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ORIGINAL RESEARCH

Observer Strategy and Radiographic Classification of Healing after Grafting of Cystic Defects in Maxilla: A Radiological Appraisal

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ABSTRACT

Aim: The aim is to radiographically quantify the bone density and relate the same with observer strategy in the bone healing.

Objectives: To assess pattern of bone regeneration following grafting of defects with hydroxyapatite after apicoectomy/cystic enucleation.

Materials and methods: An observer strategy involving trained and experienced examiners used in large series of cases, evaluated radiographically over a period of 1 year with intervals. The cases were grouped into different categories depending on (1) surgical site outline merging with material margin, (2) internal portion of surgical site (i.e. bone formation characteristics) and (3) density of surgical site. The radiographs examined by blind process and the findings were tabulated. Operating surgeon (oral surgeon) has done the interpretation of data to create observer strategy of grafting cases.

Observations and results: The outline of the defect was changed, partly reduced and completely absent along with remodeling, which showed ground glass, specular or trabecular pattern of bone over a time with increasing density correlating bone regeneration within a short duration. The applied strategy and classification are recommended for follow-up studies. In this study the characteristics of the new bone formation were also delineated. This strategy is helpful for follow-up studies; implant procedures and so; to know quality and condition of bone after treatment.

Keywords: Bone regeneration, Bone density, Bone graft, Radiographic strategy, Dental radiography, Radiovisiography, Hydroxyapatite graft.

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INTRODUCTION

The assessment of healing after endodontic surgery/cystic enucleation has been extensively studied by many and later correlated histologically and radiologically with suggestion of radiographic classification.[1-3] This classification is used and evaluated also by others.[4-15]

To our knowledge study of pattern of the bone regeneration of cystic or apicoectomy bone defects after hydroxyapatite grafting has not been done yet using radiographic strategy. The regeneration of bone with graft material had been done using histological and scintigraphic and radiological studies.[4-6,10-15] But none of them gave criteria/strategy with density correlation, which would have prevented the patients to go for second surgery or for biopsy–for histological examinations to verify the radiological findings and its consistency with histology of bone regeneration.

Although animal experiments and clinical studies have thoroughly elicited the radiographic alterations of bone healing without grafting.[1-3,7-9] Most of these reports have illustrated the final results of healing process. To our knowledge, none of the reports have described the stages of radiographic alterations observed at various time intervals throughout the entire process of bone healing after the grafting of bony defects. So, we conducted the prospective randomized blind study to delineate radiographic features of bone healing. The purpose was to investigate radiographic alterations at specific time intervals through the entire healing process to obtain observer strategy.

MATERIALS AND METHODS

The total of 48 patients were included in this study over a period of 3 years from 2008 to 2011 had been treated for

periapical lesions, residual cyst, radicular cyst in the Department of Oral and Maxillofacial Surgery. Patients were excluded if the graft has lost or infected and were lost follow-up examination.

Materials

Commercially available pure hydroxyapatite graft material used for grafting of the bony defects after cystectomy/apicoectomy.

Clinical Evaluation

Follow-up examinations were done on 7th day, 1st, 2nd, 4th, 6th and 12th months postsurgically. Mucosal color, postoperative pain or swelling was noted during clinical evaluation. Visual analog scale was used for pain measurements.

Radiological Evaluation

A total number of 48 patients with 288 radiographs and radiovisiographs were examined. The radiographs and radiovisiographs were obtained immediately after surgery and 1st, 2nd, 4th, 6th, 12th months postsurgically to evaluate and correlate the radiological observations with density. Standardized intraoral periapical radiographs were taken and automatically machine was processed. The radiographs evaluated for surgical site outline and internal portion of surgical site and density of bone formation on the bases of criteria are illustrated in Figures 1 to 3. Both the examiners were blindly performed radiographic evaluation and tabulated by operating surgeon. In case of gross inconsistency with observation the third examiner observed radiograph and results were tabulated to prevent observer bias.

