Dental implant placement in the posterior maxilla often meets with difficulty due to the severe atrophy caused by tooth loss, periodontal disease, and pneumatization of the maxillary sinus. Since Tatum and Summers reported maxillary sinus floor elevation by the lateral approach (LSFE) and the transcrestal approach (TSFE), respectively, it became the most common bone augmentation technique to overcome the deficiency of bone in the maxillary posterior region for implant placement.1,2 According to the consensus conference of 2008 in Germany, LSFE could be applied to solve the insufficient residual bone height (RBH) ≤ 5 mm.3 However, LSFE is regarded as an invasive and time-consuming method that increases the treatment duration,4 which may complicate the procedure and lead to more severe complications, such as infections.5 Therefore, there have been more efforts to challenge the maxillary posterior with RBH < 5 mm with a TSFE approach.6–9 Substantial studies indicated that the TSFE approach was predictable and safe for implant placement in the maxillary posterior region with RBH in the range of 4 to 5 mm.6,7

Recently, Gonzalez et al attempted to place implants in the posterior maxilla with RBH < 4 mm via TSFE.10 However, since TSFE is blindly operated, perforation of the sinus membrane would be more likely to happen.11 Clinically, surgeons always confirm the integrity of the sinus membrane by compressing the patients’ nostrils and asking them to blow their nose to check the air-leaking situation. This indirect and inaccurate method could not confirm the location and size of the perforation. Inspired by endoscope application in otorhinolaryngology, Engelke and Deckwer first described utilization of the endoscope via pernasal approach as a low-invasive adjunctive technique in sinus floor augmentation. Endoscope-assisted sinus floor elevation (ESFE) might contribute to a reduction of perioperative morbidity and well-managed graft position.12 Interestingly, the endoscope could offer direct magnification of the sinus membrane through the osteotomy site in TSFE, and was more precise in detecting small perforations. ESFE via a transcrestal approach was regarded as

**Endoscope-Assisted Maxillary Sinus Floor Elevation with Platelet-Rich Fibrin Grafting and Simultaneous Implant Placement: A Prospective Clinical Trial**

Jia Wang, PhD1/Xiaolin Sun, PhD1/Huixin Lv, MS1/Liuyi Du, MS1/Lin Wang, PhD1/Yanmin Zhou, PhD1

**Purpose:** To evaluate the clinical and radiographic outcomes of endoscope-assisted maxillary sinus floor elevation with platelet-rich fibrin grafting and simultaneous implant placement (PESS) in atrophic maxillae. **Materials and Methods:** Twenty-three implants were placed to rehabilitate atrophic maxillae. Patient satisfaction was measured with a visual analog scale (VASpain). CBCT was taken to assess the bone changes for the elevated sites. **Results:** Twenty-two of 23 implants fulfilling the survival criteria represented a 1-year survival rate of 95.65%. The VASpain score decreased with time. The residual bone height was 4.45 ± 1.44 mm. The elevation height was 6.72 ± 1.84 mm. The definitive restoration was completed in the 4th month postsurgery. The peri-implant bone level value was 6.04 ± 2.30 mm, 6.32 ± 2.25 mm, and 6.71 ± 1.97 mm at the 3rd, 9th, and 15th month postsurgery. The crestal bone level value decreased by 0.22 ± 0.56 mm from the 3rd month to the 15th month postsurgery (P > .05). Bone mineral density increased with time at the neck, middle, and root site of implant. **Conclusion:** PESS in the maxilla resulted in predictable peri-implant bone formation. This strategy is a relatively safe and effective approach with less invasion, which provides new insights into the choice of implant treatment plans. *Int J Oral Maxillofac Implants* 2021;36:137–145. doi: 10.11607/jomi.8723

