Posterior atrophic jaws rehabilitated with prostheses supported by 5 × 5 mm implants with a novel nanostructured calcium-incorporated titanium surface or by longer implants in augmented bone. Preliminary results from a randomised controlled trial

**Key words**  bone substitutes, inlay graft, short dental implants, sinus lift, vertical augmentation

**Purpose:** To evaluate whether 5 × 5 mm dental implants with a novel nanostructured calcium-incorporated titanium surface could be an alternative to at least 5 × 10 mm-long implants placed in bone augmented with bone substitutes in posterior atrophic jaws.

**Materials and methods:** Forty patients with atrophic posterior (premolar and molar areas) mandibles having 5 to 7 mm of bone height above the mandibular canal and 40 patients with atrophic maxillae having 4 to 6 mm below the maxillary sinus, were randomised according to a parallel group design to receive one to three 5 × 5 mm implants or one to three at least 5 × 10 mm-long implants in augmented bone at two centres. Mandibles were vertically augmented with interpositional bovine bone blocks and resorbable barriers and implants were placed after 4 months. Maxillary sinuses were augmented with particulated porcine bone via a lateral window covered with resorbable barriers and implants were placed simultaneously. All implants were submerged and loaded after 4 months with provisional prostheses. Four months later, definitive screw-retained or provisionally cemented metal-ceramic or zirconia prostheses were delivered. Outcome measures were prosthesis and implant failures as well as any complication.

**Results:** Patients were followed to 4 months post-loading with the exception of one patient who underwent mandibular augmentation and had multiple complications at and after grafting, and subsequent graft failure, who did not want to go ahead with the treatment. This case was considered a complete failure. There were no statistically significant differences in prosthesis and implant failures. In mandibles, apart from the complete graft failure, one 5 × 10 mm implant failed at placement of the provisional prosthesis. In maxillae, one 5 × 5 mm implant failed with its provisional crown 3 months after loading. All complications occurred before loading. Significantly more intra- and postoperative complications occurred at both mandibular and maxillary grafted sites: 16 augmented patients were affected by complications versus 8 patients treated with short implants in the mandible (P = 0.022; difference in proportion = 0.40; CI 95% 0.12 to 0.68), and 5 sinus-lifted patients versus none treated with maxillary short implants (P = 0.047; difference in proportion = 0.25; CI 95% 0.06 to 0.44).

**Conclusions:** Short-term data (4 months after loading) indicate that 5 × 5 mm implants achieved similar results compared to longer implants placed in augmented bone. Short implants might be a preferable choice to bone augmentation especially in posterior mandibles since the treatment is faster, cheaper and associated with less morbidity. However, 5 to 10 years of post-loading data are necessary before making reliable recommendations.
Conflict-of-interest statement: MegaGen partially supported this trial and donated implants and prosthetic components, whereas Tecnoss donated the biomaterials. Data belonged to the authors and by no means did the manufacturers interfere with the conduct of the trial or the publication of its results.

Introduction

Short dental implants, having an intra-bony length of 8 mm or less, can be used as an alternative to bone augmentation procedures for allowing the placement of longer implants which may have a better long-term prognosis. There are a few short-term studies comparing the effectiveness of dental prostheses supported by short implants with those supported by longer implants placed in augmented bone. Preliminary results of these randomised controlled clinical trials (RCTs), having a follow-up of up to 3 years after loading, suggest that 5 to 8 mm-long implants can be a viable or even a better alternative to augmentation procedures, especially in the posterior mandible. The longest follow-up from an RCT on short implants (6.5 mm long) placed flapless and loaded immediately or early was 4 years and the initial good clinical results were maintained.

