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WIDE-DIAMETER IMMEDIATE POST-EXTRACTION IMPLANTS *VERSUS* SOCKET PRESERVATION AND DELAYED PLACEMENT OF NORMAL-DIAMETER IMPLANTS IN THE MOLAR REGION: 5-YEAR POST-LOADING OUTCOME OF A RANDOMISED CONTROLLED TRIAL

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OBJECTIVES. To compare the effectiveness of 6- to 8-mm-wide diameter implants placed immediately after tooth extraction with conventional diameter implants (4.0 or 5.0 mm) placed in preserved sockets after a 4-month healing period in the molar region.

MATERIALS AND METHODS. Just after extraction of one or two molar teeth, and in the presence of no vertical loss of buccal bone in relation to the palatal wall, 100 patients were randomly allocated to either immediate placement of one to two 6- to 8-mm-wide diameter implants (immediate group; 50 patients) or one or two 4.0- or 5.0-mm-wide delayed implants to be placed four months after socket preservation using a porcine bone substitute covered by a resorbable collagen barrier (delayed group; 50 patients) by a single operator according to a parallel group design. Bone-to-implant gaps at immediate implants were filled with autogenous bone retrieved with the trephine drill used to prepare the implants sites. Implants were loaded 4 months after placement with provisional acrylic fixed prostheses, joining both implants when present.
After 4 months, definitive metal-ceramic fixed prostheses were fitted. Patients were followed up to 5 years after loading. Outcome measures were: restorations and implant failures; complications; aesthetics, assessed using the pink aesthetic score (PES); peri-implant marginal bone level changes; and patient satisfaction, recorded, when possible, by blinded assessors.

RESULTS. Five years after loading, seven patients from the immediate group and eight from the delayed group dropped out. Ten out of 43 patients in the immediate group (23.3%) experienced one implant failure *versus* two out 42 (4.8%) in the delayed group, the difference being statistically significant (difference in proportion = 18.5%, 95% CI: 4.3 to 32.7%, P = 0.03). Sixteen patients in the immediate group were affected by 21 complications, and four patients by four complications in the delayed group, a statistically significant difference (difference in proportion = 26.0%, 95% CI: 9.4 to 42.6%, P = 0.005). Five years after loading, patients in the immediate group lost on average 1.82±0.72 mm of peri-implant marginal bone, and those in the delayed group lost 0.84±0.33 mm, the difference being statistically significant (1.04 mm; 95% CI: 0.75 to 1.32; P <0.0001). Photographs of only two immediate implants were taken, so no aesthetic evaluation could be performed. All patients were fully or partially satisfied with both function and aesthetics, and would undergo the same procedure again.

CONCLUSIONS. Despite all the limitations of this study, the findings indicate that immediate placement of 6- to 8-mm-wide diameter implants in molar extraction sockets yielded unacceptable outcomes when compared to ridge preservation and delayed placement of conventional 4- or 5-mm diameter implants.

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CONFLICT OF INTEREST STATEMENT. This trial was partially funded by the manufacturer of the implants evaluated in this investigation (MegaGen Implant, Gyeongbuk, South Korea) up to 1 year after loading, and then by the producer of the bone substitutes and membranes used in this study (Tecnoss, Giaveno, Italy) thereafter. However, the data belonged to the authors and the manufacturers did not in any way interfere with the conduct of the trial or the publication of its results.

INTRODUCTION

Traditionally, osseointegrated dental implants are placed in healed ridges after tooth extraction[1]. In this approach, extraction sockets are left to heal for 3 to 6 months before placing dental implants, which inevitably involves long treatment times and a second surgical intervention. In addition, many patients find the removable prostheses often employed during the implant healing period uncomfortable. It would therefore be beneficial if the post-extraction healing period could be shortened without jeopardizing implant success.

Immediate post-extraction implants are those placed immediately after tooth extraction in a fresh extraction socket. The main advantage of placing implants immediately after tooth extraction is the shorter treatment period, and another potential advantage of immediate post-extraction implants is that they could reduce the bone resorption that naturally occurs after tooth extraction[2-5]. In fact, a randomised controlled trial (RCT)[6] comparing immediate with early and delayed implant placement over 3 years showed that immediate placement significantly improved the final aesthetic outcome, suggesting that bone resorption could be decreased by placing implants immediately after extraction. Nevertheless, the clinical relevance of this finding needs to be critically evaluated in view of the higher risk of complications and implant failures that the literature suggests may be associated with immediate placement[6-8].

Another strategy to further minimize bone loss at post-extraction implants could be the use of wider diameter implants, which could be more easily stabilized in wide sockets and require less bone grafting. No RCT has yet compared wide- with conventional-diameter implants, but a small RCT with 1-year post-loading follow-up did compare 7-mm-wide post-extraction implants with 7-mm-wide delayed implants placed in preserved sockets after 4 months of healing; this indicated some statistically significant differences in favour of delayed implants in terms of peri-implant bone loss (0.4 mm) and pink aesthetic score (1.6)[9].

When opting for delayed implant placement after complete socket healing, ridge preservation procedures are often used to counteract the naturally occurring contraction of the alveolar ridges after tooth extraction[2-5]. Various ridge preservation techniques are currently used, ranging from soft tissue grafts to autogenous or bone substitutes grafts[2,4,5,10-22]. The number of reliable RCTs on their respective benefits is limited[2,5,19], but show that the various ridge preservation procedures are effective in decreasing natural bone resorption[2,4,5,10,15], even though some preservation techniques have been associated with a substantial number of failures and complications[4,23,24], or appear to be ineffective[13].

It would be useful to know whether similar or even better clinical outcomes could be achieved by immediately placing wide-diameter implants in post-extraction sites, or whether the better option is the more cautious conventional approach, preserving the extraction sites and allowing time for the bone to heal before placing conventional-diameter implants. The aim of this RCT was therefore to compare the effectiveness of 6- to 8-mm-wide diameter implants placed immediately after tooth extraction *versus* 4- or 5-mm conventional-diameter implants

placed in preserved sockets after a 4-month healing period in the molar region. The 1-year post-loading data have previously been published[25].
At the protocol stage, it was planned to follow the patients up to 3 years after loading; however, this deadline was not met, and data were collected at 5 years after loading instead. This article is reported according to the CONSORT statement for improving the quality of reporting on parallel-group randomised trials (http://www.consort-statement.org/).

