Transcrestal sinus floor augmentation with immediate implant placement applied in three types of fresh extraction sockets: A clinical prospective study with 1-year follow-up

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Funding information
The National Key Research and Development Program of China, Grant/Award Number: 2016YFC1102705/2016YFC1102700; The Fundamental Research Funds for the Central Universities, Grant/Award Number: 2016SCU04805

Abstract

Background: Immediate implant insertion and transcrestal sinus augmentation both can provide a lot of advantages for patients and clinicians.

Objective: This prospective study aims to verify the use of a modified technique for immediate implant insertion simultaneously with sinus augmentation in different types of sockets.

Materials and methods: Thirty-seven patients were recruited for the clinical study and were divided into 3 groups according to the relationship of their maxillary molar roots and sinus floor: group 1 with none of the teeth roots contacts sinus floor; group 2 as at least 1 teeth root contacting sinus floor, but no root is observed penetrating into sinus cavity; group 3 with at least 1 teeth root penetrating into sinus cavity. Implants were inserted after transcrestal sinus floor augmentation and immediately after tooth extraction. The change of mucosa thickness, diagnosis of rhinosinusitis, marginal bone loss (MBL), pocket depth (PD), and sulcus bleeding index were examined through radiographic measurement or clinical monitoring.

Result: During the study period, no implants failed. The relationship of the root of maxillary molars and sinus floor may have an effect on the bone height of the interradicular crest. Sinus mucosa was observed thicker after surgery. After healing period, sinus mucosa returned as thin as presurgery. At the time of 1-year follow-up, MBL was measured on X-ray (group 1: mesial: 0.63 ± 0.20 mm, distal: 0.70 ± 0.14 mm; group 2: mesial: 0.67 ± 0.21, distal: 0.65 ± 0.22 mm; group 3: mesial: 0.70 ± 0.15 mm, distal: 0.73 ± 0.19 mm). No statistical difference was found in MBL and PD as well as bleeding index among 3 groups.

Conclusion: In consideration of the advantages of sinus floor augmentation and immediate implant placement, our clinical result confirms that it is promising to combine the 2 techniques for replacing maxillary molars especially when using residual roots as implant orientation and taking full advantage of the interradicular crest bone.

KEYWORDS
immediate implants, marginal bone loss, sinus augmentation

1 INTRODUCTION

Sinus floor augmentation procedure has become a widely used technique in maxillary bone augmentation in the last decade. Kobecka and colleagues reported in their study that subsinus bone height declined toward posterior maxilla and the mean height for the first molar and the second molar was 3.3 and 4.5 mm.1 In a retrospective study conducted by Seong, there were more than half (54.2%) of the maxillary posterior implants involved with a sinus augmentation procedure among 502 implants.2
Moreover, immediate implant placement is now widely accepted in clinical dentistry. This procedure has several advantages, such as prevention of bone resorption, reduced number of surgical visits, promising esthetics, and positive patient satisfaction.3–5 However, this approach often requires careful evaluation of bone quality to assure primary stability for implant insertion.6,7

The combination of immediate implant placement in fresh sockets simultaneously with transcrestal sinus floor augmentation has been reported in several case series studies. The authors harbored the idea that the intact interradicular bone was able to assure primary stability.3–10 Crespi and colleagues stated in their study that 32 patients received tooth extraction, sinus floor elevation, and implant insertion simultaneously. The success rate of the 2-year follow-up is 98.57%.11 Similar result has been discovered in the clinical trial conducted by Taschieri and colleagues.12 No implant failed after a mean follow-up of 35 months. When taking advantage of the interradicular bone, we think it is predictable to combine these 2 techniques in implant surgery and patients would benefit from the shortened treatment time as well as less surgical procedures.

