Radiographic and Clinical Outcomes of Ridge Augmentation in Molar Extraction Sockets with Severe Bone Wall Defect

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Objective: *To describe a technique for socket augmentation in molar extraction sockets with severe bone wall defect.*
Methods: *Five teeth in four patients were included in this study. Each tooth had buccal and/or lingual bone loss identified by bone sounding and periapical radiographs before removal. After a flapless, minimally invasive tooth extraction, the socket was grafted with deproteinized bovine bone mineral with or without a collagen membrane. At the buccal and/or lingual bone defect area, the buccal and/or lingual gingival walls may act as holders, to support the materials. Finally, colloidal silver gelatin sponge was packed gently on top of the graft or membrane to avoid graft or membrane exposure, without attempting to achieve primary closure of the soft tissue. Six months after augmentation, changes in ridge width, ridge height and keratinised tissue were measured on clinical photographs or radiographs.*
Results: *The alveolar bone widths observed at implant surgery were all greater than 6 mm. All patients showed bone augmentation in terms of ridge height. Keratinised tissue width showed increased or minor reductions.*
Conclusion: *Treated with this technique, the deficient socket was re-established in the molar area. Clinically, the quantity and quality of the bone obtained in the grafted sockets allowed for successful implant placement.*
Key words: *flapless surgery, gelatin sponge, molar teeth, severe bone wall defect, socket augmentation*
Chin J Dent Res 2015;18(4):221–228; doi: 10.3290/j.cjdr.a35146

Loss of ridge volume and shrinkage of ridge contour after tooth extraction have been documented in numerous animal[1-3] and human studies[4-6]. It was reported that the average dimensional reduction within 6 months after tooth extraction were 3.80 mm in ridge width and 1.24 mm in ridge height[7]. Such alterations in socket dimension may interfere with subsequent rehabilitation treatment. To maintain as much alveolar bone as possible, various surgical protocols designed for socket preservation have been proposed. Allografts[8,9], xenografts[10,11] and different bone substitutes[5,12,13], with or without membranes[14], have been used. Interventions applied to intact sockets should be referred to as 'ridge preservation' because they are intended to preserve the ridge volume within the envelope[15]. It has been reported that the ridge volume reduction can be decreased after ridge preservation[16].

In patients with advanced periodontitis, some teeth should be extracted due to severe bone loss. After removal of these teeth, the bone walls of the sockets are not intact, which often results in ridge volume, which is severely reduced during socket healing. In such cases, the ridge volume would be severely insufficient for implantation. To prevent such unexpected results, 'ridge augmentation' was proposed and was to be performed immediately after teeth extraction[15]. This term emphasises that the grafted ridge volume extended beyond the skeletal envelope that was present at the time of extraction, and should be distinguished from

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'ridge preservation'. A few previous ridge augmentation studies focused primarily on non-molar sockets with only buccal wall defects[17-19]. However, the predictability and expected outcome of ridge augmentation in sockets with severely deficient plates in the molar area remains unknown.

Primary wound closure has always been considered a key factor for success in socket preservation/augmentation therapy. Many approaches to wound closure have been reported. The raising of a full-thickness flap and coronal advancement are generally used[10,20]. However, due to high tension and postoperative swelling[21], patients often develop wound dehiscence during healing. Furthermore, mobilisation of the buccal flap often causes displacement of the mucogingival junction, resulting in a reduction of keratinised tissue on the buccal side[22]. Another method for wound closure is the use of an additional soft tissue graft, which overcomes the disadvantages of coronal flap advancement. However, a second surgical area is required and the benefits of a supplementary tissue graft have been questioned because reports did not show obvious advantages[1,15,23].

To manage wound closure after preservation/augmentation, Wang[8,9] and Sisti[17] reported a technique for wound sealing, by covering the wound with a bioabsorbable collagen plug. This technique, drawing inspiration from the Bio-Col technique proposed by Sclar, showed predictable outcomes. A colloidal silver gelatin sponge (Gelatamp; Coltene, Altstätten, Switzerland) is a biomaterial applied routinely after tooth extraction for hemostasis and promotion of wound healing. To date, no study has reported the effectiveness of using such a gelatin sponge for wound closure in ridge preservation or augmentation.

