI), and bleeding indexes (BI) were recorded with reference to maxillary right molars, left central and premolars, mandibular right central and premolars, and left molars before surgery to assess overall periodontal status.[4] Patients diagnosed with chronic periodontitis underwent oral hygiene education and scaling procedures at the Department of Periodontology. Oral hygiene status of the patients was monitored for 4 weeks, and all patients were deemed ready for periodontal flap surgery. Flap surgeries were performed under local anesthesia in the mandibular premolar and molar regions planned for the study. After sulcular incisions, full-thickness periodontal flaps were raised, followed by subgingival scaling and root planing. No resective bone surgery was performed. Patients were recalled for suture removal after one week, and no postoperative complications were observed. Treatments in areas outside the scope of the research design were completed over time.

Radiographic Imaging Procedure

Periapical radiographs of the periodontal surgical sites were obtained by the same operator at the preoperative, 3rd, and 6th postoperative months. All imaging and processing conditions were standardized to avoid any limitations in evaluating and analyzing radiographs. The parallel technique was used for imaging to ensure standardization and minimize distortion. A total of 180 periapical radiographs obtained from 60 sites (before and 3rd and 6th months after surgery) were obtained in the Department of Oral Diagnosis and Radiology using a Gendex (Kavo Dental Co., Lake Zurich, IL) periapical X-ray machine, Kodak ektaspeed film (Eastman Kodak Co., Rochester, NY, EUA), 80 KVp, 10 mA, 0.34 s exposure time. A 40 cm long cone was used to fix the focal spot object distance and to apply the parallel technique correctly. XCP (Dentsply Rinn Co., Elgin, Ill) film holders were used to place the film in the patient's mouth in the same position each time and to keep the object-film distance constant. In order to ensure consistent biting from the same position and occlusal closure during all examinations, occlusal stents were prepared using cold resin material (Dentalon Plus, Kulzer GmbH, Germany) for the patients.[16] These stents, obtained during preoperative imaging, were disinfected and stored for use in the 3rd and 6th-month follow-up imaging sessions.[17] Following the completion of preoperative and postoperative 3rd and 6th month imaging, all films were processed under identical and optimal conditions using a Dürr Dental DL 24 automatic developing device (Dürr Dental GmbH & Co. KG. Bietigheim-Bissingen). Subsequently, radiographs were digitized at 300 dpi with 8-bit resolution using an Epson Expression 10000XL (Epson, USA) scanner equipped with a high-resolution transparency unit, and saved in Tagged Image File Format (TIFF).[18–20] Efforts were made to standardize factors potentially impacting density, contrast, and geometry of the pre- and post-operative radiographs.

Image Processing Procedure:

To detect alveolar bone changes in radiographs obtained from surgically treated areas, digital subtraction processing was applied between preoperative (0) and 3-month follow-up radiographs, between 0 and 6-month follow-up radiographs, and between 3 and 6-month follow-up radiographs using Emago Advanced Diagnostic Radiography 2006 version 5.0 (Oral Diagnostic Systems, Amsterdam, Netherlands). Although imaging conditions were standardized, an advanced subtraction process was preferred to eliminate minor angular and density differences.[11,12,21,22] In the subtraction process, corresponding pixels in radiographs with the same imaging geometry and density were subtracted from each other. As a result, areas with the same grayscale value in both images appeared empty, while regions with different pixel values appeared lighter or darker. After the subtraction process, dark areas indicated material loss in the follow-up image, whereas light areas indicated material gain (Figure 1).

The radiographs included in the study and the obtained subtraction images were evaluated by an expert radiologist (Y.Y.) with 30 years of experience and an expert periodontologist (X.X.) with 15 years of experience in terms of alveolar bone change amounts in the flap-operated areas, based on three parameters: "alveolar bone loss present", "no change in the alveolar bone", and "alveolar bone gain present" Evaluators were blinded to the time period and patient identity of the images. These assessments were repeated one month later to determine intra-observer consistency.

Intra-observer and inter-observer consistency were tested with radiographs and subtraction images.

