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Hounsfield unit comparison of grafted versus non-grafted extraction sockets

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Abstract: Volumetric changes of the alveolar ridge after socket preservation with various techniques have been investigated frequently. However, changes in bone density and quality of bone within the extraction sockets have seldom been studied. The purpose of this study was to evaluate the bone quality of grafted versus non-grafted socket sites prior to dental implant placement using Hounsfield unit (HU) values derived from cone-beam computed tomography (CBCT) imaging. The data was collected from 39 healed extraction sites reviewed over a one-year period. Subjects eligible for the study had a bone replacement graft and barrier membrane. Both study and control groups had CBCT scans performed immediately after extraction and four to five months after extraction for planning implant placement. HU values were measured from the CBCT scans and compared between groups. Intragroup variability was assessed utilizing standard deviation and standard error of the mean. Intergroup differences were evaluated using unpaired *t*-test. A generalized lack of significant difference in bone quality was observed between groups with the only statistically significant difference observed in the posterior maxilla. Future radiographic and histologic assessments of bone quality after socket preservation are required to determine the 'ideal' approach to preserve an extraction socket prior to implant placement. (J Oral Sci 57, 195-200, 2015)

Keywords: socket preservation; CBCT; Hounsfield unit.

Introduction

Bone resorption occurs most rapidly in the first three months following extraction. Site preparation for implant placement after tooth extraction depends on developing areas by controlling this resorption and remodeling phenomena during healing of extraction sites. Reduction in alveolar ridge height and width may hinder optimal implant placement, especially in the anterior maxilla, where the dimension and morphology of the alveolar ridge cannot easily accommodate implants after bone loss (1). At the time of extraction, immediate ridge preservation has been shown to be important to maintain the bone dimensions, both vertically and horizontally (2).

Numerous materials have been used for socket graft augmentation including autogenous bone, allografts, xenografts, alloplasts, and combinations of these. Autogenous bone is the first choice for augmentation due to its inherent osteogenic, osteoconductive, and osteoinductive properties, but limited quantities and harvest

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site morbidity make a substitute material desirable. The use of mineralized and demineralized allografts has been reported in numerous studies with acceptable outcomes. Molly et al. (3) reported that allografts provide a scaffold for the blood clot, supporting osteogenic cells from the bone wall, which may enhance the quantity and quality of the resulting bone and aid in obtaining successful treatment outcomes with dental implants.

Primary implant stability, which is the key factor for long-term success of implant treatment, can be difficult to achieve in patients with extremely low bone density. Several systems have been proposed for radiographic assessment of bone density and quality prior to implant placement. Misch (4) used computed tomography (CT) to identify five types of bone based on Hounsfield units (HU), which are commonly defined as a linear transformation of the measured X-ray attenuation coefficient of the material with reference to water (5,6).

Cone-beam computed tomography (CBCT) systems offer many advantages over medical CT for dental treatment and planning, including a lower radiation dose to the patient in most instances, shorter acquisition times for the resolution desired in dentistry, an affordable cost alternative to medical CT, better resolution and greater detail (7). Despite these preference factors, the reliability, consistency and accuracy of HU values derived from CBCT imaging systems in bone quality evaluation remain controversial. The imprecision of the intensity values of CBCT systems are commonly attributed to differences in characteristics of the devices, the imaging parameters and the position of the area being evaluated (8,9). However, CBCT systems have improved quantification ability, and the HU values highly correlate with findings of other established methods under certain circumstances.

The purpose of this study was to evaluate the bone quality of grafted versus non-grafted socket sites prior to dental implant placement using HU values derived from CBCT imaging.

Materials and Methods

This case-control study included patients treated with socket preservation and delayed implant placement. The data was collected from 39 healed extraction sites reviewed from the patient database of Case Western Reserve University School of Dental Medicine Department of Oral and Maxillofacial Surgery over a one-year period. Institutional Review Board of Case Western Reserve University, Cleveland OH, USA exemption was obtained from the Case Institutional Review Board Protocol #20120111, and all research was performed in accordance with the Helsinki declaration guidelines.