The postsurgical radiographic pattern of surgical margins (Fig. 1) were classified as: (1) Unchanged–when the radiographic margin of the lesion was altered less than one-fourth of circumference, (2) slightly changed–when the clarity and width of surgically created margin was reduced more than one-fourth and less than two-third of circumference, (3) partly reduced–when clarity margin was decreased more than three-fourth of circumference due to merging of graft material margin with natural bone. Finally this leads to (4) complete absence of margin–where there is inability to differentiate the surgical and material margin.

The postsurgical radiographic appearance of internal portion of surgical site (Fig. 2) was classified as: (1) 'Changed'–when the area will be grafted (2) 'ground glass'–when a slight increase in radiopacity was noted, (3) 'spiculed'–when bone spicules were visible from periphery to center of the surgical site and (4) 'trabecular'–when radiating trabecule enclosing marrow spaces were observed indicating complete bone regeneration.

The density of bone formation inside the grafted defects is summation of the two processes, i.e. material resorption and new bone tissue deposition. The digital radiographic imaging has the program to measure density (Fig. 3). The mean density values and standard deviation was calculated using Digora unit (Soredex, Finland).

All of the radiographs in this study were evaluated by three of the authors independently; who were blinded to the time interval of the radiograph taken. The images at recall and baseline were viewed and compared side by side. When a marked density difference between postsurgical immediate radiograph and follow-up radiographs was noted, comparison of the images was performed with variable intensity light.

For radiological tracking of the progression of bone regeneration of grafting, we analyzed the radiographic changes in the margin and interior of the surgical site at specific time intervals after surgery in correlation with density changes using Mann-Whitney U-test and Wilcoxon matched paired test.

RESULTS

The 48 patients with periapical lesion/radicular/residual cyst underwent cystic enucleation/apicoectomy and grafted with commercially available hydroxyapatite graft material with mean age of 29 ± 8 years (Table 1). Clinically, the wound healed uneventfully in all cases without any complications and suture removal done on 7th day postsurgery. There was

