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Comparison of procedures for immediate reconstruction of large osseous defects resulting from removal of a single tooth to prepare for insertion of an endosseous implant after healing

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Abstract. This study evaluated the treatment outcome of immediate reconstruction of 45 large osseous defects resulting from removal of a single tooth with a 1:2 mixture of Bio-Oss® and autologous tuberosity bone, and three different procedures for soft tissue closing (Bio-Gide® membrane, connective tissue graft, full-thickness palatal mucosa graft; n = 15 per group). All defects had an unfavourable osseous–gingival relationship and vertical bone loss of >5 mm. The hard and soft tissues were immediately reconstructed after removal of the tooth. Implants were inserted after 3 months. Patients' acceptance, complications and postoperative morbidity were prospectively evaluated by standardized clinical and radiographic examinations up to 12 months after the augmentation procedure. The patients completed a questionnaire on subjective complaints related to the procedure. All hard–soft tissue procedures resulted in sufficient bone volume for the insertion of implants and a favourable aesthetic outcome. The gingival mid-buccal aesthetics before, and 1 year after, treatment significantly favoured the full-thickness palatal mucosa graft, showing a gain in gingival contour of 0.5 ± 0.8 mm; the other procedures resulted in a 1.2 ± 1.6 mm decrease. Of the procedures evaluated, a full-thickness palatal mucosa graft was the most predictable for immediate reconstruction of the socket after tooth removal.

Keywords: sockets; single tooth replacement; dental implants; autologous bone; augmentation.

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The success of dental implants is determined by their survival rate and other factors including subjective judgement of the aesthetic outcome[13]. Many patients want to replace a lost tooth with an implant-supported crown. Various implant treatment strategies have been proposed to achieve an optimal final result, including immediate, delayed (4–6 weeks) or late (12–16 weeks) insertion of implants in fresh extraction sockets[26]. Identical strategies have been proposed for the reconstruction of socket-wall defects: immediate reconstruction (at the time of tooth removal); delayed immediate reconstruction (as soon as a closed soft-tissue cover has developed); and late reconstruction (on completion of bone healing)[10,26].

Patients and clinicians are interested in whether an immediate, delayed or conventional implant-supported single tooth replacement represents a reliable and effective therapy to re-establish optimal function and aesthetics following the loss of an anterior tooth. Insufficient data are available to decide whether peri-implant health, prosthesis stability, degree of bone loss and aesthetic outcome of immediate and early placed implants are comparable with the treatment outcome of implants placed in healed sites[20]. Traditionally, dental implants were placed in healed extraction sites following a two-stage surgical procedure allowing for an undisturbed load-free period of 3–6 months[16]. Recently, installation of implants in fresh extraction sockets and reducing the load-free period by immediately restoring implants after insertion have been adopted. These approaches reduce the total treatment time, require fewer surgical interventions and eliminate the need for a temporary prosthesis. They may also lead to a reduction in peri-implant crestal bone loss and better soft tissue healing, and as a result may improve the aesthetic appearance[5,7–9].

The benefits and success rates of immediate tooth replacement (immediate implant and provisionalization) have shown it to be a reliable treatment option with a favourable aesthetic outcome[14,15]. It has been assumed that aiming for minimal gingival recession after insertion of an implant, an intact labial bony plate along with an osseous–gingival relationship of 3 mm on the labial aspect of the failing tooth are prerequisites[14]. When the width of a socket-wall defect exceeds one-third of the mesiodistal dimension between the adjacent teeth, staged reconstruction with autologous block and particulate bone grafts, and, if needed, soft tissue grafting, will yield the most predictable aesthetic results[25]. Despite favourable initial outcomes, data on the intermediate and long-term results are lacking[11]. The aim of this study was to evaluate the outcome of immediate reconstruction of large osseous defects resulting after removal of a single tooth with a 1:2 mixture of autologous and Bio-Oss® bone and three different procedures for soft tissue closing.