MATERIALS AND METHODS

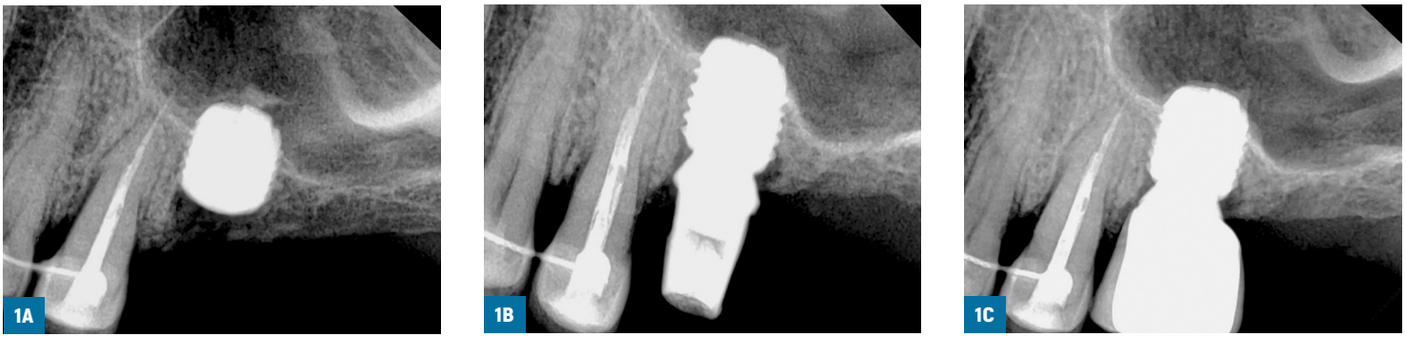
Trial design

This was a single-centre randomised controlled trial (RCT) of parallel-group design with balanced randomisation and blind assessment. The two groups were: immediate placement of post-extraction 6- to 8-mm-wide diameter implants (test group; **FIGS. 1A-C**) *versus* delayed placement of 4.0- or 5.0-mm-wide diameter implants in preserved molar sites 4 months after extraction (control group; **FIGS. 2A-C**).

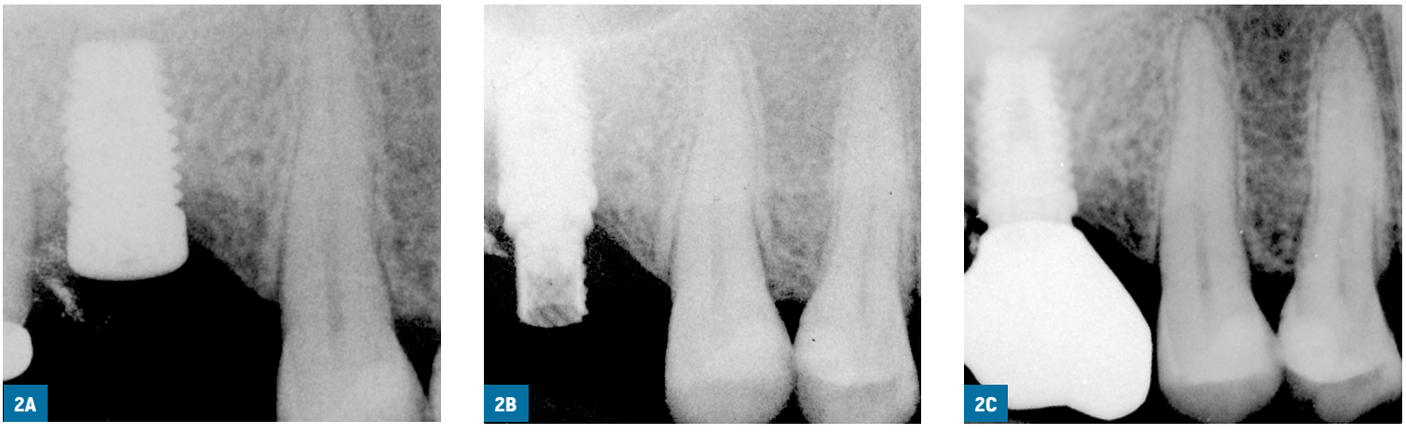
Eligibility criteria for participants

Any patient requiring at least one immediate post-extraction implant in first and/or second molar sites, being at least 18 years old and able to sign an informed consent form, was eligible for inclusion. There was also to be sufficient bone to allow immediate placement of implants of length at least 5 mm and diameter at least 6 mm. For patients with multiple molar areas to be restored, the operator was free to select the implant sites to be included in the trial at the screening visit. A maximum of two adjacent sites could be included in the study, and both implants had to be joined under the same prosthesis.
Exclusion criteria were:

- General contraindications to implant surgery;
- Immunosuppression or immunocompromised;
- Irradiation to the head or neck area;
- Uncontrolled diabetes;
- Pregnancy or lactation;
- Untreated periodontitis;
- Poor oral hygiene and motivation;
- Addiction to alcohol or drugs;
- Psychiatric disorders;
- Unrealistic expectations;



FIGS. 1A-C: *Treatment sequence of patient #99, randomly allocated to immediate placement of a wide-diameter implant: baseline radiograph after implant placement (A); radiograph at implant loading (B); radiograph at 5 years after loading (C)*



FIGS. 2A-C: *Treatment sequence of patient #7, randomly allocated to site preservation and delayed placement of an implant with conventional diameter: baseline radiograph at implant placement (A); at loading (B); at 5 years after loading (C)*

- Acute infection (abscess) in the site intended for implant placement;
- Need of sinus lift procedures;
- Inability to commit to 3-year post-loading follow-up;
- Previous or ongoing intravenous aminobisphosphonates;
- Lack of bony wall completely surrounding the implant;
- Participation in other studies interfering with this protocol.

