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Horizontal ridge augmentation using autogenous block grafts and the guided bone regeneration technique with collagen membranes: a clinical study with 42 patients

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Abstract

Objective: To analyze the clinical outcome of horizontal ridge augmentation using autogenous block grafts covered with anorganic bovine bone mineral (ABBM) and a bioabsorbable collagen membrane.

Material and methods: In 42 patients with severe horizontal bone atrophy, a staged approach was chosen for implant placement following horizontal ridge augmentation. A block graft was harvested from the symphysis or retromolar area, and secured to the recipient site with fixation screws. The width of the ridge was measured before and after horizontal ridge augmentation. The block graft was subsequently covered with ABBM and a collagen membrane. Following a tension-free primary wound closure and a mean healing period of 5.8 months, the sites were re-entered, and the crest width was re-assessed prior to implant placement.

Results: Fifty-eight sites were augmented, including 41 sites located in the anterior maxilla. The mean initial crest width measured 3.06 mm. At re-entry, the mean width of the ridge was 7.66 mm, with a calculated mean gain of horizontal bone thickness of 4.6 mm (range 2–7 mm). Only minor surface resorption of 0.36 mm was observed from augmentation to re-entry.

Conclusions: The presented technique of ridge augmentation using autogenous block grafts with ABBM filler and collagen membrane coverage demonstrated successful horizontal ridge augmentation with high predictability. The surgical method has been further simplified by using a resorbable membrane. The hydrophilic membrane was easy to apply, and did not cause wound infection in the rare instance of membrane exposure.

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Horizontal ridge augmentation of a deficient alveolar bone site is performed either simultaneously with implant placement, or with a staged approach prior to implant insertion. The main criteria to consider when choosing the procedure are the residual bone volume needed to allow correct implant positioning, the bone density needed to achieve primary implant stability, and the defect morphology of the periimplant bone defect. In the esthetic zone, additional factors must be taken into account, such as the gingival biotype and the level of the lip line.

Common sites for horizontal ridge augmentation are the anterior (esthetic) zone in the maxilla and the posterior area in the mandible. While traumatic tooth loss mostly affects adolescents and young adults, resulting in bone deficiencies in the anterior maxilla, mandibular bone atrophy is often found in the posterior

segments in elderly people who may have long-standing narrow ridges following premature tooth loss because of endodontic or periodontal problems.

A variety of surgical techniques have been described to enhance the bone volume of deficient implant-recipient sites, such as the use of onlay or veneer grafts, ridge splitting, or bone condensation. The most common methods include grafting procedures, with or without coverage by a barrier membrane (guided bone regeneration (GBR)). Horizontal ridge augmentation with autogenous block grafts and a bioinert and expanded polytetrafluoroethylene (ePTFE) membrane is well documented, with good clinical results (Buser et al. 1993, 1995, 1996). On the other hand, it has been demonstrated in several experimental and clinical studies that non-protected onlay bone grafts may undergo surface resorption, whereas graft resorption can be minimized with the use of ePTFE membranes (Widmark et al. 1997; Chiapasco et al. 1999; Antoun et al. 2001; von Arx et al. 2001). However, the utilization of ePTFE membranes has some disadvantages as well: handling and fixation of the hydrophobic membrane is difficult; incision and flap management are demanding; and the technique harbors a certain risk of wound dehiscence with membrane exposure and subsequent site infection (Augthun et al. 1995; Chiapasco et al. 1999). Therefore, clinicians and researchers started looking for alternative barrier membranes in the mid-1990s (Lundgren et al. 1994; Zellin et al. 1995; Simion et al. 1996; Zitzmann et al. 1997). Today, after more than 10 years of experimental and clinical experience, the application of bioabsorbable membranes – in particular, collagen membranes – appears to have overcome these problems (Carpio et al. 2000; Hämmerle & Lang 2001; Tawil et al. 2001; Friedmann et al. 2002). However, the barrier function and the membrane longevity of resorbable membranes may vary considerably, thereby limiting their barrier function to a few weeks (Zellin et al. 1995; Zhao et al. 2000; Owens & Yukna 2001).

In contrast, anorganic bovine bone mineral (ABBM) has been shown to be resistant to resorption following placement into bony defects or as an onlay graft (Jensen et al. 1996; Berglundh & Lindhe 1997; Araujo et al. 2002). Therefore, this bone substitute seemed appropriate to be combined with autogenous bone grafts and collagen membranes with a limited barrier function. The objective of this clinical cohort study was to analyze the outcome of a combined application of ABBM particles and a collagen membrane in order to protect autogenous block grafts from surface resorption.