Thus, the purpose of this pilot study was to describe a technique for socket augmentation in molar sockets with severe bone loss. At the same time, the efficacy of using deproteinized bovine bone mineral (DBBM; Bio-Oss, Geistlich, Wolhusen, Switzerland) as a filler and a colloidal silver gelatin sponge (Gelatamp, Coltene) as a cover after posterior tooth extraction was assessed.

Materials and methods

Four patients (two males and two females, age range: 37 to 60 years old) participated in this study. Each patient had at least one molar tooth scheduled for extraction and implant restoration. If the tooth had buccal and/or lingual bone loss, whereby at least 3 mm was identified by bone sounding and periapical radiographs before extraction, it was selected. Aside from this, all patients were physically healthy. Before surgery, all patients received initial periodontal therapy and exhibited good oral hygiene. All patients were informed of the treatment procedure and signed an informed consent form.

Surgical procedure

All teeth studied were extracted with the following procedures: after local anesthesia, a no. 15C blade was used to cut off the supracrestal gingival fibers around the tooth, and if necessary, roots were separated before extraction. The periodontal ligament was then severed with a periotome. The tooth was not extracted until it was sufficiently loose, which meant that it could be extracted gently without damaging the residual socket plate. The socket was carefully and thoroughly curetted to remove granulation tissue and repeatedly irrigated with 0.9% saline to ensure that no soft tissue remained. The integrity of the socket walls was assessed again. Once the buccal and lingual bony walls were intact, the tooth was excluded from this study. Then, the residual bone walls were scraped to generate bleeding and stimulate new bone formation and graft incorporation. Next, graft materials (DBBM, Bio-Oss) were placed into the extraction socket, as high as 1 to 2 mm below the marginal gingiva to enhance the preservation and augmentation effects. At the buccal and/or lingual bone defect area, the buccal and/or lingual gingival walls acted as holders to support the materials, in order to ensure the materials could be placed at least 3 mm beyond the residual bone envelope. The grafts were covered by a resorbable collagen membrane in patient 3 and patient 4. The colloidal silver gelatin sponge was packed gently on top of the graft or membrane to avoid graft or membrane exposure. A combination of cross-mattress and interrupted sutures was applied to stabilise the sponge, without attempting to achieve primary closure of the soft tissue.

Postoperative procedure

All patients underwent antibiotic therapy for 3 to 5 days. Ibuprofen was also given to help control pain and relieve the inflammatory reaction and swelling. All patients rinsed with 0.12% chlorhexidine twice per day for 4 weeks. The patients returned 14 days later for soft tissue evaluation and suture removal. They were then asked to visit every 2 weeks until complete wound closure was observed.

Placement of implant

All patients underwent implant insertion (Straumann Standard RN implants with an SLA® surface; Institute

