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Comparison Of Immediate And Delayed Maxillary Dental Implant Placement Using A Computerized Image Analysis Program - A Clinical Study.

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ABSTRACT

Measurement of bone density has a significant clinical use in medicine and it is based on X-ray images made with DEXA, CT, CBCT, panoramic and retroalveolar images. Aim: The aim of this clinical study was to compare the immediate and delayed implant placement by the use of computerized densitometric analysis in three time period: immediate after implant placement, after 6 months and after 12 months. Materials and methods: In this clinical study, 60 participants were divided into two groups of 30 participants, whose loss of one tooth in the premolar region of the upper jaw was replaced by the insertion of dental implant. An individually modified standard programme for computerized analysis was made, with specially designed software for measuring density of gray shadows in the region of interest (ROI) on RVG images. Results: There were statistically significant differences found in the change of the level of gray area between the immediate and delayed group in all seven regions, and at points P6 and P7. Conclusion: These results showed that the immediate technique had lower results in the first six months, regarding the shading level and bone remodeling, but the results were consistent with the results of the delayed technique one year after implant placement.

Keywords: bone density, radiographic image, dental implant, computer analysis

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INTRODUCTION

Radiology has become an indispensable part of dental medicine from the beginning of the X- ray discovery in the late 19th century. The same technique of recording and processing the image has not changed for almost 80 years, only only regarding the improvement of the sensitivity of the film itself, with a reduction in the radiation dose. The rise of the digital era in the dental medicine began in 1987 when digital radiology system called RadioVisioGraphy (RVG) appeared (1). The advantages of digital radiology compared to the X-ray analogue film are a shorter exposure time, higher quality (resolution) of shots, automatic digitalization without the loss of shutter resolution, easier storage, data exchange and time saving (2,3).

Radiological diagnosis in dental implantology is a required parameter in planning implant therapy and allows a good estimate of the condition of bone quality and quantity. It can be divided into three phases: preoperative, surgical and postoperative phase (4).

Measurement of bone density has a significant clinical use in medicine. Measurements are based on X-ray images made with DEXA (dual energy x-ray apsorptiometry), CT, CBCT, panoramic and retroalveolar images (5-9). DEXA is a gold standard for measuring long bone density and is routinely used in diagnosing and monitoring osteoporosis. The main disadvantage of DEXA is cost and massiveness of the appliance, hence the application in dental medicine is not possible (10). In 1988, Bragger described the measurement of alveolar bone density by computerized dental retroalveolar imaging using computer assisted densitometric image analysis (CADIA) area of interest, based on the medium level of gray area (associated with each pixel on previously digitized x-ray images) (10-13).

Densitometric analysis is based on the measurement of the gray scale on certain X-ray images; it is important to set the standardization criteria of the images due to differences in sharpness, contrast, color and different angles of shooting (14,15). The most common method for standardizing the X-ray image for densitometric measurement in multiple layers is the use of a copper or aluminum calibration peg placed on the edge of the x-ray film which is not covered by structures in the oral cavity (16,17).

Although CT or CBCT scan provide the most accurate radiological measurement of gray level or bone density before implant placement, they are limited in monitoring bone healing or the assessment of the degree of osseointegration, because the titanium implant projects a metal shadow around the bone itself after filming, which significantly affects the estimation of bone tissue healing. Digital retroalveolar image of implant and surrounding bone is one of the most accurate methods for monitoring bone change around implants. The deficiencies of this method are the two-dimensional bone representation, the ability to measure only the axial and distal aspect of the bone, and the necessity of calibration and standardization (18,19).

Digital subtraction radiography (DSR) is most commonly used to estimate the bone around the implant, especially for the estimation of the marginal bone. DSR is a technique that evaluates qualitative changes between two images taken at different time periods. For the purpose of the subtraction analysis, the image must be identical, which is achieved by using an RVG detector that is connected to the X-ray tube and enables standardization of the images (20-22). The disadvantage of this system is the inability to track healing by accurate determination of bone density. Gabrić (8) used the implant as a calibration peg to standardize the images in her study, because titanium has a similar atomic number as calcium, and as such is very good for calibration. A very similar principle is used in this study.

