Autogenous Bone Ring Transplant vs Autologous Growth Factor–Enriched Bone Graft Matrix In Extraction Sockets With Deficient Buccal Bone: A Comparative Clinical Study

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ABSTRACT

Purpose: The purpose of this study was to compare the efficacies of autogenous bone ring and autologous growth factor–enriched bone graft matrix as graft materials in extraction sockets.

Materials and Methods: Subjects (n = 34) requiring extraction of a single incisor or premolar in a type II socket were segregated into two groups: BR and AFG. Autogenous bone ring transplant and autologous fibrin glue with particulate bone graft (sticky bone) was used in subjects under the BR and AFG groups, respectively, for socket augmentation. After 6 months, osteotomy preparation was carried out, and implants were placed in all subjects. The efficacies of both of the procedures were compared by assessing measures of bone density, buccal/lingual plate height, implant stability quotient (ISQ) readings, and mineralized tissue volumes. Results: At 6 months, there was a highly significant gain (P ≤ .001) in the buccal (3.09 ± 1.6 mm vs 1.90 ± 0.94 mm) and lingual/palatal bone heights (3.31 ± 2.66 mm vs 1.99 ± 1.22 mm) and a significant difference in the bone density (659.6 ± 133.8 vs 552.1 ± 65.6; P = .016) in the BR group compared with the AFG group. Significant differences were observed between the two groups for ISQ values at the end of 6 months (61.60 ± 8.9 vs 45.02 ± 6.33; P = .034). Biopsy specimens from the BR group showed a highly significant increase (50.39% ± 11.96% vs 38.91% ± 12.22%; P ≤ .001) in the percentage of tissue mineralization over the AFG group. Conclusion: Autogenous bone ring procedure seemed to confer additional benefits over autologous growth factor–enriched bone graft when various parameters were compared. The sites augmented with autogenous bone ring at the end of the study period showed a sufficient gain in bone height and quality for implant placement. Int J Oral Maxillofac Implants 2019. doi: 10.11607/jomi.7614
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INTRODUCTION

There have been a plethora of procedures and protocols to preserve and augment sockets successfully after tooth extraction.\textsuperscript{1,2} Post-extraction, bone loss occurs rapidly in the initial six months as the alveolar process is a tooth dependent structure.\textsuperscript{1} These changes become more extensive if the socket’s residual alveolar walls are either damaged or missing.\textsuperscript{2-5} Resorption rate of the alveolar ridge is faster during the initial 6 months following extraction,\textsuperscript{2-6} and the height of a healed socket never reaches the levels seen at the time of extraction post operatively.\textsuperscript{7,8} Schropp et al\textsuperscript{9} estimated that 2/3 of the soft and hard tissue changes occur in the first 3 months. They reported a 50% crestal width loss in a 12-month period, 2/3 of which occurred in the first 12 weeks. In a long-term study, Ashman et al\textsuperscript{7} reported an alveolar bone shrinkage of 40–60% in height and width within the first 2-3 years.

As a consequence, socket grafting is routinely suggested after tooth extractions to preserve or augment bone volume and height.\textsuperscript{1,2,4,6} The most important factor in determining the choice of bone graft is the number of remaining walls in the extraction socket. As the number of osseous walls decrease, the use of an autogenous graft and graft immobilization may result in highly favorable outcomes.\textsuperscript{2,4,5} Most often, two-to-four-wall defects in extraction sockets lack facial bone partially or completely.\textsuperscript{7-9} In these situations, the “barrier by bulk” concept\textsuperscript{2} can be applied wherein the extraction socket is over-contoured and overfilled by several millimeters with a particulate or autogenous grafts to account for the invading gingival corium which can invade only the superficial layers.\textsuperscript{2,10,11} However, primary closure and an absence of pressure on the soft tissue is a must as micro-movement of the graft may result in a non-fixated graft or fibrous encapsulation.\textsuperscript{7,8,10} The use of autogenous grafts in these situations are thought to be
advantageous, as they have structural strength and can be adequately stabilized preventing micromovement of the grafted material.\textsuperscript{5,8,9-11}