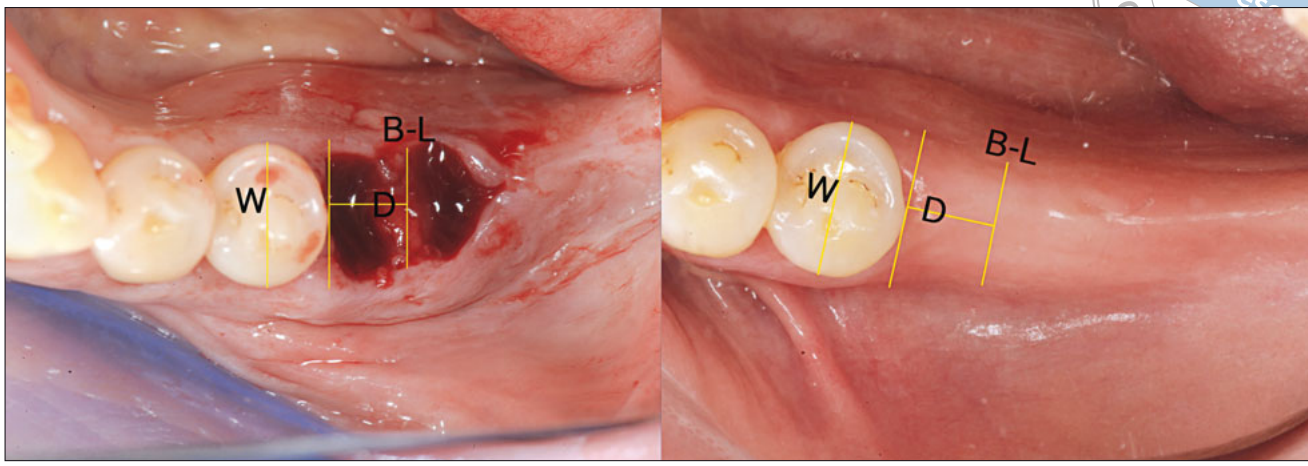

Fig 1 Linear clinical measurements of ridge contour width; W: buccal-lingual size of the adjacent tooth as a standard; D: distance from the adjacent tooth (5 mm); B-L: ridge contour width.

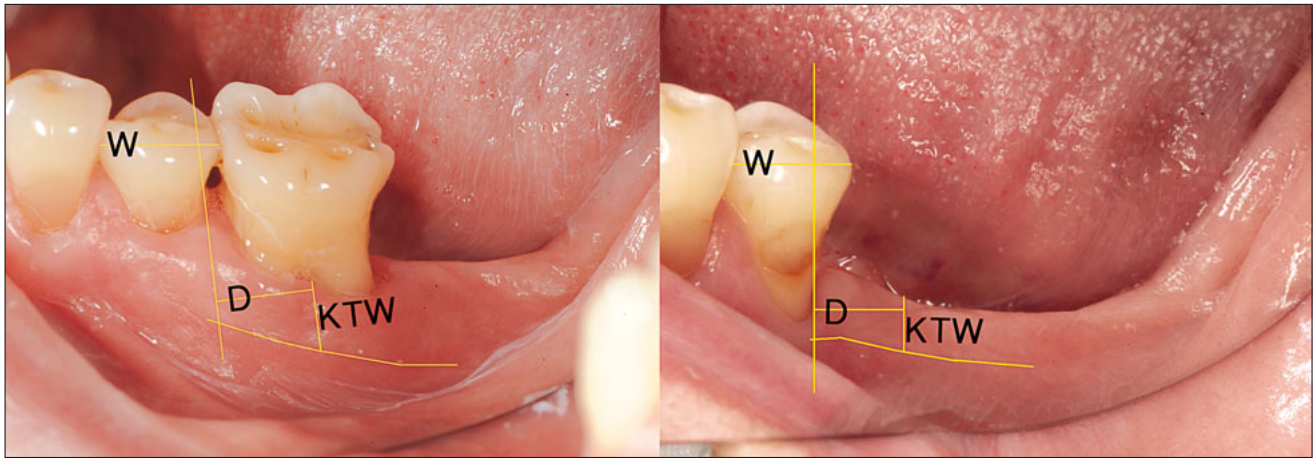

Fig 2 Linear clinical measurements of keratinised tissue width; W: mesiodistal size of the adjacent tooth as a standard; D: distance from the adjacent tooth (5 mm); KTW: keratinized tissue width.

Straumann AG, Basel, Switzerland) at least 6 months (range: 6 to 17 months) after ridge augmentation. In patient 1 and patient 4, 4.8 mm × 10.0 mm implants were used, while 4.1 mm × 10.0 mm implants were used for the others. Secondary augmentation was performed if indicated. Also whether or not the implant could be placed completely within the alveolar housing or there was a need for secondary augmentation was recorded.

Clinical evaluation

Clinical photographs were taken from the occlusive and buccal view immediately after augmentation surgery and immediately before implant surgery. Changes in the ridge contour width and keratinised tissue width (KTW) were evaluated between photographs. The tooth width was measured clinically at the patient's follow-up visit and was used to standardise the pictures, to make the measurement data comparable.

