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Flap detachment and retraction in periapical surgery

In many cases, periapical surgery is required instead of tooth extraction and implant placement. In this regard, flap detachment and retraction, affording adequate access to the periapical lesion with good visualization of the surgical field, is crucial in order to ensure meticulous, rapid and correct periapical surgery and treatment success. This in turn avoids damage to the surrounding soft tissue and neurovascular elements, allowing adequate ostectomy, with the sutures resting on hard tissue.

The raising of the flap and traction must be carried out firmly but gently in order to minimize trauma. The sulcus technique, described in apicoectomy of the mandibular premolars, allows safe stabilization of the retractor supported on the bone without harming the surrounding tissue. Adequate soft-tissue management not only results in a better postoperative course, with less pain and inflammation, but also guarantees optimum wound healing. Furthermore, an adequate flap design will increase the efficiency of surgery, resulting in a shorter operating time.

Flap detachment and retraction is fundamental in periapical surgery, but in the past has not been well addressed from the teaching perspective in the books and articles published on this subject. It is important for dental surgeons to learn, use and trust these techniques in order to adequately decide when and when not to indicate dental implant placement.

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Sinus lift surgery in severely resorbed maxillae: One-year follow-up

Abstract

Objective

The aim of this prospective study was to clinically analyze the behavior of implants inserted into severely resorbed maxillae after sinus grafting.

Materials and methods

Twenty-six wide-diameter implants with a rough surface over their entire length were inserted during 13 consecutive sinus lifts. Radiographic analysis was preoperatively requested for each patient. After Schneiderian membrane elevation, a magnesium-enriched hydroxyapatite (Mg-e HA) and collagen-based scaffold with a porous 3-D structure was used to prevent perforation during implant placement. Sinus grafting was performed using a biomimetic Mg-e HA. No membrane was used to cover the buccal window. The preoperative residual bone height ranged between 1 and 4 mm (mean value: 2.5 mm; SD: 1.0 mm).

After 6 months of healing, uncovering was carried out and the definitive restoration was seated after 2 weeks. In order to monitor the stability changes, resonance frequency analysis was performed and ISQ (Implant Stability Quotient) values were collected at the first surgery (baseline, T0), at the abutment connection (T1) and at the 1-year follow-up (T2).

In order to measure bone changes, the patients underwent panoramic radiographs after 2-year follow-up. Image analysis software calculated the grafted bone height changes at the level of the implant site, comparing preoperative and follow-up panoramic radiographs.

Results

No postoperative complications were observed. The mean ISQ value was 42.5 (SD: 2.7) at T₀, 75.3 (SD: 8.2) at T₁, and 81.5 (SD: 2.6) at T₂. Statistically significant differences (P ≤ 0.005) regarding mean ISQ values were found between T₀ and Tₘ, as well as between T₀ and T₁. After 12 months of functional loading, only 1 implant was lost (cumulative survival rate: 96.15%). During the same observation period, the mean radiographic vertical height of the grafted sinus floor was 11.05 mm (SD: 2.10 mm), with a mean gain of 8.50 mm.

Conclusion

Within the limitations of this study, despite preoperative critical residual bone height, maxillary sinus lift restoration using a biomimetic Mg-e HA and an Mg-e HA/collagen-based scaffold with a porous 3-D structure seems to be a reliable procedure.

Keywords

Sinus lift, magnesium enriched hydroxyapatite, x-ray analysis, ISQ.
**Introduction**

Sinus floor augmentation has recently become a widely accepted surgical procedure to improve the amount of bone volume before implant placement. Although the use of autogenous bone appears to be the gold standard, much attention has been paid to the use of bone substitutes. After the harvesting procedure, donor site morbidity has to be taken into consideration. Additional disadvantages for autografts are the limited availability and the tendency to resorb. In order to overcome these limitations, several biomaterials have been evaluated in experimental and clinical studies, such as demineralized freeze-dried bone allograft, bovine bone matrix, composite bone graft including platelet-rich plasma, resorbable and nonresorbable hydroxyapatite and beta-tricalcium phosphate. In particular, bioceramics based on calcium phosphate are widely used owing to their biocompatibility, absence of immunogenic factors and osteoconductivity; although, the high temperature during the sintering process could negatively influence osteoconductivity and resorption time. New hydroxyapatites enriched with magnesium (Mg-e HA) have recently been introduced on the market. Mg-e HA has been demonstrated to allow complete healing of the tissue around a graft and undergoes almost complete resorption already after 1 year. Despite its high predictability, the more recent literature has highlighted possible complications after this procedure. The main complication is membrane perforation, mostly during implant insertion. Mg-e HA/collagen-based scaffolds have been successfully used for sinus augmentation procedures, demonstrating bone formation after 6 months already. Owing to its properties, this material might be suitable to protect the sinus membrane from eventual perforation during implant insertion.

The present preliminary prospective study was designed to evaluate clinically and radiologically implant restorations 12 months after prosthetic loading in severely resorbed maxillae requiring 1-stage sinus lift surgery. The graft used was an Mg-e HA and Mg-e HA/collagen-based scaffold with a porous 3-D structure and was used to prevent Schneiderian membrane perforation.

**Materials and methods**

**Study design and patient selection**

One dental center consecutively recruited 13 patients scheduled for implant-supported restoration in the posterior maxilla with a sinus augmentation procedure. A total of 26 wide-diameter implants with a rough surface over their entire length were inserted in extremely resorbed posterior maxillae. The present study was performed following the principles outlined in the Declaration of Helsinki of 1975, as revised in 2013, on experimentation involving human subjects. All of the patients were in general good health. They were informed about the procedure and required to sign a consent form. They were followed for a period of 12 months after prosthetic rehabilitation. The principal inclusion criterion was a residual bone crest (distance between the sinus floor and bone crest) ranging between 1 and 3 mm in height and allowing wide-diameter implant insertion. Additional inclusion and exclusion criteria are summarized below:

**Subject inclusion criteria:**
- Need for fixed implant-supported prosthesis in the posterior maxilla.
- Aged > 18 years.
- No relevant medical conditions.
- Nonsmoker or smoked ≤ 10 cigarettes/day (pipe or cigar smokers were excluded).
- Full-mouth plaque score and full-mouth bleeding score of ≤ 25%.

**Study site inclusion criteria:**
- Native bone height of 1–3 mm in the sinus zone.

**Subject and site exclusion criteria:**
- Acute infection of the Schneiderian membrane or chronic sinusitis.
- Allergies involving the respiratory system.
- A history of bisphosphonate therapy.
- Uncontrolled diabetes (glycated hemoglobin A1c > 6%, glycemic level > 110 mg/dL).

**Preoperative and postoperative medication**

The patients underwent a preoperative digital panoramic radiograph, subsequently used as baseline. A cone beam computed tomography scan was also required to investigate antral anatomy (Fig. 1). One week before the surgical procedure, full-mouth professional prophylaxis was performed. The patients were instructed to use 1 g of penicillin clavulanate 1 day prior to surgery and continue with 2 g per day for 6 days. Just before surgery, the patients underwent a 5-min mouth rinse with 0.2% chlorhexidine gluconate.
Sinus lift and Mg-e HA/collagen-based scaffold

Figs. 1A & B
Preoperative digital panoramic radiograph with preoperative computed tomography scans.

Surgical technique

The sinus area was prepared under local anesthesia, as described by Boyne and James. The bony window was left attached to the Schneiderian membrane. The sinus mucosa was elevated, taking care to avoid laceration. In all cases, an Mg-e HA/collagen-based scaffold with a porous 3-D structure (RegenOss, Finceramica, Faenza, Italy) was used to protect the Schneiderian membrane and prevent any mechanical complication during grafting and implant insertion.

Implant sites were marked using a surgical template. In order to increase primary stability, osteotomies were performed using the narrowest drill able to allow implant insertion, to avoid buccal bone fracture. Residual bone height was assessed using a modified probe with a small hood. Then, the graft material (HA granules, 600–900 μ, SINTlife, Finceramica) was placed at the superior aspect of the sinus and against the medial aspect of the grafted compartment created in the sinus cavity. The graft material was meticulously condensed at each stage. Then, 2 implants (5 mm in diameter, 10–13 mm in length, Premium SP, Sweden & Martina, Due Carrare, Italy) were placed at a torque value of >10 Ncm. The root-shaped implant used in this study had a sandblasted and acid-etched surface over its entire length. No membrane was used to cover the buccal window (Fig. 2). The oral mucosa was then sutured with 5-0 resorbable interrupted sutures (Vicryl, Ethicon, New Brunswick, N.J., U.S.).

Postoperative treatment

The patients were instructed to avoid blowing their noses for at least 7 days after surgery and to cough or sneeze with an open mouth to prevent
increased pressure in the operated sinus. They underwent a new digital panoramic radiograph for postoperative evaluation. Clinical and surgical postoperative complications were measured.

**Second-stage procedure and follow-up evaluation**

Second-stage surgery to expose the implants was performed 6 months after implant placement. After performing a minimal crestal incision just over the area corresponding to the implant, the cover screws were exposed and removed. Attached keratinized mucosa was left on both the palatal and buccal aspects around all of the implants, and healing abutments were screwed in at a torque of 10 Ncm.