Materials and methods

Patients

Patients were recruited from those referred to the Department of Oral and Maxillofacial Surgery between October 2004 and June 2006. Inclusion criteria were one failing tooth in the aesthetic zone with an osseous defect on the facial bony plate (all defects exceeded one-third of the mesiodistal dimension between the adjacent teeth and showed a bone loss >5 mm in the vertical direction), surrounded by natural, healthy, uncompromised adjacent teeth, and with gingival architecture harmonious with the surrounding dentition. The mode of tooth failure could include trauma, dental caries, root resorption, endodontic and periodontal failure, all without evidence of acute infection. In all patients, implants were the treatment of choice following clinical and radiographic evaluation. The exclusion criteria were a history of smoking, a systemic disease that might compromise healing, and severe bruxism or parafunctional habits.

Forty-five patients were included; 21 men and 24 women (mean age 35.7 ± 10.0 years; range 19–59 years), with impending loss of a single maxillary anterior tooth (33 central incisors, 10 lateral incisors, and 2 canines) and compromised facial bone. In the labial walls of all the teeth to be removed there were periodontal pockets ≥ 5 mm, while the neighbouring teeth had a healthy periodontal environment. All patients received standard treatment planning and diagnosis, and gave signed informed consent for the treatment.

Random allocation

After removal of the tooth and checking whether the resulting defect met the inclusion criteria, the patients were randomly allocated to one of the three reconstructive treatment arms. For the randomization procedure, the surgeon drew one lot from a series of 45 lots (15 lots for each treatment) in a completely blind and random manner. All lots were the same size and identically folded. All lots were drawn just before the surgical procedure took place and were destroyed after each selection. The surgical procedure determined by the result of the draw was then carried out.

Removal of the teeth and bone sounding technique

Each participant, regardless of the randomization outcome, underwent the initial procedure. Before removal of the tooth, a provisional partial denture with oviate pontic was fabricated. Clasp retainers were added to prevent deleterious apicocoronal movement of the provisional restoration. All surgical procedures were performed under local anaesthesia (articaine with epinephrine). Antibiotic prophylaxis was given for 1 week (amoxicillin 500 mg), 1 h preoperatively and every 8 h postoperatively.

First, the failing tooth was extracted atraumatically without flap reflection. The marginal fibres were cut with a knife and the tooth was mobilized with forceps. The shape of the osseous defect was checked by a bone sounding technique with a periodontal probe at the midfacial, the mesial, and distal aspect of the failing tooth, and the mesial and distal aspect of the immediately adjacent teeth. The patient was subjected to a procedure allocated by lot if the buccal socket wall had a defect exceeding more than one-third of the mesiodistal dimension between the adjacent teeth and the bony defect was >5 mm in a vertical direction (range 5–12 mm). As only patients with periodontal pockets ≥ 5 mm were included, all patients met this inclusion criterion. With a large round bur all granulation tissue was removed from the labial wall and bleeding of the alveolar socket was provoked. The periosteum on the buccal site was carefully reflected using an excavator over a distance of about 3 mm.

Tuber bone grafts were harvested from the tuberosity region. After an incision, the bone graft was harvested using chisels and shaped with forceps. The wound was closed with Vicryl 4-0 (Ethicon, Johnson & Johnson, Amersfoort, The Netherlands). The cortical side of the bone graft was placed under the periosteum on the buccal site and covered the whole defect. The autogenous bone was mixed with Bio-Oss® spongiosa granules (0.25–1.0 mm, Geistlich, Wolhusen, Switzerland). This 1:2 mixture was condensed into the remaining alveolar space between the tuberosity graft on the buccal site and the native bone on the palatal site.

Reconstructive procedure

For the closure of the reconstructed alveolus, the patient underwent one of three soft tissue reconstructive procedures (random allocation).

In the first procedure, a subepithelial connective tissue graft was harvested from the palate in the premolar region approximately 3 mm apical to the gingival margin. A slightly bevelled full-thickness curvilinear incision was made. The scalpel was reoriented within the incision until it was parallel with the palatal mucosa. Approximately 1 mm below the mucosal surface a 1–1.5 cm subepithelial incision was made parallel to the external surface, creating a rectangular pouch. With the scalpel blade the complete outline of the donor connective tissue graft was shaped through the underlying connective tissue and periosteum. The connective tissue graft was dissected. The donor area was closed with Vicryl 4-0 (Fig. 1). The connective tissue graft was placed on top of the reconstructed alveolus, covered with the labial mucosa and sutured with Vicryl 4-0 (group 1; n = 15).