Socket augmentation procedures are used in clinical practice to reduce the post-extraction alveolar ridge contraction, and to preserve the hard tissue for implant placement by using various materials such as allografts, autografts, and xenografts.\textsuperscript{1,10,11} One method of preserving the socket is by using the concept of growth factor-enriched bone-graft matrix (also known as “sticky bone”) using autologous fibrin glue. Sticky bone has numerous advantages. 1) It is moldable and can be adapted over any bony defect 2) Fibrin network entraps platelets and leukocytes to release growth factors, so soft and hard tissue regeneration is accelerated 3) Fibrin interconnection minimizes soft tissue in growth into the sticky bone graft.\textsuperscript{12,13} However, the material is not without its disadvantages. The protocol is centrifuge-specific and there are chances of improper clot polymerization which cannot produce sticky bone in some instances.\textsuperscript{14} While sticky bone can be easily modeled and retains its shape during preparation and placement,\textsuperscript{5,7,11,12,13} it does not maintain its original dimensions after placement into bone defects and provides no structural stability.\textsuperscript{8,11-13}

Autogenous bone ring transplantation procedure harvests a cortical ring-shaped structural graft from the mandibular symphysis which can be used in augmentation of severely defective post-extraction sockets.\textsuperscript{15,16} The advantage of this procedure is that the both ridge augmentation and implant placement can be done simultaneously and the graft can be adequately stabilized through screws or implants ensuring an intimate, micromotion-free fit of bone ring into the socket walls.\textsuperscript{16} Stevens \textit{et al}\textsuperscript{16} stated that simultaneous onlay crestal augmentation by bone ring in the residual socket also enhances the soft tissue contour and helps resist soft tissue contraction.
when performed in esthetic zones. Over particulate grafts, structural grafts such as autogenous bone ring grafts show significantly lesser crestal bone resorption and optimum volume maintenance of the recipient site.15,16

The hypothesis of this study was that autogenous bone ring transplants are expected to be more rigid and shape confirming, micromotion-free and more resistant to bone resorption than autologous fibrin glue with particulate bone grafts leading to better volume enhancement and regeneration of buccal and palatal/lingual plates when placed in extraction sockets. In view of these advantages, the aim of the present study was to compare the efficacy of autogenous bone ring augmentation technique and autologous growth factor enriched bone graft matrix as graft materials in extraction sockets. The efficacies of both the procedures were compared by assessing measures of bone density, buccal/lingual plate height, implant stability quotient readings and mineralized tissue volumes.
MATERIALS AND METHODS

Study design

The study was designed as an experimental non-randomized, single-center trial to compare the outcomes of autogenous bone ring transplant and sticky bone in extraction socket augmentation.

Sample size

A minimum sample size of 13 per group (26 in total) was estimated with an anticipated effect size of 1.02, desired statistical power level of 0.8 and probability level of 0.05.

Study population

The target population were subjects requiring extraction of a single incisor or premolar in a type II socket (adequate soft tissue is present, but the facial plate will be partially missing following extraction of the tooth) and consenting for delayed implant placement after socket augmentation with either autogenous bone ring technique or autologous growth factor enriched bone graft matrix. Approval from the institutional ethical committee (SVSIDS/PERIO/4/2016) was obtained and informed consent was taken from all the subjects. Medically compromised individuals, subjects who underwent radiotherapy or chemotherapy within the past 12 months and subjects having uncontrolled periodontal disease and smokers were excluded. From an initial subject pool of 45 individuals, subjects (n=34) satisfying the inclusion criteria were segregated into two groups; in one group (BR), autogenous bone ring transplant was used for socket
augmentation and in the other group (AFG), autologous fibrin glue (AFG) with particulate bone graft (sticky bone) was used (Figure 2).

**Outcomes**

In both BR and AFG groups, computerized tomography (CT) images were obtained preoperatively and 6-months (Figure 3) postoperatively as per the device manufacturers’ protocol in all the participating subjects for bone density measurement and linear preoperative and postoperative measurement of the recipient site to assess increase in the height of the buccal/palatal plates. Implant stability quotient readings and mineralized tissue volume estimation were assessed at the time of implant placements in both the groups at 6-months.