Clinical evaluation criteria at the time of implant exposure included stability in all directions, eventual crestal bone resorption, and any reported pain or discomfort. One week later, after impression taking using pickup coping transfers, titanium abutments were screwed in at a torque of 32 Ncm. In the same procedure, an additional impression of the screwed-in abutment was taken using the metallic structure. The provisional restoration was seated. In order to allow better distribution of the occlusal forces, splinted crowns were used. Implants inserted in residual neighboring bone without augmentation were not splinted to the ones inserted in augmented bone. One week later, definitive crowns were cemented using a provisional cement (Temp-Bond, Kerr, Orange, Calif., U.S.) Twelve months after prosthetic loading, a digital panoramic radiograph was obtained to assess the newly formed bone and its interface with the implant (Fig. 3).

**Implant stability measurements**

Immediately after implant insertion (baseline, T0), resonance frequency analysis (RFA; Osstell Mentor, Osstell, Gothenburg, Sweden) for each implant was carried out and the values were used as baseline. The transducer was hand-screwed into the implant body as recommended by manufacturer. The RFA value is represented by a quantitative parameter called ISQ (Implant Stability Quotient). The ISQ ranges between 1 and 100. The measurements were repeated for each implant after 6 (T1) and 12 months after prosthetic loading (T2). Each measurement was taken twice buccolingually and the mean value was used. Because each transducer had a unique fundamental RF, the measurements were calibrated using a calibration block. All stable implants were considered successful.

**Complications**

Any technical (implant fracture, screw loosening, etc.) and/or biological (pain, swelling, suppuration, etc.) complications were considered.

**Radiographic evaluation**

The grafted area was evaluated with a computerized measuring technique applied to the digital panoramic radiographs (preoperative and 12-month follow-up). In each case, the surface of grafted sinus was marked with a virtual marking instrument. An image analysis software program (AutoCAD 2006, Version 2 54.10, Autodesk) calculated the total (native + grafted) bone height changes at the level of the implant site, comparing preoperative and follow-up
panoramic radiographs, with the ability to compensate for eventual radiographic distortion.\textsuperscript{14, 15} All measurements were conducted and recorded by the same trained independent examiner, without input from the implant surgeon.

\textbf{Statistical analysis}

Descriptive statistics, including mean values and standard deviation, were used to describe changes in implant stability over the time and bone area. Student’s $t$-test for paired data was performed to test the significant difference between ISQ values at $T_0$, $T_1$ and $T_2$. Student’s $t$-test was used to perform bone area comparison. Significance was set at $P > 0.05$.

\textbf{Results}

A total of 13 consecutive patients (8 females and 5 males) were treated. The mean age was 62.1 years (SD: 11.05 years). No patient dropped out during the study. The preoperative mean residual bone level was 2.5 mm (SD: 1.0 mm). Minimal perforation of the sinus membrane occurred in 4 cases. The healing period after sinus augmentation was without complication for all of the patients. Minor nosebleeds occurred in 1 case. No clinical symptoms of maxillary sinusitis occurred in any patient. Only 1 implant was mobilized during the uncovering procedure, in a light smoker. For the failed implant, the preoperative height was 2 mm, the ISQ value was 39 at $T_0$ and 42 at $T_1$. The patient did not report any symptoms during the healing period. After surgical debridement, the implant was substituted with an implant 6 mm in diameter at the same surgical stage and restored after an additional 3 months of healing. All of the other implants were osseointegrated after 12 months of prosthetic loading (cumulative survival rate: 96.15%).

The mean ISQ value was 42.5 (SD: 2.7) at $T_0$, 75.3 (SD: 8.2) at $T_1$ and 81.5 (SD: 2.6) at $T_2$. Statistically significant differences ($P \leq 0.0005$) regarding mean ISQ values were found between $T_1$ and $T_0$, as well as between $T_1$ and $T_2$. The mean radiographic vertical height of the grafted sinus floor was 13.75 mm (SD: 1.30 mm) after 12 months of prosthetic loading ($P \leq 0.0005$).

\textbf{Discussion}

This prospective study demonstrated that, even in critical conditions, osseointegration and longitudinal stability of implants with a rough surface over their entire length could be a reliable clinical outcome when placed in maxillary sinuses grafted with a biomimetic Mg-e HA. Additionally, the use of an Mg-e HA/collagen-based scaffold with a porous 3-D structure seems to prevent surgical complications due to microperforation of the Schneiderian membrane.

The main limitations of the present study were the short-term follow-up (1 year) and small sample size (13 patients). However, this study is a preliminary report proving the feasibility of the combination of an Mg-e HA/collagen-based scaffold with a biomimetic HA. Additionally, the absence of a control group does not allow for demonstration of any additional benefit compared with the gold standard in sinus lift surgery.
The graft material investigated in this study was a new generation of HA, biomimetic scaffolds, and was studied as an alternative to overcome the disadvantages of conventional graft material, simulating bone structure not only from a chemical point of view, but also microscopically, reproducing micropores and their interconnections. Within this graft material category, Mg-e HAs have chemical and morphological properties close to that of natural bone and have showed comparable results to autologous bone in regenerative procedures. This configuration seems to be able to induce migration, adhesion and proliferation of osteoblasts inside the pore network and to promote angiogenesis inside.11

A recent literature review showed the residual bone crestal height to be one of the most critical factor influencing implant survival rate. At the same time, a minimum bone height of 4–5 mm is recommended for a 1-stage implant insertion.16 However, according to Peleg et al., despite severely resorbed maxillae, no postoperative problems or complications were observed when implants were inserted simultaneously with the graft material. Although the literature describes problems during the surgical phase in sinus augmentation in patients with 1–4 mm residual bone height,23 the use of wide-diameter implants allows a sufficient primary stability.24

Although the mean value of ISQ at T2 was very low, the data reported at T1 are in line with that of previously reported findings. In fact, Lai et al. reported the same findings for rough-surfaced implants installed after minor sinus floor elevation.25

The statistically significant increase of ISQ values between T0 and T1 could be evidence of fast maturation of the graft, after just 3 months. An additional increase between T1 and T2 could indicate a further maturation of the material after 12 months of prosthetic loading. Despite some clinical studies suggesting positive results with the use of RegenOss alone in sinus lift procedures after 6 months,22 controversial outcomes with the use of a soft matrix were reached in the literature.28 In fact, Caneva et al. suggested the use of rigid materials to counteract negative pressure during respiration.26

**Conclusion**

The present study, within its limitations, demonstrated that the use of a soft matrix in association with a graft material allows bone regeneration without postoperative complications. However, further studies should aim to measure discrepancies between preoperative and long-term postoperative increments using the promising matrix used in the present study.
Sinus lift and Mg-e HA/collagen-based scaffold

References

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Immediate implants in the esthetic area: Our perspective and clinical guidelines

Abstract

The placement of implants immediately after tooth extraction has proven to be a predictable treatment strategy with a very high success rate. Nevertheless, the success of this surgery involves strict clinical criteria. A description is provided of a clinical orientation and scientific point of view based on our experience and available evidence of when and how to perform this procedure in the esthetic area.

We consider the clinical criteria in relation to

1. indications;
2. tooth extraction;
3. soft-tissue management;
4. implant placement technique;
5. the critical distance and gap filling; and
6. immediate versus delayed restoration.

These key factors, including a flapless procedure, presence of an intact buccal bone wall, absence of soft-tissue defects, gap filling to counteract the tissue changes after tooth extraction and immediate restoration when possible, should be considered to achieve good esthetic results.

Keywords

Dental implants, immediate dental implant loading, tooth extraction, alveolar process, bone remodeling.
Immediate implants in the esthetic area

Tooth extraction normally causes a remodeling process of the alveolar ridge, which normally follows a healing pattern with a dimensional shrinkage of the ridge in both shape and volume. Thus, as a consequence of the natural healing events, implant placement to restore the missing tooth might be limited because of loss of the adequate amount of bone and because of the absence of the ideal volume of the residual ridge. Several surgical procedures have been proposed to preserve or improve the volume of the alveolar ridge after a tooth extraction. Among the several available treatment options to manage a fresh extraction socket, immediate implant placement has been a debated issue in the last 25 years. During a consensus conference in 2003, Chen et al. established that immediate implants showed predictable outcomes in terms of survival rates that were similar to those of implants placed in healed ridges. These authors pointed out the need to better clarify the long-term esthetic outcomes for immediate implants. Moreover, the same authors observed that there was an absence of a clear classification, according to the timing of implant placement in extraction sockets. Thus, different authors have well clarified how to classify the timing for implant placement, in an extraction socket; nowadays, the terms “immediate,” “early” and “delayed” in relation to implant placement are universally accepted and recognized. Several publications have reported negative esthetic outcomes associated with immediate implant placement, such as gingival recession, higher marginal bone loss and interdental papillae loss. According to Buser et al., immediate implant placement in the esthetic area accounts for only 5–10% of cases, and for the rest, a different approach should be chosen, mostly early placement with hard-tissue healing (12–16 weeks), so for this reason, the clinician should develop the ability to both identify and successfully treat these few cases. The aim of this review paper is to report the most debated points in the literature and the clinical approach that could be considered predictable in terms of implant functional and esthetic implant success.

