Improvement of Implant Placement after Bone Augmentation of Severely Resorbed Maxillary Sinuses with 'Tent-Pole' Grafting Technique in Combination with rhBMP-2

Qiao ZHANG[1#], Li Li ZHANG[1#], Yang YANG[1], Yi Zhen LIN[1], Richard J. MIRON[2], Yu Feng ZHANG[1]

Objective: *To study the clinical effect of short implant placement using osteotome sinus floor elevation technique and tent-pole grafting technique with recombinant human bone morphogenetic protein 2 (rhBMP-2) in severely resorbed maxillary area.*

Methods: *Eleven patients with insufficient bone height in the posterior maxillary area were included. According to the native bone height and crown height space (CHS), the patients were divided into two groups: immediate placement of short implants with simultaneous bone augmentation (group A, 5 patients) and delayed dental implant placement (4 to 6 months) after bone augmentation. The rhBMP-2 was added into a deproteinised bovine bone mineral (DBBM) bone grafting material to shorten the treatment procedure and enhance the final effect of bone augmentation in both groups. Tent-pole grafting technique was applied for vertical bone augmentation in group B (6 patients).*

Results: *The success rate of the implants placed was 100% in both groups. In group A, the short implants treatment was successful, with a vertical gain of 1.5 to 6.4 mm in bone height after 4 to 6 months. In group B, the tent-pole grafting procedure in combination with DBBM and rhBMP-2 increased vertical bone height between 3.1 and 8.1 mm, an optimistic and adequate increase for implant placement. This bone increase was maintained following implant placement and final crown placement in the maxillary region (3.5 to 7.3 mm).*

Conclusion: *The tent-pole grafting technique was a viable alternative choice to lateral sinus floor elevation in cases with excessive CHS. The application of rhBMP-2 with a shortened treatment time demonstrated positive outcomes in sinus floor augmentation procedures.*

Key words: *sinus floor augmentation, recombinant human bone morphogenetic protein 2, deproteinised bovine bone mineral, tent-pole grafting, crown height space*

Chin J Dent Res 2017;20(1):9–17; doi: 10.3290/j.cjdr.a37737

1 The State Key Laboratory Breeding Base of Basic Science of Stomatology (Hubei-MOST) and Key Laboratory of Oral Biomedicine Ministry of Education, School and Hospital of Stomatology, Wuhan University, Wuhan, P.R. China.

2 Department of Periodontology, Department of Oral Surgery and Stomatology, School of Dental Medicine, University of Bern, Bern, Switzerland.

# These two authors contributed equally to this work.

Corresponding author: Dr Yu Feng ZHANG, The State Key Laboratory Breeding Base of Basic Science of Stomatology (Hubei-MOST) and Key Laboratory of Oral Biomedicine Ministry of Education, School and Hospital of Stomatology, Wuhan University, Wuhan 430070, P.R. China. Tel: 86-27-87686267; Fax: 86-27-87686267. Email: zyf@whu.edu.cn

This work was supported by the funds of The Youth Chenguang Project of Science and Technology of Wuhan City of China (Grant No.2016070204010147) and the funds of the National Natural Science Foundation of China (Grant No. 81570954) to YF Zhang.

Dental restoration using dental implants in the edentulous posterior maxillae following tooth loss is often associated with insufficient quality and quantity of bone caused by pneumatisation of the sinus cavity[1]. Furthermore, placement of endosseous implants with proper axial inclination is required for a favourable interarch relationship[2,3]. With these goals in mind, different surgical procedures for vertical and horizontal bone augmentation have been developed including, but not limited to, guided bone regeneration (GBR), osteotomies, sinus augmentation, titanium screws and meshes, distraction osteogenesis, onlay block grafts harvested from intraoral or extraoral sites, short implants and a combination of the above-mentioned techniques[4,8].

Among them, sinus floor elevation is one of the most predictable and commonly used procedures, includ-

ing lateral sinus floor elevation (LSFE) [9], osteotome sinus floor elevation (OSFE)[10,11] and modification of either[12-14]. Investigators have more recently shown that the residual crestal bone beneath the sinus floor is the deciding factor between the two techniques[15,16]. Traditionally, OSFE technique has been utilised as a less-invasive procedure to the lateral window osteotomy as an option when the residual bone is 4 mm or greater in height (4 mm of intact alveolar bone has been a point of demarcation for simultaneous grafting and implant placement with a typical healing period of 4 to 6 months suggested if the available host bone height is less than 4 mm[17]. Some studies described a significant difference in the success/failure rates of implants when the residual bone height was less than 4 mm[9,18].

Crown height space (CHS), the distance from the crest of the alveolar bone to the plane of occlusion, which is related to lever arm mechanics, is another important factor to consider during implant placement[19]. It has been shown that each 1 mm increase in CHS is accompanied by a 20% increase in the total cervical load[20]. Gehrke et al stated that CHS was a more significant factor than the crown/implant (C/I) ratio in influencing the biomechanical outcome and prosthetic failure for CHS > 15 mm[21].