In previous studies, very short implants (5 mm) with wide diameters (6 mm) were used. This decision was dictated by the scarcity of commercially available very short implants with a diameter less than 6 mm because of the widespread belief that wider diameters are needed to compensate for short implant lengths. When using very short implants (5 mm long) with a 6 mm diameter, up to 43% of the patients could not be rehabilitated with these implants since they did not have sufficient bone width in the posterior jaws to accommodate such an implant diameter. It was concluded that, to be able to treat larger groups of patients, the long-term prognosis of short implants with smaller diameters had to be investigated. Short-term positive results from a trial evaluating implants 6 mm long with a 4 mm diameter were recently published.

Different bone augmentation techniques are currently used, however the effectiveness of only a few of these procedures has been properly tested in RCTs. When evaluating vertical bone augmentation or sinus lift procedures, there is not yet clear evidence of which could be the more effective procedures. Augmentation procedures are more technically demanding, can be associated with significant postoperative morbidity, can be more expensive and may require hospitalisation and longer times (up to 1 year) for rehabilitating the patients. In previous studies, the present authors used sintered blocks made of anorganic bovine bone (Bio-Oss; Geistlich Pharma, Wolhusen, Switzerland) since a pilot study suggested these bone substitute blocks could be a reliable alternative to blocks of autogenous bone. The problem with sintered Bio-Oss blocks is that they are brittle and 10% of the blocks broke into small pieces during the procedures for placing them as inlays. It was therefore decided to use alternative solid blocks of collagenated cancellous bone of animal origin (Sp-Block, OsteoBiol, Tecnoss, Coazze, TO, Italy).

Short implants could be a simpler, cheaper and faster alternative with less associated morbidity to longer implants placed in augmented bone, if they could provide similar success rates. The aim of this RCT was to compare the outcome of partial fixed prostheses supported by 5 × 5 mm implants with prostheses supported by implants at least 10 mm long placed in augmented posterior jaws. This report presents the clinical outcome up to 4 months after loading. It was planned to follow-up the patients to the fifth year of function to evaluate the success of the procedures over time. The present article is reported according to the CONSORT statement for improving the quality of reports of parallel-group randomised trials.

Materials and methods

Any partially edentulous patient missing teeth in the premolar and molar area requiring 2 to 3 dental implants, being 18 years or older, and able to sign an informed consent form was eligible for this trial.
Vertical bone heights at implant sites had to be 5 to 7 mm above the mandibular canal (Figs 1a and 2a) or 4 to 6 mm below the maxillary sinus (Figs 3a and 4a). Bone thickness had to be at least 6 mm as measured on computer tomography (CT) scans. Each patient could only contribute one prosthesis in the present study. Exclusion criteria were patients with the following:

- general contraindications to implant surgery
- subjected to irradiation in the head and neck area
- immunosuppressed or immunocompromised
- treated or under treatment with intravenous amino-bisphosphonates
- untreated periodontitis
- poor oral hygiene and motivation
- uncontrolled diabetes
- pregnant or nursing
- substance abuser
- psychiatric problems or unrealistic expectations
- lack of opposite occluding dentition in the area intended for implant placement
- acute or chronic infection/inflammation in the area intended for implant placement
- patients participating in other trials, if the present protocol could not be properly followed
- referred only for implant placement and not having the prosthesis or maintenance procedures performed at the treatment centres
- extraction sites with less than 3 months of healing.

Patients were classified into three groups according to what they declared: non-smoker, moderate smoker (up to 10 cigarettes per day) and heavy smoker (more than 10 cigarettes per day). Patients were recruited and treated in different centres by two different operators. One operator (Dr Pietro Felice) treated patients in eight Italian private practices and university hospitals, whereas the other operator (Dr Roberto Pistilli) treated in a hospital; both followed similar and standardised procedures.