**Definition of the interventions**

3D computed tomography (Siemens SOMATOM® perspective AS+/64-slice Conf) with exposure parameters of 100 KVP, 20 mA, 7 cm field of view (FOV), constant slice thickness of 0.6 mm cross-section with a spacing of 1 mm was used to determine the following at baseline before tooth extraction and post-operatively after 6-months. Multi-Planar Reconstruction (MPR) was done by multiplanar reformatting by using appropriate software (syngo 3D Roadmap® Siemens Healthcare, Mumbai, India) as follows.19 An apical reference point (A1) was defined as the point on the nasal floor/base of the anterior mandible obtained by extending a line drawn from the incisal cusp/buccal cusp through the tooth apex. Post-operatively, the point on the nasal floor/base of the anterior mandible as a result of extending a line drawn through the screw axis was considered as A1. As there is no stabilizing screw to serve as a reference point after tooth extraction in sites treated with sticky bone, A1 at 6 months was defined as a point on the nasal floor/base of the anterior mandible.
floor/base of the anterior mandible as a result of extending a line drawn at 90° to a line joining the height of buccal and lingual/palatal contours. Buccal bone height and lingual/palatal bone height were defined as the linear distance from A1 to the buccal alveolar crest (B1) and the lingual alveolar crest (P1) (Figure 4). Bone density was measured by selecting B1 and P1 from the slices of each participant by obtaining Hounsfield unit (HU) measurements. The HU values were then averaged.

**Surgical procedure**

All the procedures were performed by one trained and calibrated clinician as follows (Figure 1). In the BR group, after administration of local anesthesia, a full thickness mucoperiosteal flap was reflected with vertical releasing incisions at the donor site i.e. mandibular symphysis region exposing the bone. Two trephines of diameters 5mm and 2mm were used in order to obtain the autogenous bone ring from the donor site. The selection of the trephine size was determined by the amount of bone required for the recipient site. In order to facilitate the removal of the bone ring, it was prepared to its definitive depth by using both the trephines; after harvesting the bone ring, sharp edges were identified and gently rounded by low speed fissure bur under copious saline irrigation. At recipient site, atraumatic extraction along with degranulation was done. The autogenous bone ring was placed in the extraction socket and stabilized with the help of screw followed by placement of a membrane and suturing without any tension in flaps. Any perceptible “step” or discontinuity between the graft and the recipient bone was filled with autogenous particulate graft obtained from the mandibular symphysis.
In the AFG group, atraumatic extraction was done followed by placing “sticky bone” which is a mixture autologous fibrin glue (AFG) generated as per standard production protocols\textsuperscript{12,13} and particulate bone graft (Siloss\textsuperscript{®}, Azurebio, Madrid, Spain). The protocol included drawing of 10 ml venous blood from the antecubital fossa of the patient following which the venous blood is subjected to centrifugation of 2700 rpm for 2 min resulting in an upper layer of autologous fibrin glue (AFG) and a lower RBC portion. The resulted AFG was mixed with particulate bone graft and placed in the extraction socket after degranulation, followed by placement of a membrane and sutures to obtain primary closure.

**Implant Stability Quotient Readings and Mineralized Tissue Volume estimation**

After 6 months, osteotomy preparation was carried out, and implants (Adin\textsuperscript{®} Implant systems, Afula, Israel) were placed in all subjects of both of the groups (Figure 5). Before placing the cover screw, the SmartPeg\textsuperscript{®} Type 49 (Osstell, Gothenburg, Sweden) specific to the Adin implant system was screwed onto the implant, and resonance frequency analysis (RFA) readings were made with the help of the SmartPeg mount.\textsuperscript{17} The RFA probe was assembled with the Osstell implant stability meter and held perpendicular to the smart peg at a distance of 3 mm from the magnetic portion of the smart peg to measure implant stability. Two readings were taken each in the buccolinguual and mesiodistal directions, and the average was taken as the implant stability quotient (ISQ) value in the respective direction at the time of placement. Subsequently, the cover screw was placed and flap sutured back to its position.