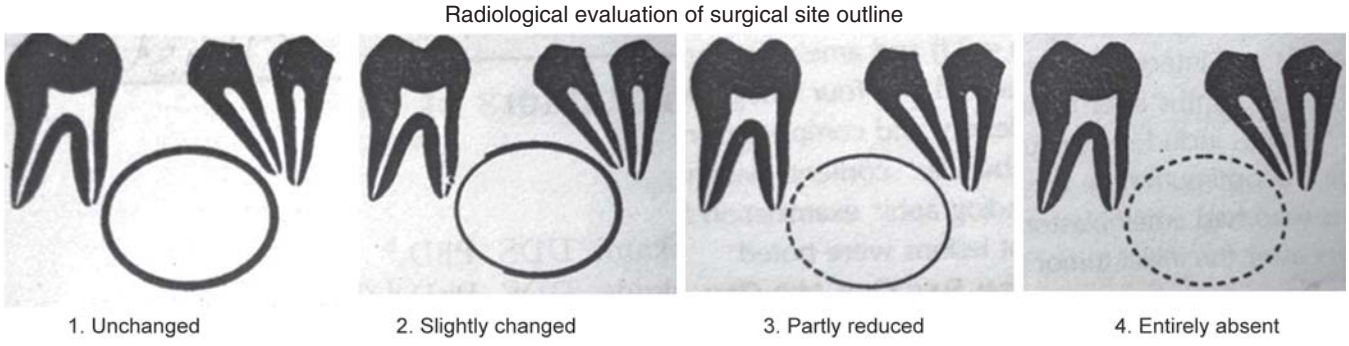


Fig. 1: Surgical site margin

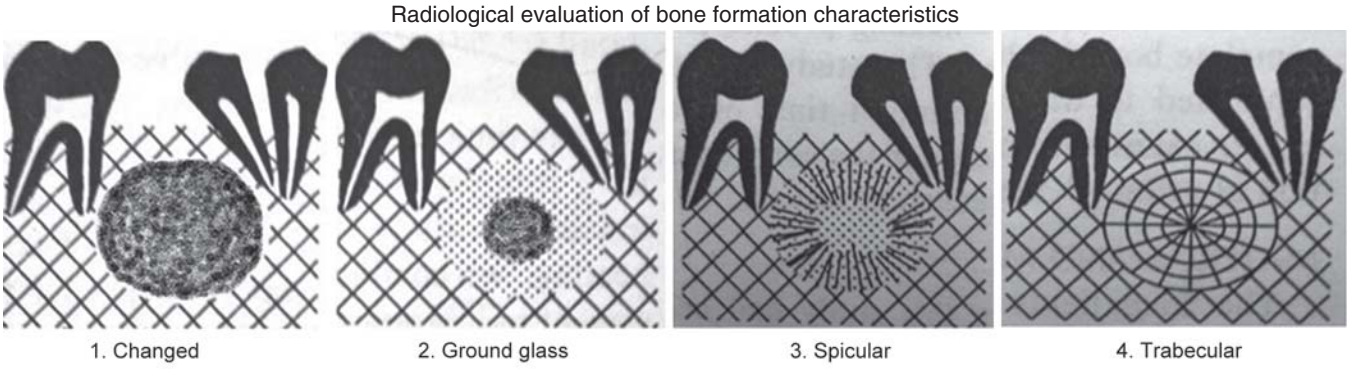


Fig. 2: Internal portion of surgical site

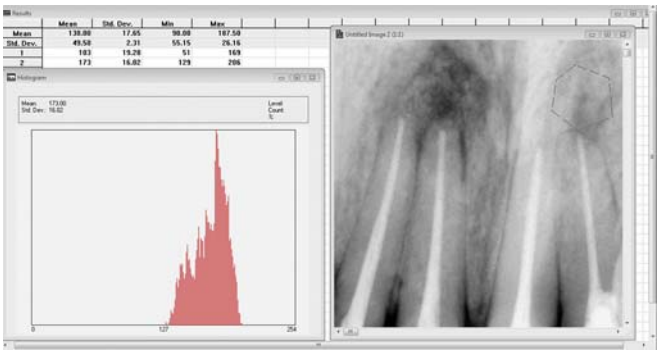


Fig. 3: Density of bone formation

Table 1: Distribution of cases according to age	
Mean	29.63
Standard deviation	8.53

no significant difference existed in the pain measurements and nor with other clinical observations.

Radiographic Changes in the Margin of Surgical Site

Margin of surgical site are categorized as 'unchanged' in 48 of the 48 observations within 1st week and the first month of postsurgical follow-up period. The unchanged category was seen in high percentage of observations during first month of surgery. The hypothesis is that radiographic changes would occur due to blending material margin and bone margin after month of surgery. The later follow-up at 2 months, categorized as 'slightly changed', 'partly reduced' accounted for 45 to 54% indicates that, the incidence of change of radiographic appearance is high during this period.

Furthermore, 13 to 88% of the sites observed after 4 months were categorized as 'partly reduced' or 'entirely absent' respectively, indicating that bone changes will almost always apparent in the site margin due to material particulate migration from center to periphery. More than 94% were classified as entirely absent by the end of the 6th month; indicating the margin blend with material will be almost complete in most of the patients.

The results (Table 2) indicate that follow-up radiographic appearance of margin is characterized by significant progression from 'unchanged' through 'slightly changed' and 'partly reduced' to entirely absent with due course of time and it was optimum at 4 to 6 months interval.