In the second procedure, a free, oval, full-thickness palatal mucosa graft was punched from the palatal mucosa from the area where the bone graft from the tuberosity region was harvested. The diameter of the punch was 2 mm larger than the socket access. That 2 mm of epithelium was removed from soft tissue graft. The 2 mm zone of the soft tissue graft denuded from epithelium was located beneath the mucosa at the recipient site, to facilitate closure and healing of the grafted area. The graft was sutured with Ethilon 4-0 (Johnson & Johnson, Amersfoort, The Netherlands) on top

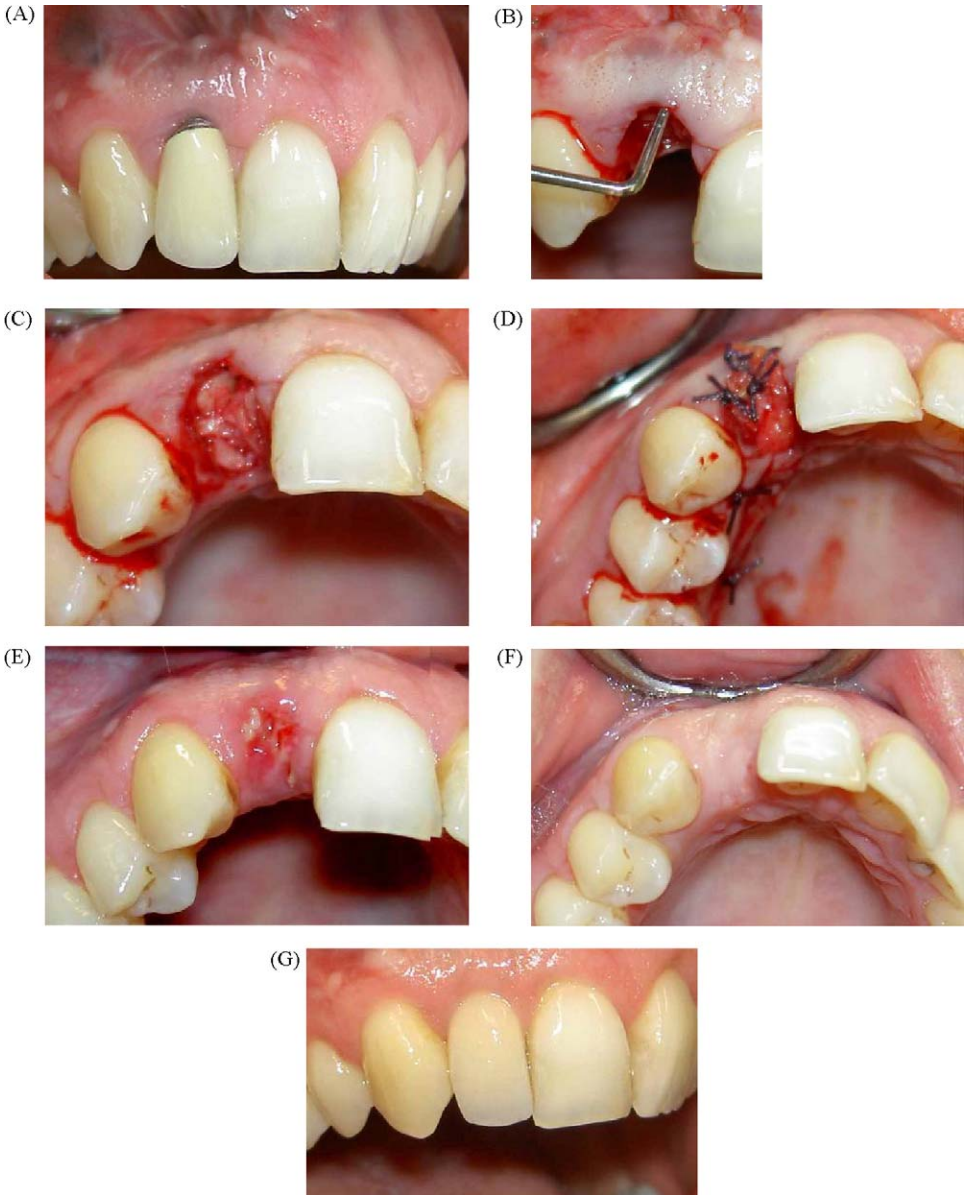

Fig. 1. Connective tissue graft procedure. (A) A 40-year-old female with a fracture of the root of the right lateral incisor. (B) The lateral incisor is removed. Sounding of the defect with a periodontal probe revealed a bone loss of 8 mm in a vertical direction. (C) The alveolar socket is reconstructed with a tuberosity bone graft on the buccal site of the defect. The alveolus is filled with a 1:2 mixture