Bone changes in the periodontal surgical areas were quantitatively evaluated as pixel grayscale values through histogram measurements on subtraction images.[19] For measurement, three points from the base of the bone defect, one point from the top, and one control point unrelated to the surgical area were selected, and pixel grayscale values were measured. The average grayscale value of the four regions obtained from the periodontal bone defect area (average of 4 test points (ATP)) was calculated. Ensuring that the selected points corresponded to the same point in all subtraction images was achieved using a millimeteric transparent grid placed on the computer screen. The grayscale value of the region identified as the control point (CP) on the subtraction image was subtracted from the average grayscale value of the surgical area and used as a parameter for radiographic density change.[19]

Statistical analysis

In the general oral and periodontal surgical areas, parameters PD, GR, GI, PI, and BI were collected to assess and follow up on the periodontal status throughout the treatment duration. Statistical analysis of these parameters was conducted using the Friedman Test. The changes in the same parameters within 0-3 months, 3-6 months, and 0-6 months intervals were evaluated using the Wilcoxon Signed Rank test. Data obtained from radiographs and subtraction images of sixty periodontal bone defect sites, through observer assessments, were assessed for inter-observer and intra-observer consistency using Kappa statistical analysis. According to Kappa analysis, a κ value ranging from 0.81 to 1.00 indicates excellent agreement, 0.61 to 0.80 indicates good agreement, 0.41 to 0.60 indicates moderate agreement, 0.21 to 0.40 indicates weak agreement, and $\kappa < 0.20$ indicates poor agreement.[23] Spearsman's rho test was employed to examine the relationship between the first and second assessments of the observers and inter-observer assessments. The change in the grayscale values obtained from the subtraction images of periodontal surgery sites over time was statistically analysed by Student paired-t test. Furthermore, Spearman's rho test was utilized to evaluate the statistical relationship between the measurement averages of periodontal defect fillings over time and observer assessments.

Results

The changes in gingival index (GI), plaque index (PI), periodontal pocket depth (PD), gingival recession (GR), and bleeding index (BI) evaluations performed to determine the periodontal health of patients before and at 3rd and 6th months after treatment within time periods are presented in Table 1, while the statistical information indicating the changes in time intervals is shown in Table 2. A statistically significant decrease was observed in GI and PD values during follow-up examinations ($p \leq 0.001$). However, there was a non-significant decrease in PI values ($p>0.05$). When GR was evaluated, a statistically significant decrease was detected between 0-3 and 3-6 month controls ($p<0.05$), but the amount of recession observed between 0-6 months was not significant ($p>0.05$). No statistically significant changes were observed in BI across all time intervals ($p>0.05$).

Descriptive statistical analysis regarding the assessment of areas with periodontal bone defects by observers is presented in Table 3.

One hundred and eighty radiographs and subtraction images obtained from sixty periodontal surgical sites were visually evaluated by an dentomaxillofacial radiology specialist (1G) and a periodontology specialist (2G). The intra- and inter-observer consistencies of observers were tested using Kappa analysis, and the κ values are shown in Table 4. In the evaluation of radiographs,

Table 1. Changes in Gingival Index, Plaque Index, Periodontal Pocket Depth, Gingival Recession, and Bleeding Index by Months

		Pretreatment	3rd Month	6th Month
GI	n	60	60	60
	mean	0,98	0,82	0,71
	SD	0,37	0,40	0,46
PI	n	60	60	60
	mean	0,70	0,67	0,61
	SD	0,30	0,27	0,43
PD	n	42	42	42
	mean	5,79	4,38	3,79
	SD	1,89	1,94	1,88
GR	n	42	42	42
	mean	1,21	2,4	2,36
	SD	1,46	2,07	2,21
BI	n	42	42	42
	mean	0,43	0,38	0,40
	SD	0,50	0,49	0,50

Friedman Test SD: Standard Deviation. GI: Gingival Index, PI: Plaque Index, PD: Periodontal Pocket Depth, GR: Gingival Recession, BI: Bleeding Index *Indicates the differences between the groups (p<0.05)

Table 2. Changes in Gingival Index, Plaque Index, Periodontal Pocket Depth, Gingival Recession, and Bleeding Index by Time Periods