Material and methods

The study sample comprised 42 patients (19 males, 23 females; mean age 34 years; range 17–75 years) who were consecutively enrolled in the study (Figs 1 and 2). Patients were fully informed about the surgical procedures and treatment alternatives. The main inclusion criterion was severe atrophy of the alveolar ridge in the horizontal plane (≤ 4 mm), or a crest width ≤ 5 mm in esthetic sites with a high lip line. Preoperative analysis included a complete medical history, a clinical and radiographic examination of the stomatognathic system, and a thorough analysis of the implant-recipient site. Cross-sectional images (reformatted CT scans) were obtained when the clinical assessment of the crest width was doubtful.

Site preparation

Patients were premedicated intramuscularly with a sedative (Dormicum®, Roche Pharma, Reinach, Switzerland), a centrally active analgesic (Tramal®, Grünenthal Pharma, Mitlödi, Switzerland), and atropin to reduce the salivary flow. The dosage of premedication was adjusted according to the body weight. In all patients, the surgery was performed under local anesthesia (Ultracain® DS forte, Aventis Pharma, Zurich, Switzerland). A palatal incision (in posterior mandibular sites, a mid-crestal incision) was made, and intrasulcular buccal and palatal incisions at the adjacent teeth including vestibular divergent-releasing incisions. Full mucoperiosteal flaps were raised on the facial and palatal/lingual aspects, and retracted with sutures. The bony crest was curetted to remove all soft tissues. The remaining crest width was measured with a pair of callipers to the nearest half of a millimeter (pre-augmentation width, Fig. 3). No template was used to determine the exact site of measurement. Measurements were taken 1 mm below the highest point of the remaining crest at the center of the future implant site that was defined as follows: for single tooth gaps, the site was chosen half-way between the adjacent teeth, whereas in multiple tooth gaps or in distal extension situations, the sites and distances were determined according to the recommendations of Belser et al. (2000). The defect dimensions were measured with a periodontal probe to determine the approximate size of the block graft to be harvested. Using a small round bur, the facial cortex was perforated to open up the bone marrow cavity to optimize vascular supply of the recipient site.

Block graft harvesting

Depending on the size of the required bone block and the donor site anatomy, the block grafts were either harvested from the symphysis (36 patients) or from the retromolar area (six patients).

In the symphysis, a curved incision was made below the muco-gingival line and a mucoperiosteal flap was raised. The size of the block graft was outlined with a small round bur. Following connection of the drill holes with a fissure bur, the block graft was mobilized. One or two gliding holes were drilled for the lag screws before removal of the block graft. Additional cancellous bone was harvested with curettes or curved chisels from the donor site. In the retromolar area, a trapezoidal flap was raised and the block graft was harvested in a similar manner. Sharp bony edges were smoothened and the donor defect was packed with collagen (TissuCone E or TissuFleece E, Baxter AG, Volketswil, Switzerland). Primary wound closure was accomplished with mattress or single interrupted sutures.

Ridge augmentation

When necessary, the bone block was slightly adapted to the defect site morphology. With a spiral drill, the holes for the bone block fixation screws (GBR-System, Straumann, Basel, Switzerland) were prepared in the residual palatal/lingual bone wall. One or two screws (diameter 1.5 mm) were used to stabilize the block graft. Sharp edges of the bone blocks were rounded off with large diamond burs. The augmented crest width was measured again with a pair

of callipers (post-augmentation width), as outlined above. Voids around the block grafts were filled with cancellous bone grafts or bone chips harvested from the donor site. An ABBM particulate graft (Bio-Oss®, Geistlich AG, Wolhusen, Switzerland) was mixed with blood obtained from the surgical site. This mixture was applied to cover the applied block graft and bone chips entirely. The augmented site was further protected with a collagen membrane (Bio-Gide®, Geistlich AG) using the double-layer technique to improve membrane stability. A periosteal-releasing incision was made to allow for flap mobilization and a tension-free primary wound closure. Wound adaptation was accomplished with single interrupted sutures.