The aim of this clinical study was to compare the immediate and delayed implant placement by the use of computerized densitometric analysis in three time period: immediate after implant placement, after 6 months and after 12 months.

The additional aim of the research was to test the reliability of an individually modified standard programme for computerized analysis, specially designed for measuring the shadow or level of gray area around the dental implant in the digital RVG image. These results would give helpful information for evaluating the success or potential risk of implant therapy.

MATERIALS AND METHODS

In this clinical study, 60 participants (age range 22-65, mean age 44.25) were divided into two groups of 30 participants, whose loss of one tooth in the premolar region of the upper jaw was replaced by the insertion of Nobel Replace Tapered Groovy (Nobel Biocare, Gothenburg, Sweden) dental implant. All participants participated voluntarily in the study and signed an informed consent which was approved by the Ethics Committee of the School of Dental Medicine, Zagreb, Croatia.

Participants with medical conditions that have been shown to affect bone healing (uncontrolled diabetes, history of immunosuppressive therapy, radiation, chemotherapy, moderate to high-risk osteoporosis, bisphosphonate therapy, pregnancy) and subjects with exceptionally poor oral hygiene, severe periodontitis and lack of co-operation have been excluded from this study.

The same experienced surgeon placed all implants at the Department of Oral Surgery, School of Dental Medicine, University of Zagreb. The first group of participants in the study were patients whose implant was inserted immediately after tooth extraction by standard surgical implant protocol. Inclusion criteria were subjects with an intact alveolar socket after extraction and having at least 2 mm of keratinized gingiva around it. In the second group of participants, also consisting of 30 patients, implants were inserted in the healed alveolar bone after previous tooth extraction by the standard delayed technique. Inclusion criteria were subjects with completed bone growth, having at least 2 mm of keratinized gingiva around the implant place and partially edentulous in the premolar region.

After the period of osseointegration, 6 months after implant placement, single metal-ceramic crowns were cemented on all implants. Implant stability quotient (ISQ) was measured on each implant with Osstell Mentor (Integration Diagnostics AB, Gothenburg, Sweden) immediately after the placement of the implant and after 6 months prior to luting metal ceramic crowns. The measurments of gingival retraction and pocket depth were also made at the same time with the periodontal probe (University of Michigan „O“, Williams, Aesculap, 0,5mm) on each side of the metal ceramic crown (labial, palatal, mesial and distal).

During each follow-up (immediately after implant placement, after 6 months and one year after implant placement), retroalveolar radiovisiographic (RVG) image of the implant was performed.

RVG images were recorded using Orix 70 (Ardet, Buccinasco, Italy, 2002). Three RVG images were performed for each patient. The first RVG image was made immediately after the implant insertion, the second image six months after, before the prosthetic suprastructure was fixed on, and the third image one year after the implant therapy was completed. All patients used an individual silicone key that was placed on a specialized RVG film carrier at a precise angle and distance associated with an RVG device, for the purpose of standardization and accurate filming, so that the X-ray was always positioned in same direction and the distortion of image was avoided.

For purpose of this research, an individually modified standard programme for computerized analysis was made, with specially designed software for measuring density of gray shadows in the region of interest (ROI) on RVG images. This software analyzes and compares RVG images of the same patient taken in different time periods.

RVG images were used in a digital form stored in computer. Although the same X-ray device and silicone key were used for standardizing images, the program contains the "standardization" option– for setting at least two lines or shapes (the width and length of implants used in our survey) on each image, and the program automatically calibrates all images based on the first image in their parameters of size, width, and direction (Fig. 1). It is necessary to set at least three correction points on the individual parts of the implant to equalize the shadow difference, or the color of each image with the first image. The first correction point was set on the apical part on the implant, the second was located on the middle part of the implant and corresponds to the empty space between the apical part of the implant and the inner part of the cover screw. The third point is on the cervical part of the implant that matches the position where the cover screw is attached to the implant (Fig. 2). After selecting the correction points on all three images, the program automatically calibrates the average shade level of correction points and equalizes them with the average shade level of the first image. Correction points were taken on a titanium implant because the shadow of the implant is constant for all three measurements and titanium has a similar atomic number like calcium which is the basic atomic element in the bone. After the equalization of all parameters, the calculation of the shade level in the ROI was made. Seven measuring points (0.5 mm x 0.5 mm) and seven measuring regions (0.5 mm x 1.5 mm) were set on the bone around the implant. After positioning the measuring points and regions, the program calculated the medium values of the shading level of the ROI, and the obtained data were graphically and tabularly shown. The computer program collected data in the binary system (numbers 0 and 1). Gray levels ranged from 0 (black) to 255 (white).