Immediate implant placement is certainly a delicate technique that requires experience and accurate case selection, based on certain indications, in order to achieve optimal results. The 3-D positioning of an immediate implant, which will be discussed later in this article, requires that the bone housing should allow for a palatal/lingual placement and a sufficient buccal bone thickness that guarantees support for the facial soft tissue, thus decreasing the risk of facial mucosal recession. When a buccal alveolar bone thickness amounts to less than 2 mm, its integrity is at risk of fenestration, dehiscence and soft-tissue recession.

Also, a possible immediate restoration of the immediate implant should be based on the measurement of ISQ (Implant Stability Quotient), the value of which has to be more than 62.

In order to summarize the indications for immediate implant placement in a short checklist that is easy for the clinician to follow, it can be suggested that the decision in favor of this technique should be made when the operator is facing these local clinical scenarios: integrity of buccal bone wall and absence of soft-tissue recession immediately after tooth extraction, presence of adequate interdental bone around adjacent teeth and presence of bone beyond the tooth apex to allow good implant stability. Moreover, the reasons for tooth extraction should be carefully evaluated when considering immediate implant placement, with the aim of identifying clinical conditions that could relatively contraindicate immediate implant placement. For example, tooth trauma, which is commonly associated with a fracture of the buccal bone plate; and periodontal disease, which is commonly associated with interdental bone loss, could represent relative contraindications to immediate implant placement (Figs. 1 & 2).

The presence of an acute infection, lack of bone beyond the tooth apex, proximity to anatomical vital structures and absence of local ideal clinical conditions should be considered as full contraindications to immediate implant placement.

Finally, it should be underlined that the experience of the clinician is a fundamental factor in the execution of this delicate technique. The esthetic outcomes can be compromised by the inexperience of surgeons, especially when the implants are placed in esthetic areas.
Immediate implants in the esthetic area

2. Tooth extraction

The atraumatic extraction of the tooth to be replaced with an immediate implant is essential to prevent damage to the buccal bone plate and to preserve the interproximal papillae and labial soft tissue. Flapless extraction should be preferred or only a minimal mucoperiosteal flap elevation\(^1^4\) to preserve the integrity of the vascular supply from the periosteum and avoid alveolar bone resorption in the exposed area (Fig. 3). \(^1^5, 1^6\)

Several measures or instruments can be adopted to aid in an extraction that is the least traumatic as possible, including sectioning the tooth to carefully remove the fragments and the use of a piezoelectric device or microsurgical instrumentation, such as periotomes.

After the extraction, the socket should be thoroughly degranulated by careful curettage. Then, the integrity of the buccal bone and soft tissue should be checked to determine whether it is favorable for immediate implant placement.

3. Soft-tissue management

The maintenance of soft-tissue contour and dimension is one of the most challenging aspects of immediate implant placement. Indeed, midfacial mucosa recession around immediate implants has been reported to occur in a high percentage of cases (40\%).\(^6, 1^7, 1^8\) and almost one-third of unsatisfactory esthetic outcomes have been associated with several factors, such as tissue biotype, thickness of facial bone wall and implant positioning.\(^1^4, 1^9\) It should also be taken into consideration that most of the soft-tissue changes can continue after implant surgery, even on a long-term basis.\(^1^5\) Today, it is well known that the surgical technique influences the soft tissue around immediate implants.\(^1^6, 2^0\)

The surgical procedure is usually performed flapless,\(^2^1\) and it has been shown that it enhances esthetics and decreases gingival recession,\(^2^2\) as previously discussed. The soft tissue at the facial level needs to be supported by a buccal bone wall of sufficient height and thickness. Therefore, a volume augmentation through grafting at the time of implant surgery seems to be strongly recommended\(^7, 2^3, 2^4\) to maintain the bone volume at the facial level on a long-term basis\(^2^5, 2^6\) and thus to avoid a soft-tissue collapse, which can be responsible for some negative esthetic effects.\(^2^7, 2^8\) Otherwise, the soft tissue can be managed by a provisional crown, and there is evidence to support that immediate implant placement with temporary restorations can provide stable esthetic results and limited recession.\(^2^9\) In fact, it has been shown that it is advantageous to avoid manipulation of soft tissue during and after initial healing because such an intervention may disrupt the soft-tissue seal.\(^3^0\) This manipulation is unavoidable when implants are placed according to the traditional two-stage protocol. Thus, the idea is that...
Immediate implants in the esthetic area

Immediate provisional restoration allows for minimal disturbance of the soft tissue during healing, and as a consequence, it could be expected that the undisturbed soft tissue will result in better maintenance of the bone level position.31

4. Implant placement technique

Several factors are involved in the esthetic success of an immediate implant, among which the most important is certainly an appropriate implant positioning. A useful tool in the decision process during the evaluation of the extraction socket hard tissue for possible implant placement is the classification of Juodzbalys et al.32 Once the alveolus is deemed adequate for the purpose, the implant placement should be performed as carefully as the already discussed atraumatic tooth extraction. A strict and standardized protocol should be followed that considers the peculiar anatomical features of a post-extraction socket, especially in the esthetic areas.

The implant site has to be prepared positioning the drills so that they follow the palatal bony wall as a guide and using the apical bone as much as the residual bone height allows. The residual apical bone will provide most of the necessary anchorage and stability for the implant. For this reason, the length of the implant should be accurately chosen accordingly during the planning. Once the implant site has been prepared, a periodontal probe should be used to verify the integrity of the walls. Finally, the implant must be placed with the platform at the marginal level of the buccal bone wall.

The palatally oriented preparation of the osteotomy is dictated by the anatomy of the post-extraction socket. The buccal wall of the socket is generally very thin and in the esthetic areas is generally less than 1 mm.33 According to Huynh-Ba et al., in the upper anterior area, this bone is equal to or less than 0.5 mm thick in 64.1% of cases.34 Although early studies supported the hypothesis that immediate implant placement could preserve the initial alveolar crest dimension,35–37 later human and animal model studies showed that the ridge will not maintain its original shape for longer than 3–4 months after immediate implant placement.17,28 For these reasons, it is important to keep a palatally oriented positioning, because the unavoidable resorption of the very thin buccal wall might compromise the success and the long-term survival of the implant if placed in close proximity to the buccal aspect (Figs. 4 & 5).

5. The critical distance and gap filling

According to many authors, the need to graft the gap between the implant and the buccal socket wall is guided by the length of this space.38,39 The critical distance, beyond which a graft is strongly suggested, is considered to be 1.5 mm.38,39 Several approaches have been proposed to fill the gap around implants, aimed at preserving or improving the dimension and contour of the ridge after tooth extraction and immediate implant placement.38,40 Different studies have shown that the use of bone substitutes might also modify the pattern of bone remodeling.41,42

Fig. 3

Tooth socket after careful atraumatic extraction of the root remnant.

Fig. 3

Tooth socket after careful atraumatic extraction of the root remnant.
Immediate implants in the esthetic area

In general, marginal bone changes around implants, when placed in fresh extraction sockets, may result in unfavorable bone thickness in the long term. For this reason, the use of guided bone regeneration techniques in this situation can be suggested. It is advisable to use cortico-cancellous porcine bone, which has a slow resorption rate, mixed or not with autogenous bone, and a resorbable membrane to stabilize the graft. The membrane can be left exposed, provided that antibiotic therapy is prescribed to the patient (amoxicillin and clavulanic acid, 1 g twice a day for 5 days, starting the day before surgery). With this technique, it was demonstrated in a previous study that implants have a cumulative survival rate of 94.6% at 7 years (Figs. 6–8).\textsuperscript{12} All of the guided bone regeneration techniques applied in the implant–socket gap are useful to limit buccal wall resorption; however, a complete preservation of the initial contour is never possible and a remodeling will always take place to some extent, although with a slower rate.\textsuperscript{41}

Several studies have shown that there is no difference in the long-term survival of implants restored with immediate or delayed provisional crowns and that, concerning the success rate, the two restorative procedures seem to be very similar in terms of soft-tissue behavior at the buccal aspect.\textsuperscript{43-45} However, various studies regarding immediate implants placed in fresh extraction sockets suggested that wider papillary shrinkage was seen in delayed restorations than in immediate restorations.\textsuperscript{46} From our point of view, the prosthetic treatment, namely immediate or delayed restoration, has to be based on strict clinical criteria, for example, the insertion torque value that should not be higher than 45 Ncm. Nevertheless, immediate prosthetic restoration may guarantee more predictable results in terms of an excellent hard- and soft-tissue prognosis for

6. Immediate versus delayed restoration

In general, marginal bone changes around implants, when placed in fresh extraction sockets, may result in unfavorable bone thickness in the long term. For this reason, the use of guided bone regeneration techniques in this situation can be suggested. It is advisable to use cortico-cancellous porcine bone, which has a slow resorption rate, mixed or not with autogenous bone, and a resorbable membrane to stabilize the graft. The membrane can be left exposed, provided that antibiotic therapy is prescribed to the patient (amoxicillin and clavulanic acid, 1 g twice a day for 5 days, starting the day before surgery). With this technique, it was demonstrated in a previous study that implants have a cumulative survival rate of 94.6% at 7 years (Figs. 6–8).\textsuperscript{12} All of the guided bone regeneration techniques applied in the implant–socket gap are useful to limit buccal wall resorption; however, a complete preservation of the initial contour is never possible and a remodeling will always take place to some extent, although with a slower rate.\textsuperscript{41}