Patients with immunocompromised health status, including diabetes, chronic steroid use and immune deficiencies, and active smokers were excluded from the study. Additionally, the extraction sites with compromised periradicular bony structure (e.g. extraction sockets neighboring a periapical lesion or a fracture line) were not included in the study. All teeth had been extracted due to severe caries, failed endodontic treatment or advanced periodontal disease. Subjects eligible for the study had a bone replacement graft and a barrier membrane placed at the time of tooth extraction in the anterior and posterior maxilla and mandible. A CBCT scan was taken in these patients prior to implant placement. The control group consisted of patients matched to the study group for age, gender, and extraction site. Both groups had CBCT scans performed 4 to 6 months after extraction for planning implant placement. The following information was collected: age, gender, and extraction quadrant. All socket preservation sites were grafted using Straumann AlloGraft (Straumann, Andover, MA, USA) freeze-dried, mineralized ground cortical bone. All grafted sites were covered with Zimmer Collagen Plug absorbable dressing, (Zimmer Dental, Carlsbad, CA, USA), sutured in place with resorbable sutures.

The final cohort consisted of 29 patients, 18 males and 11 females. The average age in the study group was 59.4 years and in the control group was 62.3 years. The patients' data was divided into two groups: the study group consisted of 19 extraction sites which had been grafted using allogenic bone graft and the control group that consisted of 20 non-grafted healed extraction sites. Groups were divided into quadrants, which were analyzed independently. In the study group, data was collected from: two extractions sites in the anterior maxilla, seven in the posterior maxilla, one in the anterior mandible and nine in the posterior mandible. The control group extraction sites were: two extractions sites in the anterior maxilla, nine in the posterior maxilla, one in the anterior mandible and eight in the posterior mandible. Due to the limited number of sites in the anterior mandible and maxilla, the findings obtained from these sites were not included in the statistical analysis.

Using Invivo (Anatomage Inc. San Jose, CA, USA) software, HU values were measured from the CBCT scans and compared between groups using axial, sagittal and coronal sections (Fig. 1). The region of interest (ROI) was determined as the point corresponding to the central portion of the alveolar socket. Using the spatial coordinate tool (x, y), a conscious effort was made to designate the ROI equally distant from the circumference of the socket in both planes. The HU values were measured

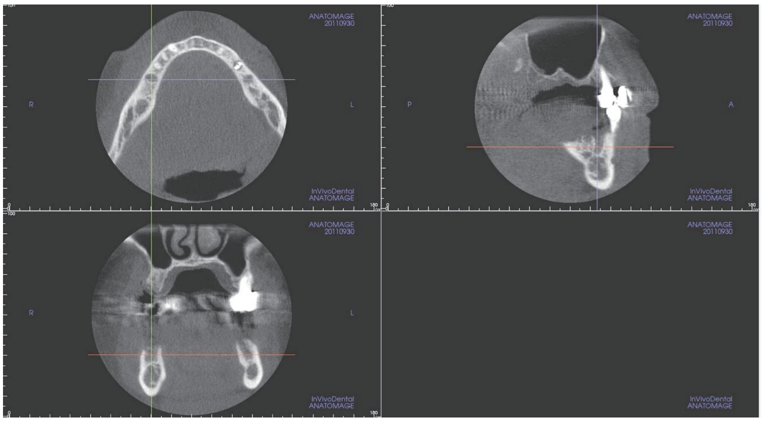

Fig. 1 Measurement of Hounsfield unit values from the cone-beam computed tomography scan and comparison between groups using axial, sagittal and coronal sections.

Table 1 Patient demographics

	Control group	Study group	*P* value		95% CI
Average age	62.3	59.4	0.52	Unpaired *t*-test	-6.26 to 12.03
Male (%)	8 (57)	10 (67)	0.71	Fishers exact	
Female (%)	6 (43)	5 (33)	0.71	Fishers exact	
Anterior maxilla	2	2	-	Excluded due to limited sample size	
Posterior maxilla	9	7	0.75	Fishers exact	
Anterior mandible	1	1	-	Excluded due to limited sample size	
Posterior mandible	8	9	0.75	Fishers exact	

Table 2 Comparison of Hounsfield units (HU) in control versus socket preservation groups

	HU control group	Standard deviation	HU socket preservation	Standard deviation	*P* value		95% CI
Anterior maxilla	$n = 2$		$n = 2$				
HU axial	-7.5		8.6				
HU sagittal	-68		29.1				
HU coronal	-352.7		122.1				
HU average	-142.7		53.3				
Posterior maxilla	$n = 9$		$n = 7$				
HU axial	-93.8	108	-139.5	114.7	0.43	Unpaired *t*-test	-74.1145 to 165.5821
HU sagittal	-96.5	110.3	-175.6	130.7	0.21	Unpaired *t*-test	-50.0994 to 208.2128
HU coronal	-113.6	94.7	-139.1	76.4	0.57	Unpaired *t*-test	-68.8857 to 119.8968
HU average	-101.3	10.7	-151.4	21	0.02	Unpaired *t*-test	12.375168 to 87.822232
Anterior mandible	$n = 1$		$n = 1$				
HU axial	83.1		247.4				
HU sagittal	80.1		220.5				
HU coronal	0.9		237.8				
HU average	54.7		235.3				
Posterior mandible	$n = 8$		$n = 9$				
HU axial	-35.1	122.8	-27.4	146.4	0.91	Unpaired *t*-test	-148.4816 to 133.0777
HU sagittal	-40.4	129.7	-28.7	129.1	0.86	Unpaired *t*-test	-145.6426 to 122.3359
HU coronal	-48.2	125.8	-45.7	131.8	0.97	Unpaired *t*-test	-136.1942 to 131.1561
HU average	-41.2	6.6	-34	10.2	0.36	Unpaired *t*-test	-26.769475 to 12.186675