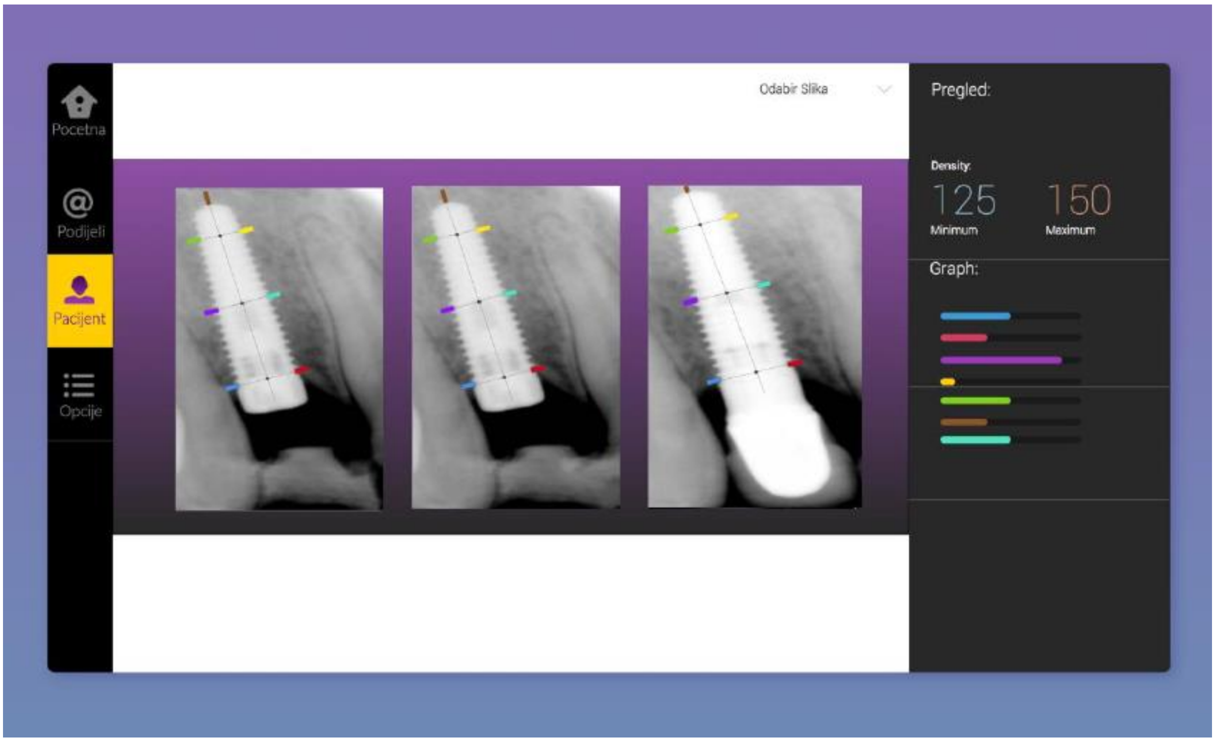

Fig 1: Specially designed software for measuring density of gray shadows in the region of interest