The principles outlined in the Declaration of Helsinki on clinical research involving human subjects were adhered to. All patients received thorough explanations and signed a written informed consent form prior to being enrolled in the trial. After informed consent was obtained, patients were randomly allocated by opening the sequentially numbered envelope corresponding to the patient recruitment number, which indicated either augmentation procedures for allowing the placement of 1 to 3 implants of 5 mm diameter and at least 10 mm long or to receive 1 to 3 short 5 × 5 mm implants. The augmentation procedures consisted of interpositional blocks of collagenated cancellous bovine bone (Sp-Block, OsteoBiol) in mandibles, or the insertion in a lateral window between the lifted sinus membrane and the sinus floor of a sticky paste made of 600-1000 micron pre-hydrated collagenated cortico-cancellous granules of porcine origin, properly mixed with OsteoBiol Gel 0 (mp3, OsteoBiol, 1 cc) in maxillary sinuses using a sterile syringe. mp3 was also used to fill the gaps between the bone block and the bone in the mandible.

### Augmentation procedure

Within 10 days prior to bone augmentation and implant placement, all patients underwent at least one session of oral hygiene instructions/debridement when required. Surgical stents were prepared to help operators to determine more precisely the amount of vertical augmentation required. All patients received prophylactic antibiotic therapy: 2 g of amoxicillin (or clindamycin 600 mg if allergic to penicillin) 1 hour prior to augmentation and rinsed for 1 minute with chlorhexidine 0.2%. All patients were treated under local anaesthesia (articaine with adrenaline 1:100,000). No intravenous sedation was used.

A paracrestal incision was made through the buccal area respecting the emergence of the mental nerve, to expose the alveolar ridge (Figs 1b and 1c). A mucoperiosteal flap was carefully retracted trying to avoid tension on the mental nerve. A horizontal osteotomy was made approximately 2 to 4 mm above the mandibular canal using piezosurgery (PIEZOSURGERY 3 starter; Mectron, Carasco, Genoa, Italy). Two oblique cuts were then made in the coronal third of the mandibular bone with the mesial cut at least 2 mm distal to the last tooth in the arch. The height of the osteotomised segment had to be at least 3 mm to minimise the risk of fracture when inserting the stabilising screws. The segment was then raised coronally sparing the lingual periosteum (Fig 1d) and a 35 × 10 × 5 mm collagenated cancellous bovine bone block (SP-Block, Fig 1e) was
Fig 1  Treatment sequence of a patient with posterior mandibular edentulism randomly allocated to vertical augmentation: a) preoperative orthopantomograph; b) clinical view; c) a vestibular incision was made and the flap was only elevated vestibularly to preserve as much as possible blood perfusion; d) a horizontal cut and two vertical cuts were made with piezosurgery to minimise the risk of soft tissue damage to the lingual side and the osteotomised bone segment was carefully elevated; e) a collagenated 35 × 10 × 5 mm block of spongiosa bone of equine origin (OsteoBiol SP-Block) is prepared; f) the block is immersed in saline solution during the trimming procedures; g) the modelled block is positioned as an interpositional graft; h) voids were filled with granules of porcine bone (OsteoBiol, mp3), an osteosynthesis plate was used to stabilise the bone and a resorbable collagen barrier derived from equine pericardium (OsteoBiol, Evolution) was positioned on the augmented side; i) postoperative orthopantomograph showing the augmented site; j) after 4 months, two long implants (Exfeel Xpeed, Megagen) are inserted; k) baseline periapical radiograph showing the two long dental implants; l) after 4 months a provisional prosthesis is delivered; m) periapical radiograph showing the implants with the provisional platform-switched abutments on which the temporary full acrylic prosthesis was fixed; n) 4 months after initial loading the definitive fixed dental prosthesis was delivered; o) periapical radiograph taken just after delivery of the definitive fixed dental prosthesis.
modelled in saline solution to the desired height and shape (Fig 1f), interposed between the raised fragment and the mandibular basal bone (Fig 1g), and fixed with titanium miniplates and miniscrews (Gebrüder Martin, Tuttlingen, Germany) to both the basal bone and the osteotomised crestal bone. Gaps in the vertical osteotomies were filled using a sterile syringe of 1 cc mp3 (OsteoBiol) collagenated bone granules of porcine origin. The grafted area was covered with a collagen resorbable barrier (Evolution, Fine 30 x 30 mm, OsteoBiol; Figs 1h and 1i) derived from equine pericardium. Periosteal incisions were made to release the flaps as coronally as needed and flaps were sutured with Vicryl 4.0 sutures (Ethicon FS-2, St-Stevens-Woluwe, Belgium) until the incisions were perfectly sealed. Ice packs were provided and 1 g amoxicillin (or 300 mg clindamycin) was prescribed to be taken twice a day for 7 days. Ibuprofen 400 mg was prescribed to be taken 2 to 4 times a day during meals, as long as required. Patients were instructed to use Corsodyl gel 1% twice a day for 2 weeks, to have a soft diet for 1 week, and to avoid brushing and trauma on the surgical sites. No removable prosthesis was allowed for 1 month. Patients were seen after 3 days, and sutures were removed after 10 days. All patients were recalled for additional postoperative check-ups 1, 2 and 3 months after the augmentation procedure. Mandibular grafted areas healed for 4 months before placing the implants.