Several studies have shown that there is no difference in the long-term survival of implants restored with immediate or delayed provisional crowns and that, concerning the success rate, the two restorative procedures seem to be very similar in terms of soft-tissue behavior at the buccal aspect.\textsuperscript{43-45} However, various studies regarding immediate implants placed in fresh extraction sockets suggested that wider papillary shrinkage was seen in delayed restorations than in immediate restorations.\textsuperscript{46} From our point of view, the prosthetic treatment, namely immediate or delayed restoration, has to be based on strict clinical criteria, for example, the insertion torque value that should not be higher than 45 Ncm. Nevertheless, immediate prosthetic restoration may guarantee more predictable results in terms of an excellent hard- and soft-tissue prognosis for
all aspects. In their study, Barone et al. showed that, with delayed restorations, loss of papillary soft tissue and bone resorption were faster and localized, whereas with immediate restorations, tissue modifications appeared slow and gradual, allowing more predictable results with an excellent soft-tissue prognosis regarding, above all, the mesial and distal aspects. Moreover, treatment time until the final restoration is longer with delayed restoration than with immediate restoration. Finally, delayed restoration had higher costs than immediate restoration did, 26% more, owing to both the adjunctive second-stage surgery and the higher number of visits required (Figs. 9–11).

**Conclusion**

Nowadays, the improvement in implant technology and knowledge of healing patterns after tooth extraction has made it possible to achieve adequate success rates and favorable esthetic outcomes with immediate implants. It should be pointed out that immediate implant placement can be considered as a possible treatment option only when strict clinical criteria are met, such as integrity of the buccal bone plate, integrity of bone peaks of the adjacent teeth, integrity of soft tissue (adequate amount of keratinized gingiva, adequate gingival scallop and adequate interdental papillae) and a thick gingival biotype. Under these clinical conditions, immediate implant placement could be considered as a viable treatment option that shows predictable outcomes. For these reasons, the following points, as discussed in this review, should be considered and reviewed before implant placement in fresh extraction sockets:

- Case selection should be made according to inclusion and exclusion criteria.
- The extraction of the tooth or root remnant should be done asatraumatically as possible in order to avoid any damage to the hard and soft tissue.
- Soft-tissue integrity should be preserved by avoiding flap elevation or, if necessary, only performing a minimal flap elevation. This will also decrease buccal bone resorption.
- The implant placement should follow the palatal wall and a vestibular orientation should be avoided as far as possible to avoid possible fenestration of the implant after unavoidable bone remodeling.
- The gap between the implant and the buccal bone wall should be grafted to avoid resorption and exposure of the buccal aspect of the implant and to provide support to the soft tissue.
- Immediate restoration, when possible, should be preferred because it can guarantee better support to the interdental soft tissue and is less expensive for the patient.

In addition, it should be taken into consideration that, when all of the clinical conditions for immediate placement are present, this procedure is still considered as a complex procedure that requires high surgical skills. When the clinician is not sufficiently experienced or when all of the requirements are not satisfied, other techniques should be considered, such as early implant placement with soft- or hard-tissue healing and late implant placement with or without socket grafting.

**Competing interests**

The authors declare that they have no competing interests and have not received any support from any companies.
Immediate implants in the esthetic area

References


Immediate implants in the esthetic area


New perspectives in periapical surgery: Flap detachment and retraction

Abstract

An update is made of the aspects to be taken into account during flap detachment and retraction in periapical surgery as one of the key elements for treatment success. Raising of the flap and traction must be carried out firmly but gently in order to minimize trauma. This requires an adequate mucoperiosteal incision. Retraction separates the flap in order to facilitate access to and visibility of the bone without damaging the flap. The sulcus technique, described in apicoectomy of the mandibular premolars, allows safe stabilization of the retractor supported on the bone without harming the surrounding tissue. Such support can be complemented by placing a piece of dressing impregnated with epinephrine to improve hemostasis and minimize damage to the flap. Adequate soft-tissue management not only results in a better postoperative course, with less pain and inflammation, but also guarantees optimum wound healing. Furthermore, an adequate flap design will produce more efficient surgery with a shorter operating time.

Keywords

Periapical surgery, flap detachment, flap retraction.
**Introduction**

In periapical surgery, and after planned incision, the flap is raised and separated from the bone. In this regard, a full-thickness or mucoperiosteal flap (comprising mucosa, connective tissue and periosteum) is detached with the aim of securing sufficient access to the bone and adequate elimination of the diseased periapical tissue. It is important to detach the periosteum from the bone together with the flap in order to minimize bleeding during surgery, reduce inflammation and pain in the postoperative period, and facilitate healing.\(^1,2\)

Once the flap has been raised, it is retracted in order to keep the bone surface visible and accessible, and to avoid damage to either the flap or the surrounding tissue during the operation.\(^1\) The present study aims to review all of the aspects to be taken into account during the detachment and retraction of the flap in periapical surgery.

**Flap detachment**

The surgical incisions delimit a flap comprising attached gingival tissue, free alveolar mucosa and a fibromucous or periosteal layer that must preserve its vitality and recover its physiological functions after being repositioned. Flap detachment should be performed firmly and gently, taking care to minimize trauma.\(^2\) This requires a well-defined full-thickness incision with adequate placement of the periosteotome on the bone. During the process, it is useful to revise the incision with a fine dissector (Fig. 1) in order to eliminate any connective tissue or periosteal fibers that have not been dissected by the scalpel. Detachment has a series of particularities, depending on the type of flap involved.

**Submarginal incision flap**

After a well-defined full-thickness incision, detachment is carried out with a periosteotome held like a pencil and placed at the junction between the horizontal and vertical incisions, with the concave surface, of the instrument facing the bone (Figs. 2A & E). The periosteotome is kept in continuous contact with the bone surface in order to avoid flap tearing or fenestration caused by possible irregularities, such as bone crest exostosis. The instrument is then gradually displaced horizontally, along the incision line, in the apical direction. The flap is raised sufficiently to expose the bone overlying the periapical lesion (Figs. 2F & H).

**Neumann intrasulcular incision flap**

After completing the incision through the gingival sulcus, the papillae are carefully separated one by one with the help of a fine dissector. The papillae should detach easily if the sulcular incision has correctly sectioned the gingival fibers and their lingual prolongation (Figs. 3A–D). The periosteotome is then positioned at the angle formed by the vertical and horizontal incisions (Fig. 3B).

It must be taken into account that in the presence of periodontal disease the bone crest is blunted or flattened, and greater resistance to detachment in the apical direction may be experienced. In some cases, this is wrongly taken to indicate the presence of a fibrous insertion or resistant insertion of the periosteum, an atypical cementoenamel junction, or an erosive margin (noncarious neck lesion). A series of particularities can be found, depending on the presence of anatomical anomalies or alterations associated with the prior surrounding disease during detachment.

**Identification of fibrous or epithelial tracts**

In the presence of a long-standing fibrous or epithelial tract, the pathological tissue of the lesion may have become integrated into the mucosa and submucosa, and in this case the flap is first raised from the surrounding tissue. With the flap kept tense, the scalpel blade is then positioned parallel to the bone surface, and the flap is detached without perforating the mucosa. The tearing of frenula or muscle insertions poses no esthetic or functional problem, and these elements should be raised as part of the flap. Once the fistular or fibrous tract has been dissected, raising of the flap is continued (Figs. 4A–E).

**Bone exostosis**

The soft tissue overlying zones characterized by large bone volumes is very thin and can easily be perforated during detachment. In such cases, it is important to work with a sharp periosteotome, keeping it in continuous contact with the bone surface.\(^1\)
Flap detachment and retraction in periapical surgery

Fig. 2A
Radiograph of an apical lesion involving a maxillary left central incisor, lateral incisor and canine.

Fig. 2B
Tomographic scan showing the bone defect in the left anterior maxillary region.

Fig. 2C
Extensive bone defect with cortical bone plate perforation.

Fig. 2D
Submarginal or full-thickness incision.

Fig. 2E
The incision is revised with the dissector, placing it between the horizontal and vertical incisions.

Fig. 2F
Detachment of the flap with the periosteotome, with its concave surface facing the bone.

Fig. 2G
Flap displaced to visualize the bone overlying the periapical lesion.

Fig. 2H
Intraoral radiograph after surgery. Perfect retrograde filling of the cavity can be observed.
**Flap detachment and retraction in periapical surgery**

**Fig. 3A**
Well-defined sulcular incision.

**Fig. 3B**
The incision is revised with the dissector, placing it at the angle formed by the horizontal and vertical incisions.

**Fig. 3C**
Insertion of the periosteotome, with its concave surface facing the bone horizontally, and checking detachment of the papillae.