Patients were categorised into three groups based on the number of cigarettes they declared smoking per day, specifically non-smokers, moderate smokers (up to 10 cigarettes per day) and heavy smokers (more than 10 cigarettes per day).

Setting and locations

Patients were recruited and treated by one single operator (Prof. Felice) at eight private practices and two university clinics (Bologna and Chieti), following identical and standardised procedures. All patients received through explanation and signed informed written consent prior to enrolment in the trial. After molar extraction, patients were randomised according to a parallel-group design to receive either one or two 6- to 8-mm-wide implants immediately post-extraction (**FIGS. 1A-C)** or a ridge preservation procedure followed by delayed placement of one or two 4.0- or 5.0-mm diameter implants (**FIGS. 2A-C**).

Interventions

Patients received prophylactic antibiotics (amoxicillin 1 g, or clindamycin 300 mg if allergic to penicillin) thrice a day for six days starting 1 day before tooth extraction. Patients rinsed with 0.2% chlorhexidine mouthwash for 1 minute prior to any intervention. Patients were treated under local anaesthesia using articaine with adrenaline 1:100,000. No intravenous sedation was used. Teeth were extracted as atraumatically as possible, attempting to preserve the buccal alveolar bone and the interdental septa, without flap elevation when possible. Teeth were decoronated and roots separated and individually extracted when needed. Sockets were carefully cleaned of any granulation tissue residue. In the presence of sufficient buccal bone completely surrounding the implant (assessed using the highest peak of the palatal wall as a reference point; if the assessment was difficult, small flaps (about 3 to 4 mm long) were

raised), patients were definitively included in the study and randomised to either the test or control group by opening their corresponding sealed envelope. The widest diameter of the socket was measured using a periodontal probe.

Sites allocated to immediate implant placement were prepared using a 5-mm diameter trephine drill, as recommended by the implant manufacturer. Different types of anatomical conditions could be present. When needed, sites were enlarged with wide-diameter conventional twist drills. To ensure adequate primary implant stability, all implant sites were underprepared by at least one twist-drill size, depending on bone quality, with a drilling speed of 1500 rpm. No crestal twist drills were used. One or two 6- to 8-mm diameter RESCUE implants (MegaGen Implant, Gyeongbuk, South Korea), 5.0, 6.0, 7.0, 8.5, 10.0 or 11.5 mm long, with external connection, were placed with the motor set at an insertion torque of 20 Ncm. Implants were placed about 1 to 2 mm subcrestally, below the most apical bone peak. The largest residual gap between the bony walls and the implant was measured in mm using a periodontal probe, and any residual gaps between implants and socket walls were filled with the granular autogenous bone previously retrieved using the trephine drill. Cover screws were placed, and clinical pictures were taken of the vestibular and occlusal aspects of the implants in place. A collagen haemostatic surgical dressing of equine origin (Gingistat, Acteon, Mount Laurel, NJ, USA) was placed over the implants and under the flaps, and stabilized by a cross suture. Wounds over the submerged implants were left partially open, and the implants were left to heal unloaded for 4 months. Baseline periapical radiographs of the study implants were taken using the paralleling technique. If peri-implant marginal bone levels were difficult to see, a second periapical radiograph was taken.

Patients randomised to the delayed group had flaps raised without incisions for 3 to 4 mm, and had their sockets loosely packed with granules of a mix of cancellous and cortical porcine-derived bone with a granulometry of 250-1000 microns (OsteoBiol Gen-Os, Tecnoss, Giaveno, Italy). A resorbable collagen membrane derived from equine pericardium (OsteoBiol, Evolution, Tecnoss) was trimmed and shaped to cover the entire socket plus at least 2 mm of the surrounding crestal bone. It was fixed with tags (Frios Membrane Tacks, Dentsply Sirona Implants, Mannheim, Germany) and partially covered by the mobilised soft tissues, sutured with a cross suture; thereby, barriers were left partially exposed since complete soft tissue coverage had not been achieved.

Ibuprofen 400 mg was prescribed to be taken 2 to 4 times a day during meals, as long as required. In cases of allergy to non-steroidal anti-inflammatory drugs or stomach problems, 1 g paracetamol tablets were prescribed. Patients were instructed to use 0.2% chlorhexidine mouthwash for one minute twice a day for 2 weeks, and to avoid brushing and possible trauma to the surgical sites. Post-operative antibiotics were prescribed, specifically amoxicillin 1 g three times a day for 6 days. Patients allergic to penicillin were prescribed clindamycin 300 mg three times a day for 6 days. After 1 week, patients were checked and sutures removed.

Four months after tooth extraction, patients in the immediate group had their implants assessed for stability, impressions taken at implant level using copy transfer and individualized trays, and were fitted with provisional acrylic prostheses.

Patients in the delayed group had implants placed 4 months after the socket preservation procedure. Prophylactic antibiotics (2 g amoxicillin or 600 mg clindamycin, if allergic to amoxicillin) were administered. After local anaesthesia, flaps were raised, implant sites were prepared without cleaning the preserved socket, and 4.0- or 5.0-mm diameter MegaGen ExFeel implants with external connection were placed. The operator opted to use the following implant lengths: 7.0, 8.5, 10.0 and 11.5 mm. If there was not enough bone around the implant to ensure good aesthetics due to coronal thread exposure, the operator could augment the si-

tes with OsteoBiol Gen-Os bone substitute and OsteroBiol Evolution resorbable barriers. Baseline periapical radiographs were taken. The same post-operative instructions as previously described were given, the only difference being that if no augmentation procedures were performed, post-operative antibiotics were not given. Implants were left to heal submerged for 4 months and then restored using provisional prostheses as in the immediate group.
Four months after loading, the provisional restorations were replaced by definitive metal-ceramic prostheses. Implant stability was assessed by tightening the abutment screws using a force of 20 Ncm. Occlusal and vestibular pictures of the study implants were taken, including the two adjacent teeth, and an independent assessor recorded patient satisfaction blind. Patients received further oral hygiene instructions, and were recalled for check-up and maintenance every 6 months. At the 1- and 5-year post-loading follow-ups, implant stability was assessed by removing the prostheses and reverse-torqueing the implants at 20 Ncm or by attempting to rock single crowns, which were not removed, using the handles of two dental instruments. Periapical radiographs were obtained, occlusal and vestibular pictures of the study implants were to be taken, and the independent assessor recorded patient satisfaction blind.