**Keywords:** growth factors, sinus floor elevation, surgical techniques

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Submitted June 12, 2020; accepted September 6, 2020. ©2021 by Quintessence Publishing Co Inc.
a precise, safe, and simple tool that routinely served at
chairside for detecting any perforations, thus accord-
ingly making the following decision.13
Bone graft materials placed into the elevated maxil-
lar sinus would easily lead to undetectable perforation
due to sharp edges and hasty addition of large incre-
ments of grafting materials. Therefore, softer bone graft
materials are more and more popular for clinicians to
avoid sinus membrane perforation. Platelet-rich fibrin
(PRF) is the second generation of platelet concentrate
prepared by Choukroun et al in 2001.14 As a new type
of autograft material, it could accelerate the growth of
soft and hard tissues by releasing varieties of growth
factors. Aoki et al proposed that sinus floor elevation
with only PRF grafting is a relatively safe procedure
that could provide favorable outcomes.15 PRF was also
reported to be used as the sole grafting material in si-
inus floor elevation procedures with great bone regen-
eration (8.5 to 12 mm increasing in height)16 and 97.8%
survival rate of implants.17 Therefore, PRF is increas-
ingly accepted as a bone grafting material placed in the max-
illary sinus for bone augmentation.
Regarding the aforementioned information, endos-
cope-assisted maxillary sinus floor elevation with
PRF grafting and simultaneous implant placement
(PESS) seems to be highly desirable. Moreover, when
treatment cost, treatment duration, and simplified pro-
cedures to patients are considered, the clinicians need
information regarding the predictability of PESS. The
aims of the present study were to assess the survival
rates of dental implants and new bone formation in the
PESS.

MATERIALS AND METHODS

Patient Selection and Preoperative Treatment
This study was approved by the ethical committee of
the School of Dentistry, Jilin University and has been
conducted in full accordance with ethical principles
(201701), including the World Medical Association Dec-
laration of Helsinki. The informed consent was signed
before treatment.
The patient inclusion criteria were as follows:

- Lack of one tooth in the maxillary posterior region
- Residual bone height from 2 to 5 mm
- Age >18 years
- Sufficient bone width in the surgical site that is
  available to accommodate the implant with a
diameter of 4.8 mm, with a bone wall of > 1.5 mm
  for each buccal and palatal side
- No sinusitis in the maxillary sinus
- No smoking
- No systemic contraindication for the surgery

Ten patients (8 women and 2 men) with 23 implants with ages ranging from 27 to 73 years
(49.77 years on average) were recruited from the De-
partment of Oral Implantology, School of Dentistry, Ji-
lin University, in the period between February 2017 and
June 2018. All patients were seeking implant placement
in the posterior maxilla and refusing the sinus floor el-
avation by lateral approach. All patients had received
fundamental periodontal treatment. CBCT (Kodak) was
performed preoperatively to measure the vertical bone
height under the sinus floor and exclude the presence of
maxillary sinusitis. All eligible implant sites were con-
sidered for analysis, and RBH was an average value of
the distance from the mesial and distal alveolar ridge
crest around the simulative implant to the maxillary
sinus floor. All CBCT scans were obtained by the same
operator with the same device at a standardized posi-
tioning of the head and body.