Interestingly, in areas where CHS is excessive, tent-pole grafting technique has been a recent grafting technique, with very successful outcomes used in the treatment of severely atrophied mandibles and maxillaes[17,22]. Dental implants[23,24], cortical bone[25], titanium screws[24,26,27] or titanium meshes[28] have all been utilised to create a tenting effect to maintain graft volume and minimise pressure on the grafted area, thereby inducing new bone to grow in the tented space. Xiao et al reported a promising result of bone gain utilising the tent-pole grafting technique with deproteinised bovine bone mineral (DBBM) and porcine collagen membrane (Bio-Oss, Bio-Gide, Geistlich, Wolhusen, Switzerland) after a prolonged treatment period[24]. But the healing time of the screw tent-pole grafting technique was approximately 10 months, which was a long procedure. Bone grafting materials have also been an important factor in both sinus floor elevation technique and tent-pole grafting techniques. Although autogenous bone has been considered the gold standard of bone grafting[29,30], a wide variety of alternative grafts, such as xenografts, allografts and synthetically fabricated bone grafts (hydroxyapatite, tricalcium phosphate, biphasic calcium phosphate and bioactive glasses) have been utilised due to the obvious drawbacks of autogenous bone, including increased patient morbidity, fast turnover rates, increased surgical time and lack of supply[31]. Ideal bone grafts share the features of osteoconduction, osteoinduction, and osteogenesis[32]. The use of rhBMP-2/ACS (absorbable collagen sponge carrier) appeared to be a realistic alternative for augmentation of atrophic anterior maxilla[33]. In order to increase the osteoinductive potential of various xenografts and alloplasts, recombinant human bone morphogenetic protein 2 (rhBMP-2) has been combined with bone grafts to improve new bone formation[29,34-36]. While some studies have investigated the use of rhBMP-2 maxillary sinus floor elevation procedures using a LSFE[4,37-40], few studies have investigated the use of rhBMP-2 in other techniques for sinus elevation. Furthermore, rhBMP-2 has been reported to improve and accelerate the bone maturation process[36,38]. Therefore, the purpose of this study was two-fold. Firstly, to evaluate the short-term outcomes of the tent-pole grafting technique in the minimal edentulous posterior maxilla with inadequate RBH. Secondly, to investigate the effect of rhBMP-2 to shorten the treatment procedure in severely resorbed maxillae.

Materials and methods

Patient selection

The requirements of the Declaration of Helsinki were used for this study, with all patients giving the informed written consents for all surgical procedures. Patients were included in the study if no systemic or local contraindications were encountered. Inclusion criteria were severe atrophy (> 7 mm) of the alveolar process in the sinus area, bi- or unilaterally, and the presence of a Misch type 3 or 4 sinus situation. All patients received oral hygiene instructions before entering the study. The indications for the procedure and possible complications were reviewed with the patients and all patients agreed to proceed and signed a consent form. A total of 11 patients (3 women and 8 men; aged 20 to 69 years old) were included in this study and provided with a total of 14 implants (Table 1). Data related to age, sex, implant location, intraoperative or postoperative complications, implant stability and implant success, and radiographic bone changes were recorded for all patients.

Preoperative work-up

Preoperative work-ups included an assessment of the edentulous alveolar ridges using casts and a diagnostic wax-up. All patients were evaluated preoperatively for the need for sinus augmentation via cone beam

tomography (CBCT) scans. On the basis of information obtained from the preoperation work-up, surgical plans were drawn up. Considering the minimum of bone height from the crest of the ridge to the floor of the sinus and the final prosthesis from the wax-up, planning was done using immediate implant placement with a surgical procedure, including maxillary sinus augmentation (simultaneous approach) (group A), or with sinus floor elevations procedures followed by delayed implant placement (group B).

The surgical procedure of this study is described in Figure 1. There were four situations according to original sinus height (OSH) and CHS: 1) OSH < 4 mm, CHS to be proper; 2) OSH ≥ 4 mm, CHS to be proper; 3) OSH < 4 mm, CHS to be excessive; 4) OSH ≥ 4 mm, CHS to be excessive. Patients in situation 1 would receive regular sinus-lifting procedure and have the dental implant placed after the healing time. In this study, we focus on the other three situations (2 to 4), in which 2 is Group A, and 3 and 4 are Group B.

Recombinant human bone morphogenetic protein-2 (rhBMP-2) (Hangzhou Jiuyuan Gene Engineering, Hangzhou, China) was combined with porous absorbable sponge fabricated from pharmaceutical gelatin, soy lecithin and hydroxyapatite. All surgical procedures were completed by the same surgeon (YZ). In six cases, the sinus height was less than 4 mm (group B), and therefore implants were placed after bone augmentation (two-stage surgery). In the remaining five cases with more than 4 mm of original sinus height (group A), the implants were immediately placed. A total of 16 titanium implants were inserted: five implants using Straumann (Straumann, Switzerland) with 10 mm (3) or 8 mm (2) in length and 4.1 mm in diameter; and 11 implants using Bicon (Bicon, Boston, MA, USA) with 6 mm in length and 5 mm in diameter. All patients received 2 g of amoxicillin 1 h before the surgery. Immediately before the surgical procedure, all patients were instructed to rinse with a 0.2% chlorhexidine solution for 2 min.

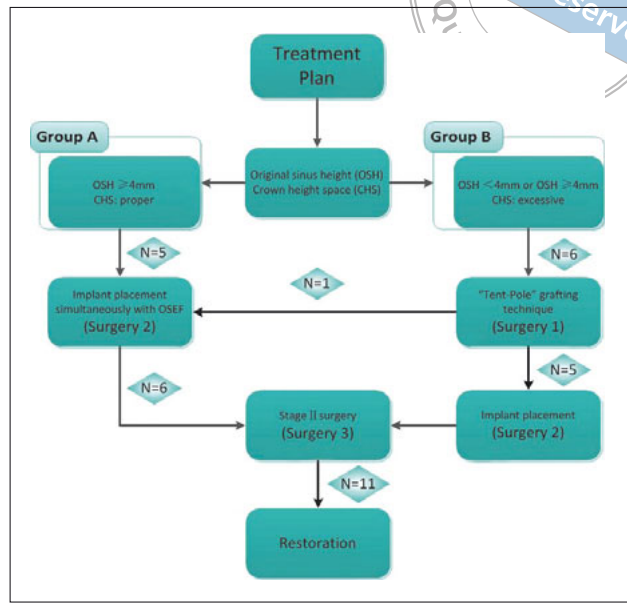

Fig 1 Treatment procedure of this study.