Bone biopsy specimens were obtained from the flutes of the burs during the surgical drilling process in both groups. Briefly, the specimens were immersed in 4% buffered formalin
and were subsequently dehydrated in an ascending series of ethyl alcohol. The specimens were then stained using hematoxylin-eosin for light microscopy analysis. 2 slides were prepared from each core and ten regions of interest (ROIs) per slide were visualized for mineralized tissue volume by using an Olympus BX 53 microscope at 40X magnification. The mineralized tissue volume was calculated as per a previously reported protocol\(^{18}\) and was expressed as (mineralized tissue/total area) \(*100\).

**Statistical Analysis**

Data was analyzed by using a commercially available statistical package (SPSS\(^{®}\) Statistics Version 25, IBM, Bangalore, India). Descriptive statistics and frequency distributions were analyzed. Intergroup comparison was done using unpaired t-test. Paired t-test was used for intragroup comparison. \(p \leq 0.05\) was considered statistically significant and \(p \leq 0.001\) was considered highly significant.
RESULTS

All participating subjects (n=34; 17 males; mean age 32.60±10.22) completed study-related interventions and one subject in the BR group was lost to follow-up at the end of study period. Complications in the BR group subjects included soft-tissue dehiscence (n=1), pain and swelling at the recipient site (n=3) and suture line breakdown in the donor site (n=2). Soft tissue dehiscence (n=1) with pain and swelling (n=3) were the complications seen in the AFG group subjects. All complications were conservatively managed and did not exacerbate during the post-operative healing phase. Implants could not be placed in two subjects from the BR group as the bone ring failed to integrate satisfactorily into native bone. Adequate primary stability could not be obtained in one subject from the AFG group. Hence, the final test statistics was limited to 14 subjects in the BR group and 16 subjects in the AFG group.

Intragroup comparisons

Buccal and palatal/lingual plate height

The mean values of buccal and palatal/lingual plate height in the AFG group were 13.5 ± 1.98 & 13.9 ± 1.11 mm at baseline and 15.1 ± 1.2, 15.93 ± 1.22 mm at 6 months. In the BR group, the buccal/lingual-palatal plate heights were 13.73 ± 2.35 & 14.18 ± 1.99 at baseline and 17.96 ± 1.63, 19.3 ± 1.73 at 6 months respectively (Table 1). The intragroup gain in bone height from base line to 6 months was highly significant in both the groups (p ≤0.001).
**Bone Density (HU)**

In BR and AFG groups, the bone density scores (in HU) were 596.2 ± 115.2 & 659.6 ± 133.8 and 520.3 ± 54.8, 552.1 ± 65.6 respectively at 6-months and baseline respectively. Highly significant intragroup differences were observed for bone density at the end of 6 months in both the groups (p≤0.001).

**Intergroup Comparisons**

**Bone gain and Bone density**

At the baseline, there were no significant differences in the buccal (p=0.789) and lingual/palatal bone heights (p=0.710) between the BR and AFG groups. At 6 months, there was a highly significant gain (p≤0.001) in the buccal (3.09 ± 1.6 mm vs. 1.90 ± 0.94 mm) and lingual/palatal bone (3.31 ± 2.66 mm vs. 1.99 ± 1.22 mm) height in the BR group over the AFG group. At the baseline, there was a significant difference in the bone density (p=0.042) between the BR and AFG groups; this significance was observable at 6-months as well (p=0.016) (*Table 1; Figure 6*).

**Implant Stability Quotient Readings and Mineralized Tissue Volume estimation**

Significant differences were observed between the two groups for ISQ values at the end of 6 months (p=0.034). The mean ISQ values were 61.60 ± 8.9 for the BR group and 45.02 ± 6.33 for the AFG group. Biopsy specimens from the BR group showed a marked increase in the percentage of tissue mineralization (50.39 ± 11.96% vs 38.91 ± 12.22% in sites from the AFG group). This difference, was highly significant (p≤0.001) (*Figure 6, 7*).
DISCUSSION