of tuberosity bone and Bio-Oss®. (D) The reconstructed alveolar socket is closed with a connective tissue graft. (E) Clinical view of the wound 3 weeks after reconstruction. (F) Clinical view of the wound 12 weeks after reconstruction. (G) Clinical view of the final crown with favourable aesthetics.

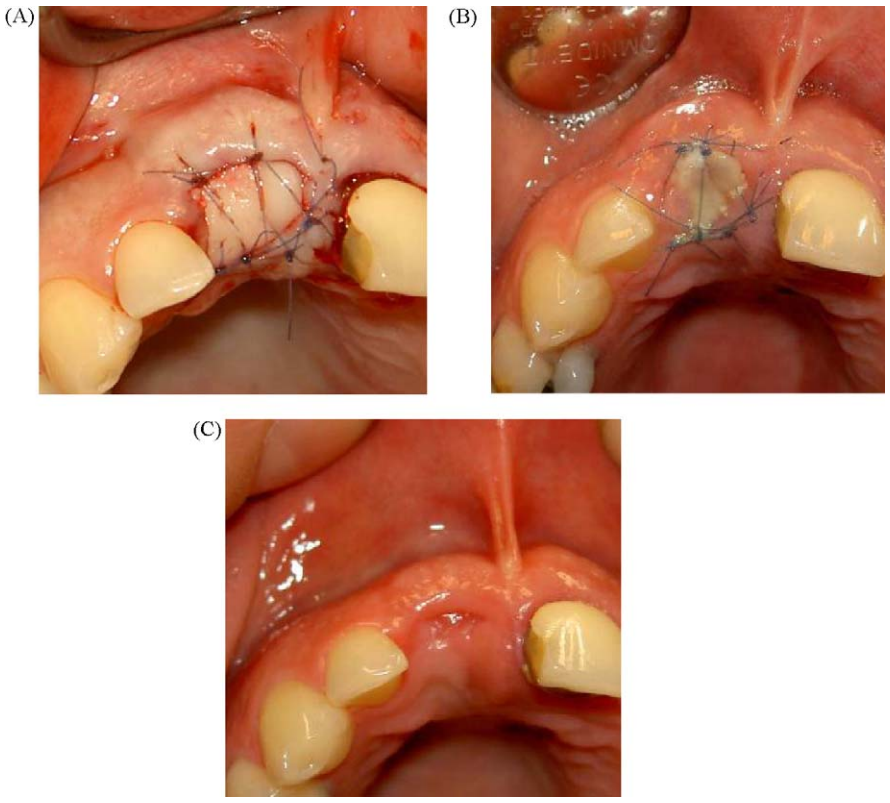

Fig. 2. Full-thickness palatal mucosa graft procedure. (A) The reconstructed socket is closed with a free oval full-thickness soft-tissue graft. (B) Clinical view of the wound 1 week after reconstruction. (C) Clinical view of the wound 12 weeks after reconstruction.

of the reconstructed socket (group 2; n = 15) (Fig. 2).

In the third procedure, a preshaped Bio-Gide® GBR membrane (Geistlich, Wolhusen, Switzerland) was carefully positioned over the reconstructed alveolus. The membrane extended under the buccal and palatal mucoperiosteal layer. Horizontal mattress sutures (Ethilon 4-0) were used to secure the membrane and to prevent its displacement (group 3; n = 15) (Fig. 3).

