Clinical evidence suggests using lateral and vertical ridge preservation procedures to make dental implant placement possible. This study evaluates and compares the radiographic and volumetric changes following ridge preservation procedures using either mineralized plasmatic matrix grafts (MPM) or bone grafts alone (non-MPM) in the existing crestal ridges of sockets in maxillary and mandibular regions using CBCT scans. Healthy volunteers (n = 26) were recruited and randomized into MPM and non-MPM groups (n = 13 patients per group). Ridge preservation (RP) was performed in sockets after extraction. Preoperative baseline vertical measurements (V1) were made from the existing highest level of the socket crestal ridges to a reference point in an apicocoronal direction. Similarly, baseline horizontal measurements (H1) were made in a buccolingual direction on CBCT scans. The measurements were repeated after 3 months (V2 and H2) and 6 months (V3 and H3) using the same reference points. Difference between V3 and V1 as well as H3 and H1 was used to assess the gains in height and width of the sockets after RP. No significant difference was found in the initial baseline V1 and H1 values in MPM and non-MPM groups. Median (Mdn) V2 and H2 scores were significantly different between MPM (Mdn = 18.91) and non-MPM groups (Mdn = 27.81) after 3 months of RP (U = 37, z = –6.302, P < .001). However, after 6 months of treatment, V3 and H3 scores were significantly different between the MPM (Mdn = 27.19) and the non-MPM group (Mdn = 37.81). MPM can be used as a valuable and predictable technique in obtaining bone fill in the maxillary and mandibular sockets after extraction. No significant difference was found in the sockets after RP.

Placement of prosthetically driven dental implants would facilitate soft and hard tissue healing, thus reducing the need for further bone augmentation procedures.

Alveolar bone grafting can be divided into ridge preservation (RP) and ridge augmentation techniques. Alveolar RP techniques have been broadly used with a primary objective to limit post-extraction ridge alterations. RP is a successful treatment modality for avoiding bone resorption, which is achieved with the use of biomaterials and membranes following atraumatic procedures.
extraction. Advanced platelet-rich fibrin, recombinant growth factors, barrier membranes, and bone grafts are effective in decreasing resorption of the alveolar ridge after tooth extraction. The autogenous bone graft is widely proposed as the gold standard for correction of severe localized ridge defects. Bone regeneration procedures can modify, correct, and augment compromised bone sites that occur due to excessive bone resorption following tooth loss because of trauma, deep root fracture, or advanced periodontal inflammatory lesions.

Currently, xenografts and synthetic bone grafts are used with predictable outcomes, as no discernible differences in implant success exist between the bone augmentation materials. Xenografts and allografts are mineralized, and their osteoconductive property is boosted as a result of a firm scaffold, useful for new bone formation. Moreover, the existence of these biomaterials within the extraction socket seems to be the reason behind the minimal observed changes in ridge dimensions.

Perisse et al have proposed a new technique called mineralized plasmatic matrix (MPM). The proposed advantage of MPM is that it utilizes the fibrin network to conglomerate all of the particles, and it offers stability for the graft because MPM acts as a sticky and homogenous component. Consequently, the bone graft will adhere to the site and act as a space maintainer for the guided bone regeneration process. MPM contains cells such as platelets, which add growth factors or cytokines, and monocytes, which aid the regulation of natural bone morphogeneic proteins. There is scarce relevant evidence that the bone grafts are beneficial in RP techniques, as 3 mm of horizontal bone loss and ≥ 1 mm of vertical bone loss were evident after bone grafting.

Currently there is no evidence to support the superiority of a particular material or technique for RP. Using CBCT scans, the present study aimed to evaluate and compare the radiographic and volumetric changes following RP procedures using either MPM grafts or bone grafts alone in the existing crestal ridges of sockets in maxillary and mandibular regions.

The null hypothesis was that there would be no comparable radiographic or volumetric changes following RP procedures using either MPM grafts or bone grafts alone.