On the occlusive view, the ridge contour width was measured at the middle point of the line that connected the mesial tooth's distal face and the distal tooth's mesial face (Fig 1). A distal-extension absence was present in patients 2 and 4, so the measurement was taken 5 mm away from the mesial tooth. As two implants were placed in patient 4, the second measurement point was 13 mm away. The KTW was recorded at the same points on the buccal-view photographs (Fig 2). Additionally, after the flap was elevated during the implant surgery, a photograph was taken and the alveolar bone width was documented using the aforementioned method.

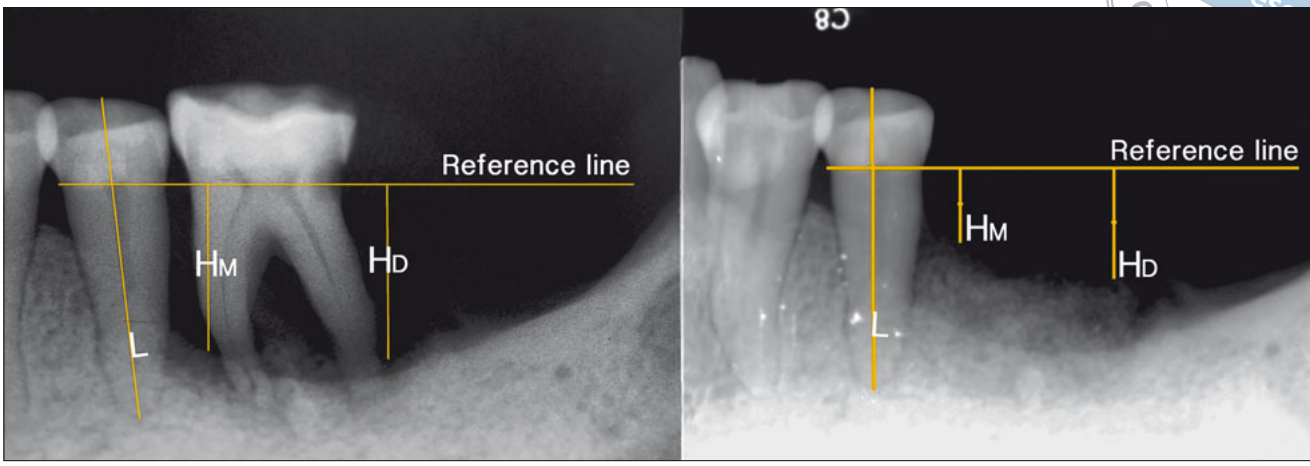

Fig 3 Linear radiographic measurements from reference line to crestal bone levels. L: the length of adjacent tooth as a standard; HM: the mesial crestal bone level; HD: the distal crestal bone level.

Radiographic evaluation

Periapical radiographs were obtained before tooth extraction and immediately before implant surgery in patients 1 and 4, and panoramic radiographs were obtained in the other patients. The images were used to evaluate the changes in the alveolar bone height. First, on the radiographs taken before tooth extraction, a reference line was made by joining the cementoenamel junctions of the adjacent teeth. Also, distances from the reference line to the bone crest at the mesial and distal points of the tooth were measured, representing the alveolar bone height (Fig 3). The greater the distance, the lower the bone crest. The length of the mesial or distal points to the root of the adjacent tooth was recorded. Using these lengths, the bone level was measured at the same position on the radiographs taken before implant surgery. Similarly, the length of a specific tooth was used as a standard to allow for data comparison.

Results

The general status of the four patients and the reasons for tooth extraction are shown in Table 1. All teeth extracted were in the molar regions, and the sockets were not intact. The buccal plate was deficient in patient 1, and the lingual plate was deficient in patient 3. Moreover, patients 2 and 4 showed almost complete loss of both buccal and lingual bony walls. At 4 to 6 weeks after treatment, complete wound coverage was achieved in all sites, with no active infection during the healing period in any of the patients.

Implant surgery was carried out 6 to 17 months after ridge augmentation (Table 1). Only one secondary bone regeneration procedure was performed for patient 4 in the second molar area.