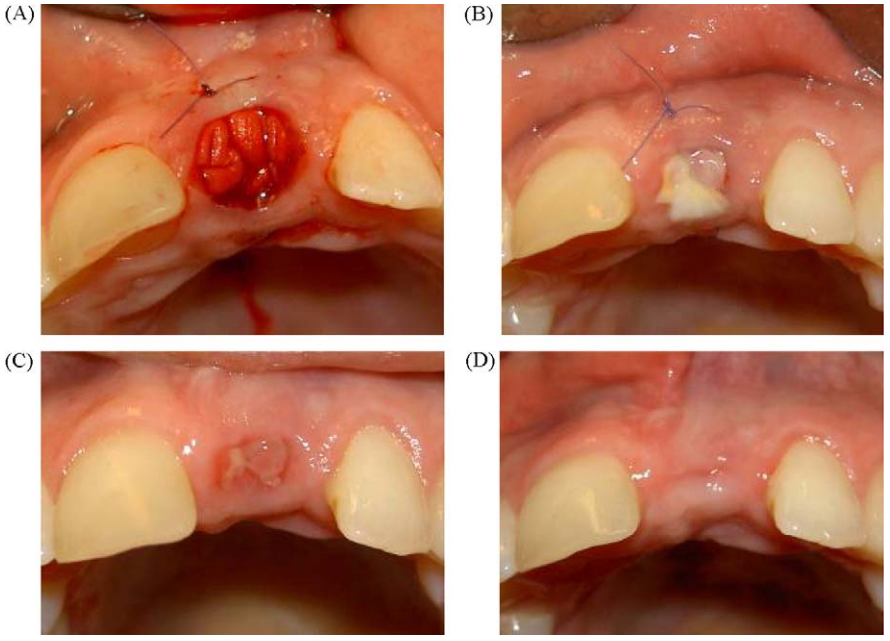

Fig. 3. Bio-Gide® membrane procedure. (A) The reconstructed socket is closed with a Bio-Gide® membrane. (B) Clinical view of the wound 1 week after reconstruction. (C) Clinical view of the wound 3 weeks after reconstruction. (D) Clinical view of the wound 12 weeks after reconstruction.

In all patients, the removable partial denture was placed immediately after reconstruction of the alveolus. The patient was instructed not to brush the surgical site, but to rinse gently with a 0.12% (w/v) chlorhexidine digluconate mouthwash twice daily. The patient was advised to prevent any activities that might compromise the site. The sutures were removed after 1 week.

Three months after removal of the tooth and reconstruction of the alveolus an implant placement procedure was performed. A pedicled mucoperiosteal flap was raised to expose the bone, after which the preparation was made using a surgical guide. The template design was based on a restoration driven approach with indications for a correct 3-dimensional implant placement respecting the comfort zones. The implant was placed (Replace Groovy, Nobel Biocare AB, Göteborg, Sweden) 2–3 mm deeper than the ideal cervical border of the future crown as indicated on the surgical guide. The wound was closed with Ethilon 4-0 (Ethicon, Johnson & Johnson, Amersfoort, The Netherlands) and the implants were uncovered after 3 months. A provisional crown with an adequate emergence profile was fabricated and placed to guide and shape the peri-implant tissue prior to definitive restoration. Oral hygiene instructions emphasizing how to clean the peri-implant region were given to all patients.

The final implant impression was made approximately 3 months after placement of the provisional crown. A full ceramic crown was fabricated on a customized zirconia abutment (Procera®, NobelBiocare, Gothenburg, Sweden).

Clinical examination

Routine clinical examinations (the patients were specifically asked about preoperative and postoperative complications, and pain at the donor site) were performed at 1, 3, 5, 7 and 12 weeks after the first surgery. Wound healing was noted. After 1 year of functional loading of the definitive implant crown the condition of the soft tissue at the donor site and peri-implant tissue was noted.

The degree to which the papillae filled the interdental spaces preceding removal of the tooth was measured using the classification described by Jemt[11]. These ranged from 0 to 4: where 0 represented no papillae; 1 less than one-half of the gingival embrasure; 2 at least one-half of the height; 3 complete closure of the proximal space; and 4 represented overgrowth. All measurements were done twice and the mean value was calculated. After 1 year of functional loading of the final crown the measurements were repeated. The mid-buccal gingival level of the tooth to be removed and the definitive implant-supported crown was assessed by measuring the difference with the buccal gingival outline of the adjacent teeth. A reference line was drawn between the level of the buccal marginal gingival of the neighbouring teeth. The difference between this line and the marginal gingival was measured to the nearest 0.2 mm. The classification ranged from 0 to 4: where 0 represented no difference in gingival level; 1 <1 mm difference, 2 <2 mm difference; 3 <3 mm difference; and 4 represented differences in buccal gingival outline >3 mm.