In group A, dental implants were placed (surgery 2) immediately after the osteotome sinus floor elevation. The recipient site was prepared using an appropriate calibrated trephine bur of the same diameter as the implant installed. The trephine ended approximately 1 mm below the sinus floor calculated from the presurgical CBCT. After removal of the trephine bur, the alveolar bone core was confirmed. Next, a calibrated hand osteotome was selected to correspond to the diameter of the trephine preparation. A gentle malleting force was used to cause initial fracture of the sinus floor. The sinus floor was then elevated to displace the Schneiderian membrane apically. This step was performed manually by an experienced surgeon, with special attention paid to avoid perforation of the membrane. Two methods were used to ascertain the integrity of the Schneiderian membrane. The elasticity of the membrane was felt when manually inserting the depth gauge and the Valsalva manoeuvere was confirmed negative. Grafting

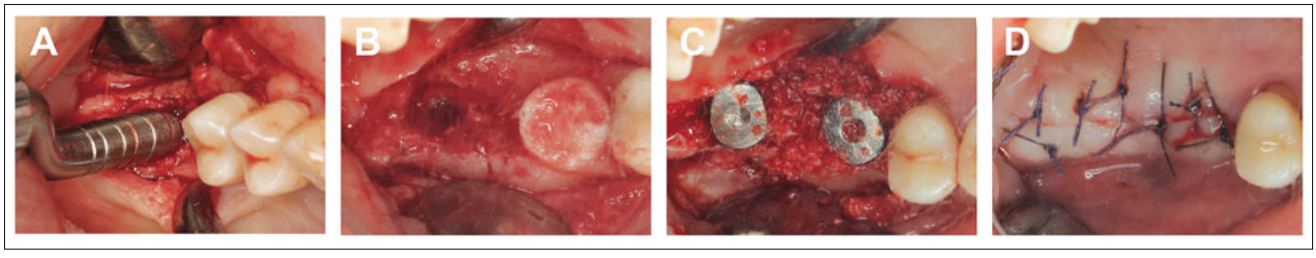

Fig 2 Immediate implant placement with an osteotome sinus floor elevation technique with rhBMP2. **(A)** A calibrated hand osteotome selected to correspond to the diameter of the trephine preparation. **(B)** 1 mg of rhBMP-2 was added apically. **(C)** Implants placed immediately after the elevation. **(D)** Tension-free, interrupted suture of the margins.

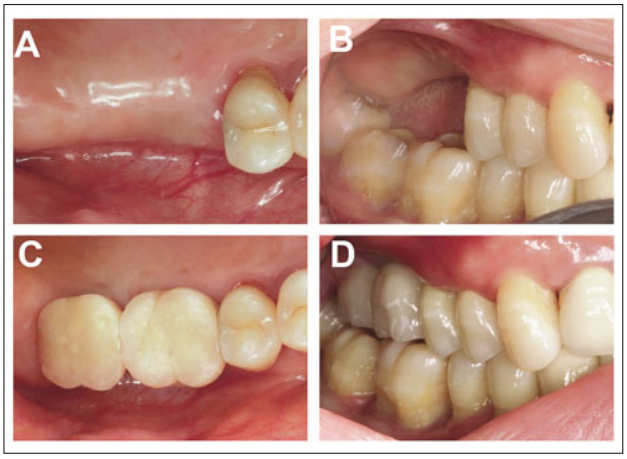

Fig 3 Final restoration **(A to D)**.

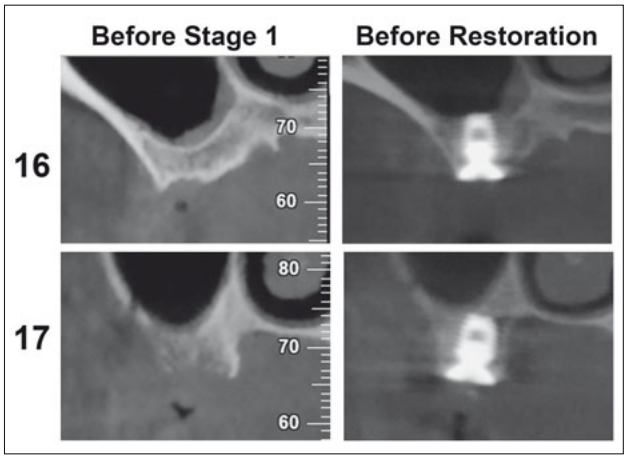

Fig 4 Changes of the sinus height as depicted by CBCT.

material (Bio-Oss collagen, Geistlich Pharma, AG, Wolhusen, Switzerland) rehydrated in blood and 1 mg of rhBMP-2 was added apically. Implants were placed immediately after the elevation. Concerning the healing outcome, the submerged approach was generally preferred for all implants being inserted into less than 8 mm of the initial alveolar bone height. Consequently, a precise tension-free, interrupted suture of the margins was necessary, allowing for primary wound closure (Fig 2). Postoperatively, all patients received 2 g of amoxicillin twice daily for 3 to 5 days after surgery and non-steroid analgesic as needed. All patients were also instructed to maintain good oral hygiene as normal and were instructed to rinse twice daily with 0.12% chlorhexidine gluconate solution over a period of 2 weeks. Patients were also instructed not to blow their nose for 15 days following sinus elevation procedures. The sutures were removed 14 days after surgery. After a healing period of 4 to 6 months, abutment connections were placed. After 6 to 8 weeks, impressions were taken at the level of the implant shoulder. Two weeks later, the prosthetic reconstructions were inserted. All patients were rehabilitated with fixed implant-supported prostheses.