independently by three investigators in all three planes and averaged to determine the final HU value. The data was analyzed using the Statistical Package for Social Sciences (SPSS) version 20.0 (International Business Machines Corp. Armonk, NY, USA) Intragroup variability was assessed utilizing standard deviation and standard error of the mean. Intergroup differences were evaluated using unpaired *t*-test.

Results

Thirty-nine extraction sockets in 29 patients treated at the Department of Oral and Maxillofacial Surgery at Case Western Reserve University were analyzed in the study. The mean age of the Control group was 62.3 years and that of the study group 59.4 years old. The subjects were male in 57% and 67% of the control group and study group, respectively. Demographic data from the patients is presented in Table 1.

Nine sockets were analyzed in the posterior maxilla in the control group and seven in the socket preservation group. The average HU was -101.3 in the control and -151.4 in the study group, with a *P* value of 0.02 after statistical analysis. In the posterior mandible, the average HU was -41.2 in the control group and -34 in the socket preservation group with eight and nine extraction sites evaluated, respectively, with no statistically significant difference present, *P* value 0.36 (Table 2).

Discussion

Bone remodeling that takes place after an extraction inevitably leads to atrophic changes of the alveolar ridge and often makes the ideal placement of dental implants complicated (10). Therefore, precise and quantitative evaluation of bone quality is essential for the clinician to establish a treatment plan for implant restoration. Accurate information on bone density helps the clinician not only to identify suitable implant sites, determine implant design, and surgical procedures, but also to ascertain when to load an implant (11,12). In order to address this concern, volumetric changes of the alveolar ridge after socket preservation with various techniques have been investigated frequently. However, changes in bone quality within the extraction sockets have seldom been studied (10).

Several radiographic imaging systems have been used for the assessment of 'bone quality', which refers to a combination of all the characteristics that influence the resistance to fracture of bone (13,14). Micro-CT scanning provides precise three-dimensional evaluation of the bone microstructure, but is a technique limited to *ex-vivo* small samples and cannot be employed in patients (14). Multi slice CT (MSCT) scan is an established method to assess the bone density in implant planning and is commonly regarded as the gold standard. However, MSCT systems are associated with 40-60 times more radiation than CBCT systems which have recently gained popularity due to several advantages, among which are lower exposure dose, adequate image quality of the mineralized tissues, low cost, and fast scanning time (9).

Despite the well-established advantages over MSCT systems, the reliability of CBCT in trabecular microstructure assessment of the bone remains controversial. Molteni (15) previously stated that the artifacts challenge the accurate conversion of density values into HUs in CBCT systems and Nackaerts et al. (8) reported variable intensity values for CBCT imaging using different CBCT scanners. Isoda et al. (16) stated that it was not clear if the density values obtained by the specific CBCT device used in their study could be applied to another device, although they reported high correlation of the obtained values and primary stability implants in their study.

There is however, strong evidence in the literature that suggests the use of HU values obtained from CBCT scans for bone density evaluation. Nomura et al. (17) found a high correlation between density values obtained using CBCT and MSCT systems. Parsa et al. (14) similarly reported a strong correlation between CBCT grey values and bone volume fraction and their gold standards, suggesting the potential use of CBCT systems in bone quality assessment of the implant site. In their study, which evaluated the regression line between voxel values of CBCT and the bone mineral density (BMD) of MSCT, Naitoh et al. (18) confirmed the usefulness of a regression line for BMD estimation in CBCT scans.

In this study, a conscious effort has been made to minimize the factors that have been commonly reported to cause inconsistency of density values of CBCT systems in previous studies. All CBCT evaluations were carried out using the same CBCT system specifically calibrated to achieve minimal scatter. Repetitive measurements were made independently by three investigators in all three planes and average final HU values were determined. In addition to favorable findings reported in the literature and our efforts to standardize measurements, we believe that the design of the study itself, which comprises the comparison of HU values obtained from the same individual, validates the use of HU values for bone density evaluation in the present study.