Materials and Methods

Study Population and Characteristics

Subjects (n = 26) were enrolled in the present prospective study conducted at implant clinics at the College of Dentistry, Jouf University. Informed written consent was obtained from the recruited patients, and the study was conducted following the Helsinki Declaration of 1975, as revised in 2013. Ethical clearance was obtained from the Local Committee of Bioethics, Jouf University (Ref no. 03-03/41). Patients with systemic health problems (eg, uncontrolled diabetes, immunodeficiency diseases, and heavy smokers (> 10 cigarettes a day)) were excluded from the study. Patients were included in the study if they met the following criteria: needing single implant placement in the sockets of esthetic and nonesthetic zones of maxillary and mandibular regions; presumed Class III ridge defects with a resorbed buccal/lingual plate immediately after extraction; an absence of prosthetic restorations or adjacent implant sites with D1 (dense cortical bone with maple tactile analog) or D2 (porous cortical bone and trabecular bone with spruce tactile analog) bone quality at the socket site. Patients were distributed into either the MPM test group (patients treated with MPM; n = 13) or the non-MPM control group (patients treated only with bone grafts; n = 13) using a simple random technique.

Radiographic Measurement of Socket Site

Preoperative evaluation of socket sites was done using OnDemand3D software (Cybermed) on CBCT scans (Scanora DX, Soredex) of the enrolled patients, using vertical and horizontal measurements as reference parameters. For the preoperative (baseline) vertical height measurements (V1), the floor of the maxillary sinus and nasal floor were taken as reference points in maxillary sockets, whereas the upper border of the mandibular canal...
was used as a reference point in mandibular sockets; measurements were taken in an apicocoronal direction from the reference point to the existing highest level of the alveolar crest (Fig 1). For the preoperative (baseline) horizontal width measurements (H1) in both maxillary and mandibular sockets, the existing highest level of the alveolar crest was taken as a reference point, from which the measurements were made in the buccolingual or buccopalatal direction to the contralateral adjacent alveolar crest level.

At 3 months postoperative (Fig 2), vertical heights were measured from the reference point to the existing highest level of the alveolar crest (spotted based on bone density changes in the apicocoronal direction; V2), and horizontal widths were measured (as done for H1) from the reference point to the existing highest level of alveolar crest (spotted based on bone density changes in the buccolingual direction; H2). At 6 months postoperative (Fig 3), the measurements were again assessed to determine the vertical height (V3) and horizontal width (H3) using the same reference points. These measurements were used to evaluate and assess the gains in height and width of treated sockets following RP in MPM and non-MPM groups.

To precisely relocate and duplicate the reference points for successive vertical and horizontal measurements, grid levels in the scanned.
CBCT images were used. To standardize the CBCT images, the same settings (field of view: 8 × 8 cm; 5.0 mA; 90 Kv; 8.5 seconds) were used and calibrated for subsequent exposure and measurements. Measurements were taken on the CBCT scans by one researcher (M.K.A.) who was blinded to the graft material used in each socket. Figure 4 shows the flowchart of subject enrollment, allocation, and follow-up, and the analysis of variables.

**Surgical Procedure**

The RP was done by a well-trained prosthodontist (M.G.S.) assisted by a periodontist (K.K.G.). All socket sites were treated with a similar approach as the other patients in the respective groups, and all procedures were carried out under local anesthesia. After extraction of the tooth, a crestal incision was made in the gingival sulcus of the teeth adjacent to the edentulous space. Full-thickness mucoperiosteal flaps were elevated for tension-free access to the alveolar ridge. Mesial and distal releasing incisions were performed when needed to achieve advancement of the flap for primary closure. Exposure of the planned implant site allowed direct measurement of the available bone, and bone mapping was performed to confirm the need for RP. Test-group patients were augmented using MPM whereas control group (non-MPM) patients were augmented with mineralized cancellous bone allograft material alone (250 to 1,000 µm; DirectGen, Implant Direct). No attempt was
made to overfill the sockets; bone grafting was done only to the level of the existing alveolar ridge height of the sockets in both groups. Guided tissue regeneration membranes (conFORM, ACE Surgical Supply) were used in both groups to cover the graft material and were stabilized by membrane fixation pins (truSCREW, ACE Surgical Supply). Primary closure of the flaps was then established by suturing (Cytoplast PTFE, Osteogenics Biomedical). Postoperatively, patients were instructed not to damage the wound, touch the wound, smoke, spit, or rinse for 2 days to enable stabilization of the blood clot and the graft material, nor apply pressure to the grafted area with their tongue or fingers, as the material is mobile during initial healing.