The long-term morbidity of the donor site was assessed from a questionnaire completed by the patients and a standardized clinical examination at 12 months after functional loading of the definitive crown. The questionnaire consisted of multiple choice questions about duration and severity of postoperative pain at the donor site, meteorotropism, sensory loss, duration of subjective rehabilitation, postoperative symptoms at the donor and recipient site, and the patient's acceptance of the procedure. Pain severity was graded on a 100 mm visual analog scale (VAS; 0 representing no pain, 100 representing severe pain). To estimate the subjective acceptability of the bone harvesting, the patients were asked to judge the procedure using a number between 0 and 100, where 0 indicated a 'very bad experience' and 10 represented 'no problems at all'.

The clinical examination was restricted to the donor site area and sensibility of the palate. Tactile sensibility was tested by lightly brushing the palate with a wisp of cotton (the patient should be able to count the number of contacts with the eyes closed). Superficial pain was tested with a needle (the patient should be able to tell whether contact with the palate was made with a sharp or dull instrument with the eyes closed). Patients were asked whether they experienced an altered sensation in the mucosa[22].

Radiographic examination

Radiographic examination was performed after placement of the definitive crown and 12 months after loading. It comprised standardized intra-oral radiographs using a long-cone paralleling technique.

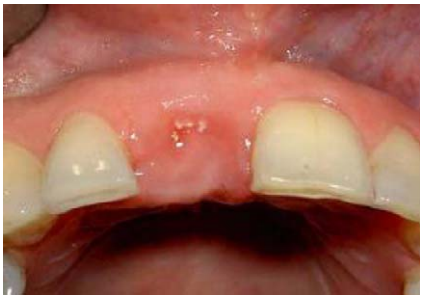

Fig. 4. Twelve weeks after removal of the tooth and reconstruction of the extraction socket, some particles of Bio-Oss® were appearing through the mucosa. The socket was closed with a Bio-Gide® membrane.

Statistical analysis

All variables were checked for normality. One-way ANOVA techniques were used to compare the three treatment groups. In cases in which post-hoc testing was required, Bonferroni tests were used. For the statistical analysis, SPSS for windows version 14.0 was used (SPSS Inc. Chicago, IL). The level of significance (α) was set at 0.05.

Results

Patients

No complications were observed during the surgical procedure. No extensive bleeding after removal of the bone graft and perforation through the maxillary sinuses was encountered. No objective signs of infection were observed during the follow up. In three patients (group 3) loss of Bio-Oss® particles was noted (Fig. 4). At 3–5 weeks the Bio-Gide® membrane was resorbed and the wound healed (Fig. 3). In 4 patients in group 1, and 3 in group 2, the graft appeared fibrinoid during the first 3 weeks of healing after reconstruction, but complete wound healing was observed after 7 weeks. In 4 patients (group 1) the removable partial denture could not be worn during the first 3 weeks due to swelling of the connective tissue graft.

Prolonged postoperative pain (>1 week) at the donor site was experienced by 11 patients (Table 1). In all 11 patients the pain lasted for less than a month. Postoperatively, one patient (group 1) described an altered sensation in the palate region where the connective tissue graft was harvested (Table 1). These complaints resolved spontaneously within 3 months.

In all patients, following the augmentation procedure and subsequent healing,

Table 1. Results for the three intervention groups.

	Group 1 (n = 15) (connective tissue graft)	Group 2 (n = 15) (full-thickness palatal mucosa graft)	Group 3 (n = 15) (Bio-Gide® GBR membrane)
Prolonged postoperative pain (> 1 week)	n = 5	n = 3	n = 3
Postoperatively altered sensation in the palate region	n = 1	n = 0	n = 0
Burden as experienced by patients (0 – 100 mm VAS)	30.4 ± 28.5 mm	16.6 ± 16.1 mm	15.4 ± 16.1 mm
Subjective acceptability of the procedure (0 – 10 scale)	8.5 ± 0.6	8.7 ± 0.7	8.0 ± 0.9
Gingival mid-buccal aesthetics before and 1 year after treatment	−1.1 ± 1.9 mm	0.5 ± 0.8 mm*	−1.3 ± 1.4 mm
Bone resorption 1 year after loading (mm).			
mesial	0.53 ± 0.15	0.52 ± 0.12	0.54 ± 0.16
distal	0.55 ± 0.14	0.54 ± 0.08	0.56 ± 0.14