For maxillae (Fig 2b), a crestal incision was made, and after flap elevation (Fig 2c) a lateral window was prepared with piezosurgery (Mectron) and carefully displaced internally after elevation of the maxillary membrane (Fig 2d). The sinus cavity was partially filled with mp3 paste of collagenated porcine bone delivered via its dedicated sterile syringe (Fig 2e). One to three 10 mm or longer (11.5, 13, 15 mm) implants (ExFeel, MegaGen Implant Co., Gyeongbuk, South Korea) having a diameter of 5 mm with external connection and a novel nanostructured calcium-incorporated titanium surface (Xpeed) sanded with hydroxyapatite particles and cleaned with acid were inserted (Fig 2f). Then the sinus was loosely packed (Fig 2g) and overfilled (Fig 2h) with mp3 paste of collagenated porcine bone and the lateral window was covered with an Evolution resorbable collagen barrier (Fig 2i). The same postoperative procedures as for the augmented mandibles were followed.

- **Implant placement**

Surgical stents were made to optimise implant positioning (Fig 4b) and sometimes CT scans were taken to assess bone volumes for planning implant surgery. In total, 2 g of amoxicillin (or 600 mg clindamycin) was administered 1 hour prior to implant placement and patients rinsed for 1 minute with 0.2% chlorhexidine. Infiltration of local anaesthesia (articaine with adrenaline 1:100,000) was used. In augmented mandibles, miniplates were removed, and knife edge ridges were flattened to reach a bone thickness of at least 6 mm, after crestal incision and flap elevation. One to three 5 x 5 mm implants (short implant group; Figs 3c, 4c and 4d) or 10 mm or longer implants (11.5, 13, 15 mm) with a 5 mm diameter (augmented group; Figs 1j, 1k and 2f) were inserted under prosthetic guidance using a surgical template. The standard implant placement procedures as recommended by the manufacturer were used. Drills with increasing diameters or trephines (Fig 3b) were used to prepare the implant sites, which were slightly under-prepared. When inserting the implants, the surgical motor unit was set to a torque of 25 Ncm and resistance at implant insertion was recorded as <25 Ncm or >25 Ncm. Implant heads were sometimes placed slightly supracrestally so that the smooth neck portion of the implant (0.34 mm in height) was not completely embedded in bone. Cover screws were placed and flaps were closed over the implants with vicryl 4.0 sutures. Intraoral radiographs (baseline) were made with the paralleling technique (Figs 1k, 2j, 3c and 4d). If bone levels around the study implants were hidden or difficult to be estimated, a second radiograph was made. Ibuprofen 400 mg was prescribed to be taken 2 to 4 times a day during meals, as long as required. Patients were instructed to use 0.2% chlorhexidine mouthwash for 1 minute twice a day for 2 weeks and to avoid brushing and trauma on the surgical sites. No removable prosthesis was allowed. Sutures were removed after 10 days.