In addition, sinusitis is known to all that would result in complications including implants failure in posterior maxilla. Mehra and colleagues found that, due to anatomical proximity of the maxillary sinus and adjacent teeth, approximately 10% of sinusitis is caused of dental origin.13,14 The infected tooth apex with necrotic pulp may lead to sequential inflammations.15 Evren and colleagues classified the relationship of the maxillary molars and sinus floor into 3 types according to the vertical distance of the molar roots to sinus floor.16 As the apices situated deeper into the sinus, risks of infection become greater.17 Furthermore, previous study have found that apical infections is positively associated with the prevalence and severity of maxillary sinus mucosal thickening which has been considered as a possible indication for sinusitis.18,19 However, thickened maxillary mucosa occurs in approximately 61% patients with edentulous posterior maxillae and for the patients without sino-nasal symptoms, it was not the absolute contra-indication for maxillary sinus floor augmentation.20,21

In light of the numerous benefits bestowed to the patient with both the sinus augmentation and immediate implant placement, there is a great interest in expanding the applicability of these 2 clinical techniques. Therefore, the aim of the present study was to assess the survival rate and clinical results including complications as well as the change of maxillary mucosa thickness, marginal bone loss (MBL) and periodontal parameters where implants were placed immediately into fresh extraction sockets of the different types classified by relationships according to maxillary molars apices and the sinus floor.

2 | MATERIALS AND METHODS

2.1 | Study design

The present study was designed as a prospective cohort study which was performed in accordance with the World Medical Association Declaration of Helsinki and was approved by the regional ethics committee (ethical registration number 2009033). All the patients have signed their informed consent which was approved by the hospital review board before the surgery.

2.2 | Samples

The study samples were comprised of patients who had been treated with implant surgery using the transcrestal sinus floor elevation technique with implants insertion immediately after molar extraction in the maxillary posterior region. Thirty-seven subjects were selected from the patients who came to the Department of Oral Implantology, West China Hospital of Stomatology, Sichuan University in China between June 2010 and June 2012.

Criteria for selecting patients were

1. Good general health, no chronic systemic diseases.
2. All subjects included in this study needed to have 1 or 2 maxillary molars to be extracted on account of root fracture, endodontic failure or severe caries.
3. The presence of cortical bone layers of sinus floor and the interradicular alveolar crest according to CBCT measurement.

Criteria for excluding patients were

1. Presence of any pathologic lesion at tooth apex or root furcation area according to Cone Beam Computerized Tomography (CBCT) before surgery.
2. Presence of active purulence or fistula at tooth apex or furcation area.
4. Untreated periodontitis.
5. Smoking >10 cigarettes/day.

2.3 | Study groups

Patients were classified into 3 groups according to the relationship of the maxillary molars and sinus floor observed by CBCT on the coronal (Figure 1 left column) or sagittal plane presurgery (Figure 1 right column):

Group 1: None of the teeth roots contacts sinus floor (Figure 1A).

Group 2: There is at least 1 teeth root contacting sinus floor, but no root is observed penetrating into sinus cavity (Figure 1B).

Group 3: There is at least 1 teeth root penetrating into sinus cavity (Figure 1C).

2.4 | Surgical procedure

All patients were injected Articaine with local infiltration before surgery. Multi-rooted molars were decoronated at the level of gingival margin. A surgical fissure bur was followed for cutting residual roots into complete individual ones (Figure 2A). This procedure was making convenience for tooth extraction.

Subsequently, a flapless approach was used to preserve the perios- teum and keratinized mucosa. With the guidance of the residual roots,
drills with a particular stopper were used (Figure 2B). According to CBCT measurement before surgery, stoppers of different height were chosen consistent with different residual bone height between the furcation and sinus floor. Once the sinus floor was penetrated with intact membrane, various membrane detachment instruments were used (Figure 2C). Then the roots were removed carefully to preserve the interradicular bone in an atraumatic way (Figure 2D).

The Valsalva maneuver which is conducted by forcibly exhaling against the closed airway was used to ascertain the integrity of the Schneiderian membrane when detachment finished. Gelatin sponge and bone substitutes were filled in the space between the sinus floor and the sinus membrane as cushioning material to protect the mucosa and maintain the space after checking the integrity of the membrane (Figure 2E). The implants (Straumann AG, Basel, Switzerland; NobelActive, NobelBiocare, Göteborg Sweden; Bicon, Boston, Massachusetts, US, Dentium, Seoul, South Korea) were installed with shoulders positioned 3 mm beneath the gingival margin. Bone substitute was filled in the space between tooth socket and implants densely. The palatal slipping flap or ultra-wide healing abutment can achieve primary closure (Figure 2F). Similar technique was reported by Rebele22 for immediate implant placement in multi-rooted sites. By applying this technique, the residual roots can be used for implant location guidance and be extracted atraumatically. One paramount point is that the interradicular bone is protected allowing the stable implant insertion. All surgeries were performed by 1 same experienced surgeon. For complete surgery process, we have recorded the whole procedure through endoscope guided technique and we have manufactured surgical videos for further manifestation.