Surgical Procedures
Figure 1 shows the major surgical process and pattern.
The surgery was performed under local anesthesia via
articaine with adrenaline 1:100,000. Crestal gingiva
was removed with a circular punch at a diameter of
4.3 mm, and the bone surface was exposed (Fig 1a). Then,
the gingiva thickness was measured with a peri-
dontal probe. The osteotomy was prepared with a
pioneer drill at the punch site under the cooling with
ice physiologic saline. According to the vertical bone
height measured before surgery and gingiva thick-
ness, implant sites were prepared to the depth nearly
1 to 2 mm away from the sinus floor. With respect to
the flapless protocol, the depth was controlled by the
value of vertical bone height + gingiva thickness – 2
mm. When the drilling depth at a gingival level came
to this value, the process of drilling ceased. Afterward,
the maxillary sinus floor was gently elevated by 3 to 4
mm using an osteotome (ZEPF) by slight malleting to
create a “greenstick” fracture on the sinus floor (Figs 1b
and 1c). This process can be monitored at any time by
an endoscope (PolyDiagnost). As shown in Fig 1d, the
endoscope lens was introduced into the sinus through
the prepared opening on the implant bed to observe
the integrity of the sinus membrane. Three glass tubes
of blood (10 mL/tube) were collected from patient’s
upper brachial vein and centrifuged at 3,000 rpm for
12 minutes at room temperature. After squeezing to
remove moisture, three pieces of PRF membranes were prepared and then filled into the maxillary sinus under the sinus membrane (Fig 1e). The elevation process was continued via osteotome by pushing PRF membranes upward. The total elevation height was the implant length (12 mm) subtracting different RBH of different patients (Fig 1f). Through immediate endoscope observation, the integrity of the sinus membrane could be judged because after PRF is grafted through the implant preparation site, PRF will move along with the intact sinus membrane during respiration. If the sinus membrane is perforated, PRF will not move (Fig 1g). To avoid potential bias from the use of different implant devices, a single dental implant (standard esthetic/wide neck/1.8-mm collar/SLA, Φ4.8 mm*12 mm, Straumann) was simultaneously placed followed by a healing screw (Fig 1h). The junction of the smooth collar and rough surface of the implant was located on the alveolar ridge crest.

Postoperative Examination and Definitive Restoration

Patient satisfaction was measured with a visual analog scale (VASpain) at 0, 24, and 48 hours postsurgery. VASpain was scored from 0 to 10, in which 0 indicated no pain and 10 meant worst pain possible, while scores in between represented different degrees of pain. Patients were asked to mark on the horizontal line to indicate the degree of pain.

CBCT was taken at the 2nd month, 3rd month (baseline), 9th month, and 15th month postsurgery. The following parameters were measured:
1. **Elevation height:** The average value of the distance from the original sinus floor to the apex of the implant assessed at the mesial and distal bone around implants at the 2nd month.

2. **Crestal bone level (CBL):** The average value of the distance from the most coronal bone-to-implant contact to the apex of the implant assessed at the bone mesial and distal around implants. CBL_{0}, CBL_{1}, and CBL_{2} represent CBL at the 3rd, 9th, and 15th month postsurgery, respectively. A decreasing CBL corresponds to marginal bone loss.

3. **Peri-implant bone level (PIBL):** The average value of the distance from the most coronal implant thread to the most apical bone-to-implant contact assessed at the bone mesial and distal around implants. PIBL_{0}, PIBL_{1}, and PIBL_{2}, respectively, represent PIBL at the 3rd, 9th, and 15th month postsurgery. An increase in PIBL corresponds to endosinus bone gain.

4. **Bone mineral density (BMD):** The BMD values were measured at the four levels of each implant: (1) cervical: at the level of the first thread; (2) middle: at the level of the third thread; (3) root: at the level of the last thread; and (4) apical: at the level of the apex of the implant. The measured area was 1 mm². The grayscale value for all subjects was measured by Planmeca Romexis (slice thickness was 0.5 mm) at a distance of 2 mm away from implants to avoid the influence of the titanium artifact (Table 1). Measurement of BMD was performed at the 2nd, 3rd, 9th, and 15th month postsurgery. The radiographic measurement was performed by another researcher (J.W.) who was not involved in the surgical procedure. At the 3rd month postsurgery, the implant stability quotient (ISQ) value was above 65, which reached the standard for an appropriate value for osseointegration. Therefore, the definitive restoration, which consisted of an all-ceramic crown adhered on a standard titanium abutment, was finished within the 4th month.

**Follow-up Procedures**

The follow-up procedures included patient assessments every 6 months after restoration. CBCT was acquired for measuring the PIBL, CBL, and BMD at the 6th and 12th month after restoration (corresponding to the 9th and 15th month postsurgery). The clinical examinations followed the standard Buser et al. and Cochran et al. had proposed: (1) there is no clinically detectable implant mobility; (2) there is no pain or any subjective sensation; (3) there is no recurrent peri-implant infection; and (4) there is no continuous radiolucency around the implant. Implant loss, implant loosening or progressive marginal bone loss, severe peri-implant infection, or implant fracture were considered as implant failure.