- **Prosthetic and follow-up procedures**

After 3 months of submerged healing, implants were exposed, and impressions with the pick-up impression copings were taken using a polyether material (Impregum; 3M/ESPE, Neuss, Germany)
Fig 2  Treatment sequence of a patient with posterior maxillary edentulism randomly allocated to sinus lift augmentation: a) preoperative orthopantomograph; b) clinical view; c) after crestal incision the flap is elevated to expose the lateral wall of the maxillary sinus; d) a lateral window was opened using piezosurgery; e) the area was partially filled with granules of porcine bone (OsteoBiol, mp3); f) one 10 mm-long implant (ExFeel Xpeed, Megagen); g) a sterile syringe was used to deliver granules of porcine bone (OsteoBiol, mp3) inside the lifted sinus cavity; h) the sinus was overfilled with the mp3 bone substitute; i) the window filled of bone substitute was covered with a resorbable collagen barrier derived from equine pericardium (OsteoBiol, Evolution); j) postoperative orthopantomograph showing the implant in place and the amount of augmented bone; k) a provisional crown was placed 4 months after implant placement; l) periapical radiograph taken at delivery of the provisional crown; m) the definitive crown was delivered 4 months after loading; n) periapical radiograph taken at delivery of the definitive crown.
and customised resin impression trays. Four months after placement, implants were manually tested for stability and provisional screw-retained or cemented crowns or reinforced acrylic restorations rigidly joining the implants were delivered on temporary abutments (Figs 1l, 2k and 3d). All implants were platform-switched using abutments with 4 mm diameters. The occlusal surfaces were in slight contact with the opposite dentition. Intraoral radiographs of the study implants were taken (Figs 1m, 2l, 3e and 4e). Four months after delivery of provisional prostheses, implants were manually tested for stability and definitive metal-ceramic, metal resin or full zirconia restorations rigidly joining the implants with occlusal surfaces in ceramic or resin were either screw-retained or cemented with provisional cement (Implacem, Dentalica, Milan, Italy by Dr Felice or TempBond, Kerr Italia, Scafati [SA], Italy by Dr Pistilli) on titanium abutments (Figs 1n, 1o, 2m, 2n, 3f, 3g, 4f and 4g), and oral hygiene instructions given again, if necessary. Patients were enrolled in an oral hygiene program with recall visits every 4 months for the entire duration of the study. Follow-ups were conducted by independent outcome assessors (Dr Laura Piana at Dr Felice’s centres and Dr Daniele Panetta at Dr Pistilli’s centre).

### Outcome measures

This study tested the null hypothesis that there were no differences in the clinical outcomes between the two procedures against the alternative hypothesis of a difference. Outcome measures were:

- **Prosthesis failure**: planned prosthesis which could not be placed due to implant failure(s) and loss of the prosthesis secondary to implant failure(s).
- **Implant failure**: implant mobility and removal of stable implants dictated by progressive marginal bone loss or infection. Stability of each individual implant was measured after removing the restorations at delivery of the provisional prostheses (4 months after implant placement), and at delivery of the definitive prostheses (4 months after delivery of the provisional prostheses) by tightening the abutment screws with the prostheses removed using a manual wrench with a 15 Ncm force.
- **Any biological or prosthetic complications**.
- **Peri-implant marginal bone level changes** evaluated on intraoral radiographs taken with the paralleling technique at implant placement and at delivery of the provisional prosthesis will be presented in the future follow-up report of this trial.