On clinical photographic assessment, a small amount of ridge contour width reduction was seen in all patients, ranging from 0.07 to 2.24 mm (Table 2). However, after flap elevation during implant surgery, the alveolar bone width in all cases was greater than 6 mm (Table 3).

The changes in the KTW are presented in Table 2. One patient showed an increase in the KTW. The others showed minor reductions in the KTW, ranging from 0.01 to 0.77 mm.

Changes in ridge height at both mesial and distal sites are shown in Table 4. Seven out of 10 sites exhibited gains in bone height (1.66 to 5.14 mm). Patients 2 and 3 showed bone augmentation at both distal and mesial sites, while the other patients showed bone augmentation at the mesial or distal sites. Two cases are illustrated in Figures 4 and 5.

Discussion

Severe alveolar bone defects often occur in periodontally compromised teeth. After tooth extraction, the socket with bony defects result in severely insufficient bone volume, compared with the remodelling of an intact socket. Such an inadequate volume can interfere with the successful placement of dental implants and make implant surgery more complex. In our pilot study, we reestablished the deficient alveolar bone at the time of tooth removal using a flapless, minimally invasive extraction and augmentation procedure. All patients

Table 1 General information about the patients.

Patient	Sex	Age	Smoking Habit	Extracted Tooth*	Reason for extraction	Time for implantation
1	Female	42	No	36	Periodontal-endodontic combined lesions	11 months later
2	Female	60	No	36	Severe chronic periodontitis	17 months later
3	Male	37	No	36	Residual roots	7 months later
4	Male	55	Yes	16 and 17	Severe chronic periodontitis	6 months later

*Federation dentaire international system

Table 2 Changes of ridge width and KTW.

Variables (Patient No.)	Initial (mm)	Final (mm)	Change (final-initial) [-:decrease; +:increase]	Percentage change (%)
Ridge contour width				
1	8.40	8.33	-0.07	-0.83
2	7.29	6.33	-0.96	-13.17
3	8.77	6.53	-2.24	-25.54
4 (16)	10.20	8.29	-1.91	-18.73
4 (17)	10.66	8.61	-2.05	-19.23
KTW				
1	3.43	3.27	-0.16	-4.66
2	3.85	4.06	+0.21	+5.45
3	0.96	0.95	-0.01	-1.04
4 (16)	4.00	3.23	-0.77	-19.25
4 (17)	4.30	4.14	-0.16	-3.72

showed promising ridge morphology and sufficient bone volume for implant placement. Implant surgery was thus simplified in these patients.

To our knowledge, there are few reports of ridge augmentation in molar sockets with severe bone loss. Although these molar sockets lost the buccal or lingual wall or both, we obtained successful results. Rasperini et al performed a study on molar socket preservation,

Table 3 Alveolar bone width measured during implant surgery.

Patient No.	Alveolar bone width (mm)
1	7.64
2	6.24
3	6.51
4 (16)	7.00
4 (17)	6.95

Table 4 Changes in ridge height.

Variables (Patient No.)	Initial (mm)	Final（mm）	Change (final-initial) [-:decrease;+:increase]	Percentage change (%)
Vertical distance (mesially)				
1	2.10	2.64	-0.54	-25.71
2	8.52	3.80	+4.72	+55.40
3	2.60	0.94	+1.66	+63.85
4 (16)	5.36	6.21	-0.85	-15.86
4 (17)	14.39	12.60	+2.79	+19.39
Vertical distance (distally)				
1	7.54	2.40	+5.14	+68.57
2	9.88	6.25	+3.63	+36.74
3	2.00	0.00	+2.00	+100
4 (16)	14.39	12.60	+2.79	+19.39
4 (17)	7.04	9.76	-2.22	-31.53