Outcome measures

This study tested the null hypothesis that there would be no differences in clinical outcome between the two procedures, against the alternative hypothesis of a difference.
Outcome measures were the following.

- Implant failures, defined as implant mobility, removal of stable implants dictated by progressive marginal bone loss or infection, and any mechanical complications rendering the implant unusable (e.g., implant fracture). Stability of individual implants was measured at provisional restoration fitting, 4 months after implant placement, and 4 months after delivery of definitive restorations by applying a torque of 20 Ncm with a dedicated wrench. Implant stability was re-assessed 1 and 5 years after loading using the metal handles of two instruments for single crowns, or after having removed the prostheses on two implants.
- Prosthesis failure, defined as a restoration which could not be placed because of implant failure, or replacement of the definitive prosthesis for any reasons.
- Any biological or biomechanical complications. Examples of biological complications would be fistula and peri-implantitis. Examples of biomechanical complications would be loosening or fracture of the abutment screws.
- Peri-implant marginal bone level changes, evaluated on periapical radiographs taken using the paralleling technique at implant placement, initial loading, and 1 and 5 years after loading. In the event of an unreadable radiograph, a second radiograph was to be taken. Non-digital radiographs were scanned into TIFF format at 600-dpi resolution, and stored on a personal computer. Peri-implant marginal bone levels were measured using Horos (Horos Project) software. The software was calibrated for each image using the implant length, if the entire implant was represented in the periapical radiograph, or otherwise using the known diameter. Measurements of the mesial and distal bone crest levels adjacent to each implant were made to the nearest 0.01 mm. Reference points for the linear measurements were the coronal margin of the implant collar and the most coronal point of visible bone-to-implant contact. The measurements at mesial and distal sides of each implants were averaged at implant level, and then at patient level, and finally at group level.
- Aesthetic evaluation of the vestibular and occlusal clinical pictures including the two adjacent teeth taken at definitive prosthesis fitting (4 months after loading), 1 and 5 years

after loading, by an independent blinded dentist (Dr. Barausse). The aesthetic evaluation was to be carried out using the pink aesthetic score (PES)[26].

- Patient satisfaction. At definitive prosthesis fitting (4 months after initial loading) and 1 and 5 years after loading, the blind outcome assessor provided a mirror to the patients, showing them the implant-supported prosthesis on which they were then asked to express their opinions. Specifically, the patients were asked "are you satisfied with the function of your implant-supported tooth/prosthesis?", with possible answers being "yes, absolutely", "yes, partially", "not sure", "not really", or "absolutely not". Then they were asked "are you satisfied with the aesthetics of your implant-supported tooth/prosthesis?", with possible answers being "yes, absolutely", "yes, partially", "not sure", "not really", or "absolutely not". Finally, patients were asked whether they would undergo the same treatment again. Possible answers were: "yes" or "no". The questions were always posed with exactly the same wording.
- The number of surgical interventions and patient appointments with the dentist, recorded from tooth extraction up to initial loading (delivery of the provisional prostheses) by study group. These have been presented in a previous publication[25].

Sample size, random sequence, allocation concealment and blinding

The sample size was estimated for the primary outcome measure of this study required to compare 1% of failures at delayed implants with 5% at immediate implants. A two-group continuity-corrected chi-squared test with a 0.050 two-sided significance level will have 80% power to detect the difference between a proportion of 0.050 and a proportion of 0.010 (odds ratio of 0.192) when the sample size in each group is 333. However, one hundred patients was the maximum number that we were able to enrol during >3-year recruitment period.

One computer-generated restricted randomisation list was created. Only one investigator (Dr. Esposito), who was not involved in the selection and treatment of patients, knew the random sequence and had access to the random list, stored on a password-protected laptop computer. The randomisation codes were enclosed in sequentially numbered, identical, opaque, sealed envelopes. After tooth extraction and quantification of the amount of buccal bone loss, the patient was finally entered into the study and the envelopes were sequentially opened. Therefore, treatment allocation was concealed to the investigators in charge of enrolling and treating the patients.

Blind outcome assessors (Dr. Soardi, replaced at the end of the 1-year follow-up by Dr. Barausse, and by Drs. Bonifazi, Berti and Di Simone for the 5-year follow-ups), not involved in the treatment of patients, evaluated implant stability and recorded patient satisfaction. Another dentist (Dr. Barausse) measured aesthetic scores and marginal bone levels blind, without knowing group allocation, although the differences in implant dimensions were clearly evident. Complications were recorded and treated by the surgeon in a non-blinded mode.

Statistical methods

All data analysis was performed according to a pre-established analysis plan by a clinician with expertise in statistics analysing the data without knowledge of the group codes (Dr. Ferri). The patient was the statistical unit of the analyses. Descriptive analysis was performed, presenting continuous variables as mean ± standard deviation (SD), while categorical variables were presented as absolute and relative frequencies. Differences in the proportions of patients with implant/prosthetic failures and complications (dichotomous outcomes) were compared between the groups using Fisher's exact test. Differences in patient means for continuous outcomes (bone levels) were compared between groups using t-tests, and betwe-

en the different follow-up periods by paired t-test. The Mann–Whitney U test was used to compare the two group medians for patient satisfaction, and Fisher's exact test was performed to compare the frequency of total satisfaction between groups. The significance level was set at 0.05.