**Fig. 3D**
Full apical retraction of the flap without tearing of the papillae.

**Fig. 4A**
Identification of a fibrous tract during flap detachment with submarginal incision.

**Fig. 4B**
With the flap kept tense, the scalpel blade is then positioned parallel to the bone surface, taking care not to perforate the mucosa.

**Fig. 4C**
Full apical retraction of the flap after dissection of the fistular and/or fibrous tract.

**Fig. 4D**
Intraoral photograph of perfect soft-tissue healing.

**Fig. 4E**
Intraoral radiograph showing the final aspect of retrograde filling.
Flap detachment and retraction in periapical surgery

Fig. 5A
Radiograph of a right central incisor with internal root resorption with an apical lesion.

Fig. 5B
Tomographic scan of the internal resorption and apical bone defect.

Fig. 5C
Radiograph after orthograde endodontic treatment insufficient to solve root resorption.

Fig. 5D
Intraoral photograph of the anterior maxillary zone.

Fig. 5E
Flap retraction. Note the retractor resting stably on the bone tissue.

Fig. 5F
Access to the apical lesion, care being taken not to affect flap integrity or the lesion.

Fig. 5G
Soft-tissue healing with a minimal scar, typical of a submarginal flap.

Fig. 5H
Radiograph showing complete retrograde filling of the internal resorption and cavity.

Flap retraction

Retraction serves to separate the flap, allowing the surgeon to visualize and access the bone without damaging the flap or the adjacent tissue.2 The edges of the tissue retractor should rest upon the bone and must not affect flap integrity or the lesion. In order to correctly position the retractor, the flap should be raised sufficiently to adequately expose the bone over the periapical tissue of the affected root (Figs. 5A–H). Different types of retractors are available. Some authors advocate the use of retractors designed with a saw-tooth zone to prevent displacement.4 Such instruments are not very comfortable to use, however, and have poor stability, thereby causing surgeon tension throughout the operation. Other authors prefer large retractors with designs adapted to the different dental groups and anatomical structures.5
Flap detachment and retraction in periapical surgery

Groove Technique

A useful option is the so-called groove technique, which was developed for mandibular premolar apicoectomies with the aim of avoiding damage to the mental nerve. Nevertheless, it can be applied to any tooth and involves the creation of a narrow groove (of scant depth and measuring about 15 mm in length) using a small rounded drill. The tip of the retractor is inserted into this groove, and after firmly fixing the body of the retractor, gentle separation from the bone is performed to safely keep the soft tissue clear of the surgical field (Figs. 6A–F).

It is also possible to place a small piece of dressing impregnated with anesthetic solution between the separator and the flap in order to preserve flap integrity and improve bleeding control (Figs. 7A–E). The tissue tends to dry out when surgery is prolonged. In this case, the flap must be periodically and freely repositioned and humidified with sterile saline solution. Optimum surgery is rapid, meticulous and decisive, and should be performed correctly and in an organized way.

Conclusion

This meticulous surgical technique allows treatment of the soft tissue with delicacy, minimally injuring the vascularization, which is very important in oral surgery, and allowing good healing of the soft tissue and of the incisions. In addition, it achieves an adequate surgical field of work that will aid the clinician in being effective and quick in the surgical procedure, which means a reduced possibility of infection and drying of the tissue.
Flap detachment and retraction in periapical surgery

Fig. 7A
Radiograph of a maxillary second premolar with an apical lesion.

Fig. 7B
Intraoral photograph of the second premolar with a metal–ceramic crown and slight retraction of the gingival margin.

Fig. 7C
After flap detachment, a narrow groove is made on the bone tissue, always apical to the lesion of the affected tooth.

Fig. 7D
Before firmly positioning the retractor, a piece of dressing impregnated with epinephrine is inserted to preserve flap integrity and improve bleeding control.

Fig. 7E
Positioning of the retractor in the groove, maintaining flap integrity with the help of the interposed piece of dressing.

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Influence of abutment material and detersion protocol on bacterial adhesion: An in vitro study

Abstract

Objective

In recent years, periimplantitis has been extensively studied as bone loss has been observed around dental implants. As a result of multiple factors, different materials might enhance different patterns of bacterial plaque accumulation. The purpose of this research was to assess bacterial adhesion to different abutments and define the efficacy of different detersion protocols in reducing bacterial adhesion.

Methods

Four kinds of prefabricated abutments were analyzed: machined pure titanium abutments without anodization, machined gold hue and pink hue anodized pure titanium abutments and zirconia abutments with titanium connectors. All of the (sterile) abutments were immersed in separate bacterial suspensions (Staphylococcus haemolyticus, Streptococcus pyogenes and Escherichia coli) and contaminated with $3 \times 10^8$ colony-forming units per mL of each bacterial species suspension. Then, the following detersion protocols were compared: no treatment representing the internal control, 10 min rinsing with water, 10 min incubation in 0.05% chlorhexidine. The microbial abatement was determined by swab collection of abutment-attached microbes and swab streaking on specific culture plates in a semiquantitative manner. Microbial growth was determined at 24 and 48 hours after inoculation.

Results

Contaminated abutments that had not undergone any cleaning treatment displayed a microbial growth up to the third quadrant of the culture plate. Chlorhexidine rinsing completely removed bacterial contamination. No statistically significant differences were found in terms of bacterial adhesion and bacterial growth among the different types of abutments.

Conclusion

All of the analyzed abutments displayed similar characteristics with regard to bacterial adhesion. A low concentration of chlorhexidine had a significant disinfectant activity, regardless of the type of abutment.

Keywords

Dental implant, implant abutment, anodization, bacterial contamination.
Introduction

Dental implants have become a common choice for edentulous sites, and implant survival rate has been demonstrated to be extremely high.\(^1\)\(^2\) For these reasons, attention has switched to different aspects, such as esthetic outcome, including shape and shade of the surrounding tissue, and benefits of different prosthetic materials. In recent years, periimplantitis has been extensively analyzed as bone loss has been experienced around many different implants due to different factors.\(^3\)

Among these factors, prosthetic components have been included as possible causes of periimplant bone loss. In particular, different materials might have different effects on periimplant soft and hard tissue and on different patterns of bacterial plaque accumulation. Titanium has been described as an optimal material, since it combines adequate precision, strength and biological compatibility.\(^4\) While not much difference in the reaction of periimplant soft and hard tissue to titanium and zirconium is present, the literature shows that titanium and zirconia are slightly superior to gold as abutment materials,\(^5\)\(^6\) even if few clinical differences have been reported.\(^7\) In recent years, all-ceramic restorations have become popular owing to their esthetic advantages concerning the soft tissue.\(^8\)\(^9\) A more natural outcome with the utilization of a ceramic abutment compared with a metal or titanium abutment has been well documented in various clinical and in vitro trials, especially when dealing with thin periimplant tissue.\(^10\)\(^11\) The utilization of pink-colored abutments and colored implant heads has also been suggested.\(^12\)

Hence, titanium anodization or nitride coating has been proposed as a method to improve the esthetic result.\(^13\)

Recently, great emphasis has been placed on the decontamination of the prosthetic components in order to exclude any possible source of bacterial colonization. The effect of chlorhexidine in disrupting and preventing plaque biofilm formation has been widely investigated.\(^15\)\(^16\) Previous studies have compared bacterial adhesion affinity to discs and abutments made of titanium or zirconia.\(^17\)\(^18\) Moreover, a wide range of cleaning methods have been proposed for abutment decontamination.\(^19\)\(^20\) No evidence is present regarding contamination and decontamination of anodized abutments. The aim of this in vitro study was to analyze the amount of bacterial colonization and to evaluate the efficacy of microbial removal of 2 different decontamination protocols on different abutment materials.

Materials and methods

Microbiological analysis of bacterial adhesion and colonization of abutments was carried out in December 2015 at the Department of Microbiology, University of Padua, Padua, Italy. Four different abutments were analyzed:

1. machined Grade 5 pure titanium abutments without anodization;
2. machined gold hue anodized titanium abutments;
3. machined pink hue anodized titanium abutments; and
4. zirconia abutments with titanium connectors (all by Sweden & Martina, Due Carrare, Italy).

Initially, each sterile abutment was contaminated with \(3 \times 10^8\) colony-forming units (CFU) per mL of 3 different bacterial types (\textit{Staphylococcus haemolyticus}, \textit{Streptococcus pyogenes}, and \textit{Escherichia coli}), representing Gram positive and Gram negative bacteria. This condition simulates a possible condition of bacteria accumulation in the oral tract.

Five minutes after the bacterial contamination, the abutments were accurately removed from the suspension with sterile forceps and divided into 3 groups of treatment: The abutments of the first group were not subjected to any decontamination treatment; the abutments of the second group were rinsed for 10 min with sterile water; the abutments of the third group were incubated for 10 min in a 0.05% chlorhexidine solution. All of the samples were collected with sterile cotton swabs and plated on Columbia agar and 5% sheep blood, MacConkey agar and Chocolate agar plates (Becton Dickinson, Franklin Lakes, N.J., U.S.) using the dilution streak technique. The first quadrant was streaked with the cotton swab, and the successive ones using a 10 µL bacteriological loop in order to dilute the initial inocula. A volume of 10 µL of the initial supersaturated bacterial solution was plated separately as a positive control. Plates were incubated at 37 °C, and the microbial abatements were measured by observing microbial growth in each plate at 24 and 48 h.