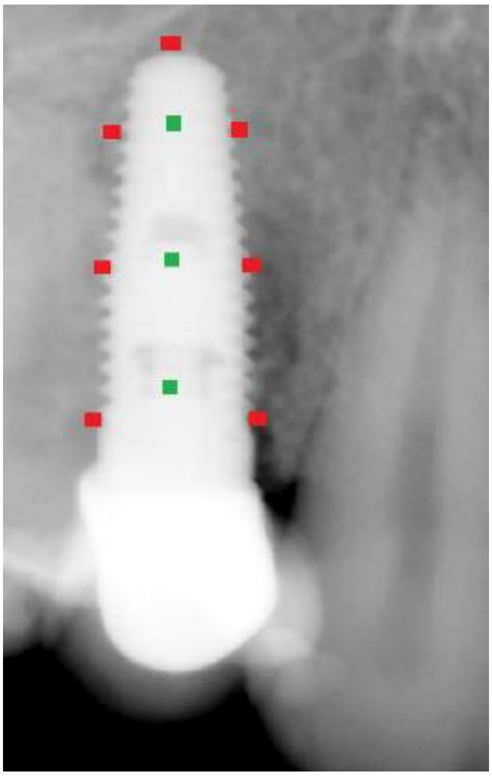

Fig 2: RVG image with correction and measuring points

Qualitative variables, such as groups, gender, smoking habits and periodontal status, were described by frequencies, and the potential dependence among them was tested with a χ2 test. Most variables of this research were quantitative, such as shading levels in seven points and regions for three time measurement points, gingival retraction and pocket depth. Their distributions were tested for normality by the Kolmogorov-Smirnov test. Testing of different hypotheses (t-tests for independent samples and correlations) was performed by parametric methods. These results were verified by appropriate nonparametric methods (Mann-Whitney test, Spearman correlation). The IBM SPSS Statistics 18 program was used for statistical analysis.

RESULTS

Differences or variations of density of gray shadows between the first and the second, and between the first and the third measurement were analyzed by the t-test for independent samples by groups. The results are presented in Tables 1. and 2. The same analysis showed that there were no statistically significant differences in these variables between men and women, and between smokers and non-smokers. These results allow that changes in shading levels were attributed only to the influence of belonging to the examined groups. It was obvious from the data (Tab. 1. and 2.) that there were statistically significant differences found in the change of the level of gray area between the immediate and delayed group in all seven regions, and at points P6 and P7.

Table 1: Differences in the change of the shading level compare to the points and the region-results of the t-test

Gray level change	Group	N	Average	Stand. dev.	t	df	p
P1-T2-T1	Immediate	30	2,43	1,96	-0,358	58	**0,722**
	Delayed	30	2,61	1,84			
P1-T3-T1	Immediate	30	1,54	1,85	-1,422	58	0,161
	Delayed	30	2,22	1,83			
R1-T2-T1	Immediate	30	1,31	1,27	2,745	58	**0,008**
	Delayed	30	0,65	0,34			
R1-T3-T1	Immediate	30	0,86	1,19	2,215	58	**0,031**
	Delayed	30	0,36	0,29			
P2-T2-T1	Immediate	30	5,98	4,59	2,264	58	**0,027**
	Delayed	30	3,89	2,17			
P2-T3-T1	Immediate	30	4,95	4,56	1,712	58	0,092
	Delayed	30	3,36	2,24			
R2-T2-T1	Immediate	30	2,72	3,2	3,124	58	**0,003**
	Delayed	30	0,86	0,6			
R2-T3-T1	Immediate	30	2,18	3,22	2,851	58	**0,006**
	Delayed	30	0,48	0,57			
P3-T2-T1	Immediate	30	5,67	2,86	0,224	58	0,824
	Delayed	30	5,53	2,07			
P3-T3-T1	Immediate	30	4,67	3,1	-0,449	58	0,655
	Delayed	30	4,97	2,05			
R3-T2-T1	Immediate	30	2,22	1,25	4,61	58	**<0,001**
	Delayed	30	1,00	0,74			
R3-T3-T1	Immediate	30	1,73	1,23	4,581	58	**<0,001**
	Delayed	30	0,57	0,64			

Table 2: Differences in the change of the shading level compare to the points and the region-results of the t-test (extension)