RESULTS

One hundred and nine patients were screened, and 100 patients were consecutively enrolled in the trial. Nine patients were not included because they did not have 5 mm in bone height (six patients, four of which required a sinus lift procedure), or because they did not have a sufficiently preserved vestibular bone wall (three patients). All patients were treated according to the allocated interventions.

Seven patients dropped out from the immediate group *versus* nine patients from the delayed group, all having a single crown.

Reasons for dropping out were the following.

Immediate group (seven patients)

- #2: not contactable after definitive crown fitting
- #16: unwilling to come in (too busy) after definitive crown fitting
- #58: moved away after definitive prosthesis fitting; replied by phone to the 1-year and 5-year satisfaction questionnaires
- #5 and 56: not contactable after 1-year follow-up
- #71 and 74: moved away after 1-year follow-up and unable to attend the clinic.

Delayed group (eight patients)

- #53, 59 and 69: not contactable after provisional prosthesis fitting
- #22: moved away after definitive prosthesis fitting; replied by phone to the 1- and 5-year satisfaction questionnaires
- #27: too busy after fitting of definitive prosthesis, then not contactable
- #28: not contactable after 1-year follow-up
- #10: moved away after 1-year follow-up; replied by phone to the 5-year satisfaction questionnaires
- #14: too busy after 1-year follow-up; replied by phone to the 5-year satisfaction questionnaire

In addition, patient #47, who was unable to attend both 4-month and 1-year follow-ups, managed to attend the 5-year-follow-up, so was no longer considered a drop-out.

The following radiographs, clinical pictures and questionnaires were missing (excluding drop-outs).

Immediate group

- Periapical radiographs at placement: 3 patients.
- Periapical radiographs at loading: 7 patients.
- Periapical radiographs at 1 year: 5 patients.
- Periapical radiographs at 5 years: 7 patients.
- Clinical pictures at 4 months: 9 patients.
- Clinical pictures at 1 year: 2 patients.
- Clinical pictures at 5 years: only pictures of 2 patients available.

Delayed group

- Periapical radiograph at placement: 5 patients.
- Periapical radiograph at loading: 8 patients.
- Periapical radiograph at 1 year: 6 patients.
- Periapical radiograph at 5 years: 8 patients.
- Clinical pictures at 4 months: 10 patients.
- Clinical pictures at 1 year: 5 patients.
- Clinical pictures at 5 years: none available.
- Questionnaires at 5 years: 3 patients.

Data pertaining to all remaining patients were evaluated in the statistical analyses.
The main deviations from the protocol were the following.

Immediate group

- One patient did not want to have the definitive crown for financial reasons, and is still wearing his provisional crown.
- In two patients the trephine drill could not be used since the septa was missing and there was too little bone available at the maxillary sinus. The implants were anchored to the palatal wall, and OsteoBiol Gen-Os was used to fill the vestibular bone-to-implant gap instead of autogenous bone collected with the trephine drill.
- Three patients received the definitive crowns directly, without having provisional crowns, for financial reasons.
- One patient received the definitive crown directly, without having the provisional, for financial reasons, with a 2-month delay since she did not show up for scheduled appointments.
- In one patient, at implant placement the bone-to-implant gap was filled with OsteoBiol Gen-Os instead of autogenous bone, because the bone-crushing device was not available.
- At 5-year follow-up, seven patients had their questionnaires and intraoral radiographs taken with a delay ranging from 12 to 19 months.

Delayed group

- One patient did not want to have the definitive crown for financial reasons and is still wearing his provisional crown.
- Four patients received the definitive crowns directly, without having the provisional crowns, for financial reasons.
- Three patients had their provisional crowns delivered with 2-, 3- and 5-month delays, respectively, since they did not show up for scheduled appointments.
- One patient showed up for the abutment connection procedure with one month's delay.
- At 5-year follow-up, five patients had their questionnaires and intraoral radiographs taken with a delay ranging from 12 to 19 months.

Patients were recruited and had their teeth extracted from May 2010 to October 2013. The follow-up was at least 5 years after implant loading. Patient demographics are presented in **TABLE 1**. Fifty-four implants were placed in the immediate group and fifty-three in the delayed group, and there were no significant baseline imbalances apparent between the two groups, with the exception that immediate post-extraction implants were much shorter than delayed implants.

TABLE 1 PATIENT AND INTERVENTION CHARACTERISTICS

	Immediate (n = 50) (%)	Delayed (n = 50) (%)
Females	26 (52%)	23 (46%)
Males	24 (48%)	27 (54%)
Mean age at implant insertion (range)	52.9 (26–72)	54.4 (27–75)
Non-smokers	37 (74%)	39 (78%)
Smoking up to 10 cigarettes/day	10 (20%)	7 (14%)
Smoking more than 10 cigarettes/day	3 (6%)	4 (8%)
Mean greatest diameter of socket in mm	9.6	10.4
Number of implants placed	54	53
Buccal bone–implant gap in mm	0.60±1.05	0
Additional augmentation at placement of delayed implants only	-	5 (10%)
Sites augmented with autogenous bone at implant placement	14 (28%)	0
Implants in upper first molar position	21 (38.9%)	15 (28.3%)
Implants in upper second molar position	12 (22.2%)	10 (18.9%)
Implants in lower first molar position	9 (16.7%)	16 (30.2%)
Implants in lower second molar position	12 (22.2%)	12 (22.6%)
Implants inserted with a torque lower than 20 Ncm	18 (33.3%)	25 (47.2%)
Partial fixed prostheses in upper jaws	3 (6%)	1 (2%)
Single crowns in upper jaws	27 (54%)	23 (46%)
Partial fixed prostheses in lower jaws	1 (2%)	2 (4%)
Single crowns in lower jaws	19 (28%)	24 (48%)
Implants of diameter 4.0 mm	0	20 (37.7%)
Implants of diameter 5.0 mm	0	33 (62.3%)
Implants of diameter 6.0 mm	9 (16.7%)	0
Implants of diameter 6.5 mm	6 (11.1%)	0
Implants of diameter 7.0 mm	22 (40.7%)	0
Implants of diameter 7.5 mm	2 (3.7%)	0
Implants of diameter 8.0 mm	15 (27.8%)	0
Implants of length 5.0 mm	17 (31.5%)	0
Implants of length 6.0 mm	18 (33.3%)	0
Implants of length 7.0 mm	9 (16.7%)	14 (26.4%)
Implants of length 8.5 mm	1 (1.9%)	19 (35.9%)
Implants of length 10.0 mm	8 (14.8%)	19 (35.9%)
Implants of length 11.5 mm	1 (1.9%)	1 (1.9%)

Implant failures

Twelve implants failed in 12 patients: 10 out of 43 patients experienced one implant failure in the immediate group (23.3%) *versus* two out 42 (4.8%) in the delayed group, the difference being statistically significant (difference in proportion = 18.5%, 95% CI: 4.3 to 32.7%, P = 0.03).

