There have been a plethora of procedures and protocols to preserve and augment sockets successfully after tooth extraction. Postextraction, bone loss occurs rapidly in the initial 6 months, as the alveolar process is a tooth-dependent structure. These changes become more extensive if the socket's residual alveolar walls are either damaged or missing. The resorption rate of the alveolar ridge is faster during the initial 6 months following extraction, and the height of a healed socket never reaches the levels seen at the time of extraction postoperatively. Schropp et al estimated that two-thirds 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, two-thirds of which occurred in the first 12 weeks. In a long-term study, Ashman reported an alveolar bone shrinkage of 40% to 60% in height and width within the first 2 to 3 years. As a consequence, socket grafting is routinely suggested after tooth extractions to preserve or augment bone volume and height. 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. Most often, two-to-four-wall defects in extraction sockets lack facial bone partially or completely. In these situations, the “barrier by bulk” concept can be applied, ...
fibrin interconnection minimizes soft tissue edema; and tapers, so soft and hard tissue regeneration is accelerated over any bony defect; (2) has numerous advantages: (1) it is moldable and can be adapted over any bony defect; (2) the fibrin network entraps platelets and leukocytes to release growth factors, so soft and hard tissue regeneration is accelerated; and (3) fibrin interconnection minimizes soft tissue in growth into the sticky bone graft. 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. While sticky bone can be easily modeled and retains its shape during preparation and placement, it does not maintain its original dimensions after placement into bone defects and provides no structural stability.

The autogenous bone ring transplantation procedure harvests a cortical ring-shaped structural graft from the mandibular symphysis that can be used in augmentation of severely defective postextraction sockets. The advantage of this procedure is that both the 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. Stevens et al 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. Compared with particulate grafts, structural grafts such as autogenous bone ring grafts show significantly less crestal bone resorption and optimum volume maintenance of the recipient site.

The hypothesis of this study was that autogenous bone ring transplants are expected to be more rigid and shape-conforming, 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 the autogenous bone ring augmentation technique and autologous growth factor–enriched bone graft matrix as graft materials in extraction sockets. 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.

MATERIALS AND METHODS

Study Design
The study was designed as an experimental nonrandomized, 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 was 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 the 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 received from all the subjects. Medically compromised individuals, subjects who underwent radiotherapy or chemotherapy within the past 12 months, 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 with particulate bone graft (sticky bone) was used (Fig 1).

Outcomes
In both the BR and AFG groups, computed tomography (CT) images were obtained preoperatively and 6 months (Fig 2) postoperatively as per the device manufacturer’s protocol in all the participating subjects for bone density measurement and linear preoperative...
In the control group (n = 16), (a, b) atraumatic extraction was done followed by (c, d) placement of “sticky bone.” (e) A membrane was placed, and (f) primary closure was obtained.

Computed tomography (CT) images were obtained (a) preoperatively and (b) at least 6 months postoperatively 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.
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and postoperative measurement of the recipient site to assess increase in the height of the buccal/palatal plates. ISQ readings and mineralized tissue volume estimation were assessed at the time of implant placement in both groups at 6 months.

Definition of the Interventions

Three-dimensional CT (Siemens SOMATOM perspective AS+/64-slice Conf) with exposure parameters of 100 kVp, 20 mA, 7-cm field of view (FOV), and 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 postoperatively after 6 months. Multiplanar reconstruction (MPR) was done by multiplanar reformatting using appropriate software (syngo 3D Roadmap Siemens Healthcare) as follows.17 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. Postoperatively, 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 receiving autologous fibrin glue (AFG) and particulate bone graft, 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 degrees 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) (red lines).