Radiographic Changes in Interior of the Surgical Site

The 'changed' categories seen in 100% observations as all of the defects were grafted (Table 3). The hypothesis is that the radiographic changes would occur during the first month of surgery and assessed by Wilcoxon matched pairs test to analyse the incidence of changed, ground glass, spiculed or trabecular. In other words it is suggested that most follow-up radiographic features in comparison with those seen immediately after surgery will show changes in first month. As the reaction of normal healing process to grafted site is summation of graft resorption and bone deposition, 96% of the surgical site interiors were classified as trabecular after 4 months. These changes are apparent due to osteoconductivity of graft material which are detectable in correlation with increased density when compared with previous radiographs. These results indicate the follow-up radiographic appearance of the site interior progressed from changed to ground glass appearance to spiculed and trabecular within 4 months postsurgery.

The Density of Bone Formation

The density of the lesion is progressively increased (Graph 1); soon after the grafting it was almost similar in all observations as graft material is radiodense. There were changes in the density at 2nd, 4th month observations and it remained static or more than normal over 6th and 12th month follow-up indicating the bone deposition with significant p-value (Table 4). The radiopaque areas were static for a prolonged period of time ranging from first month to several months indicating no resorption/slight resorption of graft material with deposition of bone. These findings are well correlated with density changes. Increased calcification of the site interior compared with the surrounding normal bone also.

Table 2: Comparison of surgical site margin at 1st, 2nd, 4th, 6th and 12th months interval by Wilcoxon matched pairs test

Time	*Absent*	*%*	*Partially reduced*	*%*	*Slightly reduced*	*%*
1st month	0	0.00	28	58.33	20	41.67
2nd month	26	54.17	22	45.83	0	0.00
4th month	42	87.50	6	12.50	0	0.00
6th month	45	93.75	3	6.25	0	0.00
12th month	46	95.83	2	4.17	0	0.00
1st *vs* 2nd		Z = 5.9052	p = 0.0000*			
1st *vs* 4th		Z = 5.9052	p = 0.0000*			
1st *vs* 6th		Z = 5.9683	p = 0.0000*			
1st *vs* 12th		Z = 6.0308	p = 0.0000*			

*p < 0.05

Table 3: Comparison of bone formation characteristics at 1st, 2nd, 4th, 6th and 12th months by Wilcoxon matched pairs test

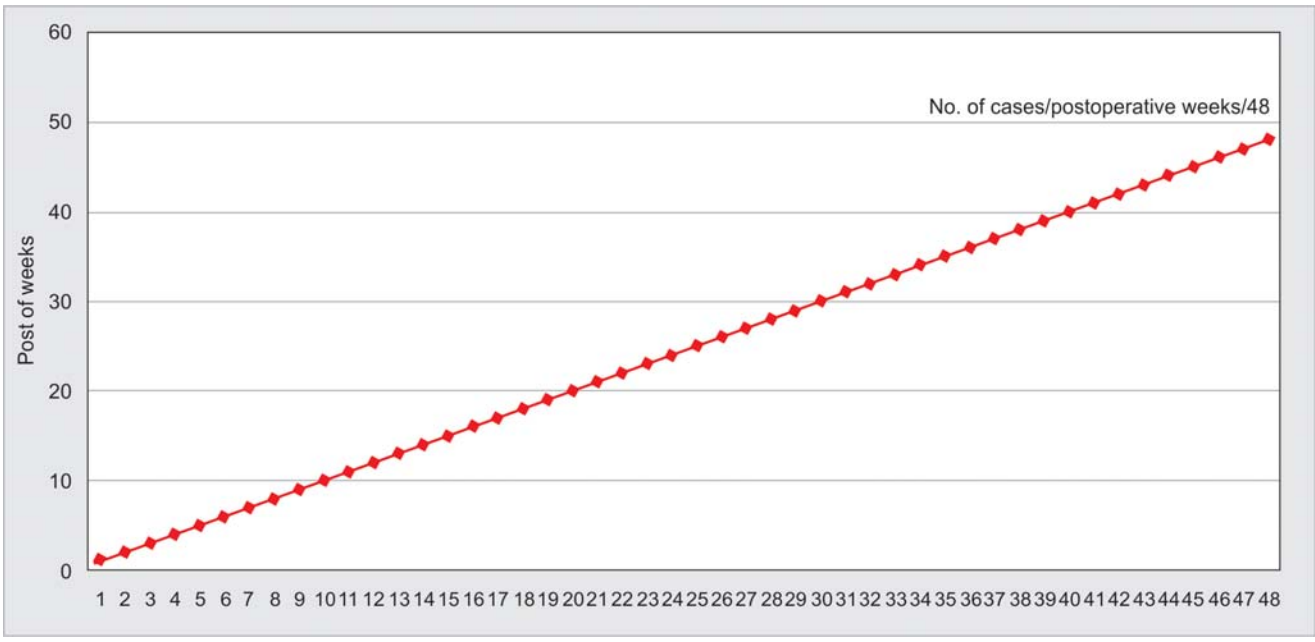
Time	*Spicular*	*%*	*Trabecular*	*%*	*Ground glass appearance*	*%*
1st month	43	89.58	0	0.00	5	10.42
2nd month	18	37.50	28	58.33	2	4.16
4th month	2	4.16	46	95.83	0	0.00
6th month	1	2.08	47	97.91	0	0.00
12th month	1	2.08	47	97.91	0	0.00
1st *vs* 2nd		Z = 2.8321	p = 0.0046*			
1st *vs* 4th		Z = 4.8029	p = 0.0000*			
1st *vs* 6th		Z = 4.8782	p = 0.0000*			
1st *vs* 12th		Z = 4.8782	p = 0.0000*			