Immediate group

- 3 months after placement, one female non-smoker (#63) presented with the coronal portion of the buccal threads exposed at her implant in position 46. The patient reported pain, and the implant was mobile and was removed. The patient refused to have the failed implant replaced.
- 3 months after placement, one male smoker (#93) complained about discomfort at an implant in position 16. The implant was mobile, removed, and successfully replaced after 4 months.
- One female smoker's (#42) implant in position 26 was mobile at abutment connection; it was successfully replaced after 4 months.
- One male heavy smoker's (#77) implant in position 47 was mobile at abutment connection; it was successfully replaced after 4 months.
- One female heavy smoker (#43) presented with a mobile implant in position 17 causing discomfort 9 months after loading. It was successfully replaced after 4 months.
- 4 years and 3 months after loading, one female smoker (#45) lost her implant in position 46. The implant had caused discomfort, was mobile, and was surrounded by a large area of bone dehiscence (**FIG. 3**).
- 4 years and 5 months after loading, one male non-smoker (#13) lost his implant in position 16. The implant had been painful and was surrounded by a large area of bone dehiscence.
- 4 years and 7 months after loading, one male non-smoker (#62) lost his implant in position 16. The implant had been painful, with purulent exudate, and was surrounded by a large area of bone dehiscence.
- 4 years and 8 months after loading, one female non-smoker (#96) lost her implant in position 46. The implant had been painful, mobile and was surrounded by a large area of bone dehiscence.
- 4 years and 9 months after loading, one female non-smoker (#48) lost her implant in position 26. The implant had been painful and was surrounded by a large area of bone dehiscence.

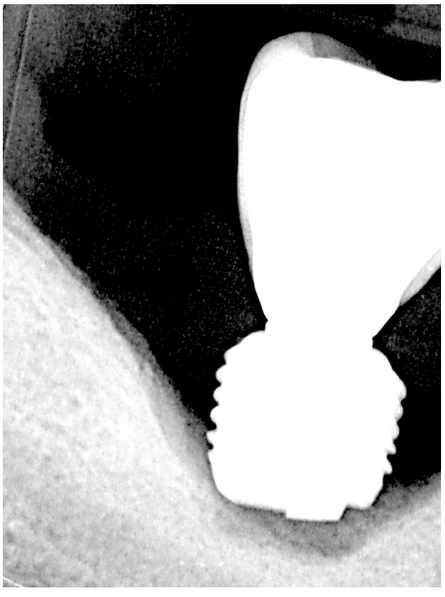


FIG. 3: *Failure of the wide-diameter implant placed immediately post-extraction to replace 46 in patient #45 observed at 4 years and 3 months after loading*

Delayed group

- One female heavy smoker's (#37) implant in position 17 was mobile at abutment connection, and successfully replaced after 4 months.
- One female non-smoker's (#49) implant in position 46 was mobile at abutment connection, and successfully replaced after 4 months.

Prosthesis failures

Closely reflected implant failures. Only single crowns could not be placed or were lost due to implant failures.

Complications

21 complications occurred in 16 patients out of 45 from the immediate group (35.6%) *versus* four complications in four patients out of 42 in the delayed group (9.5%), the difference being statistically significant (difference in proportion = 26.0%, 95% CI: 9.4 to 42.6%, P = 0.005). Complications were the following.

Immediate group

- One male non-smoker (#2) complained of pain 1 week after extraction. No exudate, but soft tissues were inflamed with abundant food residue at site 16. The site was rinsed with

chlorhexidine 0.2%, which was prescribed thrice a day for 21 days together with ibuprofen 600 mg thrice a day for 4 days. Antibiotic therapy (1 g amoxicillin + clavulanic acid twice a day for 6 days) was prolonged for another week. Resolved in 10 days.