2.5 | Healing period

During the study period, a healing period of 6 months was observed for all the implants. CBCT was taken at time 1 (T1: before surgery), time 2 (T2: immediately after surgery), time 3 (T3: 6 months after surgery). For all patients, final prostheses were delivered as implant supported full porcelain crown or porcelain fused metal crown after 6 months of healing.
2.6 | Experimental parameters

2.6.1 | Implant success rate

All implants were observed at 6 months and 1 year after implant placement. The success rate was recorded at the observing points. The success criteria proposed by Buser and colleagues\(^\text{23}\) and Cochran and colleagues\(^\text{24}\) were adopted. The criteria include:

1. no clinically detectable implant mobility;
2. no pain or any subjective sensation from patients;
3. no recurrent peri-implant infection;
4. no continuous radiolucency around the implant.

2.6.2 | Diagnosis of sinusitis

A patient questionnaire (Table 1) developed by Lanza and Kennedy\(^\text{25}\) to identify the presence of rhinosinusal clinical symptoms was used 1 week after surgery and 6 months after surgery. Each symptom question is answered “yes” or “no.” Diagnosis of sinusitis requires a “yes” answered in 2 or more major criteria, or in 1 major and 2 or more minor criteria, or purulence on nasal examination.

2.7 | Radiographic assessments

1. The bone height from the coronal apex of interradicular crest to the sinus floor was measured on presurgery CBCT (machine: CT, Morita, Kyodo, Japan; settings: voxel size, 0.125 × 0.125 × 0.125 mm; field of view: 80 × 80 × 80 mm; slice interval: 1 mm; slice thickness: 1 mm) in the coronal plane.

2. The thickness of maxillary mucosa was measured before surgery, immediately after surgery, and 6 months after surgery according to CBCT. The measurement was taken at the center of the buccal and palatal alveolar crest in the coronal plane. The use of CBCT for

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FIGURE 2  Surgical process: A, Multi-rooted molars were decoronated at the level of gingival margin and were divided into complete individual roots. B, Drills with a particular stopper were used according to CBCT measurement before surgery. C, Various membrane detachment instruments were used to elevated floor membrane. D, Then the roots were extracted carefully to preserve the interradicular bone. E and F, Implants inserted and wound closed by ultra-wide healing abutment
mucosa thickness was because that mucosa could not be recognized clearly and measured precisely in 2-dimensional radiographs.

3. Mesial and distal MBL 6 months and 1 year after surgery were measured. CBCT was used for MBL measurement at 6 months after surgery. And periapical standardized X-ray was performed for MBL measurement at 1-year follow-up.

Although the applyment of the CBCT is a standardized technique for evaluation of MBL because of its all-around angle of view, for the consideration of radiological dose and financial issue, we hold the view that periapical X-ray is a better alternative for MBL measurement at 1-year follow-up. The X-ray radiographs were scanned with a scanner. The images were processed using Image J software (NIH, Bethesda). The length of implant was used as a reference for measurement correction.

All the measurements were evaluated by 1 postgraduate student who was not involved in the surgical and restorative procedures.

2.8 | Periodontal health

Periodontal health was evaluated 1 year after surgery:

1. Sulcus bleeding index was recorded using a periodontal probe to gently slide 1 mm below the gingival margin.

Scores was recorded as 0, 1, 2, and 3. Score 0 as there is no bleeding. Score 1 represents isolated bleeding. Score 2 demonstrates bleeding as 1 red line. Score 3 manifests heavy bleeding.

2. Peri-implant pocket depth (PD) was evaluated as the distance between the bottom of the pocket and the gingival margin. PD was measured mesially and distally using a metalloid periodontal probe.

2.9 | Statistical analysis

Descriptive statistics (mean value, standard deviation, and range) were presented. The demographic characteristics (age, gender) which may be outcome variables were compared with chi-square test. And the statistical analysis was conducted using the statistical package SPSS for Windows version 20.0 (Microsoft Corp.).

Radiographic parameters were first tested if the data was in accordance with Gaussian distribution. And then Kruskal-Wallis test or 1-way analysis of variance (ANOVA) was chosen for analysis. The statistical significance level was fixed at \( P < 0.05 \) and at a confidence interval of 95%.