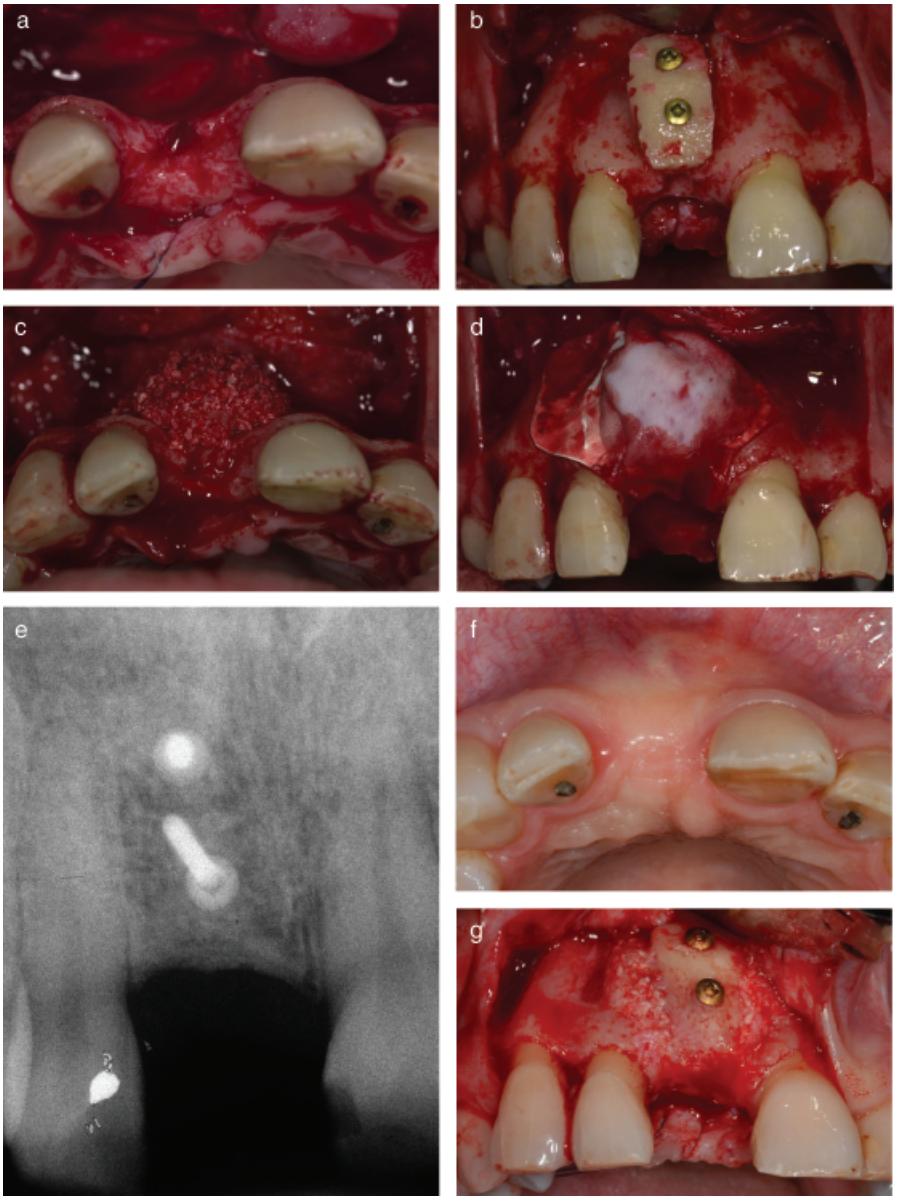

Fig. 1. Trauma case with horizontal bone deficiency in the esthetic zone (right central maxillary incisor). (a) Marked concavity of the facial bone contour. (b) A block graft harvested in the symphysis was fixed in a vertical position for horizontal ridge augmentation and convex recontouring of the future implant site. (c) The block graft was fully covered with anorganic bovine bone mineral particles. (d) The augmented site was further protected with a collagen membrane using the double-layer technique. (e) The post-operative radiograph shows the two fixation screws. (f) Healing was uneventful, and the new convex profile of the vestibule is visible. (g) Upon re-entry (6 months after the augmentation surgery), the block graft shows no surface resorption. (h) The occlusal view clearly demonstrates the horizontal gain of bone width. (i) A Straumann implant was placed in a correct oro-facial position. (j) The implant shoulder was aligned slightly apical to the cemento-enamel junction of the adjacent central incisor. (k) The clinical situation 17 months after implant placement. (l) The radiograph taken at the same time depicts stable peri-implant bone structures.

Medication and follow-up

Perioperative antibiotic prophylaxis was routinely practiced for 3–6 days. Patients were also given analgesics and chlorhexidine digluconate (0.1%) for chemical plaque control. Sutures were removed 7–10 days postoperatively. Removable provisionals were adapted, but patients were instructed to wear the provisionals with caution. Follow-up examinations were performed 3 and 5 months after ridge augmentation, before patients were scheduled for re-entry and implant placement.