Gray level change	Group	N	Average	Stand. dev.	t	df	p
P4-T2-T1	Immediate	30	6,64	3,63	-0,588	58	0,559
	Delayed	30	7,10	2,31			
P4-T3-T1	Immediate	30	5,49	3,69	-0,834	58	0,408
	Delayed	30	6,17	2,52			
R4-T2-T1	Immediate	30	2,29	0,94	5,059	58	**<0,001**
	Delayed	30	1,18	0,75			
R4-T3-T1	Immediate	30	1,66	1,07	4,325	58	**<0,001**
	Delayed	30	0,70	0,57			
P5-T2-T1	Immediate	30	5,71	2,31	-0,772	58	0,444
	Delayed	30	6,17	2,29			
P5-T3-T1	Immediate	30	5,06	2,32	-0,576	58	0,567
	Delayed	30	5,40	2,31			
R5-T2-T1	Immediate	30	2,28	0,90	4,947	58	**<0,001**
	Delayed	30	1,19	0,80			
R5-T3-T1	Immediate	30	1,67	1,00	4,183	58	**<0,001**
	Delayed	30	0,75	0,67			
P6-T2-T1	Immediate	30	10,52	4,22	4,399	58	**<0,001**
	Delayed	30	6,19	3,37			
P6-T3-T1	Immediate	30	8,67	4,61	4,133	58	**<0,001**
	Delayed	30	4,37	3,34			
R6-T2-T1	Immediate	30	4,20	2,14	7,937	58	**<0,001**
	Delayed	30	0,91	0,75			
R6-T3-T1	Immediate	30	3,09	2,25	6,668	58	**<0,001**
	Delayed	30	0,24	0,66			
P7-T2-T1	Immediate	30	10,18	3,73	5,013	58	**<0,001**
	Delayed	30	5,57	3,38			
P7-T3-T1	Immediate	30	8,20	4,47	4,197	58	**<0,001**
	Delayed	30	3,99	3,19			
R7-T2-T1	Immediate	30	4,00	2,32	6,83	58	**<0,001**
	Delayed	30	0,91	0,89			
R7-T3-T1	Immediate	30	3,11	2,58	5,789	58	**<0,001**
	Delayed	30	0,28	0,71			

Legend: Pi-Tj-T1- gray level change in time Tj,j = 2,3 compare to time T1 in point Pi,i =1,2,3,4,5,6,7
Ri-Tj-T1- gray level change in time Tj,j = 2,3 compare to time T1 in region Ri,i =1,2,3,4,5,6,7

The interdependence between the indicators of the shading level, ISQ change, gingival retraction and pocket depth was investigated using coefficients of their correlations. Tables 3 and 4 list the Pearson coefficients of correlation of these properties for the immediate and delayed group organized in the matrix form. According to statistical significance, shadowed coefficients of the immediate group (Tab. 3.) clearly indicated that variables of the change of the shading level for points and regions from 1 to 5 correlated with each other in a considerably minor measure than those for points and regions 6 and 7 which were in complete correlation. These variables were significantly correlated with Osstell test and partly with the retraction of gingiva and pockets depth. Shadowed coefficients of the delayed group (Tab. 4.), according to statistical significance, did not indicate the systematic dependence of the variables of the shading level change, and there was no correlation between the gingival retraction and the pockets depth with the variables of the shading level change and between each other.

Table 3: Coefficients of Pearson's correlation changes in the shading level, ISQ change, gingival retraction and pocket depth of the immediate group

	P1-T3-T1	R1-T3-T1	P2-T3-T1	R2-T3-T1	P3-T3-T1	R3-T3-T1	P4-T3-T1	R4-T3-T1
P1-T3-T1	---	0,33	0,262	0,055	0,438	0,36	0,131	-0,131
R1-T3-T1	0,330	---	0,029	0,029	-0,225	-0,016	0,492	0,183
P2-T3-T1	0,262	0,029	---	0,694	0,373	0,403	0,529	0,542
R2-T3-T1	0,055	0,029	0,694	---	0,052	-0,002	0,443	0,48
P3-T3-T1	0,438	-0,225	0,373	0,052	---	0,663	0,044	-0,126
R3-T3-T1	0,36	-0,016	0,403	-0,002	0,663	---	0,088	0,106
P4-T3-T1	0,131	0,492	0,529	0,443	0,044	0,088	---	0,606
R4-T3-T1	-0,131	0,183	0,542	0,48	-0,126	0,106	0,606	---
P5-T3-T1	0,333	0,012	0,161	-0,041	0,522	0,393	0,007	0,034
R5-T3-T1	0,176	0,059	0,245	0,045	0,263	0,377	-0,077	0,17
P6-T3-T1	0,179	0,314	0,222	0,127	0,137	0,14	0,105	0,102
R6-T3-T1	0,107	0,281	0,229	0,2	0,039	0,212	0,243	0,381
P7-T3-T1	0,334	0,419	0,174	-0,02	0,365	0,397	0,232	0,096
R7-T3-T1	-0,019	0,436	-0,004	0,053	0,075	0,278	0,067	0,095
ISQ-T2-T1	0,35	0,312	0,359	0,172	0,132	0,287	0,095	0,181
RET	-0,287	-0,426	-0,056	-0,138	-0,142	-0,142	-0,168	0,025
PD	0,02	-0,266	0,168	0,098	0,204	0,011	0,113	0,115