Time Period (month)	0 - 3	3 - 6	0 - 6
GI	0.0001*	0.0001*	0.0001*
PI	0.81	0.06	0.10
PD	0.001*	0.0001*	0.001*
GR	0.002*	0.003*	0.68
BI	0.62	0.78	0.74

Wilcoxon Signed Rank test, GI: Gingival Index, PI: Plaque Index, PD: Periodontal Pocket Depth, GR: Gingival Recession, BI: Bleeding Index *Indicates the differences between the groups (p<0.05)

moderate intra-observer consistency ($0.40<\kappa<0.60$) was observed for the 1st observer and good consistency ($0.61<\kappa<0.80$) for the 2nd Observer across 0-3, 3-6, and 0-6 month periods. However, inter-observer consistency was weak ($\kappa<0.40$) in both readings. In the evaluation of subtraction images, good intra-observer consistency ($0.61<\kappa<0.80$) was found for the 1st observer, while moderate consistency ($0.40<\kappa<0.60$) was observed for the 2nd observer. Inter-observer consistency was weak ($\kappa<0.40$) in the 1st reading and moderate ($0.40<\kappa<0.60$) in the 0-6 month period in the 2nd reading (Table 4).

Significant positive correlations were found between the 1st and 2nd readings of radiographs and subtraction images for both observers throughout all time intervals ($p<0.05$) (Table 5). Both observers assessed alveolar bone changes, in the direction of increase during all time periods and with both evaluation materials.

The measurements of alveolar bone defect changes performed with DSR software were statistically evaluated according to time periods. When the radiographic density change parameters obtained from the DSR images of alveolar bone defect areas were evaluated at intervals of 6 months, a statistically significant increase in bone was detected ($p \leq 0.02$) (Table 6).

When examining the correlation between radiographic density change parameters obtained from DSR measurements and observer readings, differences were found across time intervals (Table 7). Statistically significant positive correlations were observed between observer evaluations at 0–3 and 0–6 months and radiographic density change parameters ($p < 0.05$). However, during the 3-6 month period, a randomly positive correlation was identified.

Intraclass Correlation Coefficients test was used to test the reliability of the researcher conducting the DSR software measurements, and the measurement reliability was found to be 0.99.

Table 3. Observer Evaluations of Radiographs and Subtraction Images in Time Periods

		CONVENTIONAL				SUBTRACTION			
Time Period (month)	Assessment Parameters	1G1	1G2	2G1	2G2	1G1	1G2	2G1	2G2
0 - 3	Alveolar Bone Loss	13	19	6	6	22	22	17	13
	No Change In Alveolar Bone	21	19	31	33	17	17	33	30
	Alveolar Bone Gain	26	22	23	21	21	21	10	17
3 - 6	Alveolar Bone Loss	4	3	0	0	8	9	1	1
	No Change In Alveolar Bone	20	36	49	54	11	20	50	49
	Alveolar Bone Gain	36	21	11	6	41	31	9	10
0 - 6	Alveolar Bone Loss	11	16	5	6	13	13	18	13
	No Change In Alveolar Bone	10	14	28	29	10	13	22	22
	Alveolar Bone Gain	39	30	27	25	37	34	20	25

Descriptive Statistic 1G 1: 1st Observer 1st Reading, 1G 2: 1st Observer 2nd Reading, 2G 1: 2nd Observer 1st Reading, 2G 2: 2nd Observer 2nd Reading