All of the tests were repeated 3 times after abutment cleaning and sterilization under the same conditions. Differences between decontamination treatment groups were statistically
Bacterial colonization on different abutment materials

Table 1
Microbiological assessment of bacterial contamination of abutment surfaces after the 3 cleaning treatments tested. Results, expressed as number of colony-forming units (CFU) per abutment, are reported as mean (± standard deviation). Bacterial growth regarding the positive control (bacterial solution) is expressed as CFU/mL.

Figs. 1A–D
Abutments used for the protocol:
(A) machined Grade 5 pure titanium abutment without anodization;
(B) machined pink hue anodized titanium abutment;
(C) machined gold hue anodized titanium abutment;
(D) zirconia abutment with titanium connector.

analyzed according to analysis of variance and Student’s t-test.

Results

The Evita supersaturated bacterial suspensions showed growth until the third quadrant of the culture plates. The samples taken from the contaminated and not cleansed abutments showed a limited growth to the second quadrant. The sterile water solution significantly reduced the bacterial concentration on the specimens and consequently on the culture plates, limiting colony growth to the first quadrant ($P < 0.05$ with regard to abutment contamination and $P < 0.01$ with regard to bacterial suspension). Immersion in a 0.05% chlorhexidine solution prevented any bacterial growth.

When comparing different abutment types, no statistically significant differences were found between the groups. Bacterial growth on culture plates was similar for all decontamination treatments ($P < 0.05$). The results were similar for all 3 types of bacteria taken into account, as shown in Table 1.
Discussion

Abutment decontamination is considered an important factor for long-term dental implant survival. Moreover, chlorhexidine has been widely investigated for its unique properties of inhibiting bacterial growth on titanium surfaces. In the present study, chlorhexidine’s decontamination properties were confirmed, and the degree of bacterial inhibition was comparable between all of the abutments considered.

*S. haemolyticus*, *S. pyogenes* and *E. coli* were not able to grow on either anodized or nonanodized titanium abutments after treatment with chlorhexidine. They were able to partially grow after treatment with sterile water. This is in accordance with previous studies, which reported the reduction of *S. pyogenes* on titanium discs after ultraviolet irradiation. However, uncommon oral bacterial populations were used in this study, because they were easier to stain, but, above all, because they express one of the highest adhesiveness ratios and present the worst possible conditions for the decontamination methods.

The group contamination (abutment immersed in a bacterial solution and then seeded on the culture plate) showed a surprisingly lower amount of bacterial growth on culture plates compared with bacterial suspension (growth up to second and third quadrants, respectively). This finding shows that titanium surfaces, with and without anodization, and zirconia surfaces behave similarly regarding bacterial adhesion. This result is in accordance with those of recent studies, confirming that zirconia and titanium alloy surfaces have comparable properties regarding bacterial adhesion. One limitation of the present study stays in the in vitro conditions used to determine the microbial abatement. It would be desirable to assess the same conditions in a dynamic environment such as the oral microbiota. Nevertheless, this study shows evidence that the abutment surfaces have inhibitory capabilities against 3 different microbial species, including Gram-positive and Gram-negative bacteria. This study shows also that a low concentration of chlorhexidine is effective in eliminating microbial contamination from different types of abutments.

Moreover, Yamane et al. investigated bacterial affinity to titanium and zirconia discs and found no statistically significant adhesion differences. Interestingly, the bacterial count after 4 days of contamination was similar to those presented in this study (between 8 and 9 Log CFU). Bacterial adhesiveness can be influenced by the surface roughness: The rougher the surface, the greater the bacterial adhesiveness. All of the abutments used for the study were prefabricated. This fact may be a limitation of the study. In fact, clinically, all abutments placed in the patient undergo a dental technician process that increases the surface roughness characteristics, regardless of the final polishing that is applied. It would be of interest to test the same abutments after preparation.

Regarding clinical implications, further studies should test the optimal chlorhexidine concentration and especially application time to better determine good clinical practice. Moreover, the clinical procedure during maintenance with a PTFE curette or rubber cup could modify the titanium abutment surface configuration, leading to an increased roughness, greater bacterial adhesion and a potentially more difficult cleaning procedure.
Bacterial colonization on different abutment materials

Conclusion

Within the limitations of this study, anodized titanium abutments proved to have similar bacterial accumulation compared with pure titanium abutments. A low concentration of chlorhexidine for a limited period of time (0.05% for 10 min) proved to be effective in disinfecting contaminated abutment surfaces.

Competing interests

The present trial was partially funded by Sweden & Martina for the manufacture of the abutments. Nevertheless, the data belonged to the authors and by no means did the manufacturer interfere with the conduct of the trial or the publication of the results.

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Individualized CAD/CAM-produced titanium scaffolds for alveolar bone augmentation: A retrospective analysis of dehiscence events in relation to demographic and surgical parameters

Abstract

Objectives

Computer-aided design/computer-aided manufacturing (CAD/CAM) technologies may improve application of titanium scaffolds, onlay techniques and guided bone regeneration. In this study, the clinical outcome of DICOM-based individualized CAD/CAM-produced titanium scaffolds (iCTSSs) was analyzed in grafted defects, particularly with regard to relation of dehiscence to demographic and surgery-related factors.

Materials and methods

In 100 patients, 115 defects of the alveolar crest were reconstructed with an iCTS covered with a native bilayer collagen membrane or left uncovered. The volume was mostly grafted with a mixture of autogenous bone and deproteinized bovine bone mineral. The healing process was documented. Office records were analyzed for association of dehiscence with demographic and surgical parameters.

Results

Uneventful healing was observed in 82 defects. Infection of the surgical area was documented in 11 cases, 10 were resolved by medication. One defect had to be regrafted. Dehiscence was reported in 26 defects. Premature removal of exposed iCTSSs was not necessary. All of the cases showed sufficiently grafted volume for implant placement with presurgical 3-D planning. The grafted volume in the defects with dehiscence did not differ from that in sites without dehiscence. Statistical analysis revealed no significant association of dehiscence with demographic or surgical parameters, but a tendency to higher prevalence of dehiscence with mesiodistal width of the defect.

Conclusion

Combination of an iCTS with guided bone regeneration offers a reliable grafting technique with low sensitivity to dehiscence. Dehiscence did not correlate with demographic or surgical factors. In addition, it did not affect the final outcome, as implant insertion was possible simultaneously or staged in all of the cases.

Keywords

CAD/CAM, individual titanium scaffold, augmentation, wound dehiscence.
Introduction

Replacement of lost teeth with implants is a routine and effective treatment showing high survival rates after long-term monitoring. In order to achieve adequate functional and aesthetic outcomes, an optimal 3-D implant position has to be assured. In many cases, the residual bone width, height and ridge contour are not sufficient for optimal implant placement. Therefore, ridge augmentation is recommended in order to maintain the alveolar ridge and simplify subsequent treatment procedures. Despite the availability of various augmentation procedures and materials, the restoration of an adequate amount of bone remains challenging.

The use of titanium scaffolds in terms of guided bone regeneration is a widespread procedure for horizontal and vertical ridge augmentation. Clinical and histological analysis has revealed increased morphological ridge repair and bone density after application of titanium scaffolds together with deproteinized bovine bone mineral (DBBM). Larger vertical gain in ridge can be achieved using titanium scaffolds. The main disadvantage of prefabricated titanium scaffolds is the intraoperative and time-consuming manual 3-D trimming according to the individual defect size of the patient. Computer-aided design/computer-aided manufacturing (CAD/CAM) technology can be used to overcome these disadvantages. Using individual patient computed tomography (CT) or cone beam computed tomography (CBCT), the necessary augmentation volume for the defect can be estimated preoperatively. According to the calculated augmentation volume, DICOM-based individualized CAD/CAM-produced titanium scaffolds (iCTSs) can be used to avoid intraoperative trimming of the prefabricated titanium scaffolds. Application of an iCTS shortens surgery time and may reduce the overall costs of the implantation procedure. The most common complication of titanium scaffolds is flap dehiscence. Recently, Sagheb et al. reported on the use of the iCTS for alveolar ridge augmentation and found no negative impact of dehiscence on the outcome. The objective of this study was to retrospectively analyze the dehiscence rate after iCTS augmentation procedures regarding various demographic and surgery-related factors in 100 patients with 115 bony defects.

Materials and methods

Study design and patient population

The retrospective analysis included patients who underwent implant therapy with additional augmentation procedures between 2014 and 2015 in a clinic for oral and maxillofacial surgery in Filderstadt, Germany. Screening of patients who needed bone augmentation before implantation was done during regular implant consultation. Cases with indication of onlay technique together with a titanium scaffold were evaluated. All of the patients were informed about the different augmentation possibilities. One hundred patients (56 male, 44 female) decided on the Yxoss CBR system (ReOss, Filderstadt, Germany), which provides an iCTS based on the CT/CBCT DICOM data of each patient. CT/CBCT was performed for all of the patients within 3 months before surgery. The production of an iCTS took 2–4 weeks. Each iCTS was controlled and finalized via an internet-based platform provided by the supplier. Using CT/CBCT, the necessary augmentation volume for the defect was calculated and documented. In addition, demographic (age, sex, smoking, periodontitis history) and surgical parameters (region, defect size, flap design, gingival morphotype, graft volume, use of membrane) were recorded. The gingival morphotype was classified into thin gingival morphotype A1 or A2 and into thick gingival morphotype B as follows:

- A1: high-scalloped, gingival thickness of < 1 mm, gingival width of < 3.5 mm, oval tooth form.
- A2: high-scalloped, gingival thickness of < 1 mm, gingival width of < 4–5 mm, oval tooth form.
- B: low-scalloped, gingival thickness of > 1 mm, gingival width of > 6 mm, square tooth form.