	P5-T3-T1	R5-T3-T1	P6-T3-T1	R6-T3-T1	P7-T3-T1	R7-T3-T1	ISQ-T2-T1	RET	PD
P1-T3-T1	0,333	0,176	0,179	0,107	0,334	-0,019	0,35	-0,287	0,02
R1-T3-T1	0,012	0,059	0,314	0,281	0,419	0,436	0,312	-0,426	-0,266
P2-T3-T1	0,161	0,245	0,222	0,229	0,174	-0,004	0,359	-0,056	0,168
R2-T3-T1	-0,041	0,045	0,127	0,2	-0,02	0,053	0,172	-0,138	0,098
P3-T3-T1	0,522	0,263	0,137	0,039	0,365	0,075	0,132	-0,141	0,204
R3-T3-T1	0,393	0,377	0,14	0,212	0,397	0,278	0,287	-0,142	0,011
P4-T3-T1	0,007	-0,077	0,105	0,243	0,232	0,067	0,095	-0,168	0,113
R4-T3-T1	0,034	0,17	0,102	0,381	0,096	0,095	0,181	0,025	0,115
P5-T3-T1	---	0,473	0,235	0,031	0,241	0,223	0,321	-0,212	-0,066
R5-T3-	0,473	---	0,086	0,191	0,082	0,345	0,464	-0,372	-0,298

T1									
P6-T3-T1	0,235	0,086	---	0,744	0,686	0,545	0,509	-0,324	-0,354
R6-T3-T1	0,031	0,191	0,744	---	0,620	0,551	0,5	-0,369	-0,344
P7-T3-T1	0,241	0,082	0,686	0,62	---	0,603	0,537	-0,433	-0,270
R7-T3-T1	0,223	0,345	0,545	0,551	0,603	---	0,452	-0,496	-0,456
ISQ-T2-T1	0,321	0,464	0,509	0,500	0,537	0,452	---	-0,534	-0,47
RET	-0,212	-0,372	-0,324	-0,369	-0,433	-0,496	-0,534	---	0,582
PD	-0,066	-0,298	-0,354	-0,344	-0,27	-0,456	-0,47	0,582	---

Legend: p=0,005 p=0,001

Table 4: Coefficients of Pearson's correlation changes in the shading level, ISQ change, gingival retraction and pocket depth of the delayed group

	P1-T3-T1	R1-T3-T1	P2-T3-T1	R2-T3-T1	P3-T3-T1	R3-T3-T1	P4-T3-T1	R4-T3-T1
P1-T3-T1	---	0,378	0,210	-0,114	0,136	-0,054	-0,027	-0,199
R1-T3-T1	0,378	---	-0,046	0,180	0,238	0,46	-0,294	0,007
P2-T3-T1	0,210	-0,046	---	-0,084	0,109	0,034	0,096	-0,027
R2-T3-T1	-0,114	0,180	-0,084	---	0,022	0,547	0,057	0,327
P3-T3-T1	0,136	0,238	0,109	0,022	---	0,53	0,045	-0,045
R3-T3-T1	-0,054	0,460	0,034	0,547	0,530	---	-0,239	0,139
P4-T3-T1	-0,027	-0,294	0,096	0,057	0,045	-0,239	---	0,505
R4-T3-T1	-0,199	0,007	-0,027	0,327	-0,045	0,139	0,505	---
P5-T3-T1	0,002	0,034	-0,013	0,064	0,184	0,171	-0,010	0,276
R5-T3-T1	-0,043	0,298	-0,184	0,268	0,302	0,533	0,243	0,704
P6-T3-T1	0,264	0,515	-0,162	0,239	0,583	0,562	-0,116	-0,014
R6-T3-T1	-0,181	0,036	-0,219	0,734	-0,027	0,340	0,0191	0,463
P7-T3-T1	0,200	0,363	-0,025	0,323	0,458	0,566	-0,049	-0,007
R7-T3-T1	-0,077	0,171	-0,252	0,434	0,441	0,599	-0,095	0,214
ISQ-T2-T1	-0,083	0,02	0,188	0,423	0,311	0,483	0,084	0,081
RET	-0,099	-0,002	-0,032	0,020	-0,049	0,019	-0,051	-0,207
PD	0,057	0,017	-0,085	0,118	0,132	0,034	0,302	-0,008