---

**Fig 3** Treatment sequence of a patient with posterior mandibular edentulism randomly allocated to 5 mm-long implants: a) preoperative orthopantomograph; b) a trephine with a stop was used to prepare both implant sites; c) postoperative baseline periapical radiographs showing the two implants in place; d) the provisional acrylic crown was delivered 4 months after implant placement; e) radiograph taken at delivery of the provisional fixed dental prosthesis; f) 4 months after initial loading the definitive fixed dental prosthesis was delivered; g) periapical radiograph taken just after delivery of the definitive fixed dental prosthesis.
Methodological aspects

Two dentists (Dr Laura Piana and Dr Daniele Panetta) not involved in the treatment of the patients performed all clinical measurements without knowing group allocation, however mandibular augmented sites could be easily identified because of the different anatomy of the two sides after the augmentation procedure.

No sample size calculation was performed. Eighty partially edentulous patients with posterior jaw atrophies were included: 40 patients were partially edentulous in the maxilla and 40 in the mandible.

A computer-generated restricted random list was created. Only one of the investigators (ME), not involved in the selection and treatment of the patients, was aware of the random sequence and could have access to the random list stored in his password protected portable computer. The information on how to treat each patient was enclosed in sequentially numbered, identical, opaque, sealed envelopes. Envelopes were opened sequentially after the patients signed the informed consent form agreeing to participate in the trial. Therefore, treatment allocation was concealed to the investigators in charge of enrolling and treating the patients.

All data analysis was carried out according to a pre-established analysis plan. A biostatistician with expertise in dentistry analysed the data, without knowing the group codes. The patient was the statistical unit of the analyses. Differences in the proportion of patients with prosthesis failures, implant failures and complications (dichotomous outcomes) were compared using the Fisher exact test. Differences in the proportion of patients with prosthetic failures, implant failures and complications were compared between the two centres using the Fisher exact test. All statistical comparisons were conducted at the 0.05 level of significance and the data for maxillae and mandibles were analysed separately.
Results

Ninety-four patients were screened for eligibility, but 14 patients were not included in the trial for the following reasons: 4 patients were unable to attend regular follow-ups for at least 5 years, 3 patients because they were under treatment for periodontal disease with questionable oral hygiene control, 3 patients because they were affected by uncontrolled diabetes and 2 patients for immune deficiencies. Eighty patients were considered eligible and were consecutively enrolled in the trial, 40 at each centre (20 with partially edentulous posterior atrophic mandibles and 20 with partially edentulous posterior atrophic maxillae). All patients were treated according to the allocated interventions, no dropouts occurred up to 4 months after loading, and the data of all patients were evaluated in the statistical analyses. One patient did not continue with the treatment after a series of intra- and postoperative complications at the augmented mandible, which lead to graft failure. This patient was considered as a complete failure. No substantial deviations from the protocol occurred with the exception that two patients treated by Dr Felice did not have the mandibular graft blocked with the osteosynthesis plate since it was not available.

Patients were recruited and treated from February 2010 to January 2011. The follow-up of all patients was 4 months after initial loading.

The main baseline patient and intervention characteristics, divided by study group and location, are presented in Table 1 (mandibles) and Table 2 (maxillae). Initially, 68 implants were placed in the augmented group and 68 in the short implant group. There were no apparent significant baseline imbalances between the two groups.

The main results are summarised in Table 3. Twenty-nine patients (36.2%) experienced complications, which all occurred in the immediate postoperative period: 21 (52.5%) patients had complications at augmented sites and 8 patients (20%) at short implants. More patients experienced complications in mandibles than in maxillae (24 versus 5).
There were statistically significantly more complications both at mandibular augmented sites (16 versus 8; \(P = 0.022\); difference in proportion = 0.40; CI 95% 0.12 to 0.68) and maxillary augmented sites (5 versus 0; \(P = 0.047\); difference in proportion = 0.25; CI 95% 0.06 to 0.44).