**Statistical Analysis**

Statistical analysis of data was performed by SPSS software (SPSS 22.0). Descriptive statistics, mean, and standard deviation were used to assess the VAS, RBH, and elevation height. A nonparametric rank sum test analyzed PIBL, CBL, and BMD. Pearson correlation coefficient was used to assess the correlation between RBH and PIBL and CBL, and between elevation height and PIBL and CBL. P values < .05 were considered to be statistically significant.

**RESULTS**

Figure 2 shows the radiographic follow-up before surgery and at the 2nd, 3rd, 9th, and 15th month postsurgery. Endoscopic observation showed no perforation of the sinus membrane in all patients. VAS_{pain} at 0, 24, and 48 hours postsurgery was plotted in Fig 3a, indicating the reduced pain feeling with time extension. Even at the sharp time point of surgery, the average of marked pain level was only less than three, which was a mild pain for patients. In addition, no patient complained about signs of sinusitis or suppuration. One patient was excluded from the study because of implant loss at the 2nd month postsurgery. The implant was removed, and debridement and then suture were performed. A new implant was placed after 3 months. The other 22 patients finished restoration within 4 months postsurgery and completed the scheduled follow-up visits up to 1 year after definitive restoration. The survival rates were 95.65%. None of the 22 patients suffered from any related sinusitis during

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The average RBH at the implantation site was 4.45 ± 1.44 mm. Four of the patients even had an RBH less than 3 mm, and the lowest RBH was 2.1 mm. The mean elevation height was 6.72 ± 1.84 mm. Eight patients had an elevation height of more than 8 mm. The highest elevation height was 10.85 mm.

Regarding the endosinus bone gain, the values of PIBL0, PIBL1, and PIBL2 were 6.04 ± 2.30 mm, 6.32 ± 2.25 mm, and 6.71 ± 1.97 mm, respectively (Fig 3b). At each predetermined time point, the endosinus bone gain dramatically increased more than 6 mm. Interestingly, the mean PIBL showed a significant increase from 6.04 mm to 6.71 mm after 15 months postsurgery (P = .037). The CBL at the 3rd, 9th, and 15th month postsurgery was depicted in Fig 3c. Starting from the 3rd month to the 15th month postsurgery, marginal bone loss was 0.22 ± 0.56 mm. Although there was bone loss after restoration, no statistically significant difference was found in each time point (P > .05).

BMD was determined by the degree of gray value. Figure 4a shows BMD at different sites around implants at the 2nd, 3rd, 9th, and 15th month postsurgery. The scatters represent the data distribution. Figure 4b depicts a line chart for BMD changes of different sites (neck, middle, root, and apex of implants) over time. The mean BMD of measured sites gradually increased with time except at the apex of the implant between the 2nd and 3rd month postsurgery. Regarding the site dissimilarity, Fig 4c indicated that the BMD around the implant decreased from the neck of the implant to the apex for each time point. Note that the BMD at the apex of the implant could reach a similar level to that at the root of the implant 15 months after surgery (P = .372).