* p,0.05, group 2 versus groups 1 and 3.

sufficient bone was available to insert implants with good initial stability (>45 N/cm) and an appropriate length of 12 mm or more. In three cases (group 2: one patient; group 3: two patients) dehiscence of the implant occurred on the buccal site (2–3 mm). One of these patients had lost Bio-Oss® particles during the healing period. A mixture of cortical bone was collected when preparing the hole for implant placement and in the adjacent alveolar process with a bone scraper. Bio-Oss® was condensed over the bone graft and covered with a Bio-Gide® GBR membrane. After three months all implants were uncovered and appeared to be osseointegrated.

After 1 year of function, all implants were stable and none had lost osseointegration. This corresponded to an overall cumulative implant success rate of 100%. Objectively, no disturbed sensibility of the palatal mucosa was observed in any patient at 12 months after surgery.

When comparing the gingival mid-buccal aesthetics before and 1 year after treatment a significant difference between group 2 and groups 1 and 3 was noted (Table 1). There was no significant difference between groups 1 and 3. There was no significant difference between the observed interdental papilla before and after treatment in all groups. No signs of soft tissue complications were noted at the donor site or regarding the peri-implant tissue.

Mean mesial bone resorption at 1 year after functional loading was 0.53 ± 0.14 mm and the distal bone resorption was 0.55 ± 0.12 mm. No marginal bone changes >1 mm were observed at the mesial and distal aspects of any implants. There were no significant differences between the study groups

Questionnaire

The burden of the bone-harvesting procedure from the tuberosity region as experienced by the patients appeared to be low (Table 1). No significant differences were observed between the three groups regarding the severity of postoperative pain, although in absolute terms, patients subjected to the connective tissue graft procedure perceived more pain (group 1; Table 1). All patients mentioned that the postoperative course was in accordance with their expectations. None of the patients had complaints about pain after 1 year. Overall the subjective acceptability of the procedure was rated as very satisfactory in all groups.

Acceptance was rated equally in the three groups (Table 1). All patients were willing to repeat the procedure when necessary. There was no significant negative relation between the patient's judgment of the procedure and the occurrence of postoperative complications, gender, pain, and the time needed for full recovery as experienced by the patients.

Discussion

In this prospective study immediate reconstruction of bone and soft tissue of the socket wall was performed with a 1:2 mixture of autologous bone and Bio-Oss® in combination with one of three soft tissue closure procedures. All procedures demonstrated a reliable treatment with enough bone volume for the insertion of implants. The implant survival rate was 100% and the patients were satisfied. The morbidity and complication rates of all procedures were low and there was no significant difference between the morbidity of the groups. The aesthetic appearance of the peri-implant soft tissue was significantly better in group 2 than in the other groups. After 7 weeks the grafts showed complete healing, in accordance with the literature[12].

The gingival mid-buccal recession was more prominent in group 3. The sample size in the present study is small and statistical testing is hampered by power problems, but this might be an important observation needing further study. There were no differences regarding the quantity of the interdental papilla between the preremoval of the tooth and 1 year after placement of the definitive crown. The reason for these favourable results could be that no mucoperiosteal flap was raised when removing the tooth. Sealing the socket promotes healing and is important if bone grafts are used to isolate the bone particles from the contaminated environment of the oral cavity. Sealing the extraction socket with soft tissue also prevents shrinkage-related displacement of the marginal gingival and arrests the natural process of scar shrinkage. This will ideally keep the papillary tissue in the vertical plane, counteract migration of the mucogingival junction, and stabilize the position of the marginal wreath of dentogingival fibres for subsequent use as a soft-tissue channel accommodating the implant-supported restoration[26]. The stimulus for scar shrinkage will abate once a wound has completely epithelialized. For this reason, the process of soft-tissue shrinkage cannot be arrested by any socket sealing techniques relying on the use of extraneous materials facing the oral cavity. Sealing of the alveolus with Bio-Gide® is possible, but may cause more buccal gingival recessions. In three patients particles of bone substitute became visible after resorption of the

membrane. The wound healed completely, which accords with another study[27].