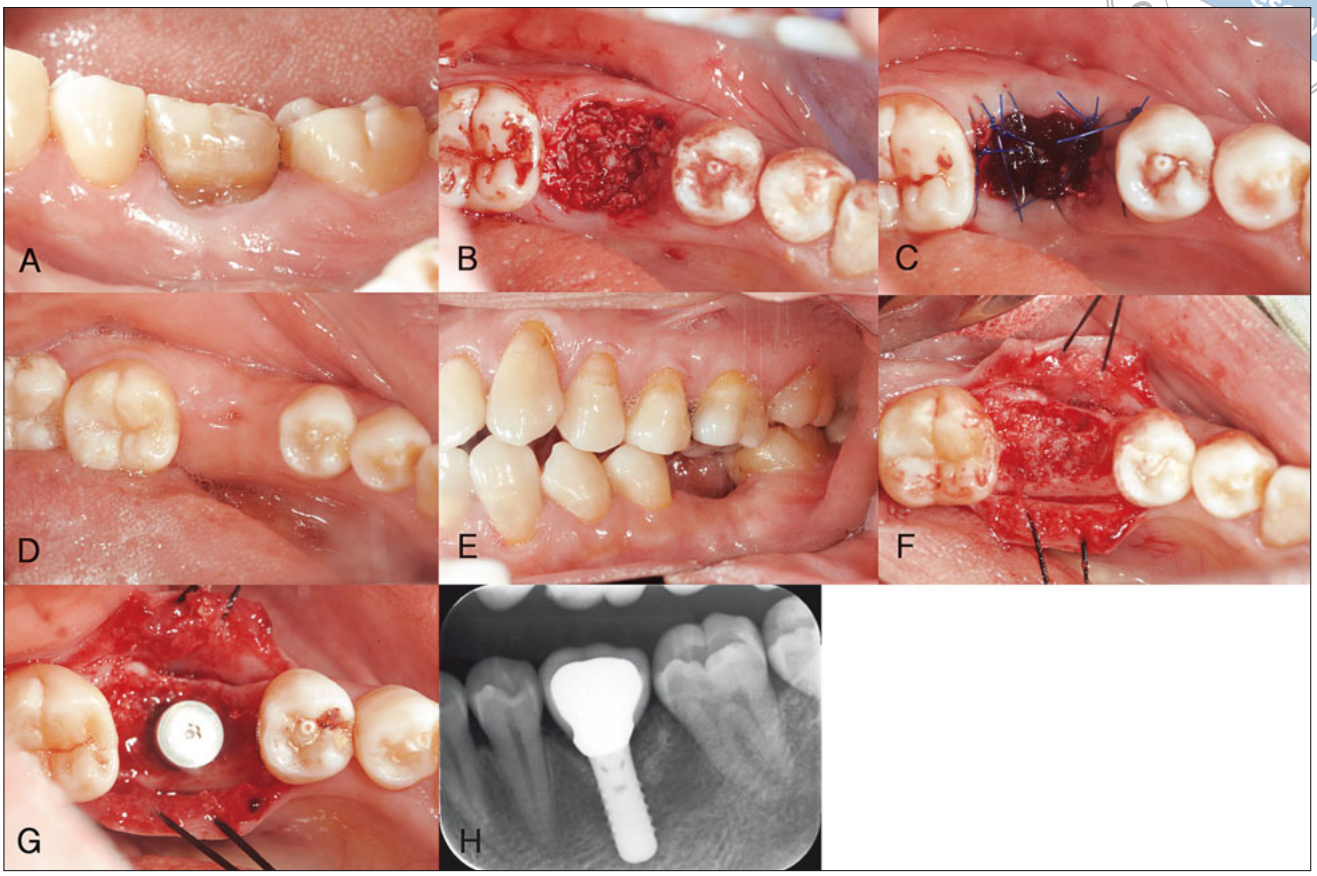

Fig 4 Patient 1. **A)** Buccal view of tooth 36 before extraction. **B)** Occlusal view after the Bio-Oss was placed. **C)** Occlusal view after packing and the suturing sponge on top of the socket. Grafts were completely covered by sponge. **D)** Occlusal view at 11 months postoperatively. **E)** Buccal view at 11 months postoperatively. **F)** Occlusal view after flap elevation. **G)** Occlusal view after implant placement. **H)** Periapical radiograph taken 3 months after implant insertion showed that both implant and augmented bone were stable.