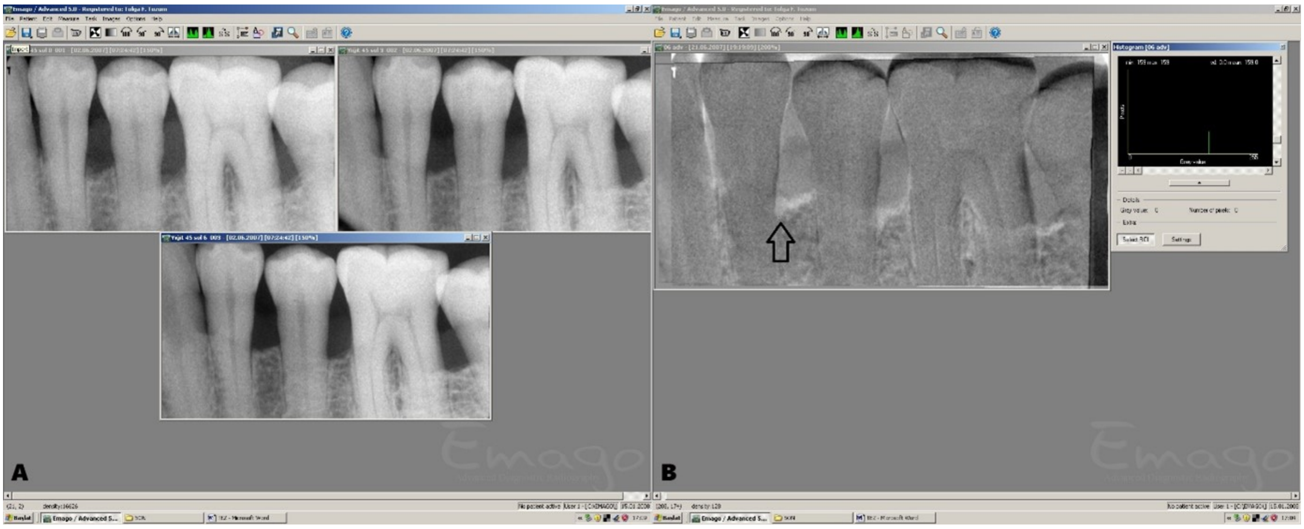

Figure 1. A. Periapical radiographs obtained at pretreatment, 3rd, 6th months. B. Digital Subtraction Radiography image; alveolar bone gain (arrow)

Table 4. Intra- and Inter-Observer Consistency Table

	CONVENTIONAL			SUBTRACTION		
Time Period (month)	0 - 3	3 - 6	0 - 6	0 - 3	3 - 6	0 - 6
1G1 - 1G2	0.47	0.34	0.54	0.62	0.48	0.61
2G1 - 2G2	0.67	0.44	0.65	0.43	0.56	0.52
1G1 - 2G1	0.26	Not Valued	0.29	0.38	0.10	0.30
1G2 - 2G2	0.30	Not Valued	0.28	0.36	0.21	0.58

Kappa statistical analysis, 0.81 - 1.00 excellent agreement, 0.61 - 0.80 good agreement, 0.41 - 0.60 moderate agreement, 0.21 - 0.40 weak agreement, $\kappa < 0.20$ poor agreement 1G 1: 1st Observer 1st Reading, 1G 2: 1st Observer 2nd Reading, 2G 1: 2nd Observer 1st Reading, 2G 2: 2nd Observer 2nd Reading

Discussion

This study evaluated the efficacy of DSR in detecting alveolar bone changes after treatment in individuals undergoing periodontal surgery due to chronic periodontal disease. Although radiographs are considered the primary diagnostic tool for detecting bone changes, their effectiveness in detecting early interproximal bone changes is debatable due to artifacts and imaging techniques. The parallel radiography technique provides the most accurate measurement of alveolar bone loss, but doubts about personal interpretation differences and the inability of radiographs to detect minor changes in alveolar bone density have led to the development and use of effective DSR software for comparing changes in images taken at periodic intervals and demonstrating minimal changes in alveolar bone density.[7] The DSR analysis is influenced by angular differences in imaging due to the method of overlaying and subtracting radiographic images obtained at different times. To minimize these differences, the obtained images should have the same imaging parameters and geometry. For this purpose, the use of acrylic or silicone stents is recommended to ensure the repeatability of geometric parameters for standardization.[17?]

In their study evaluating postoperative changes for the long-term survival of movable partial denture abutment teeth, Watanabe et al[11] utilized the DSR imaging technique and found no periodontal changes in the abutment teeth during long-term follow-up. However, in this study where non-standardized images were used, although the DSR program could correct the angle and density differences between images obtained at different times, they also reported that differences in angulation that may occur in non-standardized radiographs could lead to errors in DSR images.[11] In our study, imaging of periodontal surgical areas was conducted using the parallel technique in accordance with the literature. Imaging was performed with standard imaging parameters, and film holders and prepared occlusal stents specifically for the patient were used to ensure geometric standardization. Custom-made occlusal stents and film holders were utilized for geometric standardization purposes. To prevent any influence from minimal geometric and density differences, advanced features of the DSR program were also employed. Consequently, any potential errors due to angulation or density differences were completely eliminated. The primary limitation of DSR utilization is the standardization of imaging parameters, particularly geometry. Although the advanced features of the program partly mitigate this necessity, standardization of imaging geometry remains essential.