Surgical procedure

Surgery was performed under general anesthesia or under local anesthesia. Intraoperative defect assessment was performed using a poncho flap with a deep vestibular incision, a midcrestal ridge incision, a split-thickness flap or the tunnel technique. In some cases, an additional palatal rotational flap was performed. For augmentation, a combination of a deproteinized bovine bone mineral (DBBM; Geistlich Bio-Oss granules, 1–2 mm; Geistlich Biomaterials,
Individualized titanium scaffolds

Intraoperative view of a DICOM-based individualized CAD/CAM-produced titanium scaffold after loading with grafting material and placement on the defect. The iCTS was fixated with a minimum of 1 bone screw.

Fig. 1

Wolhusen, Switzerland) and autogenous bone in a ratio of 1:1 (n = 104), autogenous bone alone (n = 2), bone substitute material (KNE) alone (n = 5), an allograft (n = 1) or no material (n = 1) was used. Autogenous bone was harvested from the retromolar region using a hollow trephine drill with an inner diameter of 6 mm, followed by grinding of the small bone cylinders in a bone mill (Bull Bone Mill, MONDEAL Medical Systems, Mühlheim an der Donau, Germany). The iCTS was loaded with grafting material, placed on the defect and fixated with a minimum of 1 bone screw (Fig. 1). The iCTS was covered in situ with a porcine native bilayer collagen membrane (Geistlich Bio-Gide, Geistlich Biomaterials; n = 79) or left uncovered (n = 35). The surgical area was completely closed and the flap fixed with mattress, sлин or single sutures. After surgery, antibiotics were prescribed orally for 5 days (amoxicillin, 1,000 mg, 1-0-1). Radiographic control of the graft and the iCTS were performed using CBCT after healing. Postsurgery, patients were recalled for follow-ups to control the surgical area for wound dehiscence and inflammation. Removal of the iCTS and simultaneous implantation were performed depending on the healing period (5–8 months) postsurgery. The same surgical approach was used for the baseline defect assessment. After loosening of the fixing screw, the iCTS was carefully removed by applying rotating forces to predetermined breaking points of the summit of the iCTS at the top of the scaffold with a standard periosteal elevator. The surgical area was closed without tension and the sutures removed 1 week after surgery. Implants were placed simultaneously (n = 63) with augmentation or after 5–8 months (n = 50).

Statistical data analysis

Statistical analysis was performed using IBM SPSS Statistics for Windows (Version 21.0, IBM, Armonk, N.Y., U.S.). Quantitative data (augmentation volume) were descriptively analyzed for arithmetic mean and standard deviation. For comparison of augmented volumes in the defect sites with and without dehiscence, the Mann–Whitney U test was used because the data were not normally distributed (according to the Shapiro–Wilks test, P < 0.001). Association of dehiscence with demographic (age, sex, smoking, periodontitis history) and surgical parameters (gingival morphotype, surgical access, region, use of membrane) were analyzed using the chi-squared test or Fisher exact test (if cell occupancy numbers were < 5). Two-sample tests were performed. The impact of predictive factors on the risk of dehiscence was investigated using univariate and multivariate models for logistic regression analysis. Results were considered to be statistically significant if the P value was ≤ 0.05. Adaptation for multiple testing was not performed, since the analysis was explorative and used to test the hypothesis. Nonconsideration of intrapatient correlations influencing P values might have influenced the statistical analysis.

Results

One hundred patients with 115 defect regions in total were retrospectively analyzed. Of these patients, 56 were male and 44 female, with an
average age of 54.8 ± 13.1 years (range: 18–82 years; Table 1). Twelve of the patients were smokers (12%). Sixty-two patients presented with periodontitis (62%; Table 1) and were treated by the referring dentist before surgical intervention. Of the 115 defect regions to be augmented, 72 were located in the maxilla (62.6%) and 43 in the mandible (37.4%; Table 2). Seventeen defect regions were horizontal (14.8%), 5 were vertical (4.3%) and the remaining 91 regions had a combined defect type (79.1%). For 2 cases, the defect type was not recorded. Sixty of the defect regions presented with thin gingival morphotype A1 (52.2%), 5 with thin gingival morphotype A2 (4.3%) and 47 with thick gingival morphotype B (40.9%; Table 2).

The following surgical approaches were used to assess the defect sites: In 85 cases, ridge incision (73.9%); in 12 cases, poncho incision (10.4%); in 9 cases, split-thickness flap (7.8%); in 4 cases, palatal flap (3.5%); and in 3 cases, tunnel technique (2.6%; Table 2). In 2 cases, the surgical approach was not documented. For ridge augmentation, a mixture of autogenous bone and DBBM was used in 106 defect regions (92.2%) and other materials in 8 defect regions (6.9%), and in 1 defect region (0.9%), the material used was not documented. The iCTS was covered with a native bilayer collagen membrane in 79 of the defect regions (68.7%) or left uncovered in 36 cases (31.3%; Table 2).
Depending on the initial situation and potential for primary implant stability, implants were inserted simultaneously with iCTS placement in 65 cases (56.5%) or 5–8 months after augmentation in 50 defect regions (43.5%; Table 3). A superstructure was available in 42 defect regions (36.5%). Mainly 1 or 2 implants were inserted in each defect region (39.1% and 38.3%; Table 3).

**Wound healing and exposure of iCTS**

During the follow-up period of 6 months until re-entry, no healing complications were observed in 82 of the defect regions (71.3%; Table 4a). For the other 33 defects, the following healing complications were identified: 15 cases with iCTS exposure (13.0%), 7 cases with post-operative infection of the surgical area (6.1%) and 6 cases with loosening of the iCTS (5.2%). In 3 of the defect regions, exposure or loosening of the iCTS, together with postoperative infection, was documented (2.6%; Table 4a). Premature removal of exposed iCTSs was not necessary in any of the cases. In 1 defect region, healing complications were not specified (0.9%). One augmented site without any signs of dehiscence had to be regrafted owing to postoperative infection (0.9%; Table 4a).

Six months postsurgery, all of the augmented regions showed sufficiently grafted volume. Staged implant placement was possible in all of the cases. The following postoperative complications were documented: Minor loss of the grafted volume in 45 cases (39.1%) was regrafted at re-entry when deemed necessary, an intervening layer of fibrous tissue between the bone graft and scaffold was observed in 46 defects (40.0%), and overgrowth of the scaffold by bone occurred in 25 regions (21.7%; Table 4b).

**Wound dehiscence**

Overall, 26 of the 115 defect regions developed wound dehiscence (22.6%), while 89 did not (77.4%; Table 5a). According to wound dehiscence classification, wound dehiscence was point-shaped in 8 of the cases (30.8%), < 10 mm in 11 of the cases (42.3%) and > 10 mm in 2 of the cases (7.7%). In 5 of the cases with dehiscence, the classification of wound dehiscence was not specified (19.2%).

**Effects of demographic and surgery-related factors on wound dehiscence**

The grafted volume in the defect regions with dehiscence ($1,173 \pm 1,145 \mu L$) was not statistically different from that in the regions without dehiscence ($923.3 \pm 751.6 \mu L$; $P = 0.395$; Fig. 2 & Table 5b). Surgery-related parameters, including gingival morphotype ($P = 0.183$), surgical access ($P = 0.205$), membrane coverage ($P = 0.927$) and regio iCTS, coded ($P = 0.173$), did not show significant association with the prevalence of dehiscence (Table 5c). However, it should be noted, that a tendency to higher prevalence of dehiscence with mesiodistal width of the defect (regio iCTS: $P = 0.062$; Table 5c) was observed, but statistical significance was not achieved. No association of wound dehiscence with demographic (age, sex) or potential risk factors (smoking, periodontal disease) was found, as proved by different statistical approaches (Tables 6a & b).