Surgical Procedure

All the procedures were performed by one trained and calibrated clinician (A.A.R.) as follows (Fig 4).15,16 In the BR group, after administration of local anesthesia, a full-thickness mucoperiosteal flap was reflected with vertical releasing incisions at the donor site, ie, mandibular symphysis region exposing the bone. Two trephines of 5-mm and 2-mm diameters 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 of the trephines; after harvesting the bone ring, sharp edges were identified and gently rounded by low-speed fissure bur under copious saline irrigation. At the 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 a screw followed by placement of a membrane and suturing without any tension in the 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 of autologous fibrin glue (AFG) generated as per standard production protocols12,13 and particulate bone graft (Siloss, Azurebio). The protocol included drawing of 10 mL venous blood from the antecubital fossa of the patient, following which the venous blood was subjected to centrifugation of 2,700 rpm for 2 minutes, resulting in an upper layer of AFG and a lower RBC portion. The resulting 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 Implant systems) were placed in all subjects in both groups (Fig 5). Before placing the cover screw, the SmartPeg Type 49 (Osstell) 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. The RFA probe was assembled with the Osstell implant stability meter and held perpendicular to the SmartPeg at a distance of 3 mm from the magnetic portion of the SmartPeg to measure implant stability. Two readings were taken each in the buccolingual and mesiodistal directions, and the average was taken as the 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. Two slides were prepared from each core, and 10 regions of interest (ROIs) per slide were visualized for mineralized tissue volume by using an Olympus BX 53 microscope at 40× magnification. The mineralized tissue volume was calculated as per a previously reported protocol and was expressed as (mineralized tissue/total area) *100.

Statistical Analysis
Data were analyzed using a commercially available statistical package (SPSS Statistics Version 25, IBM). Descriptive statistics and frequency distributions were analyzed. Intergroup comparison was done using an unpaired t test. A paired t test was used for intragroup comparison. \( P \leq .05 \) was considered statistically significant, and \( P \leq .001 \) was considered highly significant.

RESULTS
All participating subjects (n = 34; 17 men; mean age: 32.60 ± 10.22 years) completed study-related interventions, and one subject in the BR group was lost to follow-up at the end of the 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 postoperative 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 were 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 and 13.9 ± 1.11 mm at baseline and 15.1 ± 1.2 and 15.93 ± 1.22 mm at 6 months. In the BR group, the buccal/lingual-palatal plate heights were 13.73 ± 2.35 and 14.18 ± 1.99 mm at baseline and 17.96 ± 1.63 and 19.3 ± 1.73 mm at 6 months, respectively (Table 1). The intragroup gain in bone height from baseline to 6 months was highly significant in both groups (\( P \leq .001 \)).

**Bone Density (HU).** In the BR and AFG groups, the bone density scores (in HU) were 596.2 ± 115.2 and 659.6 ± 133.8, and 520.3 ± 54.8 and 552.1 ± 65.6, at
6 months and at baseline, respectively. Highly significant intragroup differences were observed for bone density at the end of 6 months in both groups ($P < .001$).

**Intergroup Comparisons**

**Bone Gain and Bone Density.** At baseline, there were no significant differences in the buccal ($P = .789$) and lingual/palatal bone heights ($P = .710$) between the BR and AFG groups. 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 (3.31 ± 2.66 mm vs 1.99 ± 1.22 mm) height in the BR group over the AFG group. At baseline, there was a significant difference in the bone density ($P = .042$) between the BR and AFG groups; this significance was observable at 6 months as well ($P = .016$). At the baseline, there were no significant differences in the buccal ($P = .789$) and lingual/palatal bone heights ($P = .710$) between the BR and the control groups. At 6 months, there was a highly significant gain ($P < .001$) 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 ($P = .034$). Biopsy specimens from the BR group showed a marked increase in the percentage of tissue mineralization, which was highly significant ($P < .001$) over the control group.

**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 ($P = .034$). 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 ($P < .001$) (Figs 6 and 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

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**Table 1  Comparison of Clinical Parameters (Buccal, Lingual/Palatal Height) at Baseline and 6 Months Using Unpaired t Test**

<table>
<thead>
<tr>
<th></th>
<th>Autogenous bone ring</th>
<th>Growth factor–enriched bone graft matrix</th>
<th>t value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative buccal height (mm)</td>
<td>13.73 ± 2.35</td>
<td>13.5 ± 1.98</td>
<td>0.270</td>
<td>.789†</td>
</tr>
<tr>
<td>Postoperative buccal height (mm)</td>
<td>17.96 ± 1.63‡</td>
<td>15.1 ± 1.2‡</td>
<td>5.09</td>
<td>.000**</td>
</tr>
<tr>
<td>Preoperative lingual/palatal height (mm)</td>
<td>14.18 ± 1.99</td>
<td>13.9 ± 1.11</td>
<td>6.376</td>
<td>.710†</td>
</tr>
<tr>
<td>Postoperative lingual/palatal height (mm)</td>
<td>19.30 ± 1.73‡</td>
<td>15.93 ± 1.22‡</td>
<td>5.710</td>
<td>.000**</td>
</tr>
</tbody>
</table>

**Notes:**

*Highly significant, †Not significant.
‡Intragroup comparison of bone height from baseline to 6 months is highly significant ($P < .001$).