In the delayed implant group (group B), the bone augmentation procedure was performed (surgery 1) in the edentulous area with severe bone loss (ridge less than 4 mm). Where necessary, inflammatory tissue was carefully removed from the defect area. Then the ridge was prepared with a specific drill for the placement of titanium screws (Straumann, Switzerland), with 1 mg of rhBMP2, with its carrier being gently placed in the

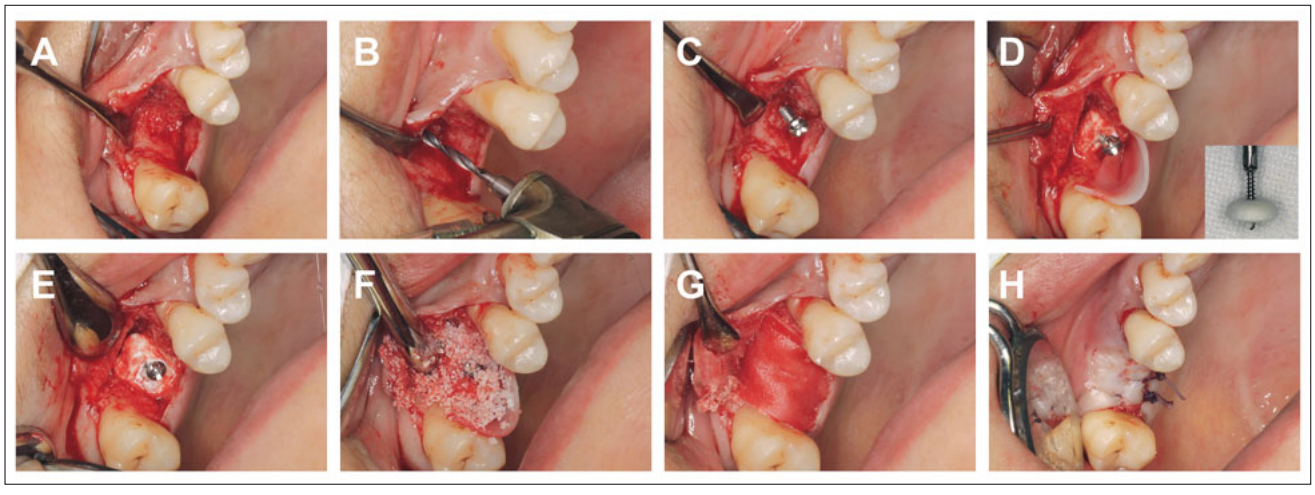

Fig 5 Bone augmentation procedure in group B. **(A)** Demonstration of the initial bone defect **(B to E)** where the ridge was prepared with a specific drill for the placement of titanium screws (Straumann, Switzerland); rhBMP-2 fixed with titanium screws was gently placed in the defect area **(F to G)**. Use of DBBM and with a resorbable porcine-derived collagen membrane covering the defect **(H)** flap closure.

Table 1 Variables and results of the 16 implants during the study period

Case	Age	Sex	Area	Stage	Implant			Before surgery 1	Before surgery 2		Around restoration	
					System	Diameter (mm)	Length (mm)	OSH (mm)	SH1 (mm)	VI1 (mm)	SH2 (mm)	VI2 (mm)
1	60	M	26	1	Bicon	5	6	4.5			8.5	4.0
2	43	F	16	1	Bicon	5	6	4.3			8.6	4.3
			17	1	Bicon	5	6	4.2			10.6	6.4
3	33	M	16	1	Bicon	5	6	5.4			8.1	2.7
4	69	M	16	1	Bicon	5	6	5.3			6.8	1.5
			17	1	Bicon	5	6	3.6			9.8	6.2
5	20	M	16	1	Bicon	5	6	4.5			8.9	4.4
6	45	M	16	2	Bicon	5	6	5.4	13.5	8.1	-	-
7	45	F	16	2	Bicon	5	6	3.1	9.4	6.3	8.6	5.5
8	43	M	16	2	ITI	4.1	10	7.4	11.5	4.1	-	-
			17	2	ITI	4.1	8	3.1	10.4	7.5	9.2	6.1
9	45	F	16	2	ITI	4.1	10	3.9	10.8	6.9	11.2	7.3
10	50	M	16	2	Bicon	5	6	3.2	8.7	5.5	6.7	3.5
			17	2	Bicon	5	6	2.8	8.1	5.3	7.2	4.4
11	59	M	15	2	ITI	4.1	10	7.1	10.2	3.1	10.6	3.5
			17	2	ITI	4.1	8	2.1	7.6	5.3	8.1	6.0
Total			16									
Average										5.8		4.7

OSH: Original sinus height
SH 1: The sinus height after the bone augmentation process (surgery 1)
VI 1: Vertical increase of the sinus between SH1 and OSH (the increase in ridge height)
SH 2: The sinus height after the implant placement (surgery 2) and before the final restoration
VI 2: Vertical increase of the sinus between SH2 and OSH (a combination of the increase in ridge height as well as bone gain on the sinus floor)

defect area and fixed with titanium screws. A bone grafting material (DBBM) rehydrated in blood was filled up to the level of the mesiodistal bone plate. Then the bone-grafted area was completely covered with a resorbable porcine-derived collagen membrane (Bio-Gides, Geistlich Pharma) to prevent bone graft spreading and soft tissue invasion. The incision was repositioned and sutured using 4/0 resorbable suture material (Trofilorc, LorcaMarin, SA, Murcia, Spain) to achieve tension-free closure. Following a 4 to 6-month healing period, after standard preoperative anaesthesia, the tenting screws were removed and implant placement surgery (surgery 2) was then carried out. The regular dental implant placement surgery was taken when the alveolar bone height was sufficient for 5 patients. In the other patient, the bone was still insufficient for regular implant placement despite the bone augmentation procedure. Thus, the implants were placed simultaneously with osteotome sinus floor elevation in the same way as group A. The ostoperative instruction of group B for surgeries 1 and 2 was the same as described for group A.