In their study evaluating the efficacy of Digital Subtraction Radiography (DSR) in detecting periodontal bone losses compared to radiographic methods, Nummikoski et al[24] reported that DSR exhibited higher diagnostic accuracy in detecting alveolar crestal bone

Table 5. Evaluation of Alveolar Bone Changes in Periodontal Surgical Sites by Observers

		CONVENTIONAL			SUBTRACTION		
Time Period (Month)		0 - 3	3 - 6	0 - 6	0 - 3	3 - 6	0 - 6
1G1 - 1G2	r	0,40	0.46	0.59	0.70	0.64	0.76
	p	0.001**	0.000**	0.000**	0.000**	0.000**	0.000**
2G1 - 2G2	r	0.71	0.47	0.69	0.55	0.59	0.72
	p	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**
1G1 - 2G1	r	0.38	0.32	0.47	0.54	0.31	0.68
	p	0.003**	0.01*	0.000**	0.000**	0.01*	0.000**
1G2 - 2G2	r	0.36	0.28	0.46	0.51	0.40	0.76
	p	0.005**	0.03*	0.000**	0.000**	0.001**	0.000**

Spearsman's rho test, 1G 1: 1st Observer 1st Reading, 1G 2: 1st Observer 2nd Reading, 2G 1: 2nd Observer 1st Reading, 2G 2: 2nd Observer 2nd Reading ** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

Table 6. Evaluation of the radiographic density change parameters of the alveolar bone defect region according to control periods

Time period (Month)		**0 - 3**	**3 - 6**	**0 - 6**
Average Test Points (ATP)	n	60	60	60
	mean	125.27	129.04	131.35
	SD	19.74	21.58	23.37
Control Points (CP)	n	60	60	60
	mean	124.93	129.18	123.86
	SD	9.86	8.52	9.11
ATP- CP	n	60	60	60
	mean	0.34	0.14	7.49*
	SD	22.81	20.57	24.96*

Student paired-t test Mean: Mean, SD: Standard deviation, Ctrl: Control point
*Indicates the differences between the groups ($p \leq 0.02$)

losses compared to periapical radiographs. They demonstrated that DSR is an important and effective method in the diagnosis and monitoring of advancing periodontal lesions in routine clinical practice. They also mentioned that simple imaging standardization can be achieved with radiographs without the need for personalized stents or cephalostats. However, they noted that the use of X-ray guiding devices enhances image accuracy in the DSR technique.[24] In their study evaluating the survival rates of removable partial denture abutment teeth and changes in periodontal conditions in patients with and without type 2 diabetes, Watanabe et al[12] utilized Digital Subtraction Radiography (DSR) to assess bone density. They reported that DSR analysis confirmed evidence of decreased bone density at the apex of the alveolar bone of the denture-supporting teeth five years after the placement of partial dentures in patients with type 2 diabetes who received regular treatment. Okano et al[25] evaluated alveolar bone changes through quantitative analysis using DSR at the 1st, 3rd, and 6th months post-therapy following initial periodontal treatment (curettage and root planing). They found a significant monotonic increase in the grayscale value difference of fifteen crestal bone regions over time, with a significant difference observed between the 1st and 3rd months as well as between the 3rd and 6th months. Additionally, they observed a monotonic increase in pixel count in the crestal bone region over time, with a significant increase in pixel count between the 1st and 3rd months, although no statistically significant increase was detected between the 3rd and 6th months. Consequently, they argued that DSR is a repeatable and numerical method for evaluating the outcomes of periodontal treatment.[25] The results obtained from quantitative measurements using DSR in our study are consistent with those in the literature. Evaluation of grayscale value changes in the alveolar bone defect areas included in the study, both preoperatively and at 3rd and 6th months postoperatively, revealed a significant increase in density change over time; however, pairwise comparisons did not reveal a statistically significant increase between the 3rd and 6th months (Table 6). Although there are studies in the literature demonstrating that DSR technique is diagnostically more effective and accurate compared to conventional radiography techniques, Bittar-Cortez et al[19] conducted a study in 2006 where they evaluated peri-implant bone density changes by performing histogram (mean grayscale value) measurements on digitized conventional radiography and DSR, yielding quite different results. Their study concluded that maxillary and mandibular bone morphologies did not affect radiographic density. Furthermore, they indicated no significant difference in measurements between digital conventional radiography and DSR. They mentioned that implant surrounding bone density could be evaluated as mean grayscale value through histogram measurement in both DSR and digital conventional radiography techniques. The researchers argued that the use of a time-consuming and expensive technique like DSR was meaningless. However, they also stated that the chosen method could influence the obtained result, and the DSR technique might be more sensitive in areas with mineral loss around implants.18 In their in vitro studies, Wenzel and Sewerin[26], Janssen et al[27] stated that DSR's numerical measurements were highly accurate in evaluating artificial periodontal bone defects. However, Bittar-Cortez et al[19] argued that this result would decrease in vivo due to standardization difficulties between reference and follow-up radiographs and changes in irradiation parameters. In our study, bone defect areas treated surgically were evaluated with histogram measurements consistent with the study by Bittar-Cortez et al[19], and it was concluded that DSR technique is an effective method for detecting bone healing. It has been observed that DSR, when adhered to with sensitivity to standardization conditions and fully implemented program content, is highly beneficial for research purposes, although it may not be suitable for routine clinical practices.