MPM Preparation
Blood samples were collected from the enrolled patients with no history of aspirin intake or other medications over the previous 2 weeks that might interfere with coagulation. For each subject, a 10-mL blood sample was obtained from an antecubital vein. After blood collection, the MPM is prepared by a single spin in empty tubes without anticoagulants. The test tubes were centrifuged at 1,700 rpm for 10 minutes at room temperature.23,24 After centrifugation, the plasma was collected from the tube using a sterile 10-mm syringe and placed in a sterile metal cup. Plasma was then mixed with the mineralized cancellous bone graft (250 to 1,000 µm; DirectGen) in a sterile dappen dish container. After the initial preparation, about 0.5 mL of fresh blood was obtained from the defect site and added to the dappen dish. The contents were mixed thoroughly to obtain a homogeneous single component that is compact and stable, containing the graft, and dense fibrin network. The resulting mass was unified with semisolid consistency, then placed in the ridge defect areas as a filler material (Fig 5).

Statistical Analysis
G*Power computing analysis determined that a sample size of 13 patients per group was sufficient to detect a clinically significant mean difference of new bone fill as a result of the RP procedure based on number of groups, number of observations, effect size, significance level ($\alpha$), and Power (1-$\beta$). Anticipating a potential dropout rate of 15%, with a minimum of 85% of patients expected to be fully compliant under the study protocol, a total of 31 patients were enrolled. Five patients were excluded, and 26 completed the study period and were included for analysis (Fig 4). Both Kolmogorov-Smirnov and Shapiro-Wilk (for normalcy) tests suggested that variables measuring the level of bone height and socket width after RP were not distributed normally, which was confirmed by the histogram with a long left tail. Therefore, Mann-Whitney $U$ test was used to determine whether a significant “difference in level of bone height and width of the sockets after ridge preservation” existed between the two groups. Median (Mdn) values were determined for height and width, measured individually in both groups. The $U$ value was used to determine the statistical significance. $Z$ static was calculated from the $U$ value to obtain a range, and based on this range, the null hypothesis was rejected or accepted. Data were considered statistically significant when $P < .05$.

Results
From the 26 patients (18 men and 8 women) enrolled in the study, RP was performed in the sockets of maxillary incisors ($n = 9$), mandibular premolars ($n = 12$), and maxillary premolars ($n = 5$). All patients presented with no signs of uneventful healing and dehiscence at the 3- and 6-month postoperative follow-ups. Patients’ ages ranged between 18 and 45 years (mean age: 38.44 ± 3.8 years). Mann-Whitney test indicated that initial baseline scores obtained using the reference points (Fig 1) in apicocoronal (V1) and...
buccolingual directions (H1) were not significantly different in MPM and non-MPM groups (Mdn: 26 mm; Fig 6). The obtained V2 and H2 scores at 3 months (Fig 2) were significantly different between MPM and non-MPM groups (Mdn: 18.91 and 27.81, respectively; U = 37, z = −6.302, P < .001) (Fig 7). However, 6 months after treatment, the obtained V3 and H3 scores (Fig 3) were significantly different between MPM and non-MPM groups (Mdn: 27.19 and 37.81, respectively; Fig 8). The gains in vertical height (difference of V3 and V1) and horizontal width (difference of H3 and H1) were an average of 4 mm and 3 mm greater, respectively, in the preserved sockets of the MPM group than the non-MPM group. There were no statistically significant findings concerning the gains in socket height and width related to gender variations for MPM and non-MPM groups.

**Discussion**

Implant placement and grafting after extraction with severe bone deficiencies often represent a challenging situation for clinicians. Numerous bone augmentation procedures have been described in the literature to correct bone dimensions insufficient for implant placement.32 The present study demonstrated that MPM has an additive potential for bone formation in comparison with bone grafts alone for RP techniques, and so the null hypothesis was rejected. MPM is a product of the mixing of two phases: the mineral and plasma phases. The result of this mixture is a homogeneous single component, which is a compact dense fibrin network containing the graft that promotes healing.33 This procedure allows all of the bone particulates to link together in one product, forming a homogenous mixture with adequate strength and stability. MPM adheres with bone particles that are linked together by a strong fibrin network that offers a scaffolding unit for MPM stability at the augmented site. The present study represents the first randomized controlled clinical trial comparing MPM and bone graft alone (non-MPM) for RP. Clark et al demonstrated that advanced platelet-rich fibrin alone or augmented with freeze-dried bone allograft is a suitable biomaterial for ridge preservation.34 Clinical outcomes obtained from the present study suggest a beneficial

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*Two-sided test.*

**Fig 6** Comparison of z and P values in vertical (V1) and horizontal (H1) measurements of MPM and non-MPM groups at baseline.
**Fig 7** Comparison of P values in vertical and horizontal measurements of MPM and non-MPM groups after 3 months.