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as a graft material in extraction sockets. De Molon et al.\(^ {20} \) 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 immunologic response, and is rigid and tougher than particulate bone grafts.\(^ {20,21–27} \)

Both treatment modalities resulted in significant gain in bone height from baseline to 6 months. Peck et al.\(^ {27} \) stated that the efficacy of leukocyte- and platelet-rich fibrin (L-PRF) in ridge augmentation procedures is a result of the release of growth factors, thereby stimulating healing and new bone formation. In the present study, from baseline (13.5 ± 1.9 to 5.1 ± 1.2 mm) to 6 months (13.9 ± 1.1 to 15.9 ± 1.2 mm), 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 Girish Rao et al.\(^ {28} \) 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 implants.\(^ {15,16,20–24} \) Giraddi and Saifi\(^ {21} \) reported a bone gain of 3.70 ± 1.10 mm medially and 3.69 ± 1.10 mm distally, and Crespi et al.\(^ {22} \) found a mean bone gain of 3.70 ± 1.10 mm on the mesial aspect and a mean bone gain of 3.69 ± 1.10 mm on the distal aspect when autogenous bone ring was placed simultaneously around an implant. The present study 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 ± 1.6 mm and 9.3 ± 1.7 mm for buccal and lingual/palatal plates, which were 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.\(^ {15,16} \) Aimetti et al.\(^ {23} \) 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.\(^ {5,7,11–13} \) In contrast, a structural graft such as autogenous bone ring shows significantly less crestal bone resorption and optimum volume maintenance of the recipient site.\(^ {15–17} \) Parallels can be drawn from the following studies. Joshi et al.\(^ {25} \) suggested that the use of block grafts for socket augmentation results in significant preservation in vertical ridge height. Kaufman and Wang\(^ {26} \) conducted a study on localized vertical maxillary ridge augmentation using syphslyseal bone cores and noticed increases in vertical height and width of the ridge as well.
At baseline, there was a significant difference in the bone density ($P = .042$) between the BR and AFG groups; this significance was observable at 6 months as well. Omara et al., 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 buccal aspects (mean bone density changes were 393.21 HU mesially and 429.69 HU buccally). However, higher values were obtained in the present study in both 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 entrap platelets and leukocytes to release growth factors, so soft and hard tissue regeneration is accelerated, resulting in increase in bone density. Absence of complications also contributes to good-quality bone; in a case report on bone ring autogenous graft transplantation with early implant placement, clinical or 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.

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 modeling and remodeling characteristics, reduction in micromotion of the graft, and its osteoconductive properties. Platelet concentrates result in good-quality bone. However, unlike structural grafts, platelet concentrate–alloplastic material combinations show more resorption than structural block grafts and are very sensitive to micromovements, and such micromovements may result in lower mineralization volumes compared with autogenous bone rings. 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, enhancing the soft tissue contour and helping 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. Block grafts also demonstrate better formation of vital and mineralized bone with lamellar organization at the grafted sites over other grafts.

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., who attributed the stability to the good bone remodeling and osteoconductivity of autogenous graft material. Increase in buccal plate height and improvement in bone quality 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.; 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. This study compared autogenous cortical bone ring with autologous growth factor–enriched alloplastic bone graft. Both materials have widely differing biologic and physical characteristics. The autogenous bone ring transplant procedure was traditionally done along with simultaneous implant placement in previous reports; however, the present study 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 were obtained from studies that utilized a ring-shaped graft of different origin, such as autogenous dentine or allogenic tooth graft; 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.

**CONCLUSIONS**

The following conclusions can be made with reference to the observations in this study. The 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 the study period showed sufficient gain in bone height and quality for eventual implant placement. Both procedures were well tolerated by all the participating subjects with no untoward effects or complications.
ACKNOWLEDGMENTS

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REFERENCES