Several authors have recommended immediate placement of endosseous implants into extraction sockets[14,15,18,20,23]. They concluded that a delayed implant protocol might be considered in the aesthetic zone due to recession at the level of the mid-buccal gingival especially if there is a U- and UU labial bone defect[14]. When augmentation procedures are applied, delayed implantation is recommended[18] because of the risk of recession at the level of the mid-buccal gingival[15]. The most predictable aesthetic results can be achieved only when underlying labial and interproximal osseous support is provided. The better the clinical margin is provided at the buccal gingival level with bone and soft tissue, the more reliable the aesthetic appearance of the attached mucosa is assumed to be. Spontaneous bone healing was found in 3-wall infra-bony pockets associated with implants placed into extraction sockets[23]. Controlled prospective studies are needed to define the potential for spontaneous healing for a 1-wall and 2-wall infra-bony pocket and to determine the long-term prognosis for immediate implant placement into fresh extraction sockets.

In the present patients, autologous tuberosity bone was used to reconstruct the labial bone. A mixture of autologous bone and Bio-Oss® was used to prevent ridge reduction[2,19]. Resorption of bundle bone cannot be prevented, but filling with a slowly resorbing bone replacement material resulted in regeneration of the socket, which compensated, to a large extent, for the horizontal and vertical bone loss. The elimination of Bio-Oss® is a slow process that may require many years[3]. It is thought that the xenograft is eventually replaced with host bone during the process of remodelling, but the mechanism is not fully understood[1]. De novo bone formation may be limited at the socket entrance of such sites and be replaced by formation of a dense connective tissue[1]. Why connective tissue is occasionally formed in a reconstructed area instead of bone is not understood. It might be that in incompletely healed sites the coagulum formation following root extraction is compromised. Alternatively, the wound may have become contaminated, resulting in early degradation of the coagulum which jeopardizes new bone formation[2]. In the present cases, there was no intact labial bone lamella. A sole reconstruction with Bio-Oss® could result in failure of the (re)modelling processes needed for uneventful healing of an extraction socket when no labial lamella is present because of ingrowth of soft tissue. This is why the authors used an autologous bone graft from the tuber region to reconstruct that lamella. A tuberosity graft can be shaped easily to the required dimensions beneath the periosteal layer. The Bio-Oss® decreases the higher resorption that encompasses tuberosity bone when compared with mandibular bone and promotes bone modelling[21]. Bio-Oss® also significantly reduces resorption of buccal bone in a horizontal direction[4]. Conflicting results have been reported regarding the long-term behaviour of Bio-Oss® (whether it will be resorbed or maintained), but at least up to 6 months after grafting the material will still be present[17].

A striking observation in the present study was the preservation of the interproximal papillae. It appeared that there was no difference in the volume of the papillae before tooth removal and 1 year after placement of the definitive crown. This observation is in accordance with the results of a controlled clinical trial evaluating the appearance of the interproximal papilla of early and delayed placement of implants[24]. In that study and the present one the tooth was removed without raising a mucoperiosteal flap.

Free bone grafts should be safely covered by a well-vascularized soft-tissue flap. A full-thickness flap may influence the vascularity and could move the mucogingival junction to an unfavourable location on the labial aspect. In this study, the authors performed the procedure through the socket without the elevation of a mucoperiosteal flap. Leaving the periosteum in place decreases the resorption rate of the extraction socket[6]. The socket can be closed with a substantial soft-tissue flap. This soft tissue graft showed successful biological and aesthetic integration into the local host tissues[12].

Within the limits of the present study, the authors conclude that extraction socket preservation can be a predictable procedure when applying a mixture of tuberosity bone and Bio-Oss® in combination with adequate closure of the socket. Among the favourable outcomes of the three soft tissue procedures evaluated, the full-thickness palatal mucosa graft was the most predictable graft for closure of the socket in case of immediate reconstruction after removal of a tooth. The latter approach can help to prevent ridge collapse, allowing for implant placement in a position that satisfies aesthetics and function. The authors suggest that for a better result, teeth that are to be replaced by an implant should be removed by a surgeon who is trained in augmentation techniques and insertion of endosseous dental implants.

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None

Competing Interests

None

Ethical Approval

All subjects signed an informed consent

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