After a healing period of 3 to 4 months for five of the patients and 5 months for the sixth, abutment connections were placed. After 6 to 8 weeks , impressions were taken at the level of the implant shoulder. Two weeks later, the prosthetic reconstructions were inserted. All patients were rehabilitated with fixed implant-supported prostheses.

Radiographic examinations

We used flat panel detector (FPD)-based CBCT (New Tom FP, Quantitative Radiology, Verona, Italy) for imaging from within our department in the Wuhan University Dental School (China). CBCT scans were obtained before the surgery, immediately after the sinus augmen-

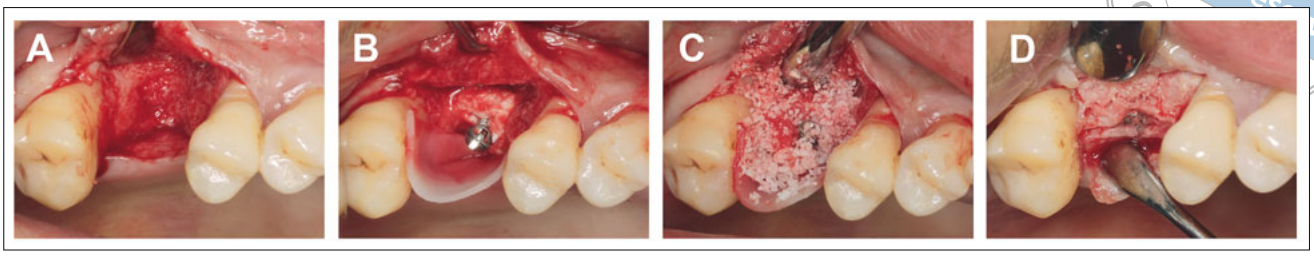

Fig 6 Intraoral changes of the vertical bone height. **(A)** The original defect area. **(B)** Use of a titanium tenting screw with rhBMP-2. **(C)** Use of DBBM and with a resorbable porcine-derived collagen membrane covering the defect. **(D)** The new-formed bone encircling tenting screws replacing the DBBM after the 5-month healing time.

tation (group B only), before the implant placement and before restoration. All measurements were made twice by one blinded investigator. The height was analysed and measured by NNT-Viewer software.

Results

The success rate of implants in this study was 100% in both groups A and B. All the implants were clinically stable and loaded without pain or any subjective sensation. No sinus membrane perforations were reported. The radiographic results (Table 1) demonstrated that the mean sinus increase was 5.8 mm after surgery 1, and 4.7 mm after surgery 2. All cases presented satisfactory results. Figures 2 to 4 present a typical case from Group A and Figures 5 to 9 from Group B.

Discussion

Alveolar bone insufficiency in the posterior maxilla with ridge resorption and sinus pneumatisation is a commonly reported challenge in implant dentistry[41]. Traditionally, the choice of procedure to correct this anatomic deficiency is via maxillary sinus floor elevation[42]. Lateral sinus floor elevation (LSFE) and osteotome sinus floor elevation (OSFE) are two main approaches well documented in the literature. LSEF permits a better effect of bone augmentation to the atrophic maxilla, but requires a much more invasive and longer surgical procedure. With appropriate case selection according to native vertical bone height, reports have now demonstrated no difference in final implant outcomes when case selection be appropriately applied[43]. Initial sinus bone height of less than 4 mm reduced the success rates of implants inserted in combination with osteotome sinus floor elevation[15]. When the native bone height is > 4 mm, implants can routinely be placed simultaneously with OSFE[9,18]. In this study, patients (group A, from case 1 to case 5) with native bone height > 4 mm (except 3.6 mm at tooth 17 in case 4) were treated with the OSFE technique with short implants (Table 1). All implants osseointegrated accordingly with satisfactory final restoration results (Figs 7 to 9).

In sites with < 4 mm bone height, and especially with excessive CHS, LSFE technique would result in a long crown, associated with a longer and increased morbidity treatment period. Screw tent-pole grafting technique has therefore been described as a potential alternative method[17,28]. Xiao et al reported a successful case report of applying this method for bone augmentation, but in their protocol, they used a long healing period of 10 months prior to implant placement[24].

While autogenous bone is considered the gold standard of bone grafting[32], obvious disadvantages, including a limited harvesting supply, unpredictable resorption rates and additional surgical time, have made bone substitution materials necessary in implant dentistry[30]. DBBM is considered one of the most widely used bone

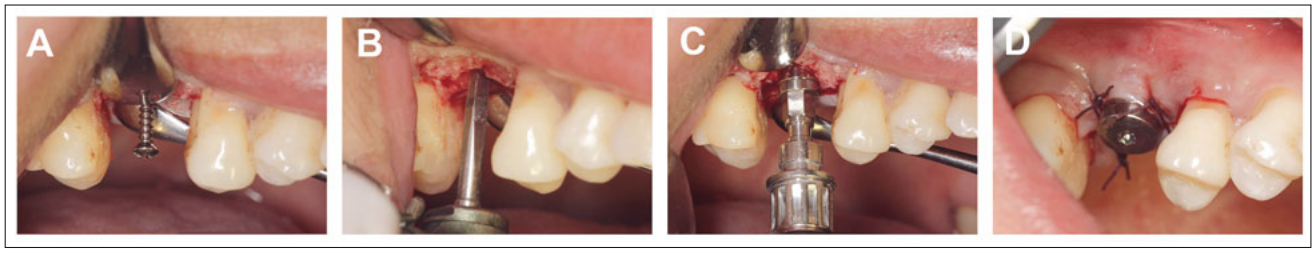

Fig 7 Implant placement surgery (surgery 2). (A) Removal of the titanium tenting screw. (B to D) Tenting screw removal followed by regular implant surgery with a Straumann 4.1 × 10 mm implant.