<table>
<thead>
<tr>
<th>Table 3</th>
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<td><strong>Distribution of defect regions in maxillae and mandibles. Total number of defect regions: $n = 115$.</strong></td>
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<table>
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<tr>
<th>Parameter</th>
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Individualized titanium scaffolds

Table 4a

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<th>Healing</th>
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<tr>
<td>No healing complications</td>
<td>71.3 (82)</td>
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<td>Exposure of scaffold</td>
<td>13.0 (15)</td>
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<tr>
<td>Infection of surgical area</td>
<td>6.1 (7)</td>
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<tr>
<td>Loosening of scaffold</td>
<td>5.2 (6)</td>
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<tr>
<td>Loosening of scaffold and infection of surgical area</td>
<td>1.7 (2)</td>
</tr>
<tr>
<td>Exposure of scaffold and infection of surgical area</td>
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<tr>
<td>Infection of surgical area and regrafting</td>
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<tr>
<td>Not specified</td>
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Table 4b

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<th>Parameter</th>
<th>Distribution in % (number of cases)</th>
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<td>Loss of the grafted volume</td>
<td>No (60.0 (69)</td>
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<tr>
<td>Intervening layer of fibrous tissue</td>
<td>Yes (40.0 (46))</td>
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<tr>
<td>between bone graft and scaffold</td>
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<tr>
<td>Overgrowth of iCTS by bone</td>
<td>Yes (21.7 (25))</td>
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</table>

Discussion

Prediction and improvement of factors influencing the healing process and treatment outcome are of great importance in implant dentistry. In the present study, the application of an iCTS with DBBM and autogenous bone was found to result in sufficient grafted volumes and satisfactory clinical outcome. Prevalence of dehiscence was not affected by the demographic or surgical parameters analyzed. The presence of dehiscence did not influence the augmentation volume or implant insertion.

In the present study, an iCTS, together with a mixture of DBBM and autogenous bone, was mainly used (in 92.2% of defects) for complex alveolar bone augmentation. Typical complications, including infections and dehiscence, were easily treated. Dehiscence did not affect the final outcome, since augmented volumes were not affected and implant insertion was possible in all of the cases. These results are in line with previous studies showing similar effectiveness of iCTSs in the healing process that is comparable with that of custom-made titanium scaffolds.4, 11 Application of an iCTS, together with a mixture of DBBM and autogenous bone, was previously shown to result in sufficient augmented volume and good clinical outcome.11 Although 7 out of 21 cases showed exposure after 5–12 weeks, grafting was successful in all of the cases and implant survival was 100% after mean follow-up of 12 months.11 No negative impact of dehiscence on the clinical outcome was found. Another study compared custom-made titanium devices with conventional titanium scaffolds for alveolar bone augmentation in 26 patients.9 In this study, mucosal rupture was observed less frequently with the use of custom-made titanium scaffolds (in 1 patient, 7.7%) in comparison with application of the conventional titanium devices (in 3 patients, 23.1%), but the difference was not statistically significant. However, the operation time was significantly shorter and the number of retaining screws used significantly fewer in the custom-made group than in the commercial titanium device group. Taken together, application of custom-made titanium scaffolds is associated with fewer complications and shorter operation time.

Different factors have been shown to have an impact on the success of dental procedures. To the best of our knowledge, the association of wound dehiscence with various demographic and surgical parameters was investigated for the first time in our retrospective analysis. Important influencing factors, including age, sex, smoking, periodontitis, gingival morphology, surgical access, membrane coverage and regio iCTS, were taken into account. However,
Individualized titanium scaffolds

<table>
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<th>Parameter</th>
<th>Distribution in % (number of cases)</th>
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<tr>
<td>Dehiscence</td>
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<td>No</td>
<td>77.4 (89)</td>
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<td>Yes</td>
<td>22.6 (26)</td>
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<tr>
<td>Dehiscence according to classification</td>
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<tr>
<td>Point-shaped</td>
<td>30.8 (8)</td>
</tr>
<tr>
<td>&lt; 10 mm</td>
<td>42.3 (11)</td>
</tr>
<tr>
<td>&gt; 10 mm (large-scale)</td>
<td>7.7 (2)</td>
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<tr>
<td>Not specified</td>
<td>19.2 (5)</td>
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Table 5a
Wound dehiscence. Total number of defect regions: n = 115.

Table 5b
Grafted volume is similar in defects with dehiscence to those without dehiscence. Total number of defect regions: n = 115.

Fig. 2
Distribution of augmented volumes was not statistically different between defect sites with and without wound dehiscence, as calculated by the Mann–Whitney U test. Total number of defect sites: n = 115.

no statistically significant association between the prevalence of dehiscence with demographic or surgical parameters was found. A tendency to greater dehiscence with region iCTS might point to increasing prevalence of dehiscence with the width of the defect. One possible reason could be the greater disturbance of blood supply in larger defects that impairs optimal wound closure. However, this hypothesis needs further clinical and experimental analysis. Application of native collagen membranes did not show increased prevalence of membrane exposure or wound dehiscence.15, 16

An important advantage of iCTSs is the easy handling and the perfect fitting of the scaffolds, resulting in fewer injuries and shorter operation time. In contrast, conventional titanium scaffolds need to be adapted during surgery, necessitating time-consuming cutting and bending of the scaffolds.9, 10

An evidence-based review on clinical results in alveolar ridge augmentation showed that an average horizontal and vertical volume gain of 3.7 mm is possible using particulate guided bone regeneration techniques.5 These results can be significantly improved by inlay or onlay bone grafts using extraoral bone blocks or by distraction osteogenesis. However, these techniques seem to be accompanied by a higher complication rate, that is, infection and loss of block
Individualized titanium scaffolds

Parameter

| Gingival morphotype | | | |
|---|---|---|
| A1 | 52.2 (60) | 40.0 (10) | 56.6 (50) |
| A2 | 4.3 (5) | 8.0 (2) | 3.3 (3) |
| B | 40.9 (47) | 52.0 (13) | 37.8 (34) |
| Not specified | 2.6 (3) | 0 | 3.3 (3) |

| Surgical access | | | |
|---|---|---|
| Poncho incision | 10.4 (12) | 4.0 (1) | 12.2 (11) |
| Ridge incision | 73.9 (85) | 72.0 (18) | 74.4 (67) |
| Split-thickness flap | 7.8 (9) | 12.0 (3) | 6.7 (6) |
| Palatal flap (rotational) | 3.5 (4) | 4.0 (1) | 3.3 (3) |
| Tunnel technique | 2.6 (3) | 8.0 (2) | 1.2 (1) |
| Not specified | 1.7 (2) | 0 | 2.2 (2) |

| Regio iCTS | | | |
|---|---|---|
| 1 | 39.1 (45) | 28.0 (7) | 42.2 (38) |
| 2 | 36.5 (42) | 32.0 (8) | 37.8 (34) |
| 3 | 17.4 (20) | 20.0 (5) | 16.7 (15) |
| 4 | 4.3 (5) | 12.0 (3) | 2.2 (2) |
| 5 | 1.7 (2) | 4.0 (1) | 1.1 (1) |
| 10 | 0.9 (1) | 4.0 (1) | 0 |

| Regio iCTS, coded | | | |
|---|---|---|
| 1–2 tooth width | 75.7 (87) | 64.0 (16) | 78.9 (71) |
| 3–4 tooth width | 21.7 (25) | 36.0 (9) | 18.9 (17) |
| ≥ 5 tooth width | 2.6 (3) | 0 | 2.2 (2) |

| Membrane coverage | | | |
|---|---|---|
| Yes | 68.7 (79) | 69.2 (18) | 68.5 (61) |
| No | 31.3 (36) | 30.8 (8) | 31.5 (28) |

Table 6a

<table>
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Table 6b


Table 6c

Table 6a

Table 6b

Table 5c

Table 6c

Table 6a

Table 6b

* Fisher exact test. ** Chi-squared test.

grafts subsequent to exposure. By using titanium mesh in combination with particulate grafts, the user is able to perform larger-sized bone grafting, and the technique appears to be much more forgiving of exposure. The results of our retrospective study are in strong accordance with these results.

Our study has some limitations. The data were analyzed retrospectively; thus, information regarding postoperative complications and some surgical parameters was missing in a few cases. The clinical outcome of iCTSs was not compared with that of conventional titanium scaffolds or in combination with other

Table 6c

Table 6a

Table 6b

Table 5c

Effects of surgical parameters on wound dehiscence. Total number of defect regions: n = 115.

Table 6a

Distribution of possible influencing factors. Total number of defect regions: n = 115.

Table 6b

Logistic regression analysis on possible influencing factors. Total number of defect regions: n = 115.
augmentation techniques. This would be of interest for future studies. Therefore, further prospective long-term and randomized controlled clinical trials in larger patient cohorts are of interest to provide more evidence for improved clinical outcomes using the iCTS in comparison with other techniques.

### Conclusion

The results of this study suggest that application of an iCTS with an equal mixture of autogenous bone and DBBM offers a reliable grafting technique with low sensitivity to wound dehiscence. Prevalence of dehiscence was not influenced by the demographic or surgical parameters analyzed.

### Competing interests

Data analysis by an independent statistician was supported by a grant from Geistlich Pharma AG, Switzerland. The authors declare that they have no other competing interests.

### Ethical approval and informed consent

This retrospective study was performed without any further consequences for the patient. According to this and the hospital laws of the individual states (Krankenhauslandesgesetz von RLP), no approval by the local ethics committee is necessary. Furthermore, for this type of study, formal consent is not required.

### References

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– Materials and methods
– Results
– Discussion
– Conclusion

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Authors are required to declare any competing financial or other interests regarding the article submitted. Such competing interests are to be stated at the end of manuscript before the references. If no competing interests are declared, the following will be stated: “The authors declare that they have no competing interests.”
**Acknowledgments**

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