	P5-T3-T1	R5-T3-T1	P6-T3-T1	R6-T3-T1	P7-T3-T1	R7-T3-T1	ISQ-T2-T1	RET	PD
P1-T3-T1	0,002	-0,043	0,264	-0,181	0,200	-0,077	-0,083	-0,099	0,057
R1-T3-T1	0,034	0,298	0,515	0,036	0,363	0,171	0,020	-0,002	0,017
P2-T3-	-0,013	-0,184	-0,162	-0,219	-0,025	-0,252	0,188	-0,032	-0,085

T1									
R2-T3-T1	0,064	0,268	0,239	0,734	0,323	0,434	0,423	0,020	0,118
P3-T3-T1	0,184	0,302	0,583	-0,027	0,458	0,441	0,311	-0,049	0,132
R3-T3-T1	0,171	0,533	0,562	0,34	0,566	0,599	0,483	0,019	0,034
P4-T3-T1	-0,010	0,243	-0,116	0,191	-0,049	-0,095	0,084	-0,051	0,302
R4-T3-T1	0,276	0,704	-0,014	0,463	-0,007	0,214	0,081	-0,207	-0,008
P5-T3-T1	---	0,29	0,261	0,188	0,34	0,146	0,222	-0,021	0,065
R5-T3-T1	0,290	---	0,371	0,373	0,304	0,660	0,308	-0,269	0,113
P6-T3-T1	0,261	0,371	---	0,207	0,783	0,536	0,367	-0,113	0,230
R6-T3-T1	0,188	0,373	0,207	---	0,326	0,557	0,266	-0,080	0,253
P7-T3-T1	0,340	0,304	0,783	0,326	---	0,458	0,446	-0,017	0,244
R7-T3-T1	0,146	0,660	0,536	0,557	0,458	---	0,537	-0,237	0,197
ISQ-T2-T1	0,222	0,308	0,367	0,266	0,446	0,537	---	-0,284	-0,017
RET	-0,021	-0,269	-0,113	-0,080	-0,017	-0,237	-0,284	---	0,150
PD	0,065	0,113	0,23	0,253	0,244	0,197	-0,017	0,150	---

Legend: p=0,005 p=0,001

DISCUSSION

The methods of radiological monitoring of alveolar bone changing around the implants are described in a small number of studies. They can be simple and inaccurate, while others are extremely precise but expensive and complex (23-25). In dental implantology, the analysis of the Houndsfield unit (more than 4000 shades) obtained by CT or CBCT (26) is most commonly used for preoperative assessment of bone density and estimation of bone quality. The limitation of the CT / CBCT device is a shadow created by the material of the dental implant and monitoring only the change in bone density around the inserted implant has proved ineffective. Digital retroalveolar image has been shown to be the most accurate and safest method to evaluate the change of bone density around implants (18,19). Measurement of bone change can be divided into absolute and relative methods. For the absolute estimate of the bone, the reference object (calibration peg) is used, whereas the standardized region of the picture, which does not change on a series of x-rays and serves to standardize a series of images without a calibration peg, is used for the relative estimate. Calibration pegs are used to correct readings of the shading level and to measure bone density, so it is possible to standardize the images and precisely diagnose the bone change. Gabrić Pandurić et al. (8) measured the bone thickness around the implant in their pilot study where the implant was used as a correction factor for equalizing all measurement images. Implant design has three different thicknesses which provide three correction points. Titanium has a similar atomic number compared to calcium, so it is a suitable material for standardizing series of shots. In this research, a specialized computer programme for measuring the shading level around implant was used. It can encompass all tools for standardizing and processing of image, with faster and more precise processing of the image itself. In this study, two techniques of dental implant placement (immediate vs. delayed) were compared to test this programme. Clinical findings including gingival retraction and pocket depth were also used for programme testing.