The degree of changes in bone quality largely depends on the duration of healing in addition to resorption rate of the grafting material and its ability to encourage bone formation (10). The remnants of the grafts often interfered with the normal healing process in line with preclinical results (19). Decreased bone density caused by the presence of residual graft particles might negatively affect the ability to obtain primary stability. This situation is amplified if the remaining particles are encapsulated with connective tissue (10). Despite its significance however, the ideal healing time before implant placement remains unclear. Studies on ridge preservation have generally provided healing times of 2-12 months before implant placement (20). Wallace (21) reported findings of his study, which analyzed guided bone regeneration for socket preservation using histomorphometric and 3D CT evaluations 12 weeks after the procedure. Beck et al. (20) previously compared healing in grafted extraction sockets after 6 months and undisturbed sockets after 3 months and reported no statistically significant differences in the amount of newly formed bone or residual graft particles between the two groups. Fotek et al. (22) histologically evaluated new bone formation 16 weeks after alveolar ridge preservation and reported a range of 27-32% vital new bone formation in 18 sites, with an average of 14-15% residual bone graft particles and 53-58% non-bone connective tissue. When these findings and the natural healing process of an extraction socket are taken into consideration, we believe that the healing time allowed in our study (ranging between 4-6 months, an average of 4.98) is adequate for the assessment of bone density in extraction sockets.

In our study, we compared HU values from extraction sites of the control and study group to determine if there was a difference in bone density between grafted and non-grafted extraction sites. When averaged between three planes, HU values in the grafted group were significantly lower than those in the control group (P = 0.02) in the posterior maxilla. Although this finding may be interpreted as indicative of slower bone formation in the extraction site with socket preservation, it should also be noted that the difference between the individual measurements on the axial, sagittal, and coronal views were independently non-significant. The generalized lack of significant differences between the grafted and non-grafted sites as individually measured on axial, coronal and sagittal views may indicate that bone density may be similar between grafted and non-grafted sites following healing. The findings of this study correlate well with the systematic review by Horvath et al. (19) on the comparison of alveolar ridge preservation versus unassisted socket healing. The authors have reported that there is conflicting evidence on the benefit of alveolar ridge preservation at the histological level, as it does not seem to promote de novo hard tissue formation routinely. It is noteworthy however, that they have suggested interpretation of their conclusions with caution due to the weak-to-moderate strength of their evidence, highlighting the broad variety of employed materials, techniques, defect morphologies, healing periods, and limitations in sample sizes of the studies in the literature (19). The mineralized ground cortical nature of the allograft used in this study may have had an impact on our findings as this specific type of allograft is more commonly used for volume preservation when additional mechanical resistance of the graft is required. Therefore, we find it safer to state that the efficacies of ridge preservation with allografts of different characteristics still remain to be determined.

Although addressed to a certain extent, limitations of this study should be noted. The magnitude of ridge alterations after tooth extraction with/without socket preservation varies both between and within subjects (23). Several factors affect the ridge resorption and socket-healing patterns, among which are: presence and the number of neighboring teeth, socket morphology, and patient compliance. These factors undoubtedly have an impact on the findings of this study. However, we believe that evaluation of the bone quality changes within same subjects, and excluding patients who are smokers as well as individuals with systemic conditions that could interfere with wound healing, have contributed to a more objective evaluation of the findings in this study.

Additionally, the sole evaluation in this study was carried out with pre- and post-operative radiographic imaging, which necessitates caution when interpreting its findings. Histological evaluation of specimens obtained at the time of implant insertion, which was prohibited due to the nature of the study, certainly would have provided a better understanding of the healing stage and bone quality in extraction sockets and should be included in the design of future prospective studies. Finally, the sample size, which was very limited in certain portions of the jaws in this study, precludes accurate statistical analysis and an improved understanding of the obtained results. Therefore, the data obtained from extraction sites in these quadrants were not included in the statistical processing. This highlights the need for further studies with larger sample sizes, which may not only contribute to precise evaluation of the role of socket preservation by means of accurate statistics but also overcome amplification of individual factors in the obtained findings.

The findings of this study did not indicate a statistically significant difference between study and control groups. Despite the application of a specific allograft and other limitations, we believe that the findings of this study may provide a basis for future research on the healing and bone quality in the grafted extraction sites. Future radiographic and histologic assessments of bone quality after socket preservation with different grafting materials are required to determine the 'ideal' approach to preserve an extraction socket prior to implant placement.

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