A clinical and comparative study was done to assess the efficacy of autogenous bone ring transplant over autologous growth factor enriched bone graft matrix as a graft material in extraction sockets. de Molon et al\textsuperscript{20} stated that autogenous block grafts harvested for immediate reconstruction of buccal plate demonstrate horizontal and vertical bone gain with minimal marginal bone loss. An autogenous bone ring is a block bone-graft and is expected to have the same outcomes when placed in an extraction socket as it retains viable osteoblasts, does not evoke immunological response and are rigid and tougher than particulate bone grafts.\textsuperscript{20, 21-27}

Both the treatment modalities resulted in significant gain in bone height from baseline to 6-months. Peck et al\textsuperscript{27} stated that the efficacy of L-PRF in ridge augmentation procedure is a result of the release of growth factors, thereby stimulating healing and new bone formation. In the present study, from the baseline (13.5 ± 1.9 to 5.1 ± 1.2 mm) to 6 months (13.9 ± 1.1 to 15.9 ± 1.2) the buccal, palatal/lingual plate height gain in sites treated with autologous growth factor enriched bone graft matrix was statistically significant. Similar findings were observed by Rao et al\textsuperscript{28} who stated that the use of platelet concentrates is a valid method to accelerate hard tissue regeneration in extraction sockets. Autogenous bone ring is traditionally used for augmentation of deficient sockets along with simultaneous placement of dental implant.\textsuperscript{15,16,20-24} Giraddi et al\textsuperscript{21} reported a bone gain of 3.70 ± 1.10 mm medially and 3.69 ± 1.10 mm distally and Crespi et al\textsuperscript{22} found a mean bone gain of 3.70 ± 1.10 mm on mesial aspect and a mean bone gain of 3.69 ± 1.10 mm on distal aspect when autogenous bone ring was placed simultaneously around an implant. We have utilized the autogenous bone ring for initial augmentation of extraction socket with a delayed implant protocol. One of the findings of this study is that placement of bone ring
placed purely for initial socket augmentation results in a higher bone gain than when used with simultaneous implant placement; the obtained bone height gains were $7.9 \pm 1.6$ and $9.3 \pm 1.7$ for buccal and palatal/lingual plates which was higher than the previously reported studies.

At 6 months, there was a highly significant gain in the buccal and lingual/palatal bone height in sites treated with autogenous bone ring transplant over sites treated with autologous growth factor enriched bone graft matrix. Sticky bone is a mixture of AFG and particulate bone graft and particulate grafts show more resorption than structural block grafts.\textsuperscript{15,16} Aimetti et al\textsuperscript{23} found no significant vertical bone gain when sites were grafted with collagenated bovine-derived xenograft. Sticky bone is very sensitive to micromovements and such micromovements between native bone and any implanted material may trigger differentiation of mesenchymal cells to fibroblasts instead of osteoblasts resulting in the development of fibrous tissue instead of an osteoid tissue.\textsuperscript{5,7,11,12,13} In contrast, a structural graft such as autogenous bone ring shows significantly lesser crestal bone resorption and optimum volume maintenance of the recipient site.\textsuperscript{15-17} Parallels can be drawn from the following studies; Joshi et al\textsuperscript{25} suggested that the use of block grafts for socket augmentation results in significant preservation in vertical ridge height. Kaufman and Wang\textsuperscript{26} conducted a study on localized vertical maxillary ridge augmentation using symphyseal bone cores and noticed increase in vertical height and width of the ridge as well.

At the baseline, there was a significant difference in the bone density ($p=0.042$) between the BR and AFG groups; this significance was observable at 6-months as well. Omara et al\textsuperscript{24} in a study on simultaneous implant placement with ridge augmentation using an autogenous bone ring transplant found a statistically significant increase for both the mesial and distal aspects.
around the implant. Bone density at the ring–implant interface showed a statistically significant increase for both the mesial and buccal aspect (mean bone density changes were 393.21 HU mesially and 429.69 HU buccally). We obtained higher values in our study however in both the treatment arms (596.2 ± 115.2 HU to 659.6 ± 133.8 HU for autogenous bone ring and 520 ± 54.8 HU to 552.1 ± 65.6 HU for autologous growth factor enriched bone graft matrix). Sticky bone entraps platelets and leukocytes to release growth factors, so soft and hard tissue regeneration is accelerated resulting in increase in bone density.12-13 Absence of complications also contribute to good quality bone as well; in a case report on bone ring autogenous graft transplantation with early implant placement, clinical nor radiographic success was directly related to absence of complications such as dehiscence, graft exposure and infection on the bone and soft tissue around the implants.29