3 | RESULTS

During the study period, a total of 37 patients were included. Patients were grouped into 3 groups according to the relationship of the root of their maxillary molars and sinus floor (Figure 1). There are 11 patients in group 1 comprised by 4 males and 7 females. The age ranged from 29 to 46. Group 2 consisted of 5 males and 7 females with the age range from 25 to 49. As for group 3, there were 7 males and 7 females from age 35 to 49, as displayed in Table 2.

The bone height between the coronal apex of interradicular crest and sinus floor was displayed in Table 3. Mean bone height for group 1 was 6.60 ± 1.01 mm, group 2 was 5.33 ± 0.63 mm, and group 3 was 4.54 ± 0.64 mm.
4.54 ± 0.64 mm. We discovered the bone height decreased with the penetration of the root to sinus cavity.

The thickness of maxillary mucosa was presented in Table 4. At T1, the mucosa emerged to be thicker in group 3 and group 2 than in group 1. Mean thickness in group 1 was 0.81 mm, group 2 was 1.03 mm, and group 3 was 3.34 mm. Interestingly, the mucosa went thicker after surgery at T2 in group 1 (Figure 3B) and group 2 (Figure 4B). Moreover, it returned as thin as presurgery at T3 that is 6 months after surgery. However, for group 3, the mucosa thickness decreased during T1, T2, and T3. The mean thickness at T3 for group 3 was 1.41 and was comparatively thinner than T1 and T2 (Figure 5).

At 1-year follow-up, periodontal evaluation was performed (Figure 6). Periapical standardized X-ray was delivered. As shown in Table 5, the average for mesial and distal MBL was 0.66 and 0.65 mm in group 1 at 6 months after surgery, 0.63 and 0.70 mm 1 year after surgery. As for group 2, mesial MBL was 0.59 mm at 6 months and 0.67 mm 1 year, distal MBL was 0.66 and 0.65 mm in 1-year follow-up. In group 3, after 1 year, the MBL was 0.70 and 0.73 mm for mesial and distal site. No statistical difference was found among the 3 groups when compared at different time points.

In terms of periodontal health examination, PD and sulcus bleeding were displayed in Table 6. Mesial PD and distal PD were 1.71 and 1.62 mm for group 1. As the case of group 2, mean PD was 1.74 mm at mesial side and 1.77 mm for distal side. In group 3, PD was 1.72 and 1.81 mm. No statistical difference was detected among the peri-implant PD in 3 groups. As for the sulcus bleeding index, there was 1 patient in group 2 scoring 1. This patient had been suffered from mental stress and forgot to use dental floss daily. We earnestly gave him a thorough dental health education.

During the evaluation period, the survival rate of implants was 100% without the implants placed failed. There were no surgical complications. One patient in group 1 suffered from 1 minor criterion for rhinosinusitis. Main complaint was coughing and it lasted 3 days after surgery. One patient from group 2 was observed fatigue as 1 minor criterion. For group 3, 1 patient was complaining fatigue and another patient suffered dental pain. The patients were asked to take good rest and the symptoms disappeared in 1 week after surgery. None of the patients was diagnosed as rhinosinusitis at T1, T2, and T3 in all groups.

### DISCUSSION

The present study discussed sinus floor augmentation combined with immediate implant placement applied in 3 types of relationships between maxillary molar roots and sinus floor.

Sinus floor augmentation as a successful technique to allow implants placed in atrophic maxillary sinus, has been proved as a predictable method. Transcrestal technique has several advantages such as less trauma and decreasing healing time over the lateral technique. Nedir and colleagues reported in their study that even in extremely atrophic maxillary sinus, transcrestal technique was still predictable.