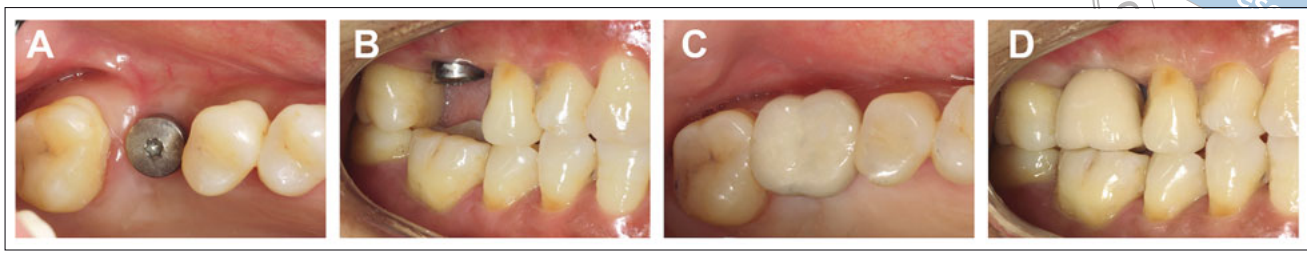

Fig 8 Crown placement (A to D) for case presented in Figs 5 to 7.

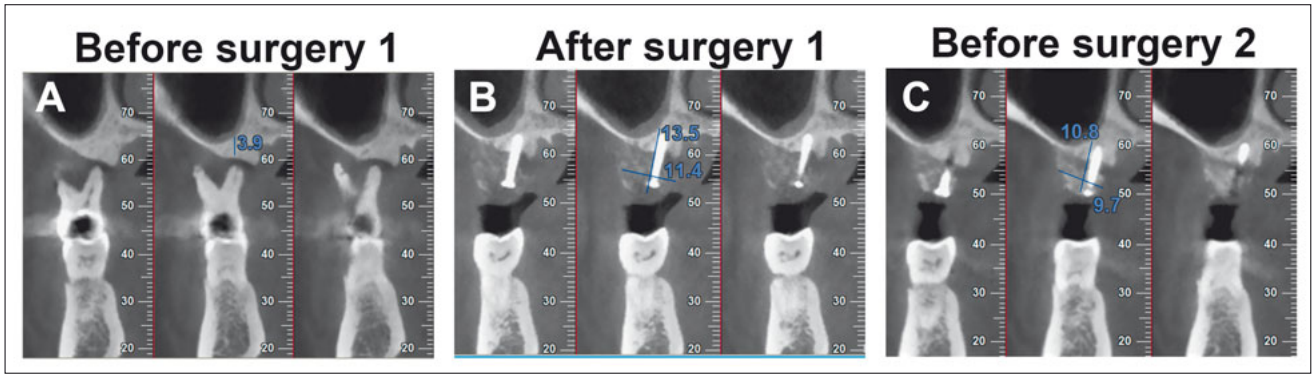

Fig 9 CBCT showing the changes of the vertical bone height. **(A)** The less-optimistic periodontal situation of tooth 16, with an available bone height < 4 mm. **(B)** Situation following extraction of tooth 16 and bone augmentation 2 weeks later. **(C)** After 5 months of healing, the increased density indicating new bone formation in grafted area with rhBMP-2.

substitute materials in oral and maxillofacial surgery due to its low substitution rate, and numerous articles describe its successful use over long healing periods. Despite this, DBBM is not considered osteoinductive and its additional combination with rhBMP-2 is considered a safe and promising alternative for alveolar ridge augmentation procedure[4,29,39,40]. Chen et al have also recently shown that the combination of inlay osteotome sinus floor elevation, concentrated growth factor application and simultaneous short implant placement was a reliable surgical procedure in severely atrophic maxillae[44]. The use of rhBMP-2/ACS appeared to be a realistic alternative for augmentation of atrophic anterior maxillae[33]. Moreover, rhBMP-2 has been reported to improve and accelerate the bone maturation process[36,38]. It therefore became of interest to our group to apply rhBMP-2 in combination with a screw tent-pole grafting technique to better augment atrophic maxillary sinuses with shorter healing periods.

Interestingly, in our case series, group B (patients with < 4 mm alveolar bone height) received a bone augmentation procedure with screw tent-pole grafting technique, and the graft utilised comprised DBBM and rhBMP-2. After a 4 to 6-month (instead of the suggested 10-month) healing period, the acquired bone height increased from 3.1 to 8.1 mm – an optimistic and adequate outcome for implant placement. Following this healing period, stage-two surgery was carried out and final prostheses were adequately fixed (Figs 5 to 9). In this study, the combination of DBBM with rhBMP-2 using the tent-pole grafting technique further corrected the excessive CHS.

In our study, the tent-pole grafting technique with rhBMP-2 in severely atrophic maxillae was utilised successfully to augment vertical bone with little observed resorption. Other authors using the inlay osteotome protocol also reported obvious resorption of their bone core[45,46]. In their study, Chen et al indicated less dynamic bone remodelling during the late stage after surgery[44]. The vertical bone height was relatively stable after surgery using the traditional osteotome technique[47].

In our study, short implants were often utilised (< 10 mm). CHS was a more significant factor than the C/I ratio in influencing biomechanical outcome and prosthetic failure occurred at CHS > 15 mm[21]. Short implants are obvious alternative choices in such cases where maxillary sinus resorption has previously

occurred with documented success rates similar to conventional dental implants[48-50].

In conclusion, the present study reports that:

- With careful planning, tent-pole grafting technique achieved excellent results, especially in clinical situations where the CHS was excessive.
- The cases treated with rhBMP-2 appeared to enhance bone augmentation in both OSEF and tent-pole grafting technique groups.

It may therefore be suggested that both protocols led to adequate results in the severely atrophic maxillary region. Future large randomised comparative studies are needed to fully characterise the influence and necessity of rhBMP-2 during such procedures.

Conflicts of interest

The authors reported no conflicts of interest relating to this study.