Biopsy specimens from sites treated with autogenous bone ring transplant showed a marked increase in the percentage of tissue mineralization over sites treated with autologous growth factor enriched bone graft matrix. The quality (density) of the newly formed bone is directly dependent on the qualities of the graft including the presence of growth factors, favorable modelling and remodeling characteristics, reduction in micromotion of the graft and its osteoconductive properties.5,7,11-13,15,16 Platelet concentrates12,14 and other growth factors1 result in a good quality bone. However, unlike structural grafts, Platelet concentrate-alloplastic material combination show more resorption than structural block grafts5,7,11-13 and are very sensitive to micromovements and such micromovements may result in lower mineralization volumes when compared to autogenous bone rings.8,11-13 In contrast, bone rings can be adequately stabilized through screws or implants ensuring an intimate, micromotion-free fit of bone ring into the
socket walls\textsuperscript{16} enhancing the soft tissue contour and helps resist soft tissue contraction when performed in esthetic zones. Autogenous bone rings can also act as an osteoconductive scaffold for vascular and cellular ingrowth, maintaining a constant and adequate volume for constant remodeling and adequate mineralization.\textsuperscript{4,8,15-17} Block grafts also demonstrate better formation of vital and mineralized bone with lamellar organization at the grafted sites over other grafts.\textsuperscript{30}

The average implant stability was significantly higher in sites treated with autogenous bone ring transplant over sites treated with autologous growth factor enriched bone graft matrix (60 ± 8.9 for the BR group and 45.02 ± 6.33 for the AFG group). The values obtained from sites treated with autogenous bone ring graft are similar to the readings (ISQ=58) obtained by Kim et al\textsuperscript{31} who attributed the stability to the good bone remodeling and osteoconductivity of autogenous graft material. Increase in buccal plate height\textsuperscript{16} and improvement in bone quality\textsuperscript{8,11-13} may have also contributed to good primary stability. The implant stability values obtained from sites treated with autologous growth factor enriched bone graft matrix were lower than the value (59.89) obtained from the study of Atia et al;\textsuperscript{32} However, they utilized a sticky bone and CGF-enriched fibrin membrane which may have resulted in better growth factor release and optimum soft tissue healing.

The present study has some limitations that need to be considered. We have compared autogenous cortical bone ring with autologous growth factor enriched alloplastic bone graft. Both the materials have widely differing biological and physical characteristics.\textsuperscript{11-13,15,16} Autogenous bone ring transplant procedure was traditionally done along with simultaneous implant placement in previous reports,\textsuperscript{15,16,21,24,26,29} but we have utilized the autogenous bone ring for initial augmentation of extraction socket with a delayed implant protocol and there is a
paucity of studies utilizing this protocol. Additional comparative data was obtained from studies which have utilized a ring-shaped graft of different origin such as autogenous dentine\textsuperscript{31} or allogenous tooth graft\textsuperscript{25} or have utilized different comparators such as platelet-rich fibrin, autologous platelet rich fibrin gel and free-dried bone allograft. In these conditions, a direct head-to-head comparison of predictions and outcomes was not possible with these studies.

To conclude, following conclusions can be made with reference to the observations in this study. Autogenous bone ring procedure seems to confer added benefits over autologous growth factor enriched bone graft when various parameters were compared. The sites augmented with autogenous bone ring at the end of study period showed sufficient gain in bone height and quality for eventual implant placement. Both the procedures were well tolerated by all the participating subjects with no untoward effects or complications.
REFERENCES


**TABLE 1:** Comparison of clinical parameters (buccal, palatal/lingual height) at baseline and 6-months using unpaired t-test