*p < 0.05

Table 4: Comparison of density of bone formation at 1st week, 1st, 2nd, 4th, 6th and 12th months by paired t-test

Time points	*Mean*	*Std. dev.*	*Mean diff.*	*SD diff.*	*Paired t-test*	*p-value*
1st week	105.8750	7.8079				
1st month	126.2500	8.6995	–20.3750	6.3569	–22.2063	0.0000*
1st week	105.8750	7.8079				
2nd month	146.5833	9.8625	–40.7083	10.3861	–27.1552	0.0000*
1st week	105.8750	7.8079				
4th month	164.3750	15.0822	–58.5000	17.1054	–23.6942	0.0000*
1st week	105.8750	7.8079				
6th month	164.3750	15.0822	–58.5000	17.1054	–23.6942	0.0000*
1st week	105.8750	7.8079				
12th month	164.3750	15.0822	–58.5000	17.1054	–23.6942	0.0000*
1st month	126.2500	8.6995				
2nd month	146.5833	9.8625	–20.3333	9.5145	–14.8063	0.0000*
1st month	126.2500	8.6995				
4th month	164.3750	15.0822	–38.1250	16.1991	–16.3057	0.0000*
1st month	126.2500	8.6995				
6th month	164.3750	15.0822	–38.1250	16.1991	–16.3057	0.0000*
1st month	126.2500	8.6995				
12th month	164.3750	15.0822	–38.1250	16.1991	–16.3057	0.0000*
2nd month	146.5833	9.8625				
4th month	164.3750	15.0822	–17.7917	9.2850	–13.2757	0.0000*
2nd month	146.5833	9.8625				
6th month	164.3750	15.0822	–17.7917	9.2850	–13.2757	0.0000*
2nd month	146.5833	9.8625				
12th month	164.3750	15.0822	–17.7917	9.2850	–13.2757	0.0000*
4th month	164.3750	15.0822				
6th month	164.3750	15.0822	0.0000	0.0000	0.0000	1.0000
4th month	164.3750	15.0822				
12th month	164.3750	15.0822	0.0000	0.0000	0.0000	1.0000
6th month	164.3750	15.0822				
12th month	164.3750	15.0822	0.0000	0.0000	0.0000	1.0000

*p < 0.05



Graph 1: Density of bone formation

DISCUSSION

The radiological categorization of progression of healing was used in many previous animal and clinical studies.[1-6,10-15] Now the observations of radiological pattern of bone healing done after grafting, in prospective manner to categorize the observer strategy in correlation with density of bone formation after grafting of bone defects.