but all sockets preserved in the test group had four walls intact[6]. Other researchers have studied socket preservation in molar and premolar areas without mentioning the integrity of the bony walls after tooth removal. Sisti et al described a socket augmentation procedure for severely resorbed alveolar sockets and obtained satisfactory results in terms of horizontal width[17]. Barone et al and Wang et al also treated bone deficiency in fresh sockets and described promising outcomes[18,19]. However, their studies were performed only in non-molar regions, and only the buccal plate was absent. Bone defects in molar and non-molar regions are not the same. The dimensions of the missing bone wall are usually larger and wider in molars, which makes socket augmentation procedures and bone regeneration more difficult. It is a great challenge when managing a molar extraction socket with severe bone wall defects, and our study describes our successful experience and provides evidence for dealing with such cases.

The ridge augmentation approach in this study was effective. To reestablish the original shape and dimensions of the ridge, DBBM was placed in the socket, 1 to 2 mm below the gingival margin. The remaining soft tissue walls on the buccal and lingual sides were used to house the grafts in the sockets. Additionally, the gelatin sponge not only protected the graft materials from exposure but also stabilised the wound and finally promoted wound coverage, which is favourable for bone regeneration. The vertical height of the alveolar bone was increased from 1.66 to 5.14 mm at most sites. Due to a lack of similar research, we compared the vertical height alteration in our study with data from studies of non-molar sockets. Previous findings also showed a bone level improvement from 0.7 to 6.5 mm, similar to our results[17,19]. The few occurrences of decreased bone levels occurred in sites with relatively intact bone walls. This is consistent with the results of previous studies on ridge preservation, which found