As for the teeth which need to be extracted, there is an open debate to choose immediate implant placement or delayed implant placement. Previous studies have proven that placing an implant at the time of tooth extraction helps to preserve the remaining bone and decreases the need for subsequent ridge augmentation procedures, which reduces the total treatment time, number of surgical procedures,

![Figure 3](image-url) CBCT illustrated maxillary mucosa thickness change in T1, T2, and T3 in group 1. The mucosa was at normal thickness before surgery (A) and went thicker after surgery (B) and returned normal at T3 (C). Red line in horizontal direction demonstrated as the connecting line between buccal and palatal alveolar crest. Red line in vertical direction demonstrated as the extension cord of the membrane measurement at the midpoint of horizontal line.
and the overall cost.\textsuperscript{31–33} Some studies have shown the efficacy of immediate implant placement in fresh lower molars sockets with different success rates and follow-up periods. Cafiero and colleagues reported a 100% success rate after 1 year,\textsuperscript{34} and Fugazzotto 99% after 6 years\textsuperscript{35} while Schwartz-Arad 92% after 5 years.\textsuperscript{36} Despite the high success rate of immediate implant placement, one of the crucial points is to achieve primary stability. In the present study, the presence of sinus floor and interradicular cortical layer helped seize the implant body and guarantee good primary stability. Other researchers also found the importance of taking advantage of the interradicular bone for immediate implant placement.\textsuperscript{8,37} We also choose longer implants than the residual bone height to gain good hard tissue support. The residual roots played a good role for implant orientation guidance and can be extracted smoothly after drill preparation.

The present study showed a possible relationship between the bone height of residual interradicular crest and the relationship of molar roots and sinus floor, however, with a small sample size. Therefore, we should interpret the result with caution. In our study, the mean bone height for group 1, group 2, and group 3 was 6.6, 5.33, and 4.54 mm. Ananda and colleagues studied 60 CBCT scans of 30 Malay and 30 Chinese subjects, they found the mean length of the socket was 7.70 mm (range 5.70–9.00 mm) and harbored the idea that the residual bone would allow immediate implant placement and could also reduce the amount of bone graft.\textsuperscript{17}

The thickened maxillary mucosa is the most common lesion of chronic sinusitis and occurs in approximately 61% patients with edentulous posterior maxillae.\textsuperscript{20} Previous studies have reported that mucosal thickening of the maxillary sinus is affected by infection or apical periodontitis of the posterior maxillary teeth.\textsuperscript{18,38} Furthermore, Teeth with periapical lesions were 9.75 times more susceptible to mucosal thickening than teeth without periapical lesions.\textsuperscript{39} The results of the present study suggested that roots that penetrate to the maxillary sinus are a risk for the sinus mucosal thickening.

As for the mucosa change for implant surgery, our study illustrated for mucosa with a normal thickness (group 1 and group 2), mucosa went thicker after surgery and returned as normal as presurgery 6 months after surgery. We speculated that a blood clot would form under the lifted maxillary mucosa and the clot is important for bone regeneration of sinus floor. Conversely, Timmenga and colleagues found the postsurgical maxillary mucosa thickened triggered by the increasing number of goblet cells, which could be interpreted as a non-specific response of the sinus mucosa.\textsuperscript{40} Therefore, we suppose the thickening of maxillary mucosa as a protective reaction to surgical trauma. During the healing period, the formed blood clot underwent a severe shrink and so the lifted mucosa collapsed.\textsuperscript{41} What’s more, the number of goblet cells descended and the structural aspects of the epithelium and sub-mucosa returned to normal.\textsuperscript{40} As for the patients with a thickened mucosa before surgery, we speculate the infected root as a major factor for mucosa thickening and once the odontogenic infection was removed, the mucosa become thinner as the healing went on.

MBL around the implant is considered one of the most important criteria of implant survey.\textsuperscript{42,43} Albrektsson reported in his study that MBL should not exceed 1.5 mm during the first year of implant function.\textsuperscript{44} In our study, the mean MBL of all the implants was between

\begin{figure}
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\includegraphics[width=\textwidth]{fig4.png}
\caption{CBCT illustrated maxillary mucosa thickness change in T1, T2, and T3 in group 2. The mucosa was at normal thickness before surgery \textbf{(A)} went thicker after surgery \textbf{(B)} and returned normal at T3 \textbf{(C)}. Red line in the horizontal direction demonstrated as the connecting line between buccal and palatal alveolar crest. Red line in the vertical direction demonstrated as the extension cord of the membrane measurement at the midpoint of horizontal line.}
\end{figure}