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*aTwo-sided test.

**Fig 8** Comparison of P values in vertical and horizontal measurements of MPM and non-MPM groups after 6 months.

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*aTwo-sided test.
effect of MPM over non-MPM methods, which are in agreement with the findings of recent reports such as Bassir et al.35 Findings from the non-MPM group in the present study are in agreement with the findings of Beitlitum et al, who demonstrated that large horizontal and/or vertical ridge defects can be treated with freeze-dried bone allograft and collagen barrier membranes cross-linked with ribose for better clinical outcome.36

Findings from the MPM group of the present study show a limitation of the sockets’ existing residual crestal ridges as well as a gain in vertical height and horizontal width of the socket, decreasing the socket size. The main contributing factor for such results is the addition of MPM to mineralized cancellous allograft, as Corbella et al.37 reported that allograft was not related to higher new bone formation than naturally healed sites. In the present study, no attempt was made to overfill the socket defect with graft material in the MPM and non-MPM groups. In both groups, bone grafting was only done to the existing height of the socket’s alveolar ridges. Overfilling the socket would only result in the sequestration of the coronal graft particles, likely contributing to the creation of an infectious source that can adversely affect bone formation.38,39 Findings from the present study are in agreement with Schwartz et al.40 as the bone fill with freeze-dried bone allograft in MPM and non-MPM groups is independent of gender effect.

Growth factors play an essential role in the initial osseous regeneration process.41 In the present study, predictable results were achieved because the platelet cells from the MPM released the growth factors,42 or cytokines, and the monocytes that help in the regulation of natural BMP formation at the defect site, as stated by El Moheb et al.24 and Omar et al.25 Success of guided bone regeneration largely depends on the use of collagen membranes in the defect site.43 Reports demonstrated that the use of the collagen membrane achieved superior ridge preservation results,44,45 and thus the use of collagen membranes was justified in the non-MPM group to compare it with MPM group. MPM offers an advantage in this aspect with its adherence to the defect site and the extemporaneous mixture that helps stabilize the collagenous guided tissue regeneration membranes covering the graft material.

The particle size of the bone allograft used in the present study ranged from 250 to 1,000 µm, which were very suitable and ideal for the sockets. Particles that are too small (<125 µm) provoke a macrophage reaction and are resorbed too quickly with little to no bone formation; particles that are too large may restrict interparticle space for vascularization and may be sequestered. Shapoff et al. studied the particle size of freeze-dried bone allograft for hard tissue grafting around teeth and concluded that 100 to 300 µm was the optimal particle size that would enable bone particles to stay at the grafted site for a sufficient time while maximizing vascularization.46

Recent reports demonstrated that CBCT images provide reliable information regarding the fate of bone grafts in the maxillofacial region.47,48 In the present study, the outcome variable is evaluated only using volumetric bone changes through CBCT scans, and thus the expected outcomes (image reconstruction and image procurement protocol), which should be wisely considered when interpreting the clinical outcomes. More histologic studies are needed in this regard to validate the bone fill obtained by MPM so that it can be widely used in RP. Limitations of the present study include that no comparison was made of the MPM effect specifically to location characteristics for RP of maxillary and mandibular alveolar defects. Therefore, further research is needed to validate the regenerative potential of MPM concerning alveolar defect features of the maxilla and mandible.

Conclusions

MPM can be used as a valuable and predictable technique in obtaining bone fill in maxillary and mandibular sockets with residual crestal ridges requiring RP for implant therapy.

Acknowledgments

Author contributions: Conception and design of the work: M.G.S., A.S.K., and K.K.G.; acquisition of data, or analysis and interpretation of data: S.M.B.B., M.K.A., and K.K.G.; drafting the article or revising it critically for important intellectual content: M.G.S., K.K.G., A.S.K., S.A.R., and S.M.B.B.;

This research project (no. DSR2020-04-2550) was supported by a grant from the Deanship of Scientific Research, Jouf University. The authors declare no conflicts of interest.

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