**DISCUSSION**

In the present study, survival rates of dental implants and new bone formation in the PESS were assessed with 1-year follow-up. PESS expanded the indications for implant placement in the atrophic posterior maxilla. In the present study, when RBH was < 5 mm, the application of PESS could successfully place the implant and ensure the long-term success rate after restoration. Twenty-two of 23 implants achieved osseointegration with bone around in the first 3 months. The endosinus bone gain dramatically increased more than 6 mm. The marginal bone loss was < 2 mm. BMD values increased with time. Even at the apex of the implant, the BMD value was at a similar level to that at the root of the implant 15 months after surgery.
The treatment options of maxillary sinus floor elevation largely depend on RBH. Del Fabbro et al had suggested that when the RBH is at least 5 mm, the prognosis can be more favorable via the transcrestal sinus floor elevation technique, while it was proposed that a lateral window sinus floor elevation approach is considered as the first choice for cases with RBH < 5 mm. However, there is still no conclusion about what minimum amount of residual bone is actually needed to retain implants placed in conjunction with transcrestal maxillary sinus floor elevation. The present study with RBH in the range of 4.43 ± 1.43 mm had a highly favorable implant survival rate (95.65%). Though the follow-up time was short, it was consistent with other studies that have been followed for 1 year. For a long-term follow-up study, the implant survival rate was 95.1%. Longer follow-up time is needed for further investigation to determine the long-term success rate. As previously reported, poor oral hygiene, smoking, and periodontitis are regarded as the main risk factors for the occurrence of peri-implantitis. According to clinical observation, the main reason for the implant loss in this study might be attributed to the poor oral hygiene. Severe bacterial infections could lead to peri-implantitis that disrupts osseointegration. The surgical placement of implants typically causes postoperative pain of mild-to-moderate intensity. All patients only suffered a kind of mild pain that nearly disappeared at 48 hours postsurgery via VASpain, since this flapless approach for implant placement has been indicated to have a lower pain score than the conventional techniques.

For traditional transcrestal sinus floor elevation, the inability to obtain a clear vision of the surgical field was a major drawback that may easily lead to perforation of the sinus membrane and then lead to postoperative complications, such as chronic sinusitis and postoperative infection, finally resulting in graft failure.
Some scholars demonstrated that the success rate of implantation surgery is only 81% on the occasion of sinus membrane perforation. On the contrary, the success rate of implantation surgery could reach 97.6% for those without perforation. Traditionally, the sinus floor underwent greenstick fracture with Summers’ osteotome followed by the grafting material placement into the maxillary sinus. This procedure would easily lead to perforation of the sinus membrane, and small tears are difficult or impossible to detect. Kennedy proposed the concept of Functional Endoscopic Sinus Surgery (FESS) in 1985 and mentioned that localized irreversible disease in the maxillary sinus may be removed endoscopically with minimal trauma, which greatly facilitates the application of endoscopes in stomatology. Engelke and Deckwer later used the endoscopic technique on sinus floor elevation and confirmed it as a low-invasive adjunctive technique. Endoscopically controlled osteotome sinus floor elevation has been reported to observe perforations of the sinus membrane and increase the success of implantation. In a retrospective study, the researchers reported that endoscopic-guided sinus floor elevation had a perforation rate of 6%, while with a lack of visual control, the perforations occurred up to 25%. In this study, sinus membrane elevation was controlled by endoscope without perforation of the sinus membrane, which reduced postoperative bleeding, swelling, and other adverse reactions.

Lundgren et al reported that the elevation height should not exceed 3 to 4 mm in TSFE. An endoscopic study has also shown that the sinus floor elevation height could reach up to 5 mm without membrane perforation. However, some researchers reported that the elevation height reached 8.5 to 12 mm after sinus floor elevation using PRF as the sole grafting material. PRF played an important role in protecting the sinus membrane from perforation. PRF placement between the osteotome and sinus membrane could effectively reduce the tension of the osteotome on the sinus membrane during the elevation process, thereby reducing the risk of membrane perforation, which may be the reason why the present study could get the highest elevation height of 10.85 mm. Even in the presence of sinus membrane perforation, PRF could also promote the healing of perforation due to the growth factors in PRF such as vascular endothelial growth factor (VEGF). Equally important, the rounded and blunt geometry of apex would guarantee that the implant would not puncture the adjacent sinus membrane. The surgeon’s skills and clinical experience are also of significance. Therefore, inexperienced surgeons still need to pay careful attention to the precise operation of the maxillary sinus floor elevation due to the high perforation rate. Combined with the aforementioned factors, the average elevation height of this study reached 6.72 ± 1.84 mm in the case of no perforation.