In our study, in addition to quantitative measurements conducted with DSR, radiographs and subtraction images were reviewed by a dentomaxillofacial radiologist and a periodontologist to evaluate how alveolar changes were interpreted. The intraobserver consistency of the dentomaxillofacial radiologist participating in the study was found to be moderate in detecting alveolar bone changes in radiographs, while consistency in interpreting subtraction images was determined to be good. The periodontologist observer's consistency in radiograph evaluation was good, whereas consistency in interpreting subtraction images was moderate. The good consistency of the periodontology specialist in detecting alveolar bone changes in radiographs was attributed to the high specificity of perception in the studied area, while the high consistency of the radiology specialist in DSR was attributed to the ability of radiology expertise to provide a general perspective that is not specific to the region but adaptable to different areas and techniques. Interobserver consistency was found to be weak for repeatable radiograph readings. However, when subtraction images were evaluated, it was noteworthy that the interobserver consistency for alveolar bone changes in the 0–6 month time frame was weak in the first reading but reached a moderate level in the second reading. It was concluded that the DSR method is more effective in reaching consensus among evaluators (Table 4).

In their study investigating observer reliability during the evaluation of color-coded DSR for assessing changes in alveolar bones,

Table 7. Evaluation of the radiographic density change parameters of the alveolar bone defect region with observer assesments according to control periods

		CONVENTIONAL				SUBTRACTION			
Time Period (month)		**1G1**	**1G2**	**2G1**	**2G2**	**1G1**	**1G2**	**2G1**	**2G2**
0 - 3	r	0,27	0.55	0.52	0.35	0.71	0.62	0.47	0.70
	p	0.03*	0.001**	0.001**	0.001**	0.001**	0.001**	0.001**	0.001**
3 - 6	r	0.24	0.50	0.23	0.24	0.52	0.45	0.36	0.22
	p	0.07	0.001**	0.07	0.06	0.001**	0.001**	0.001**	0.08
0 - 6	r	0.26	0.38	0.31	0.27	0.67	0.61	0.56	0.68
	p	0.04*	0.001**	0.01**	0.03*	0.001**	0.001**	0.001**	0.001**

Spearsman's rho test, 1G 1: 1st Observer 1st Reading, 1G 2: 1st Observer 2nd Reading, 2G 1: 2nd Observer 1st Reading, 2G 2: 2nd Observer 2nd Reading ** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

