Evaluation of Extraction Site Dimensions and Density Using Computed Tomography Treated With Different Graft Materials: A Preliminary Study

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Purpose: *The preliminary human study was designed to evaluate extraction site changes using CT after socket preservation (SP) with different materials.*

Materials and Methods: *Fifty-two sockets from 17 Turkish individuals (8 women and 9 men; mean age 44.70 ± 9.99 years) localized at the maxillary anterior area were treated with demineralized bone matrix + collagen membrane (CM) (N = 14), hydroxyapatite bone substitute (HBS) + CM (N = 14), CM (N = 13), or left empty (N = 11). CT scans were taken 10 and 120 days after the procedure. Horizontal and vertical socket dimensions and Hounsfield unit (HU) values were evaluated.*

Results: *First 3 groups showed a significant horizontal decrease from day 10 to 120. No significant change was detected in vertical socket dimension. For both horizontal and vertical, no intergroup difference was detected at days 10 and 120. At days 10 and 120, HU values in HBS + CM group were significantly higher compared with others. Apical and coronal HU values were not different at any period.*

Conclusion: *Even if it did not provide better socket dimensions, HBS + CM treatment brought higher tissue density and thus, can be recommended to increase the bone quality and implant success after SP in upper anterior area. (Implant Dent 2017;26:270–274)*

Key Words: biocompatible materials, extraction socket, bone substitutes

After extraction, the alveolar ridge undergoes bone loss that may compromise the functional and esthetic implant placement.[1] Socket preservation (SP) is highly recommended in such circumstances with use of various biomaterials either alone or combined with membranes.[2,3]

Hard tissue density and volume are strong determiners of the type of surgery and dental implant selection.[4] From numerous imaging techniques (conventional radiographs, CT, cone-beam CT, dual-energy X-ray absorptiometry, and diagnostic software),[5–9] CT can accurately provide a separate analysis of the cortical and trabecular bone.[10] Hounsfield unit (HU) measurement (has a scale between −1000 and +3000),[11] which is accepted to be a standard method for density measurement, is also available in CT scanning.[6] Even though it provided valuable information about hard tissue density in implant recipient sites,[7] HU use for quantifying the tissue volume and density changes after graft procedures has not been demonstrated widely.[12,13]

Beneficial clinical outcomes have been reported for individual biomaterials, but the search regarding finding the ideal substitute for SP still proceeds.[14] Moreover, there is still a lack of knowledge in the field of evaluating the density changes after biomaterial utilization. Therefore, this preliminary study aimed to evaluate the effects of different biomaterials (demineralized bone matrix [DBM] and hydroxyapatite bone substitute [HBS]) alone or in conjunction with the collagen membrane (CM) on dimension and density changes after SP.

Materials and Methods

The preliminary, randomized, controlled, single-masked, parallel group study was conducted between April 2007 and January 2008 with local ethics committee consent (Research Approval no: FON 04/23–16). Patients were informed about the entire protocol, and written consent was also signed. After preassessment of 59 participants,

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Table 1. Demographics and Localization of Extraction Sockets

Parameter	N
Age (mean ± SD [min–max])	17 (44.7 ± 9.99 [26–58])
Sex	
Male	9
Female	8
Socket localization	52
Central incisor	16
Lateral incisor	16
Canine	6
1st premolar	9
2nd premolar	5

The randomly included sockets were predominantly localized at incisor sites.
Min indicates minimum; max, maximum.

Table 2. Socket Width and Height Measurements

Group	HOR (HU-1) N	HOR (HU-1) Mean ± SD	HOR (HU-2) N	HOR (HU-2) Mean ± SD	*P*
DBM + CM	14	7.57 ± 0.97	14	6.64 ± 0.71	0.0082*
HBS + CM	14	8.14 ± 0.94	14	7.14 ± 0.84	0.0067*
CM	13	8.00 ± 1.11	13	6.96 ± 0.77	0.0111*
Control	11	8.36 ± 1.16	11	7.72 ± 1.25	0.2313
Group	**VER (HU-1) N**	**VER (HU-1) Mean ± SD**	**VER (HU-2) N**	**VER (HU-2) Mean ± SD**	***P***
DBM + CM	14	16.78 ± 3.94	14	15.53 ± 3.77	0.3989
HBS + CM	14	16.50 ± 4.15	14	15.25 ± 3.91	0.4196
CM	13	15.53 ± 3.43	13	14.26 ± 3.14	0.3354
Control	11	14.59 ± 3.99	11	13.45 ± 3.44	0.4831

No intergroup difference was seen at HU-1 and HU-2, and except untreated sockets, all biomaterial-applied groups exhibited HOR, but not VER decrease from HU-1 to HU-2.
*Significant ($P < 0.05$).