Re-entry

The flap outline was similar to the first surgery. However, vestibular-releasing incisions were shorter and surgical access was limited to the crestal area. Following mucoperiosteal flap elevation and debridement, the healed crest width was measured again with a pair of callipers (re-entry width). The bone block fixation screws were removed, and implant bed preparation and implant insertion were accomplished according to standard surgical protocols (Buser & von Arx 2000; Buser et al. 2004).

Results

All 42 patients completed the study and could be re-evaluated at the time of implant placement (prospective closed cohort). A total of 58 sites were augmented (Tables 1 and 2). The mean width of the residual alveolar ridge was 3.06 mm (range 0.5–5 mm) (Table 3). The mean width of the augmented ridge measured 8.02 mm (range 6–10 mm).

Healing was uneventful in all but four patients (9.5%). In one patient, a hematoma required incision with subsequent wound dehiscence. Three patients developed small membrane exposures shortly after ridge augmentation, probably because of tension of the wound margins. However, all sites showed normal healing, with spontaneous re-epithelization within 2–4 weeks.

The average period from ridge augmentation to re-entry was 5.8 months (range 4.5–13.5 months, the latter a patient who became pregnant in between the two surgeries). At re-entry, the healed augmented alveolar crest had a mean width of 7.66 mm (range 6–10 mm). The mean