The results of our study have shown statistically significant differences between the two groups of participants. Comparing results per measuring points and measuring regions, statistically significant differences were best shown in points 6 and 7 and in regions 6 and 7. These regions of interest corresponded to marginal bone regions. The most negative effects which reduce the bone density due to large amounts of dental plaque, inflammation of the gingiva, smoking or their combination could be expected in the coronal region. Almost all participants in this study had a lower level of shading in the coronal area compared to the apical region. The comparison of the immediate and delayed technique showed no statistically significant difference between the measurement points while a statistically significant difference was found between the measurement regions.

Vignoletti et. al. (27) reported that the immediate technique had greater changes in the remodeling, or greater changes in the shading level compared to the delayed technique. These findings are similar to our results where greater changes were described in all seven measuring regions and two measuring points (P6 and P7) in patients with immediate implant placement. In the second measurement (six months after implant placement without functional loading) there was a significant increase in the level of shading in both techniques, especially in the immediate technique, while in the third measurement (one year after implant placement, or six months after functional loading) there was a decrease in the level of shading around implants, especially in the measurement regions 6 and 7 in both groups of participants. Botticelli et al. (28) suggested that the voluminous bone change was described in the area of the alveolar ridge in the first year after implantation due to functional remodeling. One of the most important advantages of immediate implant placement in the extracting wound was the preservation of the buccal wall and reduced resorption of the alveolar ridge.

In the study published by Gulsahi et al. (29), the healing of dental implants inserted by condensing and conventional technique in the premolar region of the maxilla was followed by DEXA and intraoral images. The implants were placed in the healed alveolus and loaded six months after the insertion. The results showed a significant difference in bone density six months after the insertion and a slight change between six and twelve months. Our results also describe a statistically significant difference of increased bone density in delayed implant placement after six months and a slight decrease in the level of shading between six and twelve months. The results showed that functional remodeling always induced some bone loss.

Bone quality in the premolar region of the maxilla is between D2 and D3 with a significantly better prognosis than the molar region with the most common D4 bone, so it is less likely to achieve primary stability (30). Because of these facts implant failures in the upper jaw can be up to 20% (30,31). There was no implant failure in this research during 18-months follow up. The average ISQ values in this study before functional loading were 66.23 for immediate and 68.83 for the delayed technique. These findings satisfy the loading protocol for successful implant therapy. Changes in Osstell test between the first, the second and the third measurment were not statistically significant among groups. In comparison with the results of Kim et al. (32) ISQ in this study was lower because we included only the upper jaw while they did research on both jaws and ISQ values of the mandible were higher than in the maxilla. Kim et. al. also reported that ISQ values in the posterior maxilla were not suitable for assessing the risk of implant therapy because they lost three implants in this region with ISQ values higher than 62 measured immediate after placement. Comparing the results of Osstell test and the change of the shading level in the images, a statistically significant correlation was found between the change of ISQ with the changes of the shading level in measuring points and regions 6 and 7. We can conclude from these results that the value of Osstell test was directly affected by bone remodeling, especially in the alveolar ridge.

The results of this study showed that smoking significantly correlates with the change of the shading level in the region of the alveolar ridge, with the results of Osstell test and with the pockets depth and the recession of the gingiva. Comparing the loss of the marginal bone around inserted implants between smokers and non-smokers, it was established that the loss was three times higher in smokers than in non-smokers. Marginal bone loss and more frequent complications in smokers are reported for implants in the upper jaw (33,34).

In conclusion, the specialized custom-made computer programme for computerized densitometric analysis of digital RVG images proved to be reliable in finding the region of interest in successive shots and measuring the average values of the gray shadow in the zone of interest. The values of shading between delayed and immediate techniques have been statistically significant. These results showed that the immediate technique had lower results in the first six months, regarding the shading level and bone remodeling, but the results were consistent with the results of the delayed technique one year after implant placement. Both techniques are reliable and safe for everday clinical use.

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