Author contribution

Dr Qiao Zhang and Dr Li Li Zhang carried out the data collection, interpretation and statistical analysis, as well as preparing the manuscript; Dr Richard J. Miron prepared and revised the manuscript, Dr Yu Feng Zhang directed the study, performed the surgery, and revised and finally approved the manuscript. All the authors participated in the design of the study.

(Received Nov 12, 2016; accepted Dec 30, 2016)

References

1. Rossetti PH, Bonachela WC, Rossetti LM. Relevant anatomic and biomechanical studies for implant possibilities on the atrophic maxilla: critical appraisal and literature review. J Prosthodont 2010;19:449–457.
2. Avila-Ortiz G, Neiva R, Galindo-Moreno P, Rudek I, Benavides E, Wang HL. Analysis of the influence of residual alveolar bone height on sinus augmentation outcomes. Clin Oral Implants Res 2012;23:1082–1088.
3. Spinato S, Bernardello F, Galindo-Moreno P, Zaffe D. Maxillary sinus augmentation by crestal access: a retrospective study on cavity size and outcome correlation. Clin Oral Implants Res 2015;26:1375–1382.
4. Freitas RM, Spin-Neto R, Marcantonio Junior E, Pereira LA, Wikesjö UM, Susin C. Alveolar ridge and maxillary sinus augmentation using rhBMP-2: a systematic review. Clin Implant Dent Relat Res 2015;17 Suppl 1:e192–201.
5. Deshpande S, Deshmukh J, Deshpande S, Khatri R, Deshpande S. Vertical and horizontal ridge augmentation in anterior maxilla using autograft, xenograft and titanium mesh with simultaneous placement of endosseous implants. J Indian Soc Periodontol 2014;18:661–665.
6. Le B, Rohrer MD, Prasad HS. Screw "tent-pole" grafting technique for reconstruction of large vertical alveolar ridge defects using human mineralised allograft for implant site preparation. J Oral Maxillofac Surg 2010;68:428–435.
7. Felice P, Barausse C, Pistilli R, Spinato S, Bernardello F. Guided "sandwich" technique: a novel surgical approach for safe osteotomies in the treatment of vertical bone defects in the posterior atrophic mandible: a case report. Implant Dent 2014;23:738–744.
8. Teng M, Liang X, Yuan Q, et al. The inlay osteotome sinus augmentation technique for placing short implants simultaneously with reduced crestal bone height. A short-term follow-up. Clin Implant Dent Relat Res 2013;15:918–926.
9. Tatum H Jr. Maxillary and sinus implant reconstructions. Dent Clin North Am 1986;30:207–229.
10. Summers RB. A new concept in maxillary implant surgery: the osteotome technique. Compendium (Newtown, Pa) 1994;15:152,154–156,158; quiz 162.
11. Emmerich D, Att W, Stappert C. Sinus floor elevation using osteotomes: a systematic review and meta-analysis. J Periodontol 2005;76:1237–1251.
12. Pontes FS, Zuza EP, de Toledo BE. Summers' technique modification for sinus floor elevation using a connective tissue graft. A case report. J Int Acad Periodontol 2010;12:27–30.
13. Merli M, Moscatelli M, Mariotti G, Rotundo R, Nieri M. Autogenous bone versus deproteinised bovine bone matrix in 1-stage lateral sinus floor elevation in the severely atrophied maxilla: a randomised controlled trial. Eur J Oral Implantol 2013;6:27–37.
14. Trombelli L, Franceschetti G, Rizzi A, Minenna P, Minenna L, Farina R. Minimally invasive transcrestal sinus floor elevation with graft biomaterials. A randomized clinical trial. Clin Oral Implants Res 2012;23:424–432.
15. Călin C, Petre A, Drafta S. Osteotome-mediated sinus floor elevation: a systematic review and meta-analysis. Int J Oral Maxillofac Implants 2014;29:558–576.
16. Woo I, Le BT. Maxillary sinus floor elevation: review of anatomy and two techniques. Implant Dent 2004;13:28–32.
17. Zakhary IE, El-Mekkawi HA, Elsalanty ME. Alveolar ridge augmentation for implant fixation: status review. Oral Surg Oral Med Oral Pathol Oral Radiol 2012;114:S179–189.
18. Li TF. Sinus floor elevation: a revized osteotome technique and its biological concept. Compend Contin Educ Dent 2005;26:619–620, 622, 624–626 passim; quiz 630, 669.
19. Misch CE, Goodacre CJ, Finley JM, et al. Consensus conference panel report: crown-height space guidelines for implant dentistry-part 1. Implant Dent 2005;14:312–318.
20. Misch CE, Goodacre CJ, Finley JM, et al. Consensus conference panel report: crown-height space guidelines for implant dentistry-part 2. Implant Dent 2006;15:113–121.
21. Gehrke SA. Importance of Crown Height Ratios in Dental Implants on the Fracture Strength of Different Connection Designs: An In Vitro Study. Clin Implant Dent Relat Res 2015;17:790–797.
22. Jung UW, Unursaikhan O, Park JY, Lee JS, Otgonbold J, Choi SH. Tenting effect of the elevated sinus membrane over an implant with adjunctive use of a hydroxyapatite-powdered collagen membrane in rabbits. Clin Oral Implants Res 2015;26:663–670.
23. Marx RE, Shellenberger T, Wimsatt J, Correa P. Severely resorbed mandible: predictable reconstruction with soft tissue matrix expansion (tent pole) grafts. J Oral Maxillofac Surg 2002;60:878-888; discussion 888–889.
24. Xiao T, Zhao Y, Luo E, Hu J. "Tent-Pole" for Reconstruction of Large Alveolar Defects: A Case Report. J Oral Maxillofac Surg 2016;74:55–67.
25. Le B, Burstein J, Sedghizadeh PP. Cortical tenting grafting technique in the severely atrophic alveolar ridge for implant site preparation. Implant Dent 2008;17:40–50.