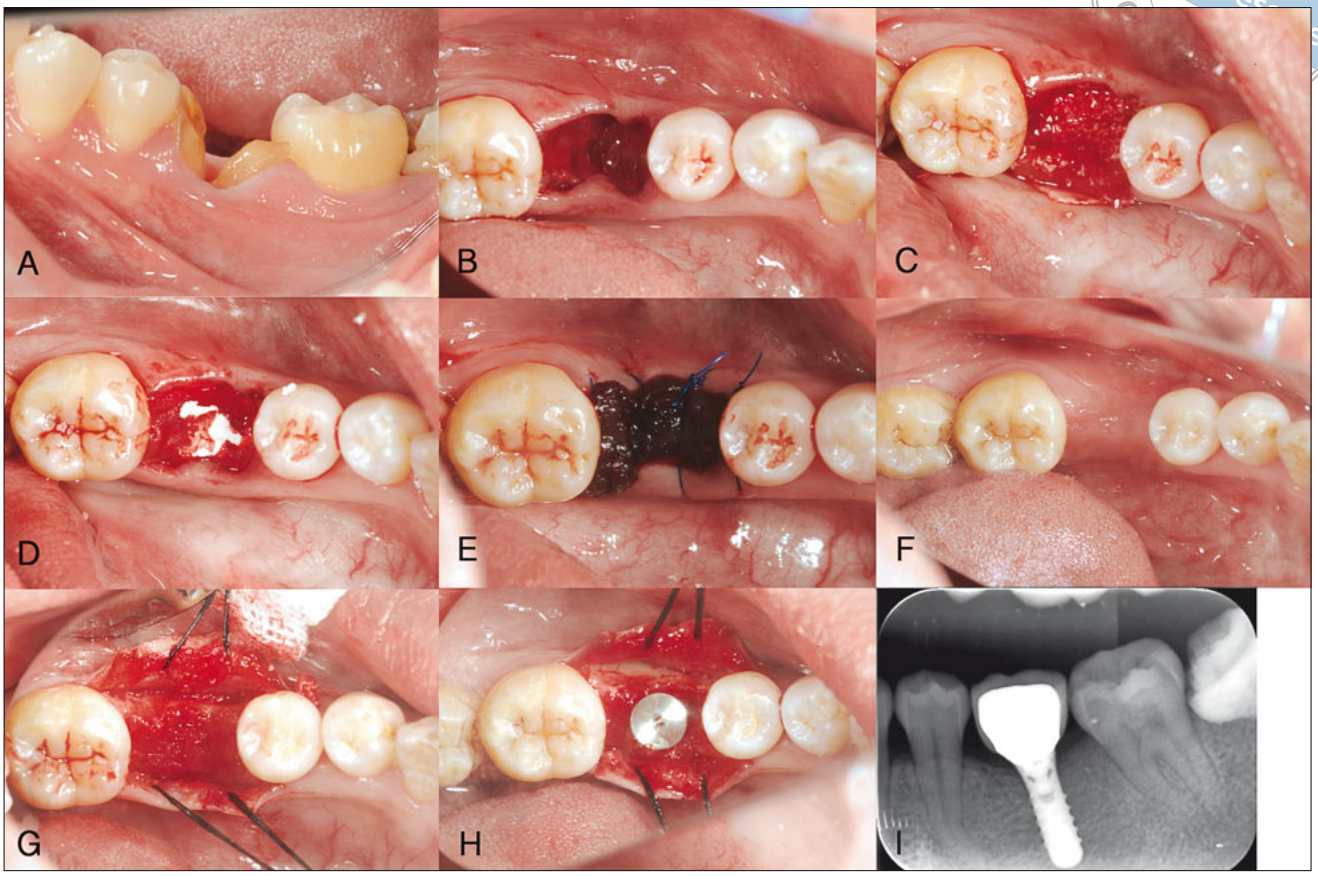

Fig 5 Patient 3. **A)** Buccal view of tooth 36 before extraction. **B)** Occlusal view after tooth extraction and debridement of the socket. **C)** Occlusal view after Bio-Oss was placed in the socket. **D)** Occlusal view after Bio-Gide membrane covered the lingual defect and folded on top of the graft. **E)** Occlusal view after packing and suturing sponge on top of the socket; grafts and membrane were completely covered. **F)** Occlusal view at 7 months postoperatively. **G)** Occlusal view after flap elevation. **H)** Occlusal view after implant placement. **I)** Periapical radiograph taken 3 months after implant insertion showed both implant and augmented bone were stable.

that changes in ridge dimension can be reduced, but not prevented[16]. A small reduction in the ridge contour width (0.07 to 2.24 mm) was seen in our patients, but the alveolar bone width was still greater than 6 mm, and standard implants could be inserted successfully. A similar result was reported by Cardaropoli et al[11]. In the premolar and molar areas, the socket preservation group showed an average reduction of 1.04 mm in ridge width from baseline to 4 months as shown by cast measurements.

Keratinised tissue was another outcome variable, and minor reductions were detected. This could have been due to the flapless method, gelatin sponge use, and overfilling with DBBM. In an animal experiment, the additional flap elevation led to 0.7 mm more shrinkage of the buccal aspect compared with a flapless procedure[24]. The reflection of a full-thickness flap would disrupt the blood supply to the plate, and this was considered to negatively affect bone remodelling[25]. Furthermore, a flapless procedure could make the mucogingival junction stable. The gelatin sponge used in our trial had the advantage of promoting soft tissue coverage. It seemed to be as effective as other materials in the literature. Moreover, when compared with a soft tissue graft, the gelatin sponge was easy to use and reduced patient suffering. Given that keratinised tissue is always considered a significant factor in terms of implant function and aesthetics[22], more attention should be given to soft tissue volume preservation at the time of tooth removal.

Limitations of this pilot study include the method of the measurements i.e. no fixed device was used. Furthermore, the width and height of the alveolar ridge were measured on photographs and radiographs. However, because of the standardised images, the data still demonstrates the effectiveness of our protocol to some degree.

Conclusion

Our surgical protocol for ridge augmentation in molar sockets with bone defects showed predictable outcomes. With this treatment, the clinical quantity and quality of the bone obtained in the grafted sockets ensured successful implant placement. Future randomised controlled clinical trials with sufficient sample sizes and precise measurements are needed to validate the effectiveness of this surgical procedure. Additionally, long-term observation is needed to ensure the long-term stability of implants in the grafted areas.

Conflict of interest

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

Author contribution

Dr Wen Yang for collecting the clinical data, assisting the surgery and research, and writing the paper; and Dr Xiangying Ouyang for the design of the study, for directing the research and for completing the surgery.

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