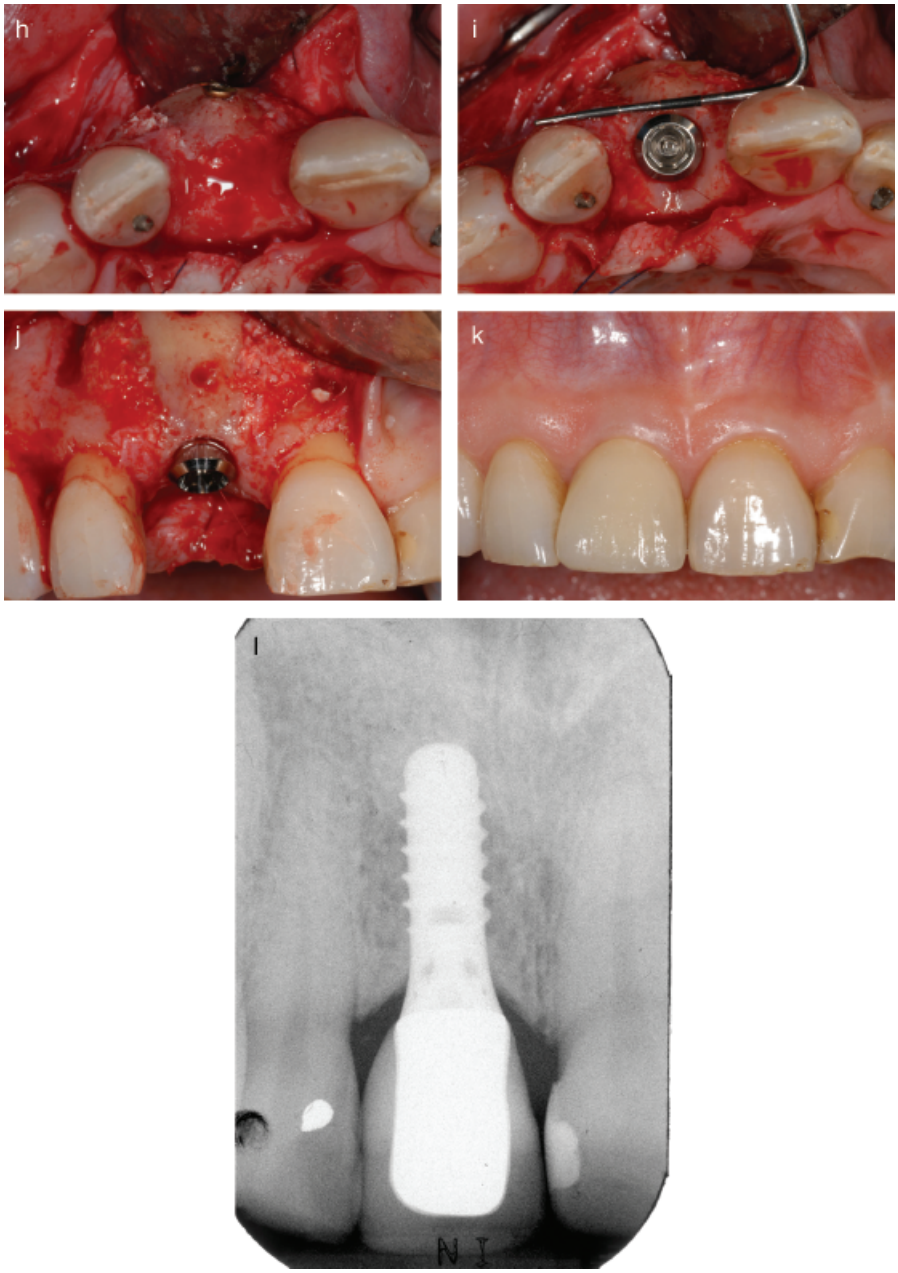

Fig. 1. Continued

calculated gain of lateral ridge augmentation was 4.6 mm (Table 3). The overall surface resorption of block grafts was minimal (0.36 mm), with only two sites requiring minor re-grafting upon implant placement. This surface resorption or bone loss of 0.36 mm equals 7.2% of the original thickness of the applied block graft.

Discussion

The present study confirmed the results of a previous study (Buser et al. 1996) in which an autogenous block graft was also used for horizontal ridge augmentation prior to implant placement, but in combination with ePTFE membranes. While the former surgical protocol included the application of a non-resorbable barrier membrane (ePTFE), the present study evaluated the protection of block grafts provided by a non-resorbable filler material (ABBM particles) together with a collagen membrane. While Buser et al. (1996) reported a mean crest width gain of 3.53 mm, the mean gain in the present study amounted to 4.6 mm.

The advantage of the presented technique is the utilization of a resorbable collagen membrane that clearly simplifies the surgical technique. However, as collagen membranes have a relatively short duration of barrier function (Miller et al. 1996; Zhao et al. 2000; Owens & Yukna 2001), the block grafts have to be protected from surface resorption by other means. In a recent clinical comparative study, Maiorana et al. (2005) have shown the beneficial effect of block graft coverage using ABBM particles. They reported resorption of only 9.3% for sites treated with ABBM particles, whereas sites without such a coverage demonstrated a bone resorption of 18.3%. While this application of ABBM particles on the outer surface of autogenous bone blocks has not yet been investigated histologically, experimental studies have shown that this bone substitute, when placed into bone defects, demonstrates slow and minimal resorption, if any (Jensen et al. 1996; Araujo et al. 2002; von Arx et al. 2002).

With regard to osseous integration of ABBM particles placed in alveolar ridge defects or extraction sockets, conflicting results have been reported in clinical and experimental studies. While the majority of experimental studies reported osseous integration of ABBM particles (Fukuta et al. 1992; Klinge et al. 1992; Thaller et al. 1993; Jensen et al. 1996; Berglundh & Lindhe 1997; Schmitt et al. 1997; Hämmerle et al. 1998; Hürzeler et al. 1998; Hockers et al. 1999), reduced osteoconductivity was found in a number of other studies (Pinholt et al. 1991; Young et al. 1999; von Arx et al. 2002). In clinical studies, ABBM particles have shown promising results, particularly in smaller periimplant defects (Skoglund et al. 1997; Zitzmann et al. 1997; Artzi et al. 2000). In contrast, use of ABBM particles in extraction sockets resulted in limited new bone formation (Carmagnola et al. 2003; Norton et al. 2003).

In the present study, however, the ABBM filler material was used for block graft protection and not for osteopromotion. As the filler particles were placed onto the outer cortical portion of the block graft, osseous integration of the particles was not anticipated because of the lack of vascular supply from the block graft (Zerbo et al. 2003). At re-entry, the ABBM particles showed fibrous encapsulation and were deflected from the block graft when the mucoperiosteal flaps were raised.