52 sockets of 17 Turkish patients (9 men and 8 women) with mean age of 44.7 ± 9.99 years were included. Patients were nonsmokers, systemically healthy, and needed multiple upper teeth extraction because of caries and/or endodontic failure. None of the extracted teeth had periodontal lesions, and candidate regions had at least 5-mm socket depth and 5-mm keratinized gingiva. All patients received phase I periodontal therapy, and only those with full-mouth plaque and bleeding score <20% were transferred to surgical stage.[15]

Fifty-two sockets including 16 central incisor, 16 lateral incisor, 6 canine, 9 premolar, and 5 second premolar localizations were used in the study. They were randomly assigned to 4 groups: DBM (Musculoskeletal Transplant Foundation 250–850 μ; Dentsply, Lakewood, CO) + CM (BioMend; Zimmer Dental, Carlsbad, CA) (N = 14), HBS (OSTIM; aap Biomedicals, Dieburg, Germany) + CM (N = 14), CM (N = 13), and no treatment (N = 11). Block randomization process was applied to allocate each socket to 1 of the techniques. For this purpose, a concealed lot out of a box containing 4 × 15 lots was casted.[16] No stratification was performed during allocation.

After local anesthesia, study teeth were extracted by using surgical blades and Periotomes. During extraction, extreme care was shown to preserve the surrounding bone and keratinized tissue. Sockets were gently debrided and rinsed with saline. Integrity of the alveolar walls was examined, and the sockets that did not exhibit 4 intact walls were excluded from the study. According to the manufacturer instructions, biomaterials were moisturized with saline and applied particularly into the sockets. The CM was shaped according to the form of sockets and then adapted and placed over the substitutes or socket by undermining at least 3 mm to the surrounding gingiva and secured with cross-mattress sutures at DBM + CM, HBS + CM, and CM groups. No treatment was applied at the fourth group. Antibiotics (Alfoxil, amoxicillin 500 mg; Actavis, Istanbul, Turkey), analgesics (Majezik, flurbiprofen 100 mg; Sanovel, Istanbul, Turkey), and antiseptic mouthrinse (Klorhex, chlorhexidine gluconate 0.2%; Drogsan, Ankara, Turkey) were prescribed. Sutures were removed 10 days after surgery.

Maxillary spiral CT scans (Siemens AR-SP40, Munich, Germany) were obtained at 10th (Hounsfield unit at day 10 [HU-1]) and 120th (Hounsfield unit at day 120 [HU-2]) postoperative days. Spiral CT protocol consisted of 130-kV tube voltage, 83-mA tube current, and 1-mm-thick sections reconstructed at 1-mm intervals. For standard cross-sectioning, the hard palate was used as reference.[14] CT equipment provided cross-sectional images as well as the coronal and the axial images for the maxilla. Axial scans of the maxilla were obtained parallel to the hard palate.

Table 3. HU Values in Transverse and Sagittal Cross-Sections

Group	Transverse Cross-Section, No.	HU-1, Mean ± SD	HU-2, Mean ± SD	Difference, (HU-1)–(HU-2)
DBM + CM	35	160.8 ± 49.072	436.18 ± 158.68	275.30 ± 140.55*
HBS + CM	35	416.92 ± 178.65	708.36 ± 265.26	291.44 ± 202.96*
CM	29	35.56 ± 43.51	358.84 ± 144.64	323.28 ± 148.48*
Control	30	53.31 ± 70.65	417.30 ± 164.50	363.99 ± 147.93*
Group	**Sagittal Cross-Section, No.**	**HU-1, Mean ± SD**	**HU-2, Mean ± SD**	**Difference, (HU-1)–(HU-2)**
DBM + CM	28	156.51 ± 65.60	434.10 ± 161.79	277.60 ± 146.53*
HBS + CM	28	348.49 ± 151.42	642.04 ± 217.74	293.55 ± 233.91*
CM	27	45.68 ± 51.80	345.32 ± 146.13	299.64 ± 163.34*
Control	22	55.30 ± 73.24	448.87 ± 262.44	393.56 ± 252.10*

A separate analysis of transverse and sagittal cross-sections showed the highest density for HBS + CM, and the values were relatively lower for DBM + CM. No time-dependent change was detected.
*Significant ($P < 0.05$).