<table>
<thead>
<tr>
<th></th>
<th>Autogenous bone ring</th>
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<th>p-value</th>
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<td>15.1 ± 1.2¶</td>
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<td>0.000**</td>
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<tr>
<td><strong>Pre-operative palatal/lingual height</strong></td>
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<td>13.9 ± 1.11</td>
<td>6.376</td>
<td>0.710†</td>
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<tr>
<td><strong>Post-operative palatal/lingual height</strong></td>
<td>19.30 ±1.73¶</td>
<td>15.9 ± 1.22¶</td>
<td>5.710</td>
<td>0.000**</td>
</tr>
</tbody>
</table>

** Highly significant † Not significant

¶ Intragroup comparison of bone height from base line to 6 months is highly significant (p ≤0.001)
Figure Legends

Figure 1: In the BR group, autogenous bone ring transplant was used \( (n=14) \) for socket augmentation. At the recipient site (A), atraumatic extraction along with degranulation was done (B) followed by raising a full thickness mucoperiosteal flap (C) at the donor site i.e. mandibular symphysis region exposing the bone. Two trephines of diameter 5mm (C) and 2mm (D) were used in order to obtain the autogenous bone ring from the donor site (E). In order to facilitate the removal of the bone ring, it was prepared to its definitive depth using both the trephines. The autogenous bone ring was placed in the extraction socket (F) and stabilized with the help of screw (G, H & I).

Figure 2: In the control group \( (n=16) \), atraumatic extraction (A, B) was done followed by placement of “sticky bone” (C, D). A membrane was placed (E) and primary closure was obtained (F).

Figure 3: Computerized tomography (CT) images were obtained preoperatively (A) and at least 6-months postoperatively (B) as per the device manufacturer's protocol in all the participating subjects for bone density measurements and linear preoperative and postoperative measurements of the recipient site to assess increase in the height of the buccal/palatal plates.

Figure 4: An apical reference point (A1) was defined which is the point on the nasal floor/ base of the anterior mandible obtained by extending a line drawn from the incisal cusp/buccal cusp through the tooth apex (1). Post-operatively, the point on the nasal floor/base of the anterior mandible as a result extending a line drawn through the screw axis was considered as A1 (2). In sites receiving autologous fibrin glue (AFG) and particulate bone graft, because there is no
stabilizing screw to serve as a reference point after tooth extraction, A1 at 6 months was defined as a point on the nasal floor/base of the anterior mandible as a result of extending a line drawn at 90° to a line joining the height of buccal and lingual/palatal contours (3). Buccal bone height and lingual/palatal bone height were defined as the linear distance from A1 to the buccal alveolar crest (B1) and the lingual alveolar crest (P1) \textit{(Red Lines)}.

**Figure 5:** After 6 months, implants (Adin Implant systems) were placed in all subjects of both of the groups. Radiographs generally showed good bone integration in sites treated with autogenous bone ring; in two subjects, the bone ring failed to integrate satisfactorily into native bone and implants could not be placed.

**Figure 6:** Intergroup Comparisons of bone gain, bone density, Implant Stability Quotient (ISQ) and Mineralized Tissue Volume (MTV) estimation. At the baseline, there was a significant difference in the bone density (p=0.042) between the BR and the control groups; this significance was observable at 6-months as well (p=0.016). At the baseline, there were no significant differences in the buccal (p=0.789) and lingual/palatal bone heights (p=0.710) between the BR and the control groups. At 6 months, there was a highly significant gain (p≤0.001) in the buccal and lingual/palatal bone height in the BR group over the control group. Significant differences were observed between the two groups for ISQ values at the end of 6 months (p=0.034). Biopsy specimens from the BR group showed a marked increase in the percentage of tissue mineralization which was highly significant (p≤0.001) over the control group.
Figure 7: Bone biopsy specimens were obtained from the flutes of the burs during the surgical drilling process in both groups. Two slides were prepared from each core and ten regions of interest (ROIs) per slide were visualized for mineralized tissue volume by using an Olympus BX 53 microscope at 40X magnification. The mineralized tissue volume was calculated as per a previously reported protocol using ImageJ software and was expressed as (mineralized tissue/total area) *100.
Fig 2
Fig 3
Fig 4
Fig 6
Fig 7