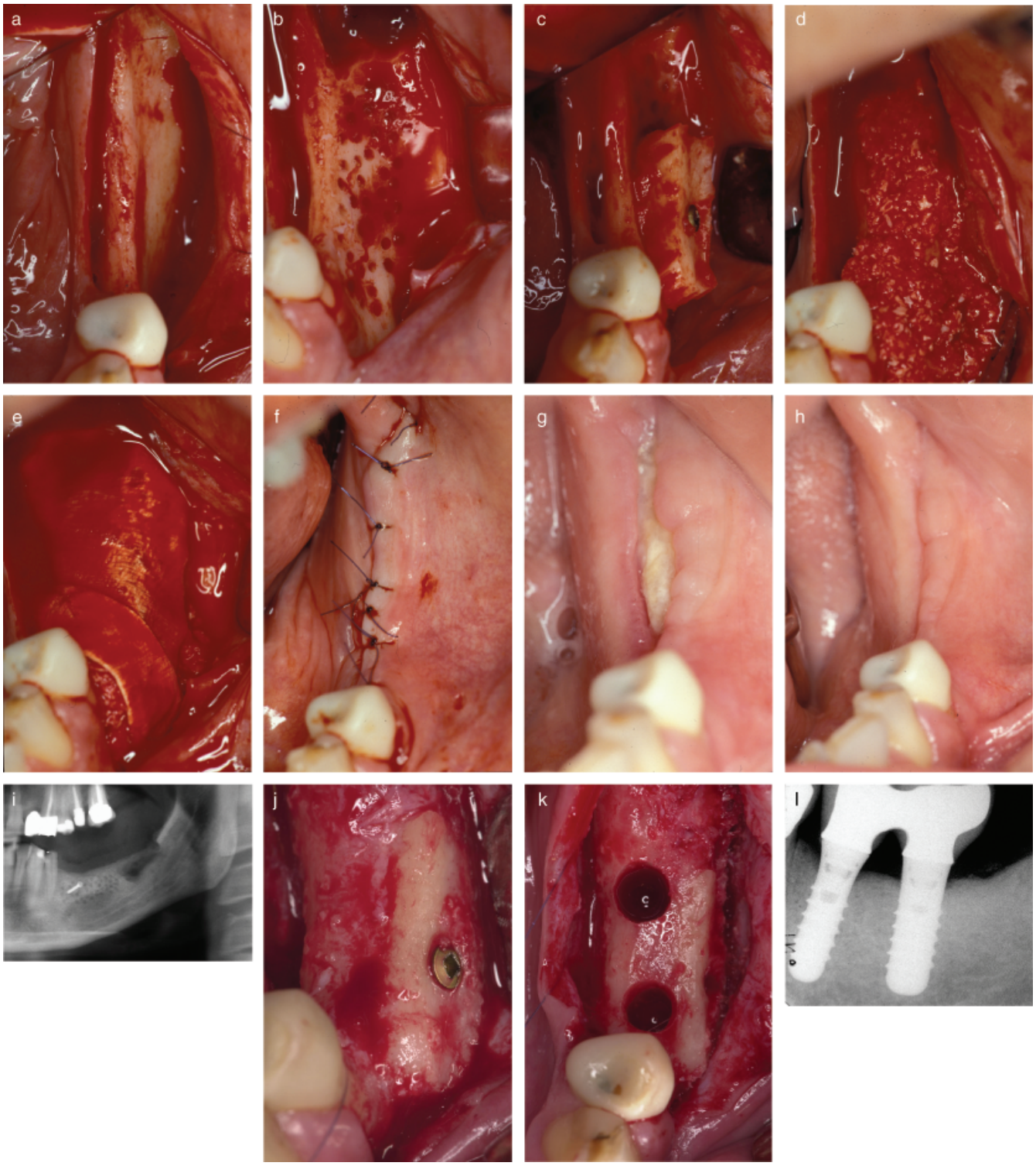

Fig. 2. Distal extension situation in the posterior mandible with horizontal augmentation of a knife-edge thin ridge. (a) Following a crestal incision with vestibular release incisions and mucoperiosteal flap elevation, the thin residual ridge is clearly visible. (b) The bone cortex was perforated with a small round bur to induce bleeding from the marrow cavity. (c) A block graft was harvested in the retromolar area posterior to the augmentation site and was stabilized with a fixation screw. (d) A mixture of blood and anorganic bovine bone mineral particles was placed to cover the augmentation site entirely. (e) A collagen membrane was applied using the double-layer technique. (f) Primary wound closure was accomplished with single interrupted sutures. (g) Membrane exposure was evident two weeks after ridge augmentation. (h) After 2 more weeks, the site had healed spontaneously. (i) The panoramic radiograph depicts the augmentation site as well as the harvest site in the left posterior mandible. (j) Although a membrane exposure had occurred, the volume of the block graft was fully maintained, as observed during re-entry. (k) Two implant beds could be prepared correctly, with sufficient bone width at the vestibular aspects. (l) The radiograph taken 17 months after implant insertion demonstrates stable peri-implant bone conditions.