Table 4. HU Values in Apical and Coronal Cross-Sections

Group	Cross-Section Number	Apical HU-1, Mean ± SD	Coronal HU-1, Mean ± SD	Difference, Mean ± SD
DBM + CM	14	145.18 ± 50.21	166.54 ± 51.59	21.36 ± 20.54
HBS + CM	14	430.1 ± 200.41	369.46 ± 170.33	60.64 ± 45.76
CM	13	26.93 ± 49.75	40.67 ± 38.35	13.74 ± 45.67
Control	11	53.13 ± 93.41	54.55 ± 41.82	1.42 ± 1.45
Group	**Cross-Section Number**	**Apical HU-2, Mean ± SD**	**Coronal HU-2, Mean ± SD**	**Difference, Mean ± SD**
DBM + CM	14	410.43 ± 137.27	463.37 ± 187.34	52.94 ± 45.79
HBS + CM	14	702.04 ± 234.18	710.21 ± 234.18	8.17 ± 5.43
CM	13	368.56 ± 159.47	386.56 ± 128.78	17.5 ± 12.65
Control	11	398.9 ± 121.07	386.22 ± 223.14	11.68 ± 12.87

A separate analysis of apical and coronal cross-sections showed similar results for transverse and sagittal cross-sections (highest density for HBS + CM, a relatively lower density for DBM + CM, and no time-dependent change).

To provide standardization, the incisive channel and base of the sinus were used as the anatomical reference points. From scans, the horizontal socket width (HOR) in the crestal region and vertical height of the alveolar ridge (VER) were determined. HOR was measured from the buccal margin of the socket wall to its palatal analogue whereas VER was determined by measuring the midcrestal distance from the alveolar crest to the opposing landmark. Mean change from first to second measurement was also calculated for both radiographic parameters. Hard tissue density was measured and recorded as HU from coronal, middle, and apical thirds. For every density measurement, standard 2- or 3-mm diameter circles were drawn adjacent to the surrounding radiopaque borders, and HU was recorded from inside of these circles. In sagittal reconstruction, the section showing the clearest view of the socket was selected from 2 consecutive sections, and HU was calculated by referring to the rectangle that was drawn adjacent to the center of the socket by placing inside the surrounding compact borders of the socket.

Statistical analysis was performed with a software program (SPSS for Windows version 11.5, Chicago, IL) Time-dependent change of HU values was evaluated with a one-way analysis of variance. Differences between the apical, median, and coronal sections were evaluated with a 2-way variance analysis. *P* values <0.05 were considered significant.

Results

Although barrier membranes or other materials were left exposed after surgery, no postoperative complication was seen. Demographics are given in Table 1. CT measurements were performed on 129 transversal and 105 sagittal cross-sections that exhibited clear display at HU-1 and HU-2.

All biomaterial applied groups (DBM + CM, HBS + CM, and CM) showed a significant HOR decrease from HU-1 to HU-2 ($P < 0.05$) except empty sockets in which the mean dimensional change was not statistically remarkable ($P = 0.231$). On the other hand, none of the study sockets showed a statistically significant change in VER values ($P > 0.05$). For both HOR and VER, no intergroup difference was detected at HU-1 and HU-2 ($P > 0.05$) (Table 2).

When HU values were separately evaluated in transverse and sagittal cross-sections, HBS + CM showed the highest density. DBM + CM showed higher density at HU-1 and HU-2 compared with other study groups ($P < 0.05$). However, no group demonstrated a significant time-dependent change from HU-1 to HU-2 ($P > 0.05$) (Table 3). The apical and coronal HU values also demonstrated a similar course with transverse and sagittal cross-sections in terms of intergroup and time-dependent evaluations (Table 4).

Discussion

This trial aimed to evaluate the efficiencies of DBM and HBS with CM in SP by comparing with empty sockets. In the trial, outcomes related to the dimensions were consistent with several others in which bone resorption could not be prevented after extraction.[17–19] The similarity in treated and nontreated groups might be dependent on the following reasons: inclusion criteria of 4 intact socket walls, the absence of incision and extensive tissue manipulation, a standard atraumatic extraction protocol, and an elongated healing time.[20,21] Although several authors determined a higher horizontal loss of alveolar crest than its vertical component,[17,19,22–24] horizontal and vertical bone loss was considerably equal in this trial. The difference can be attributed to the inter-individual variations in both the patients and the clinicians. Only a few studies investigated HU change after different biomaterial use in SP.[25–28] From those, both Wallace et al[26,27] (applied bone morphogenetic protein-2/absorbable collagen sponge and cancellous allograft + CM) and Loveless et al[28] (applied freeze-dried allograft + collagen plug vs nongrafted sites) detected HU values similar to our results 4 to 6 months after SP.