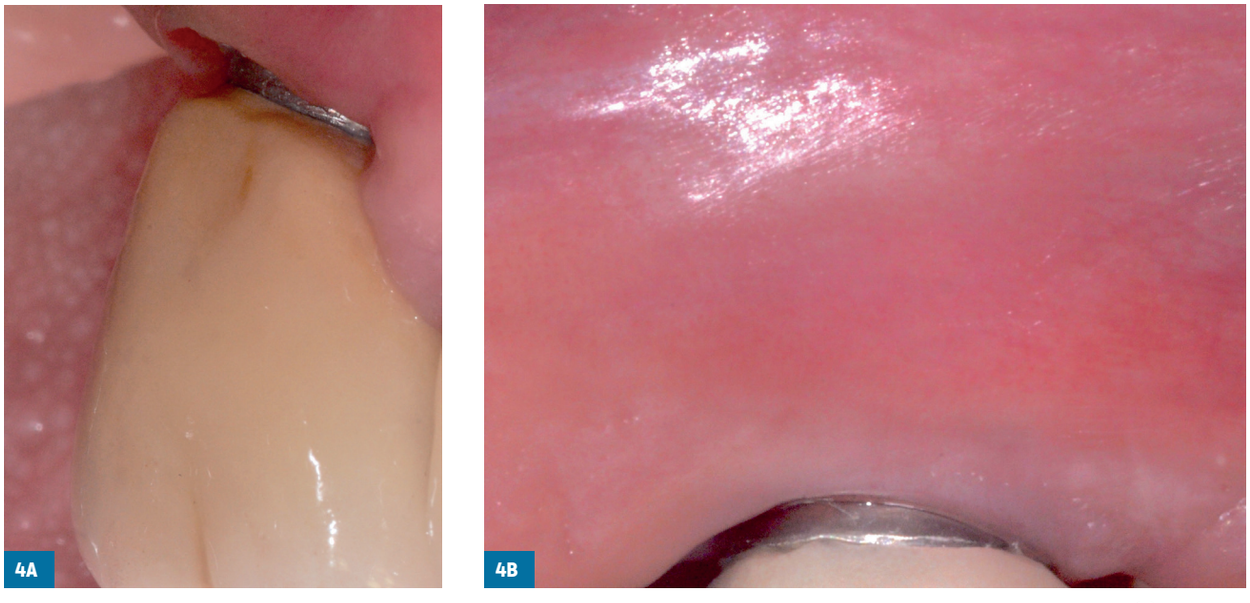
- 3 months after implant placement, one female non-smoker (#63) complained of pain at site 46. The buccal threads were exposed, and the implant was mobile. It was removed but the patient refused to have it replaced.
- 3 months after placement, one male smoker (#93) complained of discomfort at an implant in position 16. The implant was mobile and was successfully replaced.
- In one female smoker (#45), vestibular bone/soft tissue dehiscence was observed at an implant in position 46 at the abutment connection procedure. The area was treated with a bone substitute (OsteoBiol Gen-Os) and resorbable collagen barrier (OsteoBiol Evolution), and left to heal for 6 months before loading the implant. Four years and 3 months after loading, the patient reported discomfort at the same implant, which was mobile and surrounded by a large area of bone dehiscence. The implant was removed.
- 6 months after loading, one female non-smoker (#25) complained of pain at implant in position 37. Vestibular recession with pockets and peri-implant mucositis was present. Soft tissues were in direct apical contact with the implant threads. Chlorhexidine 0.2% rinse thrice a day for 21 days was prescribed. Symptomatology improved, but the patient was not willing to undergo further treatment.
- One male smoker (#36) complained of discomfort at implant in position 16 six months after loading. Vestibular recession with bone loss and peri-implant mucositis was present. Chlorhexidine 0.2% rinse thrice a day for 21 days was prescribed. Symptomatology improved but the patient was not willing to undergo further treatment.
- One male non-smoker (#38) presented with vestibular recession at an implant in position 37 seven months after loading. He did not complain of anything except for slight peri-implant mucosa discomfort. Chlorhexidine 0.2% rinse thrice a day for 21 days was prescribed. The patient refused further treatment.
- One male non-smoker (#56) complained of pain at his implant in position 36 seven months after loading. A vestibular pocket was present, corresponding to bone loss, and the buccal implant threads were in direct contact with the inflamed mucosa. Chlorhexidine 0.2% rinses were prescribed thrice a day for 21 days. Symptoms improved, but the patient was not keen to have additional treatment.
- One male smoker (#24) complained of discomfort at an implant in position 16 nine months after loading. The coronal third of the implant was exposed in the mesiovestibular location, but the implant was stable. Chlorhexidine 0.2% rinses thrice a day for 21 days were prescribed. Symptomatology resolved but the patient did not want any further treatment.
- One female heavy smoker (#43) presented with her implant in position 17 mobile and causing discomfort 9 months after loading. It was successfully replaced after 4 months.
- One male non-smoker (#13) presented with pain at implant 16 four years and 5 months after loading. Considerable peri-implant bone loss was evident on radiograph, and the implant was removed.
- One male non-smoker (#62) presented with pain, purulent exudate and an unpleasant taste at implant 16 four years and 7 months after loading. Considerable peri-implant bone loss was evident on radiograph, and the implant was removed.
- One female non-smoker (#96) presented with pain at implant 46 four years and 8 months after loading. The implant was mobile and considerable peri-implant bone loss was seen on radiograph. The implant was removed.

- One female non-smoker (#48) presented with pain at implant 26 four years and 9 months after loading. Considerable peri-implant bone loss was evident on the radiograph, and the implant was removed.
- One male non-smoker (#54) presented with 4 mm vestibular recession (**FIG. 4A**) exposing the implant in position 36 and signs of peri-implant mucositis 5 years after loading. Chlorhexidine 0.2% rinses thrice a day for 21 days were prescribed.
- One male smoker (#21) presented with 3 mm mesiovestibular recession exposing the implant in position 26 just after 5 years post-loading (**FIG. 4B**). The crown was also chipped and repaired chairside.

Delayed group

- One male smoker (#20) complained of pain 1 week after extraction. No exudate, but soft tissues at site 47 were inflamed, with abundant food residue. Chlorhexidine 0.2% rinse thrice a day for 21 days was prescribed, together with ibuprofen 600 mg thrice a day for 4 days. Antibiotic therapy (1 g amoxicillin + clavulanic acid twice a day for 6 days) was prolonged for another week. Resolved in 10 days.
- One male non-smoker (#72) complained of discomfort 1 week after extraction. No exudate, but soft tissues at site 37 were inflamed, with abundant food residue. Chlorhexidine 0.2% rinse thrice a day for 21 days was prescribed, together with ibuprofen 600 mg thrice a day for 4 days. Resolved in 10 days.
- One patient (#35) complained of mobility at implant in position 36 eight months post-loading. The screw was loose, and retightened at 30 Ncm.
- One screw loosening was noted at an implant in position 17 at the 1-year post-loading check-up (#32). It was retightened at 30 Ncm.

  NB: Implants which were found to mobile at various follow-up visits without any symptoms or visible signs were not considered complications, just failures.



FIGS. 4A, B: *Vestibular soft tissue recession at immediate wide-diameter post-extraction implants, as they presented in patients #54 (A) and #21 (B) at 5 years after loading*

Aesthetic evaluation

Only the pictures of two crowns from the immediate group were taken at 5 years, so no aesthetic evaluation could be attempted. Aesthetics data at 4 months and 1 year after loading have previously been published[25].