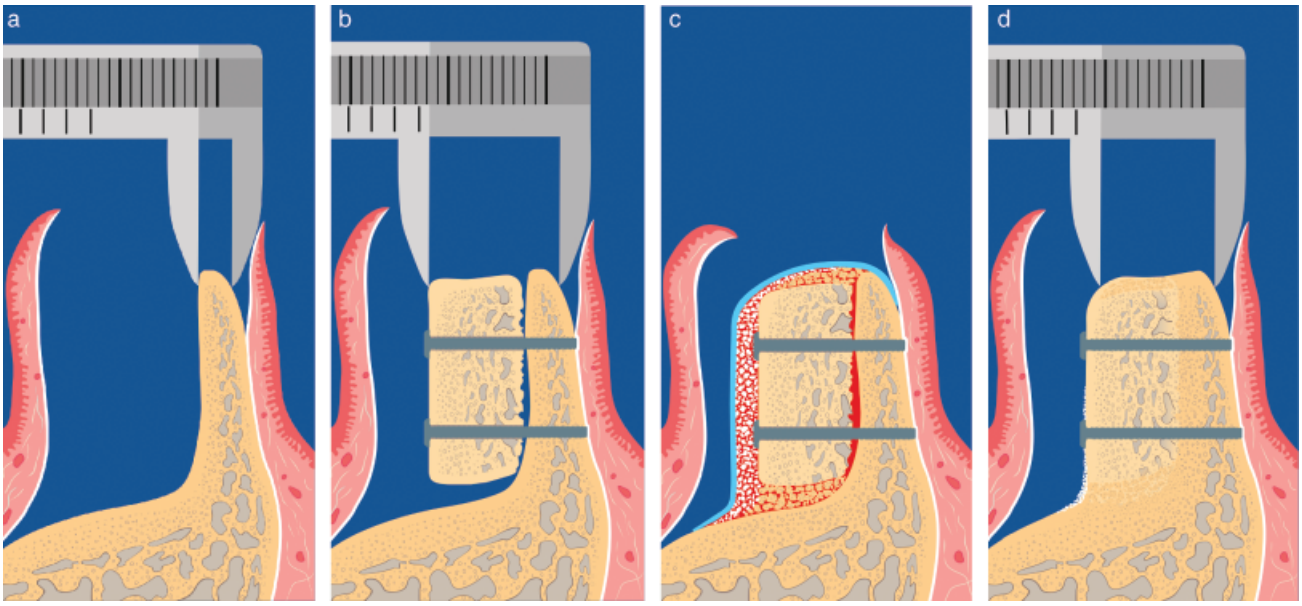

Fig. 3. Schematic illustrations of the measurements of ridge width and of the technique of horizontal ridge augmentation. (a) Measurement of the residual ridge width following flap elevation and debridement of all soft tissues. (b) Measurement of the augmented ridge following block graft fixation. (c) Voids around the block graft were filled with autogenous bone chips and the block graft was fully covered with anorganic bovine bone mineral particles and collagen membranes. (d) Measurement of the healed ridge at re-entry.

***Table 1.* Extension of sites ($n = 58$) to be augmented per patient ($n = 42$)**

Extension of sites	*n* patients	*n* sites
One site	27	27
Two sites	14	28
Three sites	1	3
Total	42	58

***Table 2.* Location of sites ($n = 58$)**

Location	*n* sites
Maxilla, anterior (incisors, canines)	41
Maxilla, posterior (premolars, molars)	3
Mandible, anterior (incisors, canines)	0
Mandible, posterior (premolars, molars)	14
Total	58

However, in the periphery of the block graft, i.e., on the distal and mesial aspects where particulate grafts have been applied, ABBM particles were often found incorporated into the newly formed bone.

The surface resorption of block grafts in the present study was only 7.2%, similar to the reported bone loss of 9.3% in the study of Maiorana et al. (2005). It is possible, however, not proven, that the additional application of a barrier membrane may have resulted in a better outcome in the present study. The mere placement of a particulate graft without additional stabilization onto the surface of a block graft might explain the different outcome in Maiorana's study compared with the technique of filler stabilization using a collagen membrane in the present study.

A marked resorption of 17% was reported for onlay block grafts used for vertical alveolar ridge augmentation (Proussaefs et al. 2002). In that clinical study with eight patients, ABBM particles were only applied to the periphery but not onto the block grafts, and sites were not covered with barrier membranes. Interestingly, the authors observed exposures of the block grafts in three out of eight patients, occurring 3 months after bone grafting in two of three patients.