New bone formation, material retention, and connective tissue formation are the events that may occur after biomaterial placement.[29] The possibility of these events mainly depends on the root number and size, present disease status, presence of bony defects, and traumatic manipulation. In this trial, to reduce the possible confounding effect of these factors, only single-rooted teeth with no pathology/defect were chosen. Moreover, extreme care was given to preserve the socket integrity (16 sockets were removed from the study because of the loss of integrity after extraction). Socket defects have a specific morphology that heals partially exposed to the oral cavity and thus, material selection is also crucial for success. Although DBM, HBS, and CM have already been utilized in SP,[24,30,31] this trial is the first to test their effect simultaneously on extraction site dimensions and HU. Additional materials including autografts, freeze-dried bone allograft or bioactive substances with different flap techniques might also be tested in this trial. In addition to clinical expectations, presently applied materials were selected owing to their long-term stability, biological content, predictable resorption period, and other well-known advantages.[32–34] Moreover, limitations such as the high possibility of morbidity in autogenous bone harvesting and the absence of permission for direct use of bioactive mediators in European countries had to be considered. Flap management techniques either including incisions or not demonstrated success in SP.[35] Because intact sockets were included, a flapless approach was preferred in this study to preserve the vascularization as much as possible.

Another issue was the assessment times. The first measurement was carried out at day 10, when the early osteoid tissue was detected after extraction.[36] Evian et al[37] indicated that in untreated sockets, dense bone formation takes approximately 120 days and at this stage, CT scans show new bone formation with no or some mineralization. Moreover, horizontal and vertical bone loss of the maxilla mainly substantiates at first three 3 months after extraction.[38] Thus, follow-up evaluations were performed at day 120, which was also compatible with analogous trials.[26–28]

Besides dimensions, CT provides noninvasive density evaluation after surgery.[13,26–28] When compared with other radiographic techniques, it is possible to make a more objective and precious evaluation based on HU and differentiate the contribution of lateral cortical plates in determining the bone density.[39] Depending on the lower primary stability values and higher failure rates seen in the alveolar bone regions with low density (especially in maxilla), bone quality is still considered as one of the major factors for success in implant treatment.[40,41] By referring to HU, bone quality has been classified (>850 quality 1, 500–850 quality 2/3, and 0–500 quality 4),[42] and a significant correlation has been demonstrated between bone quality and HU.[43] In the present trial, HU-1 matched with quality 2/3 at HBS + CM group, whereas it was quality 4 at remaining groups, and both substitute applied groups showed higher HU-1 values. In addition to the own densities of the materials used, this result is associated with denser tissue at those sites. Then, all groups demonstrated HU increase and matched with the quality value at one step above, and the HBS + CM group preserved its highest mean amount among all groups that can be referred to its high density. The separate analysis of apical and coronal values also showed similarity with general cross-section evaluations. In total, even though it is not completely possible to differentiate the effect of bone substitute remnants in the healing sites, HBS + CM treatment provided a higher tissue density in SP.

Horowitz et al[44] conducted SP with tricalcium phosphate and did not evaluate HU because short-term results would have given false increased density measurements owing to the nonresorbed remnants. Therefore, one of the limitations of this study is the absence of a histological evaluation of newly formed tissues. Such an analysis might have provided relatively more objective results that might explain the similarity of the outcomes in treated and empty left sockets. Moreover, as supporting data, implant success evaluations might be added as the ongoing part of the study.

CONCLUSION

The present findings showed a higher density in sockets preserved with HBS when compared with DBM, CM, or empty sockets. From dimensions perspective, none of the materials added benefit to natural empty socket healing. One hundred twenty days can be considered as an adequate time for implant placement. In conclusion, by using HBS in SP, a higher tissue density can be obtained at the anterior maxilla before implant placement without expecting any dimensional improvement, and thus HBS + CM can be recommended to increase the bone quality after SP in the upper anterior area before implant treatment. However, it should always be remembered that density is just one of the parameters that contribute to the clinical implant success, and it is not possible to directly correlate the higher HU values with better clinical outcomes.[45] Among the other determinants, the presence of a viable and well-structured alveolar bone that can only be examined with histology is still the main need for successful osseointegration. Within its limitations, thist study may provide a basis for future research on following dimension and density changes after SP. Further trials including histological analysis and evaluation of postsurgical implant success are still needed to support the conclusion.

DISCLOSURE

The authors claim to have no financial interest, either directly or indirectly, in the products or information listed in the study. The study protocol was supported by Clinical Research Foundation of Hacettepe University (05 01 201 001). The results of the trial were presented as a poster at Europerio 8 (June 3–6, 2015, London, United Kingdom).

APPROVAL

The study protocol was approved by Local Ethics Committee of Hacettepe University (FON 04/23–16).

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