Marginal bone levels

Were evaluated by a blind outcome assessor on periapical radiographs taken at implant placement after bone grafting (when performed), at initial loading, and at 1 and 5 years after loading (**TABLE 2**). At 5 years, the average bone levels around immediate implants were -1.89 ± 0.73 mm, *versus* -0.92 ± 0.33 mm at delayed implants, the difference being statistically significant (difference = 0.96 mm; 95% CI: 0.68 to 1.27; P <0.0001). Bone level changes at 5 years were -1.86±0.72 mm at immediate implants and -0.82 ± 0.33 mm at delayed implants. Significantly more bone loss occurred at immediate implants (mean difference = 1.04 mm; 95% CI: 0.75 to 1.32; P <0.0001; **TABLE 3**).

Patient satisfaction

Was assessed at 4 months and at 1 and 5 years after loading only in those patients who did not experience an implant failure. At 5 years, one out of seven patients from the immediate

TABLE 2 PERI-IMPLANT MARGINAL BONE LEVELS UP TO 5 YEARS AFTER LOADING BY STUDY GROUP

	Immediate		Delayed		Difference		P-value intergroup
	N	Mean±SD	N	Mean±SD	N	Mean (95% CI)	
Implant placement	47	-0.04±0.04	45	-0.11±0.87	45	0.07 (0.02; 0.12)	<0.0001*
Initial loading	39	-0.43±0.14	40	-0.36±0.15	39	0.07 (0.01; 0.13)	0.03*
1 year after loading	38	-1.11±0.37	37	-0.74±0.27	37	0.37 (0.07; 0.67)	<0.0001*
5 years after loading	25	-1.89±0.73	32	-0.92±0.33	25	0.97 (0.68; 1.27)	<0.0001*
P-value intragroup	<0.0001*		<0.0001*		<0.0001*		

**Statistically significant difference*

TABLE 3 PERI-IMPLANT MARGINAL BONE LEVEL CHANGES UP TO 5 YEARS AFTER LOADING BY STUDY GROUP

	Immediate		Delayed		Difference		P-value intergroup
	N	Mean±SD	N	Mean±SD	N	Mean (95% CI)	
Difference placement initial loading	39	-0.40±0.04	40	-0.26±0.87	39	0.14 (-0.06; -0.22)	<0.0001*
Difference placement 1 year	37	-1.06±0.14	36	-0.63±0.15	36	0.43 (-0.15; -0 .61)	<0.0001*
Difference placement 5 years	25	-1.86±0.72	32	-0.82±0.33	25	1.04 (0.75; 1.32)	<0.0001*
P-value intragroup	<0.0001*		<0.0001*		<0.0001*		

**Statistically significant difference*

group, and three out of eight patients from the delayed group who did not attend the check-up (drop-out), did express their satisfaction score by phone. Five years post-loading, seven patients out of the 34 in the immediate group and two patients out of 39 from the delayed group declared being partially satisfied with the function of their prostheses, with all the remaining patients expressing total satisfaction (P = 0.07). Four patients out of 34 in the immediate group and 0 out of 39 in the delayed group declared being partially satisfied with the aesthetics of their prostheses, with all the remaining patients expressing total satisfaction (P = 0.04). At all time-points, all patients declared that they would undergo the same procedure again.

DISCUSSION

This trial was designed to assess whether it may be advantageous to place 6- to 8-mm-wide implants immediately after molar extraction, or whether preserving the socket, allowing the bone some time to heal and then placing implants with a conventional diameter of 4.0 or 5.0 mm remains the best strategy. The most striking finding of this study was that ten implants (23.3%) failed in the immediate post-extraction group while only two implants (4.8%) failed in the delayed group.

This implies that placing wide-diameter implants immediately post-extraction in the molar area cannot be considered the best option; it would be much wiser to preserve the socket, wait for bone healing and then place delayed implants of conventional diameter. Indeed, our data lends weight to the notion that immediate post-extraction implants are at higher risk of failure than delayed implants, which supports the findings of other RCTs[6,8,27-29] comparing immediate *versus* delayed implant placement. Complications were also more common in the immediate group (21 *versus* 4), again in agreement with findings from previous RCTs[6,8,27-29]. However, of note, we encountered a specific complication which has never been reported in previous RCTs[8,27-31], even in those conducted by our group[6,8,29]. Specifically, seven patients (14%) immediately fitted with 6- to 8-mm wide-diameter implants after extraction displayed vestibular bone dehiscence, which developed from 3 months after implant placement to 9 months post-loading.

This permanent early complication, along with the others noted, at least partially jeopardised implant success rates over time, and is another clear indicator against the use of wide post-extraction implants. The reasons behind these differences can only be speculated upon, but in light of these findings it is evident that site preservation and delayed placement of implants with conventional diameters is the therapeutic option of choice at molar post-extraction sites.

Since in the present investigation both procedures were tested in real clinical conditions, and patient inclusion criteria were broad, results can be generalised with confidence to a wider population with similar characteristics. At baseline, the two groups were comparable except for implant length. In fact, immediate implants were on average much shorter than delayed implants. However, in view of the good results published on short implants[32-42], it is unlikely that this difference would have strongly influenced the short-term results of this trial.

The main limitations of the present trial are the total lack of aesthetic evaluation (pictures of only two patients were actually taken), and the high number of periapical radiographs not taken (radiographs of 15 patients missing) at the 5-year post-loading follow-up. While these limitations are impossible to justify, the data we do present clearly show the superiority of socket preservation with delayed placement of conventional-diameter implants over wide-diameter implants placed immediately post-extraction.

CONCLUSIONS

Despite all the limitations of this study, it can be concluded that immediate placement of 6- to 8-mm wide implants in molar extraction sockets yielded unacceptable clinical results, as compared with delayed placement of conventional 4-or 5-mm diameter implants after ridge preservation.

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