In one patient, a small intrasurgical haemorrhage occurred and the osteotomised portion of the mandibular graft fractured when placing the plate, so a mini-plate was placed instead. After 10 days, a patient was affected by muscular trisma that did not allow him to open the mouth and the inferior lip was swollen. The patient was treated with two muscle relaxing drugs: Muscoril (Sanofi-Synthelabo, Guildford, Surrey, UK) 4 mg/2 ml and Lyseen (Pindol mesilate; Novartis Consumer Health, Origgio [VA], Italy) 2 mg/ml intramuscularly twice a day for 5 days. One month after surgery the bone block was exposed at its distal portion. A bone fragment was removed and the remaining exposed bone was cleaned with ultrasound. At the second month, the mini-plate was also exposed and the major portion of the osteotomised bone segment was lost. The mini-plate was removed and the area was debrided. As a consequence of the mandibular graft failure and its associated negative sequelae of complications, the patient discontinued the treatment and is considered a complete failure.

Table 3  Summary of the main results expressed as number of patients experiencing at least one negative event in mandibles (40 patients) and maxillae (40 patients).

<table>
<thead>
<tr>
<th>Failure to place at least 10 mm-long implants in mandibles (= graft failure)</th>
<th>Long implants</th>
<th>Short implants</th>
<th>(P) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Failure to place at least 10 mm-long implants in maxillae (= graft failure)</td>
<td>0</td>
<td>Not applicable</td>
<td></td>
</tr>
<tr>
<td>Failure of mandibular prostheses</td>
<td>1</td>
<td>0</td>
<td>1.00</td>
</tr>
<tr>
<td>Failure of maxillary prostheses</td>
<td>0</td>
<td>1</td>
<td>1.00</td>
</tr>
<tr>
<td>Failed mandibular implants</td>
<td>1</td>
<td>0</td>
<td>1.00</td>
</tr>
<tr>
<td>Failed maxillary implants</td>
<td>0</td>
<td>1</td>
<td>1.00</td>
</tr>
<tr>
<td>Complications (mandibles)</td>
<td>16</td>
<td>8</td>
<td>0.022*</td>
</tr>
<tr>
<td>Complications (maxillae)</td>
<td>5</td>
<td>0</td>
<td>0.047*</td>
</tr>
</tbody>
</table>

*Statistically significant difference

There were no statistically significant differences for failures and complications between the two centres (Table 4).
Discussion

This study evaluated whether a 5 × 5 mm implant with a novel surface could be a viable alternative to augmentation procedures for placing longer implants when rehabilitating posterior atrophic jaws with implant-supported partial fixed prostheses. The present authors were interested in assessing the clinical performance of very short implants with a 5 mm diameter because there was a recent trial in which 5 mm short implants with a diameter of 6 mm were evaluated6,8 and about half of those patients who had sufficient bone height to accommodate a 5 mm long implant did not have a sufficient bone width in the posterior areas to accommodate a 6 mm diameter implant. All of the screened patients were eligible for this trial with respect to the available bone width, which suggests that a 5 mm implant diameter is sufficiently small to allow treatment of the great majority of patients.

Previous studies suggested that short implants can achieve short-term clinical results similar if not better than longer implants placed in augmented bone, however surgeons used short implants with wider bodies to compensate for the lack of implant height6,8,10. It remains unclear whether this ‘compensation’ is actually needed, however results of this and another trial13 in which 6 mm long implants with a 4 mm diameter were used suggest that short implants with diameters of 4 to 5 mm also perform well, at least in the very short term.

When comparing the present short term data to those of previous similar trials5,11,13,32, the trends are similar: more complications and failures at augmented sites, especially in mandibles. Obviously, longer follow-ups (at least up to 5 years) are needed to draw more reliable conclusions, nevertheless it is interesting to observe that in two RCTs with medium-term follow-ups of 311 and 4 years12, short implants did perform very well.