26. Le B, Rohrer MD, Prasad HS. Screw "tent-pole" grafting technique for reconstruction of large vertical alveolar ridge defects using human mineralized allograft for implant site preparation. J Oral Maxillofac Surg 2010;68:428–435.
27. Pozzi A, Moy PK. Minimally invasive transcrestal guided sinus lift (TGSL): a clinical prospective proof-of-concept cohort study up to 52 months. Clin Implant Dent Relat Res 2014;16:582–593.
28. Louis PJ, Gutta R, Said-Al-Naief N, Bartolucci AA. Reconstruction of the maxilla and mandible with particulate bone graft and titanium mesh for implant placement. J Oral Maxillofac Surg 2008;66:235–245.
29. Zhang Y, Yang S, Zhou W, Fu H, Qian L, Miron RJ. Addition of a Synthetically Fabricated Osteoinductive Biphasic Calcium Phosphate Bone Graft to BMP2 Improves New Bone Formation. Clin Implant Dent Relat Res 2016;18:1238–1247.
30. Miron RJ, Sculean A, Cochran DL, et al. Twenty years of enamel matrix derivative: the past, the present and the future. J Clin Periodontol 2016;43:668–683.
31. Misch CM. Comparison of intraoral donor sites for onlay grafting prior to implant placement. Int J Oral Maxillofac Implants 1997;12:767–776.
32. Miron RJ, Zhang YF. Osteoinduction: a review of old concepts with new standards. J Dent Res 2012;91:736–744.
33. de Freitas RM, Susin C, Spin-Neto R, et al. Horizontal ridge augmentation of the atrophic anterior maxilla using rhBMP-2/ACS or autogenous bone grafts: a proof-of-concept randomized clinical trial. J Clin Periodontol 2013;40:968-975.
34. Urist MR. Bone: formation by autoinduction. Science 1965;150:893–899.
35. Bessa PC, Casal M, Reis RL. Bone morphogenetic proteins in tissue engineering: the road from the laboratory to the clinic, part I (basic concepts). J Tissue Eng Regen Med 2008;2:1–13.
36. Jung RE, Glauser R, Schärer P, Hämmerle CH, Sailer HF, Weber FE. Effect of rhBMP-2 on guided bone regeneration in humans. A randomized, controlled clinical and histomorphometric study. Clin Oral Implants Res 2003;14:556–568.
37. Kelly MP, Vaughn OL, Anderson PA. Systematic Review and Meta-Analysis of Recombinant Human Bone Morphogenetic Protein-2 in Localized Alveolar Ridge and Maxillary Sinus Augmentation. J Oral Maxillofac Surg 2016;74:928–939.
38. Gomes-Ferreira PH, Okamoto R, Ferreira S, De Oliveira D, Momesso GA, Faverani LP. Scientific evidence on the use of recombinant human bone morphogenetic protein-2 (rhBMP-2) in oral and maxillofacial surgery. Oral Maxillofac Surg 2016;20:223–232.
39. Whitesides LM, Radwan A, Sharawy M. Sinus floor augmentation using a composite graft of bone morphogenic protein-2 and allogenic cancellous bone (Puros): case report. J Oral Implantol 2006;32:259–264.
40. Boyne PJ, Lilly LC, Marx RE, et al. De novo bone induction by recombinant human bone morphogenetic protein-2 (rhBMP-2) in maxillary sinus floor augmentation. J Oral Maxillofac Surg 2005;63:1693–1707.
41. Woo I, Le BT. Maxillary sinus floor elevation: review of anatomy and two techniques. Implant Dent 2004;13:28–32.
42. Tetsch J, Tetsch P, Lysek DA. Long-term results after lateral and osteotome technique sinus floor elevation: a retrospective analysis of 2190 implants over a time period of 15 years. Clin Oral Implants Res 2010;21:497–503.
43. Patel S, Lee D, Shiffler K, Aghaloo T, Moy P, Pi-Anfruns J. Resonance Frequency Analysis of Sinus Augmentation by Osteotome Sinus Floor Elevation and Lateral Window Technique. J Oral Maxillofac Surg 2015;73:1920–1925.
44. Chen Y, Cai Z, Zheng D, et al. Inlay osteotome sinus floor elevation with concentrated growth factor application and simultaneous short implant placement in severely atrophic maxilla. Sci Rep 2016;6:27348.
45. Nedir R, Nurdin N, Khoury P, Bischof M. Short Implants Placed with or without Grafting in Atrophic Sinuses: The 3-Year Results of a Prospective Randomized Controlled Study. Clin Implant Dent Relat Res 2016;18:10–18.
46. Lo Giudice G, Iannello G, Terranova A, Lo Giudice R, Pantaleo G, Cicciù M. Transcrestal Sinus Lift Procedure Approaching Atrophic Maxillary Ridge: A 60-Month Clinical and Radiological Follow-Up Evaluation. Int J Dent 2015; 2015:261652.
47. Keestra JA, Barry O, Jong L, Wahl G. Long-term effects of vertical bone augmentation: a systematic review. J Appl Oral Sci 2016;24:3–17.
48. Nisand D, Renouard F. Short implant in limited bone volume. Periodontol 2000 2014;66:72–96.
49. Kang N, Wu YY, Gong P, Yue L, Ou GM. A study of force distribution of loading stresses on implant-bone interface on short implant length using 3-dimensional finite element analysis. Oral Surg Oral Med Oral Pathol Oral Radiol 2014;118:519–523.
50. Felice P, Pistilli R, Barausse C, Bruno V, Trullenque-Eriksson A, Esposito M. Short implants as an alternative to crestal sinus lift: A 1-year multicentre randomized controlled trial. Eur J Oral Implantol 2015;8:375–384.