The efficacy of membrane coverage of block grafts has also been demonstrated in a comparative clinical study (Antoun et al. 2001). However, the authors evaluated a non-resorbable ePTFE membrane. Graft sites with membrane showed a mean surface resorption of 0.3 mm (mean initial graft width of 4 mm = resorption rate of 7.5%) compared with graft-alone sites exhibiting a mean resorption of 2.3 mm (mean initial graft width of 5.1 mm = 45% resorption rate). Shortcomings of ePTFE membranes have been reported, however, such as wound infection following membrane exposure (Gher et al. 1994; Augthun et al. 1995; Nowzari & Slots 1995) and outcome correlation with healing complications (Simion et al. 1994; Zitzmann et al. 1997; Machtei 2001).

***Table 3.* Measurements of width in mm ($n = 58$)**

	A: pre-augmentation width	*B*: post-augmentation width	*C* = *A*–*B*: thickness of block graft	*D*: re-entry width	*E* = *D*–*A*: actual gain of crest width following block graft healing	*F* = *B*–*D*: amount of surface resorption of block graft
Mean (standard deviation)	3.06 (± 0.84)	8.02 (± 1)	4.97 (± 1.01)	7.66 (± 0.99)	4.59 (± 1.05)	0.36 (± 0.52)
Minimum	0.5	6	3	6	2.5	0
Maximum	5	10	7	10	7	2

Zitzmann et al. (1997) have demonstrated significantly less new bone formation comparing exposed with non-exposed membrane sites treated with ePTFE membranes in conjunction with implant placement. No such difference was found in sites treated with collagen membranes, which further exhibited a discernible tendency toward spontaneous healing following wound dehiscences. In collagen sites, the exposure rate of 16% at suture removal had decreased to 9% at the 6-week examination, whereas in ePTFE sites, exposure rates increased from 24% to 44% within the same period.

Recent data of experimental studies with resorbable membranes in cultures of human fibroblasts and osteoblasts have shown that collagen membranes appear to have direct effects on tissue proliferation (Marinucci et al. 2001; Rothamel et al. 2004). In the present study, all sites with membrane exposures healed uneventfully by secondary wound healing and spontaneous re-epithelialization. This is in contrast to the clinical findings in sites treated with ePTFE membranes, where infection following wound dehiscence often necessitated the premature removal of ePTFE membranes.

Conclusions

(1) The combination of autogenous block grafts and ABBM particles covered with a collagen membrane provided successful horizontal ridge augmentation in partially edentulous patients, with high efficacy and high predictability. The mean gain in crest width measured 4.6 mm.

(2) The surgical procedures and healing periods were characterized by a low complication rate. In the case of soft tissue dehiscence, no signs of infections in the membrane site were noted.

(3) This surgical technique, using a collagen membrane, is clearly simpler than the well-documented ridge augmentation procedure with bioinert ePTFE membranes.

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要旨

目的：無機牛骨ミネラル材料（ＡＢＢＭ）と生体吸収性コラーゲン・メンブレンで被覆した自家骨ブロック移植を用いた水平的顎堤造成の臨床的結果を分析すること。

材料と方法：重度の水平的骨萎縮の患者４２名において２回法によって、水平的顎堤造成術を行った後にインプラントを埋入した。ブロック移植片は、オトガイあるいは臼後三角の部位から採取し、固定用スクリューで移植部位に固定した。ブロック移植骨はその後ＡＢＢＭとコラーゲン・メンブレンで被覆した。テンションがかからない一次創閉鎖に続く平均治癒期間５．８ヵ月後に局所を開いて、インプラント埋入前に歯槽堤頂を再評価した。

結果：造成を行った５８箇所のうち４１箇所が上顎前歯部であった。術前の歯槽頂幅は平均３．０６ｍｍであった。二次手術時の顎堤幅は平均７．６６ｍｍであり、水平的骨の獲得量計算値は平均４．６０ｍｍであった（２－７ｍｍの領域）。０．３６ｍｍのわずかな骨面吸収が造成術から二次手術までの間に観察された。

結論：ＡＢＢＭフィラーを併用した自家骨ブロック移植片をコラーゲン・メンブレンで被覆するという本稿で述べた顎堤造成術のテクニックは、高い予知性をもって水平的顎堤造成に成功することを示した。術式はさらに吸収性メンブレンを用いることで単純化された。親水性メンブレンは扱いやすく、まれにメンブレンが露出することがあっても、創感染は起きなかった。

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