The augmentation procedures used in the present trial were extensively tested in previous trials: vertical bone augmentation with interpositional bone blocks5,6,11,13,20,21 for atrophic mandibles and 1-stage sinus lift with a lateral window approach using 100% bone substitute6,8,9,13,24,26. In this trial, the present authors decided to use blocks of collagenated bovine bone instead of the blocks of sintered bovine bone used in previous studies5,6,20, the reasons being that blocks of sintered bone tended to be brittle and sometimes broke into small pieces during the insertion procedure. A more solid block of animal origin was therefore used. Only one of the collagenated bovine blocks (5%) used in this trial became infected, thereby determining the failure of the augmentation procedure. In previous trials the present authors had more problems at mandibular augmented sites8,11. It appears that graft infection remains the major problem to be solved when vertically augmenting the mandible. On the other hand, no other serious complications, such as permanent paraesthesia of the lip, occurred in this trial and all but one vertical augmentation procedure were successful.

It was decided to lift maxillary sinuses using a one-stage procedure, i.e. placing implants simultaneously at augmentation, in order to decrease the patient waiting time to receive a fixed prosthesis. Results were excellent since not a single implant was lost and the 5 lacerations of the sinus membrane did not produce any problems for the patients.

In the present trial, only 2 implants were lost: one was a short 5 × 5 mm single maxillary implant found

| Table 4 | Summary of complications and failures by study centre; each centre treated 40 patients. |
|-----------------|-----------------|-----------------|
|                | Dr Felice | Dr Pistilli | p value |
| Patients with mandibular graft failures | 0          | 1           | 1.00   |
| Patients with implant failures | 1          | 1           | 1.00   |
| Patients with prosthesis failures | 0          | 2           | 0.49   |
| Patients with complications | 16         | 13          | 0.64   |
| Patients with sinus membrane laceration at grafting | 2          | 3           | 1.00   |
| Patients with transient lip paraesthesia | 13         | 9           | 0.45   |
to be mobile 3 months after loading, and one was a 5 × 10 mm implant placed in an augmented mandible that was found to be mobile at delivery of the provisional prosthesis. Both implants could be easily replaced. So the results of this trial are substantially positive with only one patient that underwent mandibular augmentation who could not have his fixed dental prosthesis because of the graft failure and its related negative consequences.

Bone augmentation procedures are technically more demanding than placing short implants, they are associated with higher postoperative morbidity, complications, longer treatment periods and an increased number of surgeries. Therefore, taking together the findings of the present study with the results of previous RCTs5,6,8-11,13,33, and systematic reviews3,4, it is possible to suggest that short implants may be as effective, if not more effective, than longer implants placed in augmented posterior mandibles, at least up to 3 years after loading, keeping in mind that the long-term prognosis is yet unknown and the sample size of the present and other published RCTs5,6,8-11,13,33 are still relatively small to draw definitive conclusions.

The main limitations of the present trial are the small sample size and the short duration of the follow-up, however longer follow-ups will be presented in the future and the data of this trial will be meta-analysed in future updates of systematic reviews3,4 to increase the sample size.

Trials with larger sample sizes are definitely needed to confirm or reject the present results. The positive aspects of this study are that all treated patients were accounted for with no exclusions and all assessments were performed by independent assessors. The tested interventions were evaluated in real clinical conditions and the patient inclusion criteria were rather broad, therefore similar results should be obtained by other experienced operators treating patients with similar characteristics.

Future trials should assess the long-term performance of super-short implants (4 to 5 mm long) with a 4 mm diameter. It would also be interesting to compare the long-term prognosis of short implants with longer implants placed in bone augmented with less invasive procedures such as 1-stage sinus lift via a crestal approach10,27.

Conclusions

Short-term data (4 months after loading) indicate that 5 × 5 mm implants achieved similar (in the maxilla) if not better (in the mandible) results than longer implants placed in augmented bone. Short implants might be a preferable choice to bone augmentation especially in posterior mandibles since the treatment is faster, cheaper and associated with less morbidity, however 5 to 10 years post-loading data from larger trials are necessary to produce reliable recommendations.

References