Shi et al [28] found a significantly high level of intra-observer agreement, while inter-observer agreement was notably high in the second assessments of observers. The increase in agreement during the second assessment was attributed to observers' increased familiarity with black-and-white images and their enhanced experience in evaluating color-coded images during the second assessment. Similarly, our study also demonstrates an increase in both intra- and inter-observer agreement during the second assessment, particularly in DSR images. In their study, Cury et al [29] compared the effectiveness of DSR and radiographic evaluation in detecting periodontal bone changes occurring during long-term monitoring of class II furcation defects. They observed a low inter-observer agreement rate in radiographic evaluations. Alignment between DSR images and radiographic evaluations was found to be low for each observer. Consequently, conventional radiographic evaluations for the diagnosis and monitoring of class II furcation defects in mandibular molars were shown to be more subjective and less accurate compared to DSR images. Consistent with the findings of Cury et al [29] intra-observer agreement in our study was higher in DSR images compared to conventional radiographs, while inter-observer agreement was weak (Table 4).

Nicopoulou-Karayianni et al [16] utilized radiographic and DSR images to evaluate the effect of root canal treatment on periapical lesions and tested observer agreement. When DSR images were evaluated, both inter- and intra-observer agreements were found to be statistically significant compared to conventional radiographs. This study demonstrated better observer agreement in DSR images, consistent with our study results. [16] In our study, the correlation between the first and second readings of the same observer, as well as the correlation between the readings of the first and second observers, was examined. Across all time intervals, significant positive correlations were found between the assessments of two observers in the evaluation of radiographs and DSR images (Table 5). Observers made similar assessments of the datasets. This finding was consistent with the study by Bittar-Cortez et al. [19] Both observers assessed alveolar bone changes, in the direction of increase during all time periods and with both evaluation materials (Table 3). Furthermore, our study assessed the correlation between histogram measurements (mean grayscale value) obtained through DSR and observer evaluations. Statistically significant positive correlations were detected between observer assessments at 0–3 and 0–6 months and changes in radiographic density parameters ($p < 0.05$). However, a sporadic positive correlation was observed during the 3-6 month period. It was concluded that observer evaluations yielded similar results to DSR histogram measurements (Table 7).

In our study, gingival index (GI), plaque index (PI), periodontal pocket depth (PD), gingival recession (GR), and bleeding index (BI) were recorded for the purpose of monitoring oral hygiene control and periodontal health before and after periodontal surgery, and the changes in these indexes over time were evaluated (Table 1). It was observed that there was a statistically significant decrease in GI and PI over time. Hochstetter et al [30] in their study on oral hygiene education conducted on 58 preschool children, reported a statistically significant decrease in GI and PI indexes in the group receiving oral hygiene education. Hugoson et al [31] evaluated PI and GI in their study testing the effectiveness of three different preventive dental health programs in four hundred patients. As a result, they found a decrease in PI and GI values over a two-month period. [31] In our study, it was observed that after oral hygiene motivation, patients' index values rapidly decreased and continued to decrease as long as patient follow-up continued. Gaspirc and Skaleric [32] used GI, PI, BI, clinical attachment level, and PD parameters in their study comparing periodontal flap surgery performed with Er: YAG laser and modified Widmann flap surgery, which we also used as parameters. They reported that both treatments resulted in a significant decrease in GI, PI, BI, and PD parameters over time, while there was an increase in clinical attachment level gain. [32] In our research, a decrease in GI, PI, BI, PD, and increase in GR values over time were observed, and the increase observed in GR was thought to be related to the selected incision type. No significant change was observed in the BI value (Table 2).

Conclusion

Radiographic examination is a necessary and practical method to detect osseous changes caused by periodontitis and to evaluate the long-term outcomes of periodontal treatment. However, due to factors such as observer experience, assessment, and imaging conditions, minimal tissue changes may be overlooked in radiographs. In cases where precise evaluation is required, as demonstrated in our study, DSR can provide quantitative data, enabling a more objective assessment of the examined area. However, the need for standardization in the imaging geometry and parameters of DSR complicates its routine clinical use.

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Conflict of Interest

The authors declare no conflicts of interest.

Ethics Approval

The study was conducted in accordance with the principles outlined in the Declaration of Helsinki and received approval from the Ethics Committee of Medical, Surgical and Pharmaceutical Research at Hacettepe University (IRB Approval No: LUT04/65, 2005).

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