\begin{figure}
\centering
\includegraphics[width=\textwidth]{fig5.png}
\caption{CBCT illustrated maxillary mucosa thickness change in T1 \textbf{(A)}, T2 \textbf{(B)}, and T3 \textbf{(C)} in group 3. The mucosa went thinner after surgery at T3. Red line in horizontal direction demonstrated as the connecting line between buccal and palatal alveolar crest. Red line in vertical direction demonstrated as the extension cord of the membrane measurement at the midpoint of horizontal line.}
\end{figure}
0.63 and 0.73 mm, which was considered clinically acceptable average. In a recent review, Ozgur and colleagues found that for maxilla posterior implants, the MBL was 0.76 mm for mesial side and 0.82 mm for distal side averagely and the longest follow-up time was 6 years. MBL may be due to bone remodeling and maturation and can be influenced by several factors, such as compression, biological change, and loading condition. For the present study, longer period of follow-up is needed for continuing MBL observing. Furthermore, we consider the PD and sulcus bleeding as important parameters for soft tissue health around implant site. Therefore, we examined PD and bleeding on probing at 1-year follow-up. The PD of mesial and distal site was below 2 mm and showed no statistical difference in 3 groups.

5 CONCLUSION

1. In consideration of the advantages of sinus floor augmentation and immediate implant placement, our clinical result confirms that it is predictable to combine the 2 techniques for replacing maxillary molars especially when using residual roots as implant orientation and taking full advantage of the interradicular crest bone.

2. The relationship of the root of maxillary molars and sinus floor may have an effect on the bone height of the interradicular crest. Comparing with the sockets of none roots penetrating into the sinus cavity, sockets with penetration of the roots may present with lower bone height of the interradicular crest. Conversely, the penetration of the roots may increase the probability of the sinus mucosa thickening.

3. Normally, sinus mucosa went thicker after surgery because of the blood clot formation and goblet cells proliferation. After healing period, sinus mucosa returned as thin as presurgery. For the cases with thickened mucosa, during the healing time, the mucosa becomes thinner than presurgery. We speculate the infected root

<table>
<thead>
<tr>
<th>Table 5</th>
<th>Marginal bone loss of the mesial and distal side of implant site at 6 mo and 1 y after surgery</th>
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<tbody>
<tr>
<td>Group</td>
<td>MBL (mm) at 6 mo</td>
</tr>
<tr>
<td></td>
<td>Mesial</td>
</tr>
<tr>
<td>1 (n = 11)</td>
<td>0.66 ± 0.16</td>
</tr>
<tr>
<td>2 (n = 12)</td>
<td>0.59 ± 0.16</td>
</tr>
<tr>
<td>3 (n = 14)</td>
<td>0.54 ± 0.16</td>
</tr>
<tr>
<td>P</td>
<td>0.13*</td>
</tr>
</tbody>
</table>

MBL was displayed as mean ± SD.
No statistical difference (*P > 0.05) was found comparing MBL at 6 and 12 mo among group 1, 2, and 3.

<table>
<thead>
<tr>
<th>Table 6</th>
<th>Pocket depth and sulcus bleeding index at 12-mo follow-up after surgery</th>
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<tbody>
<tr>
<td>Group</td>
<td>PD (mm) at 12 mo</td>
</tr>
<tr>
<td></td>
<td>Mesial</td>
</tr>
<tr>
<td>1 (n = 11)</td>
<td>1.71 ± 0.32</td>
</tr>
<tr>
<td>2 (n = 12)</td>
<td>1.74 ± 0.30</td>
</tr>
<tr>
<td>3 (n = 14)</td>
<td>1.72 ± 0.26</td>
</tr>
<tr>
<td>P</td>
<td>0.96*</td>
</tr>
</tbody>
</table>

PD was presented as mean ± SD and index score was displayed in frequency.
No statistical difference (*P > 0.05) was found when PD was compared among group 1, 2, and 3.
as a major factor for mucosa thickening and once the odontogenic infection was removed, the mucosa become thinner as the healing went on.

CONFLICT OF INTEREST

The authors have stated explicitly that there are no conflicts of interest in connection with this article. And all authors agreed to the submission.

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How to cite this article: Chen Y, Yuan S, Zhou N, Man Y. Transcrestal sinus floor augmentation with immediate implant placement applied in three types of fresh extraction sockets: A clinical prospective study with 1-year follow-up. *Clin Implant Dent Relat Res.* 2017;00:1–10. [https://doi.org/10.1111/cid.12529](https://doi.org/10.1111/cid.12529)