The early stages of normal healing in bone takes place by hematoma, blood clot, coagulation, granulation tissue or immature fibrous connective tissue formation during first 2 weeks of surgery.[1-3,7-9] In this study because of grafting; the process of normal bone healing process has been altered. At the initial stage the changed status of internal portion of wound is radiopaque due to graft material. The categories of slightly changed, ground glass appearance in the site margin and interior of the surgical site respectively corresponded to second stage of normal bone healing;[1-3,7-9] which occurs earlier compared to normal healing and is consistent with study done by others.[4-6,10-15] This process normally develops within 4 to 8 weeks. In addition the new bone formation rather extends from outside the marrow spaces to the center of graft material and which has been confirmed in correlation with steady increase in the density of the area; along with blending of the graft material margin with bone margin.

These phenomenons are visualized with radiography as peripheral ossification and decrease of the distinction between the material and bone margin. The bone creeps in to the material as graft acts as osteoconductive material.[4-6] The categories 'partly reduced' and 'spiculed' for site interior correspond to third stage which occurs very soon compared to normal healing without graft.[4,6] In this stage bone develops from wall and base of wound and hard callus will creeps in to the internal portion of graft.

The categories of entirely absent for the site margin and trabecular for the site interior correspond to stage of final remodeling in the bone cavity[4,6] where mature bone tissue will increase the calcification and attains original bone density or more, with normal architecture of bone. It is very interesting that these correlation and phenomenon of graft healing have not been described radiologically in previous studies.

The density of healed bony cavity, which presumably increased from that of surrounding bone tissues, which is also overcalcified because of initial bone deposition laid down in the marrow spaces adjacent to graft material.[4-6,10-13] Furthermore, the decrease in bony cavity volume in all directions to obscure the outline of graft material and bony margin to 'absent' is sooner than normal bone healing studies. These findings are persistent in subsequent observations without fall in density indicating that graft material has very less resorption with incorporation of graft into mineral matrix of bone, which has been correlated with increasing density and radiopacity of internal portion of wound. The density attained at the end of 4th month was almost equal or more than normal compared to surrounding bone may be due to the radiopaque quality of graft material.

Based on these observations we consider that the present radiographic categorization of surgical site margin and interior of surgical site and density of bone formation; for correlation is in general an appropriate and useful method for follow-up examination of patients. Instead of going for second surgery or biopsy or scintigraphy techniques which have morbidity and is costly for patients; also which is not feasible and possible with all patients just for study purpose.

Subtle changes including either 'slightly changed' 'ground glass' appearance may not be demonstrated without adequate X-ray exposure settings and proper viewing conditions; so better to use digital radiograph to control and maintain the standardization of these. The evaluation of radiographs obtained at 1st, 2nd month might reveal changes due to particulate migration as it acts as creeping substitute for bone healing. Our data suggest the optimal time for early detection of increased density of internal portion of bone is 2 to 4 months after surgery.

Evaluation of radiograph 4 months after grafting if reveals the radiolucent margins as of previous radiographs or radiolucency in the wound may indicate the unsuccessful surgery, secondary infection, graft failure or graft migration. In our study we have not found such a single case. The radiopacity of bone margin and graft material margin merged consistently with increasing density and visual changes of internal portion of bone within short duration.

CONCLUSION

After removal of cyst/apicoectomy the changes in surgical margin parallels that of surgical site interior and relates to density in the grafted wound. The fourth month postsurgery was found to be optimum time lag for the follow-up radiographic examination to evaluate whether the healing is normal or not. Any observations of radiolucency after 4 months indicate the graft failure. This radiographic categorization will be helpful in sinus lift procedures and other implant procedures to know regarding quality of bone formed secondary to grafting. This strategy can be used for clinical and study purpose.

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