It is still a debate whether or not it is necessary to apply grafting material in maxillary sinus floor elevation. Numerous studies indicated that there was still new bone formation at the apex of the implant after maxillary sinus floor elevation without bone graft. Recently, some studies have attempted to apply PRF as the sole bone graft material in the maxillary sinus floor elevation with a favorable osteogenic effect. The endosinus new bone formation was probably explained by the following two reasons. First, hematoma and inflammation induced by sinus floor fracture promotes the aggregation of mesenchymal stem cells. Second, the osteogenic differentiation potential of the sinus membrane may play a role in the process of endosinus osteogenesis. Numerous studies have confirmed that sinus membranes contain the cells that are of osteoprogenitor origin with osteogenic marker expression. Furthermore, simultaneous implant placement during the transcrestal maxillary sinus floor elevation procedure is crucial for endosinus bone regeneration by creating a “tent” and providing space for graft placement and/or blood clot formation. In this procedure, TSFE using a set of osteotomes of varying diameters to prepare the implant site intended to increase the density of the soft, type III, and type IV maxillary bone for facilitating better primary implant stability, which is important for implant success. Different implant surfaces and the buccal-palatal width of the sinus could also affect the amount of endosinus bone gain. Sinus floor elevation with deproteinized bovine bone grafting or nongrafting gets bone gain of 8.59 ± 0.74 mm and 4.85 ± 0.5 mm, respectively. A prospective study showed that transcrestal sinus floor elevation and simultaneous implant placement with two pieces of PRF as the sole bone graft material had an increasing PIBL of 4.62 mm at the 9th month postsurgery. In the present study, PIBL increased with time and reached 6.71 ± 1.97 mm at the 15th month postsurgery. This large increasing amount of PIBL may mainly be attributed to more PRF grafting and prolonging predetermined time. To some extent, PRF could serve as a “placeholder,” providing the necessary scaffold for bone generation. It also contains a large number of growth factors that could induce the proliferation, migration, and differentiation of osteoblasts, effectively promote the vascularization of the inner wall of the sinus, and accelerate the process of osteogenesis. As Fig 2 shows, new bone gain can obviously be seen. The new bone formation begins from the absorption of PRF to the reconstruction of bone. Finally, new cortical bone forms on the sinus floor around the implant. This structure of double cortical bone is more conducive to implant stability.
One of the criteria for successful implantation is the stability of crestal bone around the implant. Stable marginal bone level is of great importance, since a reduction of bone level can lead to the loss of the implant’s bone anchorage. The marginal bone loss was 0.22 ± 0.56 mm during the 1-year loading phases in the present study. Bone density is another important factor for obtaining and maintaining osseointegration of oral implants. Until now, there has been no report about the BMD value around implants that were simultaneously present study. Bone density is another important factor for osseointegration of oral implants. Until now, there has been no report about the BMD value around implants that were simultaneously placed using PRF as the sole grafting material in maxillary sinus floor elevation. In a previous study, BMD values around implants with hydroxyapatite nanoparticle grafting were 548 ± 25 at the 9th month postsurgery. In the present study, the BMD values of the neck and middle of the implant at the 9th month were similar to that of the above study. The mean BMD of the whole implant in measured sites gradually increased with time. However, the small sample size and the short follow-up time are limitations of the present study. Therefore, the outcomes should be interpreted with caution, and further clinical studies are required to confirm the present results.

CONCLUSIONS

Within the limitations of this study, it can be concluded that sinus floor elevation via PESS results in predictable endosinus bone gain with a high implant survival rate during a 1-year follow-up. Twenty-two of 23 implants had survived the definitive restoration in the 4th month. The mean BMD of the whole implant in measured sites gradually increased with time. Therefore, PESS is a less invasive, safe, and effective clinical method that can promote endosinus new bone formation, shorten the treatment cycle, and expand the indications of the treatment of transcrestal sinus floor elevation.

ACKNOWLEDGMENTS

This study was financially supported by National Science Foundation of China (81570983) and International Cooperation of Science and Technology Jilin (20180414030GH). The authors declare no conflict of interest.

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